Smart cities in Qatar toward a sustainable digital transformation

A Thesis Submitted for the Degree of Doctor of Philosophy

By

Maryam Majareh

Department of Computer Science, Brunel University London

2025

Abstract

The rapid progression of digital transformation has reshaped urban landscapes globally, fostering the development of smart cities. This thesis investigates the sustainability of digital transformation within the context of smart cities, focusing specifically on Qatar. With its ambitious national vision and substantial investments in smart city technologies, Qatar is a critical case study for understanding how digital transformation can be implemented to drive long-term sustainability.

The research delves into critical areas such as governance frameworks, technological infrastructure, data management, and citizen engagement, all crucial for building resilient and sustainable smart cities. It also explores how digital solutions contribute to environmental, social, and economic sustainability, highlighting the role of emerging technologies like AI, IoT, and blockchain in improving city operations, resource management, and quality of life.

The study uses quantitative and qualitative data from a survey and interviews with expert stakeholders to evaluate digital transformation efforts in Qatar's smart cities, including Lusail and Msheireb Downtown. It assesses their alignment with sustainability goals and recommends fostering an inclusive, efficient, and future-proof digital infrastructure. It also identifies challenges related to cybersecurity, regulatory frameworks, and digital inclusion, offering insights on how these can be mitigated to ensure the sustainability of Qatar's smart city initiatives.

This research identifies key lessons applicable to other developing smart cities through evaluating Qatar’s approach, including the requirement of a well-defined regulatory framework, which can help in maintaining a balance between innovation and security, the significance of public-private partnerships in increasing technological adoption, and the role of digital literacy programs in ensuring inclusive participation. The thematic map and PRISMA synthesis together show that long-term sustainability depends not only on infrastructure investment, but also on governance capacity, interoperability, stakeholder trust, and adaptive regulation.

This research contributes to the broader discourse on smart cities by presenting a comprehensive framework for sustainable digital transformation that is supported by survey

analysis, stakeholder interviews, thematic mapping, and PRISMA-based evidence synthesis. It offers valuable lessons for Qatar's policymakers, technologists, urban planners, and others.

Declaration

I declare that the research in this thesis is the author's work and submitted for the first time to the Post Graduate Research Office at Brunel University London. The study was originated, composed and reviewed by the mentioned author in the Department of Electronic and Computer Engineering, College of Engineering, Design and Physical Sciences, Brunel University London, UK. All information derived from other works has been referenced and acknowledged.

Maryam Majareh

March,2025

London, UK

Dedication

This thesis is dedicated to the spirit of knowledge and understanding, as invoked by Prophet Musa (peace be upon him):

In the Holy Qur'an (Verse 114)

{وَقُلْ رَبِّ زِدْنِي عِلْمًا} (الآية 114)

Which translates as "And say, 'My Lord, increase me in knowledge.'" This verse embodies the belief that our quest for knowledge is a perpetual journey. We learn not to surpass each other, but to continually grow and complete one another, recognizing that no one holds all the wisdom. In this light, I dedicate my efforts to all who believe in the enriching power of continuous learning

Acknowledgements

Completing this PhD thesis has been a challenging yet immensely rewarding journey, and it would not have been possible without the support, guidance, and encouragement of many individuals and organisations. I would like to take this opportunity to express my heartfelt gratitude to all those who have contributed on this work.

First and foremost, I would like to thank my supervisor, **Prof George Ghinea,** for guidance, patience, and unwavering support throughout my research. Their expertise, insightful feedback, and encouragement have been instrumental in shaping this thesis and my growth as a researcher. I m deeply grateful for the time and effort they have invested in mentoring me.

I am also profoundly thankful to my co-supervisor, **Dr Stasha Lauria**, for their constructive criticism, thoughtful suggestions, and continuous support. Their perspective has greatly enriched my work and broadened my understanding of the field.

I extend my sincere gratitude to the members of my progression panel, **Prof Steve Counsell, Dr. Dr Fang Wang** and **Dr Fotios Spyridonis,** for their valuable feedback and encouragement during my progress reviews. Their insights have significantly improved the quality of this thesis.

On a personal note, this journey has been marked by both profound loss and joyful new beginnings. I dedicate this thesis to my **beloved parents**, who are no longer with us, but whose love, encouragement, and sacrifices continue to inspire me every day.

My father, in particular was a source of immense motivation, always encouraging me to pursue my dreams and complete my PhD. Losing both my parents during this journey has been one of the most difficult experiences of my life, but their memory has been a guiding light, pushing me to preserve.

At the same time, I am filled with gratitude for the new additions to our family. The arrival of my grandchild’s, **Hamad** and **Muneera**, brought immense joy and hop, reminding me of the beauty of life and importance of cherishing every moment. To my beloved spouse, **Ali**, and my wonderful children, **Al Dana, Mohammed, Al Maha, Noora** and **Saeed**. Thank you for your endless patience, understanding and unwavering belief in me, especially during the most challenging times. Your love and support have been my anchor, and this achievement is as much yours as it is mine.

Finally, I would like to thank all the participants, collaborators, and individuals who contributed directly or indirectly to this research. Your support has been invaluable, and I am truly grateful for the opportunity to work with you.

This thesis is a culmination of the efforts of many, and I am humbled by the generosity and kindness I have received along the way. Thank you all.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AI	Artificial intelligence
AR	Augmented reality
ARPU	Average revenue per user
BCA	Building and Construction Authority
BDA	Big data analytics
CASP	Critical Appraisal Skills Programme
CDP	Compliance and Data Protection Department
CGB	Civil Service and Government Development Bureau
CHP	Combined heat and power
CMC	Central Municipal Council
CPTED	Crime Prevention Through Environmental Design
CRA	Communications Regulatory Authority
CUD	Connected Urban Development
DA 2030	Digital Agenda 2030
DDoS	Distributed Denial of Service
D-DUP	Data-driven urban planning
DT	Digital transformation
E2PO	Energy Efficiency Programme Office
FaaS	Freight as a Service
FDI	Foreign direct investment
FIFA	Fédération Internationale de Football Association
GCC	Gulf Cooperation Council
GCO	Government Communications Office
GIS	Geographic Information Systems
HMC	Hamad Medical Corporation
HVAC	Heating, ventilation and air conditioning
IoT	Internet of Things
ITS	Intelligent transport system
KPI	Key performance indicator
KYC	Know your customer
LCCC	Lusail Control and Command Centre

LMS	Learning management system
LNG	Liquefied natural gas
LTA	Land Transport Authority
MaaS	Mobility as a Service
MCIT	Ministry of Communications and Information Technology
MEHE	Ministry of Education and Higher Education
MENA	Middle East and North Africa
ML	Machine learning
MME	Ministry of Municipality and Environment
MNC	Multinational corporation
MRT	Mass Rapid Transit
MoU	Memorandum of understanding
MoTC	Ministry of Transport and Communications
NGF	National Geo-Spatial Framework
PPP	Public-private partnership
PTZ	Pan-tilt-zoom
QAST	Qatar Academy for Science and Technology
QCB	Qatar Central Bank
QCS	Qatar Construction Specifications
QFZA	Qatar Free Zone Authority
QGBC	Qatar Green Building Council
QMIC	Qatar Mobility Innovations Center
QNBN	Qatar National Broadband Network
QNV’30	Qatar National Vision 2030
QoL	Quality of life
QRSC	Qatar Robotic Surgery Center
QSAS	Qatar Sustainability Assessment System
QSTP	Qatar Science and Technology Park
QU	Qatar University
QWC’22	Qatar FIFA World Cup 2022
REAMS	Rail Enterprise Asset Management System
SC	Smart city
SCC	Smart City Cologne

SCT	Smart city technology
SCTF	Smart City Transformation Framework
SD	Standard deviation
SDG	Sustainable Development Goal
SDT	Sustainable digital transformation
SNDGO	SMART Nation and Digital Government Office
SNSP	Smart Nation Sensor Platform
SOC	Security operations centre
STEM	Science, Technology, Engineering, and Mathematics
TASMU	Smart Qatar Program
TIS	Traffic Information System
TOD	Transit-oriented development
TOGAF	The Open Group Architecture Framework
UDP	Urban Data Platform
URA	Urban Redevelopment Authority
VR	Virtual reality
WHAN	Wireless Home Area Networks
Wt. Av.	Weighted average

CHAPTER 1
Introduction

1.1. Background

1.1.1. Digital Transformation (DT) and Smart Cities (SCs)

Modern urban planning is facing unprecedented opportunities and challenges with the emergence of revolutionary new technologies and systems of production, and fundamental changes in the way people live within and use spaces. Researchers and practitioners are seeking to develop solutions to emerging issues, considering questions such as what makes a city "smart" in the digital age? How can a complex urban fabric develop intelligence that drives planning and decision-making and positively impacts the lives of its residents? What are the organisational, technological, or cultural components that enable a city to reinvent its way of working and achieve sustainable development steps? In brief, how can governments and other stakeholders build a "smart city" (SC) and achieve public value using sustainable digital transformation?

The concept of a smart city is inherently multi-faceted and extends beyond the deployment of information and communication technologies (ICTs). Albino, Berardi & Dangelico (2015) stated that smart cities integrate technological infrastructure with human capital, social inclusion, governance mechanisms, and environmental sustainability. Therefore, smart cities are not only technology-driven urban spaces but socio-technical systems that focuses on enhancing the quality of life (QoL), economic competitiveness, and environmental performance with the help of coordinated digital innovation. This multi-faceted behaviour makes the smart cities a well-suited and required context for evaluating sustainable digital transformation. SCs function as complete systems to evaluate the relationship between digital infrastructure and social and environmental objectives (Wessel et al., 2021). Smart Cities represent urban environments that leverage ICT infrastructure alongside human and social capital to enhance quality of life and sustainable development (Albino et al., 2015; Nam & Pardo, 2011). Digital Transformation (DT) is defined as the fundamental reconfiguration of organisational activities, processes, and competencies to leverage digital technologies strategically.

Digital transformation (DT) refers to the intelligent transformation of organisational activities, businesses, processes, and models to fully leverage the changes and opportunities of a mix of digital technologies and their accelerating impact across society in a strategic and prioritised way considering the changes that have happened in the past and might happen in the future. Vial (2021) describes a systematic process that creates substantial improvements for an organization through the application of information technology, together with computing systems, communication tools, and network connection systems. Hence, DT is redefining the way goods, services, and information are produced, consumed and traded (Dengler & Britta, 2018). In contrast, some studies highlight that DT is not merely about technology adoption, but about fundamental organisational and institutional change. DT is also a process that triggers significant changes in value creation, structures, and governance and distinguishes DT from traditional IT-enabled transformation by indicating its strategic, systemic, and continuous nature.

Moreover, based on the "digital city" definition, *de facto* SCs are already widely used in daily livelihoods, environmental protection, public security, city services and other fields, albeit in different and even unacknowledged ways (Su et al., 2011). By extension, Sustainable Digital Transformation (SDT) denotes the incorporation of sustainability components into the transformation of digital platforms. Specifically, SDT is focused on key areas encompassing collaboration and governance, social equity, economic development and resilience against adverse conditions (Das, 2024). Therefore, SDT offers a conceptual bridge between digital transformation initiatives and the long-term sustainability objectives reinforced within the development of smart cities.

Nowadays, digital technology in society and business is going rapidly from the margins to dominate the mainstream. Assuming a central and commanding position, digital technologies entail fundamental innovation in many sectors, such as media, communications, and manufacturing. These developments raise many serious questions about the wider impacts of DT and the implications of digitalisation in various economic, business, and societal fields.

Despite the increasing academic awareness, there is limited empirical insights about how SDT can be operationalised within smart city initiatives, particularly in emerging economies and resource-rich states. It is essential to reconsider the human dimension in this process, which is all too frequently ignored (Klewes et al., 2017), and this study seeks to address this gap by examining SDT within the smart city context of Qatar.

Internet, communication, and smart technologies are increasingly integral parts of life for most people, thus governments are seeking DT and the use of technology to streamline and improve public services, which can have diverse impacts including promoting livelihoods and consequently improving living standards, as well as increasing transparency, accessibility, and equity in governance. However, successful digital transformation requires a connection among technological capabilities, institutional readiness, and public acceptance, factors that remain under-examined in relation to smart city sustainability. One of the most effective approaches to find a solution for transformation and innovation is to learn from other domains where a solution for similar problems is already available (Kim, 2015).

The next step after SCs is to create digital or smart nations, which require national transformation across different institutions including urban and rural areas of society. Various existing studies and policy interventions mainly emphasised on the city-level transformation but Kar et al. (2019) in their study state that sustainable outcomes demand a broader national perspective which indicate a further research gap which concerns about how smart city-level SDT initiatives can be scaled and coordinated at the national level.

There are many studies regarding Social Change (SC) in both Western and Eastern Asian settings; however, empirically-based frameworks for Sustainable Digital Transformation (SDT), specifically within GCC member-states, continue to be limited. The empirical framework deficit is most apparent in the case of Qatar, where large hydrocarbon reserves enable the rapid adoption of digital technologies, while regulatory and cultural conditions necessitate a theoretically-constructed model that accounts for local conditions, as reviewed in Chapter 2, but few discussed the role of SDT and how it can contribute to smart nations, specifically within the Gulf Cooperation Council (GCC) context. The studies conducted by Salem (2016) and Zhu et al. (2022) highlights that technological infrastructure and governance frameworks are very important foundation but there is insufficient exploration of stakeholder engagement, sustainability integration, and long-term value creation through SDT. In result, this study will address this gap by evaluating SDT in Qatar’s smart city initiatives.

1.1.2. About Qatar

This section examines Qatar's general state of affairs regarding digital transformation (DT), including Qatar’s background, form of governance, and socio-economic progress.

Furthermore, this section will assess Qatar's ability to achieve Smart City (SC) and Sustainable Digital Transformation (SDT) goals as outlined by Qatar National Vision 2030 (QNV 2030).

Qatar has developed considerably in terms of both economic growth and technological advancement; nonetheless, there are still several hurdles that Qatar must overcome. As an example, Qatar relies very heavily on exporting hydrocarbons. Additionally, Qatar performs few diversification activities economically. Lastly, Qatar is attempting to create a balance between modernizing its economy, while also continuing to preserve its culture.

Qatar received its first autonomous status from the UK in 1868; notwithstanding having been subject to British or Ottoman rule at different times throughout history, Qatar maintained its own identity until achieving full sovereignty in 1971, primarily as a result of agreements and constitutional reforms that were implemented at that time.

The Emir leads Qatar's ruling authority which includes the Council of Ministers and the Advisory Council. The Constitution of Qatar establishes the separation of the three branches of government into their respective spheres (executive, legislative and judicial). Government agencies act as facilitators for implementing the policies of government as well as acting as coordination bodies for many governmental operations within Qatar.

As a result of massive scale developmental programs and a high level of living standards, Qatar has had unprecedented levels of economic and social growth. The Permanent Constitution was enacted in 2004 to protect the rights of citizens as well as to develop new institutions. The modernization process continues today, but it is done so with the intention of protecting Qatar's cultural identity, and addressing problems such as fast paced population growth and the reliance on foreign workers.

Additionally, in addition to improving Qatar's international image through hosting various international events like the upcoming 2022 FIFA World Cup, Qatar has also made sizeable investments in the areas of sports and infrastructure.

While a great deal of work has been accomplished toward the realization of DT- and SC-based initiatives, there are still a number of obstacles to be overcome prior to these initiatives can reach their full potential. These include limited capabilities to innovate; skills shortage; and sustainability concerns. For example, TASMU represents a demonstration of the commitment toward DT; however, presently there is no one integrated framework linking DT and long-term SDT objectives. While most of the current research focuses on individual elements of DT as opposed to creating a holistic SDT plan that corresponds to QNV 2030.

1.2. Research Aim

This research focuses on addressing the determined research gap by creating an overall framework for Sustainable Digital Transformation (SDT) to support the adoption and scaling of smart city projects in Qatar. It seeks to analyse progress, challenges, success and failure factors, and future opportunities associated with DT, with particular emphasis on sustainability, stakeholder engagement, and long-term public value creation. The main dimensions pertaining to the research are displayed in Figure 1.1.

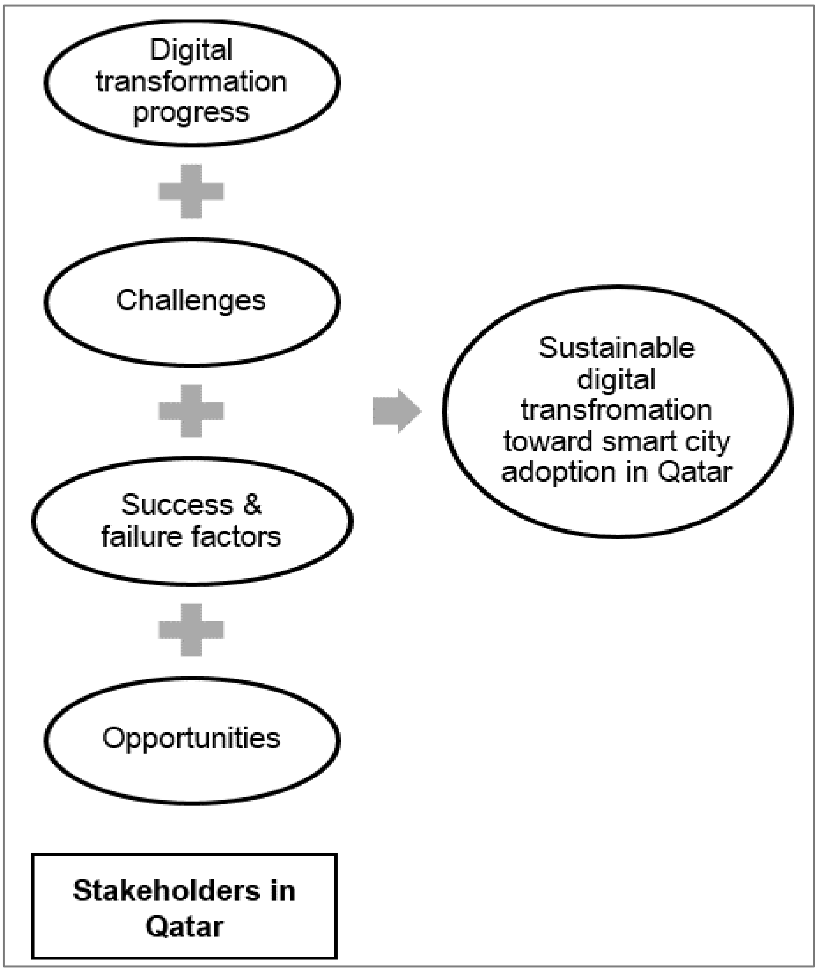


Figure 1.1: Research aim dimensions

Source: Author

1.3. Research Questions and Objectives

In order to achieve its aim, this research seeks to answer the following identified questions:

1. What are the chief challenges, key failure factors, and possible opportunities associated with sustainable digital transformation of smart cities in Qatar?
2. What is the current progress made toward digital transformation in Qatar?
3. What are the elements of the roadmap that might foster digital transformation Qatar?
4. What are the key stakeholders' views about the proposed roadmap for fostering digital transformation in Qatar?

These questions can be delivered through achieving five key objectives, namely to:

1. Critically examine related literature on SC theory and practice, in general and with particular relevance to Qatar.
2. Conduct a study to assess the progress, challenges, failure factors, and future opportunities for digital transformation and innovation for smart cities in Qatar, based on interviewing key stakeholders.
3. Identify key elements and propose a framework for fostering digital transformation for smart cities in Qatar.
4. Evaluate the proposed framework.
5. Draw conclusions and recommendations for research and practice.

1.4. Research Hypothesis

H1: Stronger smart governance mechanisms positively influence SDT outcomes

H2: Technological maturity mediates the relationship between governance and sustainability

H3: Stakeholder collaboration moderates the effectiveness of SC initiatives

1.5. Thesis Structure

Chapter 1: Introduction

In this chapter, background information on DT and SCs is provided, as well as the particular context of Qatar, describing the governance and development of the country and its national development goals, especially concerning technological advancements. The research aim, objectives and research questions are explained and presented.

Chapter 2: Literature Review

The authors used a systematic literature review method (PRISMA Page et al., 2021) to find in English all relevant publications from Scopus, IEEE Xplore and Web of Science, from 2014 through 2024 that are peer reviewed. The search terms used were the following ("smart city/cities" or "intelligent city") and ("digital transformation/digitalization" or "digital transformation/digitalization") and ("sustainability/sustainable development" or "sustainability/sustainable development").The literature review chapter examines the existing scholarly information concerning SCs, expounding prevalent theoretical frameworks and approaches to DT in general and in Qatar. It explains the conceptualisation of smart cities and related theories and technologies, including Artificial Intelligence (AI) and the Internet of Things (IoT). It then explains DT approaches and SC challenges, including cost, data issues, the regulatory environment, and community engagement. It identifies opportunities for SC development in relation to transport, the environment, and public finances and safety, as well as potential improvements for education, governance, and innovation. Studies on the current status of DT in Qatar are reviewed, considering public and private stakeholders' perceptions in Qatar and internationally. The chapter concludes by identifying research gaps that this study seeks to address.

Chapter 3: Methodology

This chapter explains the research philosophy and design underpinning this research, shaping its epistemology and the mixed methods used to gather data. It presents the rationale for the data collection methods (interview, questionnaire, and systematic review), and links them to the research objectives. It describes the sampling technique used to recruit a representative sample of participants, and the techniques used to analyse the emergent data. The ethical considerations undertaken in this study for participants' safety and protection are described. Finally, the chapter acknowledges the limitations of the selected methodology.

Chapter 4: Comparison of Current SC Framework of Qatar with Singapore

This chapter presents the profile of Qatar's smart transportation configuration, and then compares it with that of Singapore in terms of scale, energy efficiency, Data-Driven Urban Planning (D-DUP), smart healthcare, and smart security and safety. The main outcome of this analysis is that Qatar has achieved tangible progress, but is poised to go a lot further to attain a similar profile to Singapore.

Chapter 5: Results and Analysis

This chapter presents and discusses the findings arising from in-depth qualitative interviews and a quantitative survey of key stakeholders in Qatar's DT. The identified themes emerging from the analysis of interviews include current progress towards DT, associated challenges and opportunities, prerequisite elements for a DT roadmap, and stakeholders' views about the latter. Survey data is analysed in relation to inferential statistics (gender, age, occupation, experience, and perceived challenges relating to infrastructure), the regulatory environment, funding, technology adoption factors, and public acceptance and awareness.

Failure factors pertaining to the incorporation of SDT are then described, relating to inadequate planning, insufficient stakeholder-engagement, lack of skilled-workforce, technological barriers, and resistance to change. The identified opportunities are then described, including government support, Public-Private Partnership (PPP), technological advancements, international collaborations, economic growth potential. In relation to this, the current level of DT progress in Qatar is acknowledged, in relation to essential strategic elements, justified by descriptive statistics and correlation analysis, which can be used in the future to develop a model for Qatar's DT towards SC.

Subsequently, the findings from the quantitative survey are presented, including inferential statistics on gender, age, occupation, DT experience, perceived challenges and failure factors for SC SDT in Qatar, opportunities and current progress, essential elements, and familiarity with the proposed roadmap, and suggestions for its improvement. Descriptive statistics and correlation analysis are presented. The findings of the systematic review of high-quality recent studies are then described, synthesising the aggregate findings of related studies and their implications for SDT in Qatar.

Chapter 6: Roadmap and Discussion

The findings of this thesis are discussed in relation to the research questions, identifying their implications for SDT in Qatar in relation to challenges and opportunities, current progress, roadmap elements, and key stakeholders' views. Based on the findings presented in Chapter 5, Chapter 6 begins with exploratory analysis of key stakeholders, considering collaborative frameworks, organisational goals and national DT objectives, centralised digital platform engagement, challenges to collaborative governance, DT initiatives and SC sustainability, suggestions for a centralised DT platform, and support for investment and collaboration for implementation.

Chapter 7: Conclusion

This chapter concludes the thesis, presenting recommendations for key stakeholders based on the empirical findings. These include international collaboration, green technology public and private investment, and a centralised DT system.

1.6. Chapter Summary

This introductory chapter has examined the research context key concepts, and motivation for the study. It has shown that the multi-dimensional nature of smart cities, the strategic and holistic character of digital transformation, and the limited scholarly attention given to sustainable digital transformation within smart city initiatives, specifically in the context of Qatar. This chapter justifies the requirement for proposed study by developing research gap. The following chapter reviews existing literature to further refine the theoretical foundations and identify gaps that inform the research design.

CHAPTER 2

Literature Review

2.1. Introduction

This chapter offers a comprehensive examination of the existing body of literature germane to SDT in Qatar and SCs. It identifies pertinent theories, methodologies, and research gaps, which informed the data exploration conducted in this thesis, thereby making a valuable contribution to the existing knowledge base (Bell et al., 2022). This research aims to establish a new framework for SDT and innovation for the adoption of SC projects in Qatar. Accordingly, this chapter encompasses a review of related theoretical and empirical literature, identifying gaps and limitations in existing studies on the subject that the current research seeks to address. Furthermore, this literature review examines the major ideas and advancements regarding Qatar's transition into a SC with an emphasis on SDT, and compares its current profile with that of Singapore, to identify opportunities and challenges. Importantly, this chapter is structured to (i) synthesise how SDT and SC literature are conceptually linked, (ii) justify the selection of theoretical models used in this study, and (iii) position Qatar's SC transition within both regional (MENA) and international contexts.

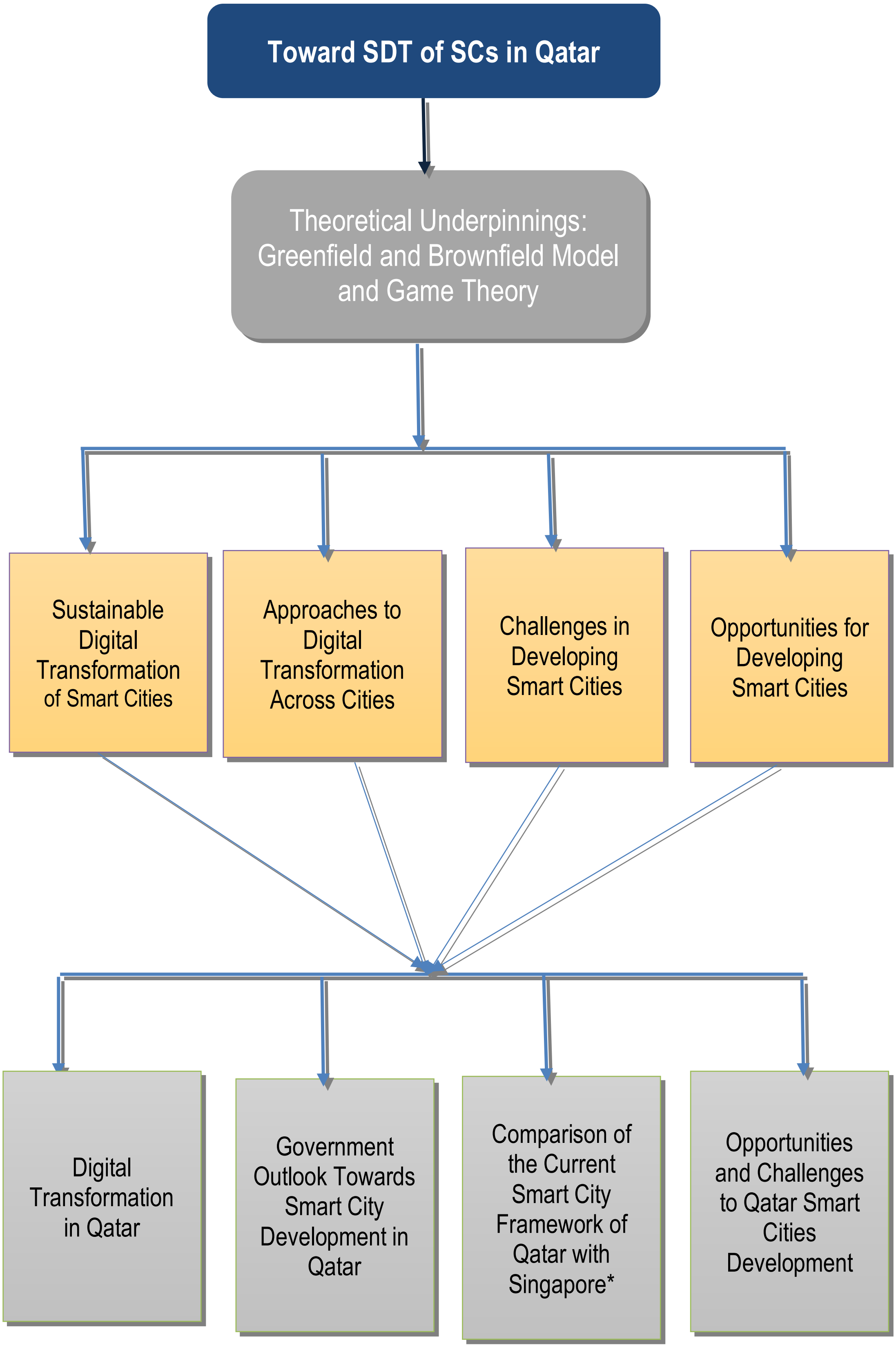
This comparative focus is justified as both Qatar and Singapore operate long-term national development visions (QNV 2030 and Singapore Vision 2030) structured around economic diversification, social development, governance excellence, and environmental sustainability, making Singapore a relevant benchmark for analysing SDT maturity and governance-led SC development.

In this study, a systematic literature review (SLR) approach is adopted to make sure rigour, transparency, and reproducibility. Peer-reviewed journal articles, policy reports, and authoritative institutional publications were sourced primarily from databases including Scopus, Web of Science, IEEE Xplore, ScienceDirect, and Google Scholar. To search these articles, some keywords were identified which consists "Smart Cities", "Sustainable Digital Transformation", "Digital Government", "IoT", "Artificial Intelligence", "Smart Governance", "Qatar Smart Cities", "MENA Digital Transformation", and "Urban Sustainability". Furthermore, backward (reference list screening) and forward citation searches were conducted to identify influential studies. Inclusion criteria focused on relevance to urban digitalisation, sustainability, governance, and policy implementation, while non-empirical or contextually irrelevant studies were excluded.

2.2. Conceptual Foundations of Smart Cities

2.2.1. Theoretical Foundation

The framework incorporates Game Theory (Myerson, 2013), and urban development theory (Greenfield/Brownfield models) as a method to consider the unique conditions of rapid urbanization in Qatar. Game Theory will be used to model the balance of competing interests of stakeholders in SDT implementation; Government, Private Sector, Citizens. The Greenfield/Brownfield model will be used to analyze the newness of development in Qatar vs. the reuse of its existing urban structure.This research fundamentally seeks to explore ways in which an SDT can be achieved in the development of SCs in Qatar. According to Hadjitchoneva (2020), “smart people” and “smart environments” are the elemental features of SDT that critically affect SCs (i.e., the human users of cities and the cities themselves). The use of renewable resources and a circular economy are other key factors associated with the SDT paradigm (Rosário & Dias, 2023). In essence, the combination of the above SDT components ensures efficiency and innovation in the optimisation of social equity and lowering environmental impact in SCs. To provide a robust theoretical foundation for the research work, a comprehensive conceptual framework has been constructed, based on the reviewed literature about DT in general, and its particular application in Qatar (Figure 2.1).



* Using smart transportation, energy efficiency, D-DUP, smart healthcare, smart security and safety.

Figure 2.1: Conceptual framework of this research

Source: Author

A conceptual framework connotes the structure followed in the research to achieve an in-depth understanding of the research phenomenon while making an in-depth inquiry into a specific topic. Essentially, it is developed for the research to organise the thoughts, explain terms and clarify the direction of the study effectively. The conceptual framework for this research shapes how this research is organised, and developed based on reviewing existing literature in this research field.

To inquire about the chosen research area, the researcher started with the conceptualisation of DT and SCs, to clarify the theoretical basis for approaching this study. The concepts of the sustainability of DT concerning SCs in Qatar and related challenges to developing SCs and opportunities for developing them are identified from past scholarly evidence in the following sections. Based on these generalised insights, the existential activities of the move towards DT in Qatar are probed in this chapter by exploring national innovation, technology revolution, information and communication infrastructure, and SC development.

This chapter also explores the government's outlook towards SC development in Qatar, with a comparison of the current national SDT framework with international norms, and identifies opportunities and challenges to the DT of Qatar's SC development. In so doing, this chapter seeks to obtain deeper insights on the research aims and objectives and identify gaps in the existing base of evidence.

2.2.2. Factors for SDT in Qatar

The conceptual framework has highlighted the factors surrounding the SDT in Qatar. SDT is also observed in Qatar in terms of the formulation of the Qatar Free Zone Authority (QFZA), which was inaugurated in 2018 to galvanise logistics, warehousing, and industrial development (Elidrisy, 2024). The core objective of QFZA is to provide citizens with a "state-of-the-art infrastructure" which is highly attractive for the local and foreign investors, offering specialisation in terms of chemicals, emerging technologies, as well as logistics related to maritime as well as ICT businesses (Mogielnicki, 2021). Moreover, QFZA has also launched a large proportion of projects through making investments in billions of riyals that are purposed towards providing facilities in terms of sustainability, communications, big data as well as cyber-security. QFZA has also launched another project in integration with Google Cloud for the inauguration of new cloud facilities within the GCC as well as other parts of the Middle East and North Africa (MENA) (Elidrisy, 2024). These practices connect with the four pillars of Qatar National Vision 2030 (QNV 2030): human development, social development, economic development, and environmental development. The SDT practices includes QFZA and cloud infrastructure investment that contributes mainly towards economic diversification and human capital development along with supporting environmentally efficient industrial ecosystems.

2.2.3. Approaches of DT Across Qatari Cities

According to Qatar’s Civil Service and Government Development Bureau (CGB, 2023) as an approach towards DT, the Qatari government launched the Government Excellence Program under Emir’s Decision No. 63 of 2023, concerning investments in DT for improving the productivity levels and effectiveness of e-governmental services. Currently, under this programme, every ministerial unit as well as related organisations that are providing e-services are engaged with each other under a singular umbrella e-government strategy that integrates the technological resources as well as human capital by offering specialised recognition and rewards.

Moreover, the above-described conceptual framework is also purposed towards exploring the approaches towards DT across cities in Qatar. DT in the public sector of Qatar is dependent on an interactive e-government strategy that is identified to occur between the technological means surrounding the backend service production systems as well as the front-end service-oriented interface. This “Qatar Digital Government 2020 Strategy” is focused on enhancing the efficiency of the government administration and development of open governmental schemes (Ministry of Communications and Information Technology [MCIT], 2024a). The DT is also dependent on governance mechanisms, and public authorities are identified to comparatively generate a high degree of control to safeguard public-oriented beliefs (Meyerhoff Nielsen & Mahmoud Ali, 2021).

Furthermore, as with general areas of economic activities, there is a need for the establishment of an equilibrium between public control as well as private autonomy. In addition to the above, the e-governance approach involves different procedures surrounding the governance as well as business decisions that are taken in the context of the technology as well as IT-based applications. E-governance is used in Qatar as the key approach for the introduction of DT, as well as ICT, for offering information as well as public-level services to individuals that involve effective implementation of decisions surrounding organisational governance (Meyerhoff Nielsen & Mahmoud Ali, 2021).

Aside from such actual practical progress on the ground, driven by executive direction, the government has also fostered grassroots awareness and readiness for DT. As noted by Malkawi (2022), the Ministry of Education and Higher Education (MEHE) planned an integrated approach that involves several projects assuring the utilisation of information as well as communication technology at different phases of education, beginning from kindergarten as well as lasting up to the delivery of university education. For example, the Qatar Academy for Science and Technology (QAST) is a high school that is designed for the development of innovators and experts having specialisation in Science, Technology, Engineering, and Mathematics (STEM). Furthermore, the QAST program begins from Grade 9 and provides three different course curricula in the fields of Computer Science, Biomedical Sciences and Engineering. The programme enables an active involvement of the individuals in the research projects and internships as well as industrial organisations across the nation, which also involves peers in the Education City (Qatar Foundation, 2024).

These projects are also purposed towards three core elements of DT: student learning and education, the preparation of technical knowledge for teachers, and providing qualifications for trainers. This further focuses on the education management surrounding digital technologies. The Supreme Education Council earlier framed the "Electronic Bag Project" in 2012 through the integration of technology by strategic approach for activation of the communication process, interaction as well as creative engagement among individuals (The Peninsula Qatar, 2013). Furthermore, the Qatari government has also formulated the AI Committee following the Communications and Information Technology as per the Cabinet Decision 10 taken in 2021. Furthermore, the "National AI Strategy" in Qatar is aimed towards implementing six dimensions - data access, education, business, research, employment, as well as ethics that help in enabling a smooth transition towards AI (MCIT, 2014b, 2024b). In addition to this, Qatar University (QU) has inaugurated the Kindi Center to enable research and growth in the computing sector. The Future Tech Forum can be considered a pioneering initiative that helps to align with the National Cybersecurity Strategy and AI Strategy, promoting growth in the AI and cyber-security domain (QU, 2022).

Moreover, the MEHE has launched the MS Teams Programme as a digitalised education system for students studying between 1 to 3 grades. For students studying in 4 to 12 grades, MEHE has deployed its own Learning Management System (LMS) to enhance communication among parents, students, and teachers. The LMS allows teachers to establish continuous interaction with the help of a chat facility through the virtual education system. This has also helped the management of the learning team after COVID-19 and has accelerated the use of technology (Teng, 2021; Tribune News Network, 2020).

It can be surmised from the above description that many public institutions in Qatar are actively engaged in DT, and Hussain et al. (2022) observed that approaches surrounding the DT in Qatar involve the installation of modernised equipment as well as software that have the ability to exert significant changes in the national communication, management, and business culture. It is further evaluated that DT strategy in Qatar involves the introduction of changes within the operational activities of an economy. The DT strategy involves inclusion of the digital economic activities that involve individuals looking for airline tickets, train ticket booking, and booking services with the help of digital applications as well as getting involved in online conferences, as well as online payment applications.

For example, the Qatar Central Bank (QCB, 2023) initiated the "Qatar Fintech Strategy" in March 2023, which is focussed on introducing DT in the financial service sector of the Qatari economic ecosystem. This has helped in enabling "Know Your Customer" (KYC) regulation, diversification of the economy, obtaining Foreign Direct Investment (FDI), and developing essential skillsets among Qatari workers for financial services in future periods (PWC, 2023). This type of DT is introduced in Qatar with the help of different types of digital as well as economic tools such as mobile applications, smartphones, as well as Internet which enhance the ease of living among individuals.

Moreover, the Communications Regulatory Authority (CRA) of Qatar is the key regulator for the communication practices of the Qatari state under the Emir's Decree No. 42 of 2014. The CRA is responsible for the management of information technology as well as the telecommunication domain. The CRA makes the current infrastructure of Qatar ready for innovative, as well as reliable communication-oriented services (CRA, 2022, 2024). In addition to this, in 2022, Qatar has also implemented advanced technologies such as AI, drones, Internet of Things (IoT) as well as digital twins in the FIFA World Cup in Qatar in 2022 (i.e., the "Qatar World Cup 2022", hereinafter "QWC'22"). Qatar has also enabled the execution of the 5G-enabled FIFA World Cup in integration with the AI-enabled connected ball technology, and audio descriptive Arabic commentary (MCIT, 2014b, 2022).

As described by Exito (2024), it is estimated that total digital spending across Qatar City had increased to USD 3.2 billion by 2023, and more than 70% of the business companies in Qatar were identified to be poised to adopt the global DT strategy in the coming years. QNV'30 is the key digitalisation approach that is used by Qatar, which is identified as the primary source behind the 360-degree national development blueprint for major business industries. This strategy has also contributed towards the transformation of Qatar into a developed nation and the implementation of an e-government strategy which is useful for enhancing the effectiveness of the governmental administration. Under the e-governance strategy, DT is introduced by the development of common governmental applications that help in minimising costs and enable optimisation (Exito, 2024).

The literature highlights that DT approach of Qatar is predominantly governance-led that indicate a top-down policy orientation consistent with other MENA states pursuing Vision-based national transformation strategies (Usetechnology, 2023). This allows for the fast infrastructure deployment but it increases the coordination challenges across ministries which shows the relevance of stakeholder interaction theories examined later in this chapter.

2.2.4. Challenges and Opportunities in Developing SCs in Qatar

Badran (2023) reviewed challenges for Qatar-specific SC development in terms of economic aspects, where the prevalence of strong competition is observed digitally among service providers as well as private-level information and communication technology companies. The ICT companies are further identified to generate regulatory concerns in terms of the projection of SCs. The legal experts as well as regulators are required to outline the rules as well as competition regulatory models like CRA for assuring the effective entry of the digital service providers and ICT companies in the newly emerging SC marketplaces.

Under the CRA, public response is considered as CRA is identified to utilise public consultations in the form of a regulatory process for receiving input from public sources as well as the industry surrounding the related matters (Badran, 2023). For example, the CRA has realised the significance of public consultation towards the proposal for obtaining the Class License regarding the Wireless Home Area Networks (WHAN). By considering the feedback of the consumers, interested parties as well as stakeholders through their personal views as well as comments, the CRA has adopted a flexible and consultative approach to making updates regarding a new technology (CRA, 2019). However, it can be found that the absence of proper competition legal frameworks as well as rules generates an unwanted fluctuation and economic flow within the monopolies; consequently, there is a need to plan more than one regulatory approach to deal with competition (Badran, 2023).

In the same vein, the Smart Qatar Program (TASMU) has further outlined the key standards as well as policies for providing support for smart country-related initiatives. This involves the execution of data protection, maintaining data confidentiality, accessibility of information, and integrity as well as minimising the ethical risks along with the environmental effects behind the deployment of emerging technologies, TASMU involves societal impact policy, interoperability policy, experience policy, security policy, data policy and electronic commerce as well as transaction policy for the elimination of the regulation-oriented barriers that assists in deploying SC-based solutions (TASMU, 2023a, 2023b).

Moreover, it is also found that the SC regulators introduce competition within the market involving competition among more than one operator for multiple customers. The SC regulators are further identified to generate a competitive environment for the operators to execute competition in the market. This is performed to execute a comparison of the overall effectiveness of DT operations (Badran, 2023). However, the planning of SCs involves the application of machines as well as smart applications that are responsible for the establishment of communication with each other without the need for any interference from humans such as the user.

In this direction, the prevalence of certain challenges surrounding privacy as well as data security due to the chances of disclosure of personal information can be observed (Edwards, 2016). One aspect of this is the deployment of sensors along with the other forms of smart devices that help in analysing, collecting, as well as preserving private data collected from private spaces, including residences, vehicles, and even the bodies of individuals (e.g., via smart fitness trackers) (Badran, 2023). Furthermore, it is found that a considerable proportion of information is developed as well as used on a timely basis for the adoption of effective SC planning-related decisions. These decisions are taken by machines in place of human users. The above issues surrounding the management of private data by machines are identified to generate regulatory challenges and fundamental public concerns concerning citizens' rights etc., intersecting with conventional regulations safeguarding personal information and human rights.

A considerable proportion of the user information as well as details collected regarding the residents of SCs is sensitive, and is not required to be shared with other residents. However, due to the involvement of smart devices, there are possibilities of mistakes in handling and managing confidential data. In this way, the private data of the users is probable to be shared with other individuals in an intentional or non-intentional manner, which results in compromising data privacy and even fundamental human rights. Similarly, the infrastructural resources, namely the centres for traffic control, airports, bridges, hospitals as well as tunnels are prone to attack due to the hacking of the susceptible smart devices integrated into the SC plan. This may generate criticality for the lives of different individuals (Badran, 2023; Van Zoonen, 2016).

Moreover, Qatar's "Personal Data Privacy Protection" (Law No. 13 of 2016) seeks to preserve data privacy by assuring personal data processing with the help of one or more operations for collection of receipt, undertaking registration, usage, modification, publication, cancellation as well as data withholding. This law further manages the cross-border flow of personal information (Compliance and Data Protection Department [CDP], 2016).

All these challenges highlight the requirement of balancing innovation with regulatory oversight and citizen trust which is the key criteria of SDT that extend beyond technical performance to include ethical, legal, and social sustainability.

2.3. Conceptualisation

2.3.1. Smart Cities

Beginning with evaluations of the social, environmental and technological factors associated with urban development (Albino et al., 2015; Hollands, 2008), the smart city is not just the application of new technology to an urban context; it encompasses socio-technical systems that incorporate the interaction between governance, economic activity, the environment and human capital. The six key dimensions of a smart city were first identified by Giffinger et al. (2007): smart governance, smart economy, smart mobility, smart environment, smart people and smart living. This conceptualisation based on multi-dimensionality underlines the fact that a smart city does not simply represent a technological artefact but a complicated socio-technical system that is complicated. It is based on the interaction of technology, human capital, social inclusion, governance mechanisms, and environmental sustainability, which contributes to the necessity of an integrated approach to sustainable digital transformation (Albino et al., 2015; Nam and Pardo, 2011). These dimensions highlight the necessity of a holistic approach to urban development.

From a social perspective, the emphasis of smart cities lies in developing human capital, creating social inclusion and enabling participation from citizens in governance. Smart people and smart governance create the conditions necessary to enhance transparency, promote citizen engagement, and improve decision-making. Furthermore, Hollands (2008) cautions against the potential negative consequences that can result when technology-driven solutions are developed without incorporating social equity into their design. As a result, rather than addressing inequality, these solutions may exacerbate it.

The environmental dimension of a smart city focuses on sustainable use of resources, energy efficiency and climate resilience through the integration of renewable energy sources, intelligent infrastructure and real-time monitoring of the environment. Albino et al. (2015) state that environmental sustainability is one of the fundamental objectives of the strategic initiatives that cities implement to develop a smart city strategy to reduce emissions and improve the environmental quality of urban areas.

A smart city relies on Information and Communication Technologies (ICTs), Internet of Things (IoT) and data analysis tools to support smart mobility and effective service delivery. Technology is primarily used as an enabling factor to promote social welfare, economic competitiveness, and environmental sustainability and should not be seen as an end in itself (Giffinger et al., 2007).

“SDT” lacks a clear definition, due to the varied nature of needs and opportunities of particular localities and communities, and the broad array of associated technologies, tools, and processes instrumental in the *de facto* process (Shcherbina & Gorbenkova, 2018). Consequently, the definition of SCs tends to vary from place to place, in line with levels of development as well as the willingness to embrace change. According to Korachi and Bounabat (2019, 2022), the “SC” is essentially a concept within a global discourse, but which has little actualisation. The authors based this view on a comparative study of different SC initiatives, which showed that most planned cities exhibit strong discursive components, as reflected in the wide availability of websites and pamphlets concerning them, but they established that there is very little spatial-physical articulation of SCs on the ground.

This is a reflection of the fundamental disconnect between theoretical models and the articulation of ideas and concepts surrounding SCs. Anthony (2021) defined an SC as an urban centre with data generation and processing capabilities enabling the implementation of predictive analytics for better provision of services. On the other hand, Al Thani et al. (2021) defined an SC as an efficient and sustainable urban centre that offers its inhabitants a high-quality life, courtesy of effective management of resources. The United Nations defines SCs as innovative cities with the capacity to deploy technology and other tools towards enhancing the QoL for their inhabitants, ensuring that the interests of future generations are protected (Salem, 2016).

In essence, all conceptualisations and developments of SC are anchored on the concept of technological development applied to urban planning, targeted at enhancing the delivery of services for the betterment of the local communities, and this consensus is reflected in the understanding of TASMU (2022), which considers SCs to be urban areas that utilise digital technologies in enhancing the efficiency as well as the sustainability of regular city operations. In this regard, they conceptualised SC in terms of the popular understanding of a nexus connecting the technological, business, social, and physical aspects of communities.

Anthony (2021) noted that modern cities are facing pressure to implement rapid development to accommodate improved socio-economic development while simultaneously minimising their adverse environmental impacts. Weber and Podnar Žarko (2019) postulated that the rapid rise in the global population over recent decades has resulted in increased pressure on available resources, which has been viewed as the main underlying driver for the shift from traditional city models toward SC models. According to Weber and Podnar Žarko (2019), SCs are implicitly assumed to be more sustainable and, hence, capable of addressing the challenges bedevilling society today. Silva et al. (2018), on the other hand, postulated that SC was developed primarily in order to solve contradictions that exist between the supply and demand of city resources, making it more of a logistical and supply chain phenomenon, facilitating economic globalisation. In essence, Silva et al. (2018) opined that the SC paradigm enhances the QoL of city inhabitants by focusing on efficient and sustainable solutions for the implementation of basic operations, including governance, healthcare, transportation, and energy management.

The MCIT (2022) declares that SC enhances the QoL of city inhabitants by focusing on efficient and sustainable solutions for the implementation of basic operations, including governance, healthcare, transportation, and energy management. Regardless of such theoretical conceptualisations, the reality of SC technologies (SCTs) and techniques on the ground in Qatar has already been evidenced by the QWC'22, which galvanised national DT, including the key updates launched by the Qatar Mobility Innovations Centre to the Wain platform (a home-enabled mobile application that provides location-related services within Qatar). The launch of updates in Wain has improved the experience of visitors and residents alike when using the roadways of Qatar and their increased traffic during the FIFA tournament. Wain is an alternative to the TASMU-based Smart Parking solution, which increases available options for the users. Furthermore, the sustainable solutions are also applied by the government of Qatar by implementing the InStadium Tech, which offers an increase of about 40% in terms of sustainable cooling in large public spaces (MCIT, 2022).

Similar to this, Abulhussain (2021) investigated the current state of research on Industry 4.0, which refers to the interoperability of technologies in the production as well as provision of services, concerned with creating a collaboration between technologies and manufacturing to maximise output while lowering resource utilisation (i.e., increasing the efficiency or resource utilisation, commensurately increasing profitability while potentially reducing environmental impacts). Angelidou (2014) acknowledged that Industry 4.0 is a major concept that intersects with SC, deeply related to the use of AI and automation to optimise production and track the movement of goods throughout their lifecycle.

In this regard, Industry 4.0 encompasses smart logistics and smart transport, all of which form an important aspect of SC. In essence, such studies indicated that Industry 4.0 asserts the smart use of resources as an integral aspect of optimising sustainability. Al-Thani et al. (2018) noted in this regard that smart technologies are identified to play a key part towards improving the efficiency of surrounding cities, along with transforming the public-level transportation systems. Information as well as communication technologies also promote intelligent systems of transportation that enable the integration of technological devices for information, transportation and communication.

More specific and localised micro applications are also key *de facto* drivers in SCs, although they may be conceptualised separately in terms of general sustainability initiatives by urban planners. For instance, Skinner and Bidwell (2016) found that bus transportation is increasingly integrated with green propulsion technologies in many urban environments, with the increasing adoption of hydrogen fuel cells and electric batteries. Furthermore, green propulsion systems can be powered through compressed natural gases as well as biofuels to provide ecological benefits to the low-density regions, where public means of transportation are otherwise considered expensive as well as unattractive. This also contributes towards reducing the negative environmental consequences and improving QoL and socio-economic development in urban areas.

2.3.2. Data Governance

DT is not necessarily sustainable, in terms of environmental impacts or indeed the social and economic needs of human communities. Qatar's MCIT (2020) discussed the characteristics of a smart government in order to foster the *sustainability* of SDT in Qatar's SC paradigm, based on government data. The key segments that formed the target of this research included open access to data for the public as well as transparency in governance. They established that good governance with support for information access can result in achieving the SDT of SC in Qatar. They argued that smart governance seeks to bolster the quality of services offered and the living conditions of local communities, in line with the general definition of SC, which is concerned with the connection of technology with the provision of services to people in urban areas. The researchers in this case argued that public information disclosures are a good example of good governance in a digital society, which is an essential part of achieving SDT.

2.3.3. Greenfield and Brownfield Models

As described by Shcherbina and Gorbenkova (2018), the greenfield transformation model concerns the adoption of intelligent decisions for spaces that were previously vacant, approaching the development of SCs from the perspective of the needs and the characteristics of the target city. The model adopts a basic process that proceeds from planning, design, delivery, consolidation, and transformation to the operationalisation phases. The model is concerned with the development of cities from the ground up with primary consideration of new technologies. This approach has, however been criticised for its failure to take into consideration traditional approaches to city development.

Carlsson (2014) identified that the principles behind the greenfield model are concerned with the elimination of centuries of knowledge and experience in urban planning and development, which entails both advantages and disadvantages. The model itself premises that the building of cities is best undertaken based on frictionless futures, anchored on the latest technologies. However, there has been increasing interest in retrofitting solutions as more inherently sustainable options for building novel cities, and Meijer and Thaens (2021) hold that SCs can be understood from a historical perspective as opposed to being developed from the ground up in a *tabula rasa* paradigm.

The brownfield model is applied to the cities that are already in existence. Ibrahim et al. (2015) describe that brownfield approaches focus on the improvement of existing cities through the installation of new technologies and retrofitting systems to improve operational performance and efficiency (particularly solutions to increase energy efficiency and reduce problems associated with traditional urbanisation). Notable improvements can be targeted in brownfield development, such as the adoption of new and improved traffic control systems, IoT applications, and the widespread deployment of public Wi-Fi points. According to Ibrahim et al. (2015), cities such as Amsterdam are notable examples of the brownfield model, where a well-established, traditional city adopted smart technologies in the implementation of its operations in the recent past, effectively deploying resources to improve sustainable mobility, the requalification of urban areas, and energy efficiency.

The main advantage of the brownfield approach is the reduced investment costs and utilisation of existing resources in development (Ibrahim et al., 2015). Given that the approach entails the installation of innovative systems in already existing cities, there are reduced costs associated with the development of buildings and fundamental infrastructure. Conversely, the greenfield model can achieve better technological and operational efficiency *per se*, generally outperforming brownfield development over the long term, but with massive up-front investment costs, and increased short-term environmental impacts is still inadequate (Ibrahim et al., 2015).

2.3.4. Game Theory

The above-listed references present a very useful starting point for further, theoretically and empirically oriented research based on the identified shortcomings in this study. The use of empirically supported Smart City implementation models that deal explicitly with complexity and coordination of stakeholders will greatly facilitate an improved understanding of Smart City and Smart Digital Transformation processes.

Prior empirical research by Saharan et al. (2020) and Mei et al. (2017) offers both theoretical and methodologically based, empirically founded suggestions that could be used as a base for such extensions, especially when it comes to the relationship between the stakeholder equilibrium and governance dynamics of multi-agents.

Saharan et al. (2020) empirically investigate Smart City implementation using a stakeholder equilibrium model and show that the success of Smart City projects depends on the aligned interests of all stakeholders involved: public authorities, private sector companies, the provider of technologies and the users themselves. The results of the study indicate that many Smart City projects do not succeed due to power asymmetry, lack of knowledge and lack of incentives among the stakeholders, rather than technical problems. Therefore, the authors illustrate, through empirically based modelling of the relationships among the stakeholders, how governance mechanisms and policy tools may be developed to create stable cooperation and reduce conflicts in complex urban systems. For example, integrating this type of stakeholder interaction into future SDT research will allow for a better understanding of how conditions of equilibrium evolve, especially in a centralised or rentier-type governance context.

Mei et al. (2017) have also conducted research into Smart Cities using multi-agent systems (MAS) and empirically modelled Smart Cities as dynamic systems, consisting of interacting agents (government agencies, infrastructure systems, service providers, etc.) and their respective behaviour and decisions. Through empirical simulation experiments, they illustrated how the decisions of individual agents influence the overall performance of the system (e.g., service efficiency, resource utilisation, and user satisfaction). A MAS-based empirical approach is highly suitable to understand Smart Digital Transformation, as it includes non-linear relationships, feedback loops and emergent behaviours, which are often neglected in static analytical models.

Using MAS-based empirical methods for modelling, as done by Mei et al. (2017), will enable future SDT research to extend the currently prevailing snapshot-orientation of SDT research to process-oriented and adaptive modeling. In particular, in fast-changing urbanisation and policy-driven environments, where institutional arrangements and stakeholder roles develop as a reaction to strategic measures of policymakers, such types of methodologies are well-suited.

By combining stakeholder equilibrium analysis with MAS-based empirical models of the kind proposed by Mei et al. (2017), the development of a rich and detailed analytical framework for the analysis of the interdependent evolution of governance structures, technological infrastructures and social actors over time becomes feasible.

Thus, the empirical contributions made by Saharan et al. (2020) and Mei et al. (2017) form a solid basis for the advancement of SDT research in resource-rich Smart City settings. In order to increase the explanatory depth, the strength of causal inference and the applicability to policy issues, future studies should combine longitudinal designs with stakeholder equilibrium models and multi-agent simulations. Furthermore, these approaches will contribute to the development of adaptive governance frameworks to manage the complexity of large-scale Smart City and SDT projects.

2.3.5. Sustainability of DT of SCs

According to Nagano (2019), corporate activities surrounding sustainable development are identified to be highly active in achieving Sustainable Development Goals (SDGs), whose attainment depends on diverse public and private stakeholders collaborating to shift society towards the introduction of DT in a sustainable manner. Guandalini (2022) emphasised that DT can potentially play a significant role in sustainability. In related research, Bracken and Greenway (2018) highlighted that the sustainability levels for DT need to be credibly communicated to governmental decision makers as well as private sector stakeholders. To promote DT, digital products must be developed cheaply and simply, and collective agreements must be fostered by “digital leaders” to disseminate DT from the governmental to local levels. A collegiate approach can reinforce the process of DT through increasing coherence between the government, HR policies, and design-related standards.

In addition, SCs can prioritise data-driven decision-making to optimise overall urban management. This can enhance the resource efficiency and improve the QoL. Lazaroiu et al. (2022) commented that the advanced systems, such as the IoT networks, can support AI and Big Data Analytics (BDA). These are used increasingly for the prediction of factors and addressing the challenges proactively. For instance, the energy efficiency in smart grids, waste management systems and the intelligent transportation networks are well implemented in minimising the environmental footprints. While fostering the growth in the economy, the participatory engagement of citizens can be reported in the shaping of the digital and physical infrastructure (Colding et al., 2024). This is to ensure the SCs remain inclusive, equitable and adaptable to the factors as per the changing societal needs.

Cities, including smart ones, face inherent challenges as a matter of course, which are exacerbated in contexts of high urbanisation (i.e., rapid growth in the urban population) and the associated increase in resource consumption (including demand for urban land and nearby water, power, and communication resources, in addition to schools and infrastructure, etc.). This fact emphasises how crucial it is to change perceptions about how cities operate to achieve sustainability (Mupfumira et al., 2024). Therefore, it is critical to develop a working definition of sustainability for this reason.

Allen and Hoekstra (2015) highlighted how crucial it is to determine the sustainability assessment scale for a system. A range of actions is needed to achieve sustainability globally and in urban contexts. Although there is no single accepted definition of sustainability at the urban scale, there are several traits that are frequently associated with it. The fulfilment of basic human needs, autonomy in communities, conservation of the natural environment, a substantial reduction in the use of non-renewable resources, economic vitality, diversity and intergenerational and intragenerational equity (e.g., social, geographic, and governance equity) are some of these.

In addition to the above, Goerzig and Bauernhansl (2018) emphasised that SCs comprise an innovative application of digitalisation practices that involve different forms of information as well as communication technology systems that seem to be infused for offering smart and upgraded facilities. A SC can also be identified as the key region that can introduce social structure in alignment with society, business, and technology. Moreover, Bokolo and Petersen (2019) have argued that an SC involves the application of technological, social, environmental, and human characteristics. SCs involve the deployment of technological innovation as well as digitalisation, which help in the generation of collective social, environmental, and financial incentives. Table 1.1 indicates the core SC attributes for consideration during planning as used in the plan for smart governance and smart mobility for the city of Qatar.

Table 2.1 Smart city attributes

Smart governance (participation)	**Smart mobility (transport and ICT)**
Participation in decision-making	Local accessibility
Public and social services	(Inter-) national accessibility
Transparent governance	Availability of ICT infrastructure
Political strategies and perspectives	Sustainable, innovative, and safe transport systems

Source: Bokolo and Petersen (2019)

These broader dimensions of sustainability in the context of DT for SCs present the application context in which the digital ICT tools envisaged by Anthony (2021) can unlock a considerable degree of development and growth. In the current time, DT is recognised as the latest means of development that seems to be driven by the help of technological progress, which causes disturbance in the existing business models within a differing business sector. The integration of smart technologies in cities in Qatar can enhance urban management in addition to promoting economic development, and it can also foster economic diversity and resilience.

In this regard, Kantam (2023) forecasts that the development of AI, ML, and IoT solutions can create opportunities for innovative business models and services, ranging from predictive maintenance and infrastructure to personalised public services. Additionally, there are instances of adopting the blockchain for the secured data sharing and transactions to further strengthen the trust and transparency among the stakeholders. This helps to enable the sustainable urban ecosystem. By leveraging of these technologies and SCs can better address challenges such as traffic congestion, energy consumption, and urban sprawl, paving the way for smarter and more efficient urban landscape.

According to Toli and Murtagh (2020), the environmental, economic, and social dimensions are all essential sustainability characteristics in themselves (although the environmental dimension tends to predominate in conceptualisations at the governmental level). The environmental dimension addresses the ecological aspect and includes preserving the natural environment (flora and fauna), natural resources and an economy centred on energy production. Urban areas' economic vitality and diversity comprise the economic dimension, while equity, community autonomy, citizen well-being and satisfaction of basic human needs comprise the social dimension. It has long been recognised that social justice, the preservation of the environment and its resources, economic growth, and a high standard of living are all essential attributes of sustainable urban development, and this concept long predates the relatively mature SC paradigm at the current juncture (Lehtonen, 2004).

Sustainability is an essential factor to take into account when planning, building and managing urban areas all over the world, particularly in the eponymous context of SCs. As explained previously, SCs essentially use cutting-edge technology, data-driven insights and creative infrastructure to improve citizens' QoL, while reducing resource consumption and environmental impact. As identified by Lee et al. (2014), SC sustainability can be examined from several perspectives, including social, political, economic and environmental. Concerning the environment, SCs seek to lessen their ecological footprint by implementing waste management plans, renewable energy sources, energy-efficient systems and environmentally friendly transit options. SC involves promoting electric cars and public transportation, integrating clean energy sources like solar and wind power and using smart grids to optimise energy distribution, all of which help to lower greenhouse gas emissions and improve urban air quality.

According to Trindade et al. (2017), certain cities have adopted the notion of sustainability in their SCs and have made the necessary efforts to reap their advantages and ensure their requirements are fulfilled. In their analysis, the following particular conceptualisations of SC in relation to sustainability can be discerned: (1) Amsterdam conceptualises SC as using innovative technologies and changes people's energy-related behaviour to tackle climate challenges; while (2) Barcelona sees SC as a high-tech, intensive, and advanced city that connects people, information, and city elements using new technologies to create a sustainable greener city, competitive and innovative commerce and increased QoL. The environmental aspect is thus more pronounced in the Amsterdam model, while in Barcelona, SC is mainly propagated under the auspices of economic modernisation. Conventz et al. (2015) mentioned that Doha's SC in Qatar practices involve more interaction between urban technologies and knowledge economy activities, which is somewhat more analogous to the Barcelona model as analysed by Trindade et al. (2017).

QNV'30 is a sustainability plan to guarantee the population's socio-economic development in alignment with global trends. According to Badran (2023), one of the main components of Qatar's SCs is economic sustainability. One of the top priorities is diversifying the economy away from hydrocarbons and petroleum; innovative city initiatives seek to do just that by luring in foreign capital, fostering domestic innovation and generating employment. Through the promotion of a knowledge-based economy and the encouragement of emerging technologies, Qatar can construct a more robust and sustainable economic foundation going forward (Al-Qahtani & Shiraz, 2023). To make sure that its urban centres are not only creative and practical but also resilient and peaceful places to live, Qatar understands the need to address environmental, economic, social, and technological challenges. In addition to reflecting its progressive mindset, Qatar's commitment to sustainability in SCs is evidence of its commitment to building a better and more prosperous future for its citizens and inhabitants.

