T.C.
ISTANBUL GEDIK UNIVERSITY
INSTITUTE OF GRADUATE STUDIES

SUSTAINABILITY ECOSYSTEM OF INFRASTRUCTURE DEVELOPMENT IN PAKISTAN

MASTER THESIS

Mouzam HAFIZ

Engineering Management Department

Engineering Management Master's in English Program

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DECLARATION

I hereby declare on my honor that the Master's thesis titled "The Impact of Transformational Leadership on Green Innovation in Organizational Management" has been written without resorting to any assistance that would contravene scientific ethics and traditions throughout all processes from the project phase to its conclusion, and that the works I have utilized are those listed in the Bibliography, and they have been used with proper citation (01/07/2025).

Mouzam HAFIZ

DEDICATION

I dedicate my work to:

My parents and family, whose daring efforts for my study, determination, love and support remains my source of motivation forever. Special thanks to my supervisor, who guided me at every stage with valuable contribution. I assure to study further and will always remember and love you.

PREFACE

I wish to express my sincere gratitude to The Almighty Allah for his kind blessings, who enabled me to perform my degree and this study. My respected study Supervisor, due to his valuable guidance, I am able to complete my study, my parents and wife for supporting and up keeping my morale for accomplishing this study, the respected teachers and other staff members of educational institutions under study for their cooperation and response to my questionnaire with interest, my class fellows and seniors who assisted me where I felt difficulties. I am thankful to all friends who helped me in this regard.

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SUSTAINABILITY ECOSYSTEM OF INFRASTRUCTURE DEVELOPMENT IN PAKISTAN

ABSTRACT

This sustainable infrastructure in Pakistan examines the multifaceted concept of sustainable infrastructure development, highlighting its crucial importance in the Pakistani context. As a developing country, Pakistan faces unique challenges in balancing the urgent need for infrastructure growth with the imperative of sustainability. The research explores the importance of integrating sustainability into infrastructure projects, particularly in underdeveloped regions where the effects of climate change, resource depletion, and socio-economic disparities are most pronounced. Sustainability in infrastructure involves not only environmental considerations but also economic and social dimensions that collectively contribute to long-term development goals. The research methodology employed in this thesis is based on secondary qualitative data, which allows for a comprehensive analysis of existing literature, sustainable projects in Pakistan, and reports on sustainable infrastructure. This approach provides a detailed understanding of how various sustainability principles have been implemented in infrastructure projects across different regions and contexts. The core of the study is an in-depth analysis of several major infrastructure projects in Pakistan, which are evaluated to determine the extent to which sustainability has been integrated into their planning, design, and execution. Among the projects examined are the Right Bank Outfall Drain (RBOD) projects 1 & 3, which are crucial for managing water resources and preventing saline water intrusion into agricultural lands. The study also reviews the Mangla and Tarbela Watershed Programs, both of which are pivotal in maintaining water supply and managing watershed areas to prevent soil erosion and degradation. Another significant project analysed is the Billion Tsunami Tree Project, a large-scale reforestation initiative aimed at mitigating the effects of deforestation, improving biodiversity, and enhancing carbon sequestration. This project is particularly important in the context of global climate change and Pakistan's commitment to international environmental agreements. The thesis also evaluates the Drawat Dam, Dasu Hydro Power Project, Diamer Bhasha Dam, and Kurram Tangi Dam Project, all of which are critical components of Pakistan's efforts to secure water resources, generate renewable energy, and support agricultural development. The findings of the thesis reveal that while Pakistan has made significant strides in incorporating sustainability into its infrastructure projects, several challenges persist. These challenges include the need for more comprehensive and long-term planning, the integration of social sustainability measures, and the adoption of advanced technologies that can enhance the efficiency and resilience of infrastructure systems. Additionally, the study highlights the importance of community involvement in the planning and implementation of infrastructure projects, as this can lead to more equitable and socially inclusive outcomes. The analysis suggests that although there has been progress, the sustainability of infrastructure in Pakistan is still in a nascent stage, with much work required to fully realize the potential benefits. The thesis concludes by offering several recommendations for enhancing the sustainability of

future infrastructure projects in Pakistan. These recommendations emphasize the importance of adopting a holistic approach that considers the environmental, economic, and social dimensions of sustainability. Moreover, the study advocates for the use of innovative technologies, such as smart infrastructure systems and sustainable building materials, which can significantly improve the sustainability outcomes of infrastructure projects. Furthermore, the research underscores the necessity of developing robust policy frameworks that support sustainable infrastructure development. This includes the creation of regulatory standards, incentives for sustainable practices, and the establishment of monitoring systems to ensure that sustainability goals are met. The thesis also calls for greater collaboration between government agencies, private sector stakeholders, and civil society organizations to foster a shared vision of sustainable development that aligns with Pakistan's national and international commitments. In conclusion, this thesis provides a comprehensive overview of the current state of sustainable infrastructure in Pakistan, identifying both the achievements and the challenges that lie ahead. The insights gained from this research are intended to inform policymakers, practitioners, and researchers about the critical factors that influence the success of sustainable infrastructure initiatives in developing countries. By addressing these factors, Pakistan can enhance the resilience of its infrastructure, reduce its environmental footprint, and contribute to a more sustainable and equitable future for its people.

Keywords: *Sustainability, Infrastructure, Resource Depletion, Renewable Energy, Ecosystem*

PAKİSTAN'DA ALTYAPI GELİŞİMİNİN SÜRDÜRÜLEBİLİRLİK EKOSİSTEMİ

ÖZET

Bu çalışma, Pakistan'da sürdürülebilir altyapı geliştirme kavramını çok yönlü bir şekilde ele alarak, sürdürülebilirliğin Pakistan bağlamında ne kadar kritik bir öneme sahip olduğunu vurgulamaktadır. Gelişmekte olan bir ülke olarak Pakistan, altyapı büyümesi için acil ihtiyaç ile sürdürülebilirlik gerekliliği arasında denge kurmakta benzersiz zorluklarla karşı karşıyadır. Araştırma, sürdürülebilirliğin altyapı projelerine dahil edilmesinin önemini, özellikle iklim değişikliği, kaynak tükenmesi ve sosyo-ekonomik eşitsizliklerin en belirgin olduğu az gelişmiş bölgelerde ele almaktadır. Altyapıda sürdürülebilirlik, sadece çevresel unsurları değil, aynı zamanda uzun vadeli kalkınma hedeflerine kolektif olarak katkıda bulunan ekonomik ve sosyal boyutları da içermektedir. Bu tezde kullanılan araştırma metodolojisi, mevcut literatürün, Pakistan'daki sürdürülebilir projelerin ve sürdürülebilir altyapı hakkındaki raporların kapsamlı bir şekilde analiz edilmesine olanak tanıyan ikincil nitel veriler üzerine kuruludur. Bu yaklaşım, çeşitli bölgelerde ve bağlamlarda sürdürülebilirlik ilkelerinin nasıl uygulandığını ayrıntılı bir şekilde anlamayı sağlar. Çalışmanın ana bölümünü, Pakistan'daki çeşitli büyük altyapı projelerinin derinlemesine analizi oluşturmaktadır; bu projeler, sürdürülebilirliğin planlama, tasarım ve uygulamalarına ne ölçüde entegre edildiğini değerlendirmek amacıyla incelenmiştir. İncelenen projeler arasında, su kaynaklarının yönetimi ve tarım arazilerine tuzlu su sızmasını önleme açısından kritik öneme sahip olan Right Bank Outfall Drain (RBOD) projeleri 1 ve 3 bulunmaktadır. Çalışma ayrıca, su arzını koruma ve toprak erozyonu ile bozulmasını önleme açısından hayati öneme sahip olan Mangla ve Tarbela Havza Programlarını da incelemektedir. Diğer önemli bir proje ise, ormansızlaşmanın etkilerini hafifletmek, biyolojik çeşitliliği iyileştirmek ve karbon tutulumunu artırmak amacıyla gerçekleştirilen büyük ölçekli bir yeniden ağaçlandırma girişimi olan Billion Tsunami Tree Project'tir. Bu proje, küresel iklim değişikliği bağlamında ve Pakistan'ın uluslararası çevre anlaşmalarına olan bağlılığı açısından özellikle önemlidir. Tez ayrıca, Drawat Barajı, Dasu Hidroelektrik Projesi, Diamer Bhasha Barajı ve Kurram Tangi Barajı projelerini de değerlendirmekte olup, bunların tümü, Pakistan'ın su kaynaklarını güvence altına alma, yenilenebilir enerji üretme ve tarımsal kalkınmayı destekleme çabalarının kritik bileşenleridir. Tezin bulguları, Pakistan'ın altyapı projelerine sürdürülebilirliği dahil etmede önemli ilerlemeler kaydettiğini, ancak birkaç zorluğun devam ettiğini ortaya koymaktadır. Bu zorluklar, daha kapsamlı ve uzun vadeli planlamaya, sosyal sürdürülebilirlik önlemlerinin entegrasyonuna ve altyapı sistemlerinin verimliliğini ve dayanıklılığını artırabilecek gelişmiş teknolojilerin benimsenmesine duyulan ihtiyacı içermektedir. Ayrıca, çalışma, altyapı projelerinin planlama ve uygulama aşamalarına toplulukların katılımının önemini vurgulamakta, bunun daha adil ve sosyal olarak kapsayıcı sonuçlara yol açabileceğini belirtmektedir. Analiz, ilerleme kaydedilmiş olsa da, Pakistan'da altyapının sürdürülebilirliğinin hala başlangıç aşamasında olduğunu ve potansiyel faydaların tam olarak gerçekleştirilmesi için daha çok çalışma gerektiğini göstermektedir. Tez, Pakistan'daki gelecekteki altyapı projelerinin

sürdürülebilirliğini artırmaya yönelik birkaç öneri sunarak sonuçlanmaktadır. Bu öneriler, sürdürülebilirliğin çevresel, ekonomik ve sosyal boyutlarını dikkate alan bütüncül bir yaklaşımın benimsenmesinin önemini vurgulamaktadır. Ayrıca, çalışma, altyapı projelerinin sürdürülebilirlik sonuçlarını önemli ölçüde iyileştirebilecek akıllı altyapı sistemleri ve sürdürülebilir yapı malzemeleri gibi yenilikçi teknolojilerin kullanımını savunmaktadır. Araştırma ayrıca, sürdürülebilir altyapı geliştirmeyi destekleyen sağlam politika çerçevelerinin geliştirilmesinin gerekliliğinin altını çizmektedir. Bu, düzenleyici standartların oluşturulmasını, sürdürülebilir uygulamalar için teşviklerin sağlanmasını ve sürdürülebilirlik hedeflerinin yerine getirildiğinden emin olunması için izleme sistemlerinin kurulmasını içermektedir. Tez ayrıca, Pakistan'ın ulusal ve uluslararası taahhütleriyle uyumlu sürdürülebilir kalkınma vizyonunu paylaşmak için hükümet kurumları, özel sektör paydaşları ve sivil toplum kuruluşları arasında daha fazla işbirliği çağrısında bulunmaktadır. Sonuç olarak, bu tez, Pakistan'da sürdürülebilir altyapının mevcut durumu hakkında kapsamlı bir genel bakış sunmakta, hem başarıları hem de önümüzdeki zorlukları belirlemektedir. Bu araştırmadan elde edilen bulgular, politika yapıcıları, uygulayıcıları ve araştırmacıları, gelişmekte olan ülkelerde sürdürülebilir altyapı girişimlerinin başarısını etkileyen kritik faktörler hakkında bilgilendirmeyi amaçlamaktadır. Bu faktörlerin ele alınmasıyla, Pakistan altyapısının dayanıklılığını artırabilir, çevresel etkisini azaltabilir ve halkı için daha sürdürülebilir ve adil bir geleceğe katkıda bulunabilir.

Anahtar Kelimeler: *Sürdürülebilirlik, Altyapı, Kaynak Tükenmesi, Yenilenebilir Enerji, Ekosistem.*

1. INTRODUCTION TO SUSTAINABILITY

1.1 Infrastructure Development in Pakistan

In an era marked by global environmental challenges and rapid urbanization, the concept of sustainable infrastructure development has emerged as a critical paradigm for nations worldwide (United Nations, 2015; Sachs, 2015). This is particularly true for developing countries like Pakistan, where the need for robust infrastructure intersects with pressing environmental and social concerns (World Bank, 2025a). Sustainable infrastructure encompasses not only the physical structures and facilities necessary for the functioning of a society but also emphasizes the integration of environmentally friendly practices, economic viability, and social equity. This approach ensures that development meets the needs of the present without compromising the ability of future generations to meet their own needs. Infrastructure development is a critical component of economic growth and societal well-being (Khan, 2022).

In Pakistan, the need for sustainable infrastructure has never been more pressing. Sustainable infrastructure encompasses not only the physical structures and facilities necessary for the functioning of a society but also emphasizes the integration of environmentally friendly practices, economic viability, and social equity. This approach ensures that the development meets the needs of the present without compromising the ability of future generations to meet their own needs. The focus on sustainable infrastructure is particularly significant in Pakistan, where rapid urbanization, population growth, and environmental challenges necessitate a more thoughtful and long-term approach to development. Pakistan's infrastructure has traditionally lagged behind its needs, with significant deficiencies in transportation, energy, water supply, and sanitation. These shortcomings have impeded economic growth, limited access to essential services, and exacerbated social inequalities. In recent years, however, there has been a growing recognition of the importance of sustainable infrastructure as a means to address these challenges. The country's strategic location, demographic trends, and natural resources offer unique

opportunities for sustainable development, but also pose significant challenges. According to the World Bank, Pakistan's infrastructure gap is a major bottleneck to economic growth and poverty reduction. The country's infrastructure quality and coverage are below regional and global averages, necessitating substantial investments and reforms (World Bank, 2019). The China-Pakistan Economic Corridor (CPEC), a flagship project under China's Belt and Road Initiative (BRI), has brought significant attention and resources to infrastructure development in Pakistan. However, ensuring that these developments are sustainable is crucial for long-term benefits (Rehman et al., 2020).

Sustainable infrastructure development is vital for several reasons. Firstly, it addresses environmental concerns by minimizing carbon footprints, reducing waste, and conserving natural resources. This is crucial in a country like Pakistan, which is highly vulnerable to climate change and environmental degradation (Adnan et al., 2024). Secondly, sustainable infrastructure promotes economic efficiency by reducing operational costs, enhancing productivity, and attracting investment. Thirdly, it ensures social inclusivity by providing equitable access to services, improving quality of life, and fostering social cohesion. The United Nations Sustainable Development Goals (SDGs) provide a comprehensive framework for sustainable development, with several goals directly related to infrastructure. These include Goal 6 (Clean Water and Sanitation), Goal 7 (Affordable and Clean Energy), Goal 9 (Industry, Innovation, and Infrastructure), Goal 11 (Sustainable Cities and Communities), and Goal 13 (Climate Action). Achieving these goals requires a coordinated effort to develop and implement sustainable infrastructure policies and projects (Rehman et al., 2020). Pakistan is experiencing rapid urbanization, with urban areas expected to house nearly half of the population by 2030 (Pakistan Gulf Economist, 2025).

This urban growth necessitates significant investments in sustainable housing, transportation, and utilities to accommodate the increasing population without exacerbating environmental and social problems. Pakistan's population is projected to reach 300 million by 2050 (Adnan et al., 2024). This demographic trend puts immense pressure on existing infrastructure and necessitates sustainable planning and development to ensure that future generations have access to essential services and a healthy environment. Pakistan is one of the countries most affected by climate

change, facing frequent natural disasters such as floods, droughts, and heatwaves. Sustainable infrastructure can enhance resilience to these impacts by integrating climate adaptation and mitigation measures into the design and construction of buildings, roads, and other facilities. Sustainable infrastructure is essential for economic growth and competitiveness. Efficient transportation networks, reliable energy supplies, and modern communication systems are crucial for attracting investment, enhancing productivity, and creating jobs. Sustainable infrastructure projects can also stimulate economic activity in various sectors, including construction, manufacturing, and services. Sustainable infrastructure development ensures that all segments of society benefit from improved services and facilities (MHRC, 2024). This includes marginalized and vulnerable groups, who often bear the brunt of inadequate infrastructure. By prioritizing inclusivity and accessibility, sustainable infrastructure projects can help reduce social inequalities and promote social cohesion. Developing sustainable infrastructure requires substantial financial investments, which are often beyond the capacity of the public sector alone. Limited fiscal space, high debt levels, and competing priorities constrain the government's ability to fund infrastructure projects. Attracting private sector investment and leveraging international financial assistance are crucial to bridge the funding gap (Qadir, 2023). Effective governance and strong institutions are essential for planning, implementing, and maintaining sustainable infrastructure. In Pakistan, weak governance structures, bureaucratic inefficiencies, and corruption hinder infrastructure development. Strengthening institutional capacity, enhancing transparency, and promoting accountability are vital for overcoming these challenges. Sustainable infrastructure development requires specialized knowledge and skills in areas such as green building design, renewable energy, and sustainable urban planning. However, Pakistan faces a shortage of technical expertise and skilled labour in these fields. Investing in education, training, and capacity-building programs is essential to develop the required human resources. Integrating environmental and social considerations into infrastructure projects can be complex and challenging. This includes conducting environmental impact assessments, ensuring community participation, and addressing potential displacement and resettlement issues. According to Naveed & Azhar, (2022) development of robust frameworks and guidelines for environmental and social safeguards is crucial to mitigate these challenges. A conducive policy and regulatory environment are

essential for promoting sustainable infrastructure development. In Pakistan, the policy and regulatory frameworks for infrastructure development are often fragmented, outdated, and inconsistent. Harmonizing policies, streamlining regulations, and adopting international best practices are necessary to create an enabling environment for sustainable infrastructure. PPPs can play a crucial role in mobilizing resources, sharing risks, and enhancing the efficiency of infrastructure projects. Developing a robust PPP framework, providing incentives for private sector participation, and ensuring transparent and fair procurement processes are essential for successful PPPs (Khan, 2020). Access to green financing is vital for funding sustainable infrastructure projects. This includes exploring innovative financing mechanisms such as green bonds, climate funds, and blended finance. Strengthening financial institutions' capacity to assess and manage environmental risks and developing policies to incentivize green investments are crucial (Zia-ur-Rehman, 2023). Building technical and institutional capacity is essential for planning, implementing, and maintaining sustainable infrastructure. This includes investing in education and training programs, developing professional standards and certifications, and fostering collaboration between academia, industry, and government. Developing coherent and consistent policies and regulatory frameworks is crucial for promoting sustainable infrastructure. This includes integrating sustainability principles into national and sectoral policies, streamlining regulatory processes, and adopting international best practices. Developing and enforcing standards for green building, renewable energy, and sustainable urban planning are also essential. Engaging communities in the planning and implementation of infrastructure projects ensures that their needs and concerns are addressed (Longsheng et al., 2022). This includes conducting participatory planning processes, promoting community ownership and stewardship, and ensuring transparency and accountability in decision-making. Leveraging technology and innovation can enhance the sustainability of infrastructure projects. This includes adopting advanced construction techniques, utilizing renewable energy technologies, and implementing smart city solutions. Promoting research and development in sustainable infrastructure and fostering innovative ecosystems are crucial for driving technological advancements. CPEC is a flagship initiative designed to enhance connectivity and promote economic growth (Ajved & Ismail, 2021). The project includes investments in transportation, energy, and industrial infrastructure.

Integrating sustainability principles into CPEC projects, such as adopting green building standards, promoting renewable energy, and ensuring social inclusivity, can enhance their long-term benefits (Fazal et al., 2023). The Diamer-Bhasha Dam is a significant infrastructure project aimed at addressing Pakistan's water and energy needs. The project includes measures to mitigate environmental and social impacts, such as reforestation, wildlife conservation, and resettlement of affected communities. Ensuring the project's sustainability requires continuous monitoring, adaptive management, and stakeholder engagement (Ullah et al., 2021). The Lahore Metro Bus System is an example of sustainable urban transportation. The project aims to reduce traffic congestion, improve air quality, and provide affordable and efficient transportation options. Integrating non-motorized transport, promoting transit-oriented development, and ensuring accessibility for all segments of society are crucial for enhancing the system's sustainability (McCartney, 2022). Sustainable infrastructure development is essential for Pakistan's long-term economic growth, environmental sustainability, and social equity. Addressing the challenges and leveraging the opportunities requires a coordinated and holistic approach. This includes developing and implementing robust policies and regulatory frameworks, mobilizing financial resources, building technical and institutional capacity, and fostering community engagement and innovation. By prioritizing sustainable infrastructure, Pakistan can create a resilient, inclusive, and prosperous future for its citizens. Infrastructure development is a critical component of economic growth and societal well-being. In Pakistan, the need for sustainable infrastructure has never been more pressing (Muhammadi et al., 2022). Sustainable infrastructure encompasses not only the physical structures and facilities necessary for the functioning of a society but also emphasizes the integration of environmentally friendly practices, economic viability, and social equity. This approach ensures that development meets the needs of the present without compromising the ability of future generations to meet their own needs. The focus on sustainable infrastructure is particularly significant in Pakistan, where rapid urbanization, population growth, and environmental challenges necessitate a more thoughtful and long-term approach to development. Pakistan's infrastructure has traditionally lagged its needs, with significant deficiencies in transportation, energy, water supply, and sanitation (Arshad et al., 2021). These shortcomings have impeded economic growth, limited access to essential services, and exacerbated social inequalities. In recent years,

however, there has been a growing recognition of the importance of sustainable infrastructure as a means to address these challenges. The country's strategic location, demographic trends, and natural resources offer unique opportunities for sustainable development, but also pose significant challenges. According to the World Bank, Pakistan's infrastructure gap is a major bottleneck to economic growth and poverty reduction (Rehman et al., 2020). The country's infrastructure quality and coverage are below regional and global averages, necessitating substantial investments and reforms. Although there is an emphasis on the importance of sustainability, the concept and practice are still new to Pakistan. Mainstream conceptions of development, especially in the infrastructure sector, continue to yield much that is ecologically destructive and socially unsustainable. The government is being pressed by global and local influences to heed the call for sustainable development, in the face of increasing ecological crises and socio-political pressures (Sharif & Tauqir, 2021). The high compressions of poverty in Pakistan—rural to urban migrations, landlessness, and rapidly growing cities—along with the current trend of development, were noted as factors that increase depletion of natural resources, damage to the environment, and perpetuation of social injustice. It has been realized that unsustainable development has contributed to these factors and, in turn, is worsening the poverty situation (Batool et al., 2022). Sustainable development is a term that has been much used, much abused, and much confusing. New to the terminology of sustainable development, Pakistan has been exposed to key challenges in the development of sustainable infrastructure. In 2002, the Prime Minister of Pakistan gave a keynote address at a seminar on sustainability, and in 2009, Pakistan became one of the countries with the National Conservation Strategy (NCS) to support a sustainable future. Only recently, through new policies, has Pakistan begun to focus on sustainability that meets the needs of the present without compromising the ability of future generations to meet their own needs (Banuri, 2022). With newly acquired funds from the Pakistan Poverty Alleviation Fund (PPAF), in collaboration with leading developmental organizations, Pakistan is attempting to adopt poverty-reducing, environmentally friendly, and sustainable development programs (Ali et al.,2023). In Pakistan, several examples of sustainable infrastructure projects aim to balance the need for economic growth and poverty reduction with environmental conservation and biodiversity protection. Despite the initiatives, the integration of sustainable practices in infrastructure projects is still

evolving. This research aims to explore the several factors influencing sustainable infrastructure development in Pakistan, focusing on policy frameworks, financial mechanisms, technological innovations, and stakeholder engagement. A structured approach to understanding the multifaceted aspects of sustainable infrastructure development in Pakistan (Waheed et al., 2021). The aim is to identify the key drivers and barriers, offering insights that can inform policy, enhance financial strategies, promote technological advancements, and foster inclusive stakeholder engagement. By addressing these factors, Pakistan can develop resilient, inclusive, and sustainable infrastructure that supports long-term economic growth, environmental conservation, and social equity.