2.3.5.1. Technological Obsolescence and Adaptive Governance

Smart Cities and Smart Digital Transformations are impacted by rapid technological advancements in many ways; however, they are particularly affected by the pace at which new technologies emerge and become obsolete. The rapid rate at which technology emerges, evolves and becomes outdated, results in a significant risk of obsolescence for Smart City and Smart Digital Transformation initiatives in urban areas that have been identified as being high-tech and/or digitally intensive. Furthermore, the rapid rate at which technology emerges, evolves and becomes outdated also creates significant financial risks and technical risks, including but not limited to: risks related to the creation of stranded digital assets and risks related to digital asset "lock-ins" (i.e., when a city's digital infrastructure is designed to operate optimally on one particular piece of hardware, software or other type of technology). Both of these types of risks are further exacerbated in cities, such as Qatar, which are experiencing significant levels of growth and modernization in their digital systems and where the deployment of these digital systems are often being implemented over compressed timeframes.

Adaptive Governance has been identified as an important institutional tool for addressing the issue of technological obsolescence. The idea behind adaptive governance is to treat digital infrastructure as a flexible and upgradeable ecosystem rather than a static, non-upgradeable capital investment. Adaptive governance reflects the goals of Qatar National Vision 2030, which emphasizes sustainability, resilience and knowledge-based development. It also represents a willingness on the part of Qatar's development planners to recognize that digital systems will need to evolve and improve over time in order to keep pace with the evolution of technologies around the world.

The modular architecture of digital systems is a critical component of adaptive governance. Modular architecture allows a digital system to be broken down into multiple components that can be used independently and that can be upgraded and/or replaced as needed, thereby increasing the longevity of the digital system and decreasing reliance on specific proprietary technologies. For example, in Smart City applications, modular architecture may include: cloud-based platforms, open data architectures, and scalable IoT frameworks. Using open standards and designing systems that are interoperable will help to mitigate the potential risks of vendor "lock-in", and will help to ensure that a city's digital systems are adaptable to changing technological trends over the long term.

In addition to creating modularly-designed digital systems, Qatar has also created a process for continuing to evaluate its regulatory policies to ensure that they do not become "obsoleted" by emerging technologies. Regulatory policies for Smart City and Smart Digital Transformation initiatives are subject to the same rapid rate of technological change as the digital systems themselves, and therefore require periodic evaluation and revision to reflect changes in the technological environment. Therefore, Qatar engages in ongoing evaluation of its regulatory policies through ongoing dialogue and consultation with stakeholders to ensure that regulatory policies are adapted to reflect emerging technologies.

In summary, Qatar's approach to addressing the problem of technological obsolescence is a dual approach, utilizing modular digital systems in conjunction with adaptive regulatory policies. The use of modular digital systems, combined with adaptive regulatory policies, provides a comprehensive model for addressing the challenges posed by the rapid rate of technological change and for supporting the continued and sustainable evolution of Smart City initiatives to achieve alignment between technological innovation and long-term national development objectives.

2.3.6. Internet of Things (IoT)

The IoT is a transformative technological framework which is featured by a network of interconnectedness devices, sensors, and systems that collect, exchange and analyse data in real-time. It is very basic for the infrastructure of a SC as it allows for the continuous integration of the digital and physical urban systems to enhance efficiency, sustainability and the standard of life (Ullah et al., 2024). According to Park et al. (2018), IoT technologies are essential to collect real-time data as various devices which include environmental sensors, traffic cameras and smart meters consistently collect the data on urban parameters which include traffic flow, energy usage and air quality.

Moreover, another study conducted by Lihore et al. (2022) reveals that in traffic management, IoT-enabled smart sensors monitor vehicle movement and congestion optimise the traffic flow with the help of adaptive traffic signals. According to the author, these systems can change the signal timing based on real-time traffic conditions that mitigate the delays in travelling, fuel consumption and carbon emissions. Overall, IoT plays an important role in the efficiency of energy by using smart grids and meters to track energy consumption patterns. Furthermore, Liang and Shah (2023) conducted a study in which they further revealed that IoT also improves the allocation of resources by offering the required and data-driven understanding.

2.3.7. Artificial Intelligence (AI)

Van Hoang (2024) in his study demonstrated that AI plays an important role in evaluating the data gathered with the help of IoT devices to optimise urban operations and improve the efficiency in SCs. According to the author, IoT devices help generate a huge data set by utilising the sensors embedded in urban infrastructure and services. In addition to this, AI plays a crucial in optimising IoT-generated data which includes predictive maintenance, transportation optimisation, energy management and environmental sustainability (Idhalama & Oredo, 2024).

Chevtchenko et al. (2023) in their study highlighted that IoT sensors track the infrastructure for anomalies which include mechanical wear or electrical malfunctions. The authors further expanded that AI evaluates these patterns to predict potential failures and schedule timely maintenance which as a result mitigates the costs, reduces the downtime and enhances operational efficiency. In addition to this, Jagatheesaperumal et al. (2024) indicated that AI processes real-time traffic data collected from IoT-enabled traffic cameras, road sensors, and vehicle telematics in transportation. They discussed that AI predicts traffic congestion, optimises signal timings and suggests alternative routes which further mitigates the delays and enhances mobility (Meduri et al., 2023).

Table 2.2 synthesises key technology enablers, their maturity in Qatar, and their relevance to SDT, addressing the need for an integrated overview of SC technologies and adoption barriers.

Technology	Role in SCs	Maturity in Qatar	Key Barriers in Qatari Context	SDT Relevance
Internet of Things (IoT)	Real-time data collection (traffic, energy, environment).	High (deployed in Lusail, WC2022 infrastructure).	Data sovereignty, interoperability between siloed systems.	High - enables precision resource management.
Artificial Intelligence (AI)	Predictive analytics, automation, personalized services.	Moderate (growing R&D, strategy in place).	Skills gap, ethical/regulatory framework for algorithmic decision-making.	Critical for optimizing systems and predictive sustainability modelling.
Blockchain	Secure, transparent transactions (energy trading, identity).	Low (experimental, limited regulatory clarity).	Regulatory uncertainty, scalability, public understanding.	Medium-High for enhancing trust in PPPs and green credentialing.
Digital Twins	Virtual simulation for planning, monitoring, and disaster response.	Emerging (pilots in major projects).	High cost, integration complexity with legacy systems.	Very High for lifecycle assessment and testing sustainability scenarios.

2.4. Approaches to DT

In recent years numerous studies have sought to determine the importance of DT in the development of smarter cities, and to establish the significance of various competencies in the handling of hurdles associated with the implantation of digital technologies in existing cities (Butschan et al., 2019). Within the smart city (SC) literature, DT is increasingly viewed not merely as a technological shift but as a socio-technical transformation that integrates governance, human capital, institutional capacity, and sustainability objectives. This perspective directly informs the conceptual framework of this study, which positions DT as an enabling mechanism linking technology, sustainability, and governance in smart cities. Anthony (2021) undertook a systematic research process to establish that the possession of high cognitive capacity, as well as processual competencies, can significantly enhance the implementation of digital technologies. This finding provides empirical justification for incorporating human and organisational capabilities as core constructs in the theoretical model developed for this research. Similarly, Viale Pereira and Schuch de Azambuja (2021) asserted the importance of putting in place adequate and skilled human resources for SC implementation. Their work reinforces the argument that DT success depends on long-term capacity building rather than short-term technology deployment, which is particularly relevant for Gulf countries such as Qatar that are investing heavily in large-scale digital infrastructure.

Pourzolfaghar et al. (2016) implemented an evaluation to determine the different types of ICT infrastructure that can be employed in SC spheres, reviewing widely adopted enterprise architecture concepts. Consequently, the researchers determined that most SC architecture did not adhere to the business plan framework, and they concluded that the inability to adhere to the business plan frameworks implied that most SC architecture is implicitly ineffective. This insight underpins the inclusion of enterprise architecture and governance alignment within the conceptual framework of this study, as it highlights the necessity of structured models to coordinate complex SC ecosystems.

Verhoef et al. (2021) further conceptualised DT as a staged process (digitisation, digitalisation, and transformation), identifying the managerial systems required at each stage. This staged understanding of DT is adopted in this study to explain how cities such as Qatar transition from digital public services to fully integrated smart city systems.

As stated by Pourzolfaghar et al. (2020), the complex ICT services that characterise SCs can be difficult to coordinate without proper models. This provides the rationale for reviewing theoretical approaches such as enterprise architecture, Greenfield and Brownfield models, and game theory later in this chapter, as these models offer structured mechanisms to analyse coordination, stakeholder interaction, and system evolution in SCs. Similarly, Van den Bosch (2020) emphasised a human-centric perspective, warning against technology-led urban development. This aligns with sustainability-driven DT and supports the argument that SC initiatives must balance efficiency with social and environmental outcomes.

Van den Bosch (2020) critically evaluated SC literature to advance the human-centric SC agenda with the use of Kate Raworth's doughnut economy model, comparing different approaches to city development such as techno-city, cooperate city, connected city, and data-driven city. Based on this evaluation, Van den Bosch (2020) concluded that an ideal city should strive to meet both ecological and social expectations, and cautioned against the development of an SC without the consideration of basic aspects such as the protection of the environment and the attainment of the social needs of the population. This assertion echoes the views of studies such as Van den Bosch (2020) which have shown the dangers of developing systems without human input.

Ostensibly, such systems elicit numerous ethical concerns regarding the capacity of technological devices to make fair decisions. In this context, Srivastava et al. (2017) noted that AI technologies have the potential to replicate human behaviour in many respects, which optimises their capacity as a replacement for human beings in key decision-making. In as much as this aspect may generate positive outcomes, there is a likelihood of bias and discrimination, or simply overlooking the real needs of sentient human inhabitants, which is a concern that may undermine the security and well-being of inhabitants in cities where it is applied.

The major limitation of Van den Bosch's (2020) study is that it is relatively difficult to remain within the circle of pleasing all stakeholders in all respects, and in practice, numerous trade-offs are inevitably required to balance competing interests and objectives. Conversely, Anttila and Jussila (2018) addressed grassroots awareness, and highlighted the significance of universities in the development of SCs as relatively impartial mediators that can help guide SC projects. Furthermore, they argued that higher education is a key driver of innovations, which by extension can enhance the development of SCs and troubleshoot emerging problems.

Anttila and Jussila (2018) asserted the importance of maintaining high-quality education practices in universities as a means of achieving a rapid transformation of local communities in tandem with the development of SCs. From the authors' perspective, the reliance on universities as the source of such talent is integral to the attainment of sustainable development for SCs. This view is based on the premise that SCs will continually generate a workforce that is skilled in the latest technologies, which by extension enhances the operationalisation of SCs and enables them to respond dynamically to changing circumstances and troubleshooting requirements. Consequently, the researchers highlight the significance of collaboration between local governments and learning institutions for the sustainable implementation of SC, as also recommended by Silva et al. (2018). Ethical concerns associated with AI-driven decision-making further highlight the need for governance mechanisms in SCs (Srivastava et al., 2017). These concerns justify the study's focus on sustainability-oriented DT (SDT), where transparency, accountability, and inclusiveness are treated as integral criteria rather than secondary outcomes.

2.5. Challenges in Developing SCs

Building SCs is intricate, complex, multifaceted, and fraught with difficulties. The literature consistently demonstrates that these challenges are interrelated rather than isolated, reinforcing the need for integrated and theoretically grounded DT approaches.

2.5.1. Cost

Silva et al. (2018) highlighted barriers to the development of SCs based on a literature review to evaluate the key features of SCs and to identify how specific factors can undermine their successful implementation. They determined that in as much as the "smart city" has become a buzzword in economic development discussion, actual SCs face numerous serious implementation challenges on the ground. A recent study by Puron-Cid and Gil-Garcia (2022) noted that the lifeblood of SCs – data and the connected networks in the IoT – forms a major barrier to SC in itself, due to the immense volumes of data processing required for operation as well as the heterogeneity of connected smart devices in terms of their practical functions, associated hardware and software, networks, and other features.

Calibrating the vast array of required tools and systems to enable SC functionality entails enormous costs, including financial costs for infrastructure and software development, and human resources for system operation and maintenance (Puron-Cid and Gil-Garcia, 2022). In addition to replacement or modification of legacy systems in urban environments entails further disruption, and direct and indirect economic, human, and environmental costs. Teng (2021) mentioned that the large volume of operations required by SCs essentially places a commensurately massive burden on operators, and in operation in real settings, SCs tend to overwhelm available technologies and capacity.

According to Silva et al. (2018), the cost of operations associated with the implementation of such technologies during initial stages impedes adoption, and such costs tend to increase during subsequent phases. This is especially true given that cities are often faced with numerous demands that in most instances outweigh their financial capacity. Consequently, the requirement to allocate funds for the purchase of the systems associated with SCs is often beyond their reach. The main limitation of their study was that it was based on a review of secondary articles, and the researchers did not collect primary data, as noted by Puron-Cid and Gil-Garcia (2022), who nevertheless affirmed their findings, and elaborated on how SC implementation is a costly venture.

In their work, Puron-Cid and Gil-Garcia (2022) examined data from 1723 municipal governments that implemented SCTs, using a panel data approach to compare the effects of ICT investments across the cities involved. The approach they used was a departure from that used by previous studies which had focused on a superficial evaluation of the impacts of SC projects. They strove to address the gaps in analysed studies by a panel data analysis to portray the effects of SM operations, digital infrastructure, as well as a wide array of contextual factors on the financial sustainability of municipalities. Notably, Puron-Cid and Gil-Garcia (2022) compared the benefits which have been acquired by three municipalities consisting of Monterrey, Benito Juarez, and El Marques. The key areas of examination included budget, cash, service level, and long-term solvency.

Puron-Cid and Gil-Garcia's (2022) analysis established a negative correlation between financial sustainability and ICT adoption, especially during the initial stages. This trend was in line with previous studies which showed that SC investments are generally expensive and not financially sustainable for local governments. From the authors' perspectives, the high costs of the systems and equipment necessary to implement SCs can be particularly significant for communities with scarce finances. The main limitation of the study is that it relied on data from a singular social-cultural environment, which reduces the applicability of the conclusions for other cultural environments and milieus.

Zamponi and Barbierato (2022) similarly highlighted that the systems used in running SC tend to be energy-consuming, which can undermine the purported objective of SCs (particularly at the policy level) of reducing cities' impacts on the environment. The high energy consumption required to run smart systems ultimately generates immense pressure on resources; however, energy analyses typically operate at a relatively abstract level, while real SCs entail more localised considerations. Lam and Yang (2017) implemented a cost-benefit analysis of SCs for local communities through the use of a case study approach, evaluating five case studies (Barcelona in Spain, Rio de Janeiro in Brazil, Singapore, Songdo in South Korea, and Tokyo in Japan). They established that PPP is a common approach that has enabled cities to overcome the initial challenges associated with the development of SCs, due to lowering dependence on public funds (Nawaz & Koç, 2020).

In this context, Cui et al. (2018) also noted that municipal and even national authorities are often unable to finance capital-intensive projects such as SCs due to their massive existing budget allocations and limited public finances. For instance, acknowledging the limitations of case studies that tend to predominate in this SC evaluation (Lam & Yang, 2017), a survey of 90 PPP practitioners involved in SC projects was conducted by Almarri and Boussabaine (2023), who found that "partnership and collaboration; financial sustainability; contractual duties and outsourcing; smart integration; and contract governance" were the most essential prerequisites in SC projects.

2.5.2. Privacy Issues and Crime

Ismagilova et al. (2022) presented a more user-centric perspective regarding the factors impeding the implementation of SCs, based on their review of the recent literature on the factors affecting SC development. In particular, they focused on the political, socio-economic, and technical challenges which have emerged as a primary concern in the development of SCs. Specifically, the researchers determined that the vulnerability to data loss and privacy concerns are major impediments to the development of SCs. Moreover, aside from virus attacks, system breaches and operational integrity were also determined to be major concerns that are affecting the adoption of SCs.

Ismagilova et al. (2022) argued that breaches associated with the handling of sensitive personal data are a primary concern that has been highlighted in most studies in the recent past concerning smart technologies, and malicious activities are even more significant for SCs, where serious public infrastructure could be compromised by cyberattacks. This dimension is consistent with recent concerns regarding the adoption of digital technological tools. As shown by Chatterjee et al. (2018), the threats associated with data privacy and information security such as unauthorised access to information can cause very serious consequences, and the implementation of SCs requires seriously addressing such concerns effectively, before any substantive development of SCs as normative urban solutions.

Cui et al. (2018) reached similar conclusions regarding the impact of security and privacy concerns on SC model adoption, based on an evaluation of available security and privacy protection technologies related to SCs. On the one hand, the researchers acknowledge that numerous technologies have been developed towards addressing security and privacy issues in SCs, while on the other, they acknowledged that such developments are inadequate for effectively addressing the privacy and security concerns associated with the development of SCs due to the massive potential harm caused by breaches in SC platforms. Rapid technological changes generate improved functionalities but can also exacerbate the risks of potentially malicious attacks (or latent technical failures), and rapid development technologies themselves undermine the effectiveness of the respective authorities in implementing the necessary licensing of tools.

The above assertion was echoed by Löfgren and Webster (2020) regarding the impediments of big data adaption in the implementation of government operations. From the researchers' perspective, issues surrounding privacy are prevalent throughout the value chain used in SCs, but they argued that security and privacy risks are not the major reasons for the low adoption of SCT. From their viewpoint, the leading contributor towards the slow adoption is the inherent lack of functionality of SCs to meet the needs of real users, due to the naïve perspective that technological advances are neutral and inherently desirable, with a commensurate tendency to ignore political, social, and economic establishments and customs of importance to stakeholders.

Sha et al. (2022) researched the application of early warning, intelligent monitoring, and public safety instruments for SCs in-depth, and revealed that SC designers have not invested adequate resources toward the management of public safety. Furthermore, they identified a lack of in-depth development as well as application of smart technologies in the handling of public safety. Cui et al. (2018) argued that the lack of scalability of traditional cybersecurity tools is responsible for the low public safety and security in SCs, given that SCs are comprised of smart devices which are often beyond the capacity of traditional systems. In essence, the researchers argued that there has been a proliferation of smart devices which have created numerous security and privacy issues in SCs, rendering the latter highly susceptible to safety and privacy issues and threats.

Given this malaise, Cui et al. (2018) contend that technologies developed to safeguard SC-related solutions are far from being adequate and effective in handling the vast security and safety issues associated with Big Data and SC use. Berry (2018) established the relationship between organised crime and technology, evaluating five-year ethnographic data regarding the manufacture and supply of illicit drugs. From the author's perspective, the technology that is used in SCs can be a major enabler of organised crime and subsequently create vulnerabilities in the city that may not be easy to rectify. The researcher further argued that crime has *evolved* with technology, rather than being eliminated (as popularly imagined, including by governments). According to Berry (2018), while limiting crime has been proclaimed as a major benefit of SC (and smart technologies in general) by proponents, SCs have been associated with the rising incidence of organised crime, in tandem with technological developments.

Put simply, organised criminals have adapted to and evolved with the systems installed in SCs, and the general laissez-faire approach to regulation and policing that is intended to be part of the intrinsic cost efficiency of SCs (e.g., due to reliance on automation) has made it relatively easy for criminal activities to prevail, despite the existence of tools and systems intended to prevent their proliferation. Based on these findings, Berry (2018) highlighted a particular example of credit chargebacks, which have become a common crime associated with the use of smart devices. However, while studies have offered in-depth and insightful evaluations of privacy issues and the relationship between organised crime and technology, they have not specifically addressed the particular challenges of Qatar.

In addition to the above, the CDP (2016) described that the Qatari authority has implemented Law No. 13 of 2016 ("Personal Data Privacy Protection Law"), under article 14 of which the privacy of users can be preserved when the controller can process personal data after procuring the consent of individuals. Furthermore, the data is also obtained unless the data processing is governed under a lawful means for the controller as well as other data recipients.

2.5.3. Regulations

Weber and Podnar Žarko (2019) noted that the development of SC solutions that are readily available in the market has been met with limited uptake and successful deployment due to the lack of necessary regulations. They argued that the development and deployment of SC solutions can result in the stakeholders involved incurring significant financial costs due to the lack of regulation, making it imperative that necessary legislation is developed, adopted, and enforced by the relevant stakeholders. They attribute the sluggish nature of the legislative process in this regard as a major impediment to the adoption of SC solutions. Such issues have led to delays, which by extension have been detrimental to the adoption and implementation of various SCTs.

Similarly, Badran (2023) indicated that the multifaceted nature of SCs implies that they stand somewhat outside and have an impact on the traditional regulatory landscape. According to his research, SCs require the integration of social, technical, and environmental components to exert an extensive impact on the social system. Consequently, this requires the adoption of new regulations to address the developing systems and approaches to commercial and social life in cities. The regulation process in this sense is often undermined by the complexities associated with SC systems themselves. He argued that numerous aspects have to be specifically regulated in SCs, and compounded delays and extensions in the regulation process entail damaging delays and costs.

Additionally, according to Visvizi and Lytras (2019), overcoming challenges with legislation is another challenge in building SCs. Legislators must find practical ways to control stakeholders, unleash economic growth, preserve benefits for the city's residents and allow investment in R&D to increase, among other significant challenges. For many policymakers, obtaining participants' consent to share their personal information and weighing trade-offs present additional challenges. People are concerned about the privacy of their personal information on the one hand. Smart streetlights equipped with a variety of IoT sensors and cameras can also give people the impression that their local governments are always keeping an eye on them.

However, the fundamental component of smart projects is the data that project partners gather. This data can result in a dynamic pricing model that balances the cost of the investment and generates income to support ongoing business operations. In this respect, Allahar (2020) explained how lawmakers are working to create a shared interest among project partners because they are aware of the interoperability and funding issues that SCs face on a global scale. Local governments can overcome their many obstacles and successfully implement SCTs with the support of legislation. For instance, in February 2017, the US Congress passed the SCs and Communities Act, which focused on creating an inter-agency council to coordinate federal funding and activities among various municipal departments involved in SCs even though the US Senate had not yet given its final approval.

2.5.4. High Dependence on Technology

The reliance on proprietary solutions from different developers has undermined the development of SCs, according to Weber and Podnar Žarko (2019). Proprietary solutions typically exhibit high incompatibility, an aspect which results in high fragmentation in SCs, whose functionality depends on the seamless interoperability of systems. Fragmentation due to the incompatibility of systems as currently observed has emerged to be a major limitation of SCs. Ang et al. (2022) claimed that the use of proprietary solutions leads to switching barriers, which can negatively affect the implementation of smart technologies. Essentially, this denotes the tendency of software developers to lock in their consumers on their systems as a means of maximising their earnings. While this may be beneficial for developers, it is potentially detrimental or fatal to the progression of urban development, as it denies cities better opportunities. According to Weber and Podnar Žarko (2019), the inability to change technologies (including both hardware and software) can be detrimental to growth, since it may inhibit the adoption of the latest and most efficient technologies.

Ang et al. (2022) reviewed modernistic transportation techniques and approaches developed for SC, considering emerging technologies in terms of geo-information, ML, BDA, AI, and deep learning techniques. Their study is a pioneering work in evaluating the impact of five driving technologies on SC transport. They established significant deficiencies in the application of driving technologies, largely due to the unavailable capacity to process the huge amounts of information that is generated, which was also noted by Szpilko et al. (2024).

These studies related this to currently available data processing tools being inherently deficient and unable to effectively process large volumes of data, presenting fundamental barriers for SC systems, particularly for transportation. According to Ang et al. (2022), some notable challenges include the emergence of traffic congestion as well as fleet management problems. The researchers determined that the failure to adopt and achieve proper integration of SCTs can increase the likelihood of failure.

Szpilko et al. (2024) also evaluated energy-related activities implemented during the development of cities, noting the importance of this approach due to the energy-intensive nature of SCs, as described previously (i.e., based on the large number of systems and dynamic data flows that need to be integrated). Consequently, the researchers postulated that it is integral that the implementation of SC should embrace effective energy management systems. Szpilko et al. (2024) argued that it is essential to identify and study all the energy requirements of SC during the development phase and that it is only through the use of this strategy that the necessary interventions can be adopted. They highlighted that it is vital to implement simulation and modelling of energy requirements during the development phase. Notable models deemed vital for SC functionality include smart grids and micro grid systems. From the researchers' viewpoint, such models offer systems whereby cities can meet demands as they emerge, and hence reduce the likelihood of resource wastage which is endemic in traditional systems.

In related work, Shichiyakh et al. (2016) investigated the shortcomings of SC systems and observed that a high dependence on technology can be seriously disadvantageous, especially as any loss of Internet connectivity or electrical power can cause all operations to grind to a halt in particular localities or across whole cities (and indeed broader regions). All devices and systems that SCs depend upon are highly dependent on energy and interconnectivity, which can be disrupted with relative ease (e.g., during extreme weather or natural disasters, or malicious attacks and sabotage) (Shichiyakh et al., 2016). Consequently, any shortfalls in energy supply can hinder the performance of the system, a condition which can be detrimental (and even fatal) to inhabitants (Szpilko et al., 2024). Shichiyakh et al. (2016) cited the particular example of Songdo in South Korea, where all operations such as the network and power regulation are managed by one system. In such systems, the failure of the network can easily result in catastrophic impacts on the city, as all operations depend on one system and network.

According to Ma (2021), the large volume of data that is exchanged in SCs makes them a significant target for hackers and malicious attackers. As described previously, SCs generate and depend upon vast volumes and flows of data, including significant information concerning the location as well as the identity of the inhabitants. Such information can easily be used to jeopardise the interests of people if it falls into the wrong hands. Liu et al. (2022) also argued that the connection and integration of systems make SCs susceptible to attacks. Given that the technologies developed to address such challenges are still in their infancy, and privacy and security risks are significantly high, and continue to evolve as criminals devote their energies to exploiting any potential vulnerabilities, the condition is further compounded by the fact that there is relatively low research on cyber security and privacy issues in SC (Ma, 2021). Such gaps in research in this regard undermine policy and regulation development, and collectively these aspects negatively affect SC development and management (Szpilko et al., 2024).

Apart from this, Keshvardoost et al. (2019) systematically reviewed the factors which may impede SC governance, with a focus on governance models, intending to establish how they determine success in the management of SCs. They noted that there is often a tendency in governments not to engage the public on issues associated with the implementation of SC operations. This failure to engage the public is often caused by security concerns and political perspectives, which causes those in leadership to maintain a distance from the public, resulting in SCs being fundamentally severed from serving the interests of those they are designed to serve (Liu et al., 2022).

2.5.5. Educating and Engaging the Community

"Smart" citizens who are involved and actively utilising new technologies are essential for an SC to succeed. In this context, the Qatar Mobility Innovations Center (QMIC) is considered the first as well as an independent centre of innovation across the entire region which is focussed towards the deployment of the research and development practices fin order to formulate as well as implement the platforms for Intelligent Mobility as well as SCs. QMIC is the result of integration between the Qatar Foundation as well as QU. QMIC was founded in 2009 by QU and was identified to get the license and valid registry from the Qatar Science and Technology Park (QSTP) to perform services as a technology innovations centre (QMIC, 2024).

In addition to the above, it is also found that the QSTP is a popular hub for technology development, which is responsible for introducing expertise to the Qatari regions for commercialising the new technologies (QSTP, 2024). In this regard, technology intersects with industrial development and education, which applies to ordinary citizens as well as industrial stakeholders. According to Zoughbi (2022), SCs can reduce citizen anxiety through education. Municipalities can more easily convey the inherent advantages of SC projects by providing technology education programs. Moreover, the idea of an SC is relatively new, which is why there are many obstacles to overcome. Nonetheless, some cities have advanced with supportive policies, enhanced digital and cyber security, better connectivity and improved education, including Singapore, Dubai, London, and New York. However, it is essential to mention that not every city chosen for the mission of SCs has reached the same stage of development;

meanwhile, some already have the required service, infrastructure, and investment models in place, as discussed with regard to Singapore (as discussed in Chapter 4).

Moreover, as remarked by Vacca (2022), any new technology project involving the entire city must include community education as a part of its implementation process. It can be accomplished by holding several town hall-style events in person, registering voters via email campaigns and maintaining an online education platform that keeps the public informed and involved. A community is more likely to use technology and encourage others to use it when it believes it is involved in the decisions that impact daily life and receives thoughtful and clear communication. The success of an SC depends on this. For example, Vacca (2022) reported that nearly a hundred projects, including smart power grids, citizen empowerment, and improved air quality, have been started in Lyon, France, to enhance urban life. To build the "city of tomorrow", the city works with citizens, business owners, major corporations, and start-ups.

To sum up, creating SCs is a difficult undertaking that requires collaboration to overcome various legal, technological, social and financial obstacles. Even though there are many potential advantages to SCs, it is imperative to recognise and address these issues to guarantee that the development of these communities is inclusive, sustainable and advantageous to all citizens.

2.5.6. Cybersecurity Risks in SCs

The implementation of IoT devices and AI technologies in SCs brings various cybersecurity challenges along with the benefits that threaten the reliability of essential services and the privacy of residents. According to a study conducted by Houichi et al. (2024), the IoT devices which include smart meters, webcams and routers, are particularly vulnerable to cyberattacks. They describe that many of these devices do not have strong security standards, which renders them susceptible to exploitation by botnets (e.g., the Mirai botnet), and threats such as Distributed Denial of Service (DDoS) attacks. Houichi et al. (2024) further revealed that these risks can disrupt critical infrastructure and essential services, with disastrous results for everyday life in addition to SC operations.

In addition to this, Sharma and Jindal (2024) revealed that AI also poses various cybersecurity risks because of their extensive use in smart applications that includes autonomous vehicles, healthcare systems and Virtual Reality (VR) platforms. According to their analysis, the hackers can exploit vulnerabilities in AI systems to manipulate their functions or access sensitive personal data. Moreover, Firmansyah and Bansal (2024) highlighted that a lack of appropriate encryption standards, insufficient data governance frameworks, and weak ethical guidelines further expand such risks. To overcome such threats, Firmansyah and Bansal (2024) suggested that SC developers must prioritise implementing stringent security measures which includes robust encryption, privacy-by-design principles and transparent governance practices as by doing so, the SCs can foster greater trust among residents and ensure the safe and sustainable development of urban environments.

2.6. Opportunities for Developing SCs

Hadjitchoneva (2020) empirically evaluated the connection between SDT and SCs in the context of Sofia after it adopted SCTs, based on the global ranking of cities. The study established significant improvements in the city’s performance after the adoption of digital technologies, including in terms of service delivery in various aspects, such as transportation, environment, mobility, health system, and education. This was corroborated by Liu et al.’s (2022) finding of strong relations between digital technologies and improvement in the handling of social functions. According to Hadjitchoneva (2020), DT can translate to enhanced delivery of vital services such as education and healthcare, because of the increased collection of data as well as coordination of services. In the particular case of education, digital technologies can easily enhance accessibility to learning materials, and hence optimise the quality of education.

2.6.1. Transportation Efficiencies

According to Korneć and Wereda (2018), SCTs can significantly enhance the efficiency of transport, based on their study portraying transport as an integral component of SCs. Wang et al. (2018) on the other hand highlighted the significance of transport infrastructure in the development of *sustainable* SCs, based on a scientometric review of 2543 articles published on the subject from 2000 to 2017. The researchers concluded that there is a strong correlation between transport infrastructure and environmental impacts, as well as economic effects (Wang et al., 2018). This view was echoed by Chung (2021), who established that the application of smart technologies in logistics and transport resulted in significant efficiencies based on a comprehensive review of major applications of smart technologies in logistics.

According to Chung (2021), the adoption of smart technologies such as those for the “sharing economy” have the potential to reduce passenger waiting times, especially during peak periods. However, the researchers acknowledged that the operational mechanisms associated with the sharing economy are still in the developmental stage, and the true potential of sharing economy can only be attained after handling such complexities and long-term implementation and empirical evaluation.

Adding to this, Secinaro et al. (2022) highlighted that there are many potential avenues to improve transportation efficiency when SCs are developed. Urban transportation might be completely transformed by integrating cutting-edge technology like AI, BDA, and the IoT. By optimising traffic flow and using real-time data, smart traffic management systems can cut down on traffic and trip time. Furthermore, the creation of strong public transportation networks (e.g., connected, intelligent cars and enhanced transit systems) is made possible by SC efforts. The utilisation of mobile apps and sensors in smart parking solutions reduces traffic and increases parking availability. Utilising SC infrastructure also makes it possible to implement environmentally beneficial and sustainable mobility solutions, including driverless or electric cars, which lower carbon emissions.

2.6.2. Environment

Anthony (2021) highlighted the opportunities created by DT in cities, based on a systematic review of 70 articles published between 1999 and 2020. While establishing that DT offers an opportunity for cities to transform into SCs, he acknowledged that this opportunity is often undermined by the challenges associated with data integration as well as the overall complexity exhibited in such systems. Similarly, Nagode and Manfreda (2022) revealed that rapidly evolving digital technologies makes it relatively difficult for cities to adapt to the changes. In essence, this condition increases the complexity which has been the primary impediment to the adoption of changes. Aside from that, the study established that DT enables communities to address the challenges associated with climate change, an aspect also emphasised by Liu et al. (2022).

According to Nagode and Manfreda (2022), DT leads to increased efficiency in the handling of activities and tasks, such as the movement of people, which reduces the adverse environmental impacts of conventional transportation, as well as actively contributing to the preservation of the environment. They noted that increased efficiency translates to reduced generation of harmful gases into the atmosphere, making it more feasible for states to achieve climate change targets. Allam et al. (2022) corroborated these assertions regarding the opportunities created by the DT of cities. Their review of recent technological developments in relation to SCs revealed that numerous opportunities have been generated by technology, as also noted by Liu et al. (2022), and they highlighted particular examples of climate change and rapid population growth. From their analysis, DT and in particular the adoption of digital platforms such as the Metaverse in cities may offer practical solutions to such challenges.

Allam et al. (2022) claimed that digital technologies offer an opportunity for resolving such emerging challenges by lowering the need for travel, reducing demand for physical infrastructure, reducing waste, and enabling overall enhancement in sustainable technologies and products. Aside from that, the study also determined that the use of digital technologies translates to an improvement in the efficiency of service provision as well as transparency in the provision of services. In terms of climate change mitigation, the researchers established that the use of digital technologies results in a reduced need for energy-consuming activities, reduced emissions from the transport sector, as well as the promotion of conservation programs, echoing the analogous findings of Liu et al. (2022).

Liu et al.'s (2022) quasi-experimental study on the capacity of SCs to restrict emissions was based on data from Chinese regional enterprises collected from 2008 to 2015, as well as data from China's SC policy over the same period. From the evaluation, the researchers determined that there was a drastic reduction in emissions with the adoption of digital technologies in Chinese cities. They found that DT, combined with other developments such as green innovation as well as innovations by businesses, contributed to a drastic decrease in emissions.

Lebrusán and Toutouh (2020) arrived at similar conclusions regarding the effectiveness of digital technologies in the reduction of emissions in cities in Madrid (Spain), where digital technologies were found to significantly lower the concentration of harmful gases such as NO2, P.M 2.0, and P.M 2.5. They revealed that the use of SCTs can enable the detection of progress in terms of environmental protection. In the particular case of Madrid Central, the SCTs allowed the respective stakeholders to monitor the changes in emissions. In essence, this study highlighted that SCTs directly contribute to environmental protection, and can also be used indirectly to monitor the effectiveness of other interventions, as also advised by Ristvej et al. (2020).

2.6.3. Revenue Collection

A study by Nukpezah et al. (2022) shows that the implementation of SCTs supports revenue collection efforts as well as the channelling of social welfare funds, based on an evaluation of data from the US Census Bureau and the 2016 International City/County Management Association's *SCs Survey*. The analysis showed that the use of SCT translated into an improved collection of trade revenue, as well as social assistance and health revenue disbursement from local institutions. They discovered that the utilisation of SCT translated to improved handling of revenue collection efforts, and enhanced service delivery functions. Similarly, Musa (2017) showed that SCs have both direct and indirect effects on the economic growth of local economies, based on a combative method evaluation of five cities in the US who had adopted smart technologies.

According to Musa (2017), cities tend to embrace smart technologies with a focus on areas such as public safety, economic development, transportation, infrastructure as well as energy and environment; findings also supported by Ristvej et al. (2020). Musa (2017) determined that most SCs in the US have high levels of social engagement, and are commercially oriented, financially stable, and environmentally friendly (particularly in terms of energy efficiency), cumulatively enabling a positive economic transformation of local communities.

Zamponi and Barbierato (2022) evaluated the importance of AI in the running of SC by reviewing secondary materials, establishing that AI can be extensively implemented in various areas such as street lighting and the development of SCs. The researchers highlighted the particular case of street lighting in Taiwan, which has experienced reduced energy consumption and consequently lowered carbon emissions from the implementation of such operations (Huang et al., 2017). As stated by Zamponi and Barbierato (2022) the street lights in Taiwan function by monitoring and dynamically responding to the movements of people. Unlike traditional forms of lighting, AI in this case ensures that the lights are dimmed by 50% if there are no movements for more than 10 minutes. A similar benefit has been experienced in regards to the running of smart buildings. There has been a notable emphasis in technological development on optimising energy consumption requirements of buildings, and subsequently minimising carbon emissions.

2.6.4. Safety

Jozsef (2022) described how public safety can be enhanced through the transformation of the city environment using proprietary strategies, utilising Crime Prevention Through Environmental Design (CPTED) in the redesigning of the city environment. The researcher recommended that careful planning of cities should take into consideration the livelihoods and safety of the inhabitants, which can be achieved through the subdivision of built up environment into small units. Such small units optimise the implementation of human observant communities. Ristvej et al. (2020) postulated that SC significantly enhances safety, given that it integrates safety in various components as a matter of course. The researchers investigated how safe cities integrate various SC concepts, such as smart transport, energy, education, government, citizens, environment, economy, and infrastructure.

Ristvej et al. (2020) observed that the safety dimension can be integrated into various aspects of SC. For instance, in the particular case of infrastructure, they indicated that the safety layer can be adopted through the use of smart devices installed to subsequently collect vital data for decision makers. A similar approach can be used in smart transport and subsequently optimising safety across the city, as also held by Srivastava et al. (2017). Risdiana and Susanto (2019) illustrated how the safe city concept in SC offers a solution for the security challenges threatening cities across the world, based on reviewing 19 publications on safe city.

According to Risdiana and Susanto (2019), the development of the safe city concept requires that the government has to evaluate the safety of the city. Furthermore, it established that the safe city concept provides an innovative way through which governments can optimise their security systems. The researchers conclude that most of the studies previously carried out on the subject have been largely implemented through survey data and simulations, and that there has been a general failure to incorporate empirical data in the evaluation of cities, which undermines the accuracy of such studies. Despite such shortcomings, they concluded that the general idea of the promotion of SC characteristics depends on identifying shortcomings that exist, which was reaffirmed by Ristvej et al. (2020).

In related work, Vivo-Delgado and Castro-Toledo (2020) systematically reviewed urban security and the prevention of crime in SCs. They recommended that SCTs should target conventional antisocial crimes concerning vandalism and destruction or theft of property, which are relatively easy to address (since they occur in public spaces, which are easy to monitor using SCTs). They argued that AI offers an opportunity for processing large volumes of data which would be impossible (or unfeasibly difficult) to handle using manual methods, and that it offers vital support for handling security issues. However, their study was limited by its reliance on secondary (as opposed to primary) research. Secondary research often exhibits inaccuracies, which can undermine their application by decision-makers (Srivastava et al., 2017).

Vivo-Delgado and Castro-Toledo (2020) reiterated many of the findings that emerged from the pioneering study by Srivastava et al. (2017) regarding the significance of AI in the handling of security issues in urban centres. The latter reviewed current smart solutions which have been applied in the handling of security issues in cities, although more recent evaluations of particular cities which have adopted smart technologies and how this has been beneficial to their operations have greatly extended this understanding (Zamponi & Barbierato, 2022). According to Srivastava et al. (2017), increasing dependence on AI has significantly improved the safety standards in SCs, although complete reliance on AI can be detrimental, since it removes human touch (and responsibility) from the handling of security issues.

Srivastava et al. (2017) further argued that the adoption of a hybrid between human and AI would be integral for SCs. Similarly, Bokhari and Myeong (2022) determined that there is a strong positive relation between AI and smart decision making, with social innovation as a mediating factor. The study was based on a cross-sectional investigation of survey questionnaire data from South Korea and Pakistan. In essence, the study highlighted the significant role that is played by social innovation in enhancing the delivery of services in SCs, which is a critical component that should be considered in the implementation of AI in SCs.

Li et al. (2021) indicated that SCTs enhance accessibility, transport, social facilities, and sustainability, due to reliance on different data collection sensors. They argued that SC tracking of people's activities can enable improved intelligent services, such as for healthcare, transport, entertainment, and travel. They noted that recent developments in AI have contributed to an improvement in data collection, with a significant reduction in resource demand, corroborating the earlier findings of Srivastava et al. (2017). Li et al. (2021) affirmed that cloud-based ML technologies can enable the sharing of scarce resources between different segments of the city, and subsequently boost efficiency and significantly enhance security levels using AI (and numerous sensors). Conversely such technologies can have detrimental impacts on especially when government use these tools for malicious purposes. As shown in countries such as China, such technologies can empower governments to monitor citizens and hence undermining their basic rights.

2.6.5. Education

Zhuang et al. (2017) highlighted the importance of SC in supporting lifelong learning, expanding learning environments from schools to other areas such as the home and indeed across the whole city. Such a trend is essential for the enhancement of living conditions of the inhabitants in such areas. Education itself is an enabler of innovation as well as problem-resolution capabilities among locals. Consequently, the development of conditions that support learning SC is vital towards improving the QoL and enhancing the perpetuity and sustainability of SC systems. They opined that SC provides smart learning, which is critical for lifelong learning opportunities, and this reciprocally supports SC evolution. This implies that education is not only a positive outcome of SC, but also an aspect that can support its continued development.

In related work, Huang et al. (2017) investigated a framework for developing SC by evaluating the significance of promoting smart education in SC. According to the study, the development of smart learning can be integral towards enhancing the living conditions of SC inhabitants, besides enhancing levels of innovation. They argued that living conditions can be enhanced by improved problem-solving capabilities. Enhanced educational attainment can enable the population to create new products and systems, which can address the challenges they encounter in their environment, as discussed previously (Pereira et al., 2018).

Huang et al. (2017) in their study mentioned that smart learning environments can support the attainment of SC objectives by ensuring SC self-evolution, with the innovation of new products to address emerging and dynamic problems in SC systems. SCs inherently require constant improvements to optimise applicability and reduce susceptibility to sabotage and service degradation, in order to maintain consistent and high-quality service. Consequently, the researchers argued that smart learning should form a key component of SC development.

Nikolov et al. (2016) evaluated the models and foundational frameworks that can be used in the development of smart learning environments, and observed that SCs provide synergic characteristics, which significantly enhance the learning process. The researchers evaluated specific examples of IoT labs that allow students to experiment remotely, without necessarily being physically present within learning institutions. This approach optimises the use of resources while minimising the risks associated with experimentation for the learners, and usability and accessibility are enhanced by improved sharing of resources between people. The researchers also determined that the use of smart technologies optimises the knowledge generation process through the sharing of views between members irrespective of location. The existence of such aspects in SC is critical for the development and sustainability of communities (Zamponi & Barbierato, 2022).

2.6.6. Governance

Pereira et al. (2018) evaluated literature on the benefits accrued from smart governance, and established that smart governance can be achieved through the reliance on latest technologies such as social media and ICT. They established that the use of ICT intelligence can significantly enhance the decision-making activities that are necessary for governance, and that the use of smart governance can enhance transparency in the handling of public resources and their improved interactions between those in leadership and the local community. They also showed that smart governance has a corresponding impact on SC initiatives. From the authors' perspective, SC operations require close interactions with the local communities for effective implementation.

Smart governance is not only an end product, but an enabling factor contributing to the implementation of SC operations. As stated by Pereira et al. (2018), good governance entails an increased focus on interactions with the population. SC smart devices can ensure that the government can effective engage with the population and issues affecting them, facilitating effective handling and resolution of challenges that may affect SC. This leads to cyclical relations between good governance and SC, which is beneficial for the local communities (Tomor et al. 2019). Similarly, Keshvardoost et al. (2019) demonstrated that governments can significantly benefit from the more effective use of existing SC ICT infrastructure to effectively coordinate their functions and reduce operational costs.

According to Keshvardoost et al. (2019), SC systems allow interoperability and replicability of functions, which boosts the efficiency of service provision. The reliance on technological tools in particular makes it possible for governments to reduce their reliance on human resources, which reduces operational costs, an aspect that can be can be catastrophic for local communities with a high proportion of public sector employment, like Qatar. Keshvardoost et al. (2019) indicated that the replicability of systems has resulted in immense savings for the concerned governments, and such savings have had a positive impact on the economic performance of SCs. This is based on the premise that the handling of governance operations is often a key determiner of economic performance. Consequently, the ability to effectively manage resources translates to improved economic performance (Weerakkody et al., 2011).

2.6.7. IoT and AI Driving SC Innovation

The integration of IoT and AI has significantly transformed urban management by creating opportunities for predictive analytics which improves the public service and allows for the real-time responses to urban challenges. IoT, through its network of interconnected devices and sensors, continuously collects vast amounts of data from various urban environments. Furthermore, when IoT is combined with AI, data is analysed to identify patterns, predict future trends, and enable proactive decision-making (Van Hoang, 2024). According to Kalusivalingam et al. (2021), the one major benefit is attained from the predictive analysis, where AI algorithms process real-time data from IoT sensors to foresee potential issues, such as traffic congestion, equipment failures, or energy demands.

In addition to this, Kalusivalingam et al. (2021) further highlighted that predictive maintenance powered by AI reduces costs and prevents disruptions by identifying issues in infrastructure or public transport systems before they occur. Similarly, Korada (2021) further outlined that AI-driven forecasting models enable the city planners to anticipate population growth and resource needs which supports in sustainable urban development. According to Korada (2021), IoT and AI also enhance public services by improving efficiency and accessibility, and AI-powered IoT systems enable intelligent transportation networks which optimises the traffic flow through real-time adjustments to signals and routes.

In the viewpoint of Damaševičius et al. (2023), IoT and AI enable real-time responses to urban challenges, such as natural disasters or security threats. SC solutions use IoT sensors to monitor environmental conditions, such as air quality or flood risks, and AI processes this information to alert authorities and deploy resources effectively. According to authors, this dynamic response system ensures faster action which reduces the harm and enhances the safety of public.

2.7. DT in Qatar

It is found that the Qatar-based Digital Agenda 2030 (DA 2030) is a key programme seeking to catalyse broad-scale DT adoption in the country, as well as improve national macroeconomic development. DT is promoted under the DA 2030 in terms of fostering technological developments in the digital as well as information and communications business segments. The key ambition of DA 2030 is to make a contribution of about USD 40 billion for improving the non-hydrocarbon-based GDP of the nation, as well as generate approximately 26,000 employment opportunities in the ICT sector (DA2030, 2024). Angelidou (2016) investigated the dynamics in terms of DT in Qatar and found that the country is undergoing a drastic transformation in its national drive to become a post-oil, diversified economy. The study showed that the key focus of the transformation has been focused on entrepreneurship, innovation, and increased private sector development and employment, as well as digital technologies and ICT.

This is significant as the latter have typically been the overriding focus of most SC projects (and studies), as described above, marking the significant inclusion of public policy and economic stakeholders in Qatar's SC adoption strategy. Angelidou (2016) also determined that the investments made by the national government have been responsible for its rapid transformation, guiding development within clearly defined public policy and economic parameters. According to a report by Statista (2023), Qatar, a country renowned for its swift progress and technological innovations, is expected to impact the SCs industry substantially. By 2024, this market category is anticipated to generate an astounding USD 0.54 billion in revenue. It points to a bright future for the nation's efforts to create SCs. In addition, from 2024 to 2028, revenue is anticipated to increase at a steady annual rate of 9.63%.

Commensurate with this drive toward DT as part of the national socio-economic development strategy, Ben Hassen (2020) cited recent data showing that Qatar is one of the most rapidly developing countries in the GCC region, despite being subject to regional embargos and various other economic inhibitors. While noting that Qatar is ranked 68th globally in terms of innovation, an aspect which suggests that it is average in terms of development and implementation of new technologies, Ben Hassen (2020) cautioned that Qatar's performance is relatively modest compared to high-performing countries in terms of business, market, and institutional sophistication.

Furthermore, it has long been noted that companies in Qatar are primarily concerned with the technical aspects of their operations, with little interest in cooperation with institutions of higher education such as universities and other community stakeholders (Al-Abdulghani, 2021). However, this trend is expected to change, based on the recent developments associated with QNV'30, as well as a natural development in a now maturing major economy, As stated by Ben Hassen (2020) the current innovations in the country are largely informed by QNV'30, and the developments geared towards the hosting of QWC'22.

Al-Abdulghani (2021) conducted an important empirical investigation of DT implementation for e-government services in Qatar, concluding that numerous complexities are hampering service provision, categorised under political, technological, social and organisational segments. Al-Abdulghani (2021) argued that the major challenge observed in the provision of e-government services was delayed authorisation of funding for such functions, and indicated that this was an interesting development, given that finances are not a major challenge at the national level of government initiatives in Qatar. However, rapid technological and indeed socio-economic and governance development in Qatar in the subsequent years has given a fillip to e-government and other aspects of DT.

Adding to the above, Al-Quradaghi (2023) highlighted that the nation has advanced remarkably in terms of DT, as exhibited in milestones in several industries. The focus on a knowledge-based economy under QNV'30 is driving major digitalisation efforts, and the government's e-government services and SC initiatives demonstrate its dedication to innovation by improving public access to digital services and promoting efficiency. The investment made by Qatar in AI is one distinctive feature. The nation is using AI to improve healthcare, education, and transportation, showcasing a forward-thinking approach to infrastructure and services. For example, predictive healthcare analysis is made possible by the AI-based technology of Hamad Medical Corporation (HMC, 2024a), the main national healthcare provider, which is modernising patient care and health services in Qatar.

In the alignment of sustainable actions for DT, Medina (2023) depicted that urban planning initiatives that integrate technology for sustainable living, such as Msheireb Downtown Doha, are examples of innovation in this regard. Creating a workforce prepared for the future is another goal of Qatar's DT, in addition to adopting technology. Aiming to promote educational growth and preserve cultural heritage, initiatives such as the Qatar Digital Library provide free access to historical documents. However, issues like protecting personal information, closing the digital gap, and cybersecurity still exist. Strategic answers to these problems are necessary for sustainable growth that is inclusive in Qatar's DT. For the country to undergo a digital revolution, social inclusion and technological growth must be balanced.

The MCIT (2023) investigated the key enablers of DT of the public sector in Qatar and identified governance, the assessment of benefit realisation, and intra-governmental cooperation. The study established that the formulation of digital government strategy as well as efforts to monitor the implementation of government policies and initiatives have been the major drivers of digital innovation in Qatar. The Ministry noted that the need to monitor government operations has led to accelerated ICT adoption in the provision of services in the country.

Evidence on the effectiveness of technology in the monitoring of service provision on the other hand is relatively hazy, with *ex post* assessment of strategic projects that applied key performance criteria in line with Qatar's Digital Government Strategy 2020 not being available for analysis. The MCIT (2023) notes that previous research indicates that standardisation and close monitoring of projects is the only way through which quality can be achieved. The inability to implement *ex post* assessment in this case undermines the effectiveness of such projects.

Aside from national-level analyses, some studies have explored the readiness of Qatari companies to adopt digital technologies. Abulhussain (2021) established that the notable barriers for firms seeking to undertake DT included a lack of clear vision to guide the adoption of the latest technologies. Previous studies identified a lack of infrastructure as well as skilled people to operate the new technologies (Weerakkody et al., 2011), although this aspect has likely diminished with the rapid development of Qatar in recent years. Al-Thani and Furlan (2020) evaluated the implementation of Transit-Oriented Developments (TODs) in enhancing liveability within West Bay district of Doha Qatar. They found that projects' reliance on TODs has been beneficial towards alleviating transport challenges in Doha, but the paper did not address the actual implementation of technology.

However, fear of the risks which could emerge due to the adoption of such technologies, especially in relation to high initial investment costs, remains a concern. Nevertheless, despite such challenges, Abulhussain (2021) found that 90% of major companies studied in Qatar had successfully adopted and employed data engineering and cloud services, in alignment with adoption of Industry 4.0 and the deployment of Vision 2030. Similarly, Ben Hassen (2020) evaluated the entrepreneurship ecosystem in Qatar's ICT sector and investigated constraints and factors supporting entrepreneurship. He established that government intervention with a particular focus on the adoption of smart technologies has been an enabling factor for entrepreneurs, supporting calls for public sector support for private sector interventions to facilitate ICT integration.

2.8. Government Outlook Towards SDT of SC Development in Qatar

According to Badran (2023), the government has made noteworthy efforts in carrying out QNV’30. The vision highlights the necessity of utilising information and communication technologies to develop intelligent urban areas. SCs rely on integrating several smart apps and their connection to the residents of these communities. The study posited that incorporating AI into an already established urban area or constructing a novel intelligent city necessitates a collection of legal, legislative, and technical underpinnings. The term “SCs” first appeared in Qatari policy documents in a white paper titled “Emerging ICT Trends: The Future Is Now”, released in 2014, in which SCs were envisaged as the way forward for Qatari urban development and design—the cities of the future (Asmyatullin et al., 2020).

Asmyatullin et al. (2020) further added that the government has recognised that SCs play a significant role in the national development plans of every GCC nation. Simultaneously, the primary objective of SC development is not solely efficient administration but predominantly enhancing the standard and calibre of inhabitants’ lives. Furthermore, the use of ML programmes and AI are essential for optimising the SDT of SCs. AI utilises real-time data from IoT devices, such GPS systems and traffic sensors, to forecast traffic patterns and suggest the best routes. This helps create more effective public transit networks in addition to easing traffic. Supporting these views, Adalbi et al. (2022) noted that as the Smart Qatar journey develops and grows, two significant real estate projects—Msheireb Downtown Doha, which has an investment of USD 5.5 billion, and Lusail City, which was introduced in response to QWC’22—have been initiated, along with a comprehensive system of e-government and digital infrastructure.

Adalbi et al. (2022) cite government support for SC development in Lusail in the form of establishing the Lusail Control and Command Centre (LCCC) to implement a building management system and citywide integrated communications, and a comprehensive and intelligent transportation system for distinct models of transportation. The latter encompasses light rail transit, public transportation, and a significant road network upgrade and expansion. Also, there is a focus on strengthening the city’s security system for citizens, and the optimisation of energy use with an intelligent automated system in infrastructure has been designed.

Highlighting a vital strategy made by the Qatar government for SC development, Asmyatullin et al. (2020) explained Qatar's e-Government 2020 strategy as necessary in linking to QNV'30. The strategy's objective is to enhance the quality of services, boost the effectiveness of public services, and broaden the scope of the state. Developing mobile applications, building a digital certificate infrastructure, building government cloud infrastructure, and other projects are a few of the strategy initiatives. Lusail SC is an essential result of the government action, representing Qatar's highly sophisticated urban area. A centralised building cooling system has been installed in the city. The intelligent pipeline network transports waste directly to recycling facilities outside the urban area. The city's green landscapes will be irrigated using recycled wastewater. In preparation for QWC'22, a completely automated and driverless metro system was constructed in Doha, whichlinks Doha and Lusail SC directly.

According to Badran (2023), the establishment of the Supreme Council of Information and Communication Technology, or "ictQatar", in 2004—the country's first ICT regulator—was a significant step towards the expansion of SCs in Qatar. Also known as the CRA, ictQatar was established as an independent regulatory agency in 2014 by the Emir's Decree No. 42 of 2014 as a more advanced step towards securing the independence of the newly established regulator. Moreover, in relation with the related Memorandum of Understanding (MoU), Q-Post as well as the Royal Mail are identified to collaborate with each other for promoting the growth of mutual cooperation.

By integrating with the Royal Mail, the MoU is purposed towards improving the skills of the management team of Q-Post to offer training regarding the technical and functional abilities. The MoU also involves consideration for the strategic assistance offered by the Royal Mail to introduce a strategic shift in the Q-Post's planning (MCIT, 2014a). The ITC regulator's primary responsibility is to facilitate Qatar's development into a smart, networked nation through creative and efficient postal and ICT regulations. In order to achieve this objective, the regulatory body must establish and implement a proactive, precise, and uniform establishment of rules and regulations that facilitate the growth of the digital economy and the postal industry, thereby benefiting Qatar's social and economic well-being (AlAli et al., 2023).

2.9. Comparison of the Current SDT of SCs of Qatar with International Countries

2.9.1. Comparison of SDT of SC of Qatar with International Countries

Achmad et al. (2018) described how all nations across the globe are facing the results of high carbon emissions from industries and transportation, climate change issues, and increasing population growth with scarce resources. Consequently, most developed nations have moved towards developing framework for SDT of SCs to augment the sustainable environment for people around the world to ensure their long and healthier lives. Countries across the West, like Europe and the USA, for instance, the UK, Spain and Germany, and the countries in the East, like South Korea, Japan and Singapore, are examined as taking robust actions to resolve global issues. In order to implement SC development, the countries have taken distinct initiatives. As it has been reviewed in the SC planning and discourse, the framework of SDT of SC is reviewed to obtain significant attention across the studies. With respect to SDT of SCs in Qatar, the MCIT (2023) primarily drives this initiative.

AlAli et al. (2023) have emphasised the design thinking framework as an approach to problem-solving. The foundation of the design thinking idea lies in identifying process problems and figuring out how to solve them effectively. This idea has presented a novel approach to design, implying a method of thinking that is both creative and analytical. The approach offers opportunities to explore, build, and prototype models, allowing for input to be gathered and redesign to be implemented. AlAli et al. (2023) covered frameworks for design thinking for SC initiatives in Qatar that foster SDT. They examined the potential consequences for individuals' privacy and security resulting from data exchange because SCs depend on gathering and analysing data to provide their services. Regulations that prioritise data security and privacy should serve as the foundation upon which to build the design thinking framework.

Differences in the SDT framework or initiatives have been reported in comparing Qatar with other international countries. AlQaoud et al. (2022) have highlighted in this context that in the USA, the Connected Urban Development (CUD) program was implemented for the SDT of SCs, to increase the traffic flow efficiency via new technologies, thus reducing carbon emissions in Chicago. In the UK, the sensor deserts network in for the SC project in Newcastle was made to highlight the investment priorities. In Germany, Smart City Cologne (SCC) was made to protect the climate and make a sustainable and resilient city. Similarly, in Japan, the initiative of Society 5.0 with the purpose of catastrophic countermeasures, U-City/ e-city in South Korea for managing environment, transportation and energy-associated problems of cities was made to explore a suitable solution distinct from the future urban challenges, like energy problems, global warming and increasing population. In Singapore, the smart initiative was initiated to support the transfer to megacities via constant urbanisation by addressing the issues associated with high energy, crowded vehicles, high population growth, and increasing consumption of natural resources (Sipahi & Saayi, 2024).

Clearly, developed countries are making dedicated efforts to compete with each other to create digitally transformed SCs and sustainable environments. However, Statista (2023) has reported that the US is considered the leading SC market globally, and is expected to bring in a healthy USD 12.74 billion by 2024. Furthermore, Wang et al. (2019) noted that some regions in Europe, Japan, South Korea, and North America have gained leadership positions in SC. China also initiated its foremost initiative of the DT of cities in 2006 to foster the country's digital infrastructure development, known as the National Geo-Spatial Framework (NGF). The establishment of digitally transformed SCs is presently being pursued by numerous local municipalities and central government organisations in China as a part of the Digital City project.

Wang et al. (2019) describe that China's "Digital City" programme can be understood as the initial stage of the SC development. The primary goals of sustainable and digitally transformed SCs in the upcoming phase will be to shift from virtual representation and digital infrastructure to information services and intelligence. On the other hand, different countries have implemented different frameworks; unlike Qatar, the Digital City of Trikala in Greece serves as a platform for online public services that provide benefits to both residents and the public administration. It establishes an e-government environment that goes beyond only providing administrative services (Wang et al., 2019).

A number of communities were able to come together on Digital City Amsterdam's networking infrastructure, which also managed to implement the city metaphor into regional information services. In Japan, Ishida is given three years to create a digital city for Kyoto. During that time, the city's interface layer offers both 2D and 3D views, its information layer incorporates real-time sensory data about the city, and its interaction layer promotes social interaction between those who live, visit, or are otherwise involved in the city (Bhattacharya et al., 2020; KPMG, 2020).

An array of comparative findings of SC development across countries was made by Shamsuzzoha et al. (2021) by conducting research based upon grounded theory and inductive reasoning to compare SC development across Helsinki (Finland), Singapore, and London (UK). Comparing all the cities, Singapore was considered to epitomise SC the most. The city has made radical innovations in Mobility as a Service (MaaS), Freight as a Service (FaaS), and innovative utilisation of next-generation technology. Also, the leadership of the Infocomm Media Development Authority, the Smart Nation Platform, and autonomous vehicles to optimise the limited space use with highly efficient, safe and reliable vehicles. For this, Helsinki has established active inter-city domestic and active bidirectional international collaboration, and London has established active collaboration within the city and passive international collaboration, while in Singapore, active national coordination and active unidirectional international collaboration have been established. At this juncture, the lessons learned from analyses of existing particular case studies and their application to Qatar can be considered, as undertaken below with regard to Singapore and Qatar's SC, and expanded in more depth in Chapter 4.

2.9.2. Comparing SDT of SC of Qatar with Singapore

According to Ferro-Escobar et al. (2022) the transformation of Singapore into a "smart city-state" was implemented based on a plan addressed the key areas such as transport, energy, security, health education and construction among other vital aspects of the society. As per Ferro-Escobar et al. (2022), the smart nation city objective was made possible by the creation of a vision which ensured an effective guidance of the other segments of society. The effectiveness of the vision according to the study is reflected in improved mobility, an aspect that was made possible by intelligent maintenance strategies largely supported by an effective communication system. Specifically, the efficiency in the transport system can be attributed to its capacity to determine congestion dynamics and the subsequent balancing of passenger comforts and demands.

Sánchez-Corcuera et al. (2019) contend that the smart mobility system has been responsible for a 92% reduction in bus services in the city and as a result a significant reduction in congestion in the transport sector. Correspondingly there has been a decrease in waiting times for the travellers across the city. The success of sustainable SC development is also reflected in energy efficiency. Specifically, the sustainable SC development incorporates data collected from consumers and subsequently being employed in the allocation of resources (Ferro-Escobar et al., 2022).

A study by Su et al. (2022) emphasised that Singapore has attained energy efficiency an aspect that has led to significant energy savings across the city-state. The above has been further supported by the increased reliance on green energy sources. As per Ferro-Escobar et al. (2022) the green energy sources have been achieved through the installation of solar energy systems. This success is also evidenced in the adoption of technological infrastructure. In this respect, the use of Smart Nation Sensor Platform (SNSP) sensor nodes has been integral towards optimizing the incorporation of IoT in the management of the city environment. According to Sánchez-Corcuera et al. (2019), the sensors were particularity focused on public security, transport as well as urban planning. The creation of IoT capabilities have been integral towards optimizing efficiency across various aspects of the city. National digital identity is another critical component of the SC vision of Singapore.