RQ. 1: What factors hinders the progress of sustainable projects in developing nations like Pakistan?

RQ. 2: What are the benefits of sustainable projects in developing nations like Pakistan?

RQ. 3: How developing nations like Pakistan achieve the sustainability through implementation of sustainable projects?

1.2 Importance of Sustainability

The importance of sustainability in infrastructure development cannot be overstated, especially in the context of Pakistan's unique challenges and opportunities. Sustainable infrastructure is vital for several reasons:

1. Environmental Protection: Sustainable infrastructure addresses environmental concerns by minimizing carbon footprints, reducing waste, and conserving natural resources. This is crucial in Pakistan, a country highly vulnerable to climate change and environmental degradation. By incorporating green technologies and eco-friendly designs, sustainable infrastructure projects can help mitigate the adverse effects of climate change and preserve the country's biodiversity (Eckstein et al., 2021).
2. Economic Efficiency: Sustainable infrastructure promotes economic efficiency by reducing operational costs, enhancing productivity, and attracting investment. In Pakistan, where economic growth is a priority, sustainable infrastructure can provide a foundation for long-term prosperity

(Malik et al., 2020). Energy-efficient buildings, renewable energy systems, and smart transportation networks can significantly reduce operational costs while improving overall economic performance.

3. Social Inclusivity: Sustainable infrastructure ensures social inclusivity by providing equitable access to services, improving quality of life, and fostering social cohesion. In Pakistan, where social inequalities are prevalent, sustainable infrastructure projects can play a crucial role in bridging the gap between different segments of society (Ali et al., 2021). By ensuring that infrastructure development benefits all communities, regardless of their socioeconomic status, sustainable practices can contribute to a more equitable and harmonious society.
4. Resilience to Climate Change: Pakistan is one of the countries most affected by climate change, facing frequent natural disasters such as floods, droughts, and heatwaves. Sustainable infrastructure can enhance resilience to these impacts by integrating climate adaptation and mitigation measures into the design and construction of buildings, roads, and other facilities (Eckstein et al., 2021). This proactive approach can help protect communities and reduce the economic losses associated with climate-related disasters.
5. Long-term Cost-effectiveness: While the initial investment in sustainable infrastructure may be higher, the long-term benefits often outweigh the costs. Sustainable practices can lead to reduced maintenance costs, lower energy consumption, and increased durability of infrastructure, resulting in significant savings over time (IRENA, 2018). This is particularly important for Pakistan, where resource constraints necessitate efficient use of available funds.
6. Global Competitiveness: In an increasingly interconnected world, countries that prioritize sustainable development are better positioned to compete in the global economy. By investing in sustainable infrastructure, Pakistan can enhance its international reputation, attract foreign investment, and position itself as a forward-thinking nation committed to sustainable growth (Sachs, 2015).

7. Health and Well-being: Sustainable infrastructure contributes to improved public health by reducing pollution, promoting clean energy, and creating healthier living environments. In Pakistan, where air pollution and water contamination are significant concerns, sustainable infrastructure can play a crucial role in improving the overall health and well-being of the population (Thacker et al., 2019).
8. Innovation and Technology Adoption: The pursuit of sustainable infrastructure encourages innovation and the adoption of cutting-edge technologies. This can stimulate research and development in Pakistan, fostering a culture of innovation and technological advancement that can benefit multiple sectors of the economy (Hussain et al., 2019).

1.3 Background

To fully appreciate the context of sustainable infrastructure development in Pakistan, it is essential to consider the global backdrop and the international commitments that shape this field. The world has increasingly recognized the need for sustainable development, as evidenced by global initiatives such as the Sustainable Development Goals (SDGs) and the Paris Agreement on climate change (Dzebo et al., 2019). Pakistan faces numerous challenges in its pursuit of sustainable economic growth, including the early stages of industrialization, market and governance deficiencies, and the need for infrastructure development that balances environmental preservation with economic progress. The country possesses abundant solar and wind energy resources, presenting an opportunity to transition towards a green economy and reduce carbon emissions (World Bank, 2025a). However, the development of a green economy is hindered by the lack of innovative, competitive markets and sufficient financial oversight for environmental tax reform. Infrastructure development, especially linear infrastructure such as roads and railroads, can significantly impact the environment by causing habitat loss, fragmentation, and disturbance of local hydrology (Ahmad & Mahmood, 2019; Rehman et al., 2018). According to the United Nations Development Programme (2003), Pakistan's GDP could increase by approximately 25% with an additional investment of 1% of GDP in infrastructure development, estimated to be about USD 3.6–4.0 billion. A later study by the International Monetary Fund (IMF) suggested

that a 2% increase in infrastructure investment could boost GDP growth by 5% (IMF, 2017). This indicates that infrastructure development is an effective means of stimulating economic growth in the country. There is a conventional consensus that creating and upgrading fundamental infrastructure in Pakistan can significantly contribute to economic progress and social development. However, recent infrastructure sector growth has primarily been driven by trends in defense and urban development sectors. During the economic boom of the 1980s, the phenomenon of DAWN (Domestic Administration Washes Neighbouring) led to the creation of an interconnected web of roads and airports of strategic value. Examples include the Karachi Northern Bypass and the Kohat Tunnel (Aziz et al., 2018). The trend in urban development has resulted from rapid urbanization, with encroachment and environmental degradation in historical cities often leading to the construction of new satellite towns, such as Islamabad and Korangi (Khan, 2020). WWF-Pakistan's Greening Infrastructure Programme aims to promote sustainable infrastructure development in the Hindukush-Karakoram-Himalaya (HKH) landscape. The program recognizes the need to address the adverse environmental consequences of unsustainable infrastructure projects in the region, particularly under the China Pakistan Economic Corridor (CPEC) (Business Recorder, 2023). It aims to mitigate the negative impacts of infrastructure development by embedding an understanding of the value of nature in development planning and decision-making and by strengthening governance and legal frameworks (WWF-Pakistan, 2022). WWF-Pakistan's Sustainable Infrastructure Initiative seeks to balance protecting nature and biodiversity with ensuring that infrastructure development does not impede economic growth and poverty reduction. The initiative conducts studies to gauge the impacts of linear infrastructure development on nature and biodiversity, focusing on key priority species such as the snow leopard. It also works towards adopting best practices, emphasizing biodiversity considerations in national policies and legislations for all stages of infrastructure development (WWF-Pakistan, 2022). With regard to infrastructure investments in priority areas like housing, roads, healthcare, development, water and sanitation, aviation, and technology, this program seeks to help the Government of Pakistan's efforts to enhance the financing climate and draw in private capital (Benhassine et al., 2025). The program is in line with the principles of Pakistan, the objective 2025, that seeks to expedite Pakistan's economic development into one of the world's top 10 by 2047, the country's centennial. In

order to support the government's efforts to strengthen the legal and institutional structure for PPPs at the federal level, the program relies on ongoing technical assistance from the Asian Development Bank (ADB) and decades of expertise in PPP growth at the provincial level (Asian Development Bank, 2019). The International Organization for Migration (IOM) has launched 13 infrastructure projects on Pakistan's Northwest Frontier to rehabilitate and reconstruct infrastructure damaged by military operations in the Malakand division. The infrastructure rebuilding activities include providing drinking water supply schemes, rehabilitating drinking water supply schemes, surface treatment of roads, constructing link roads, reconstructing damaged schools, building flood protection walls, and providing access to drinking water for villages (IOM, 2020).

1.4 Sustainable Development Goals (SDGs)

The United Nations' 2030 Agenda for Sustainable Development, adopted in 2015, outlines 17 Sustainable Development Goals (SDGs) that serve as a blueprint for achieving a more sustainable future for all (United Nations, 2015). Several of these goals are directly related to infrastructure development:

- Goal 6: Clean Water and Sanitation
- Goal 7: Affordable and Clean Energy
- Goal 9: Industry, Innovation, and Infrastructure
- Goal 11: Sustainable Cities and Communities
- Goal 13: Climate Action

For Pakistan, aligning infrastructure development with these goals is crucial for addressing pressing social, economic, and environmental challenges. Sustainable infrastructure projects can contribute significantly to achieving these goals by providing clean water and sanitation facilities, promoting renewable energy sources, fostering innovation in construction and urban planning, creating sustainable cities, and implementing climate-resilient infrastructure (Zeewaqar, 2024).

1.5 Paris Agreement

The Paris Agreement, adopted in 2015, is a landmark international accord aimed at combating climate change and accelerating actions towards a sustainable, low-carbon future. As a signatory to the Paris Agreement, Pakistan has committed to reducing its greenhouse gas emissions and adapting to the impacts of climate change (Majeed, 2025). Sustainable infrastructure development plays a pivotal role in meeting these commitments by:

1. Reducing carbon emissions through energy-efficient buildings and transportation systems
2. Implementing renewable energy projects to decrease reliance on fossil fuels
3. Developing climate-resilient infrastructure to withstand extreme weather events
4. Promoting sustainable urban planning to reduce the overall carbon footprint of cities

By aligning infrastructure development with the goals of the Paris Agreement, Pakistan can contribute to global efforts to mitigate climate change while also building resilience to its impacts.

1.6 Global Best Practices

To inform and inspire sustainable infrastructure development in Pakistan, it is valuable to examine successful initiatives from other countries. Two notable examples are India's Solar Canals project and China's Smart Cities initiative.

1.7 India's Solar on Water Canals

India's innovative approach to combining solar energy generation with water conservation offers valuable lessons for Pakistan (Business Line, 2014). The Gujarat state government's project to install solar panels over irrigation canals (Upadhyay, 2014) demonstrates how infrastructure can serve multiple purposes:

1. Energy Generation: The solar panels generate clean electricity, contributing to India's renewable energy goals (Jena, 2015).

2. Water Conservation: By covering the canals, the panels reduce water evaporation, helping to conserve precious water resources (Kaur, 2023).
3. Land Use Efficiency: The project utilizes existing canal infrastructure, avoiding the need for additional land acquisition for solar farms (Millet, 2023).
4. Cost-effectiveness: The dual benefits of energy generation and water conservation make the project economically viable in the long term (Shah, 2024).

For Pakistan, which faces similar challenges in water scarcity and energy demand, such innovative approaches could be adapted to local conditions. The country's extensive irrigation network could potentially be leveraged for similar solar projects, addressing both energy and water conservation needs simultaneously (SMEP, 2025).

1.8 China's Smart Cities

China's ambitious Smart Cities initiative provides another model for sustainable urban development that Pakistan could draw inspiration from. Key aspects of China's approach include:

1. Integrated Urban Planning: Chinese smart cities emphasize holistic planning that integrates transportation, energy, water management, and digital infrastructure (Hussain et al., 2022).
2. Technology-driven Solutions: The extensive use of Internet of Things (IoT) devices, big data analytics, and artificial intelligence to optimize urban services and resource management (Yin, 2021).
3. Green Infrastructure: Incorporation of green spaces, sustainable building practices, and renewable energy systems to reduce urban environmental impact (Liu & Wu, 2023).
4. Citizen Engagement: Use of digital platforms to enhance citizen participation in urban governance and service delivery (Wei et al., 2024).

For Pakistan's rapidly growing urban centres, the smart city concept offers a framework for sustainable urban development. By adopting similar approaches,

Pakistani cities could improve efficiency, reduce environmental impact, and enhance the quality of life for urban residents (URCA, 2025).

1.9 Rationale

The rationale for prioritizing sustainable infrastructure development in Pakistan is rooted in the pressing environmental and social challenges facing the country. These challenges not only threaten the well-being of current and future generations but also pose significant risks to economic stability and growth (World Bank, 2025b). Four key issues underscore the urgency of adopting sustainable infrastructure practices in Pakistan:

1.10 Increasing Temperature

Pakistan is experiencing a rapid rise in average temperatures, a trend that is expected to continue and intensify in the coming decades. This temperature increase has far-reaching consequences:

1. Agriculture Impact: Rising temperatures affect crop yields, potentially leading to food insecurity and economic losses in the agricultural sector, which is a significant contributor to Pakistan's economy (Khan et al., 2024).

2. Water Stress: Higher temperatures accelerate evaporation, exacerbating water scarcity issues in a country already facing water stress (Syed et al., 2022)

3. Energy Demand: Increased temperatures lead to higher energy consumption for cooling, straining the already overburdened power infrastructure (Mahmood & Hsassan, 2022).

4. Health Risks: Heat-related illnesses become more prevalent, particularly affecting vulnerable populations such as the elderly and outdoor workers (Khan et al., 2021).

Sustainable infrastructure can address these challenges by incorporating climate-resilient designs, promoting energy-efficient buildings, and implementing green spaces in urban areas to mitigate the urban island effect. Additionally,

investing in renewable energy infrastructure can help meet the growing energy demand without exacerbating climate change (Sokolova, 2024).

1.11 Floods

Pakistan is highly vulnerable to flooding, with recent years seeing devastating floods that have caused loss of life, displacement of communities, and significant economic damage. The increasing frequency and intensity of floods can be attributed to several factors, including climate change and unsustainable land use practices. The impacts of floods include:

1. Infrastructure Damage: Floods cause extensive damage to buildings, roads, bridges, and other critical infrastructure, leading to massive reconstruction costs (Waseem & Rana, 2023).
2. Economic Disruption: Flooding disrupts economic activities, affecting livelihoods and causing long-term economic setbacks (Nanditha et al., 2023).
3. Health Hazards: Flood water can contaminate water sources, leading to the spread of waterborne diseases (Manzoor & Adesola, 2022; Warraich et al., 2011).
4. Social Displacement: Floods often result in the displacement of communities, causing social disruption and increasing the strain on urban areas as people migrate from flood-prone rural regions (Manzoor et al., 2022).

Sustainable infrastructure development can play a crucial role in flood mitigation and adaptation:

- Implementing flood-resistant building techniques and materials
- Developing comprehensive flood management systems, including early warning systems
- Creating green infrastructure such as permeable pavements and urban wetlands to absorb excess water
- Improving drainage systems and river management to reduce flood risks

By prioritizing flood-resilient infrastructure, Pakistan can reduce the human and economic costs associated with these recurring disasters.

1.12 SMOG

Urban areas in Pakistan, particularly cities like Lahore, have been grappling with severe smog problems in recent years. This air pollution crisis is a result of various factors, including industrial emissions, vehicular exhaust, and crop burning (Ashraf et al., 2022). The impacts of smog are severe and multifaceted:

1. Health Issues: Smog causes respiratory problems, eye irritation, and can exacerbate existing health conditions, leading to increased mortality rates (Mushtaq & Mahmood, 2024).
2. Economic Costs: Reduced visibility and health issues lead to decreased productivity and increased healthcare costs (Nasir et al., 2025).
3. Quality of Life: Persistent smog negatively affects the quality of life in urban areas, potentially leading to outmigration of skilled workers and deterring investment (Nasar-u-Minallah, 2024).
4. Environmental Degradation: Smog contributes to acid rain and damages vegetation, affecting both urban green spaces and agricultural productivity (Nasir et al., 2025).

Sustainable infrastructure development can play a significant role in combating smog:

- Implementing advanced air filtration systems in buildings
- Developing efficient public transportation systems to reduce vehicular emissions
- Creating green belts and urban forests to act as natural air purifiers
- Promoting clean energy infrastructure to reduce industrial emissions

By addressing the smog crisis through sustainable infrastructure, Pakistan can improve public health, enhance economic productivity, and create more liveable urban environments.

1.13 Heat Waves

Pakistan has experienced increasingly frequent and intense heat waves in recent years, a trend that is expected to worsen with climate change. These extreme heat events have severe consequences:

1. Loss of Life: Heat waves can be deadly, particularly for vulnerable populations such as the elderly, children, and those with pre-existing health conditions (Mahmood & Hassan, 2022).
2. Economic Impact: Extreme heat reduces labor productivity, especially in outdoor sectors like construction and agriculture.
3. Infrastructure Strain: Heat waves put immense pressure on energy infrastructure due to increased cooling demands, often leading to power outages (Ishaque et al., 2022)
4. Water Scarcity: High temperatures exacerbate water scarcity by increasing evaporation and water demand (Razzak et al., 2022).

Sustainable infrastructure can help mitigate the impacts of heat waves:

- Designing buildings with passive cooling techniques and heat-resistant materials
- Implementing urban green spaces and cool roofs to reduce the urban heat island effect
- Developing resilient energy systems that can cope with peak demands during heat waves.
- Creating public cooling centres and improving access to water in urban areas

By investing in heat-resilient infrastructure, Pakistan can protect its population from the health risks associated with extreme heat while also ensuring economic resilience in the face of changing climate conditions (Adnan et al., 2024).

The rationale for sustainable infrastructure development in Pakistan is clear and compelling. By addressing these critical environmental challenges through sustainable practices, Pakistan can create a more resilient, healthy, and prosperous future for its citizens. The integration of sustainable infrastructure not only helps in

mitigating immediate environmental concerns but also positions the country for long-term sustainable growth and development.

1.14 Current State of Infrastructure in Pakistan

To fully appreciate the need for sustainable infrastructure development in Pakistan, it is crucial to understand the current state of the country's infrastructure. Pakistan, like many developing nations, faces significant challenges in providing adequate and sustainable infrastructure to its rapidly growing population.

1.15 Transportation Infrastructure

Pakistan's transportation infrastructure, while improving, still faces considerable challenges:

1. Roads: The country has an extensive road network, but many roads, especially in rural areas, are in poor condition. The National Highway Authority (NHA) has been improving and expanding the highway system, but maintenance remains a challenge.
2. Railways: Pakistan Railways, once a crucial mode of transportation, has seen a decline in recent decades due to underinvestment and mismanagement. Efforts are underway to revitalize the railway system, including through projects under the China-Pakistan Economic Corridor (CPEC) (Ashraf, 2025).
3. Ports: Pakistan has several major ports, including Karachi Port and Port Qasim, which play a crucial role in the country's trade. However, there is a need for modernization and expansion to manage increasing trade volumes (Usman, 2025).
4. Airports: While major cities have international airports, many regional airports require upgrades to meet international standards and handle increasing passenger traffic (Shabbir, 2025).

The sustainable development of transportation infrastructure in Pakistan would involve:

- Prioritizing public transportation systems to reduce traffic congestion and air pollution in urban areas
- Implementing green technologies in road construction to reduce environmental impact
- Electrifying railways to reduce carbon emissions.
- Developing multimodal transportation hubs to improve efficiency and reduce overall energy consumption.

1.16 Energy Infrastructure

Pakistan's energy sector faces significant challenges, including:

1. Power Shortages: Despite improvements in recent years, power outages remain a problem in many areas, affecting both quality of life and economic productivity (Opitz-Stapleton et al., 2021).
2. Reliance on Fossil Fuels: A huge portion of Pakistan's energy mix comes from fossil fuels, contributing to air pollution and greenhouse gas emissions (Jafri et al., 2021).
3. Transmission and Distribution Losses: The country faces high technical and non-technical losses in its power transmission and distribution system (Duan et al., 2022).
4. Limited Access: Many rural areas still lack access to reliable electricity (Hassan et al., 2021).

Sustainable development of energy infrastructure would involve:

- Increasing the share of renewable energy sources such as solar, wind, and hydropower
- Improving energy efficiency in both generation and consumption
- Modernizing the grid infrastructure to reduce losses and improve reliability.
- Expanding access to clean energy in rural areas through off-grid and micro-grid solutions

1.17 Water and Sanitation Infrastructure

Water and sanitation infrastructure in Pakistan faces several challenges:

1. Water Scarcity: Pakistan is a water-stressed country, with per capita water availability declining rapidly due to population growth and climate change (Ishaque et al., 2022).
2. Water Quality: Many areas lack access to clean drinking water, with contamination being a significant issue (Parveen, 2023).
3. Inadequate Sanitation: A generous portion of the population, especially in rural areas, lacks access to proper sanitation facilities (Qamar et al., 2022).
4. Wastewater Treatment: Many urban areas lack adequate wastewater treatment facilities, leading to pollution of water bodies.

Sustainable development in this sector would involve:

- Implementing water conservation technologies and practices
- Developing sustainable urban drainage systems
- Expanding access to clean water and sanitation facilities, especially in rural areas
- Investing in modern wastewater treatment plants and promoting water recycling

1.18 Urban Infrastructure

With rapid urbanization, Pakistan's cities face numerous infrastructure challenges:

1. Housing Shortage: There is a significant shortage of affordable housing in urban areas, leading to the proliferation of informal settlements (Hussain et al., 2022).
2. Solid Waste Management: Many cities struggle with effective solid waste management, leading to environmental and health issues (Iqbal et al., 2022).
3. Urban Planning: Unplanned urban expansion has led to inefficient land use and strain on existing infrastructure (Al-Rashid et al., 2021).

4. Air Pollution: Many urban areas suffer from severe air pollution due to industrial emissions, vehicular exhaust, and other factors (Anwar et al., 2021).

Sustainable urban infrastructure development would involve:

- Implementing smart city technologies for efficient resource management
- Developing green buildings and sustainable housing solutions
- Improving solid waste management through recycling and waste-to-energy projects
- Creating more green spaces and implementing urban forestry initiatives

1.19 Digital Infrastructure

While Pakistan has seen significant growth in its digital infrastructure, challenges remain:

1. Digital Divide: There is a significant gap in access to digital technologies between urban and rural areas (Jamil, 2021).
2. Cybersecurity: As digital adoption increases, so does the need for robust cybersecurity measures (Malik et al., 2022).
3. E-governance: There is potential for further development of e-governance services to improve public service delivery (Sajid et al., 2024).

Sustainable development of digital infrastructure would involve:

- Expanding broadband access to rural and underserved areas
- Implementing green data centres to reduce the environmental impact of digital infrastructure
- Developing smart grid technologies to improve energy efficiency
- Promoting digital literacy to ensure inclusive access to digital services

1.20 Challenges in Sustainable Infrastructure Development

While the need for sustainable infrastructure in Pakistan is clear, several challenges hinder its implementation:

1. Financial Constraints: Developing sustainable infrastructure often requires significant upfront investments, which can be challenging for a developing economy like Pakistan (Azeem et al., 2023).
2. Technical Expertise: There is often a lack of local expertise in sustainable technologies and practices, necessitating capacity building and knowledge transfer (Alam et al., 2019).
3. Policy and Regulatory Framework: The absence of comprehensive policies and regulations specifically targeting sustainable infrastructure can impede progress (Khan & Malik, 2020).
4. Public Awareness: Limited public understanding of the benefits of sustainable infrastructure can lead to resistance to new projects or practices (Rehman et al., 2020).
5. Coordination among Stakeholders: Effective sustainable infrastructure development requires coordination among various government departments, private sector entities, and local communities, which can be challenging (Ali et al., 2021).
6. Climate Vulnerability: Pakistan's high vulnerability to climate change impacts poses additional challenges in designing and implementing resilient infrastructure (Eckstein et al., 2021).

1.21 Opportunities for Sustainable Infrastructure Development in Pakistan

Despite these challenges, Pakistan has several opportunities to advance sustainable infrastructure development:

1. Renewable Energy Potential: Pakistan has significant untapped potential for solar, wind, and hydroelectric power, which could transform its energy landscape (IRENA, 2018).
2. Youth Dividend: Pakistan's large youth population presents an opportunity to build a skilled workforce capable of implementing and maintaining sustainable infrastructure (Hussain et al., 2019).

3. International Cooperation: Initiatives like the China-Pakistan Economic Corridor (CPEC) offer opportunities for knowledge transfer and investment in sustainable infrastructure (Saad et al., 2019).
4. Technological Leapfrogging: As a developing country, Pakistan could bypass outdated technologies and directly adopt more sustainable and efficient solutions (Malik et al., 2020).
5. Green Financing: The growing global focus on sustainable development has opened up new avenues for green financing, which Pakistan can leverage (State Bank of Pakistan, 2021).

1.22 Case Studies of Sustainable Infrastructure Projects in Pakistan

Several projects in Pakistan demonstrate the potential for sustainable infrastructure development:

1. Quaid-e-Azam Solar Park: Located in Punjab, this is one of the largest solar parks in the world, contributing significantly to Pakistan's renewable energy goals (Rafique & Rehman, 2017).
2. Gharo Wind Farm: This project in Sindh province harnesses wind energy, displaying Pakistan's potential in this sector (Mohsin et al., 2018).
3. Bus Rapid Transit (BRT) Systems: Cities like Lahore and Peshawar have implemented BRT systems, improved urban mobility, and reduced emissions (Imran, 2020).
4. Eco-friendly Housing: Projects like the Pakistan Green Building Council's certified buildings are promoting sustainable construction practices (Pakistan Green Building Council, 2022).

1.23 Future Directions for Sustainable Infrastructure in Pakistan

To advance sustainable infrastructure development, Pakistan should consider the following strategies:

1. Integrated Planning: Adopt a comprehensive approach to infrastructure planning that considers environmental, social, and economic factors (Hussain et al., 2020).

2. Capacity Building: Invest in education and training programs to develop local expertise in sustainable technologies and practices (Ali et al., 2021).
3. Policy Reform: Develop and implement comprehensive policies and regulations that incentivize sustainable infrastructure development (Khan & Malik, 2020).
4. Public-Private Partnerships: Encourage collaboration between the public and private sectors to leverage resources and expertise for sustainable projects (Saad et al., 2019).
5. Climate Resilience: Prioritize infrastructure designs that are adaptable to climate change impacts (Eckstein et al., 2021).
6. Technology Adoption: Embrace emerging technologies such as IoT, AI, and blockchain to enhance the efficiency and sustainability of infrastructure (Malik et al., 2020).
7. Green Financing: Develop innovative financing mechanisms to support sustainable infrastructure projects (State Bank of Pakistan, 2021).

In conclusion, sustainable infrastructure development is crucial for Pakistan's long-term economic growth, environmental sustainability, and social equity. While challenges exist, the opportunities for transformation are significant. By prioritizing sustainability in its infrastructure development, Pakistan can create a resilient, inclusive, and prosperous future for its citizens while contributing to global efforts in combating climate change and achieving sustainable development goals.

2. LITERATURE REVIEW

2.1 Sustainability Infrastructure

A key tactic in resolving the mounting issues surrounding energy use in the built environment is the adoption and integration of renewable energy sources with building management systems (BMS) (Sharma, 2024). Buildings become important nodes of consumption as urbanization and energy demand rise; they account for about 40% of the world's energy consumption. Sustainability demands a change from traditional energy systems to ones that give priority to renewable energy sources like geothermal, wind, and solar energy. When combined with BMS, these technologies have the power to transform buildings from inactive energy users into effective, proactive energy managers. This integration presents a socioeconomic opportunity and an environmental necessity from the perspective of sustainable development, with lower operating costs (Mahmood et al., 2024). The implementation of sustainable supply chain management, or SSCM, practices and the adoption of a glocalization strategy that is friendly can enhance economic stability and foster growth. Special economic zones (SEZs), renewable energy initiatives, and sustainable infrastructure are potent catalysts that can accomplish this. This examines how energy projects, sustainable infrastructure, and special economic zones (SEZs) can be important catalysts for constructing resilient economies. It also looks at how glocalization and SSCM function as mediators (Vakili et al., 2024). Dispersity has long been a major issue in soil science, agricultural engineering, geoenvironmental engineering, and civil engineering. Dispersive clay soils are widely distributed; however, their characteristics and distribution vary greatly throughout worldwide locales, especially in semi-arid or dry regions. When these soils come into contact with water, they become exceedingly unstable and prone to erosion because of their wide specific surfaces and high concentration of exchangeable salt ions. This might cause major damage to hydraulic infrastructure. However, identifying and stabilizing dispersive clay soils is crucial for infrastructure projects since employing untreated soils can result in catastrophic and irreversible failures due to internal erosion and

leakage. Dispersive clays need to be properly controlled in order to prevent the loss of valuable agricultural land (Marsuni 2024). The infrastructure development tactics used in Kalaotoa Village, Pasilambena District, Selayar Islands Regency, are examined in this qualitative descriptive study. The study reveals a methodical approach to infrastructure development targeted at improving all facets of community life, including the educational, social, economic, health, and religious sectors, through observations, interviews, and documentation studies. The research results highlight a comprehensive approach that prioritizes both social welfare enhancement and economic advancement. By emphasizing areas such as Health, Education, and Religion, the village shows that it is dedicated to all-encompassing community development. The study offers insightful information about how village-level infrastructure development plans can have a big impact on the welfare of society. According to Vijayakumar et al., (2024) sustainable road infrastructure promotes economic growth, sound financial management, and an improvement in people's quality of life. The current techniques of sustainability assessment give more weight to environmental and economic factors, and give less weight to the social component. By carefully gathering the body of information about the social sustainability assessment of road infrastructure, this offers insights for further research. 93 peer-reviewed books and industry representative data were the subject of a thorough and systematic investigation. Initially, the review points out the flaws in the existing assessment models and makes suggestions for additional study. Second, to assess the lifetime social impacts of road infrastructure, the study proposes nine social sustainability features and a set of 48 indicators (Zulu et al., 2024)

Although prior researches (Ding, 2008; Gibberd, 2003; Ikudayisi et al., 2022; Irade & Jalaei, 2013; Iwaro & Mwasha, 2013; Keeler & Vaidya, 2016; Reed, 2009) has emphasized the significance of integrating environmental sustainability into building designs, few studies have evaluated the degree to which design teams in developing nations take environmental sustainability into account at the building design stage. Zhalmurziyeva et al., (2024) investigated how much infrastructure design teams in underdeveloped nations take environmental sustainability into account during the design phase, using Zambia as a case study. The need for improved monitoring is refocused on raising public understanding of the social and

economic roles that infrastructure plays in a country's growth. Infrastructure development has an immediate impact on the environment, presents a number of challenges during the building phase, and eventually causes structures to decay and become unsafe for use (Negi et al., 2024). Thus, keeping an eye on things and regulating them to collect all kinds of data on the structures became essential to keeping them trustworthy, safe, and secure. The deployment of business 4.0 digitalized technologies in infrastructures has revolutionized the construction business by serving a variety of objectives, such as monitoring and regulating the infrastructures. Samaei (2024) explores the transformative potential of integrating advanced composite materials with concrete in marine engineering, backed by empirical data and numerical analysis. Materials like carbon fiber reinforced polymers (CFRP) can improve concrete structures; the concrete's lower tensile strength of 1 to 5 MPa contrasts with its typically 20 to 40 MPa compressive strength. Statistical analysis shows that although the initial costs of concrete reinforced with advanced composites may be $100 higher per cubic meter, lifecycle analysis shows that there are significant long-term savings due to lower maintenance costs and extended service life. According to Milić & Bleiziffer (2024) set of standards for evaluating the sustainability of infrastructure in the building industry is required, both in view of the changing global environment and in accordance with the ideas of sustainable development. The sustainability theory in general, the construction industry specifically, and national and international policies and strategies aimed at achieving sustainable development are given in this study. As a mechanism for assessing the application of sustainable approaches in the development of new infrastructure projects, a number of rating systems for the sustainability assessment of infrastructure are prepared. Multiatul & Sutianah (2024) examines the steps the local government is taking to remedy the natural flood tragedy that occurred in Mojokerto. Three analyses are conducted as part of the study, which focuses on the sustainable development of Mojokerto's infrastructure. Qualitative methodologies and literature reviews are employed. An issue tree analysis diagram that identifies the root causes of the flood disaster is used to display these analyses. Mojokerto's Sustainable Development Goals, which center on promoting everyone's welfare and guaranteeing a healthy existence, are the goals of the research. According to Ugochukwu et al., (2024) sustainable smart cities seek to strike a balance between environmental protection and economic development. The

contribution of Financial Technology (Fintech) to environmental sustainability in the context of smart city frameworks is examined in this study. Fintech is essential for enhancing citizen involvement, streamlining resource management, and bolstering models of collaborative government. Study tracks the evolution of smart cities historically and emphasizes how Fintech has sped development by offering cutting-edge financial services for investments in renewable energy, green financing, and sustainable infrastructure. Fintech enables more public involvement in sustainability initiatives, transparent transactions, and the effective use of resources. Fintech solutions will play a bigger role in sustainable smart city development in the future as they address environmental issues and promote sustainable urban growth. In order to advance this integration, cooperation amongst stakeholders including enterprises, governments, academic institutions, and civil society is crucial. However, Abbas et al., (2024) assets that the creation of mega-infrastructure is essential for environmental control, infrastructure modernization, and enhancing community well-being. This development can have a favorable effect on rural tourism by promoting long-term and sustainable economic revitalization, which includes places with heritage sites. Enhancing several aspects of quality of life and community well-being requires integrating large-scale infrastructure projects with sustainable tourism. The study looks at how these elements work together and support sustainability as a whole. According to Wang et al., (2024) asserts that key component of the sustainable development of civil infrastructure is structural health monitoring, or SHM. This review examines the variables that impact the application of SHM in sustainable civil infrastructure, examining the characteristics, pathways, and circumstances that impact its efficacy. The framework, affecting factors, and SHM implementation process are categorized by the study using a coding strategy based on grounded theory. In order to assist efficient SHM procedures in sustainable infrastructure, it seeks to provide a thorough understanding of the links and interactions among these components. Umoh et al., (2024) looks at how important green infrastructure is for improving the sustainability and resilience of metropolitan areas. A network of natural and artificial components that promote ecological, social, and economic aspects is known as "green infrastructure." The research examines development options, emphasizing community involvement, biodiversity, and interaction with urban frameworks. It emphasizes how crucial it is to overcome obstacles like space constraints and upkeep problems in order to create a sustainable

urban environment where urban development and nature coexist peacefully. According to Pachouri & Kothari (2024) green infrastructure might improve urban sustainability in Bangalore, Chennai, Delhi, Mumbai, and Kolkata, five significant Indian cities. They use both qualitative and quantitative techniques, such as case studies, literature reviews, resident surveys, and expert interviews in urban planning. In order to support sustainable urban development in India, the study tries to comprehend how different parts of urban environments are impacted by green infrastructure and offers ideas for how to support its implementation through legislation, community involvement, and integrated urban planning. These factors enhance sustainable infrastructure by promoting long-term economic stability, improving community well-being, and fostering environmental sustainability.

2.2 How to Achieve Sustainability

Infrastructure plays a vital role in a society's well-being; hence it is crucial to invest in its sustainable growth, especially in emerging nations. The absence of a workable framework for assessment and locally appropriate standards for determining the sustainability level, however, is one of the primary obstacles (Taherian et al., 2024). Research emphasized on customizing an existing comprehensive assessment framework (the Envision Rating System) in order to establish appropriate context-specific sustainability criteria and introduce a sustainability assessment framework for developing nations such as Iran. In-depth interviews with subject-matter specialists were used to gather research data, and the weights and points of the parameters were revised based on context-specific conditions utilizing the Analytic Hierarchy Process (AHP) approach (Liu et al., 2024). In response to the challenge of CO2 efficiency and trade-off, a novel modeling framework is provided that affords decision support in pursuit of sustainable developments of infrastructure systems. Based on this framework, it is shown that, for the case of roadway traffic infrastructure systems, different strategies for the development of roadway traffic infrastructure systems can differ in their embedded carbon footprint by up to a factor of three, yielding approximately the same economic benefits to society. This knowledge has the potential to significantly contribute to sustainable developments (Zulu et al., 2024). While research has emphasized the significance of integrating environmental sustainability into building

designs, few studies have evaluated the degree to which design teams in developing nations take environmental sustainability into account during the building design phase. Thus, this study investigated how much infrastructure design teams in underdeveloped nations take environmental sustainability into account during the design phase, using Zambia as a case study. According to Zhalmurziyeva et al., (2024) In order to raise the sustainability level of Nur-Sultan's water system (Kazakhstan), research attempts to investigate a wide range of sustainability issues and create a set of measures with their subjectively significance to each of the aspects of sustainability. Professionals and experts in the water sector evaluated the longer list of indicators that had been developed. They were asked to rate how well the suggested indicators complied with five sustainability criteria by rating them on a Likert scale. Nur-Sultan's water system, like any other city in the developing world, can be made more sustainable by using the ranked and categorized indicators as a potent tool for decision-making. Awasthi et al., (2024) explores the intersection of infrastructure development and sustainability is now the focal point for addressing the problems of resource scarcity, urbanization, and climate change. Research examines how innovative concepts and technological advancements are creating environmentally friendly infrastructure solutions. It evaluates R&D in critical areas such as social equity, resilience, smart cities, green infrastructure, renewable energy, and the circular economy. The article begins by discussing the concept of green infrastructure and how it might be applied to address environmental problems like air quality, stormwater runoff, and urban heat islands. In assessing the scalability, efficiency, and integration of solar, wind, hydropower, and geothermal systems into the existing energy infrastructures, it looks at the most recent advancements in renewable energy infrastructure. According to Whig et al., (2024) the development of modern egalitarian communities depends on infrastructure, which provide necessities like information and communication, water and sanitation, power, transportation, and other utilities. Infrastructure can have a major detrimental effect on society and the environment, depending on what kind of infrastructure is used and how it is planned, constructed, run, and maintained. For example, emissions from the burning of fossil fuels for energy production and transportation cause localized air pollution and global warming, which are harmful to human health and well-being. Additionally vulnerable to stresses and shocks is infrastructure. Extreme weather events linked to climate change, for example, have the potential to erode

infrastructure and even jeopardize its ability to function and provide services. Chen et al., (2024) narrates that for the sake of environmental preservation and urban sustainable growth, large-scale infrastructure construction must be made more sustainable. In order to address dynamics, uncertainties, and obstacles in evaluating sustainability, the research offers a perception and evaluation method employing Dynamic Fuzzy Cognitive Mapping (D-FCM). To develop a dynamic correlation matrix and a D-FCM dynamic system model, the process entails learning from expert knowledge. The prevention of light pollution, wastewater discharge compliance rate, soil pollution prevention, public social engagement, and the conservation and use of soil and water are among the key indicators for the sustainable development of large-scale infrastructure. The model aids in the proposal of cost-effective control strategies and plans for decision-making to enhance sustainability. According to Popescu (2024) creating resilience monitoring plans for infrastructure based on Sustainable Development Goals (SDGs) requires a thorough evaluation and improvement of crucial systems' robustness. These programs' main elements include developing adaptive ability in response to climate change, ensuring equitable access to basic services, and incorporating indicators to measure resilience against environmental, social, and economic challenges. In order to create resilient infrastructure and support more general sustainable development goals, these programs assist in monitoring progress, identifying vulnerabilities, and putting targeted solutions into action. According to Baskar et al., (2024) quantum computing can have an impact on many different areas by providing more effective, sustainable, and optimal solutions to challenging problems. It works effectively for improving machine learning skills, solving optimization-related challenges, and building green infrastructure for smart cities and companies. In addition to solving issues that traditional computers are unable to solve, quantum computing can execute calculations and algorithms at previously unheard-of speeds. This technology can also help build sustainable infrastructure. According to Monaco et al., (2024) Infrastructures that are both ecologically friendly and well-designed are crucial for both social and economic advancement, yet sometimes these features are overlooked during construction. Infrastructure initiatives that are eco-blind may unintentionally make social marginalization, inequality, and displacement worse. In order to reconcile environmental concerns with an appreciation for local identity, the chapter emphasizes the value of community engagement in project planning and execution.

This promotes projects that benefit communities while promoting more general environmental aims. Lewin et al., (2024) presented a method for examining alternatives on the timing of protection against climate change and explores strategic thinking regarding infrastructure resilience and adaptation. The highlighted predetermined trigger points illustrate how flowcharts can prompt the need for action in response to resilience shortcomings. The idea of a "chain of resilience" for interdependent infrastructure systems is introduced, and the roles played by national governments in enhancing resilience in important sectors are examined. Important inquiries concerning connections between systems are outlined for national governments to consider. Along with strategies for addressing cyber resilience, concrete actions that investors and private owners can do to strengthen the resilience of their infrastructure are also recommended. Actuarial technique application is also covered. According to Howe et al., (2024) the transportation infrastructure of the Metropolitan Maputo in Mozambique and the Gauteng City-Region in South Africa is examined in this chapter. The existence of different publics with conflicting mobility requirements and expectations, as well as the opportunities and problems of controlling hybrid transport systems, are highlighted as the two main discoveries. The chapter addresses the constraints and contradictions that exist between the several governmental levels in Mozambique and South Africa as it examines the contentious subject of paratransit. The utilization of paratransit serves as an example of how difficult it is to build and implement hybrid infrastructure for a variety of publics, especially underprivileged social groups. According to Ashinze et al., (2024) by incorporating natural features into the urban landscape, urban green infrastructure (UGI) improves social cohesion, economic resilience, and environmental quality in cities. By collecting carbon dioxide, lowering air pollution, and lessening the effects of extreme weather occurrences, UGI aids in the mitigation of environmental problems. It promotes biodiversity by giving a variety of plants and animals places to live. Through encouraging leisure activities, boosting mental health, and enhancing community togetherness, UGI also affects social dynamics. In terms of the economy, UGI boosts property values, helps local companies, and uses less energy by controlling temperature. Case studies of cities that have successfully implemented UGI show how it can help achieve sustainable urban development by tackling social, economic, and environmental issues from an integrated perspective. Daulat et al., (2024) asserts that road, water, and sewage co-located infrastructure networks

provide the opportunity for coordinated multi-infrastructure interventions. Two criteria are used in this study to quantify the spatial alignment of these infrastructure networks: shared trench volume and shared surface area. In comparison to single-infrastructure interventions, the degree of co-location acts as a surrogate for the potential cost savings of integrated actions. According to case studies conducted in Norwegian towns, integrated interventions have the potential to save an average of 11% in rural areas and 24% in urban areas. To further identify possible integrated treatments, future studies should synchronize the repair needs for these facilities temporally.