As shown by Hoe (2018) the national digital identity has been integral towards transforming transactions by eliminating the need for paper documents and records. By extension, this has been key in streamlining digital operations by making them less resource intensive. In comparison to Singapore, the SDT of SC is relatively low. Qatar's SCs can also be deemed to be at the planning stage with being undeveloped. Lusail for instance is a planned SC and is yet to be developed an aspect which makes it difficult to ascertain the effectiveness of the programs put in place (Adalbi, et al., 2022). However there has been an increased investment on information communication technology as an enabling factor towards the attainment of SDT of SCs (Al Sharif& Pokharel, 2022). Further Al-Thani, et al. (2018) outlined that there has been the adoption of advanced transport and communication technologies as a means of attaining SDT in Qatar cities.

AlAli et al. (2023) however argue that the implementation of SC in Qatar is faced with numerous challenges largely due to the existence of negative attitudes towards increased surveillance and the embrace of new technologies. These challenges suggest that despite the potential benefits of SC initiatives, public resistance can significantly hinder progress. Addressing these concerns and fostering a more positive public perception of surveillance and technology adoption may be critical for successful SC deployment.

2.10. Opportunities and Challenges to Qatar SDT of SCs

As observed by Tahmasseby (2022), to foster national economic and social development and offer a seamless experience while travelling, a development plan for overhauling current bus services with complete integration of other systems of multi-modal modes of transportation was suggested in the QNV'30. QNV 2030 is structured around four pillars—human, social, economic, and environmental development—which closely align with the objectives of Sustainable Digital Transformation (SDT) and Smart City (SC) initiatives. It would help realise QNV 2030 to establish favourable conditions for more effectively, conveniently, and economically organised transport patterns, locally and nationally, such as through an efficient Mobility-as-a-Service (MaaS) paradigm. This illustrates how SDT acts as an enabler that connects smart technologies with sustainability goals under the national vision.

The MaaS platform can improve transportation accessibility by facilitating affordable travel through the integration of various modes of transportation, including public transport services (such as buses, trams, and metros), shared electric scooters, shared cars, shared bicycles, ride-hailing services (e.g., Uber), and taxis, all within a single platform (Shamsuzzoha et al., 2021). However, the literature consistently highlights behavioural resistance as a key barrier to SDT in transport-oriented SCs, particularly in car-dependent societies such as Qatar. Badran (2023) argued that one of the critical challenges faced in developing SCs is Qatar's regulatory structure.

According to Badran (2023), the inherent complexity of SCs and the requirement to combine technological, social, and environmental elements are examined as posing new difficulties for regulators and upending the established regulatory framework. From a purely technical standpoint, licencing and spectrum management authorities must establish and strictly enforce regulatory frameworks. This complexity demonstrates why SDT in SCs cannot be viewed solely as a technological upgrade but must be understood as a socio-technical transformation.

Al Sharif and Pokharel (2022) argue that regulators must establish competition frameworks to avoid monopolistic behaviour in SC ecosystems. These regulatory issues are directly linked to SDT sustainability, as weak governance can undermine public trust and long-term adoption of smart technologies. In Qatar, privacy, data protection, and user security are central regulatory concerns. This aligns with broader SDT literature that identifies data governance as a foundational requirement for sustainable smart cities.

Qatar's ICT regulator has been tasked with promoting sustainable competition and ensuring a fair market environment. SCs leverage ICT to enhance service efficiency and economic value (Badran, 2023). This multi-sector and multi-level integration reflects international SC models, reinforcing the rationale for comparing Qatar with global exemplars such as Singapore. However, regulatory and legal complexities remain a significant challenge for Qatar's SDT of SCs. The incorporation of digital, cognitive, and virtual technologies—such as AI, IoT, and digital twins—defines modern SC development (Badran, 2023). The literature suggests that without adaptive regulatory frameworks, these rapidly evolving technologies may threaten the long-term sustainability of SCs. Ibrahim and Truby (2022) emphasised the importance of Qatar's Data Privacy Protection Law (2016) in safeguarding digital transactions and innovations.

The legal framework has been observed as the source of opportunities for Qatar for assisting blockchain's introduction as means of the platform for technical data sharing and retention with no or little requirement for the particular regulations focused on blockchain. It is further observed that Qatari regulatory measures are intended to provide significant opportunities to improve and upgrade the utilisation of advanced technologies within the regional financial sector (Ibrahim & Truby, 2022). However, it must be acknowledged that there are substantive legal and political challenges associated with the adoption and implementation of new digital technologies in Qatar.

For example, Ibrahim and Truby (2022) observe there has been the absence of a proper centralised authority which might regulate as well as be responsible mainly while the problems arise in the digitally generated services for the users. On the other side, the Qatar Central Bank is identified to undertake the centralised business operations for the thorough implementation of the Fintech Strategy across the strategic pillars regulated under the Fintech regulations. The Qatar Central Bank is further focussed to initiate a FinTech Journey in order to support innovation as well as diversification inside the financial services as well as enforce the QNV'30. However, lack of proper protocols, standards, knowledge of digital technologies' usage and privacy mechanism have hindered the SDT within Qatar. Considering the cybercrimes related to the digital services provided in Qatar, cyberlaw has been integrated *de jure*; however, corruptions, cyber-attacks and data-destroying activities are prevalent in this region. Thus, it is essential for Qatar-based government and legal authorities to deal with the challenge related to cybercrimes and corruptions prevalent in Qatar (Ibrahim & Truby, 2022).

Ben Hassen (2022) performed a literature investigation and identified that the policy of Qatar 2030 has been determined towards transforming Qatar by sustainable technological developments for upcoming generations. The transition of Qatar to the knowledge and technology-oriented economy has been the outcome of advancing ICT infrastructure (Ben Hassen, 2022). The encouragement of research and development, entrepreneurship, modern education, and innovation are effectively raising opportunities for Qatar to SDTs. However, the uncertainty of research and development endeavours, policy incongruity, concerns related to public safety and security, and the need for economic diversification are still challenging aspects for Qatar that hinder DT advancement. Thus, it can be evaluated that the appropriate legal policies and measures are needed to foster Qatar's DT (Ben Hassen, 2022).

More recently, Elidrisy (2024) noted the importance of Qatar's TASMU Smart Program, which brought valuable opportunities for Qatar's DT. TASMU demonstrates how SDT is operationalised through sector-specific interventions across healthcare, transport, logistics, environment, and sports, thereby linking technology adoption with sustainability outcomes. TASMU is a digital responsive strategy for the QNV'30 and is focussed towards improving the efficiency for delivery of public-level services within Qatar in the direction of five key priority zones such as healthcare, logistics, transportation, environment as well as sports (TASMU, 2023b, 2023c).

This national program is grounded on the policy framework seeking to enable a smooth transition to promote investment within major sectors such as transport, logistics, sports, healthcare and environment. The localised data centres (e.g., of Meeza, Ooredoo, and Microsoft) improve the efficacy of Qatar as a digitally transformed hub (Elidrisy, 2024). Thus, the smart program supports national and international entrepreneurial activities, contributing towards Qatar's transformation as a digital hub. Furthermore, developing the broadband infrastructure within Qatar, is intended to enhance Qatar's overall economy by flourishing tech and knowledge-based sectors.

For example, the Qatar National Broadband Network (QNBN) is installed in Qatar for granting national-level network coverage through its networking infrastructure. The QNBN networking and broadband services also help Qatar to select their preferable network services. QNBN has adopted a nationwide digitisation-related agenda that is dedicated towards setting up high speed fibre optic network infrastructure which is helpful for helping the citizens and business companies in Qatar (QNBN, 2024).

In addition, cloud-oriented services further brought opportunities for climate-oriented innovations, offering environmental monitoring as well as optimisation of resources. In this way, various technological innovations have been brought into Qatar, bringing opportunities for a successful SDT of this city (Elidrisy, 2024). For example, Qatar Cloud aims to offer a wide-range cloud computing-based services as well as products to the small-scale as well as medium enterprises (QatarCloud, 2024).

A recent review by Naji et al. (2024) revealed that DT has brought crucial opportunities for facility management in businesses. In addition, DT might be utilised for model building systems and components, such as lighting systems and Heating, Ventilation and Air Conditioning (HVAC). Such digital models might stimulate prediction of performance, operating scenarios as well as optimisation of maintenance activities, such as, sthe maintenance and operations. In addition, VR, Augmented Reality (AR), and AI have brought valuable opportunities for businesses for real-time monitoring and visualisation of the business activities. Smart devices are also being developed through DT which are saving time, improving productivity and minimising cost for the business activities.

Digital twins have become essential technological solutions for raising the industrial works specifically in construction industry. Thus, evidence is beginning to emerge that new technologies are bringing valuable opportunities for Qatar to develop and grow businesses in a DT context (Naji et al., 2024). As observed by QatarCloud (2024), DT is becoming increasingly crucial in facility management, and it can be used to model building components and systems, such as HVAC and lighting systems. These digital models can simulate operating scenarios, predict performance, and optimise operation and maintenance management, supported by cloud-based DT. Overall, the literature indicates that Qatar's SDT of SCs presents significant opportunities driven by strong infrastructure, policy vision, and technological adoption, while regulatory complexity, governance gaps, behavioural resistance, and cybersecurity risks remain key challenges.

2.11. Gaps and Limitations of Prior Studies

Research into Smart Cities (SCs) and Smart Digital Transformation (SDT) shows many conceptual, methodological and contextual shortcomings. Specifically, Burlacu et al. (2022) carried out an epistemological survey of academic literature on Sustainable Smart Cities. They aimed to assess whether the theoretical frameworks used in these studies were scientifically valid. Using Popper's Principle of Falsification, they assessed how far the dominant theories used in the surveyed literature could be tested empirically and were logistically coherent. They found that approximately 75% of the reviewed literature was based on weak or untested theoretical assumptions, thus undermining the scientific robustness and validity of the literature surveyed.

Burlacu et al. (2022) also point out that the lack of appropriate use of theory in investigating SDT within Smart City Infrastructure has led to conclusions that are either incomplete or misleading. The lack of appropriate theoretical framework limits the ability of the current models to explain and predict behaviour in complex and rapidly changing digital urban environments. Therefore, there is still a need for empirical and theoretically sound research that will investigate SDT processes rigorously instead of accepting them as effective and/or universally applicable.

There is a limited amount of research into the impact of SDT on Smart Cities from a community/stakeholder perspective, however, there is very little systematic and context specific research, especially regarding Qatar. Although, Weerakkody et al. (2011) investigated the impact of SDT on Qatari Smart Cities and although there has been considerable social economic, technological and governance changes in Qatar since then; it is now 12 years later and it would seem that there is a risk of analytical obsolescence and that the research may not be relevant to the Qatari context.

Furthermore, the importance of local context in determining Smart City outcomes further underlines the need for research in this area. SDT initiatives are heavily influenced by cultural values and beliefs, governance and institutional capabilities, as well as the actual experiences of local communities, including Smart City residents and users of services. Thus, the results of research undertaken in other countries/regions should not be assumed to be transferable to Qatar without some form of empirical validation.

Additionally, while more recent studies, such as those by Ben Hassen (2020) and Abulhussain (2021) provide valuable insight into digital transformation in Qatar; the major limitation of these studies is the availability of the data, particularly given the rapid development of infrastructure, regulations and technologies that has taken place in Qatar in recent years. In addition to the aforementioned developments, significant national initiatives, rapid urbanisation, and large scale digital investment — particularly during the period leading up to and after the FIFA World Cup — have fundamentally changed the Smart City landscape of Qatar.

In order to address the above-mentioned shortcomings, the primary objective of this study is to develop and build upon previous research on the topic of SC and SDT in Qatar through developing an empirical study of Smart City implementation and SDT in Qatar. Furthermore, the study aims to address the aforementioned theoretical and contextual shortcomings in previous research. Therefore, the study hopes to make a positive contribution to the body of knowledge on SDT dynamics and to provide policy makers with evidence-based recommendations to support the development of Smart City policies.

2.12. Chapter Summary

This chapter has reviewed studies concerning SDT conceptualisation and development, addressing key factors including the theories that govern the subject and the scholarly articles which have been published on the subject in general, and with particular regard to Qatar. The review demonstrated how SDT and SC concepts are interconnected through socio-technical systems that require strong governance, regulatory alignment, and sustainability-oriented policy frameworks. Greenfield and brownfield models were explained, along with game theory, as theoretical perspectives underpinning the described approaches to DT. Although these models have been applied in international studies, the literature reveals limited application within Qatar, reinforcing the need for further empirical investigation. The chapter identified the key challenges facing SDT development of SCs in terms of cost, privacy issues, and high dependence on technology. Opportunities for SDT were explored in terms of transportation efficiencies, environmental impacts, revenue, safety, education, and governance. Qatar's Vision 2030 and TASMU Smart Program were identified as central policy drivers linking digital transformation with sustainable development goals. Finally, the chapter identified critical gaps in existing research, particularly the lack of updated, theory-driven, and systematically conducted studies focused on Qatar. These gaps provide a clear justification for the current mixed-methods study and the development of a conceptual framework to examine SDT sustainability in Qatar's smart cities.

CHAPTER 3
Methodology

3.1. Introduction

In today's digital era, a wave of transformation has occurred, advancing technological development and realising the importance of SCs to facilitate a fundamental shift towards efficiency and sustainability. Qatar has envisaged its QNV'30 in this regard, and is making robust efforts towards sustainability and innovative city development. The current chapter examines and explores the methodological context of this study in detail. The study methodology provides the foundation for determining how data is gathered, analysed, and interpreted. Choices made in this regard are the critical aspects playing a crucial and essential part in guaranteeing the robustness and reliability of the study outcomes.

This chapter examines and justifies the research design, methods of data collection and analysis, ethical considerations, and identifies the limitations of the research pertaining to this mixed method investigation of SC efforts in Qatar. It encompasses an explanation of the philosophical base, design, research approach and research method and justifies their applicability for the studied research topic.

The following sections unpack the methodology of this research with regard to the layers of the "research onion" conceptualised by Saunders et al. (2019), as displayed in Figure 3.1.

Braun and Clarke's (2021) six-phase reflexive thematic analysis was employed: (1) familiarisation through transcription review; (2) systematic initial coding; (3) theme generation; (4) theme review for coherence; (5) theme definition and naming; (6) report production. Coding was managed using NVivo 14 software.

3.1.2. Research Site: The State of Qatar

3.1.2.1. Socio-Economic Development and Vision 2030

Qatar has developed into an advanced society that can continue to grow and give its citizens a rising QoL. Qatar's long-term objectives are outlined in QNV'30, which provides a framework for creating national strategies and action plans. Qatar's national aim encompasses the interconnectedness of economic, social, environmental, and human prosperity. QNV'30 acts as a bridge between the present and the future (GCO, 2024). It envisions a progressive and thriving country where people and the environment live in harmony and everyone can access economic and social fairness. QNV'30 considers ensuring everyone's safety and well-being, including women's equality and rights without discrimination, as a critical component of its social development strategy (GCO, 2024).

In comparison to Saudi Arabia's Vision 2030 and the UAE's National Agenda 2021, Qatar's strategy places a strong emphasis on human development. However, while the UAE has been more successful in attracting foreign investment in the tech and innovation sectors, Qatar has primarily focused on state-led initiatives, albeit the state, the corporate sector, civil society, and residents are considered to jointly own QNV'30 (GCO, 2024). Social progress indicates the growth of every individual group or social community, regardless of gender or origin, having equal access to education, jobs, and career opportunities in addition to a more accepting and egalitarian society that preserves the fundamental principles of Islam. As part of the QNV'30, Qatar seeks to become a regional and global leader, with increasing influence in MENA.

Family unity and strength serve to reinforce moral and religious values, humanitarian objectives, and the well-being of family members (GCO, 2024). Nevertheless, a robust social safety net guarantees all Qataris a living wage that respects their individuality and role in shaping their society and protects their civil rights. Nonetheless, substantial urbanisation, significant investment initiatives, and increased government spending are the primary causes of Qatar's rapid population growth that induces demand for city development in terms of commercial, residential and other facilities to ensure rising QoL (GCO, 2024). However, quick urbanization and large-scale investments have also led to rising living costs, making affordability a growing concern for many residents.

3.1.2.2. Technological Adoption

The Qatari government places a significant emphasis on investing in technology as a primary area of concentration. An innovative culture is being promoted in Qatar by creating research and development facilities (Go-Globe, 2023). Colebation on innovative projects by professionals, academics, and entrepreneurs drives tech and online development forward at these critical locations. Investing in the IT sector in Qatar has tremendous potential that can be exploited to attract MNCs or support their growth and development. It is collaborating with global corporations like Google and Microsoft to speed up its digital transition and improve the technology ecosystem. With an unprecedented Internet penetration rate of 99.7 percent, Qatar has set the record as the first country to launch 5G. From 2017 to 2023, Qatar's digital sector grew at a rate of 7.2% each year. By 2021, the ICT sector in Qatar had grown by 2.5% Real GDP (Go-Globe, 2023). While Qatar has been a regional leader in 5G deployment, the UAE has made greater strides in fostering a startup ecosystem, attracting global entrepreneurs, and developing AI-driven industries.

The market for SCs is expected to grow significantly in Qatar, a nation renowned for its quick development and technological innovations. By 2024, this market category is anticipated to generate an astounding USD 0.54 billion in revenue. It suggests that the SC initiatives being undertaken around the nation have a bright future. Furthermore, from 2024 to 2028, it is anticipated that income will increase at a steady rate of 9.63% annually (Statista, 2023). Qatar is well-positioned to compete with and possibly even outperform other nations because of its expansive plans and investments in smart infrastructure. Qatar's SCs industry is growing quickly, with a significant emphasis on cutting-edge infrastructure and sustainable technology (Statista, 2023). Despite these advancements, Qatar still faces hurdles such as digital skill gaps, reliance on foreign expertise, and cybersecurity concerns.

Qatar is making significant investments in creating futuristic infrastructure and SCs to achieve its goal. This includes combining technology such as the Web, the IoT, ML, AI, and BDA to enhance urban living, increase efficiency, and create sustainable ecosystems. However, environmental sustainability remains a challenge, as Qatar's heavy dependence on fossil fuels contradicts its green technology aspirations. Many parts of city life in Qatar are getting online and becoming more efficient thanks to the IoT (Go-Globe, 2023). Road safety is also importantly valued to be met requisite of SC. Qatar invests in digital services that allow citizens and government institutions to engage effectively. To this end, enhancing involvement and accessibility is the primary goal of everything from SC apps to digital government platforms.

Web development is essential in Qatar's booming e-commerce sector, which is fostering the creation of safe and user-friendly platforms (Go-Globe, 2023). Furthermore, in order to reduce traffic and improve mobility, SCs in Qatar are giving priority to intelligent transportation systems. It includes intelligent traffic control, electric bus and train alternatives, and programmes that encourage environmentally friendly transportation. Investing in innovative technologies specifically designed to mitigate the negative impact of economic developments can effectively decrease the degradation of the environment; avoiding abrupt and uncontrolled economic growth (e.g., as manifest in unsustainable forms of urban development) is another way to lessen it (Go-Globe, 2023).

Given that Qatar's development pattern is based partly on the extraction and production of oil, gas, petrochemicals, and heavy industries, environmental damage is inevitable despite best efforts. Infrastructural development and other needs of a fast-expanding, diversified, and technologically advanced economy have also received priority in the nation. Along with a thriving oil and gas industry, Qatar benefits from cutting-edge technical advancements, which help to build the country's human capital and economic infrastructure (Go-Globe, 2023). In addition to the above, for enabling an effective DT, Qatar actively patronises international events, such as the Web Summit Qatar in February 2025, contributing to the integration of the internationally prevalent technological founders and helping drive Qatar's DT (Websummit, 2024).

The MCIT established the TASMU programme in 2017, using innovation and technology to bring digital solutions to the public. Hence, to support Qatar's DT and advance the nation's economy towards a more varied and sustainable structure, TASMU stimulates the ICT ecosystem in Qatar by bringing together international innovators with the demands of the local market. TASMU seeks to assist new ideas and continuously build them up because start-ups have extensive knowledge and understanding of the local market and are crucial to developing Qatar's economic diversification (Deloitte, n.d.).

Thus, to coordinate the digital supply needed for TASMU, the contribution of all the major economic sectors is essential, including logistics, Ecology, Health and Welfare, and Recreational Activities. Furthermore, within the auspices of the Ministry of Transport and Communications (MoTC), the "Better Connections" project was established in 2014 with the goal of advancing and enabling DT in order to improve the social welfare of foreign employees in Qatar. In the five years since its debut, it has given 1,679,000 recipients chance to experience the DT, exceeding its initial goal of 1.5 million those who benefit (Shuaib, 2023).

Digital Transformation (DT): DT can be described as a process that attempts to enhance an entity by instigating profound alterations to its features via the synergies of information, computing, communication, and connectivity technologies. It goes beyond digitisation to include core alterations in the value creation, organizational designs, and community relations.

Smart City (SC): Moving beyond the technocentric perspective, the current study takes the holistic definition perspective based on Albino et al. (2015) definition which asserts that a smart city is defined as an urban area that will combine a variety of technological solutions to manage assets and resources in a sustainable way, with the general aim to enhance the well-being of its citizens and economically develop as a result of its participatory governance.

Sustainable Digital Transformation (SDT): This thesis refers to SDT as the strategic and systemic process of capitalizing majestically on digital technologies in order to meet and balance the long-term environmental integrity, social equity, and economic prosperity in an urban environment. It directly connects the agendas of the smart and the sustainable so that digital solutions are sustainable in terms of their lifespan, inclusiveness, and resource-efficiency early on (Straub et al., 2021).

Qatar can be described as an interesting and urgent case study of a country that is using digital transformation as one of the primary sources of post-hydrocarbon diversification and societal growth. The specificity of its context, which includes the high centralized rule, high financial capacities, fast urbanization, and the specific focus of QNV 2030 provide a unique ecosystem to research SDT. The active attitude towards digital innovation, which is shown by the Web Summit and the technologically advanced FIFA world cup 2022, make the country an ideal living laboratory in this case.

Singapore is chosen as the main international benchmark because of three main reasons. To begin with, it is a well-established and thriving global smart nation, and it has always been on the first positions on the list of the smart cities in the world. Second, its vision, Smart Nation 2030 has alarmingly similar points with the Qatar QNV 2030, especially their economic, social, and environmental pillars. Third, Singapore being a city-state functions on a smaller scale and with a greater level of governmental integration than Qatar but larger and federated states such as the USA or Germany. Such comparability will enable a much narrower and more relevant analysis of policy frameworks, integration models and sustainability outcomes to be presented, and actionable lessons to be learned, as opposed to abstract ideals.

3.2. Research Philosophy

Following Venkatesh et al. (2013), this convergent parallel design allows quantitative data to provide generalisable patterns of SDT challenges, whilst qualitative data furnish explanatory depth regarding stakeholder perceptions, ensuring methodological triangulation. A paradigm or philosophy for investigation is a systematic approach, framework, or structure used to do research. A philosophical framework is a compilation of ideas, beliefs, or understandings that serve as a structure for the execution of theories and practices in the research project, to address aim and objectives (Saunders et al., 2015). Research methodologies span the theory-practice gap by situation practical research methods (i.e., the ways in which data is gathered and analysed) within a consistent theoretical and philosophical paradigm. Methodological choices (and thus methods) should be guided by the study inquiry and contextual factors, rather than being bound by strict adherence to a doctrinaire philosophical standpoint (Allemang et al., 2022).

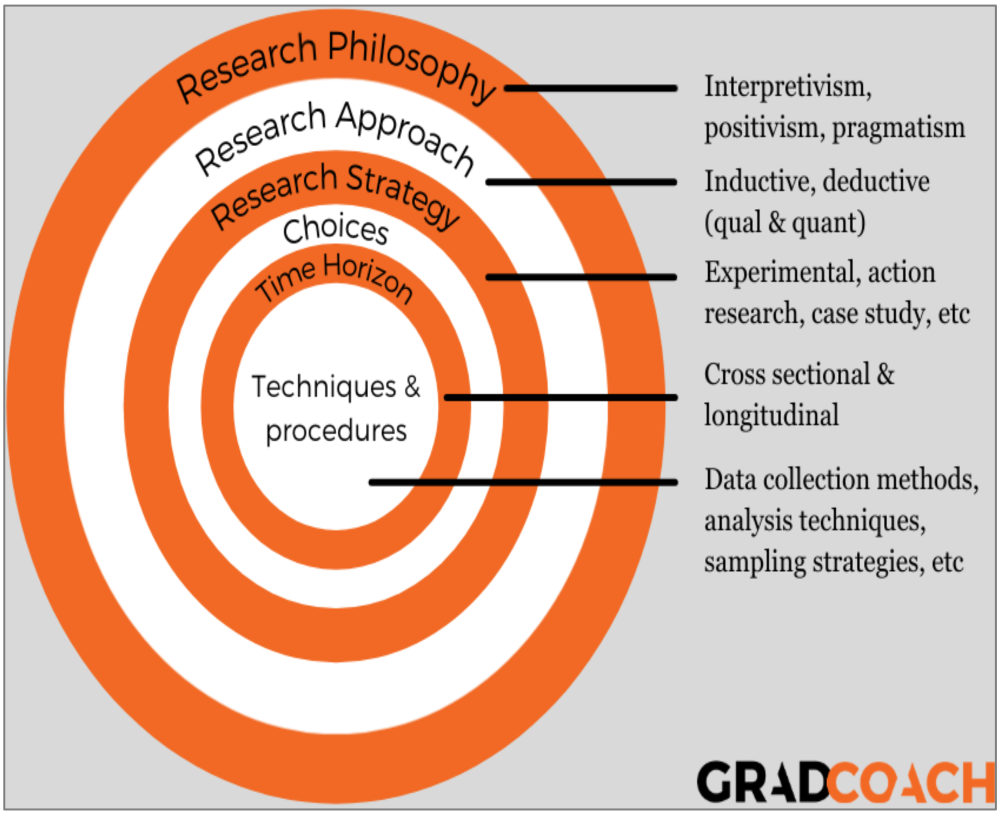


Figure 3.1: Saunders et al.'s (2019) research onion

Source: Gradcoach (2024)

Research projects employ a research philosophical approach as a guiding principle to direct data collection and analysis, relating to assumptions about what exists, and how it can be known and studied (i.e., epistemology). In most research investigations, three primary research paradigms are employed: positivism, interpretivism, and pragmatism. When conducting research, the positivism research paradigm is utilised in quantitative research studies, the interpretivism research paradigm is utilised in qualitative research studies, while the pragmatism research paradigm is implemented in mixed method research studies, which involve using components of both qualitative and quantitative research methods in conjunction with one another (Kaushik & Walsh, 2019).

For a research endeavour, choosing a paradigm is crucial since it establishes the framework for the methods and procedures that will be employed throughout the research process. A paradigm offers a concise summary of the aim, driving force, and anticipated outcomes of the research while concentrating on the study of how information is viewed and examined. The pragmatic research paradigm was applied in this study because it included both survey and interview methods. Within the current research about SCs in Qatar pertaining to SDT, the selection of pragmatism as the philosophical underpinning of the research is both appropriate and adequately supported. This study concerns both quantitative and qualitative data types, necessary to understand technological resources and human needs and perceptions.

In this study, the exploration of innovative city development in Qatar entailed the adoption of pragmatism, which entails using quantitative approaches to evaluate data on technical implementations and qualitative methods to investigate the human experience and contextual nuances (Kelly & Cordeiro, 2020). The use of pragmatism in the research supports the expedient use of quantitative and qualitative methods, contingent upon their alignment with the research objectives. Consequently, pragmatism reconciles the dichotomy between the scientific method and a structuralist viewpoint (Kaushik & Walsh, 2019). This implies that application of pragmatism in this thesis has aided to manage the knowledge gap due to the practical need to use both qualitative and quantitative (mixed) methods, in order to explore an emerging issue (i.e., SC in Qatar) with in-depth insights from stakeholders (using a qualitative approach), alongside the need for actionable data on SC outcomes (using a quantitative approach) (Creswell & Creswell, 2018). To further justify the philosophical stance, pragmatism is particularly suitable where the research problem is practice-oriented and complex, as is the case with SC development, because it allows the researcher to prioritise research questions over strict ontological or epistemological commitments. This supports combining methods to generate actionable knowledge for policymakers and practitioners.

3.3. Research Design

Selecting a research design for a project aids in formulating a study plan for defining and examining the topic. Exploratory, explanatory, or descriptive research methods could be used to address the study problem (Wilson, 2021). In the current research, the choice of an effective research design was made that shapes the whole structure and strategy of the study. A research design that is prominently used in the research inquiry is bifurcated into three types: exploratory, explanatory, and descriptive design (Asenahabi, 2019). Exploratory research is ideal to be integrated into the studies just beginning for investigation and a focus on understanding the topic in more detail prevails. When additional work on data exploration is needed, the exploratory research approach can be helpful. This approach is advisable for investigations that lack comprehensive previous research or have limited available material related to the subject matter (Creswell & Creswell, 2018).

Descriptive research describes the chosen topic in detail, and explanatory aims to explain the particular phenomenon in detail (Asenahabi, 2019; Creswell & Clark, 2011). Among them, with a focus on exploring the innovative city development in Qatar extensively to figure out its progress, opportunities for DT in the city, challenges, and innovative and failure factors, the use of exploratory research design was made. The selection of an exploratory design in this study is optimal as it has significantly facilitated the investigation of factors driving and obstructing SCs project in Qatar and also about sustainable digital development on the basis of both qualitatively and quantitatively. In order to give fresh insights and understanding of the research topic, the selected design managed data processing within the framework of the study problem and produced the presentation of exact data with extensive investigation (Wilson, 2021).

The selected methodological components, such as interpretivism and abductive reasoning, are well-suited to an exploratory research design. This implies that exploratory design in this study served to both elucidate the specific problem with wider and in-depth data exploration. The notion of SCs is currently in ongoing development, and a comprehensive comprehension of its complexities and difficulties may not yet be fully established. This design facilitates an in-depth examination of the intricate subject matter, enabling the exploration thereof and the generation of preliminary insights. This approach becomes particularly advantageous when the research problem lacks clarity, and the objective is to develop hypotheses and pinpoint crucial areas for subsequent examination (Edmonds & Kennedy, 2016).). The exploratory design also aligns with the limited empirical evidence available on SDT-enabled SC initiatives in Qatar, thereby necessitating flexibility and openness to emergent themes that can later be examined quantitatively.

3.4. Epistemology

The selection of an appropriate research approach is a crucial component of the methodology in a research project, as it provides insight into the data collection process. The choice of this option is intricately connected to the nature of the research, which can be classified into three categories: qualitative (inductive), quantitative (deductive), and mixed approach (abductive) (Wilson, 2021). This section focuses on the selection of the mixed methods research technique, in which regard the abductive approach was considered suitable for the chosen methodology. Abductive research allows researchers to make insightful conclusions from pre-existing data, leading to more thorough explanations, because it allows for incorporating new evidence with pre-existing premises and observations (Bell et al., 2022).

In contrast to research approaches such as inductive and deductive, which follow a top-down or bottom-up methodology, the abductive approach has been shown effective in providing explanations for phenomena and arriving at optimal conclusions. Data gathering to investigate phenomena, themes, and pattern identification has been aided by the selected approach (Saunders et al., 2015). To investigate phenomena and patterns, thorough and qualitative evidence/data were gathered for this thesis. These data were then further analysed or interpreted utilising survey results, literature reviews, and other data-gathering techniques.

The selection of an abductive technique is based not only on the fact that it facilitates theory change, but also on the fact that its implication overcomes the limits of employing inductive or qualitative reasoning and deductive or quantitative reasoning (Wilson, 2021). Using abductive reasoning helped the researcher come up with both qualitative and quantitative insights in order to triangulate a comprehensive understanding of Qatar's DT in relation to SC projects, in order to achieve the study objectives.

3.5. Research Method: Mixed Methods

The selection of a research method is contingent upon the intended study objective, which may involve identifying, exploring, and evaluating the aspects contributing to the advancement of DT and innovation. In the same way, qualitative, quantitative, or mixed methods study designs might be chosen. The qualitative approach is characterised by its focus on gathering in-depth and detailed information. In contrast, the quantitative approach relies on collecting facts that can be measured and quantified. The mixed methods approach incorporates qualitative and quantitative data, with researchers selecting appropriate methods based on their specific research objectives (Creswell & Creswell, 2018).

A sequential exploratory mixed-method design (Creswell & Clark, 2017) was adopted; however, the practical execution followed a pragmatically adjusted sequence. While interviews and surveys were conducted first due to time-bound access to elite stakeholders, the systematic review was subsequently used to triangulate, contextualise, and validate empirical findings rather than instrument development. This sequencing is consistent with pragmatic mixed-methods research where feasibility and access constraints influence method order. The justification for mixed methods is grounded in complementarity and triangulation. Following Venkatesh et al. (2013), qualitative interviews were used to capture in-depth contextual insights and explain mechanisms underlying SDT practices, while quantitative survey data enabled confirmation and generalisation of these insights across a broader stakeholder group. The integration of findings strengthened validity by allowing qualitative explanations to confirm, expand, and contextualise quantitative results.

By using empirical tools that facilitate the gathering and examination of both quantitative and qualitative data, the mixed research approach harnesses the advantages of both qualitative and quantitative approaches, which helps to get a better understanding of the research topic from multiple angles (Almalki, 2016). Data triangulation (i.e., systematically relating quantitative and qualitative data from different sources into a single coherent analysis) is an efficient strategy for reviewing mixed methods, because it facilitates approaching a social phenomenon from diverse angles across successive stages of research, thereby providing more in-depth insights (Sue & Ritter, 2012).

This study used a variety of approaches to achieve the research objectives, as described below, including a systematic review, qualitative interview, quantitative survey questionnaire, and preliminary prerequisite data for use to guide Qatar's future DT (Allweyer, 2016). The research described in this thesis thus utilised several research methodologies to investigate the efficacy of interventions, identify crucial elements, and assess their influence on the SDT of SCs within the context of in Qatar. The combination of multiple methods in this research to validate the study outputs has proven helpful in eliciting both objective and subjective insights that are necessary to arrive at in-depth knowledge and critical findings about SDT and interpretations with explanations (Creswell & Clark, 2017).

3.6. Research Approach

3.6.1. Types of Research Approach

The incorporation of the research approach in social research is associated with offering rational justification to the research endeavour and establishing overarching assumptions to strategise and execute the data collecting, analysis, and interpretation. These broad assumptions or research approaches are explained in three types, namely, inductive, deductive and abductive approaches (Zalaghi & Khazaei, 2016). Within the context of research, the incorporation of the inductive technique centres on employing established premises to generate untested conclusions. Conversely, the deductive approach focuses on verifying the validity of pre-existing ideas, assumptions, or hypotheses. On the other hand, the abductive approach is employed to produce verifiable findings by offering an explanation of unexpected facts or elements.

In addition to this, Okoli (2023) explained that the inductive technique involves the researcher beginning with empirical facts and subsequently constructing a hypothesis based on that data. Conversely, in the deductive technique, the researcher initiates with a theory and subsequently deduces the anticipated data outcomes based on the inferences drawn from that theory. The concept of deductive theorising is primarily linked to the "hypothetico-deductive model of the scientific method" (Okoli, 2023). Instead of using theory to deduce the data, the objective is to challenge a theory using the data. Abductive reasoning often involves analysing a particular situation and then deducing the most probable rule that might account for that case. In this way, the abductive approach assists in generating the best optimal explanation of the chosen research problem from the set of observed facts in the chosen phenomenon (Zalaghi & Khazaei, 2016).

3.6.2. Justification for the Selected Abductive Approach

Building on the above explanation regarding the types of research available to deploy for carrying out research comprised of inductive, deductive, and abductive research approaches, the latter has been selected for the context of this research, seeking the most plausible explanation of the observed phenomenon by integrating elements of deductive and inductive approaches (Liu, 2016). The rationale of integrating the abductive approach in the study to make logical conclusions on the basis of observations, integrate an approach to make all plausible explanations for the chosen observed phenomenon of SDT of SCs in Qatar, and to facilitate the researcher in deriving overarching conclusions from the restricted observations, in order to bolster the qualitative approach (Liu, 2016; Zalaghi & Khazaei, 2016). The abductive approach is found suitable for the chosen area due to the evolving and intricate nature of the subject, considering an in-depth understanding of the opportunities and challenges by considering the socio-economic landscape. Also, the flexibility offered by the approach is aligned with the exploratory nature of the topic, allowing the integration of diverse perspectives and comprehensive analysis of the SDT of SC development component.

3.7. Data Collection Methods

3.7.1. Overview

In the current research to examine the impact of innovative SDT on the SCs of Qatar, the choice of deploying primary and secondary data collection methods was made. Using the primary method of data collection, a focus on collecting fresh data directly from the area chosen as the research problem was made, while secondary data is gathered to fetch information from the existing literature developed after an in-depth inquiry into the research context. Surveys and interviews, which are widely or generally chosen approaches, were used in this research's mixed methodology to collect both quantitative and qualitative data (Creswell & Creswell, 2018).

In this research project, specific data collection techniques helped to deduce useful information about SC project in Qatar and DT. Through the use of surveys and interviews, the opinions of a sizable and interested group have been collected, to determine feasibility of SDT of SC project based on thoroughly and quantitatively acquired data. It is beneficial for the primary research to get new data from the sample using the chosen data collection methods. Claims and conclusions drawn from the survey and interview data have also been strengthened by the inclusion of secondary data in this research study. For this, systematic review was conducted, to derive data from the studies that already explored history of Qatar and SC program along with digital revolution.

The selected research methods were chosen specifically to address the research objectives described in Table 2.1. A detailed explanation of the methodological choices made around the data collection method is given below. Details about sampling and participant recruitment are given in section 3.8.

Table 3.1: Selected research methods and related research objectives

Research Method	Research Objective Addressed
Semi-structured interview	4. Evaluate the proposed framework
Survey questionnaire	2. Conduct a study to assess the progress, challenges, failure factors, and future opportunities for digital transformation and innovation for smart cities in Qatar, based on interviewing key stakeholders.
Systematic review	1. Critically examine related literature on SC theory and practice, in general and with particular relevance to Qatar.

Source: Author

Furthermore, study was conducted between February and June 2024. Interviews were undertaken prior to survey dissemination to ensure conceptual clarity, while the systematic review was completed after primary data collection to support triangulation and interpretation of findings.

3.7.2. Primary Methods

Primary methods in this dissertation aided to collect new and first-hand data using a new questionnaire designed on the basis of reviewed literature. Literature review-based ideas, concepts, findings and gap were all integrated in the questionnaire used for survey and interview purpose, to collect different opinions of the selected population and their experiences.

3.7.2.1. Semi-Structured Interviews

For the purpose of answering the fourth research objective, the selection or adoption of an interview, a qualitative data collection method, was made in this thesis investigation. Academic research requires the use of interviews as a key instrument since they are frequently the main source of data. The interview strategy enables the acquisition of comprehensive and extensive information, as well as facilitates the possibility for in-depth interaction (Bell et al., 2022). These interview technique features not only aid in the collecting of rich or in-depth data, but they also facilitate the exploration of new knowledge and a clearer or greater understanding of the research topic in question (Pajo, 2017).

In the current study, interviews were conducted through the use of the semi-structured interview method, which is a crucial qualitative research technique that permits the freedom to gather data through open-ended questions with scope to add or integrate new questions for detailed responses without doubts (Wilson, 2021). The semi-structured interview method was chosen for the fourth objective to make it easier to gather a variety of viewpoints regarding DT, with the potential to resolve any ambiguities and raise further issues in the process. In this particular context, the process of conducting interviews with the chosen respondents resulted in the identification and discussion of several elements and their respective roles in the development of a framework supporting Qatar's SDT for SCs.

The semi-structured interview guide can be seen in Appendix A. The study initially employed open-ended interviews, allowing for in-depth qualitative insights. These interviews then informed the development of a structured questionnaire (Appendix B). This study thus incorporated both qualitative and quantitative elements. This approach ensured a more detailed and critical discussion, justifying the selection of a mixed-methods approach (Vanover et al., 2021). No fieldwork was undertaken prior to receiving appropriate ethical permission (Appendix C), as described in section 3.10.

Respondents in the interview process were not provided any options or cues for the questions, to avoid issue of biased data. The focus of this data collection method is to collect diverse opinions and experiences of the respondents, to identify patterns of knowledge or new knowledge about the research subject. The semi-structured interview guide was developed based on the reviewed literature (in general), and can be seen in Appendix A. Interviews were conducted with the help of telephonic interview method and sample transcripts are presented in Appendix D.

Interviews were conducted Face Two Face (F2F) of senior stakeholders. Each interview lasted approximately 35–50 minutes, which was considered sufficient to reach depth while respecting participants' professional commitments. Interview duration and mode were selected to maximise participation and data quality. A pilot interview was conducted with one senior IT professional to refine question clarity and flow. Minor wording adjustments were made to improve probing and relevance.

3.7.2.2. Survey Questionnaire

The survey method has been selected to address the second research objective in this thesis, to exhibit the participation of employees from various departments and institutional levels in the context of SDT and innovation projects. The survey reveals clear knowledge can be gained regarding the point of view of the people who are being interviewed. The records of the operations can be supported with a clear evidence based research and having a clear idea of the responses. The utilisation of the survey questionnaire method is a highly effective method of gathering structured data from a specific cohort of individuals, which is substantially large in size and thus, helped in gaining views of a wider set of population. The method has several advantages due to which, it is used in the current research. Due to the necessity for a large amount of quantifiable data in quantitative analyses, one advantage of the survey method is the ease with which a large sample size of respondents may be reached. The advantage of cost savings with the least amount of efforts in data analysis due to quantifiable data was another benefit of selecting the survey approach for this study (Pajo, 2017).

Surveys involve the systematic collection of data on the research topic in a structured way, allowing time-efficiency to collect data from a relatively large sample, ensures standardisations, and anonymity and helps to produce quantitative data, which can be analysed in detail using statistical techniques (Sue & Ritter, 2012). In order to tap all the advantages of the method, the choice of survey was made to address the second research objective, focussing on assessing the progress, challenges, failure factors, and future opportunities for DT and innovation within the SCs of Qatar. The utilisation of the survey questionnaire method is highly appropriate for accomplishing this objective as it facilitates the researcher in acquiring insights from a diverse range of stakeholders in a systematic and efficient manner. Given the intricate nature of DT in SCs of Qatar, this method permits us to amass data on a broad range of subjects, encompassing technology adoption and urban planning challenges, as well as innovative opportunities. The structured format of surveys ensures the capturing of pertinent data points in a standardised manner, thereby simplifying subsequent data analysis (Nayak & Narayan, 2019).

Additionally, in order to obtain data via survey questionnaires, the researcher disseminated electronic surveys with the help of survey Monkey to a meticulously selected sample of stakeholders who are actively involved in DT and SC initiatives throughout Qatar (Appendix B). The surveys were carefully designed to align with the specific research objectives which emphasise on key concepts identified from the reviewed literature. Participants were invited to complete the surveys online to ensure accessibility and ease of participation. The questionnaire comprised 13 questions, including demographic and specific ones, constructed based on generally reviewed literature based on some particular studies, to collect a pertinent range of data on the research topic. This helped in exploring wider data on the progress of SC development in the city, challenges and failure factors, and future opportunities for transformation.

3.7.2.3. Pilot Study

Prior to being deployed at a larger scale, the survey instrument underwent a pilot study phase. The pilot study assessed the reliability, clarity, and construct validity of the survey instrument. This pilot project was implemented in Doha in the month of February 2024 among ten professionals working on Smart City projects. The ten were split between the public (n=5) and the private sector (n=5) to ensure the diversity of perspectives and confirmation that the instrument would be able to measure the opinions of the stakeholders who would be operating in different institutional environments. The purpose of dividing the participants equally was to provide a diversity of viewpoints concerning professional practices in order to validate that the instrument would be capable of assessing the views of stakeholders working within differing institutional settings.

Respondents' comments were systematically evaluated, and they indicated confusion regarding what they understood "digital literacy" to mean. Respondents stated that their understanding of the term depended upon both their professional experience and their experiences with technology. As a result, the term "digital literacy" was refined to better fit the Smart City context. Specifically, the term was redefined as "the ability to utilize digital platforms for engaging with urban services." By defining the term in a manner consistent with the study's context, the respondent's understanding of the term was clarified for future respondents.

As well as the qualitative comments provided by respondents, a preliminary evaluation of the reliability of the survey instrument was conducted using the pilot study's data to evaluate the internal consistency of the survey questions. A Cronbach's Alpha (α) value of 0.84 was determined. Since a commonly accepted standard is 0.70, the study demonstrated a high degree of internal reliability. Therefore, since the study has demonstrated a high degree of consistency in measuring the concepts being measured, the survey instrument can be used in the next stage of the study.

The pilot study played an essential role in the refinement of the survey instrument. The pilot study enhanced the clarity of the items, strengthened the operationalization of the constructs, and validated the reliability of the measurement scales before collecting data at a large scale.

3.7.3. Secondary Methods

3.7.3.1. Systematic Review

The placement of this systematic review at the end of primary data collection functions as a form of critical triangulation in relation to the abductive nature of the research design of the study. The purposeful ordering of methodology has therefore reversed the typical sequence of other methodologies; this time, the literature being reviewed will be analysed through empirically derived themes (developed through primary fieldwork) that have been developed after collecting primary fieldwork, instead of developing theories based on previous theories or models. As such, this type of methodology allows for the creation of grounded theory while also validating and placing the study's results into the larger body of scholarship relating to Smart Cities and Smart Digital Transformation (SDT) which significantly increases the analysis' level of rigor, credibility, and validity. This systematic review follows all guidelines set forth by PRISMA 2020 (Page et al., 2021) to provide maximum transparency, reproducibility and reduction of selection bias during the review process. The inclusion/exclusion criteria for selecting eligible studies are systematically organized using the PICo framework (Population, Interest, Context); thus, creating a strong base for selecting studies. Specifically, Population includes Smart City initiatives, digital infrastructure deployments, urban governance frameworks and municipal service innovations; Interest includes SDT implementations, post event urban development trajectories, technological innovation adoption processes and digital governance transitions; and Context includes the state of Qatar with an emphasis on developments related to the Doha metropolitan area and surrounding municipalities. Additionally, inclusion parameters include English language only peer-reviewed literature published between 2014 and 2024. This date range encompasses the period of intense infrastructure development leading up to the FIFA World Cup as well as the immediately post-tournament development of new governance structures. All source types that are acceptable as peer-reviewed include: academic journal articles, peer-reviewed conference papers and official technical reports produced by government or quasi-government agencies; whereas exclusionary source types would include: non-English language publications; studies dated prior to 2014; non-peer-reviewed grey literature without empirical support; and studies that focus primarily on general information and communication technologies (ICT) but do not relate to either Smart City or digital transformation concepts.All relevant electronic databases were searched electronically; namely Scopus, Web of Science, IEEE Xplore and Google Scholar. The search terms used were Boolean combinations of Smart City terms ("Smart City", "Intelligent City", "Digital Urbanism") and Digital Transformation terms ("Digital Transformation", "Smart Governance", "ICT Infrastructure"); with Qatar-related geographic identifiers ("Qatar", "Doha", "FIFA World Cup 2022", "Post-2022 Development"). Additional records were obtained through the use of backward citation chasing of reference lists and forward citation tracking of prominent Qatar Smart City publication(s) in order to ensure thoroughness in reviewing the available literature. After retrieving all available records they were then uploaded into Covidence systematic review software to automatically remove any duplicates, then each record was screened independently by two researchers against the predetermined eligibility criteria. Any discrepancies at either the title/abstract or full-text stage were. The MMAT (version 2018) was utilized to evaluate both the methodological quality and risk of bias present in all included study designs (qualitative, quantitative and mixed-methods) because it was designed to handle the expected diversity in study design that would result from a large number of different epistemologies. Configurative thematic synthesis was utilized as part of the analytical strategy; where coding procedures and analytical categories were determined through themes derived from the primary qualitative data rather than prior theoretical constructs or established frameworks. This analytical strategy is directly aligned with the abductive logic of the entire study, enabling the literature review to serve as an analytical tool for comparing empirical observations to existing literature, while avoiding the imposition of preconceived theoretical constructs onto empirical findings. Also, because this systematic review was completed at the completion of primary data collection, it enabled the inclusion of recently developed literature addressing Qatar's post-FIFA World Cup 2022 infrastructure governance transition developments — a body of literature largely absent from previous scholarship due to the relatively recent occurrence of these events. Therefore, this review provides a timely examination of Qatar's evolving digital transformation trajectory, including the repurposing of stadiums for legacy purposes, strategies for utilizing legacy assets, and evolving smart governance frameworks that have evolved since the close of the tournament. A systematic review allowed for an objective evaluation of gaps, contradictions, and emerging trends in the literature; ensured study selection occurred through transparent, replicable criteria that minimized selection bias and increased dependability/certainty in findings (Tawfik et al., 2019). Through combining/integrating information from various bodies of scholarly work through standardized extraction protocols and systematic quality appraisals, this review created a robust empirical foundation for evidence-based assessments of Qatar's SDT initiatives; and concurrently, provided a defensible audit trail that enhanced overall trustworthiness in conducting research.

This methodology guarantees that the ongoing study must be founded on the most recent and pertinent information, empowering the researcher to formulate educated and evidence-based evaluations in the quest for SDT in Qatar. In order to collect data using the systematic review method, the integration of robust parameters was made, which are defined with the help of inclusion and exclusion criteria (Kitchenham & Brereton, 2013; Zawacki-Richter et al., 2020), which are briefly elaborated in Table 2.2. The systematic review itself is presented in section 5.4.

Table 3.2: Systematic review inclusion and exclusion criteria

Basis	Inclusion Criteria	Exclusion Criteria
Time period	Studies within the timeframe of 2018 through 2024 for ensuring that this study would be based on current knowledge and information related to this topic.	Studies prior to 2018 or subsequent to 2024 were excluded from this review in order to keep the study current and consistent.
Nature of studies	Empirically-based studies from various peer-reviewed academic journals, including but not limited to Springer, Science Direct, Sage Publications, Research Gate and Google Scholar. All empirical studies regardless if they are qualitative or quantitative will be included. Additionally, all types of studies including peer-reviewed articles and conference proceedings are being considered	Non-empirical studies; gray literature; opinion pieces; and other non-academic credible sources will be excluded from the review due to their lack of academic credibility.
Relevance	Studies which provide specific and relevant data about digital transformation (DT), Smart City (SC) projects/efforts, specifically in the country of Qatar, will be included.	All studies which are not directly applicable to DT or SC development; do not meet the objectives of the study; will be excluded.

Source: Author

Although conducted after primary data collection, the systematic review served a confirmatory and contextual role by comparing empirical findings with established evidence, thereby strengthening analytical triangulation.

Discussion of Study Limitations

In addition to the strict evaluation criteria utilized in this systematic review, there are several constraints that must be acknowledged. The first constraint is that by only evaluating studies from the period 2018-2024, there is a possible risk that previous influential work that established the underlying theory and conceptual frameworks upon which digital transformation and Smart City development is based was excluded. While the most current literature has been emphasized (to provide up-to-date information), such an emphasis could have omitted studies that establish the foundation for today's discussions.

The second limitation is that while utilizing select academic databases can improve the quality, validity, and peer-review status of the references; it may also omit studies that were not indexed within those databases. For example, articles that contain very valuable research that may be contained in regional or specialized journals, open access repositories, etc., may not have been captured, thus potentially limiting the inclusivity of this review.

The third limitation is the exclusion of gray literature, as required for maintaining high-quality academic rigor, and ensuring the reliability of the body of evidence; but may exclude knowledge of industrial experience, policy documents and current practice, all of which offer insight into the "real world" implications of implementing new technologies, and emerging trends which are not yet documented in the academic literature.

Lastly, while focusing exclusively on studies regarding Qatar allow for an in-depth and localized examination of the subject matter; it restricts the generalizability of the results to other regional or global contexts. Therefore, while this type of study provides valuable localized data; the results may not apply to countries with different economic-social characteristics, government structure(s) or technology development stages.

Together, these limitations indicate a need for caution when interpreting the results, and reinforce the need for future studies to broaden their scope of investigation and incorporate additional types of data (e.g. temporally broaden their analysis, utilize additional types of data sources, and expand geographically) to allow for comparative evaluations and greater generalizable insights.

3.7.4. Summary

In summary, conducting interviews with key stakeholders to gain in-depth knowledge, followed by a survey, and a systematic review for adopting a mixed methods strategy in order to enhance comprehension of the study subject (Allweyer, 2016).

3.8. Sample and Sampling Technique

Selecting the appropriate samples is a very important aspect of the research methodology and therefore impacts the representative nature of the data collection. When using the mixed-methods research design, the target population was defined, the number of participants selected, and the most suitable sampling method was chosen to provide enough analytical rigor.

Qualitatively, 9 semi-structured interviews were completed, supported by the fact that there was theoretical saturation; i.e., no new theme could be identified after the 7th participant interviewed, and the last two interviews provided additional support to previously established categories and confirmed adequate thematic depth (Guest et al. 2006).

Quantitatively, a sample size was derived from Green's (1991) regression-based equation ($N > 50 + 8k$), where $k = 17$ independent variables, which resulted in a required sample size of 186. Given a 5% expected non-response rate, the desired sample size was 196 and the final sample size consisted of 98 complete survey responses – which is a limitation of the study and reflected the difficulty in recruiting participants during the COVID-19 pandemic.

Prior to deploying the full sample size, a pilot study (n=10) was implemented to test the survey instrument and make adjustments as necessary. Although the study has many positive aspects, it does acknowledge limitations based upon the homogenous nature of the sample, including senior stakeholder participants age 35-54 years and primarily from the government and IT sectors. As such, the lack of citizen and end user perspectives limits the generalizability of societal acceptance of Smart Digital Transformation initiatives.

3.8.1. Sample for Interview

For the purpose of conducting interviews, a sample population consisting of top-level managerial people and stakeholders who hold decision-making positions in the public sector was selected to investigate their support for DT. The present sample selection has facilitated the identification of the primary criteria that may influence the assessment of the established framework for achieving SDT and innovation in Qatar.

For the purpose of recruitment of the sample population, a post was given on a WhatsApp group of 98 participants from Qatar, all being IT specialists, created earlier by IT community members. The group was specifically chosen because it comprised professionals in high-level management positions, including CEOs, directors, and other senior executives. The WhatsApp group was identified through professional networking, as it was an established forum where IT leaders in Qatar discussed industry trends, shared insights, and engaged in professional dialogue.

To ensure relevance and maximize response rates, the post included a brief introduction explaining the study's purpose, its significance, and the criteria for participation. The post asked them to volunteer to take part, and, if so, accept it by email. They were then sent a consent letter to show that they are willing to take part in the data collection process by their own will. 10 respondents in all from this sample population were interviewed, after obtaining their informed consent to participate in the interview performed for this thesis and to share their perspectives. A low sample size is inevitable for interviews to process in-depth discussions about factors that support SDT for SCs.

Another factor contributing to the limited size is the challenge of accessing top-level management individuals participating in the public sector project of DT and innovation in Qatar for SCs. This effort proved to be difficult due to the busy schedules of these individuals and the governmental prohibitions on disclosing information. In order to preserve anonymity, the personal information of participants was kept confidential in the records. The selection of participants for this thesis was carried out using purposive sampling, which involves selecting individuals based on predetermined criteria and specific characteristics that align with the research aim and objectives (Ryan, 2013; Wilson, 2021).

3.8.2. Sample for Survey

In the present research, to collect meaningful data pertinent to achieving the research objectives, a combination of sampling techniques, including random sampling technique and purposive sampling technique was made. Random sampling is a fundamental method that guarantees each individual within the population an equal and ascertainable opportunity to be selected for inclusion in the sample (Obilor, 2023). Consequently, this methodology enhances the ability to make generalisations. The study utilises random sampling as a method to pick a subset of stakeholders from a larger population consisting of individuals and organisations engaged in DT and SC development in Qatar. Although random selection is a fundamental method for ensuring representativeness, it was acknowledged that it is necessary to include certain specialists and key decision-makers who offer distinctive insights into the DT landscape in Qatar.

In order to address this issue, purposive sampling, a non-probability method, was utilised to intentionally select people who possess expertise and are actively engaged in the relevant sector. Purposive sampling is a method that holds significant value in capturing comprehensive and authoritative viewpoints (Etikan et al., 2016). This allowed the strategic selection of a sample of 98 stakeholders across Qatar, who is actively, involved in DT and SC initiatives in the city by ensuring that the voices of all pivotal samples should be integrated.

The survey sample size of 98 stakeholders was deemed appropriate based on feasibility, access constraints, and the exploratory nature of the study, while still allowing for meaningful descriptive and inferential analysis.

3.9. Data Analysis Technique

The structured expert panel (SEP) process was used to establish content validity. Five academics (n = 5), who have been actively engaged in research on Smart Cities, digital governance and urban development within the context of the Gulf region, reviewed the questionnaire items based upon relevance, clarity and alignment to the conceptual framework being researched. Minor revisions to item wording and structure were made to incorporate the SEP comments to ensure that all relevant conceptual domain areas were addressed. Further, the content representativeness of the instrument was enhanced through the SEP comments.

The construct validity of the questionnaire items was further assessed through Confirmatory Factor Analysis (CFA) to assess the degree to which the measured variable accurately represented the underlying latent construct. A CFA was conducted because it is a theory-based approach to validate measurement models by examining whether the theorized factor structure fits the data. This technique allowed researchers to assess how well each item represented its corresponding latent construct. Researchers determined the strength of the relationship between each item and its corresponding construct through standardising the factor loadings. Based on established methodology guidelines, researchers defined an acceptable factor loading to be greater than or equal to 0.70 (Hair et al., 2019) and therefore any items that did not meet this criteria were removed from the final model. Therefore, retaining the items that met the above criteria confirmed the acceptability of the measurement structure and supported the construct validity of the instrument.After collecting the raw data, it is essential to select an effective method for analysing the collected data. In the presented research work, primary and secondary forms of data were collected, as described above, which entails the need for different types of data analysis method. The data collection instruments were administered in English, which is the lingua franca of business professional in Qatar and throughout the GCC (Nickerson, 2022), ensuring consistency in responses and analysis. In this regard, the data analysis techniques considered effective for the presented research work are explained below.

3.9.1. Data Analysis Techniques for Primary Data Collection Methods (Stakeholder Interview and Survey)

In the presented research work, interviews and surveys via a questionnaire have been taken into account for collecting first hand data from the selected respondents. In this regard, quantitative primary data from surveys was analysed using SPSS (version 23.0) for descriptive and inferential statistics. Raw data was thus interpreted, and trends from the opinion of the selected respondents were collected. In addition to this, different statistical tests such as correlated analysis and hypothesis testing was performed for the purpose of obtaining overall inferences from the data (Meyers et al., 2013). This technique can be considered quite effective in drawing reliable and validated research results from the primary and quantified data.

In addition to quantitative data, primary qualitative data was also collected through interviews conducted as part of this research. In this regard, thematic analysis has also been performed in the presented research work. Under the thematic analysis process, firstly the transcripts of the interview were recorded in this research. As per the six-stage data collection and analysis of Braun and Clarke (2021), based on the transcripts of the interview some codes were generated.

From the generated codes, some particular themes were developed and under those themes the responses of the interview were analysed considering the common data patterns. In thematic analysis different themes have been generated from the analysis of the interview transcripts (made by the researcher after listening to the audio recordings multiple times, during the process of achieving data immersion) (Braun & Clarke, 2021).

The six-stages of Braun and Clarke (2021) aided in attaining familiarity with the qualitative and detailed data, and data immersion enabled the researcher to identify recurrent patterns in the data, and to sequentially generate codes and themes as a whole. Themes generated through this method and key or highlighted terms and concepts along with supportive led to reaching conclusions under thematic-based analysis. These themes have reflected the core findings and interpretation of the interview data so that the final conclusion from the findings can be generated in the most effective manner.

3.9.2. Data Analysis Techniques for Secondary Data Collection Methods

Along with primary data, secondary data was also collected and presented in this research from different secondary data sources such as books, journal articles, and research reports. The secondary data in the research work was collected in qualitative form. In this regard, a method for data analysis, namely systematic review was included in the comprehensive triangulated analysis undertaken in this research (Fujita & Selamat, 2019).

In the systematic review method, different literature related to the research context has been reviewed and the entire literature article has been appraised with Critical Appraisal Skills Programme (CASP) criteria (Smith et al., 2022). After this, the information obtained from the articles was sorted and inferences were obtained for the purpose of interpreting this information and reaching to the suitable conclusion of the research work (Smith et al., 2022).

3.10. Ethical Considerations

Participants were fully aware of their rights regarding withdrawing consent from any aspect of the research (i.e., during or after the data collection) and participants had the option to do so throughout the study for up to two weeks post-completion of data collection. The participant information sheet stated this as a way to maintain full voluntarism and allow the participant to have full control of their data even after they had provided it. Participants were also made aware that withdrawing would have no adverse effects and that if they withdrew prior to the close of the study, all data previously given by them would be removed from any analyses.

Accordingly, the participant information sheet contained clear descriptions of data protection and methods for destroying the data (Appendix C). The participant information sheet explained how the participant's data will be anonymized, secured and only accessed by the researcher for educational purposes. Any data related to a participant who withdrew within the specified time frame will be completely deleted through use of digital security delete protocols, thus adhering to the requirements for confidentiality and data protection.

The actions taken reflect an adherence to ethical research practices, transparency, and the participant's autonomy, as well as the ethical principles of informed consent and responsible data management. Throughout the research endeavour, the researcher demonstrated a robust dedication to adhering to ethical concepts and practises. The devotion to this aspect is of utmost significance due to the wide range of data collection methods utilised in the study, thus several ethical considerations pertinent to the methods were followed (Gupta, 2017). While performing interviews, the researcher ensured voluntary participation of the interviewees, after gaining their informed consent and ensuring there was no implicit coercion or compulsion involved. Anonymity and confidentiality were strictly maintained in the research through the process of interview and survey, by asking no personal questions and respecting privacy. The survey participants possessed a comprehensive understanding of the survey’s objective and the potential applications of their responses (Creswell & Creswell, 2018).

Furthermore, the researcher demonstrated a high level of attentiveness in acknowledging power imbalances and possible disagreements/conflicts of interest, ensuring that the perspectives and contributions of participants were treated with respect and protected. In conducting a systematic evaluation of the available literature, it is imperative to adhere to ethical issues, which encompass the appropriate citation and acknowledgement of sources. By doing so, the researcher demonstrates respect for intellectual property rights and upholds the principles of academic honesty (Beauchemin et al., 2022; Gupta, 2017).

Throughout the course of this study, the researcher diligently followed well-established ethical guidelines, ensuring that all data collection and analysis procedures were conducted in a responsible and ethically sound manner. Prior to conducting any fieldwork, ethical approval was obtained from Brunel University London Research Ethics Online (see Appendix C for ethical approvals).

3.11. Research Limitations

This thesis utilised mixed methods to overcome the limitation of using a single method or approach for data collection. While this conscious decision seeks to triangulate numerous sources and types of data to achieve a holistic understanding from different perspectives, this also entails a potential drawback. The inclusion of diverse views and a greater range of data in the analysis of SDT may provide a level of complexity that could divert attention from the core results and hinder the accurate interpretation of accurate information (Wilson, 2021). The results of data gathered from various and extensive methods (i.e., surveys, interviews, and systematic reviews) makes data triangulation particularly complex. However, data analysis was undertaken logically, using appropriate techniques of primary and secondary data analysis (Saunders et al., 2015).

One of the conscious restrictions of the stakeholder is the fact that it is concerned with managerial and professional viewpoints (policymakers, technologists, planners). This gives the best strategic top-down view, but intrinsically lacks the representation of the citizen voice and end-user experience. This imbalance is increased by a wider scope of the survey but implies that the research is more sensitive to the supply aspect of SCs instead of the demand. The direction of the research in the future should focus on the citizen acceptance, digital divides, and perceived social impact of these technologies on various communities in Qatar.