2.3 Sustainability in Underdeveloped Countries

Sustainable projects play a crucial role in igniting sustainable development in developing nations, where socio-economic obstacles continue to impede advancement (Ukeyima, 2024). Projects generate income and jobs, which act as drivers for economic development. Effective initiatives give people in the community access to short-term work and transferable skills, enabling them to take part in more extensive economic activity. Projects are also essential for tackling social injustice and promoting diversity. Through increased access to essential services, targeted initiatives in the fields of social welfare, healthcare, and education can reduce inequities. By increasing literacy rates, educational initiatives can provide people with the tools they need to end the cycle of poverty. The advancement of developing nations depends on the development of their infrastructure. According to Benayed et al., (2024) In 28 Sub-Saharan African (SSA) nations the effects of infrastructural development on energy poverty between 2010 and 2021. are both linear and nonlinear, on reducing energy poverty and on the production of renewable energy. It does this by using the Africa Infrastructure Development Index (AIDI) as a comprehensive metric. The report emphasizes how crucial it is to have integrated infrastructure strategies that take social and environmental aspects into account in order to effectively combat energy poverty and promote sustainable development objectives in Sub-Saharan Africa. According to Buthelezi et al., (2024) the provision of high-quality infrastructure for sustainable rural living has not yet been fully realized in many South African rural areas, including Umzumbe Local Municipality (ULM) in KwaZulu-Natal (KZN). Rural communities continue to face overwhelming

problems despite legal reforms pertaining to infrastructure enhancement, which have serious effects for human and socioeconomic growth. The purpose of this study was to investigate ULM's current infrastructure in relation to achieving sustainable lives. In order to achieve optimal sustainable development, it looks at the major contributing elements that hinder infrastructure development. For this explanatory qualitative case study, data from interviews were obtained from a focused sample of 12 participants, and 30 people took part in the focus group. Secondary data was gathered and examined from pertinent official documents and literature. Sufficient and efficient core infrastructure is one of the most important variables in determining a country's level of industrial growth. Infrastructure construction and upkeep promote economic expansion and improve a country's possibilities for development. The availability and issues with Nigeria's current engineering infrastructure facilities are briefly covered in this study. It also talks about effectively maintaining Nigeria's public infrastructure. This study discusses public facility maintenance performance indicators in Nigeria. It highlights the value of spare parts and the different departments that are either directly or indirectly involved in maintenance, as well as how they might collaborate to better maintain Nigeria's public infrastructure (Adeleye et al., 2024). Nations all over the world are under pressure to adopt more environmentally friendly and sustainable practices in all spheres of life. On the other hand, the burgeoning urbanization and the persistence of ancient, unplanned towns bereft of greenery are turning into significant sources of pollution and a persistent obstacle to a sustainable future (Babar et al., 2024). Developed countries are introducing various forms of green infrastructures (GI) to address these issues. However, the adoption of these infrastructures in developing nations is severely hampered by the fact that their deployment requires careful planning and financial inputs. Thus, the purpose of this study is to design and evaluate how Geographic Information might affect the environment and the economy in a developing nation such as Pakistan if it were implemented. A geographic information system is utilized to assess the existing state of (Jatto 2024) This study covers the Global South, the resilience of onshore oil and gas pipelines, the impact of the oil and gas sector on the UNSDGs, and important principles of the United Nations Sustainable Development Goals (UNSDG). Key concerns include the challenging nature of managing onshore gas and oil pipeline infrastructure and guaranteeing security resilience while achieving the UNSDGs. The chapter recognizes that many countries, particularly the

oil-producing Global South countries like Nigeria, are having difficulty meeting the UNSDG 2030 targets for a variety of reasons. This chapter makes the case that weak governance, geopolitical risks, and everything in between are connected to the inefficient management of oil and gas pipeline infrastructure in Nigeria and the Global South, as well as disentanglement from. According to Scalamonti (2024) foreign investments (FIs) have had a major influence on the development of both industrialized and developing nations during the last few decades. The relationship between FIs and growth has been the subject of numerous research, but only a state-of-the-art analysis pertaining to developing nations is required. Pradhan et al., (2024) analyzes a subset of the recent empirical literature from 2020 to 2022 that relates to the growth-FIs nexus using data from developing and emerging economies. It does this by indicating the current state of research in this area and by placing works that can be used as a research agenda by practitioners, academics, and researchers. For nations all across the world to thrive sustainably, transportation is essential. Having a reliable transportation system is crucial for the global flow of people, products, and services. Developing effective transportation networks receives major funding in many industrialized economies. To guarantee that the transportation network has a more profound effect on economic expansion, it is imperative to step up investments in ICT and governance institutions. Lack of funding for expanding investments in cutting-edge transportation infrastructure and enhancing system governance are two major issues that many lower-income countries (LICs) face. This inhibits LICs' economic progress. Using the panel VAR model, the current study investigates the connections between institutional governance, transportation infrastructure, ICT infrastructure, and economic growth in LICs from 2005 to 2022. Safi (2024) assets that Afghanistan became well-known after the 9/11 attacks. A democratic government was created by the US and the rest of the world, and work toward building a durable political and economic structure began. Afghanistan had a legitimate government from 2001 to 2021, but sadly, in August 2021, the government fell even before the entire foreign military departed the nation. Two decades have gone by, and a large portion of that time has been wasted. The nation's primary economic sectors—agriculture, mining, and transit trade—remained underdeveloped, reconstruction was never finished, attempts to establish a state in Afghanistan were unsuccessful, and the poverty level persisted. A robust and stable economy could be created by investments in commercial mining, agriculture growth,

and the extraction of natural resources, but none of these things occurred. Afghanistan, with its enormous potential for producing electricity, is left among the richest land. Owojori & Anwana (2024) explored that developing and enhancing housing infrastructure has been recognized as a key tactic to promote socioeconomic development (SED) and lower unemployment, inequality, and poverty. The goal of the research is to shed light on how South Africa's (SA) housing infrastructure delivery process may take SED considerations into account. The goal was to look at the extent and context of how SED considerations can be incorporated into the provision of housing infrastructure in South Africa.In order to extract crucial components of socioeconomic development for housing delivery that support accessibility, social cohesion, equity, social services, and well-being, a qualitative data technique was chosen, and content analysis was applied. The study's conclusions will help stakeholders develop plans for constructing sustainable housing infrastructure in South Africa. According to Sumargo et al., (2024) inadequate green infrastructure is invariably linked to poverty. Low investment in green infrastructure and a high poverty rate is found in Indonesia. Thus, the risk associated with green infrastructure and poverty in Indonesia are examined in this study using fuzzy clustering with area weighting (FGWC-HHOP) and data from the 2018 Potential Village Census (PODES). There is poor air quality and green infrastructure in the second cluster, whereas the first cluster—which is primarily urban—is vulnerable. To lessen socioeconomic vulnerability, sustainable development—especially green infrastructure—should be promoted by future government initiatives. When preparing for urban growth and poverty reduction in Indonesia, take social vulnerability and green infrastructure into account. According to Lawrence et al., (2024) people all across the world are realizing how closely linked environmental sustainability is to human existence. As a result, discussions about environmental sustainability have gained significance on a worldwide scale. Policymakers and academics are increasingly concerned with how to preserve environmental sustainability while carrying out essential human activities. When it comes to solving this issue, history is crucial. This is due to the fact that history has a wealth of techniques that different generations have employed, albeit with some adjustments, to address problems that are comparable or related. The sustainability of the physical environment in Nigeria was degraded and undermined throughout the colonial era to a greater extent than ever before, given the exploitative nature of colonialism.

According to Mundonde & Makoni (2024) developing nations lack public-private partnership (PPP) financing structures. The purpose of this study is to provide a financial framework that Zimbabwe can use to implement PPP infrastructure projects related to water and sanitation. The secondary data gathered from both local and foreign sources is subjected to Tobit econometric models using data spanning a 25-year period from 1996 to 2021. The research creates a framework model that combines the Public-Private Partnership (PPP) concepts, financing sources, and factors that influence PPP financing for sanitation and water projects. In order to maximize the benefits of the different PPP stakeholders' networks, strengths, and resources, this study suggests that the created framework be used to develop nations' infrastructure finance policies for public-private partnerships related to water and sanitation.

2.4 Sustainability Infrastructure in Pakistan

Tagar (2024) narrates that the 21st century urban problem is extremely complicated, and it requires a long-term plan with flexible answers. The following are the main urban concerns that require extensive research on the subject. The increasing population density in Pakistan's two largest cities has led to problems with unemployment, illiteracy, health, and hygiene in the urban areas as a whole. Urban centers have a number of problems due to the unequal distribution of resource capacities, a deficient local governance structure, low stakeholder involvement in institutional reforms, and poor management of water resources. Buildings that are dangerous, infrastructure that is deteriorating, and ecological degradation are all caused by human activity, pollution, and poor waste management. Hussain et al., (2024) focuses on the indigenous social capital influenced by cultural viewpoints and examines the dynamic interaction between social capital, livelihoods, and tourist development in Gilgit-Baltistan, Pakistan. Understanding the significant effects that Gilgit-Baltistan's rapidly developing infrastructure and tourism have on the local community is essential, as these changes present both extraordinary opportunities and special challenges for sustainable development. It specifically evaluates the impacts of infrastructure projects between 1978 and 2022, including the Belt and Road Initiative and the Karakoram Highway. This qualitative study examines how these processes change community social capital, impact livelihoods and resilience,

and modify community views and adaptations through non-probabilistic sampling and contextual textual analysis. The report highlights how important it is for infrastructure, tourism, and community resilience to work together, and it calls for controlled development for cultural progress. Aziz & Anwar (2024) states that the current imperative for urban growth and sustainability is sustainable urban expansion. The goal of this study is to examine how urbanization in Islamabad, Pakistan, has affected the environment, the economy, and society. Unplanned and rapid urban expansion has created sustainability concerns for the region, which must be addressed. Land Surface Temperature and Normalized Difference Vegetation Index were utilized as environmental sustainability metrics combined with data from remote sensing and geographic information systems to classify land use over the previous 20 years. In the meantime, data from the poll, the city's 2020–2040 Revised Master Plan, historical literature, and developmental reports from the Capital Development Authority (CDA) were used to access the socioeconomic sustainability by Multiple Linear Regression Analyses. According to Malik et al., (2024) the goal of sustainable development growth, which is multifaceted, is to attain economic success while protecting social justice and the environment for both the current and future generations. This study's primary goal is to comprehend Pakistan's current development trajectory, including its implications and obstacles to a comprehensive strategy for achieving prosperity. Sustainable development is essential to achieving prosperity while maintaining environmental balance, especially in countries like Pakistan where fast industrialization and population growth pose significant challenges. This study's methodology consists of articles, a review of the literature, and the gathering of quantitative data. The report highlights that in order to achieve sustainable growth and prosperity, Pakistan must prioritize green investments, individual education, technological improvement, agriculture and household business promotion. According to Faisal & Askari (2024) it would affect China's and Pakistan's respective development, the Pakistan Economic Corridor (CPEC) is an important initiative. This research paper aims to investigate CPEC's sustainability in implementing environmental projects. It is stated that CPEC will make a significant difference in terms of enhancing trade between Beijing and Islamabad, safeguarding the environment, and building infrastructure. Both countries have enacted multifaceted environmental conservation programs. Nonetheless, this method needs to be improved because this important project still faces a lot of environmental

obstacles. In order to maintain a sustainable environment, China and Pakistan both want to work together on clean energy projects. To that end, they must develop the rules and procedures for a roadmap for green investment projects. Based on research, this study uses qualitative methodologies. Bukhari et al., (2024) examines Pakistan's severe water scarcity problems, which are compounded by natural disasters like La Nina, population increase, and declining water supplies. Significant water stress threatens livelihoods in areas like Sindh and Baluchistan and may even cause internal displacement, so government intervention must be swift and decisive. The lack of a well-thought-out national water policy exacerbates problems with irrigation, interprovincial relations, and water storage, which may put pressure on political dynamics. This report uses a thorough assessment of Pakistan's water resources to pinpoint important priorities that need authorities to take immediate action. The recommendations that have been put forth support the creation and execution of a strong national water policy, as well as the promotion of water conservation programs, interprovincial cooperation, smart investments in updated irrigation and storage infrastructure, and the search for innovative sustainable water technologies. Rehman et al., (2024) looks into how Pakistan's CO2 emissions were affected from 1990 to 2020 by changes in the country's transportation system, urbanization, financial development, and use of renewable energy sources. It examines how these variables affect environmental contamination using the wavelet quantile correlation method. The report underlines how changing policy at the federal level is necessary to solve environmental problems and accomplish the Sustainable Development Goals (SDGs). In order to meet the SDG targets for clean energy, economic growth, sustainable cities, and climate action, it offers a complete policy framework. Aziz & Anwar (2024) asserts that the capital of Pakistan is being evaluated for urban sustainability using Multiple Linear Regression Analysis in this study. While secondary data were obtained from the Capital Development Authority and other papers, primary data were collected through questionnaires with random sampling. Urban sustainability and variables including land values, property rent, and social security are correlated in the analysis. The results show that in order to solve sustainability concerns brought on by fast urbanization, population growth, and environmental degradation, a revised master plan must be put into place. According to Maeenuddin et al., (2024) The objective of this study is to measure the financial health of Pakistan's microfinance sector by developing a financial sustainability

index. The study finds important elements influencing financial sustainability by using panel data from 34 microfinance providers (2006-2018) and the Generalized Method of Moments (GMM) technique. The findings emphasize the significance of leverage, loan size, female borrowers, and liquidity in improving financial sustainability. On the other hand, elements like the total number of borrowers and the cost of borrowing per borrower have a detrimental effect on sustainability. The report highlights how COVID-19 affected the results and recommends comparing pre- and post-pandemic data in future studies. According to (Bhatti et al., (2024) by incorporating cultural values into healthcare facility designs the sustainability and adaptability of healthcare infrastructure by utilizing Virtual Reality (VR) for design interventions and end-user feedback can improve sustainability. The strategy aims to keep healthcare institutions operational during non-epidemic periods while strengthening their resistance to future outbreaks. The results highlight how crucial cultural integration is to creating healthcare solutions that are flexible and long-lasting. Lin & Ullah (2024) emphasis on the load capacity factor (LCF), the study assesses how urbanization, economic expansion, structural change, and forest depletion affect environmental sustainability in Pakistan. The study compares the LCF results with CO2 emissions and incorporates these variables into a theoretical framework. The results show how these variables affect environmental sustainability and recommend encouraging afforestation and using structural adjustments to achieve greater sustainability. Arshad (2024) investigates Pakistan's renewable energy possibilities, including wind, solar, hydropower, biomass, and hydropower, as substitutes for coal-fired power plants. It emphasizes the advantages of renewable energy supplies over coal from an environmental and financial standpoint, underscoring the necessity of implementing these sustainable energy solutions in order to satisfy future energy demands. Aleha et al., (2024) focuses on particular case study of Multan, Pakistan, the paper focuses on how urban forests might improve sustainable urban growth. The necessity of urban green infrastructure is emphasized in order to address environmental problems such as air pollution, flooding, and urban heat islands. In order to illustrate these advantages, the paper suggests a prototype design for a single site and emphasizes the significance of establishing urban forests based on resilience principles and strategic policy frameworks. Using a localized system with numerous goals, Hao (2024) assesses sustainable development indicators for the China-Pakistan Transportation Corridor (CPTC). It evaluates the

degrees of sustainable development in several areas, spotting patterns and changes in output over time. The report offers specific suggestions for enhancing the corridor's sustainability. Sain et al., (2024) focuses on both political and socioeconomic barriers, outlining several tactics and problems for attaining sustainability in Pakistan. It highlights the challenges of achieving the Sustainable Development Goals (SDGs) pertaining to economic growth, health, education, and poverty. The report highlights developments and challenges in advancing Education for Sustainable Development (ESD) in Pakistani higher education institutions. The necessity of improved development assistance, structural adjustments, and efficient governance are among the main recommendations. It is believed that increasing educational outcomes and achieving sustainability require putting a strong emphasis on SDG 4 (excellent education) and giving logistical support top priority.

2.5 Current Infrastructure Challenges

The current situation of infrastructure in Pakistan is not satisfactory, mainly due to the lack of resources and the absence of proper budgeting in the government sector (Nisar & Asif, 2023). The people of Pakistan also do not pay their taxes regularly and have adopted the habit of tax evasion, and this affects the growth of the infrastructure (Baig et al., 2023). Requirements of construction materials have increased severalfold over the past few years, and because of its dependency on foreign direct investment and loans, Pakistan has not been able to procure the amount of construction materials needed for creating infrastructure (Hanif & Sultan, 2024). Lack of resources has delayed the construction of many projects. The capital-intensive nature of the construction industry has led to the adoption of cheap and substandard methods of construction to counter the situation, resulting in infrastructure being unable to withstand natural calamities, rough usage, or the passage of time, an example is the 2005 earthquake (Sarwar et al., 2024). Natural calamities, acts of terrorism, and gory incidents have taken their toll on the infrastructure of the country too, costing millions of dollars (Lodhi, 2022). The nationalization policy in the 1970s discouraged private investment and gave way to the concept of a welfare state has had its effect on infrastructure too (Qiumei & Gang, 2022). An industry needs money and competition, and private investment in the era of globalization is considered the best way to go ahead. The effects of

privatization could not be seen, as during the 1990s and beyond, there have been governments that did not complete their tenure, resulting in a lack of continuity and national policies that were often scrapped when new governments came in (Siraj Bashir et al., 2022).

2.6 Aging Infrastructure

Infrastructure comprises the long-lived physical facilities that provide crucial services for sectors such as energy, transportation, and water. The infrastructure in Pakistan was considered to be of good quality at the time of the country's independence in 1947. However, decades of sustained neglect and a high growth rate in demand for essential services have led to a significant decline in the quality and availability of services provided by the infrastructure (Arif et al., 2021). This decline has caused a substantial adverse impact on the economy, environment, and public health. The 2005 earthquake was a stark reminder of the extent to which a lack of resilient infrastructure can leave a nation vulnerable to large-scale disasters (Andrabi et al., 2023). Aging infrastructure in water supply, sanitation, and irrigation was identified as a key factor that contributed to the large-scale devastation of rural livelihoods and dwellings. The majority of infrastructure in Pakistan is approaching the end of its design life, and much of it needs rehabilitation and reconstruction. An assessment by the World Bank found that only half of the infrastructure assets needed to deliver services were in place. The rate of investment in infrastructure has been estimated at about 4–6% of GDP since the year 2000 (Shoukat & Ahmad, 2021). This rate is considered insufficient to make significant improvements. At this rate, it has been estimated that it would take an additional 30 years and an investment of 6–8% of GDP to improve the infrastructure to a level where it can meet the demands of the population (Saleem et al., 2021). The economic life of the infrastructure would also be significantly higher than at present, with average coverage of minimum needs increasing from less than 0.5% to about 2.3% of GDP per year. This would greatly reduce the present and future costs of infrastructure-related failures and service shortfalls (World Bank 2020). An examination of the road infrastructure for the study indicates that as many as 60 percent of the roads do not meet current utilization standards, largely due to a lack of maintenance. Signs of insufficient maintenance are obvious everywhere and include potholes, cracking, and

rutting, with most damage occurring in the form of fatigue cracking and rutting, which can be attributed to overloading (Khatoon & Hina, 2022). Data for heavy vehicles indicates that gross vehicle weights frequently exceed legal limits by as much as 200 percent. These overloads do tremendous damage to road surfaces and are a factor in the high incidence of road failures. An inadequate maintenance management system increases the rate of road deterioration and leads to a situation in which small routine maintenance and repair activities are no longer effective and major rehabilitation is necessary. This then leads to a perception of rapidly deteriorating roads and a belief that road problems are beyond the scope of what current institutions can handle (Ullah, 2023).

2.7 Insufficient Capacity

Insufficient capacity for infrastructure in Pakistan has always been a source of major worry for its planners and development professionals. Efficient infrastructure is more about the provision of adequate facilities to the users (Nisar & Asif, 2023). Unfortunately, users in Pakistan have consistently been deprived of adequate services owing to structural constraints. The high fiscal burden is one of the main reasons behind the insufficient capacity of infrastructure in Pakistan (Shaikh, 2023). For the provision of adequate services to users, there is a need to ensure an adequate supply of monetary cheap services. But in most cases, this social and economic requirement has been disregarded in decision-making, which has led to excessive cost recovery, lower investment, and inadequate services (Kamran et al., 2022). Excessive decentralization and departmentalism have also contributed to the insufficient capacity of infrastructure in Pakistan. Due to the lack of clear vision and coordination within different sectors and departments, infrastructure development got compromised at various stages, and the end result was the provision of inadequate facilities to the users (Tunio & Nabi, 2021). Infrastructure in Pakistan has been a profitable weapon for the improvement of the country's economy. public and non-public sectors have performed excellently in the progress and expansion of the infrastructure sector in Pakistan (Haque & Mehmood, 2024). This sector has also contributed to the arrival of international investment in the country. Unfortunately, this sector has consistently been unnoticed and viewed as of less importance for policymakers, and it has remained stagnant in terms of development. The 2005/06

earthquake and floods in 2010 are perfect examples where the lack of capacity in infrastructure added enough damage to the miseries of the people (Thomas, 2021). In both cases, significant infrastructures were destroyed, and the rehabilitation and relocation processes suffered a huge deal owing to insufficient infrastructure capacity, which led the people towards the aggravation of their miseries (Padder & Bashir 2023).

2.8 Importance of Sustainable Infrastructure

These days, Pakistan needs investment in any area possible that can give the nation some sort of financial stability, and infrastructure investment can offer just that through building power stations to meet the energy requirements of the nation, schools and education facilities to cater for the ever-increasing population, and urban development projects (Rayan et al., 2021). This would also help the nation conserve its cultural heritage, which is now all but lost due to a lack of maintenance at these sites. A lot of money would be saved if there was prevention of any more damage to these existing structures and lasting future generations. Overall, it provides a much-needed platform for future generations (Mahmood et al., 2020).

In the economic domain, investment in infrastructure provides ample job opportunities and facilitates economic activity through the construction of various projects, and indirectly through the increase in economic activity that ensues investment (Mahmood et al., 2024). Numerous studies have shown that there is a multiplier effect in investment in infrastructure in that for every US $1 billion investment that is spent, it adds US $1.6 billion or more to the GDP (Nykyforuk et al., 2023; Ramey, 2020). With the current state of economic turmoil and political instability, infrastructure investment is needed to rejuvenate economic activity, business confidence, and job creation, leading to sustainable economic development (World Bank 2022). The construction and development of stable and reliable infrastructure in any country is of vital importance, as it is directly linked to the welfare of its people as well as its economic and social development (Srinivasu & Rao, 2013). Sustainable infrastructure provides such long-term benefits in terms of economic, social, and environmental aspects, and it is on these grounds that the government, non-governmental organizations, and international development agencies in Pakistan have been making sustainable infrastructure a core theme in

policymaking and development strategy in the last decade (Mahmood et al., 2024). A sustainable future will require a major shift in the pattern of infrastructure development. Since the independence of the nation, Pakistan has followed an inflexible strategy of infrastructure development (Sabir & Shamshir, 2020). Sustainable development led to the development of infrastructure but has also resulted in tough economic, social, and environmental costs (Thacker et al., 2019). The current infrastructure services in Pakistan are poor, especially in rural areas. The availability, access, and quality of these services have repeatedly fallen short of demand (Shahid, 2022). This has had critical implications for growth and poverty alleviation. The main aim of building sustainable infrastructure projects in Pakistan is to develop an enabling environment that will facilitate both the public and private sectors to maximize their contribution to sustainable development (Ning et al., 2023). These projects are geared towards boosting economic growth, creating the means for the reduction of poverty, and enhancing the capability of future generations (Vîrjan et al., 2023). Infrastructure is the driving force in the national and global economies (Varnavskii, 2021). The quality and quantity of infrastructure services, which include transportation systems, power and energy, telecommunications networks, and water supply and sanitation, are directly linked to the levels and quality of GDP growth (Tunio et al., 2021).

2.9 Environmental Benefits

In the long run, decreased overall costs are an important economic benefit of sustainable infrastructure development (Ekins & Zenghelis, 2021). The increased efficiency and cost effectiveness of sustainable technology will result in a cost decrease for consumers (Shoaib, 2023). The prevention of overexploitation and misuse of environmental resources will lead to cost savings in the future to recover any damage caused, along with the prevention of damage costs from natural disasters due to preventative technology (Hoodbhoy, 2023). Sustainable infrastructure development is a key aspect of economic growth in Pakistan. It is a well-known fact that infrastructure has a significant role in economic growth, quality of life, and poverty alleviation (Abbas et al., 2025). Pakistan's economic structure has a significant reliance on the agriculture sector, which is heavily dependent on irrigation (Owoade et al., 2024). With a vast population of 150 million, an agricultural

workforce, and a semi-industrialized economy, it is clear that the demand for sustainable infrastructure is a key factor in Pakistan's future economic growth (Bisbey et al., 2024).

2.10 Social Benefits

There is considerable debate regarding the sustainability of current infrastructure in the developed world and the global infrastructure needed to reduce the disparities in quality of life between different regions (Mulligan et al., 2021). With rapid urbanization and population growth in the developing world, there has been a considerable shift in the location of poverty from rural to urban areas, but the infrastructure has often not followed (Ying et al., 2022). Basic services, housing, and mobility for the world's poor are frequently inadequate, too expensive, and of poor quality, and low-paying jobs are often in the informal sector with no job security and unsafe working conditions (Choi et al., 2021). This leads to the creation of slums and shanty towns, and the world's urban population is expected to double to four billion by 2030, leaving an estimated two billion people in slums (UN-Habitat, 2008). The impact of this on the quality of life and health of the world's poor is severe, and it is vital that it is reversed through the implementation of sustainable infrastructure (Hanna & Comín, 2021). High-income nations are also facing issues of sustainability and quality of life with aging populations and rising healthcare costs, and infrastructure to enable affordable, healthy aging is needed now. More of this will be discussed in the social benefits of specific infrastructure types, such as energy and transportation (Hussain et al., 2023). The importance and necessity of sustainable infrastructure development are no longer debatable; however, what constitutes sustainable infrastructure (Faisal et al., 2022). There are various models and definitions of sustainable infrastructure, ranging from greening brown and grey fields through to ecovillages and sustainable cities, and all of these ideas have merit (Barket et al., 2021). Socially just and sustainable infrastructure would increase social capital and inclusion, enhances the quality of life, and minimizes disparities, and its origins lie in the concept of 'meeting the needs of the present without compromising the ability of future generations to meet their own needs'.

2.11 Challenges and Barriers

At present, Pakistan is developing steadily but has yet to arrive as a fully developed nation. The major flaws of conspicuous consumption can be seen, such as purchasing luxury items like cars (with no checks on emissions via vehicle testing and no emphasis on public transport), a change in overall urban planning, and no zoning laws (Willar et al., 2021). All these have contributed significantly to environmental degradation. Pakistan is blessed with natural resources, and rather than exploiting them and creating deterioration, it is feasible to exploit and harness these resources, thus not only improving the quality of life and preserving the environment but also creating a long-term economic solution (Broo & Schooling, 2023). This is directly linked to infrastructure development and is the future vision of infrastructure development in Pakistan. Introduction Civil engineers, during the course of their professional lives, spend a significant portion of their time on infrastructure development that is directly or indirectly linked to their respective fieldwork (Ige et al., 2024). By the very nature of the civil engineering discipline, infrastructure development is in the blood of every civil engineer, as they aspire to contribute significantly and visibly to the development of society (Broo et al., 2023). Thus, it becomes more of a passion than a profession. Much has been said and debated on sustainable infrastructure, but the ground realities have not changed significantly, mainly because of the lack of results due to a multitude of reasons (Srivastava et al., 2022). The success of sustainable infrastructure development can be fulfilled in a phased manner using a well-defined methodology containing appropriate steps at each stage. Phase staging will commence with the early strategic phase, followed by the target development phase, regional phase, and final implementation phase. This paper will elaborate on a defined methodology (Nisar et al., 2023).

2.12 Political Will

Existing literature indicates that one of the main challenges facing infrastructure development in Pakistan is the lack of continuous political commitment (Nisar & Asif, 2023). Political instability has been an issue in Pakistan. According to the ADB economic report, in the 1990s, Pakistan had 4 different prime ministers in the span of 3 years (Nasir, 2024). Term elongation is very low for the Prime Minister in Pakistan, with only a few staying in power for over 4 years. Each

new government brings new political agendas and changes in priority, which have had adverse effects on infrastructure development (Abbas & Sultan, 2023). In some instances, development projects initiated by the preceding government are terminated or altered. A recent example cited by the current Prime Minister was the termination of Saindak project in Baluchistan, in which the contract was given to a Chilean company (Imran et al., 2023). Political influence was cited as a reason for the termination of the contract, which has since been awarded to a Canadian company. Such acts can sometimes lead to political turmoil and unrest among people (Akram, 2023). As a result, development projects may not fulfil the intended objectives due to constant policy shifts. A study undertaken at Columbia University gave an account of policy shifts and inefficiencies in infrastructure development since Pakistan gained independence in 1947. During the 1950s and 1960s, a period of growth was seen in the infrastructure sector due to political stability and the availability of foreign investment as a result of strong ties with the US and aid received under the Marshall Plan (Husain, 2010). The report states that "such periods of favorable policy regimes did have some impact on launching an investment cycle in an infrastructure sector" (Ishaq & Jumma, 2008). The sudden death of President Ayub Khan marked a period of policy reversals and frequent changes in government (Zeeshan et al., 2022). The nationalization policies of the 1970s had drastic effects on the private sector and foreign investment. A recent survey indicates that FDI inflows into Pakistan do respond to some extent to improvements in the energy sector and infrastructure facilities (Naz et al., 2021). Random changes in government and the frequent takeover of provinces by military and non-military bureaucrats brought about various changes in the 1973 constitution (Khan et al., 2023). During General Zia's rule, an attempt was made to deregulate the economy and revise pro-private sector policies. However, due to the uncertainty of his term elongation, policy consistency was seen to be no different from previous governments. Post-1988, there have been several attempts to build up infrastructure sectors, but most initiatives have lacked continuity due to another round of frequent policy shifts and changes in government (Nawaz et al., 2021). Measures taken during the 1990s, ranging from the privatization commission to the passing of the Essential Services Act and most recently the devolution of power through the 2001 Local Government Ordinance, all had the intention of promoting infrastructure development over a long-term course (Ashraf, 2023). However, these were downsized or short-run initiatives. Efforts were seen to

have been too little and too late with the emergence of an external debt crisis, and the current decade has shown infrastructure to be the casualty (Hassan & Zeb, 2021). Today, the effects of aphorism and a lack of political commitment are evident in the present state of Pakistan's infrastructure sectors. Measures suggested by international financial institutions in the form of structural adjustment have, at most times, only worsened the state of public welfare infrastructure as a result of a multitude of transfers and cutbacks (Sheikh, 2022). Above all, deeply embedded interest groups and political patronage have been a major hindrance in resource allocation, and case studies can be found on various failed projects (Shinwari, 2024). This has been evident in the energy and telecommunications sectors, which developed into ghost public enterprises, unableto compete against the booming private sectors (Pakistan, 2020).

2.13 Funding Constraints

Historically, the development of the infrastructure sector has not been a priority for the government. There are numerous reasons for that. One of the most important is political and economic instability, with frequent martial laws, inconsistent democratic regimes, and a high rate of GDP growth (Nisar & Asif, 2023). This chronic instability happened due to frequent transitions from civilian to autocratic governments. Martial laws were imposed due to the inability and bad governance of the political representatives (Ali & Imran, 2021). All of this had a very severe impact on the economy. Political instability caused inconsistency in policies, and bad governance led to corruption. As a result of this, investment declined, and investors took out their money in fear of nationalizing the industry (Brollo, 2021). All these factors had a negative effect on the development of the infrastructure sector. Because of uncertain economic policies, access to foreign debt and grants shrank (Shahzad et al., 2023). In recent years, the government has started directing resources towards the development of infrastructure, but those resources are not sufficient to meet present demand, meet the needs of the rising population, and cater for sustainable development (Chowdhury & Chowdhury, 2024). Another issue is large-scale public investment in infrastructure. It is well known that the private sector has assumed responsibility for many projects in transportation, utilities, and social infrastructure, but the rate at which the government is spending is double the current public expenditure, which is about 4% of the GDP (Javid, 2019). The current

technical expertise of building environment professionals will not be adequate to develop sustainable infrastructure unless there is a significant improvement in technical skills and knowledge. In the build environment, professionals will need to acquire new technical skills and knowledge based on these new approaches (Jabeen & Khattak, 2021). The learning of new technical skills and knowledge should be embedded in the academic and training environment, as well as professional development programs (Kumar et al., 2022). The technical expertise of existing and future build environment professionals can be enhanced through the transfer of new technical knowledge and skills by means of codification and also through interactive learning processes involving the acquisition of new knowledge and skills tacitly from clients or leaders who have the new technical knowledge and skills (Idrees & Shafiq, 2021). The building and engineering industries are fragmented and often beset by a lack of coordination among the various disciplines, thus resulting in suboptimal outcomes in problem-solving and decision-making. This is because each of the disciplines has developed its own specialization and in-depth knowledge in its own field but lacks understanding of other disciplines. Because sustainable infrastructure is an integration of the various systems, it will thus require building environment professionals to know how to collaborate and make decisions synchronously (Ali et al., 2024). This will result in a need for a change in the culture and behavior of how decisions are made and problems solved, as well as more lifelong learning in interdisciplinary knowledge and skills. Stakeholder engagement and collaboration are very important aspects of all projects, especially when it comes to large and expensive ventures such as infrastructure development. It is considered to be one of the determinants of a project's success (Khan et al., 2023). It is important to note that stakeholder engagement is more than consultation and communication. The essence of engaging is to provide a platform for stakeholders and interested parties to influence decision-making, get involved in implementation, and be an integral part of the venture's whole lifecycle (Solangi et al., 2021). Successful engagement leads to effectiveness and efficiency in a project. Stakeholders are those individuals, groups, or organizations that have a direct or indirect interest in the organization because it can affect or be affected by the organization's actions, objectives, and policies (Saleem & Atiq, 2023). There are several types of stakeholders, from those with high and low influence to those with high or low interest. It is important to identify which stakeholder is of which type because it will determine which strategy to use in

engaging them. High-influence stakeholders would be best engaged using definite involvement techniques, and low- influence stakeholders may be best not too involved, or else the project may cause unnecessary expenses due to extra consultations and feedback (Rooh et al., 2025). High-interest stakeholders are best involved, mainly because they will involve themselves anyway in the activities of the project, whether advised or not. Low-interest stakeholders should be kept informed since they would not involve themselves in the project (Akhuand & Abbas, 2023). The key level, however, is to establish a relationship with every stakeholder in order to deliver and receive information. This relationship should be based on honesty, trust, integrity, and a clear mutual benefit between the project and the stakeholder (Phulpoto et al., 2024). This would allow both parties to understand each other and make it easier to work closely together. Successful stakeholder engagement would result in a few rewards, especially in decision-making where the interests of stakeholders are fulfilled, a reduction of overall risk in the project, and success in the completion of the project (Mahmood et al., 2020). Government demand for research and advice: Both the Planning Commission (as a central body for economic development and public sector development initiatives) and the Ministry of Finance are demanding research and advisory assistance from professionals and organizations to advise on how to develop the public sector and what should be the role of the government as a facilitator, regulator, and service provider (Asghar et al., 2023). For example, a recent initiative taken by the IRP was to talk to all parliamentarians to discuss and suggest a future for the public sector of Pakistan. International commitments and donor pressures: In various agreements with international financial institutions like the IMF, World Bank, and ADB and bilateral agreements with countries like China, the UK, etc., the government has committed to act and plan for various infrastructure development initiatives. For example, tax reforms and energy policy reforms are precursors to the development of the energy sector and the Diamer Bhasha dam initiatives (ADB, 2025; IMF, 2024).

Current posture: Various recent policy documents and budget announcements have reflected the change and initiative the government is taking for infrastructure development and the assurance that funds and planning for national interest development are cascading into society.

Pakistan's national economic policy: It is an interesting starting point for readers to understand how the NEP 2009 has exemplarily defined the role of the government in infrastructure development (Mahmood, 2008). It has recognized the "strategy of increasing the government's role as a regulator, leader, and facilitator, while simultaneously encouraging the private sector to take initiative and invest in infrastructure." The aim of gaining private sector involvement in infrastructure is to increase efficiency. For a country like Pakistan with a massive backlog in infrastructure development, providing for the growing needs of society using prevalent public sector methods is near impossible (Toor, 2005). Without going into too much economic jargon, it is clear that the rate of return on private investment in infrastructure is higher than what the private sector is currently getting from investing in government securities and bonds. As such, attitude is not the problem. The problem lies in an unfavorable risk/reward environment, which is largely a result of government regulation (Rathore et al., 2023). This is an issue that is beyond the control of the CERP and will require political commitment from the government to bring about change. However, identification of the specific areas of risk for different sectors of the private market may help the government tailor specific policy incentives (Ahmed et al., 2021). The private sector here refers to both national and multinational firms, investors, and donors. These can range from construction companies to large donors such as the World Bank. The research is particularly interested in the attitudes of national companies, as local involvement is crucial in ensuring sustainability and the transfer of control to Pakistan (Niaz, 2021). The relationship between the public and private sectors is one that has been looked at extensively in development literature. In the context of infrastructure development in Pakistan, it is seen as particularly critical due to the current limited involvement of the private sector. Historically, the development of infrastructure has largely been the responsibility of the public sector due to the nature of the infrastructure projects (Mazhar & Rehman, 2021). However, fiscal restraints and the increasing demand for quality infrastructure have forced the Pakistani government to increasingly look to the private sector for involvement (Rehman et al., 2023). As a result, it is seen as important to investigate the attitudes of those involved in the private sector towards infrastructure development in Pakistan and identify any areas requiring improvement. It is a well-documented fact that construction and development activity in the form of infrastructural investments usually leads to some form of displacement and often

results in the loss of assets and livelihoods for the affected populations. All of this occurs in the backdrop of weak governance, the absence of a rule of law, a lack of access to information, and corruption (Gill & Iqbal, 2021). In the past, NGOs have been working partly in isolation and at other times advocating for good governance and people-friendly policies to influence the government and other stakeholders to address the basic structural and legal constraints (Khan, 2021). All of this has been done through advocating and lobbying campaigns, policy analysis and research, and at the same time, capacity building for the deprived communities to enable them to speak for their rights and assist them in organizing into representative action groups. All of this is interwoven in the SID framework, and the Pakistan IDS needs to build an alliance of citizens and their associations to carry on the most basic work of rebuilding a torn social fabric by trying to address the marginalization of the poor and excluded (Rasul & Karki Nepal, 2024). This effort is being done from the national to the micro level, enabling the citizens and the associations to conduct a wide variety of actions to structure shared societal domains and to exercise their influence within them (Ayesha et al., 2024). During the post-2005 earthquake and the 2010 floods, there have been innumerable examples where communities have stuck together to face the natural adversities. This is a positive sign that can be further harnessed to strengthen civil society and influence the state and other stakeholders to have a people-friendly and just development. An alliance of citizens and their associations is the hallmark of a robust civil society and is a point of confluence for the marginalized and policy entrepreneurs (Arif Hasan, 2007, Chitral, presentation on citizenship and development). The project evaluator requires the necessary information for project monitoring. Monitoring refers to the regular, systematic collection and analysis of information to compare how a project is progressing against its plan. The importance of each component of project monitoring depends on the specifics of the project. An informal project such as slow sand filters in Pakistan may only require simple budget monitoring to check that expenditure is within the 5-year budget specified. A larger, more complex project, such as the construction of the huge Ghazi Barotha hydropower plant, would require a more comprehensive approach to monitoring. This might include setting up a separate monitoring and evaluation system with regular meetings between project stakeholders, the local community, other aid donors, and the evaluation team to share and compare information on project progress or the construction of indices to help

compare changes in development goals throughout the project (Khan, 2013). Consequently, impact assessments will be most effective where it is possible to "add and subtract in clear and useful ways" (Cernea, 1993). This requires both an understanding of what the project intends to achieve and flexibility in assessing whether changes in various development indicators are actually improvements. An assessment of a failed project is likely to affect future aid and infrastructure projects in Pakistan, so it's important that the evaluator is able to clearly identify and report the reason for project failure. Although positive assessments can be useful in maintaining funding for a successful project or repeating the project in other areas, the real value of an impact assessment is the comparison between the counterfactual and actual results. This can be used to clearly identify best practices and guidelines for future aid and infrastructure projects in Pakistan (Mahmood et al., 2020).

3. METHODOLOGY

3.1 Research Design

This study employs a qualitative research methodology to provide an in-depth analysis of sustainable infrastructure development in Pakistan. The research design is centred on a comprehensive document analysis of specific sustainable projects in Pakistan, aiming to explore their impact, implementation strategies, and outcomes in detail. The approach focuses on analyzing publicly available information about selected Pakistani sustainable infrastructure projects, allowing for a systematic examination of each project within its real-world context. This method enables the researcher to capture the complexity of sustainable infrastructure development in Pakistan to understanding the processes and rationales behind these initiatives (Graue, 2015).

3.2 Data Collection Methods

The primary method of data collection for this study is document analysis. This involves systematically reviewing and analysing documents related to key sustainable infrastructure projects in Pakistan. The use of document analysis allows for a comprehensive examination of official records, reports, and public communications related to the selected projects (Creswell & Cresswell, 2023).

3.3 Sources of Documents

1. Official project websites
2. Government publications and reports
3. Technical papers and engineering specifications
4. Environmental and social impact assessments
5. Progress reports and evaluation documents
6. Relevant online resources, including news articles and press releases

7. Public presentations and project briefs
8. Policy documents and national development plans
9. International organization reports (e.g., World Bank, Asian Development Bank)
10. Academic literature on sustainable infrastructure in Pakistan

3.4 Projects Selected for Analysis

The study will focus on the following projects, which represent a diverse range of infrastructure types, scales, and geographic locations within Pakistan:

1. RBOD-1 & 3 (Right Bank Outfall Drain)
2. Mangla Watershed Program
3. Tarbela Watershed Program
4. Billion Tsunami Tree Project
5. Drawat Dam Project
6. Dasu Hydro Power Project
7. Diamer Bhasha Dam Project
8. Kurram Tangi Dam Project

3.5 Data Collection Process

The data collection process will follow these steps:

1. Systematic Web Search: Conduct thorough web searches for each project using search engines, government websites, and relevant organizational portals. This will involve using advanced search techniques, including Boolean operators and site-specific searches, to maximize the relevance of results. Multiple search terms and variations will be employed to ensure comprehensive coverage (Petticrew & Robersts, 2008).
2. Database Exploration: Utilize academic and technical databases such as ScienceDirect, IEEE Xplore, and Google Scholar to find published papers or reports related to the projects. Specialized databases like the World Bank's

Documents & Reports database will also be accessed for relevant project documents (Arksey & O'malley, 2005).

3. Document Retrieval: Collect all relevant documents, reports, and web pages for each project. Documents will be downloaded and saved in their original format, maintaining a clear file naming convention for easy retrieval (Jesson et al., 2011).
4. Information Organization: Categorize and organize collected information by project and type of document (e.g., technical specifications, environmental assessments, progress reports). A detailed inventory of all collected documents will be created, including metadata such as source, date of publication, and document type (Jesson et al., 2011).
5. Preliminary Screening: Conduct an initial review of collected documents to ensure relevance and quality. Documents that do not meet predetermined criteria for reliability or relevance will be excluded from the analysis (Arksey & O'malley, 2005).
6. Data Saturation Check: Continuously assess whether new documents provide additional insights or if data saturation has been reached for each project. This iterative process will help determine when sufficient data has been collected for a comprehensive analysis (Arksey & O'malley, 2005).

3.6 Data Analysis Methods

The study will employ three primary methods of data analysis to ensure a thorough examination of the documents collected:

1. Thematic Analysis:

Thematic analysis will be utilized to identify and analyses patterns and themes within the collected documents. This method involves coding the data to find recurring themes, patterns, and insights related to sustainable infrastructure practices, challenges, and benefits in the context of the selected projects. The coding process will be iterative, with themes refined through multiple rounds of analysis (Braun & Clarke, 2006).

Figure 3.1: Six-Phrase Framework of Thematic Analysis

Source: Braun & Clarke (2006)

2. Steps in thematic analysis:

a) Familiarization with the data: Read through all collected documents multiple times to gain a comprehensive understanding of the content. Make initial notes on potential themes and patterns.

b) Generating initial codes: Develop a coding framework based on the research questions and theoretical framework. Use both deductive codes (derived from the theoretical framework) and inductive codes (emerging from the data). Apply codes systematically across the entire dataset.

c) Searching for themes: Group related codes into potential themes. Create mind maps or thematic networks to visualize relationships between codes and themes.

d) Reviewing themes: Check if themes work in relation to the coded extracts and the entire dataset. Refine, split, combine, or discard themes as necessary.

e) Defining and naming themes: Clearly define each theme and its significance to the research questions. Ensure themes are distinct yet coherent within the overall analysis.

f) Producing the report: Select vivid, compelling extract examples. Relate the analysis back to the research questions and literature.

3. Content Analysis:

Content analysis will be employed to systematically analyse the content of the documents. This approach will help quantify and analyse the presence, meanings, and relationships of certain words, themes, or concepts related to sustainability in the project documents (Krippendorff, 2018).

The content analysis will involve:

- Using text analysis software to identify frequently occurring words and phrases.
- Creating word clouds and frequency tables to visualize key concepts.

b) Qualitative content analysis:

- Interpreting the meaning and context of sustainability-related content.
- Analysing the tone and emphasis placed on different aspects of sustainability within project documents.
- Examining how sustainability concepts are framed and discussed in relation to project goals and outcomes.

4. Comparative Analysis:

A comparative analysis will be conducted across the selected projects to identify commonalities, differences, and best practices in sustainable infrastructure development. This will involve comparing and contrasting the approaches, challenges, and outcomes of different projects to derive broader insights into sustainable infrastructure development in Pakistan (Ragin, 2014).

Steps in comparative analysis:

a) Develop a comparison framework: Identify key dimensions for comparison (e.g., environmental impact, community engagement, technological innovation). Create a matrix to systematically compare projects across these dimensions.

b) Identify patterns and variations: Look for recurring themes or approaches across projects. Note significant differences in how sustainability is addressed in different types of infrastructure projects.

c) Contextualize findings: Consider how project-specific factors (e.g., scale, location, funding source) influence sustainability approaches. Examine how national policies and international standards shape project implementation.

d) Synthesize insights: Draw conclusions about effective practices and common challenges in sustainable infrastructure development in Pakistan. Identify potential areas for improvement or further research.

3.7 Theoretical Framework

The theoretical framework guiding this study integrates several key perspectives to provide a comprehensive lens for analysing sustainable infrastructure development in Pakistan:

1. Sustainable Development Theory: Drawing on the UN Sustainable Development Goals and the concept of triple bottom line (economic, environmental, and social sustainability). This perspective emphasizes the importance of balancing present needs with future sustainability (Elkington, 1997).
2. Infrastructure Resilience Theory: Focusing on the capacity of infrastructure systems to withstand, adapt to, and recover from shocks and stresses. This theory considers both physical resilience and socio-ecological resilience in infrastructure design and operation (Pickett et al., 2020).
3. Stakeholder Theory: Examining how different stakeholder interests are balanced in sustainable infrastructure projects. This perspective helps analyze mechanisms for stakeholder engagement and participation in project planning and implementation (Freeman, 1984).
4. Technological Innovation in Infrastructure: Exploring the role of innovative technologies in enhancing sustainability and efficiency of infrastructure projects. This theoretical lens considers the challenges and opportunities of technology transfer and adaptation in the Pakistani context (Rogers, 2003).