Primary data was sourced from top management officials and stakeholders. At the same time, experts in economics and digital technologies might have been consulted to acquire insights into the variables and processes contributing to the SDT of SCs in Qatar. The process of sample selection may have incorporated the perspectives of other individuals, such as subject matter experts or professionals in the field, in order to mitigate the potential limitations and biases associated with the available information. The expertise possessed by professionals would provide insights into the distinct elements that facilitate or impede the realisation of DT potential in the context of SC innovation in Qatar. The absence of citizen and end-user perspectives limits insights into public resistance and adoption challenges. This limitation may bias findings toward a supply-side, top-down view of SC development, which should be addressed in future research.

3.12. Chapter Summary

Based on the comprehensive analysis above, this thesis has effectively addressed its target and objectives through the utilisation of a mixed methodology approach. To address the need for both qualitative and quantitative data, this methodology employed a variety of data collection techniques for a range of aims, gathering both objective and subjective information. This thesis has utilised a mixed method approach, incorporating the philosophical framework of pragmatism, an exploratory design, and an abductive methodology. The data collection process involved many methods, including systematic review, interviews and surveys.

Subsequently, the acquired data was analysed through theme-based and graphical methods. The data collection process involved conducting surveys and interviews with various individuals, including stakeholders, members of the top management team, and decision-makers. The purpose of these interactions was to acquire insights into the variables that have contributed to the achievement of SDT. The following chapter presents the findings derived from the mixed methods approach adopted, accompanied by corresponding interpretations in relation to existing literature on SC and DT in Qatar.

CHAPTER 4
Comparison of the Current SC Framework of Qatar with Singapore

This chapter compares the SC framework of Qatar with that of Singapore. Singapore was selected throughout this analysis because specialists recognise it as the worldwide forefront leader in delivering SC programs as an independent nation-state (as alluded to in section 2.9.2). This chapter establishes a performance baseline for Qatar's SC initiatives through an analysis of Singaporean capabilities as a global smart city powerhouse.

A sector analysis between Qatar and Singapore regarding the sustainable digital transformation of smart cities will assist in understanding how Qatar can address its challenges and maximise opportunities by strengthening its framework, as per research question 1. The study also helps in answering the third research question, which focuses on the elements of the roadmap that might foster digital transformation in Qatar through an examination of Singapore's successful digital transformation practices suitable for implementing Qatar's sustainable digital transformation roadmap. In contributing to answering these questions, this chapter thus contributes to research objectives 1 (by critically examining practical SC literature) and 3 (by identifying key elements to be incorporated in the SC DT framework for Qatar).

Singapore is selected as a mature city-state with comparable population density and ambitious Vision 2030 (Smart Nation), contrasting with Qatar's nascent SC development. The study compares the performance of the SC model in Qatar with that in Singapore in terms of infrastructure, along with five key areas of the infrastructure, which include smart transportation, energy preservation policies, data-driven urban planning (D-DUP), smart healthcare services, and smart security operations. The analyses of these regions allow practical insight into the way Qatar can enhance its smart city programs using the successful implementation of smart city technology in Singapore.

The four main areas in which Qatar is working are:

1. The Environment

2. Education and Health Care

3. Family and Society

4. Business and Economy

These four areas work together to support Qatar's vision of developing a strong and prosperous nation, where all residents have access to quality education, good health care, and job opportunities, and can live in harmony with the environment.

All four pillars support each other and help to provide a healthy, happy and safe community.

The five sectors are the direct pillars of the four key pillars of Qatar development identified in Qatar National Vision 2030. To give an example, the pillar of the Environment includes Smart Transportation and Energy Efficiency, Smart Healthcare is a pillar of the Education and Health Care, Data-Driven Urban Planning supports the Business and Economy pillar, and Smart Security and Safety supports the Family and Society pillar. Through these aspects, the analysis indicates that the success of Singapore can be applied in practice to provide sector-specific lessons applicable to the overall national priorities of Qatar.

To conclude, QNV 2030 will make it a prosperous economy, a socially conscious and eco-friendly society, and will be rising as a country even beyond 2030. Saudi Arabia is excluded from the primary comparison due to differing federal governance structures and less comparable SC maturity indicators.

The research examines how Qatar’s SC framework performs against Singapore’s infrastructure, incorporating five vital sectors: smart transportation, energy conservation strategies, data-driven urban planning (D-DUP), smart healthcare services and smart security operations. The examination of these areas enables actionable knowledge about how Qatar should improve its smart city initiatives through Singapore’s proven smart city technology implementation.

In Besummary, QNV 2030 will create a thriving economy and a socially aware and environmentally friendly community and will continue to grow as a nation after 2030.

It is worth noting that there is no direct mention of the 4 pillars within the GSDP (2008), but they are supported by Al-Maadeed & Fakhroo (2019), Fromherz (2012), Hvidt (2013), and Reiche (2010).

As such, the four pillars of QNV 2030 can be seen as being consistent with the aspirations of the people of Qatar. Therefore, it can be concluded that QNV 2030 has been developed with the best interests of Qatar at heart and represents a clear and positive direction for the future of the nation.

Many factors may influence the success of this vision. These include: political stability; effective leadership; international relations; human resources; and technological advancements.

The comparative case study approach follows Yin (2018), employing theoretical replication logic. Singapore represents a polar case of mature SC implementation, whilst Qatar represents an emerging context, allowing for analytic generalisation of success factors.

4.1. Environment: Smart Transportation

4.1.1. Overview of Qatar

The smart transportation of Qatar can be discussed in the light of the flagship SC project, Lusail City. Lusail represents one of Qatar's earliest large-scale implementations of the smart mobility concept, which incorporates an Intelligent Transport System (ITS) that provides services such as car park management as well as controlling traffic signals on a real-time basis. Lusail also comprises a Traffic Information System (TIS) that is equipped with active modes arrangement features in its walkways, as well as busy urban localities and major highways (Figure 4.1). These systems collectively aim to improve traffic efficiency, safety, and commuter experience through real-time data utilisation. Lusail further comprises a multimodal facility for journey planning. Under the TIS, Lusail uses cameras for collecting data about traffic management in a non-intrusive format. Cameras record the video for processing historical and real-time traffic data. Moreover, transportation authority's use the prevalent pan-tilt-zoom (PTZ) as well as mountable cameras for estimation of vehicle numbers as well as speed (Tahmasseby, 2022).

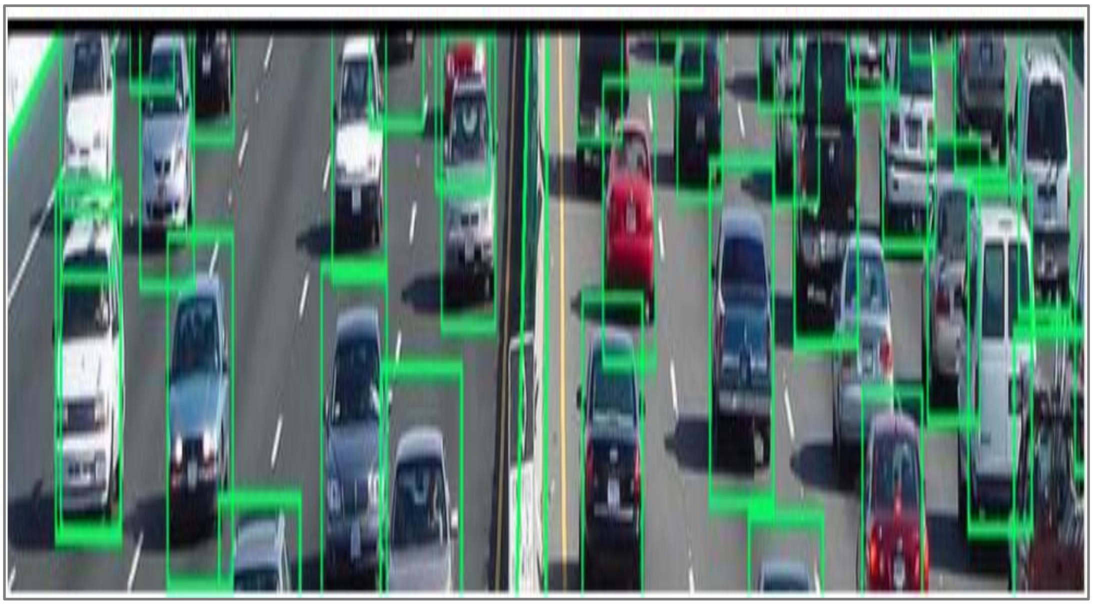


Figure 4.1: Traffic intelligence system

Source: Tahmasseby (2022)

The deployed PTZ cameras also offer details surrounding lane occupancy and average speed, as well as monitoring different situations, which include data surrounding the detection of traffic incidents and monitoring of construction zones, along with traffic violation-related information. This real-time situational awareness enables quicker response times and supports evidence-based traffic enforcement. This involves data on wrong-way drivers, as well as stationary vehicles. Furthermore, this also provides data for the presence of debris on roads for a considerable proportion of time. PTZ cameras also help in delivering quantified data surrounding pedestrians, pinch-points, increment of traffic flow and congestion (Tahmasseby, 2022).

This system enables the traffic authorities to manage transportation systems as well as issue traffic violation challenges. Such automation reflects Qatar’s gradual shift towards data-supported transport governance. As shown in Figure 4.2, the transportation system in Lusail offers good connections with the national capital, Doha. Lusail is further expected to comprise an extensive network for transiting vehicles. Furthermore, as Figure 4.3 displays, the tram network in Lusail City comprises four lines, differentiated by colour (turquoise, orange, purple, and pink), which provide services via 25 railway stations. These stations are interconnected with the Doha Metro Red Line in Lusail as well as the Legtaifiya Metro Station (Tahmasseby, 2022).

Figure 4.2: Rail-bound network for public transport

Source: Tahmasseby (2022)

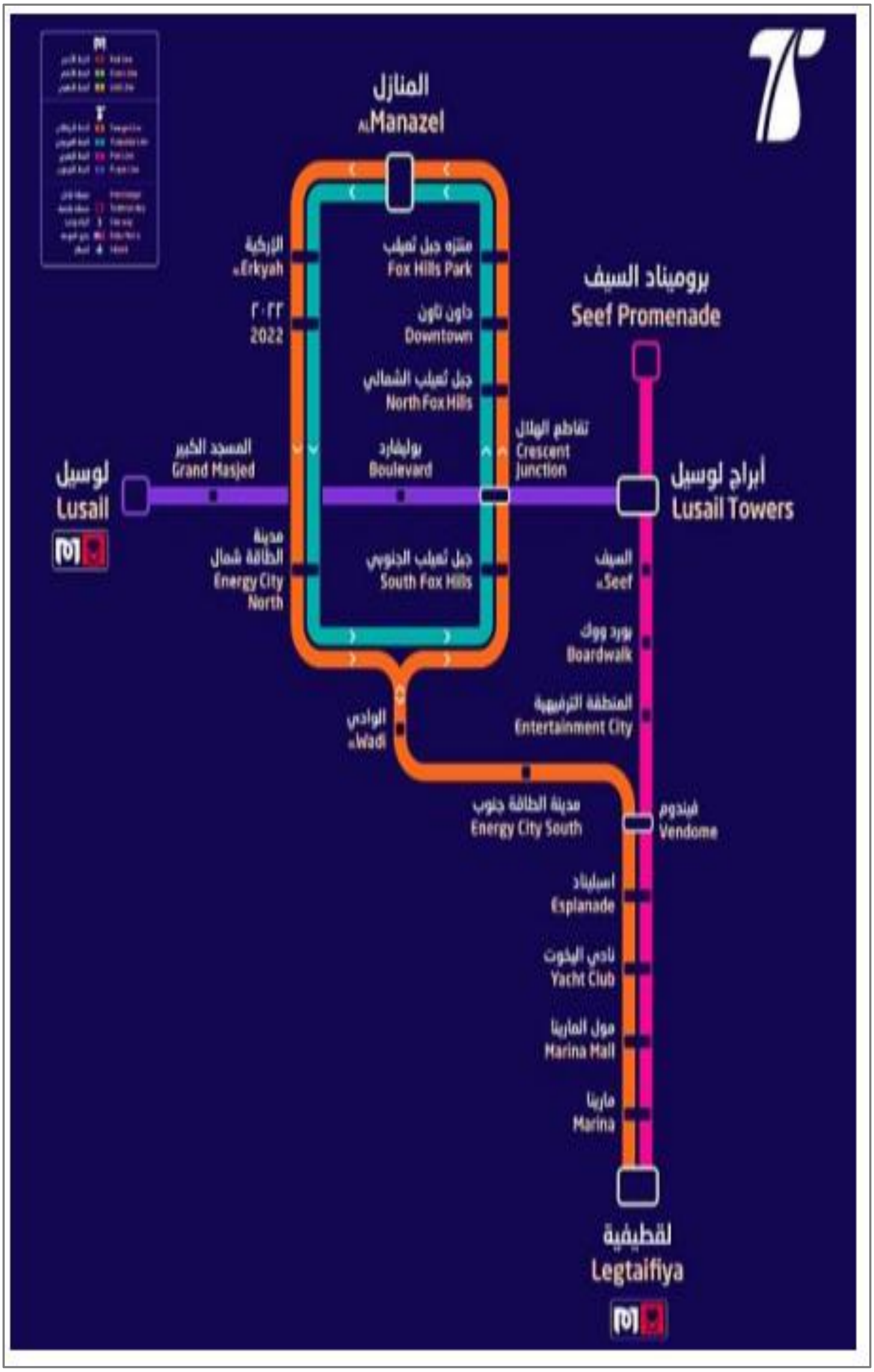


Figure 4.3: Tram network

Source: Tahmasseby (2022)

Moreover, Pearl Island is accessible by the first water taxi service in the city of Doha (Figure 4.4). This initiative illustrates Qatar’s attempt to diversify mobility modes beyond road-based transport. Service operations are identified to begin from Porto Arabia, and are active between 8:00 am and 12:00 midnight. Pearl Island is a popular source of transportation among visitors and residents. The shuttle ride can also accommodate about 10 guests. The fare for a single ride is USD 25 for a single round trip, lasting 20-25 minutes. The water taxi service is designed to promote effective levels of sea tourism (Tahmasseby, 2022).

Furthermore, in terms of improving the DT levels in public transportation, Qatari public transportation firms such as Mowasalat have introduced the Karwa Bus App that simplifies the usage of public mode of transport by visualising the entire bus network as well as planning the trips. However, user adoption and functional integration remain areas requiring further development. Furthermore, Karwa public transport services also provide transport facilities for the school and corporate domain, along with the Doha limousine services (Mowasalat, 2024). In addition to this, the Public Works Authority of Qatar (Ashghal) launched intelligent transportation for QWC’22. Ashghal has long been developing its master plan for offering solutions for smart transportation, along with the inclusion of specialised bus lanes, high-end cameras for surveillance, and an active radio station for increasing awareness regarding the traffic conditions. Special operational rooms were also designed for the management of emergency conditions and accidents (ITS International, 2012), and these measures were tested at scale during QWC’22, demonstrating Qatar’s operational readiness for major global events (Mowasalat, 2024).

Figure 4.4: Pearl Island and water transportation

Source: Tahmasseby (2022)

4.1.2. Scale

Singapore

The intelligent transport system (ITS) is a hallmark of modern urban mobility, applying a range of information and communication technologies to manage diverse modes of transportation efficiently. Sensors and IoT components gather real-time data on the vehicles, infrastructure, and weather conditions; this data is transmitted to traffic management centers where it is processed and analysed, enabling informed decision-making for urban mobility (Figure 4.5). Examples of these intelligent systems include automatic track inspection systems using imaging sensors and laser scanners to monitor train tracks in real time, and the Rail Enterprise Asset Management System (REAMS) that consolidates the information from trains and critical systems to predict and assess network conditions (Shamsuzzoha et al., 2021).

Figure 4.5: ITS vision for "Smart Mobility Plan 2023"

Source: Land Transport Authority (LTA, 2023)

The Smart Mobility Plan 2030 of Singapore exemplifies its core ambition with the agenda to create a connected and interactive land transport community. For instance, the "MyTransport.SG" app offers real-time, multimodal journey planning, enhancing commuter experience. The city state employs AI with the aim of predicting the traffic conditions, managing congestion, optimising routes and enhancing the public transport schedules, illustrating its innovative use of technology (LTA, 2023).

The decision of Singapore not to expand its 3300 kilometres of roads, which constitutes 12% of its land area, emphasised its commitment to smart solutions over physical expansion. Thus, the leadership of Singapore in ITS is also evident in its early adoption of technologies such as electronic road pricing and the Expressway Monitoring Advisory System, which provides real-time traffic information and congestion management. These systems have set a benchmark for other cities aiming to digitise urban mobility (LTA, 2023).

Qatar

In contrast, the approach of Qatar to smart transportation is in its developmental stage but rapidly progressing. Qatar's MoTC has been working on a similar ITS framework, focusing on integrating smart technologies within its public transport system and developing intelligent traffic management systems. While Qatar's efforts are commendable, it is still catching up to the advanced and extensive infrastructure of Singapore (Tahmasseby, 2022). While Singapore has seen a near doubling of its daily travel demand from 9 million to 16 million journeys between 2017 and 2022, Qatar has been working towards expanding its transport network to cater to a growing population and increased international events like QWC'22. The advancements of Qatar are promising but are still developing, aiming to integrate similar technologies to achieve efficient traffic management and smart urban planning (Tomorrow City, 2024).

Qatar has implemented ITS alongside Singapore, but its smart transportation systems operate at different levels of development with varied implementation scales and maturity degrees. Singapore operates one of the most advanced ITS systems through its utilisation of real-time sensor data from IoT components and AI technology for tripartite traffic optimisation, congestion prediction, and improved public transportation scheduling. The implementation of electronic road pricing, together with the Expressway Monitoring Advisory System, enables Singapore to lead international standards in urban smart mobility (LTA 2023). The development of ITS in Lusail City, Qatar, remains under development with indications of successful growth. Time-varying traffic monitoring combined with modern journey planning features enables Qatar to offer water taxi services and Karwa Bus App functionality (Tahmasseby, 2022; Mowasalat, 2024). The predictive features, together with the extensive integration between different components, which Singapore possesses, are absent from Qatar's transportation system. Through its "MyTransport.SG" app, Singapore provides users with excellent multimodal journey planning abilities (LTA, 2023), but its equivalent systems in Qatar have not reached the same successful combination of effectiveness and user satisfaction. Singapore chose intelligent solutions instead of road expansion due to its dedication to green urban transportation (LTA, 2023), while Qatar continues to increase its physical roads to serve the growing demand (ITS International, 2012; Mowasalat, 2024). The example of Singapore demonstrates how Qatar should invest in predictive analytics, together with better integration of public transport and develop easy-to-use digital platforms to engage public stakeholders. Various strategic measures applied by Qatar will help the nation achieve world-class status for its smart transportation system.

4.2. Business and Economy: Energy Efficiency

Qatar

Qatar is one of the largest global producers of Liquefied Natural Gas (LNG), and it is increasingly aware of the need to diversify its energy portfolio and improve efficiency across various sectors. The country's QNV'30 mainly focuses on the comprehensive strategy to achieve sustainable development. Central to this vision is the aim to reduce the energy consumption and greenhouse gas emissions through enhanced efficiency measures. Energy efficiency is therefore positioned not only as an environmental objective but also as an economic diversification strategy (Government Communication Office, 2024).

The Qatar Sustainability Assessment System (QSAS) has played a central role in improving energy efficiency in the construction sector. Its mandatory integration into national construction standards reflects a regulatory-driven approach to sustainability. Similarly, investments in CHP systems, public transport expansion, and EV infrastructure signal a gradual transition toward more energy-efficient practices (Contestabile, 2022). The Qatar Sustainability Assessment System (QSAS), developed in conjunction with the University of Pennsylvania's "T.C. Chan Centre for Building Simulation and Energy Studies", has been effective since 2009. It was incorporated in the "Qatar Construction Specifications" (QCS) as a mandatory requirement in 2011, as well as the environmental design curriculum of QU the previous year, and has now been deployed in over a hundred major developments. It encourages (and mandates) the construction of energy-efficient buildings that adhere to strict environmental standards, with initiatives such as improved insulation, energy-efficient lighting, and smart building management systems, which are increasingly common in new developments, contributing to significant energy savings on a national level (Niksefat & Taghizade, 2020).

Within the industrial sector, energy efficiency is being enhanced through the adoption of cutting-edge technologies and process optimisation. Qatar Petroleum and other major industrial players are investing in energy-efficient technologies to reduce their carbon footprint. This includes the implementation of Combined Heat and Power (CHP) systems, which simultaneously generate electricity and useful heat, thus maximising energy use and reducing waste. The transportation sector is also a focus area for energy efficiency improvements. The development of the Doha Metro network and the expansion of public transportation options are aimed at reducing reliance on private vehicles and decreasing the overall energy consumption (Contestabile, 2022). This represents a major paradigm shift in GCC countries, where public transportation in general has lagged for decades for various reasons (e.g., compared to other MENA countries such as Egypt and Iraq) (Dano & Alqahtani, 2019). These efforts are complemented by initiatives to promote electric vehicles and establish the necessary infrastructure for their widespread adoption (Contestabile, 2022).

Furthermore, Qatar is investing in renewable energy sources, particularly solar power (given the arid and high solar irradiance the country receives year-round), in order to diversify its energy mix and reduce dependency on fossil fuels. The "AI Kharsaah Solar PV Power Plant", one of the largest solar projects in the region, is expected to significantly contribute to the country's renewable energy capacity and provide a cleaner energy source for the grid. Public awareness and the education campaigns are crucial to Qatar's energy efficiency strategy. Programs aimed at encouraging energy-saving behaviours among residents and businesses are actively promoted by the government and non-governmental organisations. These initiatives highlight simple yet effective measures such as reducing electricity consumption during peak hours, using more energy-efficient appliances and improving water use efficiency (Farag & Bansal, 2023).

Singapore

Central to the energy efficiency efforts of Singapore is its "Smart Nation" initiative, which is focused on leveraging digital technologies and BDA to enhance resource management and sustainability. The government's emphasis on DT has led to the development of smart grids, which allow for real-time monitoring and management of energy consumption across the island. These smart grids are crucial in balancing supply and demand, reducing energy wastage and integrating renewable energy sources more effectively (Azhgaliyeva et al., 2020). Singapore's Building and Construction Authority (BCA) plays a pivotal role in promoting energy efficiency within the built environment. Through its Green Mark Scheme of accreditation, the BCA incentivises the construction of energy-efficient buildings by providing benchmarks and certification for sustainable building practices. This scheme encourages the adoption of energy-saving technologies such as energy-efficient lighting, advanced air conditioning systems, and high-performance building envelopes. As a result, many commercials and residential buildings in Singapore have achieved significant energy reductions, contributing to the overall energy efficiency goals (Huseien & Shah, 2022).

AI and BDA are integral to Singapore's approach to energy efficiency. AI algorithms analyse vast amounts of data from various sources, including sensors and smart meters, to predict energy consumption patterns and identify opportunities for efficiency improvements. For instance, AI-driven systems can optimise heating, ventilation and air conditioning (HVAC) operations in real time, reducing energy use without compromising comfort. Within the transportation sector, Singapore has implemented several measures to enhance energy efficiency. The LTA has developed a comprehensive public transportation network that includes an extensive Mass Rapid Transit (MRT) system, buses and cycling paths, reducing reliance on private vehicles. Additionally, the adoption of electric vehicles is being promoted through incentives and the expansion of the EV charging infrastructure, which further reduces the carbon footprint of the transport sector (Sheng, 2021).

The focus on energy efficiency also extends to public awareness and education. The Energy Efficiency Programme Office (E2PO) conducts campaigns to educate businesses and residents on energy-saving practices, emphasising the importance of reducing energy consumption in everyday activities. The layout and infrastructure of the city are mainly focused on minimising the use of energy and heavily promoting sustainability. For instance, the use of district cooling systems, which provide centralised cooling to multiple buildings, significantly reduced the energy consumption compared to the individual cooling systems (Su et al., 2022).

Energy efficiency improvement initiatives in Qatar and Singapore have distinctive operational aspects along with differing stages of development. As a leading LNG manufacturer, Qatar utilises the QSAS sustainability assessment system among other energy diversification strategies by building renewable energy facilities, including Al Kharsaah Solar PV Power Plant (Government Communication Office, 2024; Niksefat & Taghizade, 2020). The energy efficiency strategies of this nation remain under development, especially in construction and transportation spaces, because local industries focus on developing sustainable building principles and public transit frameworks (Contestabile, 2022). The smart nation initiative, along with AI and big data analytics (BDA) and smart grid technology in Singapore, enables advanced energy efficiency optimisation (Azhgaliyeva et al., 2020). Singapore achieves high levels of energy efficiency through its Green Mark Scheme and its combination of district cooling systems together with AI-powered HVAC optimisation technologies (Huseien & Shah, 2022; Su et al., 2022). Singapore's all-encompassing strategy demonstrates valuable examples for Qatar to duplicate by applying digital technologies for live energy control systems and building public energy consciousness through specialised advertising. The implementation of comparable strategies by Qatar will help the country achieve a faster path toward sustainable and energy-efficient operations. Overall, while Qatar's energy efficiency initiatives are expanding, Singapore's advanced use of AI, BDA, and smart infrastructure offers a replicable benchmark for accelerating efficiency gains in Qatar.

4.3. Environment, Business and Economy: Data-Driven Urban Planning (D-DUP)

Qatar

Qatar has been transitioning towards a knowledge-based economy, in which regard its commitment to leveraging data and technology for urban planning is evident in several key initiatives and policies. QNV'30 is central to Qatar's D-DUP, and it outlines a comprehensive framework for sustainable development. The Vision emphasises the importance of using BDA and AI to optimise urban growth, improve infrastructure, and enhance residents' QoL. One of the critical strategies in the urban planning of Qatar is the integration of Geographic Information Systems (GIS) and BDA. These tools enable planners to analyse spatial data, monitor urban growth patterns and predict future developmental needs (Al Khoury et al., 2023).

The increasing use of GIS and centralised data platforms reflects a shift toward evidence-based urban governance. The Ministry of Municipality and Environment employs GIS tools to support zoning, land-use planning, and infrastructure deployment (Niksefat & Taghizade, 2020). Moreover, the MME has also started the first stage of its SC project, mainly focused on the deployment of a smart system encompassing waste management, task distribution, and vehicle management, integrated with a centralised and operational command platform. The above project is in close linkage with the Third National Development Strategy of Qatar for the years 2024 to 2030 (Qatar News Agency, 2024).

In 2024, Qatar made significant advancements in its D-DUP efforts. The implementation of the SC Program has been facilitated by the development of AI- powered systems across various sectors, including energy management, waste reduction, and water conservation. These systems use predictive analytics to anticipate and address urban challenges, ensuring a more sustainable and resilient cityscape (Tahmasseby, 2022). In addition to the above, Qatar has indulged in the SCs' initiatives encompassing a wide range of sustainability-focused projects and solutions. These also include smart building, energy-efficient lighting systems, renewable energy integration, waste management, water conservation and green transportation. For instance, Qatar's Smart Grid program aims to modernise the electric grid infrastructure and promote the renewable energy integration to reduce reliance on fossil fuels and enhance energy security and resilience. Figure 4.6 highlights the segregation of the SCs market in Qatar (Medium, 2024).

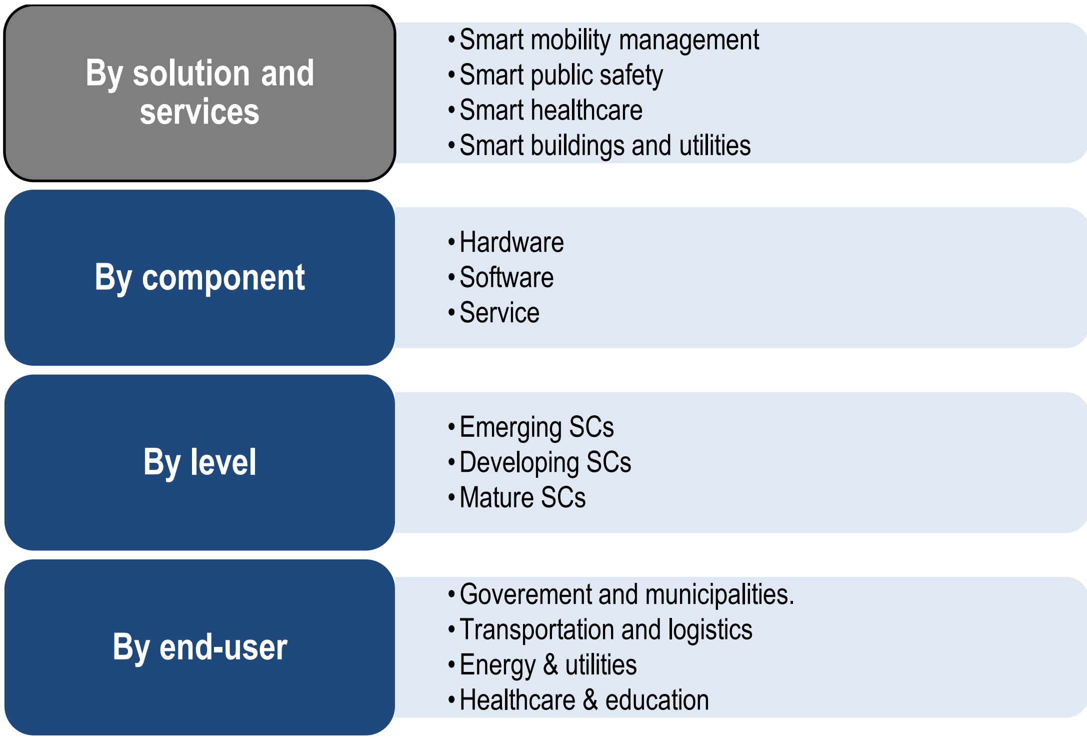


Figure 4.6: SC market factors in Qatar

Source: Author

Moreover, Qatar has also launched the Urban Data Platform (UDP), a centralised repository of urban data accessible to government agencies, researchers, and private sector partners. The launch of the Urban Data Platform (UDP) marks a significant step toward integrated urban analytics. However, the effectiveness of such platforms depends on inter-agency data sharing and analytical capacity, which are still evolving. Public engagement initiatives further indicate an inclusive planning approach, though long-term participation mechanisms remain limited (Abdaoui et al., 2020).

Singapore

Launched in 2014, Singapore's D-DUP approach is anchored in its Smart Nation paradigm. This is focused on using the data and digital technologies to improve the QoL for residents, enhance the economic opportunities, and build a more responsive government. The SNSP is a key component, deploying a network of sensors across the city to collect real-time data on various aspects of urban life, including the traffic flow, air quality and public safety (Engin et al., 2020). The Urban Redevelopment Authority (URA) also plays a crucial role in implementing the D-DUP. The URA employs GIS and advanced BDA to develop the detailed urban plans across Singapore. These tools allow planners to visualise spatial data, simulate the different development scenarios, and make informed decisions about land use, transportation network and infrastructure development. This optimises the use of limited land resources and ensure that urban growth aligns with long term sustainability goals (Bin & Low, 2019).

In addition to the above, understanding the involvement of AI, the LTA uses AI to analyse the traffic data and optimise the traffic light timings, reducing the congestion and improving traffic flow. Similarly, AI is employed in public transportation to enhance the service efficiency and passenger experience. Legislation and policies also support Singapore's D-DUP framework. The government has established regulations that promote data sharing and interoperability among the different agencies and stakeholders (Lee et al., 2019). The SMART Nation and Digital Government Office (SNDGO) coordinated these efforts, ensuring that data collected from various sources is used effectively to inform urban planning and policy making.

At the current juncture, Singapore continues to advance its D-DUP capabilities with new initiatives and technologies. The city state has expanded its use of digital twin technology, creating virtual replicas of urban areas to simulate and analyse the impact of various planning decisions in real time. This technology allows for more accurate and efficient urban planning decisions in real time. This technology allows for more accurate and efficient urban planning, reducing the risk of costly mistakes and ensuring optimal outcomes (Huseien & Shah, 2022).

D-DUP serves both Qatar and Singapore as a platform to boost sustainability yet they take different paths for its implementation. Qatar invests in the Urban Data Platform (UDP) and

Smart Grid Program which apply GIS and AI integration to propel urban development (Al Khoury et al., 2023; Tahmasseby, 2022). The present stage of development for these initiatives remains active. Using real-time data from the Singapore Sensor Platform (SNSP) and digital twin technology Singapore's Smart Nation initiative stands out for predicting urban planning (Engin et al., 2020; Huseien & Shah, 2022). The advanced level of data integration and AI-driven decision systems in Singapore serves as an example for Qatar to speed up its D-DUP advancement. Comparatively, while Qatar has established key D-DUP foundations, Singapore's advanced data integration, real-time analytics, and digital twins provide a roadmap for accelerating Qatar's transition toward fully data-driven urban planning.

4.4. Education and Health Care: Smart Healthcare

Qatar

Smart healthcare in Qatar is witnessing rapid growth, specifically in investments in digital health technologies, telemedicine services, and IoT solutions. The digital health market in Qatar is projected to accrue revenue of USD 61.95 million in 2024, with an expected annual growth rate of 7.55%, pushing the market volume to USD 82.91 million by the end of 2028. This growth is underpinned by the increasing adoption of digital fitness and well-being solutions which are expected to be the largest segment within the market, contributing USD 32.23 million by 2024 (Statista, 2024c, 2024d).

The digital health strategy of Qatar is focused on leveraging technology to enhance patient care, streamline medical operations, and provide convenient healthcare services to service users with commensurate technological literacy and skill (i.e., "tech-savvy", mainly younger Qataris and expatriates). For instance, telehealth is experiencing an urge of adoption, offering remote consultations and treatment options that are both accessible and efficient. This trend during COVID-19 lockdowns in 2020-2022, is supported by the widespread availability of high-speed Internet and the proliferation of smart devices, enabling patients to connect with healthcare providers from the comfort of their homes (Medium, 2024; Statista, 2024c, 2024d).

In the "Digital Treatment & Care" market, Qatar is projected to generate a revenue of USD 9.60 million in 2024, with an annual growth rate of 8.27%, resulting in a market volume of USD 13.19 million by 2028. The user penetration rate in this segment is expected to be 33.26%

in 2024 and is projected to reach by 35.59% by 2028, indicating a growing acceptance and reliance on the digital healthcare solutions among the population. The Average Revenue Per User (ARPU) is expected to rise from USD 9.38 in 2024 to USD 11.41 during the same period, reflecting the increasing demand for digital treatment and care services (Figure 4.7) (Statista, 2024c).

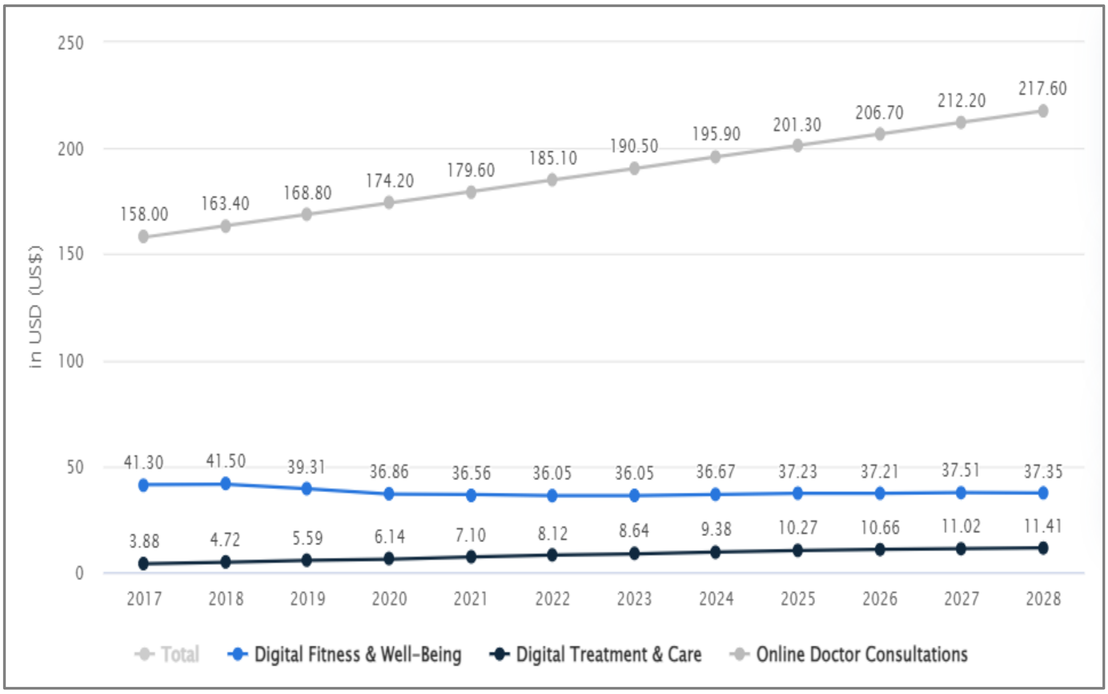


Figure 4.7: Smart healthcare: average revenue per user (ARPU) in Qatar, 2017-2028

Source: Statista (2024c)

In addition to the above, the healthcare IoT market in Qatar is also anticipated to witness significant growth. Projections indicate that the market will reach a revenue of USD 119.70 million by 2024, with a steady annual growth rate of 5.09%, leading to a market volume of USD 153. 40 million by 2029. IoT solutions are transforming patient care by enabling real-time monitoring, improving diagnostics, and facilitating proactive healthcare management. These technologies are crucial in enhancing the efficiency of medical operations and ensuring better health outcomes (Statista, 2024d).

Furthermore, the smart healthcare system in Qatar is also developed by means of the MyHealth health management portal, which enables healthcare professionals to access the main health records of the patients over an Internet connection. This smart healthcare app or portal is also helpful for accelerating patient registration at connected facilities, offering quick and easy access to patients' comprehensive medical data, such as medical diagnoses, issuing of results, making of appointments, and issuing of medications. The MyHealth application is also efficient in maintaining a singular record of medical information, irrespective of the patient's consultation in the HMC or a primary-level healthcare firm (HMC, 2024a).

Also in the healthcare context, the Qatar Robotic Surgery Centre (QRSC) at QSTP (as described in section 2.5.5.5) offers training for surgery using advanced surgical training techniques. QRSC was launched as a key healthcare initiative in partnership with HMC, and it is completely equipped with high-quality equipment as well as devices that help in performing medical simulations, so that healthcare students and professionals can train more extensively, without risk to real patients. These systems contribute effectively to implement surgical simulation training, and practice for actual surgeries that might be performed with the assistance of robots in the future (HMC, 2024b).

Singapore

The overall digital healthcare market of Singapore is expected to accrue a revenue of USD 790.10 million by the end of 2024, with an anticipated annual growth rate of 14.16%. This is translating into the market volume of USD 1342 million by 2028. The ARPU in the digital health market in Singapore is expected to amount to USD 142.30, indicating its existing profitability and future potential. The largest segment within this market is "Digital Treatment & Care", emphasising the importance and popularity of digital solutions for fitness and well-being in the country. In 2024, the healthcare IoT market in Singapore is expected to witness substantial growth, with projected revenue reaching USD 249.30 million (Statista, 2024e). This growth is anticipated to continue at an annual rate of 7.85%, resulting in a market volume of USD 363.70 million by 2029. The rapid expansion of the healthcare IoT market is driven by the adoption of advanced wearable devices and remote monitoring solutions, which enhance patient care and streamline medical operations. These IoT solutions are crucial for real-time health monitoring, predictive maintenance of medical equipment, and improving the overall efficiency of health care services (Su et al., 2022; Statista, 2024e). Figure 4.8 displays the sharp existing and projected increase in the number of healthcare IoT connections in Singapore from 2018 to 2028.

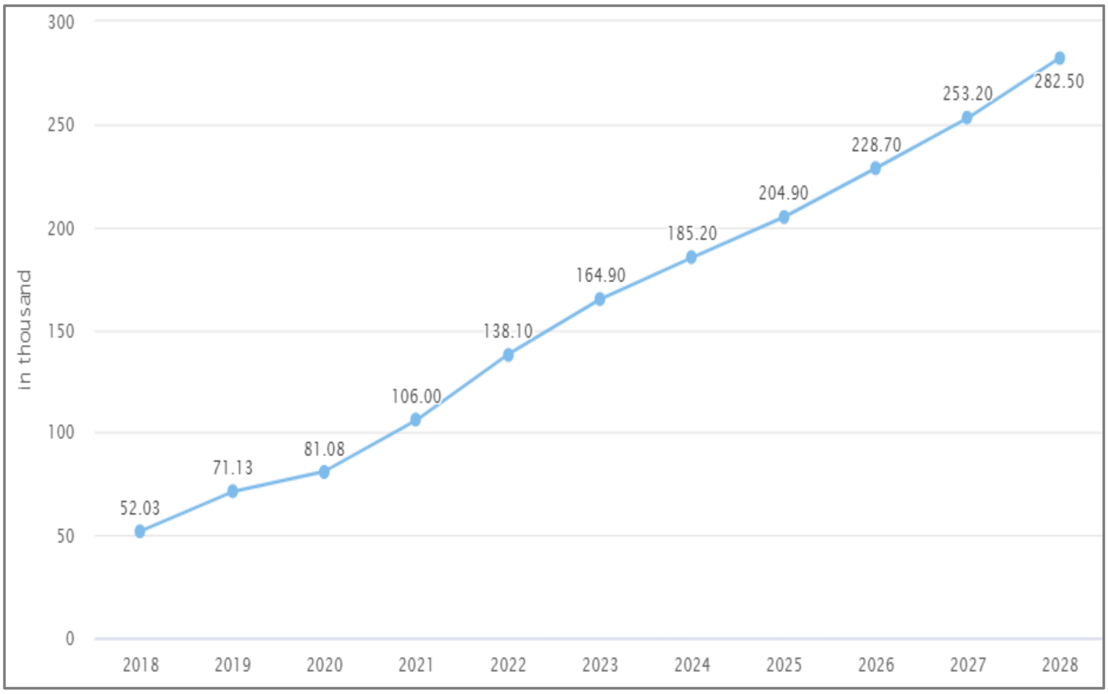


Figure 4.8: Number of healthcare IoT connections in Singapore, 2018-2028

Source: Statista (2024b)

The government of Singapore has played a pivotal role in fostering this growth through supportive policies and strategic initiatives. The SMART Nation Initiative, launched in 2014, aims to integrate digital technologies across all aspects of life, including healthcare. This initiative has facilitated the deployment of smart health technologies and promoted the use of BDA and AI within healthcare. AI is being increasingly utilised in the healthcare sector for various applications, including personalised medicine, predictive analytics and operational efficiency. AI-driven tools help in analysing the vast amounts of medical data, predicting the health trends and tailoring the treatment plans to individual patients, thereby enhancing the quality of care and improving health outcomes (Azhgaliyeva et al., 2020; LTA, 2023).

Moreover, the market segment of the Digital Treatment & Care market in Singapore is also set for significant growth, with the projected revenue of USD 438.50 million by 2024. This market segment is expected to grow at 19.4% from 2024 to 2028, reaching a projected market volume of USD 891.20 million by 2028. The user penetration rate in the segment is forecasted to be 60.94% in 2024, increasing to 92.22% by 2028, highlighting the growing interest and adoption of digital treatment and care solutions among the population in Singapore. The ARPU in this market is thereby estimated at USD 119.20, showcasing the high value of digital healthcare services by consumers (Statista, 2024b, 2024c).

Smart healthcare advancements in Qatar and Singapore exist at different levels of development, with contrasting milestones being achieved. Qatar’s digital health market continues to expand as the country allocates funding to telemedicine and IoT systems, and MyHealth and QRSC platforms boost both medical treatment excellence and surgical skill development (Statista, 2024c; HMC, 2024a, 2024b). The penetration rates combined with the market size in Qatar are not comparable to Singapore's market sector. The digital healthcare sector in Singapore operates as a worldwide leader because of its Smart Nation Initiative, which utilises AI and IoT along with BDA to both enhance medical care delivery and health system productivity (Azhgaliyeva et al., 2020; Statista, 2024e). Singapore maintains higher profits per user and higher user penetration numbers due to its well-developed digital healthcare structure. The smart healthcare transformation of Qatar can benefit from Singapore's comprehensive strategy because it combines Artificial Intelligence for predictive analytics and the expansion of IoT use to speed up the transformation.

4.5. Family and Society, Business and Economy: Smart Security and Safety

Qatar

Qatar has implemented several smart security initiatives such as deployment of advanced surveillance systems, AI powered analytics and integrated emergency response platforms. The safe city project for instance utilises over 15,000 high-definition cameras and IoT sensors to monitor urban areas in real time, enhancing the situational awareness and response times. In addition to the above, Qatar’s National Command Centre integrates data from various security agencies to provide a unified platform to manage emergencies and coordinate responses. AI and ML algorithms are employed to predict and prevent security threats, streamline incident management and improve decision-making processes (Contestabile, 2022).

In 2024, Qatar’s smart security market was projected to reach a revenue of USD 150 million with an expected annual growth rate of 10%, leading to a market volume of USD 220 million by 2028. Thus. These efforts reflect Qatar’s commitment to leveraging cutting-edge technology to maintain a secure environment, underscoring its position as a regional leader in smart security and safety initiatives. The continuous investment in smart technologies ensures that Qatar remains at the forefront of global security standards (Statista, 2024c).

Moreover, SC planning in Qatar prioritises the inclusion of AI, and the enforcement of DT in Qatar is related to the National Cyber Security Strategy 2024. This seeks to improve understanding of the significance behind safeguarding digital resources, as well as assets, along with increasing investment in research and innovation. The strategy also notes the need for personnel training in commensurate skills for the expedient rollout of DT (Pasha, 2024).

Furthermore, QNV'30 is also identified to play a key role towards the deployment of advanced technologies, namely AI, to improve international-level competitiveness for the introduction of DT as well as achieving economic growth. Qatar's DT solutions in Qatar involve the integration of real-time data protection features by the use of Cortex XSIAM, which is a popular security operations centre (SOC) platform empowered by Precision AI technology. This data protection system is backed by the advanced cloud computing service infrastructure as well as AI services that are offered by Google Cloud. This helps the digital technology organisations in Qatar to enable real-time data protection across the diverse cybersecurity-related service offerings (Pasha, 2024).

Singapore

In comparison to Qatar, the SC planning applied in Singapore evidently makes more extensive use of AI technology, as in the case of elderly alert systems. The AI-enabled smart alert system is an integral part of the design of the SCs in Singapore, as it has helped in understanding as well as processing the real-time data regarding the regular motion of individuals who belong to the old age group to improve their safety by finding out the unusual activity or falls, which allows for the immediate response of emergency services. This system also helps in enhancing the safety and security of old age groups by covering public areas as well as their homes. Similarly, the SC in Singapore also makes use of AI-enabled chatbots that are capable of interacting with the aged and other individuals. The AI chatbots also assist elderly users in exchanging information regarding community-specific activities, along with the integration of messages that foster health and well-being (Thales Group, 2023).

Singapore is also identified to execute the initiatives surrounding increasing the educational opportunities in the field of AI, which plays an important role in security by making the workforce more skilled to establish and handle AI-driven security interventions (Shivhare, 2024). With the help of the TechSkills Accelerator scheme, this educational scheme works on two different aspects: the first one is named AI for Everyone, and the second is named AI for

Industry. This initiative was started by AI Singapore and is aimed towards up-skilling about 12,000 workers, as well as students from the AI domain (Thales Group, 2023).

The government of Singapore also introduced the “National AI Strategy” in 2019 to project key plans to intensify the use of AI as well as transform the economy. The strategy is focused on displaying the importance and usage of AI technology in domains such as public safety, crime prevention, cybersecurity, education, security and healthcare. For example, Singapore was the first nation to introduce the digital contact-tracing system by developing an application named ‘TraceTogether' in March 2020. This app uses Bluetooth signals to detect close contact with infected individuals, which improves the safety public at the time of the COVID-19 pandemic (Fontes et al., 2022). AI technology generates both risks as well as opportunities for Singapore, in terms of planning the SCs and determining how the involved individuals establish communication with the digital technologies (Smart Nation, 2023).

Furthermore, enhancing the skillset in AI is beneficial for SC-based businesses as well as residents in terms of generating new opportunities for employment, along with value addition. AI is assistive towards revealing the upcoming opportunities for economic growth. However, AI needs to be managed in a responsible and sustainable manner to safeguard individuals against the critical adverse consequences of smart technologies. Singapore has also implemented strict cybersecurity laws like the Cybersecurity Act to safeguard its AI-driven security infrastructure from cybercrimes (Thomas, 2024). There is still a need for AI and related skills to be taught (in relevant education and professional contexts) and communicated to the public, and to raise awareness of possible wrong utilisation of systems and problems surrounding cyber threats and data confidentiality (Smart Nation, 2023).

The implementations of smart security through advanced technology vary between Qatar and Singapore, even though both nations use these technologies. The Safe City Project together with the National Command Centre utilizes AI integrated with IoT technology as well as real-time surveillance to enhance disaster responses and situational monitoring (Contestabile, 2022; Pasha, 2024). Its market continues to grow in addition to its ongoing expansion of artificial intelligence capabilities. Singapore’s smart security system stands out through its advanced maturity because it uses AI technology to operate elderly alert systems alongside digital contact-tracing software (such as TraceTogether) (Fontes et al., 2022; Thales Group, 2023). The National AI Strategy of Singapore and its rigid cybersecurity legislation establish the country as a leader in security practices powered by AI. The holistic smart security system of

Singapore serves as an inspirational model for Qatar particularly regarding public safety solutions and workforce development to enhance its smart security infrastructure.

4.6. Chapter Summary

This chapter has compared the SC frameworks of Qatar, as a novice developing country seeking to make rapid progress in SC, and Singapore, as a pioneering and mature SC paradigm, in terms of transportation, energy efficiency, D-DUP, healthcare, and security and safety. Because of the fundamentally different adoption statuses of the two countries, it is not possible to compare them directly, but offering a parallel analysis of their current topographies in relation to these dimensions helps to contextualise the progress Qatar has made and where it faces challenges.

Based on the comparative analysis unpacked above, it can be seen that Qatar has made impressive strides towards DT in terms of advancements in smart transportation, energy efficiency, D-DUP, and smart healthcare. Although Singapore presents more sustained and ingrained digital technology integration, it can be said that Qatar is poised to catch up rapidly if it continues to invest and actively pursue its strategic objectives. Urban planning in Qatar focuses on integrating advanced technologies to improve mobility, sustainability and urban development. Key elements of smart transportation include the development of intelligent traffic management systems, automated public transport and electric vehicle infrastructure. The government of Qatar is also investing in digital solutions such as real-time data sharing to enhance traffic flow, reduce congestion and promote safer roads. Having explained the relative position of Qatar with regard to SC development, the following chapter presents the empirical results of this thesis.

CHAPTER 5
Results and Analysis

5.1. Introduction

This chapter presents and analyses the findings explored using different methods to address the research objectives. It explains participants' views, patterns of knowledge, and scholars' different and similar perspectives, and the preliminary data necessary for Qatar's future DT. Consistent with the mixed-methods design outlined in Chapter 3, this chapter explicitly integrates qualitative, quantitative, and secondary evidence to enhance analytical rigour and validity through triangulation. The focus of this chapter is quite broad, as it integrates qualitative and quantitative data analyses to explore the progress of SDT, challenges, failure factors, opportunities, roadmap and stakeholders' views to attain innovative SC development in Qatar. Furthermore, participants' opinions covered in this chapter are underpinned by theories and models relevant to the research subject, to present new data with credibility. This chapter synergises and triangulates diverse findings from the different methods described in detail in Chapter 3, including thematic analysis of interviews with key stakeholders; quantitative survey findings in the form of SPSS-based outputs, descriptive statistics, and graphical representations; and systematic review-based evidence that contextualises the primary findings within the wider scholarly discourse. It discusses the major outcomes of each method separately while comparing them with the other methods, before a comprehensively synergised discussion in section 5.6 to answer the research questions, followed by associated recommendations for key stakeholders.

5.2. Results and Findings of Interviews

The qualitative analysis used Braun & Clarke's (2021) six-stage reflexive thematic analysis. Braun & Clarke (2021) describe this as both conceptually and procedurally different from framework analysis; therefore, Braun & Clarke (2021) are used here because their methodological approach was flexible, allows for greater reflexivity, allows researchers to have a deeper level of interpretation, and allows researchers to engage more fully with the data; all of these characteristics support Braun & Clarke (2021), as they are most suitable for use in exploratory studies on complex and contextualized phenomena such as Smart Digital Transformation.

Braun & Clarke (2021) suggest that, in accordance with reflexive thematic analysis, codes should be developed inductively from the transcript data, rather than being imposed deductively using a predetermined coding frame or guide. Braun & Clarke (2021) argue that developing codes inductively will allow the researcher to develop patterns of meaning from the participants' accounts organically, therefore allowing the researcher to develop themes based on the data itself, rather than developing themes based on prior theoretical assumptions. Braun & Clarke (2021) also argue that developing codes inductively provides the researcher with the opportunity to remain sensitive to the possibility of discovering new insights or nuances of perspective that may not be captured by a structured analytical framework.

During the six stages of Braun & Clarke's (2021) thematic analysis—familiarisation with the data, initial coding, theme development, theme review, defining the themes, and reporting the findings—each stage involved the researcher engaging in iterative reflection and comparing the data across the transcripts continually. Braun & Clarke (2021) suggest that the researcher's continual comparative analysis across the transcripts enhances the researcher's analytical rigour and ensures that the researcher develops coherent and data-driven themes that reflect the participant's experience and interpretation of their reality, while at the same time remaining transparent about the researcher's own interpretative role.

The interviews were conducted with various professionals working in different departments and fields. The sample comprised nine top-level managerial people and stakeholders holding decision-making positions to support DT in their respective sectors (Table 5.1). The research analysed interview findings, which revealed four essential themes that demonstrated stakeholder experiences during digital transformation and smart city development in Qatar. The core building block of Strategic Infrastructure begins with participants who identify strong connectivity as a crucial requirement for innovation. The Qatar National Vision 2030 functions as a vital component for cross-sector coordination, which the Governmental Leadership uses to strengthen this framework. The main objective of Sustainability and Efficiency is to develop data-driven solutions to enhance urban resource management. Cultural Readiness highlights the need to balance rapid technological progress with the cultural values of local communities, helping create a comprehensive and inclusive process of digital development.

Table 5.1: Interviewees' profiles

Code Assigned	Profession/Department	Experience (years)
PA	Director of SC Initiative for the government	9
PB	Qatari expert, IT business founder and alumnus of CAN-Qatar	25
PC	Academia, and worked in areas which intersect with SCs (e.g., networking, communications, and IoT applications) concerning eHealth, smart health applications, smart traffic, AI and many IoT applications	11
PD	Strategy and planning department	Not mentioned
PE	Director of the IT department of the government	10
PF	Working in the IT industry	25
PG	Working for the Smart Qatar Program (TASMU) public initiative	5
PH	IT manager at the Ministry	Not mentioned
PI	An expert worked in different sectors of Qatar's public services (electric and water, oil and gas)	26

Source: Author

The thematic map in Figure 5.1 summarises the final qualitative coding structure. It shows how the interview data moved from initial codes to four overarching themes, with Theme 2 containing the three interconnected sub-themes of challenges, failure factors, and opportunities. The map was used analytically rather than decoratively: it guided the order of presentation in this chapter and informed the cross-method discussion in Chapter 5.

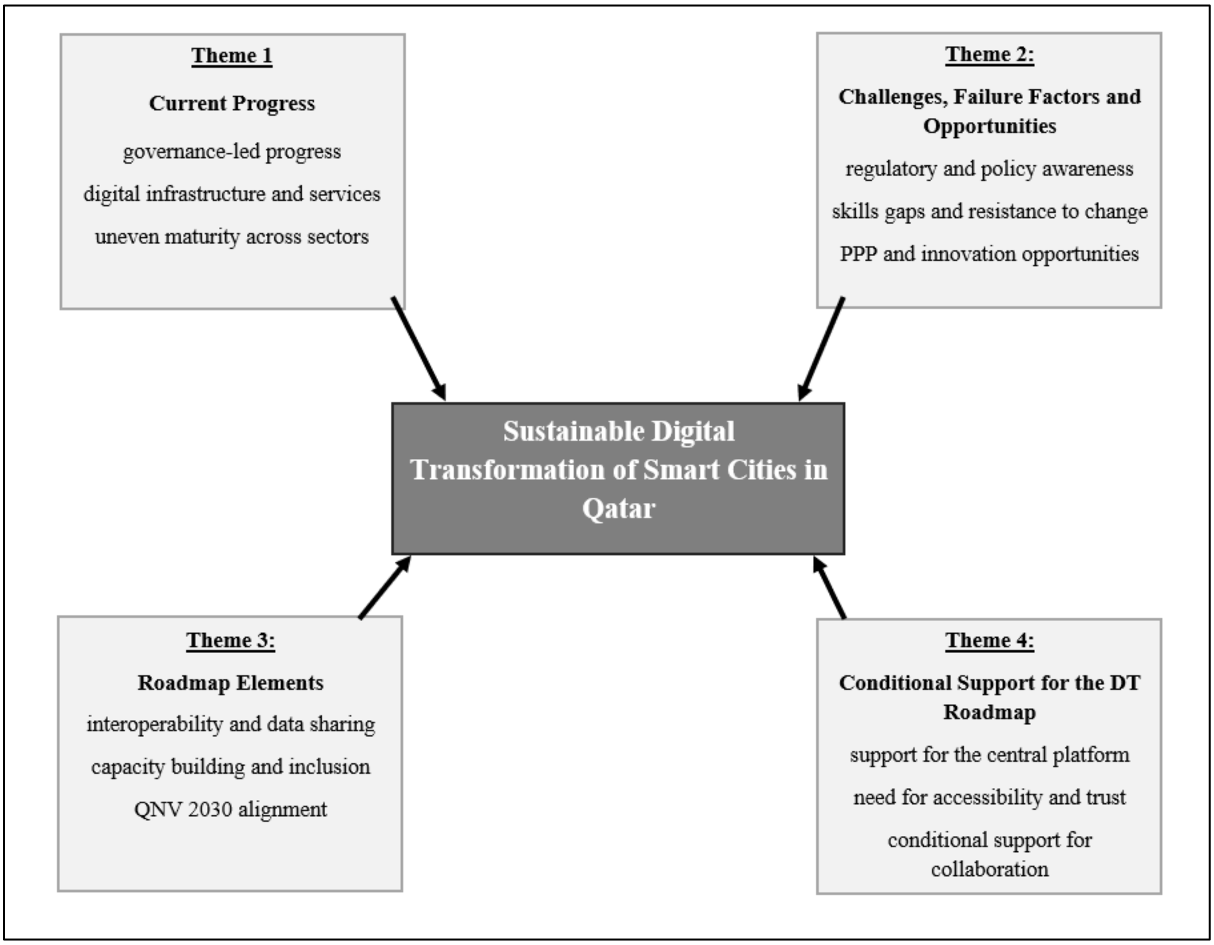


Figure 5.9: Final thematic map of the interview

Source: Author

5.2.1. Theme 1: Current Progress of Qatar towards DT

The first theme that emerged from the analysis of the data concerned awareness and perceptions of the current level of progression made by Qatar towards DT. On the current progress of DT and SC development in Qatar, a mixed set of views from the interviewees was obtained. Some participants supported the viewpoint of the positive progress of the DT, while others considered that private sector maturity was lacking in comparison to the public sector, as exemplified in the following excerpts.

> "I believe there is good progress; there is a good level of awareness in the government, and even the private sectors, [but] in terms of maturity, the government is still higher than the private sectors". **[PA]**

> "The current progress is commendable. Many government services have gone digital, and there are ongoing initiatives for smart transportation, healthcare, and energy management. However, there is a disparity in the level of digital adoption across different sectors". **[PB]**

> "I can see that the development has been happening a lot. I have heard about many projects on this. Some are relevant, others are probably not, but they still contribute to the SC". **[PC]**

These findings align with national-level evidence from the literature, which highlights initiatives such as TASMU, QNBN, and QFZA as central drivers of Qatar's DT agenda. Participants articulated a clear awareness that Qatar has demonstrated measurable progress, particularly in government-led initiatives. However, disparities in sectoral adoption, bureaucratic procurement processes, and fragmented implementation structures were repeatedly emphasised. An analysis by Villegas-Mateos (2022) asserted that the MoTC's TASMU "Smart Qatar" agenda seeks to achieve DT in Qatar to the level of a world-class modern SC, leveraging advanced digital solutions for improving the living standards and enhancing the competitiveness of Qatar at the international level. This project has been focused specifically on raising the strength of innovation and technology for driving diversification of the economy in a sustainable manner while enhancing the delivery of public services across major sectors and the quality of life within Qatar (Villegas-Mateos, 2022). Similarly, another study by Elidrisy (2024) mentioned that there are multiple projects, including the QNBN and QFZA, which will perform the DT of the city.

Under these projects, massive investments (of billions of riyals) have been made to develop IT infrastructure for initiating the practices of cybersecurity, BDA, digital communication and online collaborations. The QFZA was specifically instituted to encourage and assist technological and scientific research for bringing valuable digital innovations with the expansion of interconnectivity. Furthermore, QNBN has invested heavily in bringing high-speed Internet to all residents, with liberalisation of the market to enable alternative service providers to compete, placing tough competition on the national carrier (Elidrisy, 2024).

Participants articulated a clear awareness that Qatar has shown substantial progress towards DT, which is traced across both government and private sectors. Though disparities prevail in digital adoption across distinct sectors, an increase in awareness and robust initiatives is being examined for implementation in the city. Furthermore, it can be interpreted that the above interview excerpts indicate the prevalence of awareness of the critical significance of issues such as delays in DT practices caused by the issues in procurement practices, as well as the allotment of funds for each of the projects. It is found that bureaucratic practices, as well as ineffectiveness in the funding process, are hindering the rate of DT in Qatar. The identified project delays affect the duration as well as the effectiveness of the project implementation.

Importantly, the interview data reinforce that progress is often slowed by structural and procedural barriers rather than a lack of strategic intent. Delays related to procurement, funding approval, and inter-agency coordination were identified as key impediments. In addition, participants noted that AI capabilities and data integration remain underdeveloped when benchmarked against more advanced smart cities such as Singapore (as discussed in Chapter 4). The interviews further revealed that DT efforts in Qatar are often fragmented and siloed, with limited collaboration across entities. This finding is consistent with the literature, which highlights governance fragmentation as a persistent challenge in emerging smart city ecosystems. While awareness and investment are evident, the absence of cohesive coordination mechanisms reduces implementation effectiveness.

> "There is progress, and more things are happening; I would say it is slow because we started very early, we had a huge momentum, and the emotion was huge, but it slowed down a little bit, maybe because we were ahead of many people, we slowed down. There is progress; it is fragmented, as you initially mentioned; different people are doing similar things, but there is limited collaboration, but I would say it is happening in a slow and fragmented way". **[PC]**

> "In Qatar, I cannot say there is no current progress. We can say there is individual progress. Each entity is working separately and working like competitors. DT for the SC should include the whole city, and open data portals need to be updated with data, *quality* data, especially". **[PE]**

On the other hand, **PD** highlighted that while working for DT in Qatar Foundation Education City, progress remained challenging, mainly in the government sector. The participant felt that the sector has no clear path and regulations to embrace DT. Also, the inefficiency of the education curriculum is another crucial factor that is not supporting students to generate transformational thinking when they assume positions in related professional roles following graduation. Other participants identified diverse barriers related to procurement, funding, technological immaturity (i.e., of AI itself, rather than Qatar-specific issues), and data policy (particularly concerning data sharing among stakeholders):

> "A lot of delays [exist] because of the procurement process, and granting the funding for individual projects". **[PG]**

> "It improves, they have progressed… [there is a] need for AI to become mature". **[PH]**

> "I think that halfway, I can see that there are lots of initiatives coming right now, and there are contracts that are being awarded to telecom companies, for example, Ooredoo to establish several hubs within Lusail city, for example, to convert it to an SC, so I think we are halfway towards that vision. But as I mentioned, the relations and data transformation policy have to be made with a data sharing policy, friendly, and it has to be made easier for all stakeholders to have a stake in making decisions and in leveraging the data and use it to serve better, I think TASMU is about services, but not about data". **[PF]**

Based on the analysis of the distinct views of the interviewees, the progress of SC development and DT of Qatar is affected by various issues, despite growing awareness and focus. Issues like slow progress, fragmented development, "silos" of individual, uncoordinated efforts (rather than as part of a coherent, multi-stakeholder SC strategy, as described in section 5.2.2), lack of clarity on the path forward, lack of robust regulations, limited DT-related thinking among students, and delays in accessing funds and the procurement process for SC projects are predominant in Qatar.