5. Project Management Theory: Applying principles of sustainable project management to understand how sustainability is integrated throughout the project lifecycle. This perspective helps examine risk management and decision-making processes in sustainable infrastructure projects (Silvius & Schipper, 2015).
6. Institutional Theory: Analysing the role of formal and informal institutions in shaping sustainable infrastructure development in Pakistan. This theory considers how institutional capacity and governance structures influence project outcomes (DiMaggio & Powell, 1983).

3.8 Quality Assurance and Trustworthiness

To ensure the rigor and trustworthiness of the research, several strategies will be employed:

1. Data Triangulation: Using multiple sources of documents for each project to corroborate findings. Cross-referencing information across different document types to ensure consistency and accuracy (Lincoln & Guba, 1985).
2. Peer Review: Engaging with colleagues familiar with sustainable infrastructure development to review findings and interpretations. Seeking feedback on the coding framework and thematic analysis from experts in qualitative research methods (Creswell & Cresswell, 2023).
3. Audit Trail: Maintaining a detailed record of all data sources, analytical decisions, and research processes. Creating a research journal to document the evolving understanding of the data and emerging themes (Lincoln & Guba, 1985).
4. Reflexivity: Acknowledging and documenting potential biases and their influence on the research process. Regularly reflecting on how the researcher's background and assumptions might impact data interpretation (Charmaz, 2014).
5. Thick Description: Providing detailed accounts of the context and findings to allow readers to assess the transferability of results (Lincoln & Guba, 1985).

6. Negative Case Analysis: Actively seeking out and analyzing cases that do not fit emerging patterns to refine and strengthen the analysis (Lincoln & Guba, 1985).

3.9 Limitations

While this study aims to provide a comprehensive analysis of sustainable infrastructure development in Pakistan, there are potential limitations:

1. Reliance on publicly available information, which may not capture all aspects of the projects or internal decision-making processes.
2. Potential bias in official project documents and reports, which may emphasize positive outcomes.
3. Inability to verify information through primary data collection methods like interviews or site visits.
4. Limited generalizability of findings from the selected projects to other contexts or countries.
5. Potential gaps in available documentation for some projects, particularly older initiatives.
6. Language barriers if some documents are only available in local languages.

3.10 Ethical Considerations

As the study involves analysis of publicly available documents, ethical considerations include:

1. Proper citation and acknowledgment of all data sources to respect intellectual property rights.
2. Fair and balanced representation of project information, avoiding selective reporting or misrepresentation of findings.
3. Adherence to principles of academic integrity in data analysis and reporting.
4. Sensitivity to potential socio-political implications of the research findings.
5. Transparency about the study's limitations and potential biases.

This comprehensive methodology provides a robust framework for analysing sustainable infrastructure development in Pakistan through document analysis of specific projects (Trochim & Donnelly, 2001).

4. ANALYSIS

4.1 RBOD-I and RBOD-III

The Right Bank Outfall Drain (RBOD) projects, particularly RBOD-I and RBOD-III, are critical infrastructure developments in Pakistan that have contributed significantly to sustainable water management, agricultural productivity, and environmental protection. These projects are part of a broader effort to mitigate waterlogging and salinity, enhance drainage systems, and rehabilitate vast tracts of agricultural land. Through their implementation, RBOD-I and RBOD-III have played a pivotal role in cleansing the earth by improving soil quality and water resources, thereby supporting sustainable development in Pakistan (Sindh Irrigation Department, n.d).

Figure 4.1: RBOD I, II & III Layout

Source: Sindh Irrigation Department, (n.d.)

4.1.1 RBOD-I: An overview

RBOD-I, the first phase of the Right Bank Outfall Drain project, was primarily designed to address the drainage issues in the upper reaches of the Indus Basin. This project was developed to provide outfall facilities for existing and future drainage projects (Sindh Irrigation Department, n.d.). The objectives of RBOD-I include:

1. Environmental Improvement: RBOD-I aims to enhance the environmental conditions in critical water bodies like Manchar and Hamal Lakes. These lakes have historically been affected by pollution and poor water management practices. By improving the drainage system, RBOD-I helps restore the ecological balance of these lakes, promoting biodiversity and supporting local communities dependent on these water bodies.

2. Agricultural Productivity: One of the core goals of RBOD-I is to rehabilitate the existing drainage system, thereby improving agricultural productivity across a vast area. The project directly impacts approximately 1.28 million acres of agricultural land. By reducing waterlogging and salinity, RBOD-I helps reclaim fertile land, allowing for increased crop production and contributing to food security in the region.

3. Water Resource Management: RBOD-I plays a critical role in managing water resources more efficiently. By providing an outfall for excess water, the project helps prevent waterlogging, which can lead to soil degradation and reduced agricultural yields. Efficient water management is crucial for Pakistan, a country facing significant water stress due to its growing population and climate change impacts.

4.1.2 RBOD-III: An overview

RBOD-III is an extension of the drainage system initiated by RBOD-I, focusing on enhancing the drainage capacity and covering additional areas in Sindh and Balochistan (Sindh Irrigation Department, n.d.). The main objectives of RBOD-III include:

1. Enhanced Drainage Capacity: RBOD-III is designed to increase the drainage capacity of the region, helping to reduce waterlogging and salinity in the project areas. This is particularly important in regions like Nasirabad and Jaffarabad Districts in Balochistan, and Jacobabad and Kambar-Shahdadkot Districts in Sindh, where waterlogging has been a significant issue.

2. Effluent Disposal: The project provides facilities for the disposal of effluents from existing and proposed drainage projects. Proper disposal of effluents is

essential to prevent the contamination of water bodies and to maintain the health of the ecosystem.

3. Agricultural and Economic Benefits: By enhancing the drainage system, RBOD-III contributes to increased crop production and improved cropping intensity over a Gross Commanded Area (GCA) of 0.709 million acres. This directly benefits the local economy by boosting agricultural output and providing livelihoods to farmers in the region.

4.1.3 Agricultural productivity and food security

The RBOD-I and RBOD-III projects have significantly improved agricultural productivity by addressing the critical issues of waterlogging and salinity. These problems have long plagued the agricultural sector in Pakistan, particularly in the Indus Basin, where excess water and salt accumulation have rendered large areas of land unfit for cultivation. Through effective drainage, RBOD-I and RBOD-III have reclaimed vast tracts of land, transforming them into fertile fields capable of supporting diverse crops. The increase in agricultural productivity has had a ripple effect on food security in Pakistan. By ensuring that more land is available for cultivation, these projects have contributed to higher yields and a more stable food supply. This is particularly important in a country like Pakistan, where agriculture plays a crucial role in the economy and where a significant portion of the population depends on farming for their livelihoods (Mahessar et al., 2019).

4.1.4 Environmental improvement and biodiversity preservation

RBOD-I and RBOD-III have also played a crucial role in improving environmental conditions in regions affected by poor water management. The projects have helped restore ecological balance in important water bodies like Manchar and Hamal Lakes, which were previously suffering from pollution and reduced water quality due to poor drainage. By improving the flow of water and reducing the buildup of pollutants, these projects have helped preserve the biodiversity of these lakes, supporting both aquatic life and the communities that rely on these ecosystems. The environmental benefits of these projects extend beyond the lakes themselves. By improving the quality of water and soil in the surrounding areas, RBOD-I and RBOD-III have contributed to the overall health of the

environment. This, in turn, supports sustainable development by ensuring that natural resources are available for future generations (Khashkheli et al., 2024).

4.1.5 Efficient water management

Efficient water management is essential for sustainable development, particularly in water-stressed countries like Pakistan. The RBOD projects have made a significant contribution to this by providing an efficient drainage system that prevents waterlogging and ensures that excess water is properly managed. This is particularly important in regions where the water table is high, and where improper water management can lead to severe environmental degradation. By improving water management, RBOD-I and RBOD-III have also contributed to the long-term sustainability of agriculture in the region. Proper drainage ensures that crops receive the right amount of water, preventing both drought and waterlogging. This not only improves crop yields but also ensures that the soil remains fertile and productive over the long term (Sindh Irrigation Department, n.d.).

4.1.6 Land reclamation and economic growth

One of the most significant benefits of the RBOD projects has been the reclamation of land that was previously unsuitable for agriculture due to waterlogging and salinity. This reclaimed land has been transformed into fertile agricultural fields, contributing to increased agricultural productivity and economic growth in the region. The economic benefits of these projects are substantial. By increasing the amount of arable land, RBOD-I and RBOD-III have provided farmers with more opportunities to grow crops and generate income. This has had a positive impact on the local economy, particularly in rural areas where agriculture is the primary source of income. The increased agricultural output has also contributed to the overall economic growth of the country, helping to reduce poverty and improve living standards (Sayeed et al., 2019).

4.1.7 Flood management and disaster mitigation

Although not explicitly stated in the project documentation, the RBOD projects contribute indirectly to flood management by facilitating the smooth discharge of excess water. This is particularly important in regions prone to seasonal

flooding, where the ability to quickly drain excess water can prevent disasters and reduce the impact of floods on communities and agriculture (Otto et al., 2023).

By improving drainage, the RBOD projects help reduce the risk of flooding, protecting both lives and property. This is an important aspect of disaster mitigation, particularly in a country like Pakistan, where natural disasters such as floods are a regular occurrence. The RBOD projects, therefore, play a critical role in enhancing the resilience of communities to natural disasters.

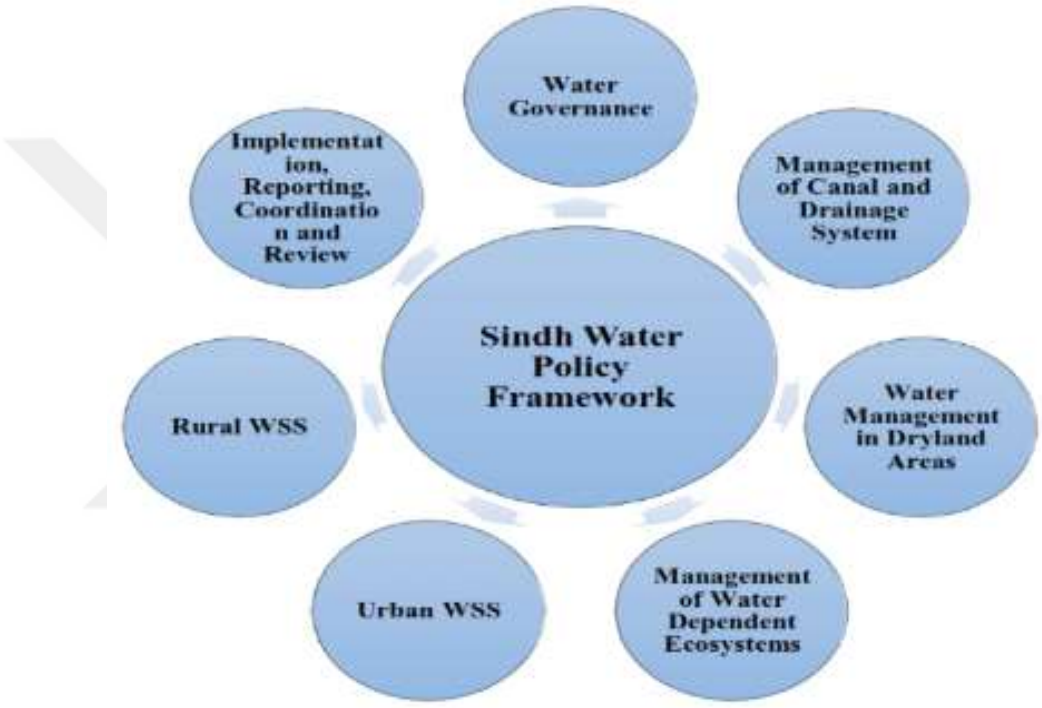

Figure 4.2: Sindh Water Policy Framework

Source: Sindh Irrigation Department, (n.d.)

4.1.8 RBOD-I and RBOD-III as a cleansing mechanism

The concept of "cleansing the earth" through infrastructure like RBOD-I and RBOD-III can be understood in the context of improving soil and water quality. Waterlogging and salinity are significant problems in the Indus Basin, where excess water and salt accumulation degrade the soil, making it less productive and even harmful to crops. By providing an efficient drainage system, these projects help remove excess water and salts from the soil, effectively cleansing it and restoring its fertility. In addition to soil cleansing, the RBOD projects also play a role in cleansing

underground water resources. Poor drainage can lead to the contamination of groundwater with salts and other pollutants, reducing the quality of this vital resource. By improving drainage, RBOD-I and RBOD-III help prevent the contamination of groundwater, ensuring that it remains a valuable resource for drinking water and irrigation. This cleansing process is crucial for the long-term sustainability of agriculture in Pakistan. By maintaining the quality of soil and water, the RBOD projects ensure that these resources remain available and productive for future generations. This is particularly important in a country like Pakistan, where population growth and climate change are placing increasing pressure on natural resources (Dey & Dutta Roy, 2025).

4.1.9 Challenges and future considerations

While the RBOD projects have brought significant benefits to Pakistan, they also pose challenges that need to be addressed to ensure their long-term sustainability. One of the primary challenges is the maintenance of the drainage systems. Over time, these systems can become clogged with silt and debris, reducing their effectiveness. Regular maintenance and monitoring are essential to ensure that the drainage systems continue to function as intended. Another challenge is the potential environmental impact of the effluent disposal systems. While the RBOD projects are designed to improve environmental conditions, there is a risk that improper disposal of effluents could lead to contamination of water bodies and soil. It is important to ensure that effluent disposal is carried out in a way that minimizes environmental harm and supports the overall goals of the project. Finally, the success of the RBOD projects depends on the continued cooperation of all stakeholders, including government agencies, local communities, and farmers. Effective communication and collaboration are essential to ensure that the benefits of the RBOD projects are realized and that the projects continue to support sustainable development in Pakistan.

RBOD-I and RBOD-III represent significant infrastructure investments that have contributed to the sustainable development of Pakistan. By improving drainage, reducing waterlogging and salinity, and enhancing agricultural productivity, these projects have helped cleanse the earth and underground resources, supporting the long-term sustainability of agriculture and the environment.

Table 4.1: RBOD Waterflow Chart

Source: Sindh Irrigation Department, (n.d.)

4.2 Mangla Watershed Program

The Mangla Watershed Program is a vital infrastructure project that has played a significant role in Pakistan's environmental, social, and economic sustainability. Located in the northeastern part of Pakistan, the transboundary Mangla Watershed spans from 73°55’ to 75°35’ east of longitude and 33°25’ to 34°40’ north of latitude, covering an area of approximately 33,490 square kilometers. This watershed is crucial as it feeds into the Mangla Dam, built on the Jhelum River, which is a major tributary of the Indus River (Haider et al., 2020).

4.2.1 Environmental sustainability

One of the primary achievements of the Mangla Watershed Program is its contribution to environmental sustainability. Since its inception, significant investments have been made in the Tarbela and Mangla watersheds. For instance, during the period 2004-2005, the Tarbela watershed saw the establishment of 96 nurseries, the plantation of 8,000 acres, the provision of check dams on 2,320 acres, terracing of 525 acres, and general maintenance activities across 30,000 acres of land. These efforts were mirrored in the Mangla watershed, where 4,500 acres were afforested under the Mangla Watershed Management Project. These environmental conservation activities have had profound impacts. By 1984, these interventions led

to a 25% reduction in sediment load, a decrease in peak water flows, and an increase in total water supplies. The reduction in sediment load is particularly important as it extends the lifespan of the Mangla Dam by reducing siltation, thereby ensuring a continued water supply for irrigation, domestic use, and hydropower generation (Butt et al., 2021). The geographical characteristics of the Mangla watershed, with elevations ranging from 182 meters to 5,840 meters above mean sea level, contribute to its importance as a natural water reservoir. The immense icecaps within the watershed provide a large volume of water to the Jhelum River through melting, which ultimately contributes to the Mangla Dam reservoir. This natural water replenishment system is vital for maintaining the dam's water levels, especially during dry seasons. Furthermore, the watershed's environmental management practices, such as reforestation, construction of silt traps, check dams, and terracing, have enhanced water conservation. These measures help in controlling soil erosion, reducing the speed of water flow, and trapping sediments, which collectively contribute to maintaining the quality of water entering the Mangla Dam. By improving the health of the watershed, these activities ensure the long-term sustainability of the water resources that are crucial for Pakistan's agricultural and energy needs (Rahim et al., 2023).

Social Sustainability. The Mangla Watershed Program has also had significant social benefits, particularly in the context of poverty reduction and community empowerment. The watershed conservation activities are part of broader projects aimed at "Poverty Reduction through Participatory Watershed Management." These projects support the establishment of community organizations and the creation of employment opportunities, which are essential for the socio-economic development of the region. The participatory approach in watershed management ensures that local communities are actively involved in the conservation efforts. This not only enhances the effectiveness of the projects but also empowers the communities by providing them with the knowledge and skills needed to manage their natural resources sustainably. The creation of nurseries, afforestation, and maintenance activities offer direct employment opportunities, which help in reducing poverty in the region. Moreover, the social sustainability of the Mangla Watershed Program is further supported by the global discourse on payments for environmental services (PES). This debate, stimulated by organizations like the International

Institute for Environment and Development (IIED), suggests that downstream beneficiaries of wise upstream land and water use should contribute financially to these conservation efforts. While this concept is still evolving in Pakistan, it holds the potential to provide additional financial resources for sustaining the watershed management activities, thereby ensuring the long-term viability of the program (Imran & Haider, 2024).

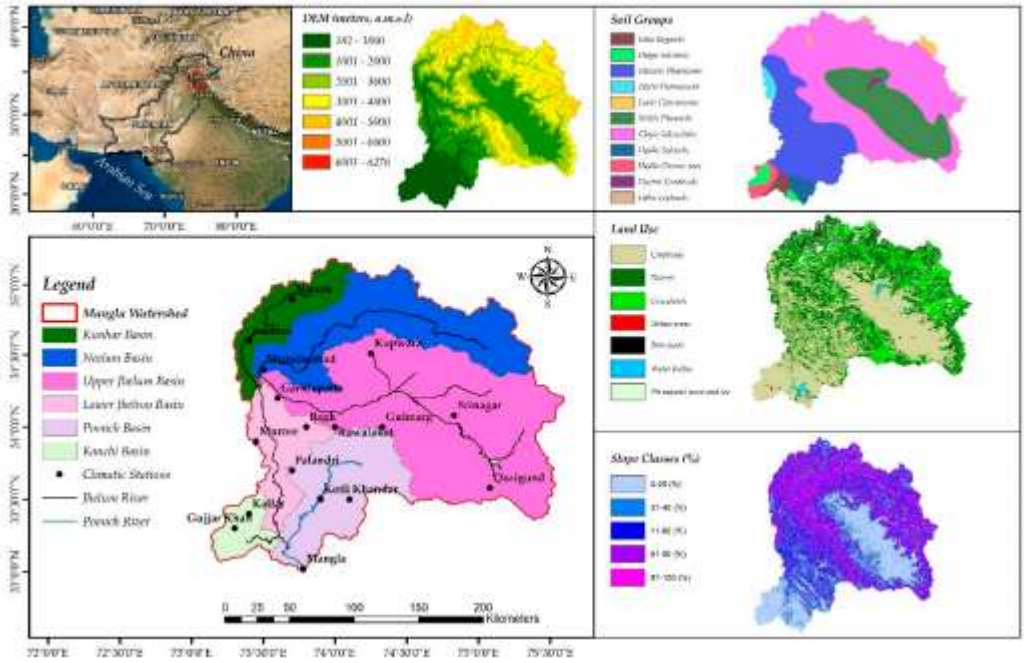

Figure 4.3: Mangla Watershed Program Catchment Area

Source: Haider et al., (2020)

4.2.2 Economic sustainability

The Mangla Watershed Program is economically sustainable, primarily due to its contributions to water resource management and hydropower generation. The Mangla Dam, with a storage capacity of 6.5 billion cubic meters of water, plays a critical role in Pakistan's irrigation and energy sectors. The dam's hydropower generation capacity of approximately 1,310 MW is a significant contribution to the national grid, providing a renewable source of energy that reduces the country's reliance on fossil fuels. The watershed's role in maintaining the water inflows to the Mangla Dam is crucial for sustaining its hydropower generation capacity. The total inflows into the dam are 1,699.01 cubic meters per second, while the outflows are 566.34 cubic meters per second. This balance between inflows and outflows is essential for the optimal operation of the dam, ensuring a steady supply of water for

power generation, irrigation, and domestic use. Additionally, the Mangla Watershed Program's contribution to reducing sedimentation in the dam reservoir has significant economic benefits. By lowering the sediment load by 25%, the program has extended the operational life of the Mangla Dam, thereby delaying the need for costly dredging operations or the construction of new reservoirs. This cost-saving aspect is a critical component of the program's economic sustainability. Furthermore, the program's emphasis on reforestation and soil conservation has positive economic impacts on agriculture. By preventing soil erosion and improving soil fertility, the program enhances agricultural productivity in the region. This is particularly important for the livelihoods of the local communities, who rely on agriculture as their primary source of income (Khan, Khan & Iqbal, 2019).

4.2.3 Climate resilience and future sustainability

The Mangla Watershed Program also contributes to Pakistan's resilience to climate change. The digital elevation model (DEM) used for watershed delineation helps in understanding the watershed's properties, such as soil, slope, elevation, and stream flow, which are crucial for climate modeling and adaptation planning. The Soil and Water Assessment Tool (SWAT) model, used for simulating hydrological processes, provides valuable insights into how climate change might impact the watershed. For instance, the program's data indicates that the mean temperature in the Mangla Watershed is expected to rise by 3.34°C by 2070 and by 2.54°C from 2070 to 2100. This warming trend will likely increase the rate of glacial melt, altering the flow regimes of rivers feeding into the Mangla Dam. By incorporating climate models into its planning, the Mangla Watershed Program can develop strategies to manage these changes, ensuring that the watershed continues to provide reliable water supplies in the face of a changing climate. The program's focus on afforestation and soil conservation also contributes to carbon sequestration, helping to mitigate the impacts of climate change. Trees and vegetation within the watershed absorb carbon dioxide from the atmosphere, thereby reducing the country's overall carbon footprint. This aspect of the program aligns with Pakistan's commitments to international climate agreements, such as the Paris Agreement, and enhances the country's reputation as a responsible global citizen (Hussain Cattapan & Franca, 2018).

Table 4.2: Mangla Watershed Program Catchment Area Class and Coverage

Sr. No.	Slope Class (%)	Area Covered (%)	Area Covered (Km2)
1	0-20	27.79	9306.9
2	21-40	20.96	7019.5
3	41-60	21.24	7113.3
4	61-80	16.07	5381.8
5	>80	13.93	4665.2

Source: WAPDA, (2020)

The Mangla Watershed Program stands as a model of sustainable infrastructure for Pakistan. Its multifaceted approach to environmental conservation, social empowerment, and economic development ensures that it remains a valuable asset for the country. By reducing sedimentation, enhancing water conservation, supporting local communities, and contributing to climate resilience, the program not only sustains the Mangla Dam's operations but also supports the broader goal of sustainable development in Pakistan. As the country faces the challenges of climate change and population growth, the continued investment in and management of the Mangla Watershed will be essential. By maintaining the delicate balance between environmental conservation, social well-being, and economic growth, the Mangla Watershed Program will continue to play a critical role in securing Pakistan's water resources and supporting the livelihoods of millions of people.

4.3 Tarbela Watershed Program

The Tarbela Watershed Program has been instrumental in advancing environmental sustainability and social progress in Pakistan. Significant investments were made in the 2004-05 period, which included the establishment of 96 nurseries and the afforestation of 8,000 acres. Furthermore, 2,320 acres were equipped with check dams, 525 acres were terraced, and maintenance was carried out on 30,000 acres. These activities had a marked impact on water conservation, leading to a 25% reduction in sediment load, a decrease in peak water flows, and an increase in overall water supplies by 1984. The Mangla Watershed Management Project also made substantial environmental contributions during this period, with 4,500 acres being successfully afforested. These efforts collectively enhanced the environmental resilience of the region, ensuring that vital water resources were better managed and conserved (Munir et al., 2022). On the social front, the watershed conservation

efforts were integrated into broader "Poverty Reduction through Participatory Watershed Management" projects. These initiatives not only helped to establish community organizations but also created employment opportunities, which played a crucial role in addressing poverty and promoting social development in the region. The Tarbela Watershed Program represents a sustainable infrastructure that has had lasting positive impacts on both the environment and the communities in Pakistan. By focusing on both environmental conservation and social development, the program has provided a model for sustainable development that other regions can emulate. This dual focus on environmental and social objectives has ensured the long-term viability and success of the watershed management initiatives, contributing to the overall resilience of the region (Mazhar et al., 2023).

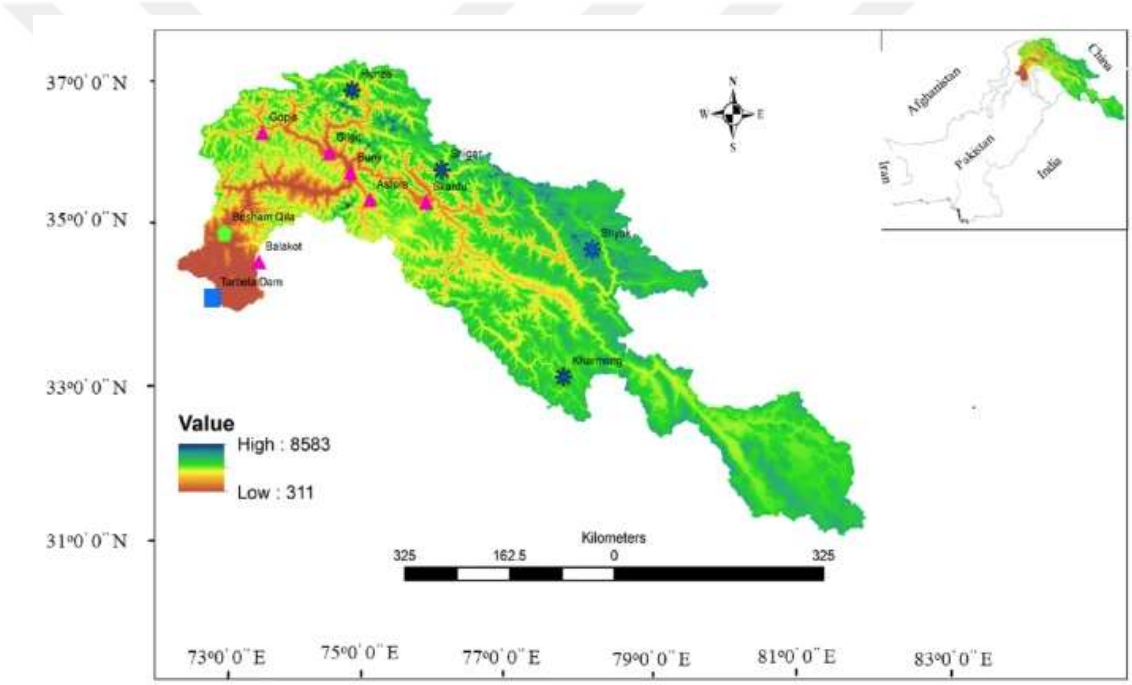

Figure 4.4: Tarbela Watershed Program Catchment Area

Source: Khan, (2022)

4.4 Billion Tsunami Tree Project

The Billion Tree Tsunami Project (BTTP) has emerged as a critical initiative for promoting environmental sustainability in Pakistan. With a total Public Sector Development Program (PSDP) allocation of Rs. 109.38 billion for the forest component and Rs. 15.59 billion for the wildlife component from 2019-2023, the project has made significant strides despite financial challenges. In the fiscal year 2019-2020, the project faced a substantial financial cut of 52.3%, receiving Rs. 7.5

billion against the requested Rs. 15.6 billion (Hussan et al., 2024). Similarly, in the fiscal year 2020-21, the project received Rs. 4.9 billion against a requested Rs. 23 billion, reflecting a 78.69% reduction. Despite these financial constraints, 91% of the staff hiring for National and Regional Support Units (NSSU and RSSU) was completed, with ongoing efforts to station staff across Pakistan for monitoring and evaluating the BTTP activities (Shafeeque et al., 2022). During the COVID-19 pandemic, the BTTP provided much-needed green jobs to 84,609 daily wagers, highlighting its role in addressing both environmental and socio-economic challenges. By June 30, 2021, the project achieved a plantation target of 430 million trees, with an ambitious goal of planting one billion trees by the end of the same year. The BTTP aligns with the current government's vision of Green Growth, which emphasizes sustainable forestry development in Khyber Pakhtunkhwa, the generation of green jobs, gender empowerment, and the preservation of Pakistan's natural capital. This initiative is not only a response to the global challenge of climate change but also a testament to Pakistan's commitment to ecosystem restoration, as exemplified by its leadership in the UN Decade on Ecosystem Restoration (2021-2030). In light of Pakistan's vulnerability to climate change, with only 5% forest cover compared to the global average of 31%, the BTTP represents a sustainable infrastructure that addresses both environmental degradation and socio-economic needs (Haq et al., 2024). The project also contributes to increasing the country's Protected Areas to 15% by 2023, supporting long-term ecosystem restoration efforts. Additionally, the BTTP has created nearly 85,000 jobs, demonstrating its impact on improving livelihoods while fostering environmental stewardship (Sabir et al., 2022). The Billion Tree Tsunami Project is a sustainable model for Pakistan, contributing to both the restoration of natural ecosystems and the enhancement of human well-being. By tackling climate change, restoring degraded landscapes, and creating green jobs, the BTTP has established itself as a cornerstone of Pakistan's environmental and social infrastructure (Kmal et al., 2019).

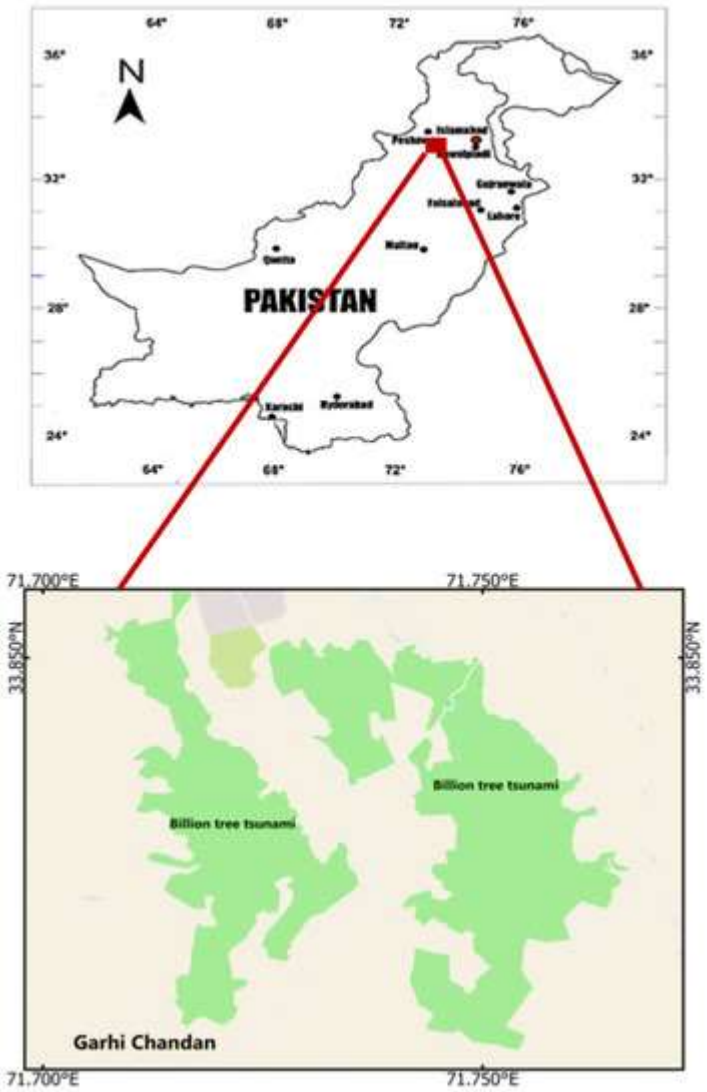

Figure 4.5: Billion Tsunami Forest Location

Source: Mateen et al., (2022)

4.5 Darawat Dam Project

The Darawat Dam, a concrete gravity dam constructed across the Nai Baran River near the village of Jhangri in the Jamshoro district of Sindh, Pakistan, is a prime example of sustainable infrastructure development in a region characterized by arid and saline conditions. The dam's construction began in March 2010, and its completion was inaugurated by the former President of Pakistan, Asif Ali Zardari, on March 9, 2013. The project, with an estimated cost of PKR 9.3 billion, was envisioned to address the critical water management and irrigation challenges in the Kohistan area of Sindh, an agrarian region that heavily depends on its irrigation systems for agricultural productivity (WAPDA, n.d.).

4.5.1 Background and significance

Sindh, one of Pakistan's four provinces, has a predominantly agrarian economy, with agriculture serving as the backbone of its economic activities. However, the Kohistan area within Sindh faces unique challenges due to its saline and deep groundwater, which threaten the sustainability of agriculture in the region. In response to these challenges, the Sindh government, in collaboration with the Sindh Irrigation Department, embarked on the construction of the Darawat Dam. The primary objective was to create a reliable reservoir for rainwater storage, which could be utilized for irrigation and agricultural purposes in the region. The significance of the Darawat Dam lies not only in its ability to store water but also in its strategic role in mitigating the adverse effects of saline groundwater on agriculture. The dam spans 250 meters in length and 43 meters in height, with the capacity to store approximately 150 million cubic meters (120,000 acre-feet) of water. This storage capacity is crucial for irrigating around 10,000 hectares (25,000 acres) of land, which in turn sustains the livelihoods of thousands of farmers in the region (Shaikh et al., 2024).

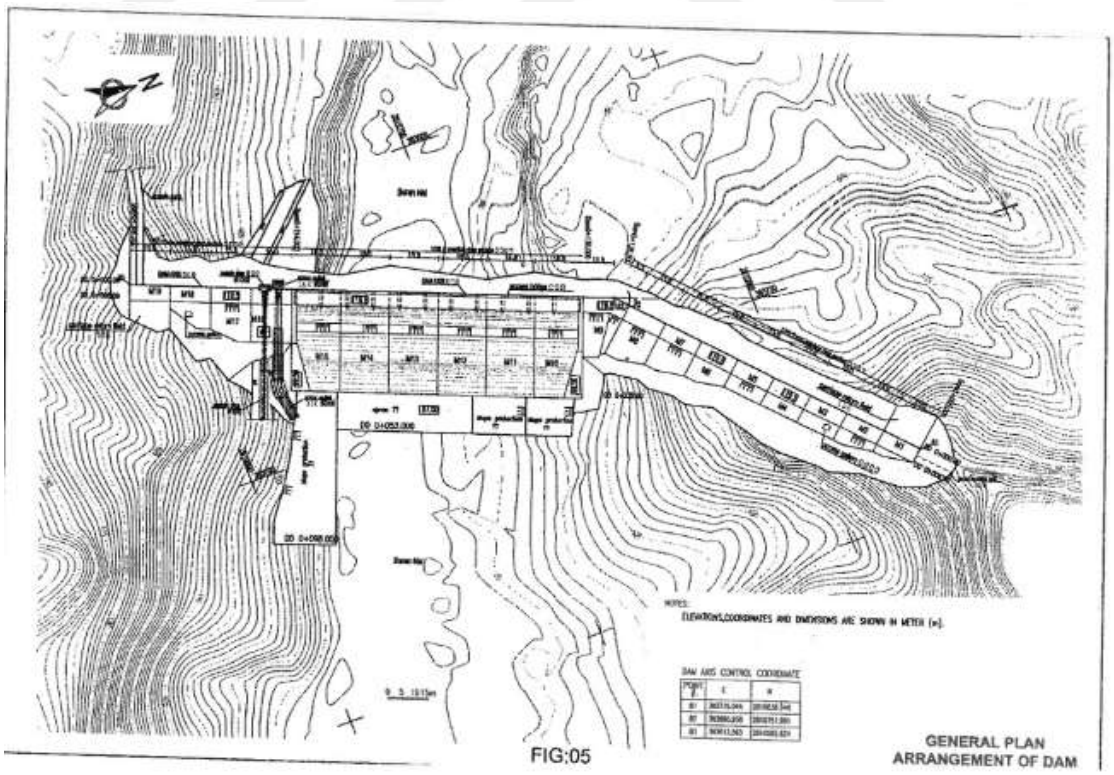

Figure 4.6: Darwat Dam Project Layout Plan

Source: Sindh Irrigation Department, (n.d.)

4.5.2 The role of darawat dam in water resource management

The Darawat Dam serves as a critical component of water resource management in the Kohistan area. The region's reliance on groundwater for agriculture has been increasingly threatened by the high salinity levels, which compromise crop yields and soil quality. The dam's ability to capture and store rainwater provides a sustainable alternative to the over-extraction of groundwater. By regulating water supply, the dam ensures that local farmers have access to a reliable source of water for irrigation, even during periods of low rainfall. In addition to its irrigation benefits, the dam also plays a vital role in domestic and industrial water supply. The off-taking canals constructed alongside the dam are designed to deliver water to local communities, ensuring that their domestic water needs are met. This multi-purpose use of the dam's water resources underscores its importance as a sustainable infrastructure project that addresses both agricultural and non-agricultural water demands (WAPDA, n.d.).

Table 4.3: Darawat Dam Project Details

Type	Ungated Ogee
Capcity	3600 Cumecs (127152 cusecs)
Outlets	
Irrigation	
Sill Level	104 m
Diaeter	1.4 m
Max flow	4.2 cumecs
Supply Pipe Length	869.45 m
Secour	
Sill Level	98.5 m
Diameter	2 m
Max flow	6.54 cumecs

Source: Sindh Irrigation Department, (n.d.)

4.5.3 Addressing salinity issues

One of the most pressing challenges in the Kohistan area is the salinity of the groundwater, which poses a significant threat to agricultural productivity. The Sindh government's strategy for managing salinity involves a combination of groundwater recharge projects, saline water exclusion schemes, and soil improvement initiatives. These measures are designed to combat the adverse effects of salinity on crop yields

and to ensure the long-term sustainability of agriculture in the region. The Darawat Dam plays a central role in these salinity management strategies. By providing a reliable source of freshwater for irrigation, the dam reduces the reliance on saline groundwater, thereby mitigating the impact of salinity on crops. Moreover, the dam's reservoir can be used for groundwater recharge, which helps to dilute the saline content of the groundwater and improve its quality for agricultural use (Sindh Irrigation Department, n.d.).

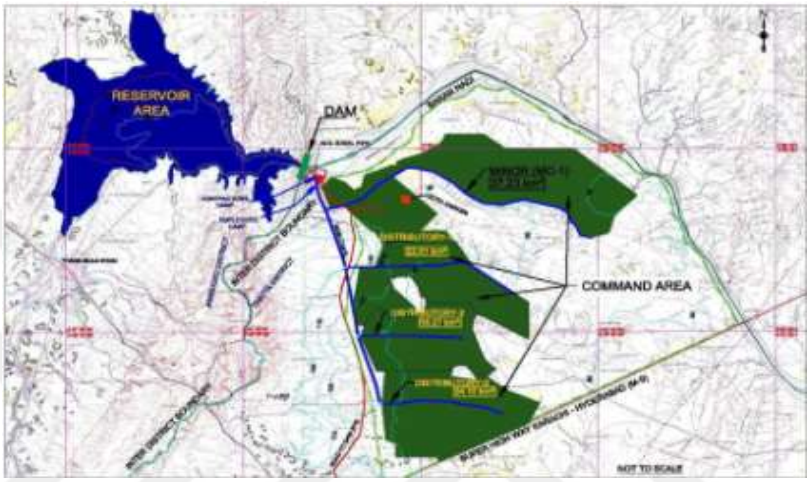

Figure 4.7: Darwat Dam Catchment Area

Source: Sindh Irrigation Department, (n.d.)

4.5.4 Environmental sustainability

Environmental sustainability has been a core consideration in the design, construction, and operation of the Darawat Dam. The project was undertaken with a strong commitment to minimizing its ecological impact, preserving biodiversity, and promoting environmentally friendly agricultural practices among local farmers. The construction of the dam was carefully planned to avoid disrupting the natural habitats of the region. Measures were implemented to protect the local flora and fauna, and efforts were made to minimize the ecological footprint of the project. Additionally, the dam's operation is closely monitored to ensure that it does not negatively impact the downstream ecosystems or lead to the depletion of local water resources. In line with global best practices, the Darawat Dam project also emphasizes the importance of sustainable agricultural practices. Farmers in the region are encouraged to adopt techniques that reduce water wastage, improve soil health, and enhance crop yields without harming the environment. These practices include drip irrigation, crop

rotation, and the use of organic fertilizers, all of which contribute to the long-term sustainability of agriculture in the region (Sindh Irrigation Department, n.d.).

Table 4.4: Darawat Dam Irrigation Area

Name of Canal	Length (KM)	Outlet No's			Design Discharge (Cusecs)	Area to be Cultivated (Acres)
		Right	Left	Total		
Main Canal	11.929				156	25000
C-1	14.6	20	4	24	58	9251
D-1	8.52	12	5	17	35.2	5652
D-2	5	7	8	15	25.3	4067
D-3	5.9	8	9	17	37.6	6030
Total	45.949	47	26	73	156	25000

Source: Sindh Irrigation Department, (n.d.)

4.5.5 Community engagement and stakeholder involvement

The success of the Darawat Dam project can be attributed in large part to the active engagement of local communities, farmers, and other stakeholders. From the outset, the Sindh government recognized the importance of involving these groups in the planning, implementation, and management of the dam. Their participation ensured that the project was aligned with the needs and priorities of the local population, and that their concerns were addressed at every stage. Collaboration with relevant governmental agencies, academic institutions, and non-governmental organizations was also a key component of the project. This multi-stakeholder approach allowed the Sindh government to leverage expertise and resources from a wide range of sources, thereby enhancing the effectiveness of the dam and its associated initiatives. The involvement of these stakeholders also helped to build trust and foster a sense of ownership among the local communities, which is critical for the long-term success of the project (Sindh Irrigation Department, n.d.).

4.5.6 Economic impact and job creation

Beyond its environmental and agricultural benefits, the Darawat Dam has also had a significant economic impact on the region. The construction of the dam and its associated infrastructure created numerous job opportunities for local workers, providing a much-needed boost to the local economy. Moreover, the dam's ability to support agricultural activities has helped to secure the livelihoods of

thousands of farmers, many of whom rely on agriculture as their primary source of income. The availability of a reliable water supply has also opened up new opportunities for economic development in the region. With access to sufficient water resources, local farmers are able to cultivate a wider range of crops, including high-value cash crops that can be sold in local and regional markets. This diversification of agricultural activities has the potential to increase household incomes and reduce poverty in the region (Abid et al., 2021).

4.5.7 Long-term sustainability and future prospects

The Darawat Dam project represents a model of sustainable infrastructure development that can be replicated in other regions facing similar challenges. Its success lies in its ability to address the complex interplay of environmental, social, and economic factors that impact water resource management and agricultural productivity. By providing a reliable source of water, mitigating the effects of salinity, and promoting environmentally sustainable practices, the dam has laid the foundation for long-term sustainability in the Kohistan area. Looking to the future, the Sindh government is committed to building on the success of the Darawat Dam by implementing additional projects and initiatives that enhance water resource management in the region. This includes the development of new dams, the expansion of irrigation networks, and the implementation of advanced water management technologies. These efforts will be guided by the principles of sustainability, environmental stewardship, and community engagement, ensuring that the benefits of these projects are realized for generations to come (Nasreen & Ashraf, 2020).

Figure 4.8: Darawat Dam Spillway

Source: Sindh Irrigation Department (n.d.)

The Darawat Dam is a testament to the power of sustainable infrastructure development in addressing the challenges of water resource management and agricultural productivity in arid and saline regions. By providing a reliable source of water, mitigating the impact of salinity, and promoting sustainable agricultural practices, the dam has made a significant contribution to the socio-economic development of the Kohistan area in Sindh. Its success is a result of careful planning, community engagement, and a commitment to environmental sustainability. As Pakistan continues to face the challenges of climate change and water scarcity, projects like the Darawat Dam will play an increasingly important role in ensuring the long-term sustainability of its natural resources and the well-being of its people.

4.6 Dasu Hydro Power Project

The Dasu Hydropower Project represents a crucial step toward sustainable energy production in Pakistan. Situated on the Indus River, approximately 7 kilometers upstream of Dasu Town in the Upper Kohistan district of Khyber Pakhtunkhwa, the project is a run-of-the-river initiative that harnesses the natural flow of the river to generate electricity. Located 74 kilometers downstream of the proposed Diamer Basha Dam site and 345 kilometers from Islamabad, the project is positioned strategically to contribute significantly to the country's energy needs (WAPDA, n.d.).