However, the literature review (Chapter 2) and systematic review (section 5.4) investigation also clarified that Qatar is progressively taking essential steps for raising the accessibility of digital technology for everyone. It has been identified that Qatar has attained fifth position in the index of digital-access rights (Othman et al., 2023). Qatar's rate of Internet penetration rose from 90% of households in 2013 to 94% in 2018. However, certain challenges have also been identified in the digital progress of Qatar, as there is a lack of a regulatory framework for social inclusion of individuals having disabilities or disorders that may prevent their access to information and smart technologies, and certain data formats (Othman et al., 2023).

Correlated with the emergent insights from interviewees, it can be inferred that the country has achieved considerable accomplishments along with the clear vision within the development of SC and driving DT at the policy level, but the level of tangible progress is depleted through the considerable challenges on the ground. These include educational shortcomings, regulatory inadequacies, fragmentations in efforts (i.e., "siloed" activities), logistics problems, and procurement funding-oriented issues. Managing such barriers is regarded as the important endeavour for Qatar's achievement its ambitions related to SC and attaining a more effective and integrated digital ecosystem. Upcoming efforts need to be inclined towards developing cohesive strategic plans, boosting intersectoral collaborative efforts, enhancing frameworks related to regulations, strengthening programs of education, growing funding procedures and streamlining procurement for accelerating and sustaining SC's and DT's initiatives within Qatar.

The literature investigation also helped in interpreting that Qatar has progressively been embarking on its journey for transforming the region into high-class smart-city by multiple strategic initiatives, led by government and Smart Qatar projects like TASMU. The initiative has been brought for fostering the deployment and usage of advanced digital measures for rapidly improvising the public services, thus enhancing the quality of people's lives. With the help of strengthening the DTs, Qatar has been putting constant efforts to bring economic diversification by raising the level of innovation and deploying modern digital technologies. Through emphasising on these fields, Qatar reinforces its level of competitiveness across the globe by managing itself to be the leader in context to the smart technologies' integration into the development of urban areas.

Along with the Smart Qatar project, multiple other DT initiatives have been launched by Qatar, including the Free Zone and QNBN. The latter covers substantial investments for strengthening IT infrastructure, whose growth is vital to improving the IT-based practices, such as online communication, collaborative working, analytics for decision-making and cybersecurity standards. QNBN's major agenda is to confirm that every citizen based in Qatar has access to high-speed Internet, seeking thereby to boost Qatar's competitiveness by fostering innovation and improvising the interconnectivity-oriented capabilities.

The efforts of Qatar in context to DT are also noted to be high as means of increasing its digital accessibility. The nation has attained a leading position for enjoying digital access related rights for every of the citizen. However, a strong regulatory framework for inclusive digital accessibility, incremental funding for information technologies' infrastructure enhancement, and improved comprehensive policies and integrated actions are still required for Qatar to achieve more tangible progress towards successful DT. Overall, Theme 1 indicates that Qatar has achieved notable policy-level and infrastructural progress towards DT, but the translation of this progress into integrated, city-wide smart solutions remains constrained by regulatory gaps, educational limitations, and institutional silos.

5.2.2. Theme 2: Challenges, Failure Factors, and Opportunities Encountered in the SDT to Developing SCs in Qatar

5.2.2.1. Sub-Theme 2.1: Challenges in Implementing SDT for SCs

Participants identified multiple challenges associated with SDT implementation, including technological integration with legacy systems, policy and regulatory uncertainty, skills shortages, and resistance to change. Human and organisational factors were repeatedly emphasised as equally significant as technological constraints, highlighting that DT is fundamentally a socio-technical process.

> "The major challenges that Qatar faces in implementing SDT for SCs include the integration of legacy systems with new digital technologies, lack of comprehensive policies addressing data privacy and security, and the necessity for substantial investments in infrastructure and human capital". **[PB]**

> "I think the hardest part is dealing with humans. It is a different mentality, and people have to live this online experience, people have to reduce resistance to change, so it is a change process, not only technology introduction, so this the type of thing you need to deal with people, make sure you address their issues, make sure the new process is not similar in efficiency, make sure that people get by in and have some incentive for them to join". **[PC]**

The literature review (Chapter 2) and systematic review (section 5.4) explain that inadequate availability of resources, lack of planning of digital infrastructure, policy gaps, digital skills' gaps and poor digital literacy have been found as the challenges confronted within the DT endeavours for developing and fostering Qatar as the SCs (e.g., Abdulkareem & Basee, 2023). Thus, it is understood that there is a clear need to provide digital education within Qatar for improving the skills and capabilities of individuals to use digital knowledge in their job roles.

Furthermore, policies regarding digital infrastructure planning, availability of sufficient resources for digital skill development and digital technologies' integration are noted to be essential for making Qatar the SC (Abdulkareem & Basee, 2023).

Similarly, **PG** offered detailed insights on the challenges by mentioning that government silos, data fragmentation in government entities, lengthy procurement process of government, matured local market, and cost occurrence in attracting and retaining the pool of talent in the emerging technology field is examined. On the other hand, **PD** emphasised the problem of maintaining talent, unclear regulation for SC development, digital currencies or crypto-currency and poor capacity building. The following excerpts also support such views, and the repeated refrain of a lack of regulations was salient:

> "Main challenges in Qatar… maybe because there are no clear regulations, clear policies and no standards for the DT and each entity or each organisation is trying their best to have their policies and initiatives in this journey". **[PE]**

> "I can see that regulations are still not being done in a place that not being adopted and supported by the government and on a large scale, and so there are many things that are not yet regulated and awareness about existing regulation is not mature in the country". **[PF]**

Overall, the analysis reveals that in implementing SDT for SCs, Qatar is facing a myriad of challenges, including policy and regulation (especially concerning data), human resources and skills, individual mindsets and institutional isolation ("silos"), and IT infrastructure and security issues.

As a whole, it has been considered as highly challenging for Qatar-based SCs to incorporate sustainable means of DT with consideration of financial, technological, human, regulatory and institutional fields. The management of such challenges need a robust technique comprising comprehensive reforms of the policies along with sufficient investments into human capital and infrastructural developments, rigorous measures of cybersecurity, proficient procurement procedures and enhanced strategies of change management for boosting digital collaboration and acceptance related culture.

The discovery of lack of clear regulation as one of the challenges is a subtle dilemma to the mainstream discourse in the existing Western smart cities where regulation is commonly viewed as hindrance to innovation. This observation points to Qatar being in another stage of the innovation-adoption curve. In this case, the lack of a mature and adaptive regulatory framework puts investors in doubt and reduces interoperability and slow the scaling of pilot projects. It highlights the necessity of pro-innovation regulations, rules that would create certainty, security, and equity and empowerment, as opposed to limiting, and it is a vital move in the development of the SDT ecosystem Qatar. The findings corroborate existing literature, which identifies gaps in digital skills, infrastructure planning, and policy coherence as critical barriers to smart city development in Qatar. Notably, the repeated emphasis on unclear or absent regulations contrasts with Western smart city contexts, where regulation is often perceived as a constraint on innovation. In Qatar's case, regulatory ambiguity appears to hinder investment confidence, interoperability, and scalability.

5.2.2.2. Sub-Theme 2.2: Failure Factors in Implementing SDT

In linking to the challenges, the interviewees were asked to mention factors that are leading to the failure of implementing SDT, and various views were elicited in response, among which change management issues were clearly a key domain, as exemplified below.

> "Resistance to change, or silos, some want to maintain ownership and perceive our involvement as a potential threat, skill gap and centralised approach for procurement, which is not leading to innovation". **[PG]**

> "I think one of the most challenging things is a change management aspect". **[PA]**

> "Inadequate training and awareness about the new digital platforms, misalignment between the DT strategy and the actual needs of the residents, and resistance from certain stakeholders fearing obsolescence". **[PB]**

Failure factors identified by participants closely mirrored the challenges discussed above, with change management, skills deficits, and strategic misalignment emerging as dominant themes. Resistance to change within public sector institutions and the rapid pace of technological evolution were perceived as particularly problematic. Creation of the productive and modern society needs acquisition of knowledge in the direction of digital technologies (Mohamed et al*.,* 2022). It is observed that the sustainable development in Qatar needs accomplishment of the contemporary needs with no loss of resources for future generation. Amongst the other resources, human capital has always been noted as the critical one for bringing DT. However, poor skills and lack of education deprive personnel from comprehending the full scope of digital technologies in Qatar, which is commonly considered a key failure factor in sustainable development and DT in the GCC (Mohamed et al., 2022).

Others considered resistance to be rooted in the inertia of public sector bodies, who were perceived to be latently resistant to change and lacking in a strategic impetus to adopt new technologies, compounded by a lack of cohesive regulation:

> “The main challenge is the fixed structure for the government entities, it takes a while to change, technology is so fast in changing and updating, the structure takes ten to fifteen years to be updated, and this is not helping to foster the DT. Strategy, some of the government entities don’t have the strategy to align with the DT”. **[PH]**

> “As I said, there are no regulations, so there are no authorised tools you are using for DT.” **[PE]**

> “Actually, it’s the holistic approach, and no infrastructure that unites all agencies into a common language, and regulation that enable information sharing or data sharing”. **[PF]**

The literature-derived facts also emphasised that the relatively new e-government system in Qatar has evoked factors that may be instrumental in the failure to bring DT in SC. For example, the systems of e-government require multiple forms of legislation as well as regulations for overcoming the new changes they entail. Legislative changes might involve data protection rights and issues, archiving, electronic signatures, prevention of hacking, and other crimes related to digital computer systems (Weerakkody et al., 2011). Regulatory modifications are needed for the digital activities’ host, who might be anyone, either in the procurement or delivery of digital services.

Currently, the e-government system of Qatar is identified to comprise of an independent system for the management or e-governance where every ministry comprises of its unique system in a decentralised form, whereby the best practices are performed for adoption of a centralised system, seeking to enhance the simplicity with which the public can execute digital services under a singular unit, facilitated by a “QID” number and password protection (CGB, 2023; MCIT, 2024a).

Nevertheless, legal risks are entailed by the exposure of public agencies by novel technologies, with severe liabilities. Consequently, newly introduced e-services legal acts need to be developed over time, to remain abreast of emergent risks and outcomes, while facilitating the delivery of DT-related projects, including SC systems. Thus, due to complex and strict legal liabilities, changes are required in the legislation system, and unanticipated delays within e-services might contribute to the failure factors confronted while sustainably incorporating the DT (Weerakkody et al., 2011). These nebulous legal and policy issues were succinctly articulated in the following example:

> “I’m saying it’s the lack of clear vision and strategy from the beginning of some of the projects”. **[PI]**

It has been interpreted from the synthesis of the views of the interviewees that various factors are causing efforts to implement SDT to fail. The commonly identified factors are resistance to change, skills gaps, rapidly changing and updating technology, lack of effective strategy of government entities aligned to DT, no regulations in most of the new technologies, inadequate training, and imbalance between the DT strategy and the actual needs of residents.

5.2.2.3. Sub-Theme 2.3 Opportunities for SDT

Despite these challenges, participants identified substantial opportunities for SDT in Qatar. These include a robust economic base, strong government commitment, high-quality digital infrastructure, and increasing public familiarity with digital technologies following COVID-19. Youth engagement, international partnerships, and advanced technologies such as AI, IoT, blockchain, and 5G were consistently framed as strategic enablers.

In this regard, **PB** made an important explanation of the wider opportunities of the transformation:

> “Leveraging Qatar’s robust economy and willingness to invest in technology. Building partnerships with international tech firms and academic institutions. Engaging the youth and tapping into their tech-savviness. These opportunities can be harnessed by creating a conducive environment for innovation, fostering

> international collaborations, and implementing public awareness campaigns”. **[PB]**

The views highlighted that the opportunities for SDT in Qatar include leveraging the robust economy, partnering with international tech firms and academic institutions, engaging the tech-savvy youth, and creating an innovative environment. **PH** considered the current juncture, following on from the experience of COVID-19 and the increased familiarity of residents with digital technologies, as discussed in section 4.4 (Teng, 2021; Tribune News Network, 2020; Troisi et al., 2022), to be particularly amenable to build on Qatar’s robust infrastructure for DT, and **PD** also alluded to the strong underlying readiness of the country:

> “The strong infrastructure, the government support as well for the DT, the people’s awareness about the importance of DT special after COVID-19” **[PH]**

> “The opportunities are clear, the readiness of the infrastructure. Grow the population, which means you need to manage the people through SCs”. **[PD]**

Some participants related SDT to the macroeconomic context of national development (in alignment with QNV’30), including with regard to economic diversification, private sector growth, the afterglow of hosting QWC’22, and the country’s excellent Internet infrastructure (QU, 2022):

> “Diversifying the economy and not only depending on oil and gas as income. Investing in the development of tech assets will attract eventually businesses and start-ups”. **[PG]**

> “There is a huge opportunity first of all Qatar is transforming quickly into digital technologies and there are mature strategies being put in place and also the infrastructure has benefited a lot from the World Cup hosting”. **[PF]**

> “We have the new technologies right now we have AI we have predictive analytics we have the IoT and we have blockchain which is also useful, so we have blockchain for secure transaction IoT and we could have a lot of good things connected to the Internet” for example 5G”. **[PI]**

The analysis revealed that the strong infrastructure, government support, post-Covid awareness, and potential for diversifying the economy away from oil and gas are seen as key opportunities. The rapid transformation into digital technologies, mature strategies, and infrastructure improvements, especially due to hosting QWC'22, also contribute to these opportunities. Furthermore, the adoption of new technologies like AI, predictive analytics, IoT, blockchain, and 5G present additional opportunities for DT in Qatar (QU, 2022).

While cross-investigating and verifying the literature findings, it is further noted that various opportunities have been brought into Qatar in relation to the SDT. For instance, the viewpoints of Elidrisy (2024) and Ben Hassen (2022) comprehensively underscore the strategic efforts of Qatar for SDT being the important element of its vision 2030. It is emphasised by the prevailing literature that R&D endeavours, ICT infrastructure, modernising system of education and innovative approach are bringing valuable opportunities within this transformation. Qatar Smart Program has been the major and important national initiative which derived DT through the distinct areas of the city's economy. Broadband connections, cloud-oriented services and investment into digital technologies are moving forward to support various fields like healthcare, sports, transportation and logistics (as described in Chapter 4). Businesses are being continuously supported by advanced technological innovations with the help of Microsoft and Google-based technological firms located in Qatar. These firms reflected as the opportunities for Qatar' SDT. The findings align closely with the literature, which positions SDT as a core pillar of Qatar National Vision 2030. Collectively, these opportunities suggest that Qatar possesses strong foundational conditions for SDT, provided that governance, regulation, and coordination mechanisms are strengthened.

5.2.3. Theme 3: Essential Elements of the Roadmap Fostering DT in Qatar

The achievement of any undertaking and the effectiveness of investments made towards a nation's growth are contingent upon the constituent components of the strategic plan. These factors are crucial in ensuring the project's success by formulating plans and evaluating the level of risk, both at the macro and micro levels. The absence of a roadmap for a DT endeavour might lead to aimless navigation, posing significant risks to the future of an organisation. DT in Qatar, with a focus on the development of SCs, involves the careful consideration of various crucial components within the roadmap.

These components include the formulation of a clear vision, the establishment of an effective strategy or strategic actions, the identification of critical activities, the setting of milestones, the analysis of stakeholders, and the assessment of potential risks. These elements identified from the thematic analysis of interview data (as explained in Section 3.7.3.2, the results of which are presented in Section 5.5), and are inherently essential in determining the factors that contribute to the success or failure of the project. Specifically, interviewees were asked to share their opinions about essential roadmap elements that could foster DT in Qatar. **PA** opined that:

"This is an interesting question; I think I'll talk about what exists and what we have done. That actually kind of supported the digital adoption for a smart country. What we have done is mapping it to the 2030 Vision, but also going to the national development strategy of the sectors themselves. We looked at the main Key Performance Indicators (KPIs) that they had, which actually had very high potential with the DT…. So, it's related to existing KPIs of the sector on the five-year roadmap". **[PA]**

However, **PB**, presented different elements of the roadmap leading to DT in Qatar, even though his opinion also aligned with the 2030 SDGs:

> "Prioritise sectors that directly impact residents, like healthcare, transportation, and public safety. Involve multiple stakeholders, including residents, in the planning phase. Ensure continuous training and skills development programs for the workforce". **[PB]**

Furthermore, in the same contexts, the views of other participants (C, D, and E) could be summarised as citing cultural change, ICT, leadership focus, and skills development along with stakeholders' integration, people active involvement and participation, clear guidelines, documents and unified working with clear agenda and motivations are the key elements of the roadmap. As per the participants' opinion, information about QNV'30 is insufficient, but information about the precise implementation of such vision is more important.

Participants considered it to be more important for all government departments and officials to work together as a combined entity to target or achieve a defined vision. This implies that elements of the roadmap for DT in Qatar must clearly state factors leading to successful implementation. **PI** in a similar context reflected the need for a clear vision, objectives, and complete assessment of the project, including current and future progress, precise time, and a unified work process along with a feedback mechanism. Other participants mentioned different elements essential for a roadmap fostering DT in relation to data and data issues:

> "As I said the regulations being put in place and privacy being protected because it's a main killer for the project when citizens who refuse certain things because of the privacy so if they have if they insure that privacy is protected and you are benefiting out of this technology… serve data from Hamad Medical all of that can also be helpful in terms of SCs some, so these would be very much helpful if I got your question right". **[PF]**

> "Without the common infrastructure layer (central platform) where we aggregate the data from everyone, there is no DT". **[PG]**

It has been reflected that data collection and sharing with the people or stakeholders is essential for DT success. Different opinions of participants in this theme have reflected that the roadmap is not about describing the vision for SDT. However, all essential factors leading to the success of this endeavour are significant, including the implementation plan, timeline, data collection and privacy, culture, feedback sharing mechanism and stakeholders' participation or integrated efforts.

A supporting study by Badran (2023) also discussed that QNV'30 has brought clear planning to work in collaboration with the stakeholders for Qatar's successful DT. The focus has not only been on ICT but also on AI to systematically and effectively grow Qatar as the digitally transformed economy. The literature-centred data also revealed and reflected that the collaborative mechanism is needed as the essential element for coordinating the efforts from manufacturing companies, regulatory agencies, organisations of consumer protection and other stakeholders to ensure successful DT of Qatar. From the regulatory agencies, it is anticipated to confirm that full assurance of security and privacy mechanism to be enforced efficiently (Badran, 2023).

For companies making DT-related products (e.g., smart devices), incentive schemes for deploying privacy as well as security measures through the design mechanisms, could be the important regulatory tool which might address the issues regarding security and privacy within SCs. In the same manner, manufacturing firms need to undertake every precautionary measure, including assessments of the privacy and security of the services and products they offer. They must ensure that the smart and advanced technology used in digital devices are safe and fully secured to be utilised by the users. In this manner, there are multiple elements that work as the roadmap for fostering and boosting DT across Qatar (Badran, 2023).

5.2.4. Theme 4: Stakeholder Perspectives on the Digital Transformation Roadmap

The results of theme 3 highlighted varied elements of the roadmap, and in continuation of the identified factors, theme 4 presents and analyses stakeholders' views about the DT roadmap in Qatar. In order to identify stakeholders' views about DT, they were asked about their "understanding of Qatar's key stakeholders involved in DT and suggestions for roadmap improvisation", and responses alluded to differentiating public and private as well as national and international stakeholders, and the need for a dedicated office to mediate multi-stakeholder collaboration:

> "Okay, so stakeholders, we have the government, the private sector, SMEs, research and academia. We would separate the private sector from SMEs because we have the big companies, multi-national well established, and they are huge stakeholders in the development of the smart country". **[PA]**

> "Having a focus DT office under a minister-level establishes an accelerate and maintains that level of conscience and this is something that I hope actually supports our road map and in my opinion, it can really approve". **[PA]**

However, in the context of stakeholders' views for a roadmap, **PB** alluded to strengths like "ambitious vision and the allocation of significant resources" and weaknesses such as the "lack of a comprehensive feedback mechanism to iterate and improve based on real-world challenges", and also stated different suggestions, including:

> "Clear feedback loop mechanism, incorporate success stories and lessons from other countries, and set up a dedicated task force to handle change management, ensuring seamless adoption of new digital initiatives". **[PB]**

Participants C and D only referred to the TASMU and Digital Valley initiatives, as they were not aware about a roadmap, and thus did not provide any suggestions for improvisation in the roadmap. **PE** mentioned suggestions for modifications to the proposed roadmap to address some critical issues:

> "I have not seen the roadmap, but I have attended several meetings with various teams working under the TASMU initiative. There appear to be multiple

> underlying interests and complexities within the initiative that are not always explicitly stated…” **[PE]**

As per the evaluation, participants’ suggestion for improvisation in the roadmap should focus on revealing a clear aim and vision of the SC with the system collaboration and coordination with the intended focus on cost, time and overall sustainability management, to assure successful outcome of the SDT. However, **PF** highlighted different suggestions, such as the adoption of the recent IT advancements, such as AI, being potentially fruitful. With the recent emergence of ML and AI, a task force can assist in locating missed opportunities and overshoots in current systems. With enough data, AI models can discover previously unknown use cases and adjust their approach to plan accordingly (e.g., resolving traffic congestion on a roadway may highlight certain places that need more care). AI models and root cause analysis may benefit from this as per the overall views of **PF**. Similarly, **PI** also emphasised:

> “The use of the latest technologies, some of them in this call for example smart devices connection connectivity for example even using solar power which is available in the country”. **[PI]**

Participants indicated that a roadmap for a sustainable digital platform could be enhanced and modified for improving SCs in Qatar through AI and other smart technologies. However, **PG** stated the requirement for the equal and active participation of all stakeholders, and their role as the project owners, strategy implementers, experts, and funding arms. The participant considered this to be an issue of accountability and funding, along with project delayed or time constraints. This highlights that stakeholders play a vital role in the project's success and implementation of the roadmap, in specific to the project's aim. Similar to the views of **PG**, **PI** also highlighted that the government is a major stakeholder responsible for a significant portion of major projects in Qatar, and that citizens themselves are project stakeholders for SDT in Qatar for SC development. In answer to the question about the suggestion, **PG** mentioned:

> “I believe it’s high-level endorsement in the country [i.e., from top-level political policymaking], and giving a clear direction that it’s for the benefit of the country”. **[PG]**

It has been determined, on the basis of the opinions or suggestions that have been gathered from participants, that stakeholders play a vital role in the success of the roadmap designed for the attainment of the vision. However, it is essential to be concerned with the strengths and limitations of the roadmap from the stakeholders' perspectives, to meet their expectations along with project success as a whole. For the purpose of improving and altering the planned roadmap, various proposals have been given, such as cultural reforms, regulations, clear guidelines, unified work culture and system, engaging and participatory work style, clear feedback mechanism, data collecting and privacy, and the usage of AI tools.

The literature data also puts focus on the aspect that, from the perspectives of stakeholders, the roadmap of Qatar's DT is being created robustly. For example, the government is all set to offer valuable services on digital platforms for elderly people above 60 years old, for their care facilities, pensions, social security, and financial support (Al Thani et al., 2021). In addition, NGOs are working with strong efforts and dedication to eliminate the resistance among the elderly to using digital technologies for fostering the consumption of these technologies among older people.

In addition to this, the technology awareness programmes, digital education and raising accessibility to advanced information and communication technologies have become the major elements of the roadmap as per the stakeholders, to confirm DT of Qatar successfully and sustainably (Al Thani et al., 2021). Stakeholder perspectives provide essential insights which show how digital transformation works in real-life situations. The participants demonstrated different engagement levels, which revealed the need for organizations to establish trustworthy relationships through their communication and transparency efforts. Successful implementation requires multiple agencies to work together with both private companies and public citizens. Through inclusive decision-making, leaders can establish a framework that leads to wider participation while creating strategies that meet various requirements. The findings show that organisations need meaningful stakeholder engagement because it serves as a foundation that drives their digital initiatives while increasing their accountability and operational efficiency.

Overall, this topic has focused a lot of attention on the role of the external stakeholders as the primary players in the sustainable digital project. These external stakeholders include the government, citizens, investors, and ministries. With the combined efforts of all stakeholders and the use of the most recent technology to manage an effective communication, feedback, and response system, it is possible to achieve the success envisioned by the proposed roadmap.

5.3. Results and Findings of Quantitative Survey

This section analyses the results obtained from survey responses, represented graphically and statistically using primarily descriptive statistics, supported by inferential analysis where applicable, followed by correlation analysis. The quantitative findings provide an empirical overview of stakeholder perceptions regarding SDT for SC development in Qatar.

5.3.1. Inferential Statistics

5.3.1.1. Gender

While interpreting the gender-related information, there were 52.04% male and 47.96% female participants in the survey (Table 4.2), which reflects a relatively balanced gender distribution within the sample and supports fair representation of perspectives rather than implying statistical gender equivalence in the wider population.

Table 5.2: Gender

Answer Choices	Responses	
Male	52.04%	51
Female	47.96%	47
	Answered	98
	Skipped	0

Source: Author

5.3.1.2. Age Group

As shown in Table 4.3, the age-group-related information clarified that 1.02% of participants were 18-24 years old, while 14.29% were from the 25-34 years old group. 36.73% of participants came under the group of 35-44 years old, while a third (33.67%) were from the 45-54 years old age-group. 12.24% of the other participants were from the 55-64 years old age group. The remaining 2.04% of participants were above 65 years. The majority of survey participants (70.4%) were aged 35-54 years, who are middle-aged adults with awareness and enthusiasm for moving towards SDT for making SCs in Qatar (contrary to assumptions about relatively older people being less receptive to innovations and DT being primarily geared towards the young, as discussed in section 5.6.3).

Table 5.3: Age group

Answer Choices (years)	Responses	
18-24	1.02%	1
25-34	14.29%	14
35-44	36.73%	36
45-54	33.67%	33
55-64	12.24%	12
65+	2.04%	2
	Answered	98
	Skipped	0

Source: Author

5.3.1.3. Occupation

As shown in Table 4.4 concerning occupation, it was found that 40.82% of participants worked in the private sector, while 36.73% worked in the public sector. Smaller portions cited the academic and research sector (7.14%) and "other" sectors (15.31%). The high population representation within the government and private sectors reflects that the job opportunities and demands are high in these fields. However, the low representation within the research and academic sectors means that extra efforts are required to confirm the applicability of the findings to these particular groups, especially as academia conventionally drives technology adoption (AlAli et al., 2023).

Table 5.4: Occupation

Answer Choices	Responses	
Government sector	36.73%	36
Private sector	40.82%	40
Academic/research	7.14%	7
Other	15.31%	15
If other, please specify:		13
	Answered	98
	Skipped	0

Source: Author

5.3.1.4. Experience in DT for SC in Qatar

While observing the data findings in Table 4.5 concerning occupation, it can be seen that 33.67% of participants had 0-2 years of work experience related to SCs and ST in Qatar, and 14.29% of participants had 3-5 years of experience. 16.33% of the other participants had 6-10 years of experience, while 11.22% of participants had 11-15 years of experience. A quarter (24.49%) of participants had 16 or more years of experience. A significant level of experience has been noted in the context of DT for building SCs in Qatar.

Table 5.5: Experience

Answer Choices (years)	Responses	
0-2	33.67%	33
3-5	14.29%	14
6-10	16.33%	16
11-15	11.22%	11
16 or more	24.49%	24
	Answered	98
	Skipped	0

Source: Author

5.3.1.5. Level of Challenges in Incorporating SC SDT in Qatar

Challenges to SDT in Qatar identified from the questionnaire included those related to infrastructure, regulations and policies, funding, technology adoption, and public awareness and acceptance, as shown in Table 4.6, and discussed below.

Table 5.6: Perceived challenges

On a scale of 1 to 5, with 1 being "least challenging" and 5 being "most challenging", rate the following challenges in implementing SDT for SCs in Qatar:

1			2		3		4		5		∑
%	N		%	N	%	N	%	N	%	N	
		Infrastructure									
20.48	17		12.05	10	28.92	24	26.51	22	12.05	10	83
		Regulations and policies									
7.23	6		10.84	9	33.73	28	22.89	19	25.30	21	83
		Funding									
18.07	15		18.07	15	25.30	21	24.10	20	14.46	12	83
		Technology adoption									
10.84	9		9.64	8	42.17	35	25.30	21	12.05	10	83
		Public awareness and acceptance									
4.82	4		22.89	19	33.73	28	26.51	22	12.05	10	83
		Other									
24.24	8		3.03	1	27.27	9	21.21	7	24.24	8	33
		If other, please specify:									
											14
									Answered		83
									Skipped		15

Source: Author

Infrastructure

In relation to infrastructure, 28.48% of participants rated infrastructure the "least challenging" aspect of DT, while 12.05% of participants said it was the "most challenging", with a further 26.51% considering it considerably challenging. The data findings interpreted that infrastructure development and management have been considered to be challenging in the DT process of Qatar to make SCs. The reviewed literature (Chapter 2) and systematic review (section 5.4), and comparative analysis in Chapter 4 also revealed that SC development in Qatar warrants proper planning and deployment of digital infrastructure, which supports in maintaining Internet-connectivity, fostering digital networks, enhancing Internet-based communication and offering digital services. Furthermore, the literature also indicated that along with the planning and proper development of digital infrastructure, it is also necessary for Qatar to improve the digital participation and remove the illiteracy prevalent in the context to provide digital knowledge among the citizens based in the city.

Thus, infrastructure's scenario for digital technologies' deployment has not been found as appropriate for transforming Qatar into the SC (Abdulkareem & Basee, 2023). The reviewed literature (Chapter 2) and systematic review (section 5.4) also revealed that the broadband network of Qatar is the leading player and contributor towards the digital infrastructure of Qatar (e.g., Elidrisy, 2024; QNBN, 2024). The broadband network program has been working on connecting high-speed Internet throughout the Qatari region and bringing valuable opportunities for digital innovations within the region. However, along with the input into infrastructure development for Qatari DT, it is equally essential to foster policies for improving smart technologies' education across the region for ensuring successful transformation.

Regulations and Policies

The majority of participants considered that compliance with regulations and policies has been a major challenge for SDT of SCs in Qatar, with 25.30% and 22.89% selecting "5" and "4", respectively. While the reviewed literature generally denoted that policy initiatives such as QNV'30 remained progressive in the direction of Qatar's DT, it was also noted that there are certain complications related to the telecom regulations' implementation in Qatar because of needing high-speed Internet connectivity (e.g., Badran, 2023). In relation to the regulations for bringing digital technologies into the city, there is also a challenge related to data privacy related policy management. This is because users' privacy data is noted to be in a vulnerable condition as it might be unintentionally or intentionally got disclosed. The issue related to the protection of data and security of users reflects as the barrier for implementing regulations in the SCs. Thus, regulatory barriers remain prevalent in the endeavours of DT and SC development within Qatar (Badran, 2023).

Funding

A quarter (24.10%) of participants considered funding challenging (4) for DT, while 14.46% considered it the most challenging (5). However, 18.07% perceived it as the least challenging (1). This reflects that funding is moderately challenging for the DT of Qatar-based SCs. The literature-reflected data is that the government has the crucial role and contribution toward funding for the deployment and adoption of ICT within Qatar and overall DT of this city. The support from government has always been crucial for funding the ICT infrastructure's development, management and enhancement that dictates the readiness of the country for DT.

The success of the DT within Qatar is majorly reliant upon the funding stream for the research and innovation work (Othman et al., 2023).

However, another study by Al-Mulla et al. (2022) revealed that the financial sources of Qatar have been regarded as the most unsustainable ones within the long-term as the entire country remains the rentier state. It is further noticed in the literature that the funding sources' size is found to be limited in Qatar as well as not conveniently accessible to the wider societal proportion. Although there are numerous financial institutions operating within Qatar, and multiple angel investors are activated within Qatar, there is no official platform for linking entrepreneurs and investors. Many individuals have monetary assets as well as interest for investing their assets; however, they lack sufficient knowledge, experience and network for starting their financial activities. Considering these issues, it is clear that there is lack of sufficient funds for technological adoption, implementation and DT (Al-Mulla et al., 2022).

Technology Adoption

Over a quarter of participants perceived technology adoption as challenging (4) (25.30%) and most challenging (5) (12.05%). The interpretation of this finding is that technology adoption is considerably challenging in itself for SDT for developing SCs in Qatar. The reviewed literature (Chapter 2) and systematic review (section 5.4) asserted that technology's usage for the purpose of education remained less used in Arabic education institutions, as the members of faculty often show resistance in context to the digital technology's integration because of multiple reasons, such as disbelief regarding the benefits of technology, technology-related fear, and the absence of technical and institutional support (e.g., Karkouti, 2023).

A recent study by Abdelmoneium et al. (2023) indicated that parents in Qatar commonly feel anxiety as well as fear regarding the adoption of new technology for their children in the education system. Most children are nowadays getting highly engaged into digital technologies, with various potentially negative impacts on their health, including sedentary lifestyles, increasing obesity, and disrupted sleep-wake cycles due to screen time. Furthermore, cases of cyberbullying have also been observed as the ones that affected the parents and other citizens of Qatar to a huge extent. By considering such risks and negative aspects linked to technology adoption, the digital technology adoption in this region has been noted as complex (Abdelmoneium et al., 2023).

The reviewed literature (Chapter 2) and systematic review (section 5.4) also emphasise that AI-based systems are well accepted and adopted in Qatar. For example, in Qatar-based banks, AI has started increasingly being used for security purposes to protect customers' data from fraud, phishing, cyber-attack and other criminal activities that are harmful for the customers' data security (Shuaib, 2023). The AI-powered system of security is well adapted to overcome the limitations observed of the traditional method of data security such as encryption technique and resetting of passwords.

However, in the adoption of technologies like AI, employee training has been a considerable challenge for the businesses of Qatar. The absence of technical staff, no training provision and lack of skills might hinder the successful adoption of AI technology in Qatar (Elidrisy, 2024). Furthermore, in relation to making digital communication and collaboration productivity, Qatar also needs strong privacy legislation. It is because hackers are able to utilise AI capabilities that raises vulnerability for the consumers to be attacked on the online platforms (QU, 2022). Thus, it is necessary for Qatar to bring strong privacy legislation and cybersecurity measures for successful DT (as discussed in section 2.5.6).

Public Awareness and Acceptance

There was a middling distribution of participants concerning public acceptance and awareness being challenging, with 22.89%, 33.73%, and 26.51% selecting options "2", "3", and "4", with smaller proportions (4.82% and 12.05%) selecting "1" and "5". Thus, public awareness, as well as acceptance levels, are considered moderately challenging for SDT to develop SCs in Qatar. While reflecting on the literature review (Chapter 2), it can be noted that public acceptance and awareness were considered to be the major factors that tend to determine the success measure of the adoption of solar energy within the Qatari state (e.g., Alrawi et al., 2022). Consequently, the relatively moderate role of this aspect uncovered in this survey may indicate changing public attitudes, and more technology acceptance (possibly related to the post-COVID-19 context), and greater familiarity with smart technologies (as discussed in Chapter 4).

It is essential to consider cultural factors and changes in the development of new policies, and it is essential to promote public awareness of advanced technologies, which can increase their usefulness and adoption for successful DT. In this regard, the public of Qatar requires proper education regarding the potential and capabilities of advanced technologies within Qatar. Individuals must have proper awareness of the usefulness and importance of the technical initiatives for raising the level of acceptance in the region (Alrawi et al., 2022).

5.3.1.6. Failure Factors in Incorporating SDT for Qatar SC

Perceived failure factors for SDT in Qatar identified from the questionnaire included inadequate planning, insufficient stakeholder engagement, lack of skilled workforce, technological barriers, and resistance to change, as shown in Table 4.7, and discussed below.

Table 4.7: Failure factors

On a scale of 1 to 5, with 1 being "least significant" and 5 being "most significant", rate the following failure factors in implementing SDT for SCs in Qatar:

1		**2**		**3**		**4**		**5**		**∑**	**Wt. Av.**
%	N	%	N	%	N	%	N	%	N		
Inadequate planning											
8.00	6	5.33	4	36.00	27	24.00	18	26.67	20	75	3.56
Insufficient stakeholder engagement											
4.00	3	5.33	4	22.67	17	41.33	31	26.67	20	75	3.81
Lack of skilled workforce											
6.67	5	10.67	8	22.67	17	28.00	21	32.00	24	75	3.68
Technological barriers											
5.33	4	25.33	19	37.33	28	22.67	17	9.33	7	75	3.05
Resistance to change											
2.67	2	10.67	8	24.00	18	38.67	29	24.00	18	75	3.71
Other											
23.33	7	13.33	4	30.00	9	16.67	5	16.67	5	30	2.9
If other, please specify:											
											11
								Answered			75
								Skipped			23

Source: Author

Inadequate Planning

Approximately 26.47% of participants considered inadequate planning as the "most significant" factor, and a further 24% of participants considered it a significant factor for the failure of SDT of SCs based in Qatar, collectively accounting for over half of survey participants.

Insufficient Stakeholder Engagement

26.67% of participants perceived insufficient stakeholder engagement as the most significant factor for the failure to integrate SDT in Qatar's SCs. Apart from this, 41.33% of the other participants perceived it as a significant factor for the same aspect. The data findings emphasised that stakeholder engagement is a necessary aspect to successfully incorporate and integrate SDT within Qatar's SCs.

Lack of Skilled Workforce

32% of participants perceived the lack of skilled personnel as the most significant factor, while 28% of the other participants mentioned it as a significant factor. This reflects that the lack of skills among the workforce leads to the failure of SDT incorporation in the development of SCs in Qatar.

Technological Barriers

An estimated 25.33% of participants considered technological barriers as a slightly significant factor while 22.67% of the other participants mentioned this factor as considerably significant for the failure of SDT for making SCs in Qatar.

Resistance to Change

An estimated 24% of participants perceived resistance to change as the most significant aspect, while 38.67% of the other participants considered it a significant aspect of failure in emerging SDT for SC based in Qatar.

Overall findings from this section highlight that soft governance-related factors (planning, engagement, skills, and resistance) outweigh purely technical barriers, indicating that organisational and human dimensions are central to SDT success.

5.3.1.7. Level of Opportunities for Qatar SC SDT

Opportunities were most strongly associated with government support, PPPs, and technological advancement, suggesting that Qatar possesses favourable structural conditions for SDT if challenges are strategically managed, as shown in Table 4.8, and discussed below.

Table 5.8: Opportunities

On a scale of 1 to 5, with 1 being "least significant" and 5 being "most significant", Rate the following opportunities for SDT in Qatar's SCs.

1		**2**		**3**		**4**		**5**		**∑**	**Wt. Av.**
%	N	%	N	%	N	%	N	%	N		
Government support											
2.67	2	13.33	10	24.00	18	33.33	25	26.67	20	75	3.68
Public-private partnerships											
5.33	4	12.00	9	29.33	22	33.33	25	20.00	15	75	3.51
Technological advancements											
2.70	2	12.16	9	40.54	30	18.92	14	25.68	19	74	3.53
International collaborations											
4.05	3	13.51	10	41.89	31	22.97	17	17.57	13	74	3.36
Economic growth potential											
2.67	2	16.00	12	36.00	27	25.33	19	20.00	15	75	3.44
Other											
25.93	7	14.81	4	25.93	7	18.52	5	14.81	4	27	2.81
If other, please specify:											
											10
								Answered			75
								Skipped			23

Source: Author

Government Support

An estimated 26.67% of participants mentioned government support as the most significant while 33.33% of participants considered it a significant opportunity in relation to progress towards the SDT of SCs in Qatar.

Public-Private Partnership (PPP)

A fifth (20%) of participants considered PPP as the most significant, while 33.33% of the other participants perceived this as a significant factor in contributing towards opportunity building for SDT of SCs in Qatar, collectively comprising over half of the sample.

Technological Advancements

Over a quarter (25.68%) of participants perceived technological advancement as the most significant factor, while 18.92% considered it a significant factor; however, 12.16% of the other participants mentioned this factor as being only slightly significant. The data findings emphasised that technological advancement drives significant opportunities for SCs' SDT within Qatar.

International Collaborations

The largest cohort of participants (a relatively modest 22.97% considered international collaborative efforts to be significant, while 17.57% considered it to be a significant factor. A slightly smaller proportion (13.51%) considered it to be slightly significant. Thus, international collaborations are considered an opportunistic factor for SDT for developing SCs in Qatar.

Economic Growth Potential

In respect of economic growth potential, 20% of participants considered it most significant, while 25.33% deemed it significant, collectively comprising the majority of participants. A relatively negligible proportion (16%) considered it to be slightly significant. These findings indicate that economic growth potential is perceived to have a valuable impact on raising opportunities for SDT within Qatar's SCs.

5.3.1.8. Current Level of DT Progress in Qatar

An estimated 31.94% of participants mentioned significant progress while 19.44% of participants mentioned slight progress in Qatar's DT to develop and evolve its SCs, as shown in Table 4.9.

Table 5.9: Current progress

On a scale of 1 to 5, how would you rate the current progress of DT in Qatar, with 1 being "no progress" and 5 being "significant progress":

1		2		3		4		5		∑	Wt. Av.
%	N	%	N	%	N	%	N	%	N		
The current progress of DT in Qatar											
2.78	2	19.44	14	38.89	28	31.94	23	6.94	5	72	3.21
								Answered			72
								Skipped			26

Source: Author

The findings indicate moderate progress in DT, with relatively fewer participants perceiving progress as highly significant. This suggests that while foundational initiatives are in place, full-scale transformation is still evolving.

5.3.1.9. Importance of Elements Fostering DT in Qatar

The identified elements considered important for fostering SDT in Qatar identified from the questionnaire included those related to developing a clear strategy, investing in infrastructure, enhancing regulations, promoting R&D, and improving public awareness and acceptance. There was notably high agreement with all of the survey items, as shown in Table 4.10, and discussed below.

Table 5.10: Supportive elements

Rate the importance of the following elements in fostering DT in Qatar, with 1 being "least important" and 5 being "most important":

1		2		3		4		5		∑
%	N	%	N	%	N	%	N	%	N	
Developing a clear strategy										
0.00	0	14.29	1	14.29	1	42.86	3	28.57	2	7
Investing in infrastructure										
0.00	0	0.00	0	28.57	2	57.14	4	14.29	1	7
Enhancing regulations and policies										
0.00	0	14.29	1	42.86	3	28.57	2	14.29	1	7
Promoting innovation and R&D										
0.00	0	14.29	1	14.29	1	57.14	4	14.29	1	7
Improving public awareness and acceptance										
0.00	0	0.00	0	42.86	3	28.57	2	28.57	2	7
Other (please specify):										
										0
								Answered		7
								Skipped		91

Source: Author

Clear Strategy Development

The largest cohort (42.86%) of participants mentioned clear strategy development as important, while 28.57% mentioned it as the most important element, indicating an overwhelming acknowledgement of the significant importance of developing a clear strategy in raising DT within Qatar.

Investing in Infrastructure

Almost 57.14% of participants said that investment in infrastructure is important for DT enhancement in Qatar-based SCs while 14.29% of the other participants considered it as the most important aspect of Qatar's digital progress.

Enhancing Regulations

The largest cohorts selected “3” (42.86%) and “4” (28.57%) for the importance of enhancing regulation and policies, perhaps reflecting the sustained and extensive efforts the Qatari government has taken in developing regulations over the last two decades (Chapter 2).

Promoting Innovation and R&D

Clear majorities considered promoting innovation and R&D as important (57.14%) and most important (14.29%), and these were clearly considered to be absolutely essential aspects for DT progress in Qatar.

Improving Public Awareness and Acceptance

No participants selected “1” or “2” for improving public awareness and acceptance, while 42.86%, 28.57%, and 28.57% selected “3”, “4”, and “5”, indicating that promoting and improving public awareness and acceptance was acknowledged to be essential by all participants.

5.3.1.10. Familiarity with Qatar’s Proposed Roadmap to Foster DT

Concerning their familiarity with the proposed roadmap of Qatar for boosting DT for SC progress, 21.88% of participants claimed high familiarity, while 40.63% of participants selected moderate familiarity, as shown in Table 4.11.

Table 4.11: Familiarity

How familiar are you with Qatar’s proposed roadmap for fostering DT?

Answer Choices	Responses	
Extremely familiar	4.69%	3
Very familiar	21.88%	14
Moderately familiar	40.63%	26
Slightly familiar	17.19%	11
Not at all familiar	15.63%	10
	Answered	64
	Skipped	34

Source: Author

An estimated 25% of participants mentioned that the roadmap addresses opportunities and challenges, 21.88% of participants said that the roadmap is aligned with the national goals of

QNV'30. A quarter (25%) of participants considered the roadmap proposal to be achievable and realistic, and 48.44% of participants had moderate knowledge of the realistic nature of this roadmap. Overall, it is noted that regarding the proposed roadmap's efficacy, there is a moderate level of agreement among the stakeholders in the context of DT enhancement.

5.3.1.11. Suggestions for Improvements in the Proposed Roadmap

Only 17 participants answered this query by mentioning that parties' involvement, engagement, tracking of progress of implementation, clarity of vision, reliability, implementation progress, community participation and adequate team selection are important for the proposed roadmap's progress for successful DT, as shown in Table 4.12.

Table 5.12: Suggested improvements

Rate your agreement with the following statements regarding the proposed roadmap, with 1 being "strongly disagree" and 5 being "strongly agree":

1		**2**		**3**		**4**		**5**		∑	**Wt. Av.**
%	N	%	N	%	N	%	N	%	N		
The roadmap adequately addresses challenges and opportunities											
7.81	5	14.06	9	48.44	31	25.00	16	4.69	3	64	3.05
The roadmap is realistic and achievable											
6.25	4	15.63	10	48.44	31	25.00	16	4.69	3	64	3.06
The roadmap is aligned with Qatar's national vision and goals											
7.81	5	10.94	7	42.19	27	21.88	14	17.19	11	64	3.3
The roadmap considers the needs of various stakeholders											
9.38	6	20.31	13	39.06	25	20.31	13	10.94	7	64	3.03
								Answered			64
								Skipped			34

Source: Author

5.3.1.12. Progress Towards SDT

As shown in Table 4.13, 43.57% of participants strongly agreed regarding the governmental role's importance, while 42.19% of participants emphasised the need for investment in private sector firms for sustainable development. Almost 50% of participants were in support of education and training needed for SDT of Qatar-based SC.

Table 5.13: Progress

Agree or disagree with the following statements on a scale of 1 to 5, with 1 being "strongly disagree" and 5 being "strongly agree":

1		2		3		4		5		∑	Wt. Av.
%	N	%	N	%	N	%	N	%	N		
The government should play a leading role in driving SDT in developing SCs in Qatar											
1.56	1	4.69	3	21.88	14	28.13	18	43.75	28	64	4.08
Private sector companies should invest more in SDT in developing SCs in Qatar											
3.13	2	3.13	2	23.44	15	28.13	18	42.19	27	64	4.03
Citizens should be actively engaged in the decision-making process for SDT in developing SCs in Qatar											
0.00	0	4.69	3	20.31	13	39.06	25	35.94	23	64	4.06
Education and training programs should be developed to address the skills gap for SDT in developing SCs in Qatar											
0.00	0	3.13	2	23.44	15	23.44	15	50.00	32	64	4.2
									Answered		64
									Skipped		34

Source: Author

5.3.2. Descriptive Statistics

Descriptive statistics encompass the process of gathering, examining, interpreting, displaying, and arranging data. The main objective of this is to succinctly and accurately outline and explain the key characteristics of a dataset, offering a brief and significant overview. Descriptive statistics aid in the simplification of vast quantities of data, enabling comprehension and highlighting essential attributes. Furthermore, descriptive statistics encompass measures of central tendency, specifically the mean, which is calculated by dividing the sum of all values by the total number of occurrences. Additionally, it encompasses the concept of the median, which represents the middle value in a data set whenever it is arranged in order. Furthermore, descriptive statistics encompass the computation of the mode, which represents the number of observations that appear most often in a given dataset (Witte & Witte, 2017).

This research seeks to investigate the current progress attained in the direction of achieving DT in Qatar. The analysis of the descriptive statistics shown in Table 4.14 reveals that the mean score concerning the current advancement of DT in Qatar is 3.2083. This moderately average value indicates that there is potential for enhancing the apparent advancement of DT in Qatar. The Standard Deviation (SD) as well as variance suggest a moderate proportion of variation, indicating a range of viewpoints amongst respondents. The variation in distribution could be linked to differing levels of understanding or involvement with existing digital campaigns. In addition to the above, regarding the formulation of a distinct strategy, the acquired average is 3.8571. The high average score indicates a strongly favourable opinion concerning the simplicity of the DT-related strategy. The minimal SD as well as variance implies a substantial amount of agreement among participants, indicating a collective comprehension and concurrence regarding the efficacy of the current strategy.

Table 5.14: Descriptive statistics

	N	Range	Min.	Max.	Mean	SD	Variance
Current progress of DT in Qatar	72	4.00	1.00	5.00	3.2083	.93353	.871
Developing a clear strategy	7	3.00	2.00	5.00	3.8571	1.06904	1.143
Investing in infrastructure	7	2.00	3.00	5.00	3.8571	.69007	.476
Enhancing regulations and policies	7	3.00	2.00	5.00	3.4286	.97590	.952
Promoting innovation and R&D	7	3.00	2.00	5.00	3.7143	.95119	.905
Improving public awareness and acceptance	7	2.00	3.00	5.00	3.8571	.89974	.810
Valid N (listwise)	7						

Source: Author

Furthermore, regarding the choice of whether to invest in infrastructure, the obtained average value is 3.8571. The mean score indicates a favourable assessment of the amount of investment in SC facilities similar to the process of formulating a well-defined strategy. The presence of a small SD along with variance indicates a strong consensus among respondents, implying that there is a general agreement regarding the sufficiency of funding for infrastructure. This consensus suggests perceived adequacy of infrastructure investment, though it does not capture disparities that may exist between different cities or population groups.

Moreover, in relation to the research aim of investigating the opportunities for achieving SDT towards the development of the SCs in Qatar, the statistics indicate that there are opportunities regarding the improvement of regulations and policies, for which the obtained mean value is 3.4286. The average score, while somewhat lower than before, still suggests a fairly favourable opinion concerning the improvement of legislation and regulations. The SD and variance indicate an acceptable level of variation in viewpoints, implying the existence of divergent perspectives regarding the efficacy of existing laws and regulations. This divergence highlights the need for further qualitative insights to understand regulatory implementation challenges.

Regarding the opportunity for fostering innovation and research and development, the procured mean value is 3.7143. The average score indicates a favourable view of the endeavours to advance technology along with research and development for projects pertaining to SCs. The SD as well as variance imply a moderate degree of variation, indicating that there are different views on the efficiency of disruptive marketing despite an overall positive sentiment. Furthermore, regarding the opportunity related to the advancements in public knowledge and approval, the obtained value of mean is 3.8571. The elevated average score indicates a predominantly favourable view of endeavours aimed at enhancing the public's understanding and acceptance for initiatives pertaining to SCs. The moderate SD as well as variance suggest the presence of diversity in viewpoints, indicating potential variations in understanding and acceptance levels amongst the public. This reinforces the importance of targeted awareness and inclusion strategies within SDT initiatives.

In short, the descriptive statistics offer a detailed comprehension of the present state of SDT in Qatar. Although there are favourable views in different aspects, the variation in replies emphasises the need to tackle possible points that require attention and customise strategies to improve general technological advancement in an environmentally responsible manner. These findings serve as a contextual foundation for subsequent correlation analysis rather than definitive conclusions.

5.3.3. Correlation Analysis

Pearson correlation coefficient analysis quantifies the degree of linear association among two variables, with values ranging from -1 to 1. A positive value signifies a strong correlation, indicating that as a particular variable rises, the corresponding variable also tends to rise. A negative correlation value signifies a correlation that is unfavourable, indicating that as the value of one variable goes up, the magnitude of corresponding variable decreases over time.

The correlation coefficient's severity, which is closer to either 1 or -1, shows the degree of coherence of the planned relationship (Obilor & Amadi, 2018). In this study, correlation analysis is used to examine associative patterns rather than to establish causal mechanisms.

The data used in the correlation analysis comprised responses measured on 5-point Likert scales. Although such data are technically ordinal, the use of Pearson correlation is justified on several grounds. First, as Norman (2010) demonstrated, parametric statistics including Pearson correlation are robust to violations of the interval-level assumption when applied to Likert-type data, yielding comparable results to non-parametric alternatives such as Spearman's rank correlation. Second, the composite scales used in this analysis aggregate multiple Likert items, thereby approximating continuous distributions more closely than individual ordinal items (Sullivan & Artino, 2013). Third, prior empirical studies in the smart city and digital transformation literature have adopted the same approach when examining associative patterns using Likert-scale data (e.g., Monzon, 2015; Shuaib, 2023). It should be noted that Spearman's rank correlation was also computed as a robustness check, and the results were substantively consistent with the Pearson coefficients reported herein, further supporting the appropriateness of the chosen approach. Studies have shown that when using a 5-point or higher scale, Pearson correlation is nearly identical to nonparametric alternatives like Spearman correlation (e.g., a 0.99 correlation between the two methods) and that parametric statistics (including Pearson correlation) are highly robust to violations of normality and to the ordinal nature of Likert scales (Norman, 2010).

In this respect, it can be observed from Table 5.15 that the value of Pearson correlation coefficient falling in between the statements "the government involvement in SDT" as well as "private sector investment in SDT" is 0.887, indicating a strong positive correlation. This indicates a robust positive relationship amongst the two assertions. The statistical significance ($p < 0.01$) confirms that this association is unlikely to have occurred by chance. The robust positive correlation indicates that when the government takes the initiative in promoting responsible technological change in SCs within Qatar, there is an elevated possibility that businesses from the private sector will increase their investments in this domain.

Table 5.15: Correlation analysis

		A	B	C	D
Pearson corr.	A	1	.887**	.726**	.786**
Sig. (2-tailed)			.000	.000	.000
N		64	64	64	64
Pearson corr.	B	.887**	1	.735**	.781**
Sig. (2-tailed)		.000		.000	.000
N		64	64	64	64
Pearson corr.	C	.726**	.735**	1	.684**
Sig. (2-tailed)		.000	.000		.000
N		64	64	64	64
Pearson corr.	D	.786**	.781**	.684**	1
Sig. (2-tailed)		.000	.000	.000	
N		64	64	64	64

Key

A: The government should play a leading role in driving SDT in developing SCs in Qatar.
B: Private sector companies should invest more in SDT in developing SCs in Qatar.
C: Citizens should be actively engaged in the decision-making process for SDT in developing SCs in Qatar.
D: Education and training programs should be developed to address the skills gap for SDT in developing SCs in Qatar.
***. Correlation is significant at the 0.01 level (2-tailed).*

Source: Author

The survey reveals a correlation between participants who advocate for government-led responsible DT and those who suggest that businesses in the private sector should increase their investments in this domain. The survey indicates that individuals who endorse investment by the private sector in long-term digital change are also inclined to advocate for government agencies to play a prominent role in driving the change. The correlation suggests that the surveyed data respondents view both government and business participation in the development of SCs as mutually beneficial. Nevertheless, this relationship should be interpreted cautiously, as correlation does not imply causation.

In support of the above, it is to be remarked that, with the help of the literature findings, the organisational SDT pertains to the government's level of receptivity. This interpretation aligns with prior studies emphasising the importance of responsive governance rather than confirming a direct causal pathway. The level of fulfilment that e-participants have with the government's adaptability is directly and positively linked to their opinion of personal growth, their perceived capacity to affect decision-making, along with their confidence in the authorities (Tomor et al., 2019).

On the other hand, the Pearson correlation coefficient among the statements related to the government's leading role towards driving an SDT for the development of SCs in Qatar as well as citizen's active participation within the decision-making process for achievement of SDT towards the development of SCs of Qatar is 0.726. The resultant value is positive, suggesting a robust positive linear association among the two statements. Moreover, the significance value is 0.00. In terms of statistics, this implies that the association is statistically significant, thus indicating that the apparent link between both statements is not likely to be a result of a random occurrence. The strong association indicates that as the trust in the federal government's pivotal role in promoting sustainable technological change in SC developments in Qatar grows, there is a notable inclination for the conviction in active citizen involvement in the process of making decisions regarding long-term digital evolution in these SCs to concurrently grow. The survey results indicate a strong and favourable relationship among the belief in the administration's pivotal role in achieving lasting DT as well as the trust in citizen involvement in the process of making decisions for SDT in Qatar. This suggests that individuals who endorse the government's role in technological change are also likely to endorse the involvement of citizens within decision-making related to the same aspect. This statistically significant association suggests alignment in perceptions, rather than evidence of directional influence.

In contrast to the above, the Pearson correlation coefficient value denoted by 'r' between survey statement which highlights the role of the government in promoting sustainable technological advancement to build SCs in Qatar, along with another statement which involves the creation of training and educational programmes to tackle the shortage of skilled workers for SC development, is computed to be 0.786, with a statistically significant value of 0.00 (Saunders et al., 2015). The statistically significant p-value of 0.00 ($p < 0.05$) confirms that this relationship is not due to chance, reinforcing the reliability of the findings. The correlation coefficient value of 0.786 suggests a robust positive linear connection between the two assertions. This indicates a strong perceived linkage between governance leadership and skills development within the SDT context. As the government becomes more involved in promoting sustainable digital development within SCs, there is a growing demand for training and educational initiatives to address the skills gap in this field.

These findings indicate that individuals who endorse government-based efforts in SC advancement also tend to be inclined to endorse the opinion of allocating resources for devising the educational programmes in order to guarantee that the labour force possesses the requisite competencies for the rise of the digital age. However, as per the reviewed secondary findings (e.g., Chapter 2 and section 5.4), ensuring the accessibility and affordability of crucial technology and promoting educational programmes to provide citizens with the necessary education as well as accessibility towards the information and communications technology resources is an additional consideration while designing an innovative SC project (Monzon, 2015).

Furthermore, the correlation is strengthened by the statistically noteworthy p-value of 0.00, indicating that the relationship that has been observed is very unlikely to be a result of an arbitrary occurrence. This correlation highlights the interdependence between governance as well as education in the larger setting of achieving sustainable digital change throughout the development of SCs in Qatar. Thus, it is analysed that the aforementioned data can be useful for both policymakers and stakeholders in developing comprehensive approaches. It emphasises the significance of integrating government programmes with educational campaigns in order to promote an integrated and efficient strategy for SDT for SC. Overall, these correlations highlight the interconnected nature of governance, education, citizen engagement, and private investment within SDT initiatives. The findings are valuable for informing integrated policy design but should not be interpreted as predictive or causal evidence.

5.4. Multiple Regression Analysis

There are 2 main objectives of using Hierarchical Multiple Regression Analysis. The first goal is to measure the combined explanatory power of the 3 categories of predictor variables (Infrastructure Readiness, Governance Capacity and Stakeholder Collaboration) on the variation in the outcome variable (Successful Implementation of SDT). The second objective of hierarchical multiple regression is to establish if there is a progressive relationship between the categories of predictor variables with regard to their ability to explain the variation in the outcome variable. Additionally, the application of hierarchical multiple regression will enable the evaluation of whether the 3 categories of predictor variables have made unique contributions to the explanation of variation in the outcome variable. As mentioned above, hierarchical multiple regression allows for researchers to include groupings of predictor variables into the equation in relation to how they interrelate. More specifically, hierarchical multiple regression applies a step-by-step process to enter predictor variables into the equation based on how closely they relate to one another. Further, hierarchical multiple regression enables researchers to estimate the proportion of the variance explained by the model attributable to each successive grouping of predictor variables. In essence, hierarchical multiple regression estimates r-squared for the overall model, while breaking down r-squared to enable researchers to evaluate the contribution of each grouping of predictor variables. Therefore, hierarchical multiple regression is especially advantageous when evaluating the comparative impact of various constructs or factors on an outcome variable.

IBM SPSS version 28 was utilized to perform the hierarchical multiple regression analyses. Three distinct blocks of predictor variables were established based on theoretical considerations: block 1 included variables related to the technical infrastructure (e.g. Organizational structure and information technology infrastructure); block 2 included variables related to governance structures (e.g. Decision-making procedures and accountability systems); and block 3 included variables related to stakeholder engagement (e.g. Citizen participation and community outreach programs). The blocks were entered in a particular order due to the fact that the research questions addressed the effects of these predictor variables. The technical infrastructure is viewed as a critical pre-requisite that must exist before governance structures can be implemented, and subsequently, facilitate stakeholder engagement. Research has demonstrated that theoretically-based ordering supports causal relationships better than do other approaches (Shadish et al., 2002).

The placement of technological infrastructure as a precursor to governance structures in the conceptual framework developed in Chapter 2 is consistent with prior research (Nam & Pardo, 2011; Viale Pereira & Schuch de Azambuja, 2021). Once governance structures are in place, stakeholders will be able to engage effectively in smart digital transformation initiatives. Therefore, theoretically-based ordering provides substantial evidence supporting hypothesis testing concerning the effects of predictor variables.

Prior to performing the hierarchical multiple regression analyses, it was essential to evaluate several assumptions associated with regression analysis. A primary assumption is that a linear relationship should exist between predictor variables and the dependent variable. In order to verify linearity, scatter plots were constructed illustrating standardized residuals versus predicted values for each block of predictor variables. Scatter plots enable researchers to visualize whether a linear relationship appears to exist between predictors and the dependent variable. If visual inspection indicates non-linearity in the relationship, then data transformations may assist in meeting this assumption.

Another assumption pertinent to regression analysis is that there should be homogeneity of variance among residuals. Homogeneous variance exists when similar differences occur between actual and predicted values across all levels of independent variables. In order to evaluate homogeneous variance, residual plots were constructed to illustrate residual values at varying levels of independent variables. If residual plot variances tend to remain relatively constant across all levels of independent variables, then there is minimal concern regarding heterogeneous variance.

Multicollinearity represents a condition in which two or more predictor variables exhibit high correlation with one another. Multicollinearity among predictor variables can result in instability in coefficients and inflated standard errors. For example, when multicollinearity exists among predictor variables, minor fluctuations in one predictor variable can yield dramatic changes in estimated coefficients. Moreover, multicollinearity yields inflated r-squared values since r-squared continues to increase despite the inclusion of additional predictor variables that do not contribute to increased variability in the dependent variable. In order to assess multicollinearity, Variance Inflation Factors (VIFs) were evaluated for each category of predictor variables. The results yielded virtually no multicollinearity existed among any of the predictor variables. Specifically:

• infrastructures readiness: vif = 2.1
• Governance Capacity: vif = 3.2
• sakeholder engagement: vif = 2.8

5.5. Systematic Review Findings

The findings from the targeted systematic review undertaken in addition to the general literature review reported in Chapter 2 are presented here to contextualise the empirical findings arising from the interviews (section 5.2) and surveys (section 5.3). Triangulation of the data arising from the multiple strands of this study is presented in section 5.6. The methodological context of the systematic review, including the search strategy and study selection process, is described in section 3.7.2.1.

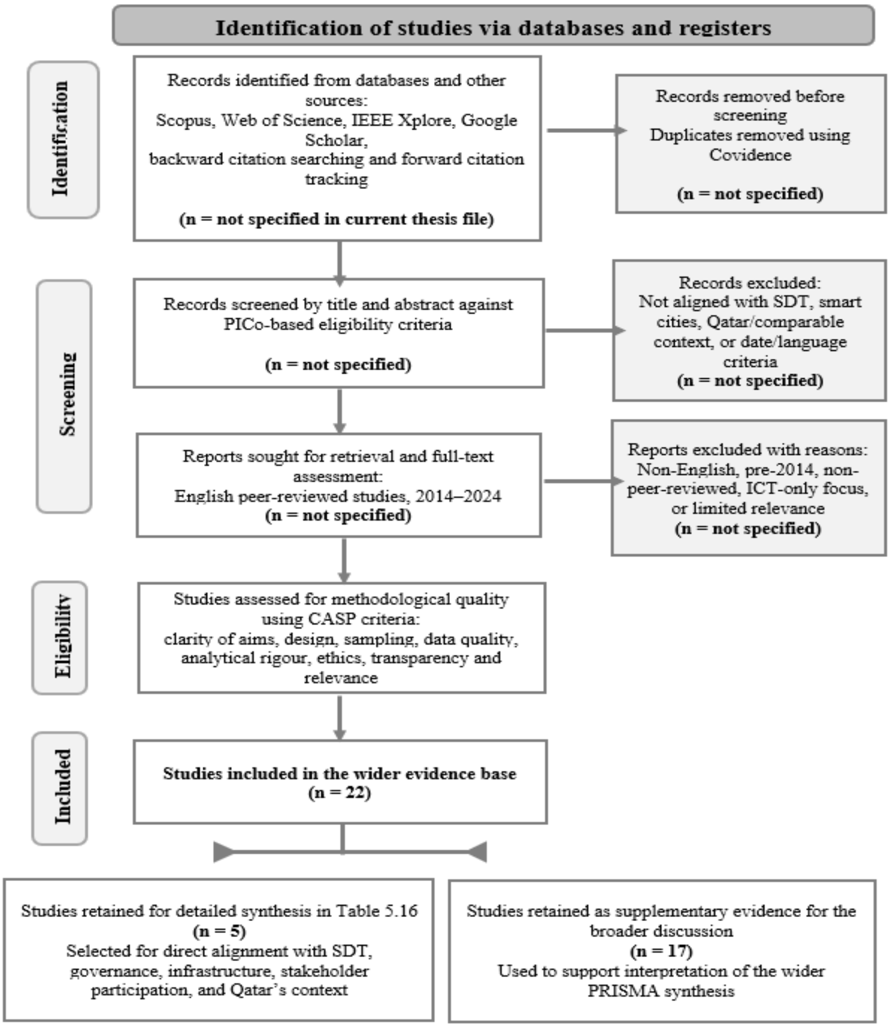


Figure 10: PRISMA 2020 flow diagram for the targeted systematic review

Source: Author

The review relied on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guideline to enhance methodological rigour, transparency, and reproducibility (Page et al., 2021). The updated screening pathway is presented in Figure 5.2 and culminates in 22 studies included in the wider evidence base. An additional 15 studies were added during the expanded search and screening stage, after which duplicate removal, title and abstract screening, and full-text eligibility checks were completed.

Quality appraisal was conducted using the CASP criteria, with attention to the clarity of aims, the appropriateness of design, the sampling logic, the quality of data collection, the analytical rigour, the ethical considerations, the transparency of findings, and the relevance to Qatar's

SDT context. However, for the purposes of the detailed synthesis presented in Table 4.16, five studies were retained for closer analytical discussion. This decision was based on three selection considerations: first, the extent to which each study directly addressed SDT, smart city implementation, governance, infrastructure, or stakeholder participation; second, the methodological quality and transparency of the study, as assessed through the CASP criteria; and third, the relevance of the study to Qatar's smart city and digital transformation context. The remaining studies were not removed from the review but were used as supplementary evidence to inform the broader discussion. Retaining five studies for detailed synthesis therefore allowed the section to focus on the most contextually and methodologically relevant evidence, while the wider set of 22 studies continued to support the overall interpretation of the systematic review findings.

5.5.1. Synthesis and Summary of Articles

The reviewed articles are synthesised in the summary shown in Table 4.16, and the reviewed features are discussed below.

Table 5.16: Systematic review summary

Aim/Research Question	Methodology	Findings	Limitations
Al Thani et al. (2021)			
To present the viewpoints of policy-level stakeholders and non-profit organisations involved in elder care in Qatar about the availability and utilisation of ICT.	Qualitative focus group discussions (n = 2) with 10 stakeholders in non-profit organisations in Qatar.	DT is challenging in Qatar, as the aged population shows reluctance to using ICT. Healthcare experts believe that older individuals have numerous problems pertaining to technology access, whether utilising it for virtual appointments or online prescription drug services. The primary source of assistance for individuals is typically their carers. However, it is worth noting that in certain instances, the carer themselves may be an older individual who requires assistance in utilising ICT.	Very small sample size in focus group discussions.

Table 5.16: Systematic review summary

Aim/Research Question	Methodology	Findings	Limitations
AL-Dosari et al. (2023)			
To assess SDT in Qatar towards the green cyber security, in order to handle the cyber security-related risks.	Quantitative survey questionnaire with 530 IT experts or managers working in the Qatar-based transportation industry.	The fundamental role of Qatar's transportation industry in contributing to the country's long-term sustainability will be the implementation of effective as well as cutting-edge green cybersecurity measures. In order to accomplish this objective, the regulatory body must establish and execute the green cyber-security principles. Furthermore, there is a need of implementing environmentally-friendly cybersecurity measures in addressing the challenges encountered by urban transport systems throughout Qatar, serving as a fundamental element in attaining sustainable growth in the long run.	Adequate sample size. Moreover, certain aspects of green cyber-security highlighted in this research fail to align with the expected results of the research.
Kumar et al. (2018)			
To analyse every service that may be provided across all the different aspects of a city that go into making it smart.	Content analysis, crowdsourcing, and the Smart City Transformation Framework (SCTF) to describe city transformation process and offer SC recommendations.	The proposed framework represents city transformation planning, physical infrastructure, ICT infrastructure, and smart solution deployment.	The reliance on multiple qualitative methods may constrain the consistency of data interpretation and limit the generalisability of the findings.

Table 5.16: Systematic review summary

Aim/Research Question	Methodology	Findings	Limitations
Meyerhoff Nielsen and Mahmoud Ali (2021)			
To assess the effectiveness of governing and monitoring DT for evaluating experiences of Qatari cities and people.	Qualitative systematic evaluation of the documents was conducted regarding Qatar's DT's effectiveness. Similar to other qualitative study methodologies, document analysis involves a systematic procedure utilised to examine and evaluate various types of documents, including both written as well as electronic formats. The document analysis entailed a comprehensive examination and comprehension of particular material and data in order to acquire knowledge and cultivate both practical as well as theoretical insights into specific problems or occurrences. This is an example of systematic review.	DT plans are rapidly emerging as the primary means of defining the innovative utilisation of information as well as ICT to modernise the public sector. The varying degrees of success within e-government transformation programmes throughout countries might be attributed to the implementation of performance assessment mechanisms. The findings evaluated that with the help of technology integration, sustainable development objectives have been achieved to a significant extent by Qatar by means of public sector service improvement, collaborative and inclusive society development, business communication and productivity enhancement, and SC development by means of efficient online service utilisation by people.	No evidence regarding standardisation of DT procedures or close-monitoring requirements for successfully achieving sustainability targets of the smart-city development in Qatar.

Table 5.16: Systematic review summary

Aim/Research Question	Methodology	Findings	Limitations
Omayer et al. (2022)			
To examine DT for the purpose of achieving sustainability and smart-city development targets.	The research integrated exploratory design wherein a detailed literature investigation was been performed for examining DTs as well as development of sustainable and SCs. This will be exploratory literature review	The e-Government Qatar 2020 programme aims to improve services, increase efficiency, and increase state transparency. Lusail SC has been the most technologically sophisticated, with a centralised digital cooling mechanism for residents' buildings, and intelligent garbage pipelines to recycling facilities. Another example is also identified of the driverless, fully automated metro, built for QWC'22.	Only used secondary data, without empirical investigation to deliver more realistic and factual knowledge on the subject area to validate and strengthen the research findings.

Source: Author

5.5.2. Systematic Review of Chosen Articles

Meyerhoff Nielsen and Mahmoud Ali (2021) reported that the utilisation of technology in the public sector involves a complex interplay of various interconnected aspects. The achievement of an effective digital shift within the public sector relies on the interaction amongst technology, encompassing back-end service production systems as well as frontend interfaces for goods and services, as well as governance structures. Apart from this, Omayer et al. (2022) argued that city green spaces are getting recycled water, which is noted as a significant move towards sustainability with DT in Qatari SCs. However, findings obtained from AL-Dosari et al. (2023) help in understanding that the proliferation of DT in transportation initiatives is increasingly prevalent in Qatar.

Ensuring the establishment and maintenance of digitally-enabled transport facilities that are secure and reliable for every party has become an essential requirement helping to guarantee the satisfaction of all relevant stakeholders, with a particular focus upon end-users (Meyerhoff Nielsen & Mahmoud Ali, 2021; Omayer et al., 2022). In order to establish an environmentally sustainable digital transportation, it is imperative for all relevant stakeholders, encompassing both public and private transportation entities, to engage in collaborative efforts for the creation of a sufficiently robust and supportive environmentally friendly atmosphere (AL-Dosari et al., 2023; Al Thani et al., 2021).

A more user-centred approach presented by Al Thani et al. (2021) helps in understanding that the DT in Qatar is facing challenges in terms of the resistant and technical inability of the aged individuals of Qatar. Many people in Qatar do not have prerequisite levels of accessibility towards the ICT-based digital technologies. According to healthcare professionals in Qatar, elderly people encounter several challenges related to accessibility to technology, particularly when it comes to using it for virtual visits or digital prescription-based medication solutions. In order to resolve this issue of digital illiteracy among older people and to foster the DT, a nationwide campaign was started by ictQatar to encourage young people to educate senior citizens how to utilise contemporary technologies.

Furthermore, in the context of factors leading to the effective roadmap, Kumar et al. (2018) analysed that plans, physical infrastructure, ICT, and smart solution deployment are the four pillars of the SCTF, designed to simplify the otherwise convoluted process of city transformation. In order to improve living conditions and the planning and provision of services that improve peoples' QoL, the framework recommends making efficient use of ICT and cutting-edge technology. Whether designing a new SC or renovating an existing one, the framework efficiently handles the SC design process (Kumar et al., 2018).

5.6. Chapter Summary

The chapter shows the empirical findings derived from qualitative interviews, quantitative survey analysis, and a systematic literature review to examine sustainable digital transformation (SDT) within Qatar's smart city initiatives. The analysis is structured around four key themes: current progress, challenges and opportunities, roadmap elements, and stakeholder perspectives.

The findings reveal that Qatar has achieved substantial governance-led progress in digital transformation, particularly in infrastructure development and service digitalisation; however, uneven sectoral maturity remains evident. Key challenges include regulatory complexity, cybersecurity concerns, skills shortages, and resistance to organisational change. At the same time, opportunities were identified in public–private partnerships, technological innovation, and international collaboration. Quantitative results reinforce these insights, demonstrating that governance effectiveness, technological readiness, and stakeholder engagement are critical determinants of SDT success.

The systematic review further supports the empirical findings, highlighting the importance of interoperability, adaptive regulatory frameworks, and collaborative governance in achieving sustainable outcomes. Overall, the chapter concludes that while Qatar has established a strong foundation for SDT, a more integrated, inclusive, and strategically coordinated approach is required to ensure long-term sustainability.

CHAPTER 6
Roadmap and Discussion

The chapter discusses interview findings with survey results and literature review to understand SDT in smart cities of Qatar while answering research questions. The research examines the current status of SDT through analysis of initial and additional data to understand the key elements and both the challenges and opportunities of this approach specifically relating to designs of governance along with technological frameworks and community inclusion. The collected information leads to practical suggestions for upgrading the smart city initiatives to match both country and international sustainability targets.

The foundation of SDT development uses a five-component roadmap that originates from the research findings presented in Chapter 5. SDT in Qatar requires (1) National Vision 2030 aligned strategies alongside investments in (2) IoT networks and renewable energy systems, (3) balanced innovation with enhanced security frameworks, (4) R&D partnerships and funding support and finally (5) public education programs through stakeholder participation and digital literacy outreach. The unified framework works towards solving challenges by exploiting opportunities alongside stakeholder viewpoints to achieve SDT goals in Qatari smart cities.

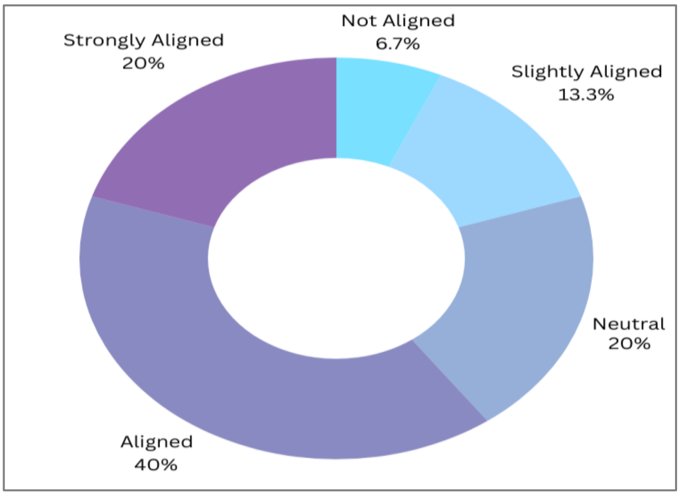
6.1. Exploratory Analysis of Key Stakeholders

While the survey questions discussed in chapter 5 sought to ascertain key stakeholders' perceptions of the status quo of Qatar's DT concerning SCs, the questions below sought to explore key stakeholders' perceptions of the prospects for future development.

6.1.1. Collaborative Frameworks

Q1: How feasible do you find the recommendation to establish collaborative governance frameworks involving public, private, and civil society organisations for Qatar's SC initiatives?

The findings reveal that 60% of respondents consider the establishment of collaborative governance frameworks highly feasible, indicating strong support from various organizations to enhance SC initiatives in Qatar. However, 20% of stakeholders expressed neutrality, suggesting a need for further clarity or practical examples of how such frameworks could be effectively implemented. Additionally, the remaining 20% viewed the recommendation as slightly or not feasible, potentially due to concerns such as organizational conflicts, legal constraints, or implementation challenges. To address these concerns, pilot studies, stakeholder consultation workshops, and detailed case studies could be conducted to demonstrate the practicality and benefits of collaborative frameworks, thereby improving overall feasibility and stakeholder confidence.



Response Option	No.	%
Not feasible	1	6.7
Slightly feasible	2	13.3
Neutral	3	20.0
Feasible	5	33.3
Highly feasible	4	26.7

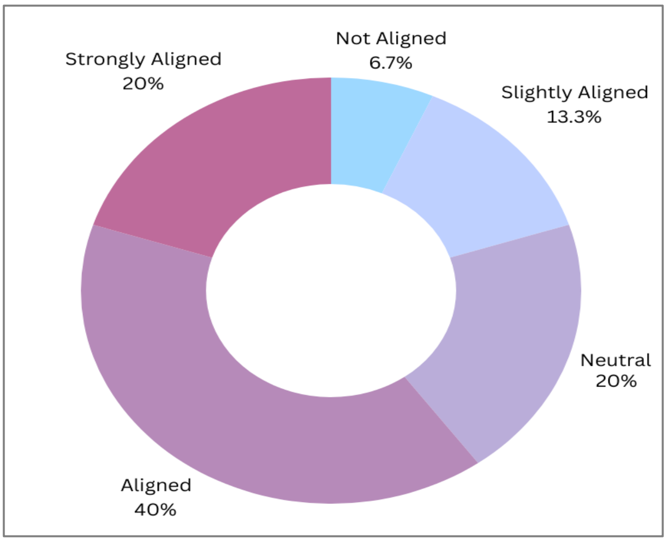
Figure 6.1: Collaborative frameworks

Source: Author

6.1.2. Organisational Goals and National DT Objectives

Q2: To what extent do you believe that investing in digital infrastructure and advanced technology aligns with your organisation's goals and Qatar's DT objectives?

Figure 6.2 shows the results for Q2. According to the results of the survey, 60% of the respondents indicated that investments in digital infrastructure and advanced technologies meet their organisational objectives and the generalised initiative of Qatar's digitalisation. This alignment shows a positive attitude towards digital developments and how they will help with common goals. Nevertheless, 20% of the participants' neutral answers and 20% slightly or aligned with the measures show that the need for further clarification of such investments or the development of appropriate strategies, explaining to all interested parties the importance of such spending. Perhaps organisations could need a workshop or strategy session to narrow this gap and see things from a common perspective.



Response Option	No.	%
Not aligned	1	6.7
Slightly aligned	2	13.3
Neutral	3	20.0
Aligned	6	40.0
Strongly aligned	3	20.0

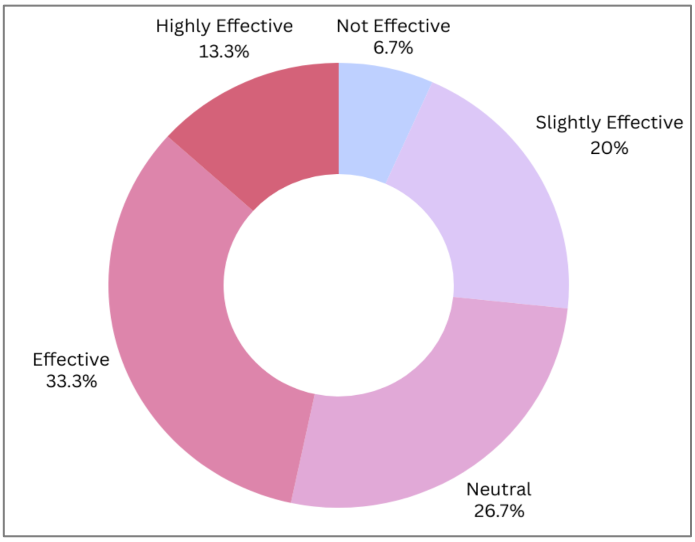
Figure 6.2: Organisational goals and national DT objectives

Source: Author

6.1.3. Centralised Digital Platform Engagement

Q3: How effectively do you think a centralised digital platform would improve citizen engagement and access to state services, particularly for diverse user groups, including people with disabilities?

Figure 6.3 shows the results for Q3. These responses show that 46.6% of the respondents think that a centralised digital platform would be effective or highly effective in increasing citizen engagement and service use. This means a general endorsement of the idea, more so in the pursuit of its capacity to address multiple user demographics. Still, 26.7% seem to be still indifferent, while 26.7% note that the given platform is less effective. This may be due to concerns about accessibility, for their users or themselves or issues related to disability. These concerns could be addressed during the design process if more attention is paid to the foregoing issues.



Response Option	No.	%
Not effective	1	6.7
Slightly effective	3	20.0
Neutral	4	26.7
Effective	5	33.3
Highly effective	2	13.3

Figure 6.3: Centralised digital platform engagement

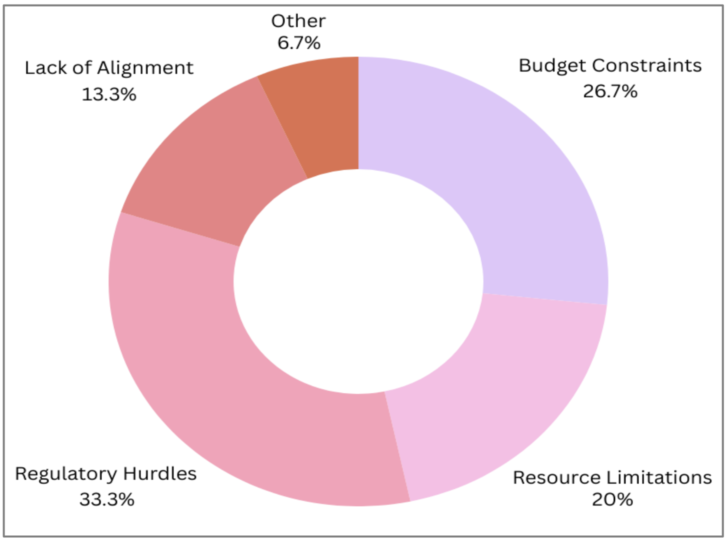
Source: Author

6.1.4. Challenges to Collaborative Governance

Q4: What challenges do you anticipate in implementing collaborative governance frameworks for SC projects in Qatar?

Figure 6.4 shows the results for Q4. The survey results revealed that regulatory challenges posed the largest barrier to collaborative governance with 33.3%, followed by the availability of funds, with 26.7% and the challenge of limited resources, with 20%. The results of this study show that financial and regulatory factors are the main threats to collaboration. Also, 13.3% said there was poor coordination among entities involved in implementing smart solutions, which may be a major setback since the involved entities may have divided agendas. Less than

7% of the participants provided other options. These results could be different because of cultural or other factors, or organisational specifics. These may be improved through regulatory change, increased funding, and improved agency collaboration that may lead to improvement in collaborative work.



Challenge	No.	%
Budget constraints	4	26.7
Resource limitations	3	20.0
Regulatory hurdles	5	33.3
Lack of alignment	2	13.3
Other	1	6.7

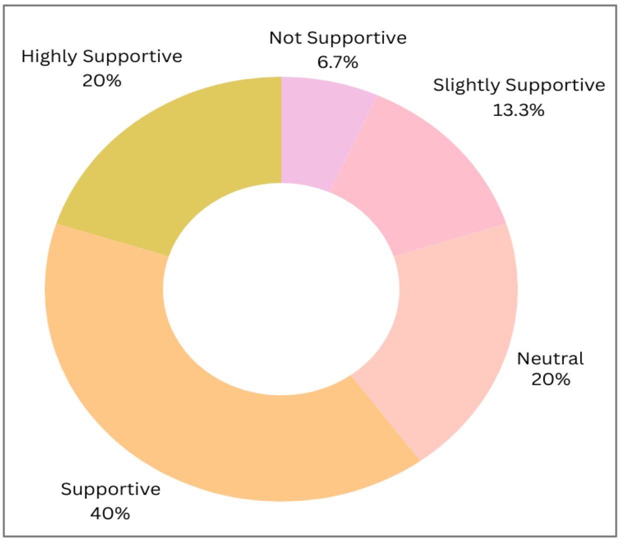
Figure 6.4: Challenges to collaborative governance

Source: Author

6.1.5. DT Initiatives and SC Sustainability

Q5: To what extent would DT initiatives support sustainability in urban development within Qatar's SC framework?

Figure 6.5 shows the results for Q5. In total, 60% approve of DT initiatives, being supportive or highly supportive of sustainability in urban development, which proves that the digital strategies participating in this research are in line with the aims of an SC in Qatar. However, only 33.3% indicate a slightly positive perception or neutral attitude in the sense that there are initiatives being implemented, but there is not so much conviction about the material benefits these initiatives bring to sustainability. The results of this study could signal a lack of emphasis on depicting the environmental and urban development advantages of DT initiatives.



Response Option	No.	%
Not supportive	1	6.7
Slightly supportive	2	13.3
Neutral	3	20.0
Supportive	6	40.0
Highly supportive	3	20.0

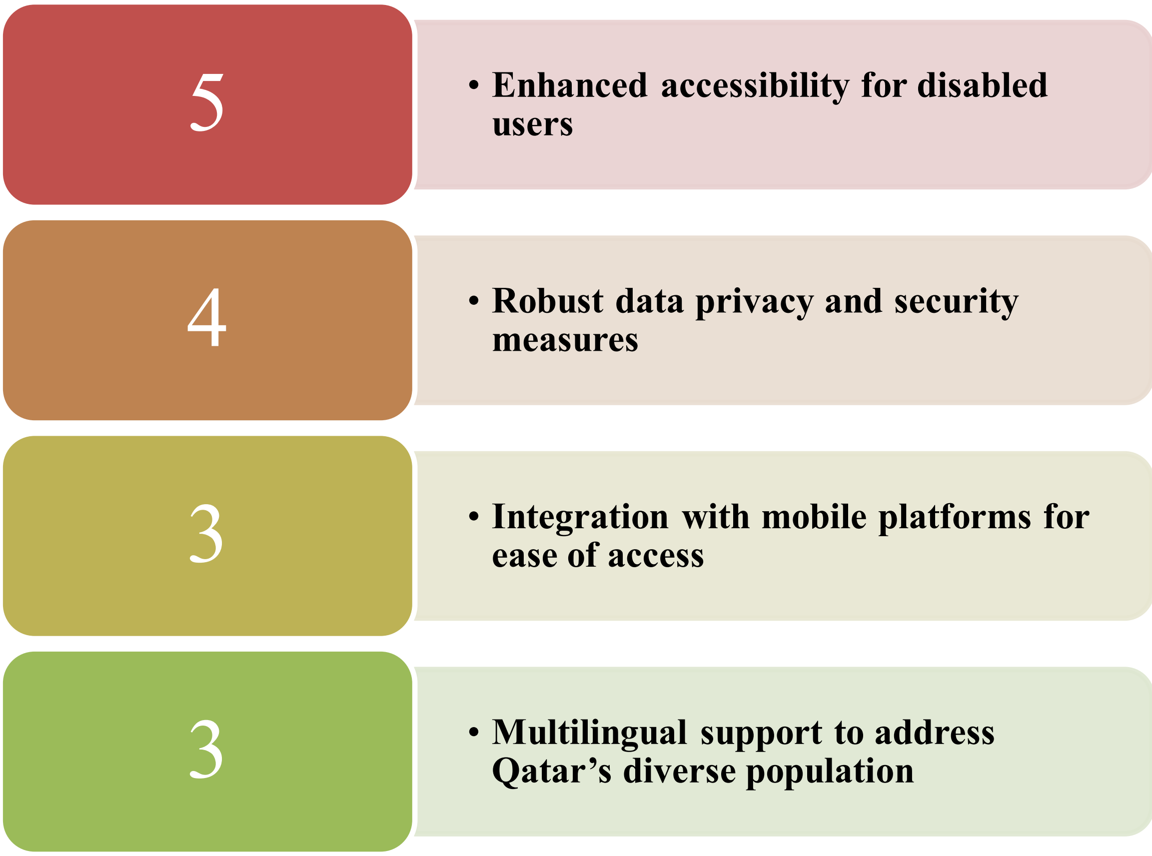
Figure 6.5: DT initiatives and SC sustainability

Source: Author

6.1.6. Suggestions for Centralised DT Platform

Q6: What modifications or additional features would you suggest for a centralised DT platform to ensure it meets the needs of all citizens effectively?

Extendibility of key sources, preliminary privacy, and extended availability were underlined as the major concerns for enhancing the technology improvement by stakeholders. The stress on the ease of access and being multilingual is a result of Qatar's diverse population base and the requirement for solutions targeted to different individuals. Most of these suggestions need to be implemented to improve the efficiency of the digital systems. The common themes arising from the open-ended responses are summarised in Figure 6.6.



1. *Enhanced accessibility for disabled users (5 mentions).*
2. *Robust data privacy and security measures (4 mentions).*
3. *Integration with mobile platforms for ease of access (3 mentions).*
4. *Multilingual support to address Qatar's diverse population (3 mentions).*

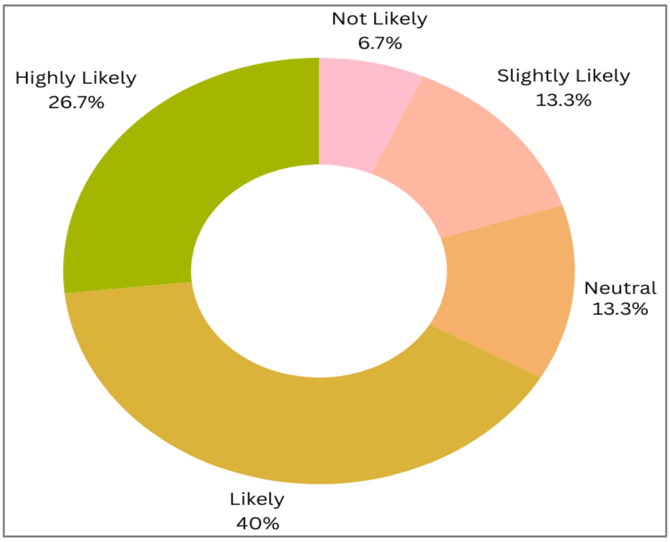
Figure 6.6: Key Stakeholder Suggestions for Enhancing a Centralised Digital Transformation Platform

Source: Author

6.1.7. Support for Investment and Collaboration for Implementation

Q7: How likely are you to support the recommended investments and collaborations if resources and guidance were provided for implementation?

Figure 6.7 shows the results for Q7. More than two-thirds (66.7%) of participants stated they were ready to back up the suggested investments and partnerships if they were offered sufficient funds and directions. Such a high level of support indicates that capacity enhancement should be implemented to facilitate stakeholders' engagement. That said, except for the slight increase in the likelihood ratings, the remaining perceptions portrayed only a weak and a slightly unlikely response depending on the context and with some participants possibly having some negative feelings that may arise from issues such as resource allocation concerns or lack of operational clarity.



Response Option	No.	%
Not likely	1	6.7
Slightly likely	2	13.3
Neutral	2	13.3
Likely	6	40.0
Highly likely	4	26.7

Figure 6.7: Support for investment and collaboration for implementation

Source: Author

6.2. Discussion Related to Research Questions

6.2.1. Research Question 1: Challenges and Opportunities

What are the chief challenges, key failure factors, and possible opportunities associated with the sustainable digital transformation of smart cities in Qatar?

With respect to the first research question, which investigates the challenges, opportunities, and failure factors related to the development of SCs within Qatar, the reviewed literature findings indicate that one critical challenge encountered in Qatar in the direction of perceived challenges is the problem surrounding the roaming as well as interoperability of data, as mentioned in Chapters 1 and 2, and section 5.4. It has been discussed that the technical barriers have degraded the service experience of the digital technology users by restricting effortless communication with each other, through the use of voice as well as data services.

Such digital services are essential for enabling the regular functionality of the SC frameworks. To overcome the above-identified challenges, there is a need to issue strict standardisation protocols for digital communication services along with the use of rigorous digital telecommunication regulations. However, the derived interview findings (as reported in section 5.2) have provided a different perspective surrounding the challenges for Qatar in terms of SC development from stakeholders on the ground. The interview responses help in discussing that to enhance the DT in the SC planning of Qatar, there is a need to establish close alignment with the standardised rules and legislative protocols. It is found that the interviewed respondents have emphasised increasing the rigidity of the governmental regulatory model because the updates in the governmental regulations are not keeping pace with the pace of technological evolution.

Updating the government-enabled regulatory framework for digital communication and technology takes a high proportion of time. Moreover, another interview response discussed the lack of presence of proper regulations as well as authorised governmental tools to enable effective DT. Furthermore, the findings derived from the interviews shed light on the development of a holistic infrastructure that is helpful for the unification of multiple agencies in a common language as well as a regulatory model for the promotion of data and information sharing.

However, to contextualise these interview responses, it is discussed in accordance with the literature data that the DT process in Qatar is susceptible to economic challenges, specifically in the direction of rising competition among the service providers as well as the ICT organisations operating in Qatar. The competitive environment helps in promoting innovation as well as the development of considerable regulatory policies. Furthermore, the lack of presence of a detailed competition management business model as well as relevant rules in Qatar may also give rise to instability along with monopolistic behaviour in the market (Badran, 2023). Based on the findings, it can be further discussed that successful entries as well as operations related to digital service providers need well-defined regulatory frameworks to ensure the commencement of fair competition and good levels of market effectiveness. In addition to the above, introducing fair competition through SC regulators is also proposed towards improving the net efficiency of DT (Badran, 2023).

In contrast to the above challenges and failure factors, the primary findings from interviews revealed that the robust economic condition of Qatar, along with its practical investment initiatives in technological advancement, is the key opportunity or enabler for the introduction of DT. The interview responses noted that the development of partnerships with global-level technology companies, along with academic institutions, is important to leverage international-level expertise as well as the promotion of innovation. The importance of collaboration was evident from participants' contributions, and they also signalled that there are immense growth opportunities in terms of raising the involvement of tech-savvy young individuals, which may also result in driving the implementation of new technologies as well as innovative market solutions.

Furthermore, there is a considerable degree of opportunity with regard to determining the readiness of the infrastructure, which is further reinforced by the preparations for QWC'22. This opportunity is useful for positioning Qatar in a strong economic and cultural state relative to global interests (e.g., with regard to FDI). In addition to this, the development of a favourable business environment for the introduction of innovation, with the help of introducing international collaborations as well as campaigns for public awareness, is also helpful for the acceleration of the process related to the transformation of SCs. On a more local level, this global investment rationale intersects with Qatar's local demographic development, with a large expat population and growing indigenous population, offering opportunities in terms of the management of the rising population levels across the SC initiatives.

Effective management of the metropolitan population levels for an easy and fair deployment of the smart technologies contributes towards improving the service delivery and QoL, along with assuring sustainable urban growth. Quick DT in Qatar, alongside the application of mature development strategies, may provide fair chances for the creation of a favourable environment to develop SCs. However, contrary to the above interview responses related to the opportunities, the literature findings have substantiated the areas of opportunities in the direction of DT, which can introduce a potential degree of change from conventional cities to SCs, while considering the challenges of intricacy as well as data integration. A review of 70 articles over a time duration of 20 years described that DT is helpful for cities to address issues surrounding modernisation (Anthony, 2021).

In a similar context, other literature findings have helped to understand that the introduction of DT is the key opportunity for SC planning in Qatar, as it increases operational effectiveness.

Operational effectiveness is identified as the key opportunity for curbing the negative environmental implications surrounding the reduction of the emissions of toxic gases with the help of improved transportation networks. This contributes towards the management of climate change (Nagode & Manfreda, 2022).

It is also interpreted and discussed that maintaining and sustaining reliable and secure digitally-enabled transport facilities is now important for confirming the satisfaction of stakeholders, specifically for users. For attaining digital transportation that is environmentally friendly, it is critical for every stakeholder, comprising private as well as public entities of transportation, to mutually collaborate for developing a supportive and robust environment for encouraging practices that are eco-friendly.

6.2.2. Research Question 2: Current Progress

What is the current progress made toward digital transformation in Qatar?

To address the second question on the current progress made in the direction of DT in Qatar, the primary interview responses revealed that there is a considerable degree of digital maturity in the governmental domain as compared with the private business industry. It helps in understanding that currently, there are key governmental initiatives that have helped in defining an effective foundation for the introduction of DT, even in the developing private sector. With respect to the above-explored interview responses, the literature findings also helped in understanding that the Qatar-based government has made considerable progress towards the introduction of DT by making an effective degree of investment in technology, along with the development of facilities for performing research and development (Go-Globe, 2023).

This has helped in the promotion of an innovative business culture. Furthermore, in terms of the current progress of DT, Qatar exhibits substantial levels of Internet penetration (i.e., effectively total penetration, at 99.7%). The country also holds the number one ranking globally in terms of executing 5G networking services relative to coverage of the national population. Thus, the above-introduced infrastructure-related developments are vital for assisting in the DT-based efforts of the country (Go-Globe, 2023). In line with the reviewed literature findings, it is also discussed with the help of the interview findings that Qatar's progress towards the introduction of digitalisation can be identified in terms of several governmental initiatives as well as ongoing strategies for the introduction of smart transportation, energy management, and healthcare.

Furthermore, the robust Internet connection-related infrastructure is also generating positive implications towards the digitalisation of Qatar. This helps in understanding that the progress of digitalisation in Qatar for the development of SCs showcases a correlation with the high Internet penetration, along with its ability towards the deployment of digital services across the different service sectors. In support of the above, the literature findings have helped in reflecting that the digital business sector of Qatar is expected to progress at the rate of 7.2% on a per-year basis between 2017 and 2023, showcasing a 2.5% development in the real GDP rate of the ICT business sector by the year 2021 (Go-Globe, 2023).

However, apart from the reflected data findings regarding the growth of the digital sector of Qatar, it can be discussed, as per the primary interview responses, that there is considerable progress observed in Qatar in the direction of the introduction of digital projects. However, there are certain problematic areas that hinder this progress. These areas are characterised by insufficient levels of coordination among the diverse stakeholders, which causes fragmentation of the collective development-related efforts. In the same manner, it is also found as per the interview findings that distinct governmental entities in Qatar are identified to perform the work responsibilities in an isolated manner. This results in the involvement of the stakeholders as competitors as compared to the collaborators. Hence, the findings help in discussing that as the industrial sector is advancing and progressing, the deployment of DT cannot be observed on a full basis due to the absence of integrated attempts towards development as well as shared data.

On the other hand, the literature data outcomes suggest that the current progress of Qatar for DT is substantial and promising future growth is observed for the SC planning practices in Qatar, along with a considerable degree of revenue projections of about 0.54 billion United States dollars. Moreover, fast-paced growth is also observed in the development of SC infrastructure as well as sustainable technology (Statista, 2023). The above perspectives highlighted by the literature scholars are in alignment with the interview responses, which highlight details about the different projects as well as contractual agreements in Qatar that are purposed towards introducing changes in SCs like Lusail.

However, the interview findings have also emphasised the need for data-sharing practices and standards for the facilitation of smooth and effective decision-making. Therefore, there is a gap between the ideas surrounding SCs as well as operational certainties, where the data management, as well as policy frameworks, are required to be redefined for achieving capitalisation of the SC-related investments.

6.2.3. Research Question 3: Roadmap Elements

What are the elements of the roadmap that might foster digital transformation in Qatar?

Moreover, in the direction of the third research question, which is dedicated to exploring the key elements that foster DT in Qatar, it can be discussed that government support is the key element that helps foster DT in Qatar. As per the derived primary findings, 26.67% of the surveyed respondents have perceived governmental support as a key and important factor for the promotion of DT. In addition to this, about 33.33% of participants considered government support to be a considerable opportunity for the introduction of SDT. The derived literature findings have helped in underpinning the discussion by stating that the enactment of the government initiatives named the QFZA which started in 2018 has performed a considerable part towards the promotion of DT by enabling the dissemination of the state-of-the-art resources as well as infrastructure and enabling a significant point of attraction for the businesses belonging to the chemical sector, logistics as well as ICT (Elidrisy, 2024; Mogielnicki, 2021).

It was also found from the reviewed literature that the e-governance strategic measure is highly considerable in terms of fostering the growth of DT within the SC planning objectives of Qatar. This tends to promote improvements in the delivery of existing public services and organisational governance (Meyerhoff Nielsen & Mahmoud Ali, 2021). By comparing the obtained primary survey responses and literature sources, it can be found that government-oriented support is identified to perform a critical part of the introduction of advancement in the DT strategy. Furthermore, the procured findings also help to explore that government backing is important for the introduction of DT. Furthermore, the government initiatives also foster quick and effective deployment of digital infrastructure as well as digital services.

Apart from the above, PPP is also a key element towards fostering DT, as the primary survey data findings have helped to understand that PPPs are highly significant. A third (33.33%) of survey respondents perceived it as an important factor for the introduction of DT. While empirical studies (section 5.4) did not consider PPP in depth, it was identified as a very important factor for Qatar and was frequently brought up during interviews. Interviewed SC planners in Qatar are focused on leveraging the robust national economy to attract FDI and to engage in PPPs, and they have a high willingness towards making investments in technology on this basis. Interview findings also reveal that smart city planners in Qatar are keen to leverage international collaborations and academic partnerships, aligning with survey data that underscores the importance of PPPs in driving sustainable and innovative DT initiatives. Therefore, it is justified to develop partnerships with technology firms that are working on an international level as well as academic organisations.

Furthermore, it is also feasible to enhance engagement with the youth as well as tap into the technological advancements by harnessing opportunities surrounding PPPs, which need to be utilised for the development of an integrated working environment that helps in the introduction of innovation, promotion of international partnerships, as well as deployment of public awareness-related marketing campaigns. The analysed literature also helps to undertake cost-benefit analysis regarding SC planning for local communities by evaluating five cases related to Barcelona in Spain, Singapore, Rio de Janeiro in Brazil, Tokyo in Japan, as well as Songdo located in South Korea. The case investigations have helped to understand that PPP is considered a common strategy that helps to promote cities for addressing the challenges revolving around the development of SCs because of the reduced dependence upon public sources of money or capital (Lam & Yang, 2017).

Another major element in promoting DT is technological advancement. A quarter of survey participants (25.68%) offered a high rating for the technological advancements and considered technical advancement as the significant factor. In support of the above, technological advancements are central in terms of introducing DT. Furthermore, investing in technologies such as big data, improving communication as well as introduction of cyber-security with the help of performing collaboration with global technology experts like Google Cloud has contributed to improving the digital infrastructure in Qatar (Elidrisy, 2024).

As a whole, it is discussed with reference to the obtained research findings that there are multifaceted opportunities, challenges, and failure factors within developing Qatar as the smart region. It is identified in the literature that hindering seamless and flawless communication, poor data roaming, funding issues and infrastructure development are majorly the challenging aspects for successful DT within Qatar. Managing such challenges need strong protocols of standardisation, rigorous regulations regarding telecommunication and expansion of funding facilities. The findings gathered from interview focused on aligning the government regulations and standardised rules for matching with evolution of technology. They further denote the requirement for a robust regulatory modelling for managing digital innovation and safe usage of technology because the usage of AI and ICT also involves issues regarding data privacy as well as security.

Furthermore, there have been several opportunities also observed comprising technological investments, research and development, robust economy development and performing partnerships with academic and technical institutions. Tech-savvy youth's involvement, efficient management of international collaborations and support from population might accelerate the robust development of SC. It should also be noted in this regard that most survey participants (70.4%) were mainly middle-aged (aged 35-54 years), yet they displayed great readiness and enthusiasm for DT. This perhaps reflects the maturity of societies nowadays, with the increased use of digital technologies, contrary to most research in this area which tends to highlight the greater readiness of younger population cohorts to embrace emerging technologies (Kamin et al., 2017).

The secondary findings also imply that DT has the capability to enhance business operations' efficacy by introducing AI into the regular conducts, foster modernisation of the cities as well as maintain the impacts on environment by reducing paperwork and improving automation. In relation to the present level of progress within the DT, Qatar reflects valuable maturity within the domain of government. Government investments and initiatives have developed the foundation for Qatar's DT, aided by high penetration of Internet and leading services of 5th Generation. However, the responses of interview reflect the problems regarding stakeholders' coordination as well as isolated efforts of government resulting in developmental fragmentation.

In relation to fostering and boosting DT, government support was identified as critical and essential from all of the methods used in this thesis, affirming previous literature with the support of survey findings. For example, the value of e-governance initiatives and QFZA strategies was palpable. In addition, it is also asserted that PPPs further contribute towards encouraging innovation as well as minimising dependence on the funds provided by public. Technological advancements involving cybersecurity and big data technologies also assist the development of digital infrastructure within Qatar. Overall, it is discussed with the support of research findings that regulatory alignments are needed within this region along with the technological investments and collaborations for mitigating the challenges as well as leveraging valuable opportunities for the development of SC within Qatar.

6.2.4. Research Question 4: Stakeholders' Views

What are the key stakeholders' views about the proposed roadmap for fostering digital transformation in Qatar?

This question was answered in detail in section 5.3.4, ascertaining stakeholders' support for collaborative frameworks, organisational goals and national DT objectives, centralised digital platform engagement, DT initiatives and SC sustainability, and support for investment and collaboration for implementation. Stakeholders also identified some challenges to collaborative governance, and made some suggestions for a centralised DT platform.

6.3. Theoretical and Practical Contributions

Theoretical Contributions

This paper contributes to the theory in two aspects. It contributes to the understanding of the Gulf urban context by involving stakeholder dynamics and institutional structures that influence SDT pathways through different mechanisms compared to Western models. Second, it suggests a combined SDT model that expressly combines the streams of literature on digital transformation and sustainable smart cities (Trindade et al., 2017) and shifts the cursory discourses to provide a comprehensive scope of future studies.

Practical and Policy Implications

This study is an evidence-based roadmap to Qatari policymakers and planners. It highlights the criticality of fragmented projects and the need to build an integrated, city-as-a-platform model, driven by digital authority that is centralised. Moreover, it emphasizes that the physical infrastructure and human capital should be balanced in terms of investment, in the form of digital literacy initiatives and incentives schemes in place to combat the social sustainability and survivability of its smart cities in the long term.

In terms of theoretical contribution this study develops a mid-level theory of Smart Digital Transformation (SDT) for resource rich, autocratic governments. A large amount of the current Digital Transformation (DT) theories and frameworks have been developed using data from either liberal democratic or market driven systems. However, these systems have limitations in terms of explaining the institutions of rentier states; as the rents generated by natural resources provide the financial base of the government, create the ability for the government to be autonomous in its decision-making process, and create the opportunity for the government to have control over the implementation of policies. Therefore, the integration of the characteristics of rentier state governance into the general DT theory will contribute to an explanation of why there may be different SDT trajectories in such systems.

Furthermore, the proposed mid-level theory will fill the gap that exists between highly abstract DT models and context specific empirical findings by identifying governance mechanisms, institutional constraints, and stakeholder configurations that exist in resource rich economies. This will also add to the body of knowledge regarding DT in resource rich economies by showing how SDT outcomes are influenced by the political economy structure of the system and the governance logic of the system rather than just the capabilities of technology. Additionally, this contextualized theoretical extension will improve the explanatory power and transferability of DT frameworks to urban areas in the Global South and other non-western systems.

Finally, the study presents a Collaborative Framework that can serve as a governance model for coordinating multi-stakeholder involvement in rapidly urbanizing, resource rich economies. The collaborative framework is a template for action for policymakers, urban planners and digital transformation leaders to coordinate government agencies with the private sector and civil society stakeholders through structured collaboration, clearly defined roles, and aligned institutional structures. The collaborative framework is also designed to function within centralized governance systems, recognizing both the benefits of coherence in policy and the availability of resources that are provided by the state. Therefore, the collaborative framework provides support for inclusive and coordinated SDT initiatives that can balance the need for efficiency, innovation and social responsiveness. The practical implications of this study provide scalable solutions to cities that seek to develop smart urban developments in response to rapid economic growth and complex governance systems.

6.4. Chapter Summary

This chapter has presented and discussed the findings of the various data collection methods used to achieve the research objectives (as described in Chapter 3). It has expounded the findings arising from the interviews undertaken with key stakeholders, whereby thematic analysis identified four key themes with related subthemes concerning Qatar’s DT toward SC.

The quantitative survey findings were then presented with appropriate statistical analysis and graphical representations, and issues, prospects, and challenges for DT in Qatar were extrapolated from the findings, followed by stakeholders' perspectives on the feasibility of future progress as per the roadmap. The findings of a systematic literature review on related factors were then presented, and based on the emergent findings from these strands, key factors for development were identified. Consequently, the findings were brought together in a triangulated discussion to directly answer the four research questions. Based on these outcomes, the following chapter concludes this thesis, offering some recommendations for various stakeholders in Qatar's DT and some concluding remarks.

CHAPTER 7
Conclusion

Based on the findings arising from the in-depth interviews, qualitative survey, and systematic review presented in the previous chapter, this concluding chapter offers some recommendations for key stakeholders in Qatar’s DT toward SC, and makes some concluding remarks.

7.1. Recommendations for Stakeholders

7.1.1. Collaboration with Multiple Governments

Establishing and strengthening collaborative governance frameworks is essential for the successful implementation of SC initiatives in Qatar. By fostering partnerships that include public sector agencies, private companies, and civil society organisations, stakeholders can create a more integrated approach to urban development. These collaborations can facilitate the sharing of best practices, resources, and technology, ensuring that the diverse needs of the community are addressed. Additionally, a collaborative governance structure promotes transparency and accountability, as stakeholders work together towards common goals. Regular stakeholder meetings and forums can encourage ongoing dialogue, enabling the continuous assessment of SC projects and their alignment with Qatar's broader sustainability objectives. Ultimately, this approach can lead to more effective decision-making and a greater sense of community ownership over the SC transformation (Go-Globe, 2023; Shuaib, 2023).

7.1.2. Investment in Green Technology and Infrastructure through PPP

Investing in green technologies and sustainable infrastructure is a critical recommendation for stakeholders aiming to enhance Qatar's SC initiatives. As urban areas face increasing challenges related to climate change and resource scarcity, prioritizing energy-efficient solutions can significantly reduce the environmental impact of urban development. Stakeholders should focus on implementing smart grids, energy-efficient buildings, and sustainable transportation systems that utilise renewable energy sources, such as solar and wind power. These investments not only contribute to reducing carbon emissions but also stimulate economic growth by creating jobs in the burgeoning green technology sector. By aligning infrastructure development with sustainability goals, Qatar can position itself as a leader in SC innovation, showcasing its commitment to environmental stewardship while enhancing the QoL for its residents (Niksefat & Taghizade, 2020).

The achievement of sustainable digital transformation (SDT) in Qatar's smart cities requires the establishment of Public-Private Partnerships (PPPs). PPPs serve as essential instruments to unify government resources with private sector capabilities which enable them to fund shortfalls and speed up technology implementation and assist with scale-up initiatives. SDT innovation together with stakeholder-endorsed collaborative frameworks aim to improve infrastructure and build a support system for SDT (Shuaib, 2023).

Qatar should direct its financial resources toward developing infrastructure based on green technology for enhancing sustainability alongside boosting resilience. A centralized digital transformation system backed by strong regulations and community education projects will enhance resource optimization together with accessibility for all stakeholders (Niksefat & Taghizade, 2020).

Through these actions together with PPPs Qatar will bring its smart city projects into harmony with both domestic development plans and worldwide sustainability targets. Collectively, over half of stakeholders (53.33%) considered PPP arrangements to be the most significant or a significant factor in driving successful SC adoption in Qatar, aligning with international findings on SC financing (Nawaz & Koç, 2020). PPP financing can directly facilitate domestic and FDI, and enhance the scope for public sector collaboration (e.g., partnerships with QU and other higher educational institutions) to help expedite technology diffusion and adoption in Qatar's SCs, and among the general public.

7.1.3. Centralised DT System

In order to foster engagement of SCs' sustainable development in Qatar in the future, the government should create a single integrated digital platform for all state services at its core. This platform would help enhance citizens' awareness because all important services would be easily accessible through this platform, and made available in simple and understandable formats. Pertinently, care should be taken to create spaces for persons with disabilities and or different abilities. Introducing simplified digital services helps to make people's interaction with the government's offerings more effective and thus increase their penetration throughout society and improve the delivery of governmental services across the general population (Anthony, 2021).

7.2. Research Limitations

Though this study has undertaken an extremely comprehensive and systematic methodology, there exists numerous limitations that warrant careful consideration. Firstly, the current study uses a cross-sectional method to obtain stakeholders' views, thus providing a snapshot view of present circumstances; however, using this method will not allow the researcher to examine dynamic and long-term processes in relation to sustainable digital transformation (SDT), specifically in a country with rapid digital change.

Secondly, although the sample used for obtaining stakeholders' views includes many knowledgeable individuals such as experts, government representatives, and IT professionals, who work within public and/or private organizations (specifically within the IT sector), the use of such a sample inherently creates biases. Although these knowledgeable individuals provide a strong 'top-down' perspective of strategic objectives, governing bodies and potential barriers to implementing SDT, they do not represent or reflect the views of citizens/residents/end-users. The exclusion of users/public's perspectives limits the researcher’s ability to fully comprehend the level of public acceptance/users experience and potential social implications of implementing digital transformation initiatives. Some examples of important missing dimensions include, but are not limited to digital inequalities/inequities, accessibilities issues, trust in digital systems, and perceived levels of support by various socio-economic/cultural subgroups.

Thirdly, as previously mentioned, the comparative component of this study focuses on Singapore as a best practice example/model of state led digital transformation. While comparisons to Singapore can be very useful/instructive and relevant to the Qatari case study, the comparative component does not adequately address other digital transformation models that focus on different governance paradigm(s). Examples of such models include, but are not limited to city-based models found in some Nordic countries that utilize citizen centred/participatory approaches. These models prioritize citizen involvement/co-creation, community participation, bottom-up innovations etc. By limiting the scope of comparative analysis, the range of applicable findings generated through this study may also be constrained.

Lastly, while the proposed conceptual framework demonstrates little generalizability outside of the Qatari context, there is no reason why aspects of this conceptual framework cannot apply to GCC member-states who have similar rentier-based economies/governance systems/development paths. However, before applying elements of this conceptual framework to any other regional/global contexts, differences in institutional capacities/regulatory frameworks/cultural factors/digital readiness must be empirically validated. Thus, additional comparative/longitudinal studies need to be conducted to validate/refine/adapt the conceptual framework for application in new contexts.

7.3. Avenues for Future Research

In this research, there are a number of fruitful directions toward the future research:

Longitudinal Studies: Following the application of the proposed SDT roadmap in 5-10 years to determine its effect and flexibility.

Citizen-Centric Research: Detailed qualitative research about the perception, acceptance, and concerns of the Qatari citizens and residents of various demographics concerning smart city technologies.

Expanded Comparative Analysis: The application of SDT framework to the comparative study of other GCC countries (e.g., UAE, Saudi Arabia) to determine the regional tendencies and country-specific trajectories.

Deep Dives in Ethics and Governance: Studies targeted the specifics of AI in social services ethics, the creation of effective models of data sovereignty, and the model of democratic digital governance that would meet the needs of the Qatari environment.

7.4. Concluding Remarks

In conclusion, this research endeavours to establish a new framework for an SDT and innovation for the adoption of SC projects in Qatar. It therefore seeks to analyse the progress made toward DT and innovation in similar projects in Qatar, identifying challenges, factors in success and failure, and future opportunities that might be encountered in mediating this innovative and fundamental change, involving diverse stakeholders. To attain the main aim of this research, the research methodology is a fundamental component of the study, as it defines how data will be collected and analysed. This study employed a mixed method methodology, blending various forms of qualitative and quantitative data collection and analysis.

The qualitative approach is characterised by its focus on gathering in-depth and detailed information. In contrast, the quantitative approach relies on collecting facts that can be measured and quantified. The mixed methods approach incorporates qualitative and quantitative data, with researchers selecting appropriate methods based on their specific research objectives. In addition to this, the techniques which include surveys is also employed that provided the understanding into the impact of digital infrastructure. The combination of these methods enables for an overall insight of the issue by reinforcing the numerical trends with in-depth perspectives.

Furthermore, a well-structured data analysis plan is necessary to interpret the collected data effectively which guarantees that conclusions are grounded in empirical evidence. So, for this research, to analyse the data, the analysis method employed is correlation analysis for the quantitative measures with the help of SPSS software and thematic analysis employed to analyse the qualitative data.

By deploying the carefully selected methods (the rationales for which are explained in Chapter 3), this research offers various insights into the DT of SCs in Qatar, and to some extent in general. The findings highlight that IoT technologies are essential to collect the real-time data as various devices which include environmental sensors, traffic cameras and smart meters consistently collects the data on urban parameters which include traffic flow, energy usage and air quality. In addition to this, AI also plays an increasingly important role in evaluating the data gathered with the help of IoT devices to optimise the urban operations and improve the efficiency in SCs.

Furthermore, this research highlighted that DT in the SCs integrate the advanced technologies which include IoT, AI and big data to improve the infrastructure of urban areas, governance and citizen services. This transformation mainly focuses on enhancing the efficiency, sustainability and standard of life by using the various digital tools to determine the challenges which include resource management, transportation and energy consumption.

In addition to this, DT initiatives also encourage the inclusivity that helps in bridging the gap of digital divide by improving the access to digital services and education. But integration of these advanced technology needs addressing the issues like cyber security, data privacy and equitable access to technology. Moreover, it is also found that SCs in practice mainly rely on the PPPs and community engagement to implement the effective data technologies. Like sustainable energy solutions, which include smart grids and renewal energy system contribute to the long-term environmental goals, diverse stakeholder needs and perspectives must be considered when designing and developing SCs, with continuous outcomes evaluation and monitoring to remain strategically dynamic and responsive.

However, implementing DT techniques poses various challenges along with the desired opportunities, including infrastructure costs and resisting to change that must be managed very carefully for the successful implementation of these tools. In addition to this, SCs also encounter various challenges that hinder their development, which include privacy concerns, inadequate regulations, and potential over dependency on the technology. The privacy and security issues which include data breaches, unauthorised access and cyber-attacks remain very important barriers to SC adoption. Even after the advancements in the privacy production tools, their scalability and effectiveness remain limited.

Moreover, regulatory frameworks can either help or hinder the progress of SC, and the absence of coherent overall legislation further delays the adoption of smart technologies along with policy makers that struggles to balance data privacy concerns, economic growth and public trust. In addition to this, the over dependency on the proprietary technology further creates fragmentation and limits the innovation is incompatibilities between the system hinder the seamless functioning of SCs. Finally, the over dependency of SCs on the energy and connectivity makes them very vulnerable to the disruptions which include power outage and cyberattacks that can block the operations. So, to overcome these challenges is very important for the successful development of SCs.

This study underscores that the transformation of Qatar is mainly driven by the strategic vision of the government, which combines modernisation with perceptions of and sensitivity to cultural values and the needs of the population, including both Qatari nationals and expatriates. QNV’30 highly prioritises sustainable development, economic diversification, and improving social welfare, aiming to intrinsically improve QoL in Qatar, and position the country as a regional leader. The economic growth of the country is supported by significant investments in infrastructure and technology, with a focus on creating SCs through innovative technologies like IoT, AI and big data.

The commitment of Qatar toward the DT is primarily displayed in flagship efforts like the TASMU program, which focuses on driving the technological integration across sectors which include healthcare, logistics and transportation. By conducting this study, it is also found that in the recent years, market of Qatar for the SCs is set to grow significantly, which is significantly driven by the substantial investments in sustainable urban infrastructure and digital services. In addition to this, the digital ecosystem of Qatar attains advantages from collaborating with global tech giants, which facilitates the growth of its ICT sector and human resources conducive to comprehensively supporting DT and SC strategies. Moreover, other initiatives of the country which include large-scale international events, such as the Web Summit further contributes towards the technological advancement of this nation.

Based on the diverse findings gained from this research, it can be concluded that Qatar is poised to attain an impressive digital transformation, setting it on par with global leaders in this regard like Singapore. This is possible due to its intrinsic features, including its centralised population, which is analogous to Singapore as a city-state, and sustained, massive public investment in supporting infrastructure such as 5G, which has been largely unhindered by the costs of replacing legacy systems (i.e., developing from something of a *tabula rasa*, Qatar is able to achieve developments that would be costlier in more mature socio-technical contexts, such as in Western Europe). What is needed now is for strategic planners to build on these findings and other recent research by conducting advanced research, including the diverse perspectives of all stakeholders and link top-down public efforts more directly to grassroots readiness among the citizens and inhabitants of Qatar, who can thereby become the residents of digitally transformed smart cities.

Finally, it is also inferred that Qatar has strong potential to carry out sustainable digital transformation while positions itself as a worldwide leader in smart city development. The combination of IoT, AI and big data investment strategies with public-private partnerships and digital centralization will help Qatar resolve all challenges including infrastructure expenses as well as regulatory holes and cyber security threats. The research proves the need for smart city implementations to follow Qatar National Vision 2030 and promote inclusivity with sustained stakeholder participation. Qatar’s central population distribution, together with its substantial funding and technological focus, positions the country to become a sustainable and resilient smart city nation.

References

Abdaoui, A., Ahmad, S. H., Tariq, H., Touati, F., Mnaouer, A. B., & Al-Hitmi, M. (2020). Energy efficient real time outdoor air quality monitoring system. In *2020 International* Wireless Communications and Mobile Computing (IWCMC) (pp. 2170–2176). IEEE. https://doi.org/10.1109/IWCMC48107.2020.9148229

Abdelmoneium, A. O., Al Fara, H., Motawaa, F., Al Sultan, A., Al-Harahsheh, S., & Baghdady, A. (2023). Parental perspectives on adolescents' excessive use of technology in Qatar: Challenges and coping strategies. *Doha International Family Institute Journal*, *2023*(2), Article 9. https://doi.org/10.5339/difi.2023.9

Abdulkareem, H. S., & Basee, D. H. (2023). Towards smart sustainable Iraqi cities: Problems and potentials. *ISVS e-journal*, *10*(4), 102–118. https://isvshome.com/pdf/ISVS_10-4/ISVSej_10.4.7.pdf

Abulhussain, F. M. (2021). *A study on evaluating the readiness level for Qatar companies to adopt Industy 4.0* [Master's thesis, Qatar University]. Qatar University QSpace Institutional Repository. http://hdl.handle.net/10576/21577

Achmad, K. A., Nugroho, L. E., & Djunaedi, A. (2018). Smart city model: A literature review. In *2018 10th International Conference on Information Technology and Electrical Engineering (ICITEE)* (pp. 488–493). IEEE. https://doi.org/10.1109/ICITEED.2018.8534865

Adalbi, M., Ferwati, M., Ahmad, A., & Lee, Y. (2022). Smart cities strategies in developing countries: The case of Lusail City, Qatar. In T. Ahram, W. Karwowski, P. Di Bucchianico, R. Taiar, L. Casarotto, & P. Costa (eds.), *Intelligent Human Systems Integration (IHSI 2022): Integrating People and Intelligent Systems* (Vol. 22). AHFE International. http://doi.org/10.54941/ahfe1001015

Al Khoury, I., Ghanimeh, S., Jawad, D., & Atieh, M. (2023). Synergetic water demand and sustainable supply strategies in GCC countries: Data-driven recommendations. *Water Resources Management*, *37*(5), 1947–1963. https://link.springer.com/article/10.1007/s11269-023-03464-6

Albino, V., Berardi, U., & Dangelico, R. M. (2015). Smart cities: Definitions, dimensions, performance, and initiatives. Journal of urban technology, 22(1), 3-21. https://www.academia.edu/download/36544466/smart_city.pdf

Al Sharif, R., & Pokharel, S. (2022). Smart city perspectives in the context of Qatar. In J. M. Corchado & S. Trabelsi (Eds.), *Sustainable smart cities and territories* (pp. 103–113). Springer International Publishing. http://dx.doi.org/10.1007/978-3-030-78901-5_10

Al Thani, D., Hassan, A., Chalghoumi, H., Othman, A., & Hammad, S. (2021). Addressing the digital gap for the older persons and their caregivers in the State of Qatar: A stakeholders' perspective. In *2021 8th International Conference on ICT & Accessibility (ICTA)* (pp. 01–06). IEEE. https://doi.org/10.1109/ICTA54582.2021.9809430

Al-Abdulghani, Y. (2021). *Exploring digital resilience in Qatar: A socio-technical perspective* [Senior honors thesis, Carnegie Mellon University]. https://doi.org/10.1184/R1/16725265.v1

AlAli, D., Manivannan, N., & Xu, Y. (2023). A framework for effective design thinking based smart cities projects in Qatar. *Smart Cities, 6*(1), 531–562. https://doi.org/10.3390/smartcities6010025

AL-Dosari, K., Fetais, N., & Kucukvar, M. (2023, February 1). A shift to green cybersecurity sustainability development: Using triple bottom-line sustainability assessment in Qatar transportation sector. *International Journal of Sustainable Transportation*, *17*(12), 1287–1301. https://doi.org/10.1080/15568318.2023.2171321

Allahar, H. (2020). What are the challenges of building a smart city?. *Technology Innovation Management Review*, *10*(9), 38–48. http://dx.doi.org/10.22215/timreview/1388

Allam, Z., Sharifi, A., Bibri, S. E., Jones, D. S., & Krogstie, J. (2022). The Metaverse as a virtual form of smart cities: Opportunities and challenges for environmental, economic, and social sustainability in urban futures. *Smart Cities*, *5*(3), 771–801. http://dx.doi.org/10.3390/smartcities5030040

Allemang, B., Sitter, K., & Dimitropoulos, G. (2022). Pragmatism as a paradigm for patient-oriented research. *Health Expectations*, *25*(1), 38–47. https://doi.org/10.1111/hex.13384

Allen, T. F. H., & Hoekstra, T. W. (2015). *Toward a unified ecology*. Columbia University Press.

Almalki, S. (2016). *Int*egrating quantitative and qualitative data in mixed methods research: Challenges and benefits. *Journal of Education and Learning*, *5*(3), 288–296. http://dx.doi.org/10.5539/jel.v5n3p288

Almarri, K., & Boussabaine, H. (2023). Critical success factors for public–private partnerships in smart city infrastructure projects. *Construction Innovation*. Advance online publication. https://doi.org/10.1108/CI-04-2022-0072

Al-Mulla, A., Ari, I., & Koç, M. (2022). Sustainable financing for entrepreneurs: Case study in designing a crowdfunding platform tailored for Qatar. *Digital Business*, *2*(2), Article 100032. https://doi.org/10.1016/j.digbus.2022.100032

Al-Qahtani, A. S. S. A., & Shirazi, N. S. (2023). What are the binding constraints for a knowledge-based economy in Qatar?. *Sustainability*, *15*(5), Article 3871. https://doi.org/10.3390/su15053871

AlQaoud, F., Carruthers, A., Kamala, M., & Abd-Alhameed, R. (2022). Implementations of Smart Cities in USA, Europe, and the Far East Countries. In *IMDC-IST 2021: Proceedings of 2nd International Multi-Disciplinary Conference Theme: Integrated Sciences and Technologies, IMDC-IST 2021* (pp. 1–12). EAI. http://dx.doi.org/10.4108/eai.7-9-2021.2315364

Al-Quradaghi, B. A. (2023). Islamic and conventional banks in Qatar: Can technology bridge the gap there?. *Journal of Namibian Studies*, *33*, 290–300. https://doi.org/10.59670/jns.v33i.1651

Alrawi, O. F., Al-Siddiqi, T., Al-Muhannadi, A., Al-Siddiqi, A., & Al-Ghamdi, S. G. (2022). Determining the influencing factors in the residential rooftop solar photovoltaic systems adoption: Evidence from a survey in Qatar. *Energy Reports*, *8*, 257–262. https://doi.org/10.1016/j.egyr.2022.01.064

Al-Thani, S. K., Skelhorn, C. P., Amato, A., Koc, M., & Al-Ghamdi, S. G. (2018). Smart technology impact on neighborhood form for a sustainable Doha. *Sustainability*, *10*(12), Article 4764. https://doi.org/10.3390/su10124764

Al-Thani, S. M., & Furlan, R. (2020). An integrated design strategy for the urban regeneration of West Bay, Business District of Doha (State of Qatar). *Designs*, *4*(4), Article 55. https://doi.org/10.3390/designs4040055

Ang, K. L. M., Seng, J. K. P., Ngharamike, E., & Ijemaru, G. K. (2022). Emerging technologies for smart cities' transportation: Geo-information, data analytics and machine learning approaches. *ISPRS International Journal of Geo-Information*, *11*(2), Article 85. https://dx.doi.org/10.3390/ijgi11020085

Angelidou, M. (2014). Smart city policies: A spatial approach. *Cities*, *41*(1), S3-S11. https://doi.org/10.1016/j.cities.2014.06.007

Angelidou, M. (2016). Four European smart city strategies. *International Journal of Social Science Studies*, *4*(4), 18–30. http://dx.doi.org/10.11114/ijsss.v4i4.1364

Anthony, B. Jr. (2021). Managing digital transformation of smart cities through enterprise architecture: A review and research agenda. *Enterprise Information Systems*, *15*(3), 299–331. http://dx.doi.org/10.1080/17517575.2020.1812006

Anthony, J. D., & Crystal, J. A. (2024). *History of Qatar*. https://www.britannica.com/topic/history-of-Eswatini

Anttila, J., & Jussila, K. (2018). Universities and smart cities: The challenges to high quality. *Total Quality Management and Business Excellence*, *29*(9-10), 1058–1073. http://dx.doi.org/10.1080/14783363.2018.1486552

Asenahabi, B. M. (2019). Basics of research design: A guide to selecting appropriate research design. *International Journal of Contemporary Applied Researches*, *6*(5), 76–89.

Asmyatullin, R. R., Tyrkba, K. V., & Ruzina, E. I. (2020). Smart cities in GCC: Comparative study of economic dimension. In *IOP conference series: Earth and environmental science,* 459(6), Article 062045. http://dx.doi.org/10.1088/1755-1315/459/6/062045

Azhgaliyeva, D., Kapoor, A., & Liu, Y. (2020). Green bonds for financing renewable energy and energy efficiency in South-East Asia: A review of policies. *Journal of Sustainable Finance & Investment*, *10*(2), 113–140. https://doi.org/10.1080/20430795.2019.1704160

Badran, A. (2023). Developing smart cities: Regulatory and policy implications for the State of Qatar. *International Journal of Public Administration*, *46*(7), 519–532. https://doi.org/10.1080/01900692.2021.2003811

Beauchemin, É., Côté, L. P., Drolet, M. J., & Williams-Jones, B. (2022). Conceptualising ethical issues in the conduct of research: Results from a critical and systematic literature review. *Journal of Academic Ethics*, *20*(3), 335–358. https://doi.org/10.1007/s10805-021-09411-7

Bell, B., Bryman, A., & Harley, B. (2022). *Business research methods*. Oxford University Press.

Ben Hassen, T. (2020). The entrepreneurship ecosystem in the ICT sector in Qatar: Local advantages and constraints. *Journal of Small Business and Enterprise Development*, *27*(2), 177–195. https://doi.org/10.1108/JSBED-04-2019-0119

Ben Hassen, T. (2022). A transformative state in the wake of COVID-19: What is needed to enable innovation, entrepreneurship, and education in Qatar?. *Sustainability*, *14*(13), Article 7953. https://doi.org/10.3390/su14137953

Berry, M. (2018). Technology and organised crime in the smart city: An ethnographic study of the illicit drug trade. *City, Territory and Architecture*, *5*, Article 16. https://doi.org/10.1186/s40410-018-0091-7

Bhattacharya, T. R., Bhattacharya, A., Mclellan, B., & Tezuka, T. (2020). Sustainable smart city development framework for developing countries. *Urban Research & Practice, 13*(2), 180–212.

Bin, T. S., & Low, D. (2019). Re-examining Singapore's urban planning and governance framework. In S. Hamnett & B. Yuen (Eds.), *Planning Singapore: The experimental city* (pp. 37–62). Routledge. http://dx.doi.org/10.4324/9781351058230-2

Bokhari, S. A. A., & Myeong, S. (2022). Use of artificial intelligence in smart cities for smart decision-making: A social innovation perspective. *Sustainability*, *14*(2), Article 620. https://doi.org/10.3390/su14020620

Bokolo, A. J., & Petersen, S. A. (2019). A smart city adoption model to improve sustainable living. *Norwegian University of Science and Technology*, 1–16. https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2631501/Version+4.pdf?sequence=2

Bracken, M., & Greenway, A. (2018). *How to achieve and sustain government digital transformation*. IDB. https://publications.iadb.org/publications/english/document/How-to-Achieve-and-Sustain-Government-Digital-Transformation.pdf

Braun, V., & Clarke, V. (2021). *Thematic analysis: A practical guide*. SAGE Publications.

Burlacu, M., Boboc, R. G., & Butilă, E. V. (2022). Smart cities and transportation: Reviewing the scientific character of the theories. *Sustainability*, *14*(13), Article 8109. https://doi.org/10.3390/su14138109

Butschan, J., Heidenreich, S., Weber, B., & Kraemer, T. (2019). Tackling hurdles to digital transformation: The role of competencies for successful industrial Internet of things (IIoT) implementation. *International Journal of Innovation Management*, *23*(4), Article 1950036. https://doi.org/10.1142/S1363919619500361

Carlsson, C. (2014). *A review of Adam Greenfield's "Against the smart city"*. Shareable. https://www.shareable.net/a-review-of-adam-greenfields-against-the-smart-city/

Chatterjee, S., Kar, A. K., Dwivedi, Y. K., & Kizgin, H. (2018). Prevention of cybercrimes in smart cities of India: From a citizen's perspective. *Information Technology and People*, *32*(5), 1153–1183. https://doi.org/10.1108/ITP-05-2018-0251

Chevtchenko, S. F., Rocha, E. D. S., Dos Santos, M. C. M., Mota, R. L., Vieira, D. M., De Andrade, E. C., & De Araújo, D. R. B. (2023). Anomaly detection in industrial machinery using IoT devices and machine learning: A systematic mapping. *IEEE Access*, *11*, 128288–128305. https://doi.org/10.1109/ACCESS.2023.3333242

Chung, S. H. (2021). Applications of smart technologies in logistics and transport: A review. *Transportation Research Part E: Logistics and Transportation Review*, *153*(2), Article 102455. http://dx.doi.org/10.1016/j.tre.2021.102455

Civil Service and Government Development Bureau. (2023). Qatar Government Excellence Program. https://cgb.gov.qa/en/AboutUs/Initiatives/Pages/details.aspx?itemID=23

Colding, J., Nilsson, C., & Sjöberg, S. (2024). Smart cities for all? Bridging digital divides for socially sustainable and inclusive cities. *Smart Cities*, *7*(3), 1044–1059. https://doi.org/10.3390/smartcities7030044

Communications Regulatory Authority. (2019). CRA issues a public consultation on the proposed Class License for Wireless Home Area Networks WHAN. https://www.cra.gov.qa/document/cra-issues-a-public-consultation-on-the-proposed-class-license-for-wireless-home-area-networks-whan

Communications Regulatory Authority. (2022). *Cloud policy framework*. https://www.cra.gov.qa/en/document/cloud-policy-framework

Communications Regulatory Authority. (2024). *About CRA*. https://www.cra.gov.qa/en/about-us

Compliance and Data Protection Department. (2016). *Law No. 13 of 2016 Personal Data Privacy Protection*. https://assurance.ncsa.gov.qa/sites/default/files/library/2020-11/Law%20No.%20%2813%29%20of%202016%20%20on%20Protecting%20Personal%20Data%20Privacy%20-%20English.pdf

Contestabile, M. (2022). A systems perspective on the sustainable development of Qatar. In L. Cochrane & R. Al-Hababi (Eds.), *Sustainable Qatar: Social, Political and Environmental Perspectives* (pp. 127–145). Springer Nature Singapore. https://doi.org/10.1007/978-981-19-7398-7

Conventz, S., Thierstein, A., Wiedmann, F., & Salama, A. M. (2015). When the Oryx takes off: Doha a new rising knowledge hub in the Gulf region?. *International Journal of Knowledge-Based Development*, *6*(1), 65–82.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. SAGE Publications.

Creswell, J. W., & Clark, V. P. (2011). *Mixed methods research*. SAGE Publications.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative and mixed methods approaches* (5th ed.). SAGE Publications.

Cui, L., Xie, G., Qu, Y., Gao, L., & Yang, Y. (2018). Security and privacy in smart cities: Challenges and opportunities. *IEEE Access*, *6*, 46134–46145. http://dx.doi.org/10.1109/ACCESS.2018.2853985

Damaševičius, R., Bacanin, N., & Misra, S. (2023). From sensors to safety: Internet of Emergency Services (IoES) for emergency response and disaster management. *Journal of Sensor and Actuator Networks*, *12*, Article 41. http://dx.doi.org/10.3390/jsan12030041

Dano, U. L., & Alqahtani, A. M. (2019). Issues undermining public transport utilization in Dammam City, Saudi Arabia: An expert-based analysis. *Journal of Sustainability Science and Management*, *14*(2), 157–171.

Das, D. K. (2024). Exploring the symbiotic relationship between digital transformation, infrastructure, service delivery, and governance for smart sustainable cities. *Smart Cities*, *7*(2), 806–835. http://dx.doi.org/10.3390/smartcities7020034

Deloitte. (n. d.). *TASMU Smart City Program*. https://www2.deloitte.com/content/dam/Deloitte/xe/Documents/deloitteprivate/TASMU-Smart-City-Program.pdf

Dengler, K., & Britta, M. (2018). The impacts of digital transformation on the labour market: Substitution potentials of occupations in Germany. *Technological Forecasting & Social Change*, *137*, 304–316. https://doi.org/10.1016/j.techfore.2018.09.024

Digital Agenda 2030. (2024). *Digital Agenda 2030*. Ministry of Communications and Information Technology. https://www.mcit.gov.qa/sites/default/files/digital_agenda_2030_report_design_eng.pdf

Edmonds, W. A., & Kennedy, T. D. (2016). *An applied guide to research designs: Quantitative, qualitative, and mixed methods*. SAGE Publications.

Edwards, L. (2016). *Privacy, security and data protection in smart cities: A critical EU law perspective* (CREATe working paper 2015/11). Zenodo. http://dx.doi.org/10.5281/zenodo.34501

Elidrisy, A. (2024). Leveraging cloud services & digital transformation for sustainability: Insights from cases of Qatar. *Journal of Innovative Research*, *2*(1), 20–28. https://doi.org/10.54536/jir.v2i1.2398

Elm, J., & Carvalho, L. C. (2020). Best practices to become a sustainable smart city: The case of Singapore. In *Conceptual and Theoretical Approaches to Corporate Social Responsibility, Entrepreneurial Orientation, and Financial Performance* (pp. 247–265). IGI Global. http://dx.doi.org/10.4018/978-1-7998-2128-1.ch013

Engin, Z., van Dijk, J., Lan, T., Longley, P. A., Treleaven, P., Batty, M., & Penn, A. (2020). Data-driven urban management: Mapping the landscape. *Journal of Urban Management*, *9*(2), 140–150. https://doi.org/10.1016/j.jum.2019.12.001

Esmaeili, M., Bahrini, A., & Shayanrad, S. (2015). Using game theory approach to interpret stable policies for Iran's oil and gas common resources conflicts with Iraq and Qatar. *Journal of Industrial Engineering International*, *11*, 543–554. http://dx.doi.org/10.1007/s40092-015-0120-z

Etikan, I., Alkassim, R., & Abubakar, S. (2016). Comparision of snowball sampling and sequential sampling technique. *American Journal of Theoretical and Applied Statistics*, *5*(1), 1–4. http://dx.doi.org/10.11648/j.ajtas.20160501.11

Exito. (2024). *Digital Transformation Summit*. https://digitransformationsummit.com/qatar/

Farag, M. M., & Bansal, R. C. (2023). Solar energy development in the GCC region–a review on recent progress and opportunities. *International Journal of Modelling and Simulation*, *43*(5), 579–599. https://doi.org/10.1080/02286203.2022.2105785

Ferro-Escobar, R., Vacca-González, H., & Gómez-Castillo, H. (2022). Smart and sustainable cities in collaboration with IoT: The Singapore success case. In G. Marques, A. González-Briones, & J. M. Molina López (Eds.), *Machine learning for smart environments/cities* (pp. 213–243). Springer. https://doi.org/10.1007/978-3-030-97516-6_12

Firmansyah, B., & Bansal, R. (2024). Standardization and regulatory challenges in modern cryptography. In B. Gupta (Ed.), *Metaverse security paradigms* (pp. 145–183). IGI Global. http://dx.doi.org/10.4018/979-8-3693-3824-7.ch006

Fontes, C., Hohma, E., Corrigan, C.C., & Lütge, C. (2022). AI-powered public surveillance systems: Why we (might) need them and how we want them. *SSRN*, Article 4112042. http://dx.doi.org/10.2139/ssrn.4112042

Foundation for Public Code. (2019). *Business Process Modeling Notation diagram of the audit process on changes in a codebase under stewardship at the Foundation for Public Code (image extracted from the Standard for Public Code, release 0.1.2)*. https://commons.wikimedia.org/wiki/Category:Business_Process_Modeling_Notation_English_diagrams#/media/File:Audit-flow.svg

Fujita, H., & Selamat, A. (Eds.). (2019). *Advancing technology industrialization through intelligent software methodologies, tools and techniques: Proceedings of the 18th International Conference on New Trends in Intelligent Software Methodologies, Tools and Techniques (SoMeT_19)*. Frontiers in Artificial Intelligence and Applications (Vol. 318). IOS Press.

Gimpel, H., Graf-Drasch, V., Kammerer, A., Keller, M., & Zheng, X. (2020). When does it pay off to integrate sustainability in the business model? – A game-theoretic analysis. *Electronic Markets*, *30*(4), 699–716. https://doi.org/10.1007/s12525-019-00361-y

Goerzig, D., & Bauernhansl, T. (2018). Enterprise architectures for the digital transformation in small and medium-sized enterprises. *Procedia CIRP*, *67*, 540–545. https://doi.org/10.1016/j.procir.2017.12.257

Go-Globe. (2023). *Shaping technology and web development innovation in Qatar*. https://www.go-globe.com/technology-and-web-development-innovation-qatar/#:~:text=Qatar%20is%20investing%20heavily%20in,efficiency%2C%20and%20create%20sustainable%20environments.

Government Communications Office. (2024). *Qatar National Vision 2030*. https://www.gco.gov.qa/en/about-qatar/national-vision2030/

Gradcoach. (2024). *Saunders' research onion: A plain-language explainer, with examples*. https://gradcoach.com/saunders-research-onion/

Guandalini, I. (2022). Sustainability through digital transformation: A systematic literature review for research guidance. *Journal of Business Research*, *148*, 456–471. http://dx.doi.org/10.1016/j.jbusres.2022.05.003

Gupta, S. (2017). Ethical issues in designing Internet-based research: Recommendations for good practice. *Journal of Research Practice*, *13*(2), Article D1.

Hadjitchoneva, J. (2020). Digital transformation, sustainability and smart city: A challenge for Sofia City?. *The Impacts of Digital Transformation*. http://dx.doi.org/10.13140/RG.2.2.21534.36165

Hamad Medical Corporation. (2024a). *MyHealth*. https://hamad.qa/en/patient-information/patient-portal/pages/default.aspx?

Hamad Medical Corporation. (2024b). *Qatar Robotic Surgery Center at QSTP*. https://www.hamad.qa/EN/Education-and-research/Medical-Education/CPD/Affiliation%20with%20Academic%20Institutions/Pages/Qatar-Robotic-Surgery-Center-at-QSTP.aspx

Hoe, S. L. (2018). Building a smart nation: Singapore's digital journey. *Asian Research Policy*, *9*(1), 86–95.

Houichi, M., Jaidi, F., & Bouhoula, A. (2024). Cyber security within smart cities: A comprehensive study and a novel intrusion detection-based approach. *Computers, Materials & Continua*, *81*(1), 393–441. http://dx.doi.org/10.32604/cmc.2024.054007

Hounwanou, H., Boumlik, L., & Mejri, M. (2021). Toward the formalization of business process model and notation. In H. Fujita & H. Perez-Meana (Eds.), *Frontiers in artificial intelligence and applications volume 337: New trends in intelligent software methodologies, tools and techniques* (pp. 248–264). IOS Press. http://dx.doi.org/10.3233/FAIA210024

Huang, R., Zhuang, R., & Yang, J. (2017). Promoting citizen's learning experience in smart cities. In S. K. S. Cheung, L. F. Kwok, W. W. K. Ma, L.-K. Lee, & H. Yang (Eds.), *Blended learning: New challenges and innovative practices* (pp. 15–25). Springer. https://doi.org/10.1007/978-3-319-59360-9_2

Huseien, G. F., & Shah, K. W. (2022). A review on 5G technology for smart energy management and smart buildings in Singapore. *Energy and AI*, *7*, Article 100116. https://doi.org/10.1016/j.egyai.2021.100116

Hussain, A., Iqbal, M., Khan, J. A., Khan, M., & Arafat, Q. Y. (2022). Digital transformation, innovation and sustainable growth. *Competitive Social Science Research Journal*, *3*(2), 403–414.

Ibrahim, I. A., & Truby, J. (2022). Governance in the era of blockchain technology in Qatar: A roadmap and a manual for trade finance. *Journal of Banking Regulation*, *23*(4), 419–438. https://doi.org/10.1057/s41261-021-00165-1

Ibrahim, M., Adams, C., & El-Zaart, A. (2015). Paving the way to smart sustainable cities: Transformation models and challenges. *Journal of Information Systems and Technology Management*, *12*(3), 559–576. http://dx.doi.org/10.4301/S180717752015000300004

Idhalama, O. U., & Oredo, J. O. (2024). Exploring the next generation Internet of Things (IoT) requirements and applications: A comprehensive overview. *Information Development*. http://dx.doi.org/10.1177/02666669241267852

Ismagilova, E., Hughes, L., Rana, N. P., & Dwivedi, Y. K. (2022). Security, privacy and risks within smart cities: Literature review and development of a smart city interaction framework. *Information Systems Frontiers*, *24*(2), 393–414. https://doi.org/10.1007/s10796-020-10044-1

ITS International. (2012). *Qatar to get Intelligent Transport System in time for 2022 World Cup*. https://www.itsinternational.com/its4/its8/news/qatar-get-intelligent-transport-system-time-2022-world-cup

Jagatheesaperumal, S. K., Bibri, S. E., Huang, J., Rajapandian, J., & Parthiban, B. (2024). Artificial intelligence of things for smart cities: Advanced solutions for enhancing transportation safety. *Computational Urban Science*, *4*, Article 10. http://dx.doi.org/10.1007/s43762-024-00120-6

Jozsef, P. (2022). How safe is your smart city?. *Interdisciplinary Description of Complex Systems*, *20*(1), 57–63. http://dx.doi.org/10.7906/indecs.20.1.8

Kalusivalingam, A. K., Sharma, A., Patel, N., & Singh, V. (2021). Enhancing smart city development with AI: Leveraging machine learning algorithms and IoT-driven data analytics. *International Journal of AI and ML*, *2*(3).

Kamin, S. T., Lang, F. R., & Beyer, A. (2017). Subjective technology adaptivity predicts technology use in old age. *Gerontology*, *63*(4), 385–392. https://doi.org/10.1159/000471802

Kar, A. K., Ilavarasan, V., Gupta, M. P., Janssen, M., & Kothari, R. (2019). Moving beyond smart cities: Digital nations for social innovation and sustainability. *Information Systems Frontiers*, *21*(3), 495–501. https://doi.org/10.1007/s10796-019-09930-0

Karkouti, I. M. (2023). Integrating technology in Qatar's higher education settings: What helps faculty accomplish the job. *Technology, Knowledge and Learning*, *28*(1), 279–305. https://doi.org/10.1007/s10758-021-09553-y

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. *Social Sciences*, *8*(9), Article 255. http://dx.doi.org/10.3390/socsci8090255

Kelly, L. M., & Cordeiro, M. (2020). Three principles of pragmatism for research on organizational processes. *Methodological Innovations*, *13*(2), 1–14. https://doi.org/10.1177/2059799120937242

Keshvardoost, S., Renukappa, S., Suresh, S., & Al-Janabi, R. (2019). *Issues and challenges of smart cities governance: A systematic review*. University of Wolverhampton. https://wlv.openrepository.com/bitstream/handle/2436/622263/Keshvardoost_et_al_Issues_and_challenges_of_smart_cities_2019.pdf

Kim, S. (2015). *Int*erdisciplinary approaches and methods for sustainable transformation and innovation, *Sustainability*, *7*(4), 3977–3983. https://doi.org/10.3390/su7043977

Kitchenham, B., & Brereton, P. (2013). A systematic review of systematic review process research in software engineering. *Information and Software Technology*, *55*(12), 2049–2075. https://doi.org/10.1016/j.infsof.2013.07.010

Klewes, J., Popp, D., & Rost-Hein, M. (2017). Managing the digital transformation: Ten guidelines for communications professionals. In J. Klewes, D. Popp, & M. Rost-Hein (Eds.), *Out-thinking organizational communications* (pp. 187–195). Springer. https://doi.org/10.1007/978-3-319-41845-2_14

Korachi, Z., & Bounabat, B. (2019). Integrated methodological framework for smart city development. In P. Kommers & G. C. Peng (Eds.), *Proceedings of the 16th International Conference on e-Society* (pp. 246–256). IADIS. https://doi.org/10.33965/csc2019_201908L030

Korachi, Z., & Bounabat, B. (2022). Towards a smart city approach: A comparative study. In M. Ben Ahmed, H. N. L. Teodorescu, T. Mazri, P. Subashini, & A. A. Boudhir (Eds.), *Networking, intelligent systems and security: Proceedings of NISS 2021* (pp. 619–633). Springer. https://doi.org/10.1007/978-981-16-3637-0_44

Korada, L. (2021). Unlocking urban futures: The role of big data analytics and AI in urban planning–A systematic literature review and bibliometric insight. *Migration Letters*, *18*(6), 775–795.

Korneć, R., & Wereda, W. (2018). Urban transport as an important element of "The smart city". *ZeszytyNaukowe. OrganizacjaiZarządzanie/Politechnika Śląska*, *128*, 205–215. http://dx.doi.org/10.29119/1641-3466.2018.128.17

KPMG. (2020). *Smart cities*. https://assets.kpmg.com/content/dam/kpmg/jp/pdf/2020/jp-en-smart-cities.pdf

Kumar, H., Singh, M. K., Gupta, M. P., & Madaan, J. (2018). Moving towards smart cities: Solutions that lead to the smart city transformation framework. *Technological Forecasting and Social Change*, *153*, Article 119281. https://doi.org/10.1016/j.techfore.2018.04.024

Lam, P. T., & Yang, W. (2017). A study of the costs and benefits of smart city projects including the scenario of public-private partnerships. *International Journal of Urban and Civil Engineering*, *11*(5), 600–605. http://dx.doi.org/10.5281/zenodo.1130339

Land Transport Authority. (2023). *Smart mobility 2030*. https://www.lta.gov.sg/content/dam/ltagov/getting_around/driving_in_singapore/intelligent_transport_systems/pdf/smartmobility2030.pdf

Lazaroiu, G., Androniceanu, A., Grecu, I., Grecu, G., & Neguriță, O. (2022). Artificial intelligence-based decision-making algorithms, Internet of Things sensing networks, and sustainable cyber-physical management systems in big data-driven cognitive manufacturing. *Oeconomia Copernicana*, *13*(4), 1047–1080. http://dx.doi.org/10.24136/oc.2022.030

Lebrusán, I., & Toutouh, J. (2020). Using smart city tools to evaluate the effectiveness of a low emissions zone in Spain: Madrid Central. *Smart Cities*, *3*(2), 456–478. https://doi.org/10.3390/smartcities3020025

Lee, J. H., Hancock, M. G., & Hu, M. C. (2014). Towards an effective framework for building smart cities: Lessons from Seoul and San Francisco. *Technological Forecasting and Social Change*, *89*, 80–99. https://doi.org/10.1016/j.techfore.2013.08.033

Lee, O. L., Im Tay, R., Too, S. T., & Gorod, A. (2019, May). A smart city transportation system of systems governance framework: A case study of Singapore. In *2019 14th Annual Conference System of Systems Engineering (SoSE)* (pp. 37–42). IEEE. https://doi.org/10.1109/SYSOSE.2019.8753829

Lehtonen, M. (2004). The environmental–social interface of sustainable development: Capabilities, social capital, institutions. *Ecological Economics*, *49*(2), 199–214. https://doi.org/10.1016/j.ecolecon.2004.03.019

Li, Q., Jiang, Z., & Yuan, F. (2022). Monitoring and visualization application of smart city energy economic management based on IoT sensors. *Neural Computing and Applications*, *34*, 6695–6704. https://doi.org/10.1007/s00521-021-06108-1

Liang, C., & Shah, T. (2023). IoT in agriculture: The future of precision monitoring and data-driven farming. *Eigenpub Review of Science and Technology*, 7(1), 85–104.

Lilhore, U. K., Imoize, A. L., Li, C. T., Simaiya, S., Pani, S. K., Goyal, N., Kumar, A., & Lee, C. C. (2022). Design and implementation of an ML and IoT based adaptive traffic-management system for smart cities. *Sensors*, *22*(8), Article 2908. http://dx.doi.org/10.3390/s22082908

Liu, L. (2016). Using generic inductive approach in qualitative educational research: A case study analysis. *Journal of Education and Learning, 5*(2), 129–135. http://dx.doi.org/10.5539/jel.v5n2p129

Liu, Y., Li, Q., & Zhang, Z. (2022). Do smart cities restrict the carbon emission intensity of enterprises? Evidence from a quasi-natural experiment in China. *Energies*, *15*(15), Article 5527. https://doi.org/10.3390/en15155527

Löfgren, K., & Webster, C. W. R. (2020). The value of Big Data in government: The case of “smart cities”. *Big Data and Society*, *7*(1). https://doi.org/10.1177/2053951720912775

Ma, C. (2021). Smart city and cyber-security; technologies used, leading challenges and future recommendations. *Energy Reports*, *7*, 7999–8012. https://doi.org/10.1016/j.egyr.2021.08.124

Malkawi, A. R. (2022). Science education in the state of Qatar. In R. Huang, B. Xin, A. Tlili, F. Yang, X. Zhang, L. Zhu, & M. Jemni (Eds.), *Science education in countries along the Belt & Road: Future insights and new requirements* (pp. 151–167). Springer. https://doi.org/10.1007/978-981-16-6955-2_10

Medina, V. J. (2023). Unmasking the young adults’ library responses during the COVID-19 pandemic: A case from Qatar. *Public Library Quarterly*, *42*(2), 155–167. https://doi.org/10.1080/01616846.2022.2046411

Medium. (2024). Qatar smart cities: Market analysis, trends, growth, research and forecast 2030. https://medium.com/@shashikant.m023/qatar-smart-cities-market-analysis-trends-growth-research-and-forecast-2030-6a44f58d3af7

Meduri, K., Nadella, G. S., Gonaygunta, H., & Meduri, S. S. (2023). Developing a fog computing-based AI framework for real-time traffic management and optimization. *International Journal of Sustainable Development in Computing Science*, *5*(4), 1–24.

Mei, H., Poslad, S., & Du, S. (2017). A game-theory based incentive framework for an intelligent traffic system as part of a smart city initiative. *Sensors*, *17*(12), Article 2874. https://doi.org/10.3390/s17122874

Meijer, A., & Thaens, M. (2021). Path dependency of smart cities: How technological and social legacies condition smart city development. In E. Estevez, T. A. Pardo, & H. J. Scholl (Eds.), *Smart cities and smart governance: Towards the 22nd century sustainable city* (pp. 31–42). Springer. https://doi.org/10.1007/978-3-030-61033-3_2

Meyerhoff Nielsen, M., & Mahmoud Ali, W. K. (2021). Governing and monitoring the digital transformation: Assessing the Qatari experience since 2003. In *14th International Conference on Theory and Practice of Electronic Governance (ICEGOV 2021)* (pp. 246–253). ACM. http://dx.doi.org/10.1145/3494193.3494227

Meyers, L. S., Gamst, G. C., & Guarino, A. J. (2013). *Performing data analysis using IBM SPSS*. Wiley.

Ministry of Communications and Information Technology. (2014a). *ICT Ministry, Royal Mail sign MoU for Q-Post modernization*. https://www.mcit.gov.qa/en/news-events/news/ict-ministry-royal-mail-sign-mou-q-post-modernization

Ministry of Communications and Information Technology. (2014b). *Telecommunications consumer protection policy*. https://www.cra.gov.qa/en/Law-and-Regulations/Policies-and-Strategy/Consumer-Protection-Policy

Ministry of Communications and Information Technology. (2020). *Executive summary: Qatar e-Government 2020 Strategy*. https://mcit.gov.qa/sites/default/files/qatar-e-government-2020-strategy-en_0.pdf

Ministry of Communications and Information Technology. (2022). *Connected tournament*. https://www.mcit.gov.qa/sites/default/files/fifa_world_cup_qatar_2022tm_-_mcit_connected_tournament_-_a_digital_legacy_english-1.pdf

Ministry of Communications and Information Technology. (2023). *QDG NextGen Strategy: Publication document*. https://services.hukoomi.gov.qa/assets/documents/digitalprojects/QDG%20NextGen%20Strategy.pdf

Ministry of Communications and Information Technology. (2024a). *Strategy & plans*. https://www.mcit.gov.qa/en/qatar-digital-government/strategy-plans

Ministry of Communications and Information Technology. (2024a). *The Artificial Intelligence Committee*. https://www.mcit.gov.qa/en/about-us/artificial-intelligence-committee

Mogielnicki, R. (2021). *A political economy of free zones in Gulf Arab states*. Springer.

Mohamed, B. H., Disli, M., Al-Sada, M. B. S., & Koç, M. (2022). Investigation on human development needs, challenges, and drivers for transition to sustainable development: The case of Qatar. *Sustainability*, *14*(6), Article 3705. https://doi.org/10.3390/su14063705

Monzon, A. (2015). Smart cities concept and challenges: Bases for the assessment of smart city projects. In *2015 international conference on smart cities and green ICT systems (SMARTGREENS)*, 1–11.

Mowasalat. (2024). *Move smart*. https://www.mowasalat.com/

Mupfumira, P., Mutingi, M., & Sony, M. (2024). Smart city frameworks SWOT analysis: A systematic literature review. *Frontiers in Sustainable Cities*, *6*, Article 1449983. https://doi.org/10.3389/frsc.2024.1449983

Musa, W. (2017). *The impact of smart city initiatives on cities' local economic development* [Master's thesis, Fort Hays State University]. FHSU Scholars Repository. http://doi.org/10.58809/YHXQ3534

Myerson, R. B. (2013). *Game theory: Analysis of conflict*. Harvard University Press.

Nagano, A. (2019). An integrated index towards sustainable digital transformation. In *2019 Third World Conference on Smart Trends in Systems Security and Sustainablity (WorldS4)* (pp. 228–234). IEEE. https://doi.org/10.1109/WorldS4.2019.8904031

Nagode, K., & Manfreda, A. (2022). IT diffusion in the society: The expansion of smart cities and their impact on the sustainable development. In A. Elbanna, S. McLoughlin, Y. K. Dwivedi, B. Donnellan, & D. Wastell (Eds.), *Co-creating for context in the transfer and diffusion of IT* (pp. 177–187). Springer. https://doi.org/10.1007/978-3-031-17968-6_14

Naji, K. K., Gunduz, M., Alhenzab, F., Al-Hababi, H., & Al-Qahtani, A. (2024). A systematic review of the digital transformation of the building construction industry. *IEEE Access* 12(2024), 31461–31487. http://dx.doi.org/10.1109/ACCESS.2024.3365934

Nawaz, W., & Koç, M. (2020). *Industry, university and government partnerships for the sustainable development of knowledge-based society: Drivers, models and examples in US, Norway, Singapore and Qatar*. Springer. https://doi.org/10.1007/978-3-030-26799-5_5

Nayak, M. S. D. P., & Narayan, K. A. (2019). Strengths and weaknesses of online surveys. *IOSR Journal of Humanities and Social Sciences*, *24*(5), 31–38. http://dx.doi.org/10.9790/0837-2405053138

Nickerson, C. (2022). English for specific business purposes in the United Arab Emirates. *World Englishes*, *41*(4), 532–544. http://dx.doi.org/10.1111/weng.12607

Nikolov, R., Shoikova, E., Krumova, M., Kovatcheva, E., Dimitrov, V., & Shikalanov, A. (2016). Learning in a smart city environment. *Journal of Communication and Computer*, *13*(7), 338–350. http://dx.doi.org/10.17265/1548-7709/2016.07.003

Niksefat, E., & Taghizade, K. (2020). A methodology for selecting and prioritizing suitable criteria for sustainability assessment of the buildings and development of Iran’s Sustainable Building Rating System (ISBRS). *Journal of Engineering and Applied Sciences*, *15*(6), 1351–1358.

Norman, G. (2010). Likert scales, levels of measurement and the “laws” of statistics. *Advances in health sciences education*, *15*(5), 625-632.

Nosike, C. J., Ojobor, O. S. N., & Nosike, C. U. (2024). Enhancing business resilience: Innovation and adaptation during and after the global pandemic. *International Journal of Financial, Accounting, and Management*, *6*(2), 217–229. http://dx.doi.org/10.35912/ijfam.v6i2.1891

Nukpezah, J., Abutabenjeh, S., & Azhar, A. (2022). Do smart cities technologies contribute to revenue performance? Evidence from US local governments. *Public Performance and Management Review*, *45*(5), 1155–1180. https://doi.org/10.1177/08912424211053599

Obilor, E. I. (2023). Convenience and purposive sampling techniques: Are they the same?. *International Journal of Innovative Social & Science Education Research*, *11*(1), 1–7.

Obilor, E. I., & Amadi, E. C. (2018). Test for significance of Pearson's correlation coefficient. *International Journal of Innovative Mathematics, Statistics & Energy Policies*, *6*(1), 11–23.

Okoli, C. (2023). Inductive, abductive and deductive theorising. *International Journal of Management Concepts and Philosophy, 16*(3), 302–316. http://dx.doi.org/10.1504/IJMCP.2023.131769

Omayer, H. M., Mobarak, M. A., & Selim, O. (2022). Digital transformation: Towards sustainable and smart new cities in Upper Egypt (New Qena case study). *IOP Conference Series: Earth and Environmental Science*, *1113*(1), Article 012027. https://doi.org/10.1088/1755-1315/1113/1/012027

Othman, A., Al Mutawaa, A., Al Tamimi, A., & Al Mansouri, M. (2023). Assessing the readiness of government and semi-government institutions in Qatar for inclusive and sustainable ICT accessibility: Introducing the MARSAD tool. *Sustainability*, *15*(4), Article 3853. https://doi.org/10.3390/su15043853

Pajo, B. (2017). *Introduction to research methods: A hands-on approach.* SAGE Publications.

Park, E., Del Pobil, A. P., & Kwon, S. J. (2018). The role of Internet of Things (IoT) in smart cities: Technology roadmap-oriented approaches. *Sustainability*, 10(5), Article 1388. https://doi.org/10.3390/su10051388

Pasha. H. (2024). *Harnessing AI to bolster cybersecurity: Safeguarding Qatar's digital transformation*. Paloalto Networks. https://www.paloaltonetworks.com/blog/prisma-cloud/harnessing-ai-to-bolster-cybersecurity-safeguarding-qatars-digital-transformation/#:~:text=Harnessing%20AI%20to%20Bolster%20Cybersecurity%3A%20Safeguarding%20Qatar's%20Digital%20Transformation,-Link%20copied & text=As%20the%20world%20embraces%20digital,has%20never%20been%20more%20important.

Pereira, G. V., Parycek, P., Falco, E., & Kleinhans, R. (2018). Smart governance in the context of smart cities: A literature review. *Information Polity*, *23*(2), 143–162. http://dx.doi.org/10.3233/IP-170067

Planning and Statistical Authority. (2024). *Social development*. https://www.psa.gov.qa/en/qnv1/pages/socialdevelopment.aspx

Pourzolfaghar, Z., Bastidas, V., & Helfert, M. (2020). Standardisation of enterprise architecture development for smart cities. *Journal of the Knowledge Economy*, *11*(4), 1336–1357. https://doi.org/10.1007/s13132-019-00601-8

Pourzolfaghar, Z., Bezbradica, M., & Helfert, M. (2016). Types of IT architectures in smart cities–a review from a business model and enterprise architecture perspective [Position paper]. *2nd AIS Pre-ICIS Workshop on "IoT & smart city challenges and applications"*. https://iot-smartcities.lero.ie/wp-content/uploads/2016/12/Types-of-IT-Architectures-in-Smart-Cities-%e2%80%93-A-review-from-a-Business-Model-and-Enterprise-Architecture-Perspective.pdf

Puron-Cid, G., & Gil-Garcia, J. R. (2022). Are smart cities too expensive in the long term? Analyzing the effects of ICT infrastructure on municipal financial sustainability. *Sustainability*, *14*(10), Article 6055. http://dx.doi.org/10.3390/su14106055

PWC. (2023). *Qatar - E-KYC Regulation, Regulating the Deployment of E-KYC by QCB-Licensed Entities*. https://www.pwc.com/m1/en/services/tax/me-tax-legal-news/2023/qatar-e-kyc-regulation-regulating-the-deployment-of-e-kyc-by-qcb-licensed-entities.html#:~:text=The%20QCB%20published%20the%20Qatar,services%20skillsets%20of%20the%20future%20(%E2%80%9C

Qatar Central Bank. (2023). *Fintech strategy in State of Qatar*. https://www.qcb.gov.qa/Documents/SuperVision/FENTECHStrategy_EN.pdf

Qatar Foundation. (2024). *Qatar Academy for Science and Technology*. https://www.qf.org.qa/education/qatar-academy-for-science-and-technology

Qatar Mobility Innovations Center. (2024). *QMIC's HUMIDEX Workshop*. https://www.qmic.com/#About

Qatar National Broadband Network. (2024). *Home*. https://qnbn.qa/

Qatar News Agency. (2024, June 23). Minister of Municipality inaugurates first phase of Smart Cities Solutions Project. *Qatar News Agency*. https://www.qna.org.qa/en/News-Area/News/2024-06/23/0051-minister-of-municipality-inaugurates%C2%A0first-phase-of-smart-cities-solutions-project

Qatar Science and Technology Park. (2024). *Where technology goes to work*. https://qstp.org.qa/

Qatar University. (2022). *National blockchain blueprint for Qatar*. https://www.qna.org.qa/en/News-Area/News/2023-03/18/0011-cra-issues-national-blockchain-blueprint-for-qatar#:~:text=Through%20the%20Blueprint%2C%20we%20have,emerging%20startups%20and%20pilot%20projects

Qatar University. (2023). *QU launches Future Tech Forum*. https://kindi.qu.edu.qa/sites/en_US/about/newsroom/kindi/QU-Launches-Future-Tech-Forum

QatarCloud. (2024). *Our products*. https://qatarcloud.qa/

Risdiana, D. M., & Susanto, T. D. (2019). The safe city: Conceptual model development – a systematic literature review. *Procedia Computer Science*, *161*, 291–299. http://dx.doi.org/10.1016/j.procs.2019.11.126

Ristvej, J., Lacinák, M., & Ondrejka, R. (2020). On smart city and safe city concepts. *Mobile Networks and Applications*, *25*(3), 836–845. https://doi.org/10.1007/s11036-020-01524-4

Rosário, A. T., & Dias, J. C. (2023). The new digital economy and sustainability: Challenges and opportunities. *Sustainability*, *15*(14), Article 10902. https://doi.org/10.3390/su151410902

Ryan, T. P. (2013). *Sample size determination and power*. John Wiley & Sons.

Saharan, S., Bawa, S., & Kumar, N. (2020). Dynamic pricing techniques for intelligent transportation system in smart cities: A systematic review. *Computer Communications*, *150*, 603–625. https://doi.org/10.1016/j.comcom.2019.12.003

Salem, F. (2016). *A smart city for public value: Digital transformation through agile governance – The case of "Smart Dubai"*. Mohammad bin Rashid School of Government.

Sánchez-Corcuera, R., Nuñez-Marcos, A., Sesma-Solance, J., Bilbao-Jayo, A., Mulero, R., Zulaika, U., Azkune, G., & Almeida, A. (2019). Smart cities survey: Technologies, application domains and challenges for the cities of the future. *International Journal of Distributed Sensor Networks*, *15*(6), Article 155014771985398. http://dx.doi.org/10.1177/1550147719853984

Saunders, M. N. K., Lewis, P., & Thornhill, A. (2019). *Research methods for business students*. 8th ed. Pearson.

Saunders, M. N. K., Lewis, P., Thornhill, A., & Bristow, A. (2015). Understanding research philosophy and approaches to theory development. In M. N. K. Saunders, P. Lewis, & A. Thornhill (Eds.), *Research methods for business students* (7th ed.) (pp. 122–161). SAGE Publications.

Secinaro, S., Brescia, V., Lanzalonga, F., & Santoro, G. (2022). Smart city reporting: A bibliometric and structured literature review analysis to identify technological opportunities and challenges for sustainable development. *Journal of Business Research*, *149*, 296–313. https://doi.org/10.1016/j.jbusres.2022.05.032

Sha, Y., Li, M., Xu, H., Zhang, S., & Feng, T. (2022). Smart city public safety intelligent early warning and detection. *Scientific Programming*, *2022*, Article 7552601. https://doi.org/10.1155/2022/7552601

Shamsuzzoha, A., Nieminen, J., Piya, S., & Rutledge, K. (2021). Smart city for sustainable environment: A comparison of participatory strategies from Helsinki, Singapore and London. *Cities*, *114*, Article 103194. http://dx.doi.org/10.1016/j.cities.2021.103194

Sharma, N., & Jindal, N. (2024). Emerging artificial intelligence applications: Metaverse, IoT, cybersecurity, healthcare-an overview. *Multimedia Tools and Applications*, *83*(19), 57317–57345.

Shcherbina, E., & Gorbenkova, E. (2018). Smart city technologies for sustainable rural development. *IOP Conference Series: Materials Science and Engineering*, *365*(2), Article 022039. https://doi.org/10.1088/1757-899X/365/2/022039

Sheng, Z. (2021). Singapore country report. In P. Han & S. Kimura (Eds.), *Energy outlook and energy saving potential in East Asia 2020* (pp. 249–269). ERIA.

Shichiyakh, R. A., Klyuchnikov, D. A., Balashova, S. P., Novoselov, S. N., & Novosyolova, N. N. (2016). Smart city as the basic construct of the socio-economic development of territories. *International Journal of Economics and Financial Issues*, *6*(1S), 157–162.

Shivhare, A. (2024). *AI technology Singapore: A smart nation's embrace of artificial intelligence*. Nive US Solutions. https://niveussolutions.com/ai-technology-in-singapore-shaping-the-future/

Shuaib, H. A. (2023). *Digital transformation from employees' perspective: The case of Qatar* [Unpublished doctoral dissertation]. Hamad Bin Khalifa University.

Silva, B. N., Khan, M., & Han, K. (2018). Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities. *Sustainable Cities and Society*, *38*, 697–713. https://doi.org/10.1016/j.scs.2018.01.053

Sipahi, E. B., & Saayi, Z. (2024). The world's first "Smart Nation" vision: The case of Singapore. *Smart Cities and Regional Development Journal*, *8*(1), 41–58. http://dx.doi.org/10.25019/dvm98x09

Skinner, R., & Bidwell, N. (2016). *Making better places: Autonomous vehicles and future opportunities*. WSP-Parsons Brinckerhoff Engineering Services.

Smart Nation. (2023). *National Artificial Intelligence Strategy 2 to uplift Singapore's social and economic potential*. https://www.smartnation.gov.sg/media-hub/press-releases/04122023/

Smith, B. W., Green, C., Jaynes, T. L., Dajani, L., Ferraro. A., Muse, L. P., Rossetti, R., Paiva, S., & Ali, S. (2021). Smart cities through the lens of human rights. In *2021 IEEE International Symposium on Technology and Society* (SS14). IEEE. https://doi.org/10.1109/ISTAS52410.2021.9629191

Smith, G. D., Higgins, J. P. T., & Egger, M. (2022). *Systematic reviews in health research: Meta-analysis in context.* Wiley.

Srivastava, S., Bisht, A., & Narayan, N. (2017). Safety and security in smart cities using artificial intelligence – A review. In *2017 7th International Conference on Cloud Computing, Data Science and Engineering-Confluence* (pp. 130–133). IEEE. http://dx.doi.org/10.1109/CONFLUENCE.2017.7943136

Statista. (2023). *Smart cities – Qatar*. https://www.statista.com/outlook/tmo/Internet-of-things/smart-cities/qatar

Statista. (2024a). *Digital health – Qatar*. https://www.statista.com/outlook/hmo/digital-health/qatar

Statista. (2024b). *Digital health – Singapore*. https://www.statista.com/outlook/hmo/digital-health/singapore

Statista. (2024c). *Digital treatment & care* – Qatar. https://www.statista.com/outlook/hmo/digital-health/digital-treatment-care/qatar

Statista. (2024d). *Healthcare IoT – Qatar*. https://www.statista.com/outlook/tmo/Internet-of-things/healthcare-iot/qatar

Statista. (2024e). *Healthcare IoT – Singapore*. https://www.statista.com/outlook/tmo/Internet-of-things/healthcare-iot/singapore

Su, B., Goh, T., Ang, B. W., & Ng, T. S. (2022). Energy consumption and energy efficiency trends in Singapore: The case of a meticulously planned city. *Energy Policy*, *161*, Article 112732. https://doi.org/10.1016/j.enpol.2021.112732

Su, K., Li, J., & Fu, H. (Eds.) (2011). Smart city and the applications. In *2011 International Conference on Electronics, Communications and Control (ICECC)* (pp. 1028–1031). IEEE. https://doi.org/10.1109/ICECC.2011.6066743

Sue, V. M., & Ritter, L. A. (2012). *Conducting online surveys*. SAGE Publications.

Szpilko, D., Fernando, X., Nica, E., Budna, K., Rzepka, A., & Lăzăroiu, G. (2024). Energy in smart cities: Technological trends and prospects. *Energies*, *17*(24), Article 6439. https://doi.org/10.3390/en17246439

Tahmasseby, S. (2022). The implementation of smart mobility for smart cities: A case study in Qatar. *Civil Engineering Journal*, *8*(10), 2154–2171. http://dx.doi.org/10.28991/CEJ-2022-08-10-09

TASMU. (2022). *TASMU healthcare smart sector: Smart services playbook*. https://tasmu.gov.qa/healthcare

TASMU. (2023a). *Policy and regulations*. https://tasmu.gov.qa/policy-and-regulations

TASMU. (2023b). *TASMU environment smart sector: Smart services playbook*. https://tasmu.gov.qa/the-playbook

TASMU. (2023c). *The future made smarter*. https://tasmu.gov.qa/

Tawfik, G. M., Dila, K. A. S., Mohamed, M. Y. F., Tam, D. N. H., Kien, N. D., Ahmed, A. M., & Huy, N. T. (2019). A step-by-step guide for conducting a systematic review and meta-analysis with simulation data. *Tropical Medicine and Health*, *47*(1), Article 46. https://doi.org/10.1186/s41182-019-0165-6

Teng, Y. (2021). *Ethics of trust-inviting digital systems: Blockchain, reputation-based platforms, and COVID19 tracing technologies* [Doctoral disseration, TU Delft]. TU Delft Research Repository. https://doi.org/10.4233/uuid:b5134895-8d70-4b2f-a416-662891b2aa0d

Thales Group. (2023). *The world's smartest city*. https://www.thalesgroup.com/en/worldwide-digital-identity-and-security/iot/magazine/singapore-worlds-smartest-city

Thomas, P. A. (2024, October 22). Singapore unveils AI system guidelines, emphasizing secure-by-design. *CSO*. https://www.csoonline.com/article/3577124/singapore-unveils-ai-system-guidelines-emphasizing-secure-by-design.html#:~:text=Singapore%20has%20rolled%20out%20new,data%20poisoning%20and%20evasion%20attacks

Toli, A. M., & Murtagh, N. (2020). The concept of sustainability in smart city definitions. *Frontiers in Built Environment*, *6*, Article 77. https://doi.org/10.3389/fbuil.2020.00077

Tomor, Z., Meijer, A., Michels, A., & Geertman, S. (2019). Smart governance for sustainable cities: Findings from a systematic literature review. *Journal of Urban Technology*, *26*(4), 3–27. https://doi.org/10.1080/10630732.2019.1651178

Tomorrow City. (2024). *Why, two decades on, Singapore's intelligent transport system is considered the best in the world*. https://www.tomorrow.city/transportation-technology-singapores-intelligent-transport-system/

Tribune News Network. (2020, March 19). Students to use MS Teams, LMS for online learning: Education Ministry. *Qatar Tribune*. https://www.qatar-tribune.com/article/185565/NATION/Students-to-use-MS-Teams-LMS-for--online-learning-Education-ministry

Trindade, E. P., Hinnig, M. P. F., da Costa, E. M., Marques, J. S., Bastos, R. C., & Yigitcanlar, T. (2017). Sustainable development of smart cities: A systematic review of the literature. *Journal of Open Innovation: Technology, Market, and Complexity*, *3*(3), Article 11. https://doi.org/10.1186/s40852-017-0063-2

Troisi, O., Kashef, M., & Visvizi, A. (2022). Managing safety and security in the smart city: Covid-19, emergencies and smart surveillance. In A. Visvizi & O. Troisi (Eds.), *Managing smart cities* (pp. 73–88). Springer. https://doi.org/10.1007/978-3-030-93585-6_5

Ullah, A., Anwar, S. M., Li, J., Nadeem, L., Mahmood, T., Rehman, A., & Saba, T. (2024). Smart cities: The role of Internet of Things and machine learning in realizing a data-centric smart environment. *Complex & Intelligent Systems*, *10*(1), 1607–1637.

Vacca, J. R. (2022). *Smart cities policies and financing: Approaches and solutions*. Elsevier Science.

Van den Bosch, H. (2020). Humane by choice, smart by default: 39 building blocks for cities of the future. *IET Smart Cities*, *2*(3), 111–121. http://dx.doi.org/10.1049/iet-smc.2020.0030

Van Hoang, T. (2024). Impact of integrated artificial intelligence and Internet of things technologies on smart city transformation. *Journal of Technical Education Science*, *19*(1), 64–73.

Van Zoonen, L. (2016). Privacy concerns in smart cities. *Government Information Quarterly*, *33*(3), 472–480. https://doi.org/10.1016/j.giq.2016.06.004

Vanover, C., Saldana, J., & Mihas, P. (2021). *Analyzing and interpreting qualitative research: After the interview*. SAGE Publications.

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems, 28(2), 118–144.* https://doi.org/10.1016/j.jsis.2019.01.003

Viale Pereira, G., & Schuch de Azambuja, L. (2021). Smart sustainable city roadmap as a tool for addressing sustainability challenges and building governance capacity. *Sustainability*, *14*(1), Article 239. https://doi.org/10.3390/su14010239

Villegas-Mateos, A. (2022). Toward a sustainable entrepreneurial ecosystem in Qatar. *Sustainability*, *15*(1), Article 127. https://doi.org/10.3390/su15010127

Visvizi, A., & Lytras, M. (2019). *Smart cities: Issues and challenges: Mapping political, social and economic risks and threats*. Elsevier Science.

Vivo-Delgado, G., & Castro-Toledo, F. J. (2020). Urban security and crime prevention in smart cities: A systematic review. *SocArXiv Papers*. http://dx.doi.org/10.31235/osf.io/7jwtc

Wang, H., Zhang, M., & Zhong, M. (2019). Opportunities and challenges for the construction of a smart city geo-spatial framework in a small urban area in central China. *Smart Cities*, *2*(2), 245–258. http://dx.doi.org/10.3390/smartcities2020016

Wang, L., Xue, X., Zhao, Z., & Wang, Z. (2018). The impacts of transportation infrastructure on sustainable development: Emerging trends and challenges. *International Journal of Environmental Research and Public Health*, *15*(6), Article 1172. https://doi.org/10.3390/ijerph15061172

Weber, M., & Podnar Žarko, I. (2019). A regulatory view on smart city services. *Sensors*, *19*(2), Article 415. https://doi.org/10.3390/s19020415

Websummit. (2024). *Web Summit Qatar coming February 23–26, 2025*. https://qatar.websummit.com/

Weerakkody, V., El-Haddadeh, R., & Al-Shafi, S. (2011). Exploring the complexities of e-government implementation and diffusion in a developing country: Some lessons from the State of Qatar. *Journal of Enterprise Information Management*, *24*(2), 172–196. https://doi.org/10.1108/17410391111106293

Wessel, L., Baiyere, A., Ologeanu-Taddei, R., Cha, J., & Jensen, T. B. (2021). Unpacking the difference between digital transformation and IT-enabled organizational transformation. *Journal of the Association for Information Systems,* 22(1), 102–129. https://doi.org/10.17705/1jais.00655

Wilson, J. (2021). *Understanding research for business students: A complete student's guide*. SAGE Publications.

Witte, R. S., & Witte, J. S. (2017). *Statistics*. John Wiley & Sons.

Zalaghi, H., & Khazaei, M. (2016). The role of deductive and inductive reasoning in accounting research and standard setting. *Asian Journal of Finance & Accounting, 8*(1), 23–37. http://dx.doi.org/10.5296/ajfa.v8i1.8148

Zamponi, M. E., & Barbierato, E. (2022). The dual role of artificial intelligence in developing smart cities. *Smart Cities*, *5*(2), 728–755. http://dx.doi.org/10.3390/smartcities5020038

Zawacki-Richter, O., Kerres, M., Bedenlier, S., Bond, M., & Buntins, K. (Eds.) (2020). *Systematic reviews in educational research: Methodology, perspectives and application*. Springer Nature. https://doi.org/10.1007/978-3-658-27602-7

Zhu, H., Shen, L., & Ren, Y. (2022). How can smart city shape a happier life? The mechanism for developing a happiness driven smart city. *Sustainable Cities and Society*, *80*(5), Article 103791. http://dx.doi.org/10.1016/j.scs.2022.103791

Zhuang, R., Fang, H., Zhang, Y., Lu, A., & Huang, R. (2017). Smart learning environments for a smart city: From the perspective of lifelong and lifewide learning. *Smart Learning Environments*, *4*, Article 6. https://doi.org/10.1186/s40561-017-0044-8

Zoughbi, S. (2022). *Planning and designing smart cities in developing nations*. IGI Global.

Appendix A: Semi-Structured Interview Guide

Brunel University London

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.

Section B: Challenges, Failure Factors, and Opportunities

1. In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.
2. What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.
3. What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?

Section C: Current Progress and Roadmap Elements

1. How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?
2. In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.

Section D: Stakeholder Views and Proposed Roadmap

1. Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.
2. Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?
3. If you could suggest any improvements or modifications to the proposed roadmap, what would they be?

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Appendix B: Survey Questionnaire

Questions for Smart City Stakeholders in Qatar

Survey questionnaire

Q1: How feasible do you find the recommendation to establish collaborative governance frameworks involving public, private, and civil society organizations for Qatar's smart city initiatives?

1: Not Feasible

2: Slightly Feasible

3: Neutral

4: Feasible

5: Highly Feasible

Q2: To what extent do you believe that investing in digital infrastructure and advanced technology aligns with your organization's goals and Qatar's digital transformation objectives?

1: Not Aligned

2: Slightly Aligned

3: Neutral

4: Aligned

5: Strongly Aligned

Q3: How effectively do you think a centralized digital platform would improve citizen engagement and access to state services, particularly for diverse user groups, including people with disabilities?

1: Not Effective

2: Slightly Effective

3: Neutral

4: Effective

5: Highly Effective

Q4: What challenges do you anticipate in implementing collaborative governance frameworks for smart city projects in Qatar?

1: Budget constraints

2: Resource limitations

3: Regulatory hurdles

4: Lack of alignment between entities

5: Other (please specify)

Q5: To what extent would digital transformation initiatives support sustainability in urban development within Qatar's smart city framework?

1: Not Supportive

2: Slightly Supportive

3: Neutral

4: Supportive

5: Highly Supportive

Q6: What modifications or additional features would you suggest for a centralized digital transformation platform to ensure it meets the needs of all citizens effectively?

Open-ended response

Q7: How likely are you to support the recommended investments and collaborations if resources and guidance were provided for implementation?

1: Not Likely

2: Slightly Likely

3: Neutral

4: Likely

5: Highly Likely

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Quantitative Questionnaire

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Demographics

Gender:

- Male
- Female

Age group:

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65 and above

Occupation:

- Government sector
- Private sector
- Academic/Research
- Other (please specify)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Years of experience in the field of digital transformation/smart cities:

- 0-2
- 3-5
- 6-10
- 11-15
- 16 or more

Section B Challenges:

On a scale of 1 to 5, with 1 being " least challenging " and 5 being " most challenging," Rate the following challenges in implementing sustainable digital transformation for smart cities in Qatar:

	Scale				
	1	2	3	4	5
Infrastructure					
Regulations and Policies					
Funding					
Technology Adoption					
Public awareness and acceptance					
Other (please specify)					

Section C: Challenges, Failure Factors, and Opportunities:

On a scale of 1 to 5, with 1 being " least significant " and 5 being " most significant," Rate the following failure factors in implementing sustainable digital transformation for smart cities in Qatar:

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

	Scale				
	1	2	3	4	5
Inadequate planning					
Insufficient stakeholder engagement					
Lack of skilled workforce					
Technological barriers					
Resistance to change					
Other (please specify)					

On a scale of 1 to 5, with 1 being " least significant " and 5 being " most significant," Rate the following opportunities for sustainable digital transformation in Qatar's smart cities.

	Scale				
	1	2	3	4	5
Government support					
Public-private partnerships					
Technological advancements					
International collaborations					
Economic growth potential					
Other (please specify)					

Brunel University London

Section D: Progress and Roadmap Elements:

On a scale of 1 to 5, how would you rate the current progress of digital transformation in Qatar (1 = no progress, 5 = significant progress)?

	Scale				
	1	2	3	4	5
The current progress of digital transformation in Qatar					

Rate the importance of the following elements in fostering digital transformation in Qatar (1 = least important, 5 = most important):

	Scale				
	1	2	3	4	5
Developing a clear strategy					
Investing in infrastructure					
Enhancing regulations and policies					
Promoting innovation and R&D					
Improving public awareness and acceptance					
Other (please specify)					

Section E: Stakeholder Views and Proposed Roadmap and suggestion

How familiar are you with Qatar's proposed roadmap for fostering digital transformation?

Not at all familiar	
Slightly familiar	
Moderately familiar	
Very familiar	
Extremely familiar	

Rate your agreement with the following statements regarding the proposed roadmap (1 = strongly disagree, 5 = strongly agree):

	Scale				
	1	2	3	4	5
The roadmap adequately addresses challenges and opportunities					
The roadmap is realistic and achievable					
The roadmap is aligned with Qatar's national vision and goals					
The roadmap considers the needs of various stakeholders					

Brunel University London

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

What improvements, if any, would you suggest for the proposed roadmap?

Agree or disagree with the following statements on a scale of 1 to 5, with 1 being "strongly disagree" and 5 being "strongly agree":

	Scale				
	1	2	3	4	5
The government should play a leading role in driving sustainable digital transformation in developing smart cities in Qatar.					
Private sector companies should invest more in sustainable digital transformation in developing smart cities in Qatar.					
Citizens should be actively engaged in the decision-making process for sustainable digital transformation in developing smart cities in Qatar.					
Education and training programs should be developed to address the skills gap for sustainable digital transformation in developing smart cities in Qatar.					

Conclusion:

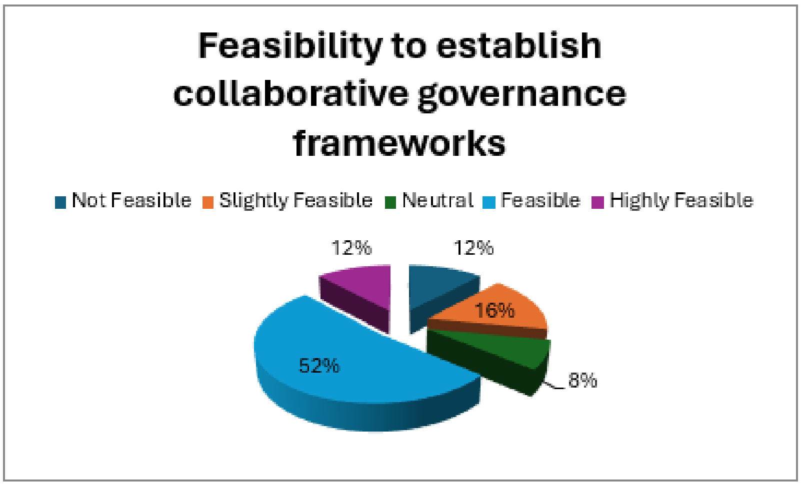
I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Outcomes

Methodology: Survey with 98 stakeholders across Qatar, who is actively, involved in DT and SC initiatives.

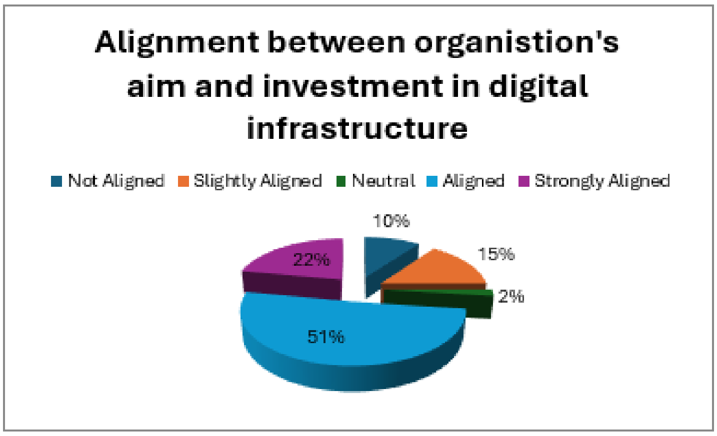
Findings:

Feasibility to establish collaborative governance frameworks involving public, private, and civil society organizations for Qatar's smart city initiatives:



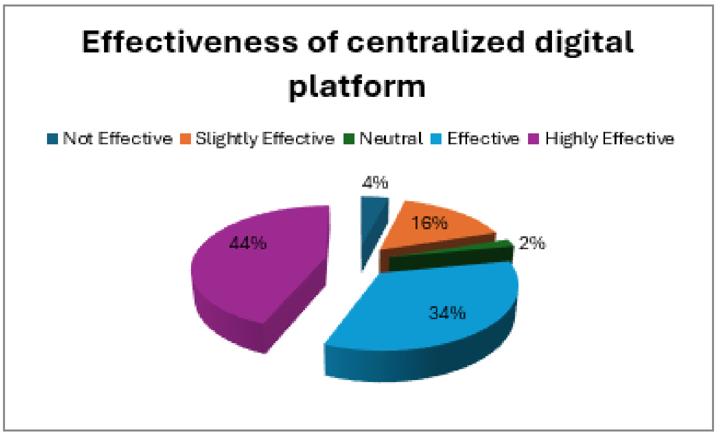
As per the results with respect to this question, majority of the respondents (52%) are showing their positive intend towards feasibility of the establishing collaborative governance related framework. With the involvement of public, private and civil society organizations for Qatar's smart city initiatives

Alignment of organization's goals and Qatar's digital transformation objectives with the investment in digital infrastructure and advanced technology



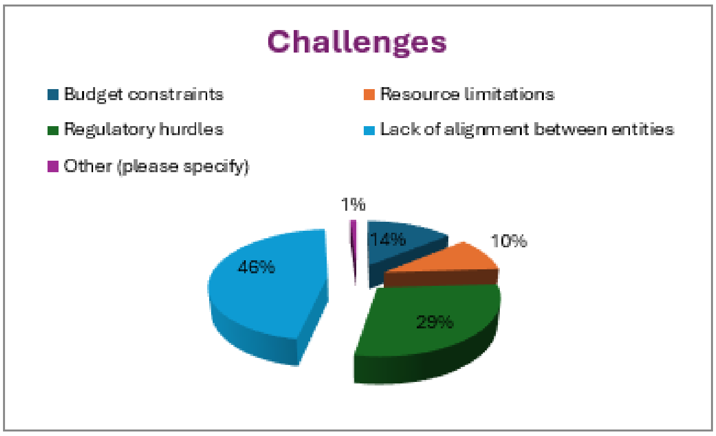
This finding is suggesting that majority of the respondents (51%) consider the positive alignment between organization's goals and Qatar's digital transformation objectives with the investment in digital infrastructure and advanced technology. Along with this 22% of the respondents consider this alignment quite strong.

Effectiveness of centralized digital platform in citizen engagement and access to state services



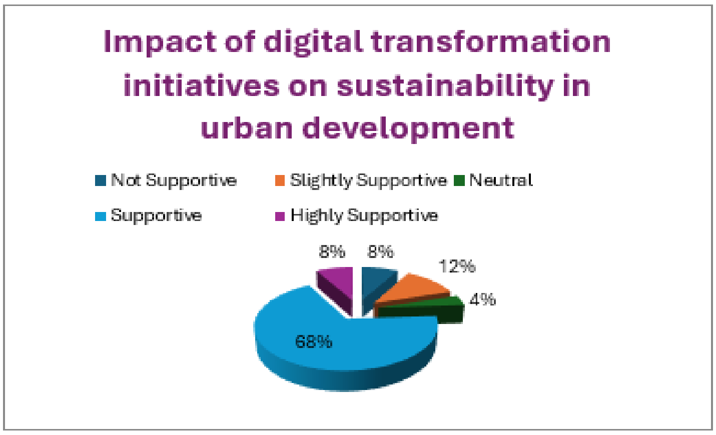
The above data finding is demonstrating that 44% of the respondent consider centralised and digital framework in provide effective services to senior citizen and access to state services in better manner.

Challenges faced in the effective implementation of collaborative governance frameworks for smart city projects



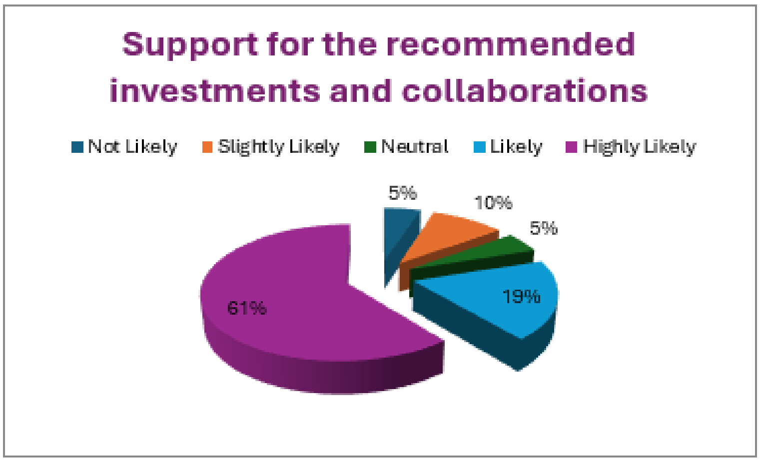
As per the data findings, budget and resources are not the major challenges in the effective implementation of collaborative governance frameworks for smart city projects. However, in the survey, lack of effective alignment between related entities such as people, government and agencies is considered as major challenge for the government.

Impact of digital transformation initiatives on sustainability in urban development



As per the finding in respect to this question, it is found that 68% of the respondents consider digital transformation supportive for increasing sustainability of the urban development of City under smart city development project. This perspective is directed to enhance the feasibility of the project for the common people of the city.

Support for the recommended investments and collaborations



The participants included in the survey have shown strong positive intention to support the overall recommendations and investments if resources and guidance were provided for implementation. Almost 80% of the respondents (61% high likely and 19% likely) are ready to support the investments. Only 5% of the respondents were there, who were not likely to support this investment and collaboration? This data depicts the effectiveness and likelihood engagement of people in this project.

Along with these closed ended an open ended question related to the suggestions of additional features for a centralized digital transformation platform was also asked to participants. Majority of the user mentioned that the interface of this system should be friendly for users who are not tech savvy. As the users of this system will involve senior citizens so it must be user friendly and well navigated.

Appendix C: Information Sheet, Participant Consent and Ethical Approval Forms

Brunel University London

Information Sheet

Title of the Study

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction

My name is Maryam Majareh, and I am a PhD candidate under the supervision of Prof. George Ghinea from Brunel University. I am conducting research on the topic of Smart Cities in Qatar: Toward a Sustainable Digital Transformation.

I want to invite you to take part in this study. Before deciding, it is important that you understand the nature and purpose of the research.

What is the purpose of the study?

The aim of this study is to explore the concept of smart cities in Qatar and the potential for sustainable digital transformation. Your participation in this study will involve answering the Qualitative and quantitative questionnaires.

Do I have to take part?

Participation in this study is entirely voluntary, and you may withdraw at any time and no to give a reason.

Page 1 of 4

What will happen if I take part?

I value your insights and experiences related to this topic, and I appreciate your time and consideration in participating in this study.

If you decide to take part in this research. The next step is to inform me of your availability to participate in this study. You will be asked to participate in a 30-minute interview. The interview will be conducted at a time and in a manner convenient for you. This may include face-to-face, or via Microsoft Teams.

During the interview,
you will be asked a series of questions related to ***(Smart Cities in Qatar: Toward a Sustainable Digital Transformation)***. Your responses will provide valuable insights into:

1. To critically examine related literature.
2. To conduct a study to assess the progress, challenges, failure factors, and future opportunities for digital transformation and innovation for smart cities in Qatar.
3. To identify key elements and propose a framework for fostering digital transformation for smart cities in Qatar.
4. To evaluate the proposed framework.
5. To draw a conclusion and recommendations.

Please note that all your responses will be kept confidential and used solely for the purposes of this research.

Will my taking part be kept confidential?

I want to reassure you that all information and data obtained from you during our study on Smart Cities in Qatar: Toward a Sustainable Digital Transformation will be treated as confidential and will be kept anonymous.
I take your privacy and confidentiality seriously and will follow all ethical guidelines to protect your personal information and data.

What are the risks and possible benefits of taking part?
I take measures to ensure that the questionnaire is designed to minimise risks and maximise participants' benefits.

By participating, you will have the opportunity to contribute to research and increase your knowledge on the topic. The questionnaire may prompt you to reflect on your experiences and beliefs, which can be a valuable personal learning opportunity. Completing the questionnaire may allow you to express your opinions and share your experiences.
.

What will happen if I want to withdraw from the study?

You have the right to withdraw from the study at any time, for any reason, without consequence or penalty. Any information or results collected from you will be destroyed and will not be included in our research. However, because the data collected will be anonymised, we will not be able to identify and remove your data after [19th of September 2023]. Therefore, if you wish to withdraw, please inform us before this deadline.
If you have any questions or concerns about your participation, please do not hesitate to contact me at [2216859@brunel.ac.uk].

What will happen to the results of the study?
The results of this study will be included in a report to Brunel University and may be used for academic purposes, such as applying for publication in a professional journal. Your identity will be kept confidential, and your personal information will not be disclosed.
After the final write-up of the thesis, a summary of the overall findings will be available upon request.

Who has reviewed the study?
This study will be reviewed by the Ethics Committee at Brunel University London.

Concerns and complaints

Any queries regarding the research can be directed to the principal investigator, whose details are listed below. If at any point during the study you have any concerns or complaints about the study, these can be addressed to cedps-research@brunel.ac.uk, or the Chair of the Research Ethics Committee. Contact details have been listed below.

Thank you very much for taking the time to read this information.

Principal Investigator details	**Chair of the Research Ethics Committee**
Prof. George Ghinea Department of Computer Science Brunel University, UB8 3PH George.Ghinea@brunel.ac.uk	Prof. Simon Taylor College of Design, Engineering and Physical Sciences Brunel University London, UB8 3PH Simon.Taylor@brunel.ac.uk

CONSENT FORM

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

	YES	*NO*
Have you read the Research Participant Information Sheet?	☐	☐
Have you had an opportunity to ask questions and discuss this study?	☐	☐
Have you received satisfactory answers to all your questions?	☐	☐
Whom have you spoken to?		
Do you understand that you will not be referred to by name in any report concerning the study?	☐	☐
Do you understand that you are free to withdraw from the study:		
• At any time	☐	☐
• Without having to give a reason for withdrawing?	☐	☐
I agree to my interview being recorded.	☐	☐
I agree to the use of non-attributable direct quotes when the study is written up or published.	☐	☐
Do you agree to take part in this study?	☐	☐

Signature of Research Participant:

Name in capitals: Date:

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

5 June 2023

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 10/06/2023 AND 20/09/2023

Applicant (s): Mrs Maryam Majareh

Project Title: Smart Cities in Qatar Toward a Sustainable Digital Transformation

Reference: 42404-LR-May/2023- 44950-2

Dear Mrs Maryam Majareh

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to any conditions that may appear above.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Simon Taylor

Chair of the College of Engineering, Design and Physical Sciences Research Ethics Committee

Brunel University London

Page 1 of 1

Appendix D: Sample Interview Transcripts

Participant A

Brunel University London

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

<u>Introduction:</u>

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

<u>Section A: Participant Background</u>

1. **Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.**

I work at the Ministry of Information Communication Technology. I have an experience of almost nine years in the field of digital transformation. Mainly in the smart country project as a strategy development since inception back in 2017, now in the execution level related to many projects in five main sectors, and this is mainly my work on Digital Transformation. related to the smart country projects. So, we focused on the health sector, Transport logistics, and Environment in the prospect of Agriculture mostly and Sports. So these are the sectors we worked on in terms of projects.

Page 1 of 9

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

So, what we have done that I can confidently say that we are a smart country, not just a city where we have built the digital infrastructure, which is the TASMU central platform, which enables sustainable development and accelerates the speed of development, so as an infrastructure in terms of cloud platform it has all the main let's say services and pillars that enable the growth of digital transformation a speed of adoption. So, this is what we had created. We enable all the sectors of any entity that would like to accelerate their Digital Transformation to be onboarded on that platform and get their services. Whether it is, let's say, analytic. service data analytics, so cross-vectorial data sharing, which is one of our main goals that actually benefits a lot of the use case applications. We actually integrated a lot of government services part of the platform, so these different existing infrastructures are integrated and easier to access through the cloud platform.

So because of the TASMU central platform development. So, this is where all the different use cases for rebuilding within the sectors (Health care, Sport, Logistics and Agriculture) are built on top of this platform as layers which enable cross-vectorial data sharing. So let's say an example. real-time crowd management case for transporting its integrated twenty entities from the ecosystem within the transport sector and the cross-data sharing between the different stakeholders enabled them to actually enhance their operations during the World Cup, so we knew how many people were coming through the airport we can mobilize public transport that goes there, even the healing services like Uber and Karem where actually notified. So these kinds of enabling mandates happened in huge cloud platforms, which actually enable us to say we are a smart country.

2. What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.

Okay, I think one of the most challenging things is a change management aspect within the entity so you can bring digital solutions that would solve many problems, but if policies within the entity do not support, it will not be a successful adoption, also one of the other facts is we emphasize in a lot, and we really focus on establishing a strong government in term of stakeholders, and no one their rules and we actually make it very clears in terms of creating a racy matrix this is your responsibility, your informed, your … So they know what is their level because some times there's conflict this is my data this is my solutions this is so a racy matrix kind of clarifies and cabin the right stakeholders in term of governance the rules and responsibility identified from the very beginning is very important for the project success and this is many of the lessons and learned that we learned through the years of implementation, so an example where we had challenge because of an existing policy that did not mis match is relating to a farming solution so its enable the community of farmers to get IoT within their farms to check their soil, satellite images, the health of their crops. However, the adoption wasn't great because of an existing policy in the Ministry of Municipalities. The engineers that are supposed to visit sites can fully adopt and utilize the system, but because they are paid, and their incentives, which will may hurt their packages. So, the policy needed to adopt is that you are working and being reskilled to use this software, which means you are still qualified and you will not lose your monitoring incentives. One of the things also a factor of adoption is the maturity of skills, so let's say out of the 300 farms in Qatar, only five actually had the right qualified people working on their farms in terms of engineers that are people capable of actually reading the data., a lot of the farms the level of literacy their farmers are very low. So this actually is a barrier for us actually to increase the speed of adoption in terms of digital transformation for certain factors, so this are three main factors I'll say: Existing policies within entities that need to be updated, Governance that's needs to be established clearly, and also the skills and knowledge of the people. We have established very strong policies and its very well maintained within the cloud and in terms of compliance we work with the NCSA (National Cyber Security Agency) and I think from that aspect, regards the government of infrastructure as a Minister no need to worry about it because there's entity to care of that. We are just making sure you always get the latest update, and when you are using a cloud infrastructure. It's much more secure. Data sharing is also one of the things we are working on. It's a continuo update and exchange of what you need as a major exercise because, by default, all entities what they will say that our data is private and will not go to share so an exercise that we are doing with them is a data classification and no also knows the data maturity, some entities actually don't have that much data to start with, so what the level of the digitization maturity of their data so this is an exercise that we go with entities from there we do the data classification (what is private that should be with the entity and what could be an anonymise as a public data and what is the open public data that is should be shared with all) and this is the exercise we did with health care, Ministry of environment, sport and logistics, now actually we do it with logistic and transport. It's really a huge exercise.

3. What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?

So, it might be grim to say that, the crisis is a very good opportunity. It's one of the fastest digital transformation catalysts for us. So, some of the geopolitical situations supported the digital adoption. We talk about the entire pandemic. It was a huge accelerator. So these are good opportunities, especially with the good infrastructure. An example of that during 2019 we actually had a very strong use case that was on an awarded project, and we developed a health care consultation remote care office and to access special care. but it wasn't a fast adoption, but at the beginning of the 2020 pandemic they wanted it a full rollout, not a pilot as we start, so it's a full rollout from the beginning, and we have so far 72 clinics awarded in that and its now part of the health care system. These are things that speed up digital transformation because it becomes a need, and from there, it becomes sustainable growth that an entity can adopt to. Again, it's not the best scenario that is actually one of the things that supported digital transformation, and it was an opportunity we harnessed. Now, we are trying to maintain it for chronic DESIS management, because those are the people who wont to continue access to medical health care, but not necessarily that they need to be in the medical faculty, so where we need actually to create policies within the medical institutions for them to have the right scenarios they actually get the right patent and filter that so this a going exercise.

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

Okay, so if I'll describe it since, let's say, five years ago, it was at the beginning again we had a lot of resistance from the entities in terms of understanding the benefits of such technologies, but now the progress and people understanding the values of AI, there's a lot of pole effect from entities rather than us pushing our project, they are actually coming to us and asking for this kind of project to be developed. I believe there is good progress, there is a good level of awareness in the government and even the private sectors in terms of the maturity of government is still higher than the private sectors. I think this needs to be balanced out near future for us to maintain the growth but the progress I think is going in the right direction special with the pom of AI as everyone wants to have AI tools.

2. **In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain**.

This is an interesting question; I think I'll talk about what exists and what we have done. That actually kind of supported the digital adoption for a smart country. What we have done is mapping it to the 2030 vision but also going to the national development strategy of the sectors themself. We looked at the main KPIs that they had, which actually had very high potential with the digital transformation and the level of the projects. because these KPIs were mapped to the main challenges that needed to be solved from these elements of these KPIs, we are able to translate them to the different projects that actually translated on the NDS timeline, which is the five years of how we are developing it to allocate the funds. Now we are in the phase two. the first phase of TASMU 1.0 was developed after the NDS, so there were missed opportunities, but now, with the third NDS (National Development Strategy) the third version, we are part of it and also delivering with that phase with the sectors. So, the projects are actually mapped to the main KPIs. So this is one of the things. Because, what's happens when go to a sector and you give them the KPIs that are not for them to own, they will not take the project very well. So this is one of the things that we actually did to maintain a good relationship because this is their KPIs to own, and this is the project that will help them reach their KPIs. So, it's related to existing KPIs of the sector on the five-year roadmap.

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.**

Yes, But I guess there is a differentiator. We have the Qatar Digital Government roadmap, which is also the transformation of the government entities. There will be a new version that will be published. And this one has its own kind of governance and establishment within the government as an executive committee. But with the current new restructuring of the government, it's actually, a sector with a clear mandate driving it, so this is one thing. And also the other thing is the country smart country establishment, which is also a clear sector with a clear mandate as of the Emiri decree that was established in 2022. So, from previously, the Emiri decree was not clear in terms of how the digital transformation should be taken and in terms of rules and responsibilities. And I think now, through that kind of positioning per the Emiri decree, this has become as a strong strength for the country. unlike the previous kind of version because it wasn't clearly mandated by law. So this is to establish strengths and weaknesses. Currently, there are weaknesses in how we communicate, get the stakeholder's words and push for these strategies to be adopted very smoothly. We are happy to see that as we are in a new position now.

For the private sector involvement, that's why the establishment of the digital industry sector that focuses on the digital economy of the country that is also posturing the maturity of the private sector, there is going be a located ICT fund for them to be enabled and get the right resources and connected kind of services. So, the important thing for us, as a digital industry department at the Ministry of Communication and Information Technology, to be up to date and roll out things is to have that dedicated focus. So, now, in the new structure, there is a dedicated department that focuses only on technology-related policies and standards, which is part of the industry sector.

2. Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?

Okay, So stakeholders, we have the government, the private sector, SMEs, research and academia. We would separate the private sector from SMEs because we have the big companies, multi-national well established, and they are huge stakeholders in the development of the smart country. I think one of the things is that I can't speak a lot of their views. I know that from my interaction with the SME's there are barriers to entry, to be part of the development due to the procurement laws that actually act as a barrier, and there are certain things are coming up in the roadmap that should enable them to access be part of that ecosystem and that we are trying to resolve and that I think is a concern it's part as a player, and when we talk about smart city innovation, you can't say that we can innovate if you are not involving research academia and the SME's, because those two are playing big role into the establishment and finding the challenges on a city. I think research and academia would like to understand the challenges more for them to dive deep and find the right solutions for them to research and focus on, and this should be established within the innovation lab services to engage them and have that kind of ecosystem where we involve them (SME's, Multinational and the research and academia with the governmental stakeholders), the government has its challenges but not very well communicated to the market, and this is what we are trying to actually kind of resolve because this what we understanding as their views. They would like to know more about our challenges in a clear manner for them to propose the right solutions, and this is something we have been working on continuously.

3. If you could suggest any improvements or modifications to the proposed roadmap, what would they be?

I think the speed-up of digital transformation is a model we would like to adopt. Hopefully, it gets by from the cabinet setting up digital transformation offices on a minister-level that connect directly with the smart country program for us to monitor ongoing projects. Because of our current model, we develop a project scope with the entity and the stakeholders. We fund it and develop it but, in this period, we hand it over to the main stakeholder, and then we monitor it within two years of maintenance. But this is coming as a challenge as you deal with different departments and many people. Having a focus digital transformation office under a minister-level establishes an accelerate and maintains that level of conscience and

Participant B

I am Mohammed Al-Jefairi, a Qatari expert born in 1982 with a doctorate in Islamic Economics from ISM, France, and a master's in Strategic Planning from HEC, France. As an alumnus of CNA-QATAR, I was among the first to graduate in ICT. My career has spanned various roles, from founding the IT security department at Ooredoo to executive leadership at Qatar IT and pivotal positions in national organizations. Internationally recognized, I was honored with the 'Best Project in the World' award at the 2018 Global Innovation Summit. Additionally, I have authored over 60 books on leadership and technology and remain an influential figure in the Qatari media landscape.

Section B: Challenges, Failure Factors, and Opportunities

The chief challenges Qatar faces in implementing sustainable digital transformation for smart cities include:

Integration of legacy systems with new digital technologies.

Lack of comprehensive policies addressing data privacy and security.

Necessity for substantial investments in infrastructure and human capital.

The main failure factors are:

Inadequate training and awareness about the new digital platforms.

Misalignment between the digital transformation strategy and the actual needs of the residents.

Resistance from certain stakeholders fearing obsolescence.

For example, a project aimed at introducing smart waste management faced resistance from traditional waste collection agencies fearing job losses.

The opportunities include:

Leveraging Qatar's robust economy and willingness to invest in technology.

Building partnerships with international tech firms and academic institutions.

Engaging the youth and tapping into their tech-savviness.

These opportunities can be harnessed by creating a conducive environment for innovation, fostering international collaborations, and implementing public awareness campaigns.

Section C: Current Progress and Roadmap Elements

The current progress is commendable. Many government services have gone digital, and there are ongoing initiatives for smart transportation, healthcare, and energy management. However, there is a disparity in the level of digital adoption across different sectors.

For a successful roadmap:

Prioritize sectors that directly impact residents, like healthcare, transportation, and public safety.

Involve multiple stakeholders, including residents, in the planning phase.

Ensure continuous training and skills development programs for the workforce.

Section D: Stakeholder Views and Proposed Roadmap

I am familiar with the proposed roadmap. Strengths include its ambitious vision and the allocation of significant resources. However, a potential weakness is the lack of a comprehensive feedback mechanism to iterate and improve based on real-world challenges.

From what I gather, most stakeholders are optimistic. However, they emphasize the importance of flexibility in the roadmap to accommodate unforeseen challenges. Their concerns can be addressed by establishing regular stakeholder meetings, and by incorporating their feedback into project iterations.

Improvements to the roadmap:

Establish a clear feedback loop mechanism.

Incorporate success stories and lessons from other countries.

Set up a dedicated task force to handle change management, ensuring seamless adoption of new digital initiatives.

Participant C

Brunel University London

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.

My main area is academia I worked on area like networking, communications, internet of things (IoT) applications as they intersect with smart cities like eHealth, smart health applications, smart traffic's, and a lot of IoT applications. But my main contribution usually is in the network communication systems components. In the recent times I worked in using AI for optimizing the network performance, so I did a lot of work there. I used AI for interjoin detection in the cloud and the edge. That is my technical background and been in academic teaching since 2012, between Qatar University and HBKU, and I am in academic science in 2005.

Page 1 of 7

If we talk about smart city perspective, I am aware about series implementation of smart city infrastructure at Msheireb, I heard that they have developed a small data centre to process the data, they deployed some sensors, smart waste management system and some other simple applications, this mean they have infrastructure with little applications, for Lusail, they have some sensors related to smart street control, and they have at least for the for the road network they try to deploy some infrastructure there in Lusail. In addition, Kahramaa deploying smart meters everywhere now, so most of those smart meters have no internet connectivity, so maybe the data is there somewhere. I also heard in general like Ashghal and all the people who's managing the infrastructure are trying to deploy more smart devices and more smartness. Also, the TASMU projects tries to make demos with different stakeholders in different areas whether its health, and I heard that they are trying to help another ministry. In general, there's more happening I don't think there is concerted efforts in organized efforts, there's efforts from different players and different small initiatives that are trying to make this area more successful. That's my knowledge about what happening now.

If we talk about digital transformation in general, the government since fifteen years ago they moved to digital portals for different services (Hukoomi, Metrash..etc) very different successful platforms specially Metrash in my opinion its very successful and lately a lot of things are moving the way that Tawtheeq where we can enter in one place an authenticate within the government and this can get you access to your health record, Ministry of Justice and the court, its can give you also access to a lot of your online presents like Ministry of Commerce where you can establish your new company. The government also invested in some infrastructure authentication and different Ministries are open to this portal where you can interact with them online and recently, we had the last two years the Civil Services and Government Development Bureau, they started a mini initiative to automate how the government monitor the services in the shared centers.

I think the government had a lot of initiatives to go for digital transformation within the government, they where very successful in very forward looking initially like fifteen years ago and there's a little bit of a gap, but in general, we see more and more be digitize overtime.

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

I think the hardest part is dealing with humans, because digital transformation is not only about technology as we ok with technology in general and we have no issue with getting good technology and installing, but to be honest to think differently about the process, and in the process digitize you have also digitize the thinking of the process so you have to streamline the process, you have to make sure that the process is not just doing the same things but online, but actually you reduce the approval chain, you make sure only the necessary people are included, so you need to reengineer this process and more important is you need to equip the people on the grand, the people who generally approve these processes and manage them first with digital skills, so they are able and aware and can go through this transformation, also new mentality because digital transformation require new mentality, its not the old one and bureaucratization and long approval. It's a different mentality, people really have to live this online experience, people have to reduce resistant to change, so it's a change process not only technology introduction, so this the type of thing you need to deal with people, make sure you address their issues, make sure the new process does not include the same in efficiency, make sure that people get by in and have some incentive for them to join, So, I think those are the biggest hurdle in my opinion and this is the reason why most of those projects are maybe will not be as successful as they should.

fifteen years ago and there's a little bit of a gap, but in general, we see more and more be digitize overtime.

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

I think the hardest part is dealing with humans, because digital transformation is not only about technology as we ok with technology in general and we have no issue with getting good technology and installing, but to be honest to think differently about the process, and in the process digitize you have also digitize the thinking of the process so you have to streamline the process, you have to make sure that the process is not just doing the same things but online, but actually you reduce the approval chain, you make sure only the necessary people are included, so you need to reengineer this process and more important is you need to equip the people on the grand, the people who generally approve these processes and manage them first with digital skills, so they are able and aware and can go through this transformation, also new mentality because digital transformation require new mentality, its not the old one and bureaucratization and long approval. It's a different mentality, people really have to live this online experience, people have to reduce resistant to change, so it's a change process not only technology introduction, so this the type of thing you need to deal with people, make sure you address their issues, make sure the new process does not include the same in efficiency, make sure that people get by in and have some incentive for them to join, So, I think those are the biggest hurdle in my opinion and this is the reason why most of those projects are maybe will not be as successful as they should.

you to come there and there is multiple thing that you need to do. So I think there's a lot of opportunities, you just need the right leadership, people who can take some risks, people who can make other people around them a little bit uncomfortable and put some discipline and have a clear targets, because the only reason you improve is you wont to enhance your KPIs, you wont to enhance how fast you serve your customers, you wont to cut cost. So if you are thinking with KPIs holding people accountable I think this agendas are possible, its not easy but they are possible there is a lot of people who can help from a technology side view, we have a very good ecosystem now of company who can help you go through digital transformation we have more expertise in process engineering, so you can bring all of these people to the table and try to understand the customer point of view and build really good service but first you need to have the right leadership, you need the right people who know what they are doing, who can execute these plans because we have a lot of ideas and plans and strategies but we don't have people on the ground who can implement them, so you need that person who can implement, who can take the strategy back to KPIs in deliver, improve. So, I think the human factors one of the biggest things specially leadership, people who know what need to happen, who can empower the right people around them. Like what's happening now in the Civil Services Development Bureau, they have the right leadership, the right people who can execute, they are empowered, they know how to manage up and manage down, so you see a lot of good changes very quickly, so it's definitely possible.

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

There is a progress, more things are happening, I would say it's a bit slow, because we started very early, we had a huge momentum, the emption was huge, but its slow down a little bit, maybe because we were ahead of a lot of people, we slow down. Theres a progress, its fragmented as you initially mentioned, different people are doing similar things, but there's limited collaboration, but I would say its happening in slow and fragmented way..

2. **In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.**

In my opinion, that everybody now knows the importance of digital transformation, its not like five years ago or even earlier where consultancies encourage for digital transformation. Now, everybody knows. Mainly, because of the online services, like Talabat, Sununu (we have those types of services almost in all of our shopping experience Talabat food experience. So, now when you tell anybody I can improve service and I can get better faster with digital, they all believe you. So, the lack of experience that we use now have not our biggest obstacle anymore, people believe that will help them, people believe it's possible. The Roadmap, I think there's no one roadmap. Because now people know in every sector of the economy, they need to do it, private sector they know they need to do it like I had some finds of mine who are managing startup whether in chemical, manufacturing or in fashion, retail and they all knows they can benefit from AI to get better faster product, to get better personalization.

So, I'll not say there's a clear road map, each business, each government entity, maybe government as a haul, big tick companies, everybody must have their own roadmap, and it has to be really based on some KPI's, something will benefit the customers. The issue that we have in general in our culture is that we don't have a lot of KPIs, we don't have people holding each other accountable, or quality of service. We usually improve after we have problems. So, we are less in the planning side, empowering, executing and more in the fire fitting. We like to find issued and address them.

I believe each entity when they go over the cultural change, when you have people in government, people in private sectors that believe in quality and believe that they need to challenge their self-every day I think this road map and times lines will happen. What I see generally, we are a attracting good companies that can deliver the technology, we are also attracting some business consulting and business consulting culture of people who know how to do digital transformation, process engineering, and a lot of the times we have the financial resources to do these things, what we need as a road map is to really try to push up our self as entities to work more with our KPIs, to push our self on a coordinated way to enhance services as we go. So, to become more competitive as a nation and as a business, usually since we know our culture the only things that get done are the things that we have a lot of leadership involvements. I will give you an example of Oman, I have my friend he is the undersecretary for Communications and Information Technology at the Ministry of Transportation and Communications, what's happens is they establish digital transformation strategy, he was giving the task by the His Majesty Sultan Haitham bin Tariq and the Prim Minister to deliver on this digital transformation agenda, so every time in quarterly basis, he report the progress on behalf of all ministries including his ministry as they sometimes reported low performance on this, and monitor. It's a nation agenda it's has the leadership focus, they don't have enough resources but what ever they have they manage deliver what they can. The lake of skills people that's an issue.

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.**

No

2. **Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?**

No, I only know about TASMU initiatives. I just here and there as I explained previously. The Bureau has their own roadmap, the ministry sometimes talks about AI, other things, but I am not sure about the national roadmap if its existing digital transformation plan at least for the government. They published cloud computing, statistic about the business environment, skills and workforce, but to be honest I think they sent us a clear message about digital transformation, plan that they are monitoring, maybe its will come as a part of the NDS (National Development Strategy).

3. **If you could suggest any improvements or modifications to the proposed roadmap, what would they be?**

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Participant D

Brunel University London

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.

All my life in QF (Qatar Foundation Education City), If you are taking about digital transformation to some extent, I covered it from two perspectives:

1- **From educational perspective:** as I work for strategy and planning department, we had to look at the challenges on digital transformation when it's come to preparing the capacity "Human capacity: the people who can lead or the people who participate on these special in QF universities". The mean object "are our university graduate students capable of working on positions or entities related to digital transformation...etc.". In short and based on the study that was done by one of our consulting firms that I participated in as well, the answer was no. The reasons behind this are two mean reasons:

Firstly, the labor market: the transition from university to the job, not clear what is digital transformation, especially in the government sector not clear how the business digital transform, no framework, no regulations. Yes, it's coming up by MCIT (Ministry of Communications and Information Technology) but still they aren't clear regulations and there's not a clear path.

Secondly, the education curriculum itself, ok now it's being solved a little bit within the University of Doha for Science and Technology, as there's a clear field related to IoT, digital transformation. Anyhow, in general the curriculum still not support the students to come out from the education system with transforaminal thinking.

So, these is the face part of educational perspective.

The second part, When I worked QCRI (Qatar Computing Research Institute), I wasn't looking at digital transformation or working on, but I worked for AI (Artificial intelligent) and introducing AI to the government and so on. Because I was part of a team that worked at the first AI National Strategy. Now that strategy being also revamped, recently as we talk by MCIT they hire consultation firm working on it. The first version was very simple as its blueprint by QCRI team and then MCIT adopted as a Qatar National AI strategy, and for sure within that National strategy there are different challenges relevant to digital transformation as well as if you talk about AI, it come to human capacity building and lack of skilled people who are leading the changes. The universities don't have the right curriculum to prepare people to take positions for jobs that relevant to digital transformation. On the other hand, regulations, laws in terms of data sharing, infrastructure. To be honest, you will find some frameworks, and no one adopted them like MCIT worked on frameworks with consultation company and came up with the plan but no one is adopted it, one more example Enterprise Architecture, they comes up with a frameworks and circulated to all government entities but no one is adopted it. Or you will find the regulations do not exist as of now, but things are moving but slowly. Like we are now talking about the data and I think last year or the year before they lunching new regulations in terms of data and the use of data even on that document there was document related to the IoT and smart cities and so on.

Brunel University London

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

In general, as I said we have the problem of maintaining the talent, some people may say its easy for Qatar to attract the talents but its not as the cost of living is high. As example, the talent students who's studying at Education City Universities like CMU " Carnegie Mellon University" they graduate and they don't find job, then there's a miss match between the job opportunities in the labour market, number of graduated students and the regulations related to visas. What is usually happened, foreigner study at CMU computer science of Information System, then when he graduates the sponsor ship get cancel so he needs to be transformed from QF to someone else (should be an employer), let's say that person didn't find the job within three months which is usually the case, then his staying in the country will be illegal. So, they must migrate, even if they want to stay, they will not stay. This one problem makes it difficult to have a high-quality people to work on digital transformation in general.

The other problem to be honest, I see this problem in general not only for digital transformation even for other issue like cyber security, IT, digital technology, AI and what so ever, ok whose usually leading those activities in the country the government and more specifically the relevant ministry in our case let's say MCIT, but what is happens is that imagine that entity that should lead the efforts, initiatives that are relevant let's say AI, digital transformation and so on you would usually assume they should have the best people, the best clever and so on but usually this not the case not because of them but because of lets go back to the laws and regulations. When person get the options to work the salary that are offered in the government services or government entities and so on are much much lower than the offer provided by private sectors. So, if you have talent let's say graduated from University of Qatar, CMU or any other grate universities abroad you will give them the options of are you welling to work for MCIT or let's say Ras Gas or Qatar Foundation, they will take Qatar Foundation (QF) and the Ras Gas because the salary much much higher, that why usually you will find not the best (talent) people are working for government, and not the best people whose taking decisions, I don't have specific number but let's estimate I would say maybe 40% or maybe maximum 50% of the people in the government are like one of the best because maybe they have their own agenda to work for the government even at the expense of having better salaries in private sectors. But usually what happens is you don't have the smart people in the government. And the drawback of this is you wont the response people to be the ones who are making the decisions in the country, the one who are leading the digital transformation, the one who are leading the AI and so on. so, for me this are a very very big challenge that need to be resolve, they should be away to attract the best mind to work on the government entities because the end of the day government entities are the ones to control what's happens in the country not like another countries the industry have sort of influence, here it's the other way around it totally the government has influence on what's happening and so on, this can be for all aspects like business, IT, eHealth and cyber security ..etc

So this is one of the main challenges, other challenge is as we discussed earlier, the regulations there's no clarity either no adopting or there are no regulations at all, again this should be fixed, I am not smart cities specialized but lets have example: cryptocurrency or digital currencies it has been a trend for three or four years now but we still don't have some sort of regulations that have regulate the process, so the people aske is it legal to purchase the cryptocurrency in finance, some people received a call from central bank to block their credit cards as they not supposed to buy the cryptocurrency, other says no its fine you can buy as long as you not importing it to Qatar or not using it at your Qatari credit card. Legislation is not clear, if there are legislations no one are adhering to them.

In short, the main two challenges are, regulations in general, two parts either no regulations or there's regulations but no one is adopted it. Secondly, capacity building for the people who can lead the transformation and part of this challenges again relent to the regulations which is related to the visa for immigration and labor process.

2. What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.

In the government the obvious problem is the bureaucracy, in the sense of that they are not quick to adapt, they are not very flexible, they like to be very stable, they don't wont to try new ideas, and to be very agile in the sense that you know we are going to try new solution, we going to see if its will work or not. They should be very planned, very slow, takes years and the moment they see something might fail directly they cut it off.

Again, a lack of collaborations between the different ministries and relevant stakeholders as well. Lets talk about my field as I am a researcher, I am in QCRI working on a research project lets say its about facial recognition as its your field, I'll find someone else at the same university in a different department working on the same project. Yes, maybe the research question might be not the same but the idea it's the same and you will be wounder why we do not work together at least like sharing resources or what's ever, imagine this can happened in the small scale as we all at the same university, then its goes within the same people at the same ecosystem. For example, lets talk about QF, I am at HBKU (QCRI) working on facial recognition system, another person who's working at HBKU (Collage of Science Engineering) working as well on Facial Recognition System and third person who working for CMU working on the same topic Facial Recognition System and suddenly you will find three or four research grants no ones know about them from HBKU or CMU, you will found someone from MCIT " TASMU" working on the same topic Face recognition System and you will find someone from free zone hiring an international consultant to work on the same topic Face Recognition system.

So, the key failure point is the lake of collaboration between stakeholders. No integration related to initiatives or efforts for the smart cities and digital transformation.

3. **What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?**

The opportunities are clear, the readiness of the infrastructure, if you look at the ranking in term of the infrastructure either as an architectures or technology infrastructure, you will find Qatar one of the tops in the world, for technology infrastructure (Internet speed, fibers, connectivity 5G, Wi-Fi connectivity).

You also might consider there is a plan as I understand to grow the population, which means you need to manage the people through smart cities.

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

Sorry I am not aware of the smart city. I have conversation with my colleagues who works for Msheireb (consider as a smart city in Qatar), she said Msheireb technically is consider as a smart city, but the way of garbage system and parking system its not consider as a smart city its consider as a smart district.

2. In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.

In general, as I said there should be better integration between the different stakeholders. And sort of guidelines, initiatives, strategy, and frameworks, to make sure the implementation aligned with a specific goal. Thers should be definition for the digital transformation from the government perspective, like we are transforming Qatar, we are calling for digital transformation, is it just automation of services or wider than that and if its wider than that so what should we do, there should be a document or guidelines to lead everyone otherwise everyone will works in silos with their agenda and motivations.

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.**

No

2. **Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?**

I am not aware about the roadmap; I know there are some initiative like TASMU and Digital Vally but I am not sure about the plan or the roadmap.

3. **If you could suggest any improvements or modifications to the proposed roadmap, what would they be?**

No idea about the roadmap.

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Participant E

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify **progress, challenges, and opportunities, and address gaps in previous studies. Findings will** contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.

From my background, I am a computer science background and my master studies I did my thesis was about the digital transformation itself and the level of Qatari companies specially in private sector where is the level of the digital transformation and where did they reach so I have a little deep study in this area.

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

   Main challenges in Qatar, maybe because there is no clear regulations clear policies and no standards for the digital transformation and each entity or each organization is trying their best to have their own policies and their own initiatives in this journey .

2. **What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.**

   The Manin failure factors, As said there's no regulations so there is no authorized maybe we can see authorized or entities can authorize that the tools you are using for digital transformation like the specialized sensors, chips devices whatever it requires for digital transformation, there is a lot of prerequisites before the digital transformation we need to have the prerequisites available we have to activate the machine learning, Internet of Things (IoT), smart sensors we have we should have the regulations and policies for these tools before we move into the digital transformation once we have this baseline so we can build on it that digital transformation so we need to activate these and to have a clear unified regulations and policies for these tools.

3. **What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?**

The only opportunity we have is coming from IT people's perspective, they are trying to encourage others for this but we always face this challenge at this resistance from others anyone that's not in IT field always resist the digital transformation they resist the technology to use the technology and the first step what about the digital transformation is beyond that using technology itself so this is one of the challenges for there's lack of opportunities here we are trying to hunt any opportunity we can find as IT people but there is no that even though we have this slogans this encourage world that we are the hub of digital transformation and Middle East we are the hub but in reality there's no create opportunity that we can catch, not that expectation not about expectations but we try because we tried I have similar of projects I have too many initiatives anywhere we submit these initiatives and discuss it with decision makers that we get no support we get no responsible of this. Keep the current as it is.

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

   The current progress of digital transformation In Qatar, I can't say that there is no current progress we can't say there's individual progresses each entity is working separately so the initiatives from each one and this is one of the main challenges for the digital transformation they are working like competitors plus once you say it's digital transformation for smart city you should include the whole city so the main point in including the whole state you should have integration, and all the entities in Qatar against integration all of them not no exceptions all of them they have these boundaries these limitations we have confidential data we have sensitive data we against integration even though all these data are belonged to the government not the entity itself this is my main challenge with other entities whenever we are trying to integrate with other entities nor our data are sensitive our data is confidential, we are using it for government not for personal use so this is the main point to have progress across city we have should have integration. GDX is a government data exchange that's live under MCIT (Ministry of Communication and Information Technology). We already have our channel through GDX, GDX is a portal each entity should have their account so once you log into the portal you have your username password you click the share so you log in you choose from the entities all the available you choose what services you want from there the data you want from the other entity, I just submit the request that I need this data from this entity, and they review it from their site and evaluate the justification that we provide then they accept to give us this data or not, it's all based on some level of a agreements, sometimes they refuse if there's no justified reasons, request but we already have some kind of integrations GAMA (General Authority for Minors Affairs) for some records of ships and vessels, they contact with us through GDX so they once if they need any data from this ages so they collect the data from us from institution to institution, and we are just couple of days discussing to have the same integration with the single window, because we have some data from their side and they need some data from our side so we are using this and also we had a meeting last week with the Planning and Statistic Authority, they have the project of open data it was with MCIT first, MCIT who initiative the open data portal and now it's move to the planning and Statistic Authority, and they are no contacting all the entities to getas much as data they can, useful data to make it available through this portal, open data portal so we asked them about the options of integration they said it's OK with the direct integration or through GDX, so we have both options sharing data is improved it's improved yes but still some entities they are open for sharing data but unfortunately they are sharing all data expire data , historical data not valued data. Some part is like open data portals need to be updated data quality data especially the objectives behind this project is to help users just like your studies or thesis, or any experiment, should be updated and quality data validated.

2. **In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.**

We have good vision (Qatar National Vision 2030) perfect from all the aspects. The main issues that we are facing but there is no clear implementation for this vision and no clear guidance and force enforcement that enforces all the entities to follow the division itself or what they work specifically as stated by His Highness The Emir, I believe the roadmap would be clear. Once they work all together as one government it will be clear roadmap and the issues that as I stated before each entity is working individually once they have one clear goal it should be the one the only goal for them or how to achieve this vision so once you collaborate together you will the roadmap will become by itself to be created once you collaborate together to targeting this vision.

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses. Please check your review on the strength and weaknesses**

   No

2. **Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?**

3. **If you could suggest any improvements or modifications to the proposed roadmap, what would they be?**

I have not seen the roadmap, but I had several of meeting with some entities or some teams that working under the initiative of TASMU (The Smart City), there's lots of lots hidden agenda in this initiative, so we had couple of meetings with them they are trying to enforce their projects and we at MOT (Ministry of Transportations) not seeing that value on this projects it's not one-one situation it's only one side winning situation that's why we are we have a lot of comments and concerns about these projects so I'm not number one fan for TASMU project. Yes, once we have a clear special that TASMU approach under the umbrella of the smart city itself, should be the TASMU more the smart city project but there's a lot of duplicated projects there is mis distribution of the projects between the entities there are bringing some projects that it's not under our specialization as MOT, some projects it's more related to Q.post they are asking us to implement it the roadmap is not clear, the requirements they are requesting it's not feasible, they asking us to implement a huge projects consumer and invest a lot of resources and asking us to implement on their platform, which is not getting us the benefit that we need if you are targeting to unify everything so you have to have a unified platform first one the government not after each entity has their own platforms in cloud and now you are coming to tell me that I should build a new infrastructure on your platform and even though it will be for the limited time for that time for the contracts only then I need to move it to my platform so this is extra costs. So this is not this is not smart solution at all, once you are asking to have it in one platform so that the data transformation will be easy within one platform you will connect it to the other entities and you will work all in the same platform so this is the target of having a smart hub smart solution you are giving me for the period of the contract only so where's the sustainability for this.

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Participant F

Brunel University London

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. **Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.**

I've been working in IT for the past 25 years and I started as a developer and then I have developed my career path toward consultancy so I'll be care business consultant and then assisting agencies in and transferring their manual work into IT so automation business process automation and business model business process remodeling this is where I spent most of my time as a in terms of consultancy and guidance to agencies and I have worked with many organizations including Qatari Diar and Lusail at the time of establishment of those two companies, Qatari Diar is the development company that built Lusail city and builds different cities around the globe not only in Qatar, but they are the one who is main contractor for building Lusail city as a smart city

Page 1 of 6

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

I can see that regulations are still not being made in a place that is not being adopted and supported by the government and large scale and so there are many things that are not yet regulated and awareness about existing regulation is not mature in the country especially among main or key suppliers that would like to provide the solutions.

2. **What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.**

Aactually, it's the holistic approach when we talk about smart cities it's not a single entity business it's usually involves different entities for example if I would like to guide the ambulance through the best road to take to reach the hospital if I am within a smart city that can provide live feedback to the Ministry of Health about busy streets then they can use this information to smartly guide the ambulance to reach to the patient quickly and which to the hospital and on the timely manner so it's kind of integration and that integration was facing lots of difficulties and there is no infrastructure that unites all agencies into a common language that can be shared among each place and also to get that kind of access from certain entity it's very difficult to obtain each entity uses its own data as its gold that nobody can access until you reach the regulation that enable information sharing or data sharing it takes a while and maybe that's why the vision of Lusail city hasn't yet been implemented as it was anticipated and currently it is being reimagined by other partner, so it's now being put in place but if you think about it should have been made at the infrastructure level, but due to the lack of regulations the lack of integration this had delayed the domination of smart city

3. **What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?**

Aactually there is a huge opportunity first of all Qatar is transforming quickly into digital technologies and there are mature strategies being put in place and also the infrastructure has benefited a lot from the World Cup hosting and there are lots of positive really infrastructure that can be utilized to implement smart city logic when we speak about smart cities it's not only about garbage collection or smart it's more about traffic management and also making an informed decision instantly on the busiest time of the day time of the week so that signals will work in the manner that does not stop the flow for the drivers for example and that thing is being put to place there are lots of cameras connections and technologies are being widely spread so now it's the layer of utilizing this infrastructure and making business, making meaningful applications now there are lots of opportunities to study and it needs kind of brainstorming kind of beings that are currently existing for example in the morning where streets are too busy we can say that most of the traffic comes because of school X or comes because of road Y oh and destination Z in that sense that information can be handed over to related committee not only to one owner because if it is only one owner that looks after this he will solve the issue from this point of view by maybe adding regulations but sometimes stakeholders can change the formula entirely let's say for example a Ministry of Education can enforce public schools to reduce transformation cost because it is the school bus the school bus fee that made bills using that facilities which then makes the road be busier with the smart cities I would think that using this technology would make every citizen's life easier I don't have to rush in the morning to reach my duty and don't have to get early or late because of traffic jams and when smart city model is enabled things will be also not only in terms of the traffic but also in terms of parking. Parking is really hard in busy areas in Qatar and many buildings are outdated so that they don't have an underneath parking if smart cities model is enabled I would anticipate Google for example or other application customer application that can guide you to where to park and how to get to my car easily and which road I can use in terms of existing transportation in Qatar, sometimes people will say my car is the best solution to travel from or Point X to point Y. but if he spent half an hour looking for parking where there's a solution that can let him park in 5 minutes and move to the area where he wants to go through other transportation options that are available in the country right now things will be much easier for him but the lack information and the lack of the technology will let people be in pain without meat they don't have to be in that situation and these are quick examples but if you can dig more also there are many areas about certain cases of for example what is the best place to build the next park in Qatar, based on analyzing the growth of the busy areas and busy times and also maybe reading smart sensor information about weather in Qatar, humidity and quality of air it will make better informed decisions where the next park should be this is what also one kind of solutions that can be made when you think about smart cities and with other regular applications for example how can we effectively run water pumps to evacuate out drain the rain fall for some after the rainfall this kind of applications can be also looked at when things are connected and that are studied in different models and AI could get clips on this and guide this should be done or maybe we have an area that needs to be served in a better way and this is what comes to my mind right now

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

I think that halfway, I can see that there are lots of initiatives coming right now and there are contracts that are being awarded to telecom companies for example like Ooredoo to establish several hubs within Lusail city for example to convert it to a smart so I think we are halfway towards that vision but as I mentioned the relations and data transformation policy has to be made data share policy sorry, has to be put to make it easier for all stakeholders to have a stake in making decisions and to leverage the data and use it to better serve, I think TASMU is about services but not about data

2. **In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.**

As I said they regulations being put in place and privacy being protected because it's a main killer for the project when citizens who refuse certain things because of the privacy so if they have if they insure that privacy is protected and you are benefiting out of this technology it's not there to monitor you this is the best to help you out provide you with better convenience and also regulations in terms of how can we connect different sources into one how can we share information across different stakeholders data from Ooredoo to serve data from MOI (Ministry of Interior) and serve data from Hamad Medical all of that can also be helpful in terms of smart cities some, so these would be very much helpful if I got your question right

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.**

Yes I'm familiar with that, well the strength now is that Qatar having a vision which is 2030 this is one of the key elements that supports digital transformation and moving towards smart cities also steering committee that has been established to overcome obstacles among, let's say delays that usually happen within the project implementation across different stakeholders from different strategies and so this this also is a good strength point that there's the steering committee is monitoring and they are progress reports being published on that across the government so and that also helps in putting the smart city vision into implementation of manners this is what comes to my mind, again the same weaknesses it's kind of common infrastructure that share the information and securely on the privately if that comes into place all stakeholders would be confident enough about information security and cyber security as well so one of the threats to me the key strength for smart cities the cyber security concern so if someone could alternate the rail route it would be a disaster, so that's why things has to be taken into consideration and establishing the central security and policy could also assist them in making those risks

2. Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?

I don't have the information.

3. If you could suggest any improvements or modifications to the proposed roadmap, what would they be?

I would say that machine learning and AI came recently and we'll take a task force that understands the opportunities and find unseen opportunities that are not currently backed in division would be very helpful, they are lots of systems that have been implemented earlier by individual organizations if that data can be collected and can be put into a certain models I think that there are use cases or overshoots that are hidden right now and are not put into the plan that we can see from that data pie letting different AI models learn from it and it could change the game in certain cases for example if the plan was to expand one street because it has traffic jam it could tell us that it's totally different place that we need to address that problem this is not the Root cause still root cause analysis could benefit a lot from existing data if it was shared and also exposed to AI models

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Participant G

Brunel University London

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.

TASMU Smart Qatar Program. I, with the team, overseen the program in the development phase and the first 5 years under the supervision of HE Reem Al Mansoori, assistant undersecretary for digital society. Developing the digital smart country strategy focusing on 5 sectors: transport, logistics, environment, healthcare and sport. Now I'm taking more of a quality assurance role in the operation stage

This initiative is under the Ministry of Communication and Information System.

Section B: Challenges, Failure Factors, and Opportunities

1. In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.

When we developed the program, we tried to capture all required work to make sure that we are heading in the right direction, so we focused on the completing the picture,

- enabling projects: focusing on regulations, funding mechanism, governance.
- the digital ecosystem: were we focusing on bringing the talent, diversify the economy. Include everyone and focus on the skills required for the future.
- developing the assets and building the roadmaps for the sectors, developing their digital transformation roadmap including the projects they need to develop to achieve our vision. Also building the common infrastructure layer where we have common services.

Some of the issues are

- From experience one of the major issues that we faced is silos in the government. Government entities don't share the data which leads to efficiency issues, and this is still an issue leading in delays.
    - Data fragmentation. Different government entities store and collect their data independently leading to fragmented insights which we try to fix by creating the common central platform but it's taking time
- government procurement process. The current procurement process takes up to a year after approving the budget of each individual project.
- The maturity of the local market. We found it a little hard to find a good match with some of our project's requirements. Technical and business expertise is not easy to find leading to retender many projects although we wanted to support the local companies in many cases.
- Attracting and retaining talent in the field of emerging technology. A lot of procedures need to be changed to overcome this one. Tech start-ups find it a little expensive to open and operate in the country.

2. What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.

- As I mentioned in previous questions, resistance to change, or silos. Currently, change management is a top priority for us. Nonetheless, it presents several difficulties due to several factors.
    - Some want to maintain ownership and perceive our involvement as a potential threat.
    - skill gap. Although we have developed a digital skills strategy, it has not yet transitioned into the implementation phase.
- Centralized approach for procurement which is not leading to innovation. It's taking long time to approve a business case which in technology field is very long

3. What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?

plenty of opportunities if we overcome the issues. I'd highlight the 2 major ones :

- Enhanced efficiency getting insights from collected information from different entities. This will lead to enhanced public services which will eventually lead to an improved quality of life
- Diversifying the economy and not only depending on oil and gas as income. Investing on the development of tech assets will attract eventually business and startups

Section C: Current Progress and Roadmap Elements

1. How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?

A lot of delays because of the procurement process and grand the fund for individual projects

2. In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.

It's Data and data collection. Without the common infrastructure layer (centre platform) where we aggregate the data from everyone there is no digital transformation

Section D: Stakeholder Views and Proposed Roadmap

- Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.

The strengths it covers all aspects as mentioned previously.

The weaknesses, it is not coming from the highest authority in the country which makes it difficult to implement effectively and on time leading to a lot of delays and collaboration from the owners

- Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?

All five stakeholders have actively participated in the strategy development phase. We consider them both as the owners and implementors of these strategies, while we assume the roles of experts and funding arm.

However, the journey hasn't been without challenges, as funding and accountability have emerged as common issues. Any delays in project implementation, regardless of the reasons, not only affect that specific project but also have ripple effects on all interrelated projects.

- If you could suggest any improvements or modifications to the proposed roadmap, what would they be?

I believe it's high-level endorsement in the country and give clear direction that's its for the benefit of the country.

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Participant H

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. **Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.**

Yeh, I am IT manager at Ministry of Education, I have enough background about the digital transformation you can say solid to make people life easier, services and reduce the traffic, lots of benefits, like working from home. Automated services should be easier not complicated. Digital transformation does not transform from manual to digital, its more than that, make the system friendly, the process model.

I have IT background, Computer science, engineering management specific in digital transformation, data management and to establish IT, I work at ministry of education to digitize schools and the ministry of education

Page 1 of 4

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

The main challenges the fixed structure for the government entities, its take a while to change, technology is so fast in changing and updating, the structure takes ten to fifteen years to be updated, and this is not helping to foster the digital transformation.

For example, some entities don't have the security department and one of the requirements of digital transformation is the secure data, the current structure the security department under the operation.

Strategy as well some of the government entities, they don't have the strategy to align with the digital transformation.

The budget as well.

2. **What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.**

As I explained previously, if that challenges not addressed it will become as a failure.

3. **What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?**

The infrastructure strong, the government support as well for the digital transformation, the people awareness about the important of digital transformation special after Covid-19

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

It improves, they had progress, the need of AI to become mature.

2. **In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.**

No idea about the roadmap

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.**

No idea about the roadmap

2. **Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?**

No idea about the roadmap, the lack of awareness and communication we don't have the chance to look at the digital transformation roadmap.

3. **If you could suggest any improvements or modifications to the proposed roadmap, what would they be?**

For sure after I have a look at that roadmap.

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.

Participant I

Questionnaire (Qualitative)

Smart Cities in Qatar: Toward a Sustainable Digital Transformation

Introduction:

This study aims to create a framework for sustainable digital transformation and innovation in adopting smart city projects in Qatar. The research scope involves examining the progress, challenges, failure factors, and opportunities in digital transformation and innovation for similar projects. The study's significance lies in its potential in the fact that it can positively impact the lives of its residents, improve the quality of government, and promote livelihoods, ultimately improving living standards through sustainable digital transformation in developing smart cities.

Data collected from questionnaires will be analysed to achieve research objectives, identify progress, challenges, and opportunities, and address gaps in previous studies. Findings will contribute to the development of a new framework for sustainable digital transformation and innovation in smart city projects. Additionally, the data will offer insights into stakeholder perceptions and attitudes, informing policy and decision-making related to digital transformation and smart city development in Qatar.

Section A: Participant Background

1. Please briefly describe your background and experience related to digital transformation and smart cities in Qatar.

I hold a degree in Electrical Engineering, and I have 26 years of experience in diver's places, vey different sectors in Qatar, including Electric and Water, government, oil and Gas, and over these years I managed a lot of different types of teams in ICT, and we work on a lot of things different types of digital transformation, including software development, business enforce management, documents management, website solutions, even in the field we think about smart fields and doing similar things not only in cities increase as well.

Page 1 of 5

Brunel University London

Section B: Challenges, Failure Factors, and Opportunities

1. **In your opinion, what does Qatar face as the chief challenges in implementing sustainable digital transformation for smart cities? Please explain.**

Some of the main challenges have been becoming less now the country over the last 26 years of my work has developed a lot has changed a lot has improved the mattresses and methods but the main things are the main challenges are mostly regulatory challenges hurdles in the process of the regulations and we have also a lot of cultural factors so people may not accept some of these changes sometimes the technology is limited so that's how its actually.

2. **What are the main failure factors in implementing sustainable digital transformation for smart cities in Qatar? Please provide examples if possible.**

I'm saying it's the lack of clear vision and strategy from the beginning some of the projects are just somebody thinks about something and just suppose and then does it and sometimes it's not approved fast enough I have a clear example in 1998 at the Ministry of electricity and water where I was an engineer and there was a project that was being proposed was not approved at the time the project was to have smart metering of all the consumers and that would have been very easy to do because the populations was the population was less than 1,000,000 people now it's above three, it's what happens simple for the ministry to pay for the current consumers and the first of the new consumers in their new to include that as a as a meeting so that would have made things much simpler for them.

3. **What opportunities do you see for sustainable digital transformation in developing smart cities in Qatar? How can these opportunities be harnessed?**

We have the new technologies right now we have artificial intelligence we have predictive analytics we have Internet of things (IoT) and we have blockchain which is also useful, so we have blockchain for secure transaction Internet of things (IoT) and we could have a lot of good things connected to the Internet for example I'm comparing Qatar to my travel in other countries in this country 5G everywhere if you're going to the middle of desert you have 5G, if you go to an area further you will have 5G, right now I'm connected to you through 5G, having everywhere probably even adding in term of devices in different places through an Internet of Things technology (IoT) won't be very doable in the country it's a good opportunity to have lots all devices connected over 5G on the network and it would just work.

Section C: Current Progress and Roadmap Elements

1. **How would you describe the current progress of digital transformation in Qatar, particularly in the context of smart city development?**

I can see that the development has been happening a lot, I hear about a lot of projects on this some of them are relevant others are probably not but it's still contributing to the smart city I will say that during the COVID period we have to be more smarts in many of the services we have so for example all of the people were used to using their mobile phones to order things online which was not there at the time but that's part of what is becoming more be smart city, people were had didn't need to travel a lot and move a lot and go to stores to buy things so that's part of the smart city to me, in the government sector we have a lot of improvements we have improve in the services I remember going to one of the government departments and we don't need to use any paper number we get SMS on our number then we got SMS to go to do whatever the process was when the time was right so everything is becoming automated the country and become more smart as a smart city I'm sure that there are many projects that are working on that

2. **In your opinion, what are the essential elements of a roadmap that could foster digital transformation in Qatar? Please explain.**

First of all a clear vision with clear objectives as well and engaging all the stakeholders in this whole process, complete assessment at the current project we have as well as the future possible projects we have as well so this are mix together, that is provided a timeline that can accommodate the digital needed to do that so we cannot do things the old way as in a 10 year plan a 20 year plan or whatever this needs to go much faster than that, having a regular margin that we have having feedback mechanisms it's crucial for the adaptation of this thing so the citizens themselves should be part of this city transmission.

Section D: Stakeholder Views and Proposed Roadmap

1. **Are you familiar with Qatar's proposed roadmap for fostering digital transformation? If yes, please share your views on its strengths and weaknesses.**

I don't have any details I just heard about it being there no detail about it, yeah we just heard that it is coming , I never heard about what it contained but it will do when it will happen and we'll make itself so I'm sure that the roadmap if it was there it would have steps

2. **Based on your understanding of Qatar's key stakeholders involved in digital transformation and smart city development, what are their views on the proposed roadmap? How can their concerns and suggestions be addressed?**

I wouldn't know about this but I think that part of the stakeholders is the government it's the citizens themselves it's all compressed country so I have no idea where they are right now

3. **If you could suggest any improvements or modifications to the proposed roadmap, what would they be?**

OK my suggestion would be to include this more in this roadmap, my suggestion would be to use the latest technologies ,some of them in this call for example smart devices connection connectivity for example even using solar power which is available in the country, the sun here is really hot and we know about this at last 11 months a year and we should be able to power the whole thing by the problem that I see as sustainable performance so you don't depend on using energy different types of energy you have the time and just use it do you think it's sustainable I think it is very sustainable all these panels need some kind of cleaning yeah yeah yeah any maintenance OK Oh no

Conclusion:

I sincerely thank all participants for their valuable feedback, which offers insights into perceptions and attitudes towards sustainable digital transformation in Qatar's smart cities. This survey's findings will contribute to a new framework, addressing gaps and analysing benefits to improve government quality, promote livelihoods, and enhance living standards. The results will benefit policymakers, researchers, and stakeholders in smart city development and digital transformation in Qatar. Thank you again for your participation and input.