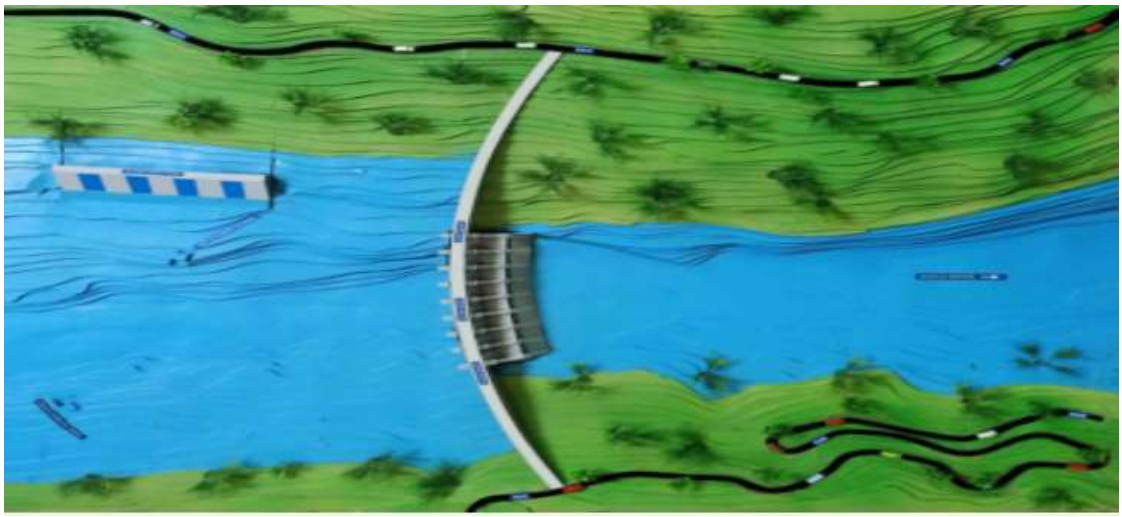

Figure 4.9: Dasu Hydro Power Project Layout

Source: DASu Hydropower Project DHPP, (n.d.)

4.6.1 Project overview and strategic importance

The Dasu Hydropower Project is designed to generate a total of 4,320 MW of electricity, with 12 hydropower units rated at 360 MW each. The project is being developed in two stages, with Stage I comprising the installation of six units that will collectively produce 2,160 MW of electricity. This stage alone is expected to generate an annual energy output of 12,222 GWh. Stage II, which will add another 2,160 MW, will increase the total annual energy output to 21,700 GWh. The completion of Stage I is anticipated within five years, making a significant contribution to the country's energy grid by 2026. This project is a priority under the Power Policy 2013 and Vision 2025, frameworks established by the Government of Pakistan to address the country's chronic energy shortages. The project aligns with Pakistan's broader strategy to diversify its energy mix, reduce reliance on fossil fuels, and enhance the sustainability of its energy infrastructure. The decision to pursue run-of-the-river technology, which does not require large reservoirs, is particularly noteworthy as it minimizes environmental disruption and reduces the displacement of local communities (WAPDA, n.d.).

4.6.2 Financial structure and investment

The financial structuring of the Dasu Hydropower Project is an exemplary model of leveraging both international and domestic financing to achieve a large-scale infrastructure project. The World Bank plays a significant role in financing the project, providing an International Development Association (IDA) credit of $588.4

million and an IDA Partial Credit Guarantee (PCG) of $460 million for Stage I. Additionally, a consortium of local banks, led by Habib Bank Limited (HBL), has extended financing of Rs144 billion ($1.03 billion), with the first tranche released in May 2017. Furthermore, Credit Suisse Bank committed $350 million, with the initial tranche of $188 million released in June 2017. The project's financing plan also includes a proposed commercial loan of $2 billion from local and foreign banks, backed by the World Bank's PCG. In March 2020, an additional loan of $700 million was secured from the World Bank specifically for constructing the transmission line necessary to deliver electricity from the project to the national grid. This multi-layered financing approach ensures that the project remains on track, even in the face of potential financial uncertainties. It also reflects a high level of confidence from both international financial institutions and domestic banks in the project's viability and its importance to Pakistan's energy future (WAPDA, n.d.).

Table 4.5: Dasu Hydropower Project Cost Components

Component	Approx Cost (million USD)
Land Acquisition	80.08
Enhanced Self-Managed Resettlement (ESMR	21.67
Temporary Relocation Payments	0.40
Project Allowances	0.03

Source: DASu Hydropower Project DHPP, (n.d.)

4.6.3 Technological and environmental considerations

The Dasu Hydropower Project employs run-of-the-river technology, which is a more sustainable and environmentally friendly option compared to traditional dam-based hydropower projects. This technology capitalizes on the natural flow of the Indus River to generate electricity without the need for large reservoirs, which can lead to significant environmental impacts, including habitat destruction and displacement of local populations. By avoiding these issues, the Dasu project sets a precedent for future hydropower projects in Pakistan and other countries with similar topographies and environmental concerns. In addition to its environmental benefits, the run-of-the-river technology used in the Dasu project ensures a more consistent and reliable generation of electricity, as it is less affected by seasonal variations in

water flow. This reliability is crucial for meeting the energy demands of Pakistan's growing population and industrial sector (WAPDA, n.d.).

4.6.4 Socio-economic impact

The Dasu Hydropower Project is expected to have a profound socio-economic impact on the local and national levels. By generating enough electricity to meet the needs of approximately four million households, the project will play a vital role in addressing Pakistan's energy shortfall, which has been a major impediment to economic growth and development for many years. The availability of reliable and affordable electricity will spur industrial growth, create jobs, and improve the overall quality of life for millions of Pakistanis. Moreover, the project is expected to stimulate economic development in the Kohistan region, one of the more remote and underdeveloped areas of Pakistan. The construction phase of the project has already created thousands of jobs, and the operational phase is expected to create more opportunities in the energy, infrastructure, and service sectors. Additionally, the development of infrastructure, such as roads and bridges, associated with the project will improve connectivity in the region, further contributing to economic growth (Mubin et al., 2019).

4.6.5 Sustainability and long-term benefits

The sustainability of the Dasu Hydropower Project is not just in its ability to generate renewable energy, but also in its contribution to the long-term energy security of Pakistan. By reducing the country's reliance on fossil fuels, the project will help to decrease greenhouse gas emissions and mitigate the impacts of climate change. This aligns with Pakistan's commitments under the Paris Agreement to reduce its carbon footprint and transition to a more sustainable energy system. Furthermore, the project serves as a model for future hydropower developments in Pakistan. Its success will likely encourage further investment in similar projects, particularly in the northern regions of Pakistan where there is significant potential for hydropower generation. This could lead to a more diversified and resilient energy system, capable of meeting the growing demands of the country while minimizing environmental impacts (Mubin et al., 2019).

Figure 4.10: Dasu Hydropower Project Location

Source: Dasu Hydropower Project Picture Gallery, (n.d.)

The Dasu Hydropower Project is a landmark initiative in Pakistan's pursuit of energy sustainability. Its strategic location, innovative use of run-of-the-river technology, and robust financial structuring make it a key component of the country's energy infrastructure. As it moves towards completion, the project promises to provide a reliable source of clean energy, stimulate economic growth, and set a precedent for future hydropower projects in the region. In a country where energy shortages have long been a hindrance to development, the Dasu Hydropower Project stands as a beacon of hope for a more sustainable and prosperous future.

4.7 Diamer Bhasha Dam Project

The Diamer Bhasha Dam Project stands as one of the most significant infrastructure undertakings in Pakistan's history, symbolizing a commitment to sustainable development and energy security. Situated on the Indus River in the Northern Areas of Pakistan, approximately 40 kilometers downstream of Chilas and 82 kilometers upstream of Dasu, this project is not only monumental in its physical scale but also in its potential impact on the country's socio-economic fabric (WAPDA, n.d.).

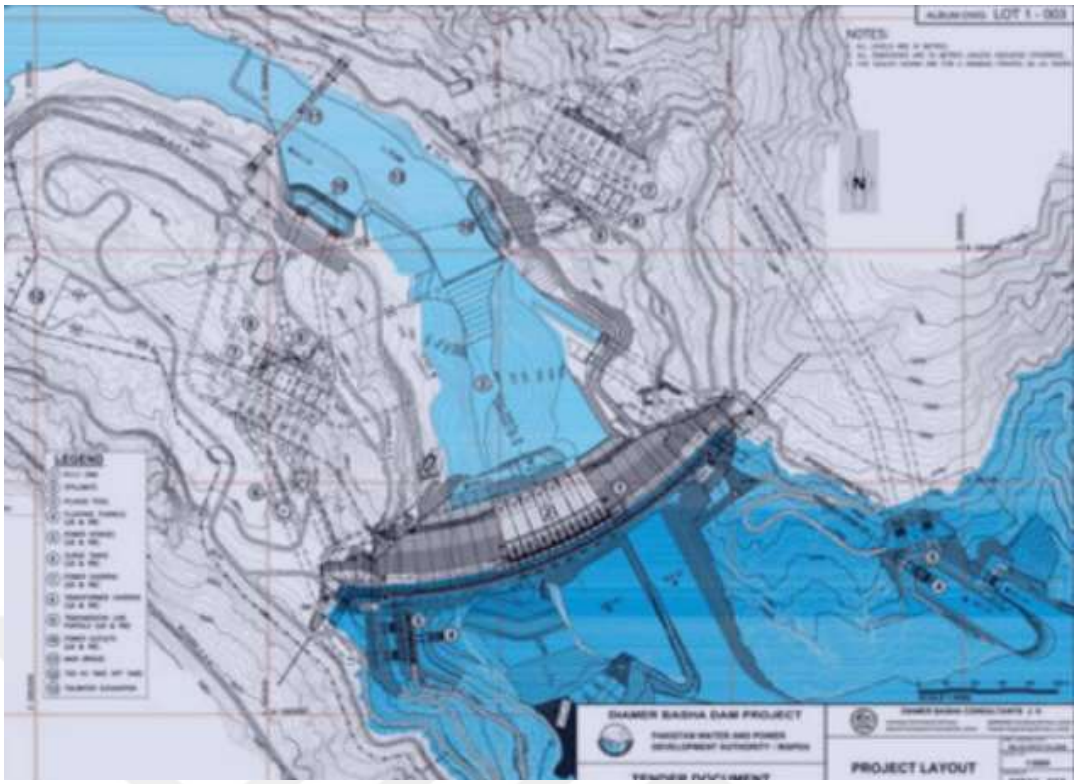

Figure 4.11: Diamer Basha Dam Project Layout Plan

Source: Luke, (2018)

4.7.1 Overview and strategic importance

The Diamer Bhasha Dam is designed as a concrete gravity dam with a towering height of 272 meters. It will feature two underground power stations, each with an installed capacity of 2,250 MW, making it one of the largest hydropower projects in the region. The project's primary objectives include water storage for irrigation, flood control, and the generation of hydroelectric power, which is crucial for a country grappling with chronic energy shortages. Strategically located in an earthquake-prone region, the dam's design has incorporated extensive seismic evaluations to ensure its resilience. The Seismic Hazard Evaluation Study determined three critical design levels for peak ground acceleration: 0.22g for Operating Basis Earthquake (OBE), 0.37g for Maximum Design Earthquake (MDE), and 0.46g for Maximum Credible Earthquake (MCE). These design parameters ensure that the dam can withstand significant seismic events, thereby securing its long-term operational stability (WAPDA, n.d.).

4.7.2 Environmental and social impact assessments

A project of this magnitude necessitates comprehensive planning to address its potential environmental and social impacts. The Environmental and Social Impact Assessment (ESIA) has been central to the Diamer Bhasha Dam Project, guiding the necessary preparatory studies, fieldwork, and research to ensure the dam's financial viability and sustainability. One of the key components of the ESIA is the Scoping Exercise, which identifies the critical issues that need thorough analysis during the project's implementation. This exercise is essential for understanding the environmental, social, and economic contexts in which the project operates. The Environmental Impact Assessment (EIA) forms the backbone of this analysis, evaluating the potential effects of the dam on local ecosystems, water quality, and biodiversity. Another critical aspect of the ESIA is the Resettlement, Land Acquisition, and Compensation Action Plan. Given the scale of the Diamer Bhasha Dam, significant land acquisition is required, which in turn affects local communities. The action plan aims to ensure that those displaced by the project are adequately compensated and resettled in a manner that preserves their livelihoods and cultural heritage. Furthermore, the Climate Change Impact Assessment has been conducted to examine trends in annual and seasonal water flow in the Indus River over several decades (Shahab et al., 2023). This assessment is crucial for forecasting changes in water availability as a result of climate change and global warming. The findings of this study help in formulating strategies to mitigate the impact of climate change on the dam's operations and ensure its sustainability in the long run. The Indigenous Peoples Plan is another vital component of the ESIA, focusing on the rights and welfare of indigenous communities affected by the dam. This plan ensures that these communities are consulted and their concerns addressed throughout the project's lifecycle. It also emphasizes the preservation of their cultural heritage, which is an integral part of the region's identity. A Monitoring and Evaluation Framework for Socioeconomic Impacts has been established to track the project's effects on local communities and the broader economy. This framework is designed to monitor key indicators such as employment, income levels, and access to basic services, ensuring that the project contributes positively to the region's development. Finally, the Cultural Heritage Preservation Plan is aimed at safeguarding the rich cultural heritage of the area. This plan includes measures to document and protect

historical and cultural sites that may be affected by the dam's construction and operation (Ilyas et al., 2024).

4.7.3 Economic and social benefits

The Diamer Bhasha Dam Project is expected to generate significant economic and social benefits for Pakistan. By providing a reliable source of hydroelectric power, the dam will contribute to reducing the country's dependence on fossil fuels, thereby lowering greenhouse gas emissions and promoting sustainable energy practices. The generation of 4,500 MW of electricity from the dam will also help address the persistent energy shortages that have hampered Pakistan’s economic growth for decades. In addition to power generation, the Diamer Bhasha Dam will play a crucial role in water management. The dam's reservoir, with a storage capacity of approximately 8.1 million acre-feet, will help regulate water flow in the Indus River, reducing the risk of floods downstream. This flood control capability is particularly important in a country where seasonal flooding has historically caused significant damage to infrastructure and agriculture. The project will also have a positive impact on agriculture, which is the backbone of Pakistan’s economy. The stored water from the dam will be used for irrigation, ensuring a stable water supply for millions of hectares of farmland. This will enhance agricultural productivity and contribute to food security in the country. Moreover, the construction and operation of the Diamer Bhasha Dam are expected to create thousands of jobs, both directly and indirectly. The influx of workers and the development of associated infrastructure will stimulate economic activity in the region, leading to increased income levels and improved living standards for local communities (Torre et al., 2021).

4.7.4 Sustainability and long-term impact

The sustainability of the Diamer Bhasha Dam Project is anchored in its multi-faceted approach to development, which balances economic growth with environmental and social responsibility. The project's emphasis on seismic resilience, environmental conservation, and social welfare demonstrates a commitment to sustainable infrastructure development. In the long term, the dam will play a pivotal role in Pakistan’s energy security. By providing a stable and renewable source of

electricity, the Diamer Bhasha Dam will reduce the country's reliance on imported fuels and contribute to energy independence (Atiq et al., 2019). This, in turn, will have a positive impact on the national economy, reducing the trade deficit and stabilizing energy prices. The project also has significant implications for regional development. The improved water management capabilities of the dam will enhance agricultural productivity, leading to increased food security and rural development. The infrastructure improvements associated with the project, including roads, bridges, and communication networks, will further integrate the Northern Areas into the national economy, fostering regional cohesion and reducing inequalities. Furthermore, the Diamer Bhasha Dam Project is expected to serve as a model for future infrastructure projects in Pakistan. Its comprehensive approach to environmental and social impact assessment, coupled with its focus on sustainability, sets a new standard for large-scale infrastructure development in the country. The lessons learned from this project will be invaluable in guiding the planning and implementation of other hydropower projects in the region (Mirza & Mahmood, 2023).

The Diamer Bhasha Dam Project is a landmark initiative that represents a bold step toward sustainable development in Pakistan. Its strategic importance, both in terms of energy security and water management, cannot be overstated. The project's comprehensive approach to environmental and social impact assessment ensures that it will not only meet its economic objectives but also contribute positively to the welfare of local communities and the preservation of the region's cultural heritage. As Pakistan continues to grapple with the challenges of climate change, energy shortages, and economic development, the Diamer Bhasha Dam stands as a beacon of hope. It embodies the principles of sustainable development, demonstrating that it is possible to pursue economic growth while safeguarding the environment and promoting social equity. In doing so, the Diamer Bhasha Dam Project is set to play a critical role in shaping the future of Pakistan's energy landscape and contributing to the country's long-term prosperity.

4.8 Kurram Tangi Dam Project

The Kurram Tangi Dam Project (KTDP) stands as a significant milestone in Pakistan's journey towards sustainable water management, energy generation, and

socio-economic development. Located in the Khyber Pakhtunkhwa (KP) province, specifically in the North Waziristan district, this multipurpose water development project is a testament to Pakistan's commitment to leveraging its natural resources responsibly. The project, which is being developed on the Kurram River, is not only expected to generate hydroelectric power but also to contribute to irrigation, flood control, and local economic development, thereby playing a pivotal role in the sustainable progress of the region (WAPDA, n.d.).

Figure 4.12: Kurram Tangi Dam Project Location

Source: Daily Times, (2022)

4.8.1 Overview of the Kurram Tangi Dam project

The Kurram Tangi Dam is designed as a multipurpose structure, aiming to address several critical issues faced by the region, including energy shortages, water scarcity, and socio-economic challenges. The dam is being constructed across the Kurram and Kaitu Weir rivers, approximately 14 kilometers upstream of the Kurram Garhi Headworks and 32 kilometers north of Bannu City. The project is set to have an installed capacity of 83.4 MW, which will be a substantial addition to the national grid, helping to alleviate the energy crisis in Pakistan. The project is being developed in a single phase and is currently under construction, with its completion expected by 2025. Once operational, the Kurram Tangi Dam will not only generate electricity but will also provide water for irrigation, which is vital for the agricultural sector in the region. The dam will also contribute to flood control, which is crucial given the frequent flooding in the area due to its topography and climate (Yousaf et al., 2018).

4.8.2 Environmental and social impacts

A project of this magnitude inevitably comes with significant environmental and social implications. However, the Kurram Tangi Dam Project has been meticulously planned to minimize its impact on the environment and the local communities. A comprehensive Environmental and Social Impact Assessment (ESIA) has been conducted to ensure that the project aligns with international standards for environmental protection and social responsibility. One of the primary environmental concerns associated with dam projects is the disruption of local ecosystems. In the case of Kurram Tangi, measures have been taken to mitigate these effects. For instance, the construction activities have been planned to minimize disruption to wildlife, particularly in the Deosai plains and the surrounding areas. The project includes provisions for the safe collection and disposal of lubricants, waste oil, and other hazardous materials to prevent contamination of the local environment. Moreover, the project addresses the issue of air pollution in the region. The provision of electricity through the dam is expected to reduce the reliance on wood and kerosene oil for fuel, which are significant contributors to air pollution. This shift towards cleaner energy sources is anticipated to improve air quality in the region, contributing to better health outcomes for the local population (Ahmad et al., 2012).

Figure 4.13: Kurram Tangi Dam Project Spillway

Source: LinkNews, (2021)

4.8.3 Social and economic benefits

The Kurram Tangi Dam Project is not just about energy generation; it is also a catalyst for socio-economic development in the region. The construction of the dam has already created numerous job opportunities for the local population, particularly in the categories of laborers and semi-skilled workers. It is estimated that the project will employ between 100 to 200 people during the construction phase, providing much-needed employment in an area that has historically faced economic challenges. In addition to direct employment, the project is expected to have a ripple effect on the local economy. The increased availability of electricity will spur economic activities, particularly in agriculture and small-scale industries, which are the backbone of the local economy. The dam will provide water for irrigation, which is critical for the cultivation of crops such as wheat, maize, and potatoes. By ensuring a reliable water supply, the project will help to increase agricultural productivity, thereby improving food security and the livelihoods of the local population. The project also includes a comprehensive resettlement, land acquisition, and compensation action plan to ensure that the local communities affected by the construction of the dam are adequately compensated and resettled. This plan is designed to minimize the social impact of the project and to ensure that the affected communities are better off as a result of the project (Matheswaran & Akhtarm, 2023).

4.8.4 Conformance with international standards

The Kurram Tangi Dam Project has been designed to conform to relevant international standards, codes, and practices, particularly in the areas of occupational health, safety, and environmental protection. All activities associated with the project are being carried out in a safe and effective manner, with strict adherence to safety protocols to protect the health and safety of workers and the local population. The project also includes measures to monitor and evaluate the socio-economic impacts of the dam. This framework is designed to ensure that the project delivers its intended benefits while minimizing any negative impacts on the local communities. For example, the project will monitor the quality of water in the Satpara Nullah downstream of the dam and the lake to ensure that the aquatic life is not adversely affected. A fish ladder will be provided in the intake structure to allow the free

movement of fish for spawning, which is essential for maintaining the ecological balance in the region (Mushtaq & Sufi, 2015).

4.8.5 Climate change and sustainability

One of the key considerations in the design and implementation of the Kurram Tangi Dam Project is its impact on climate change and its role in promoting sustainability. The dam is expected to play a significant role in mitigating the effects of climate change by reducing the reliance on fossil fuels for energy generation. The hydropower generated by the dam will provide a clean and renewable source of energy, which will help to reduce greenhouse gas emissions and combat global warming. The project also includes a Climate Change Impact Assessment to review trends in annual and seasonal water flow in the Indus River over the past several decades and to forecast changes in water flows as a result of climate change. This assessment is critical for ensuring that the dam is designed to withstand the potential impacts of climate change, such as changes in precipitation patterns and the increased frequency of extreme weather events (Malik, 2019).

The Kurram Tangi Dam Project is a cornerstone of Pakistan's efforts to harness its natural resources for sustainable development. By providing clean and renewable energy, improving water management, and contributing to socio-economic development, the project is set to have a lasting positive impact on the region and the country as a whole. Through careful planning, adherence to international standards, and a strong focus on environmental and social responsibility, the Kurram Tangi Dam Project exemplifies how infrastructure development can be aligned with the principles of sustainability. This project is not just an infrastructure undertaking; it is a model for how Pakistan can develop its natural resources in a way that benefits both current and future generations, ensuring a prosperous and sustainable future for the nation.

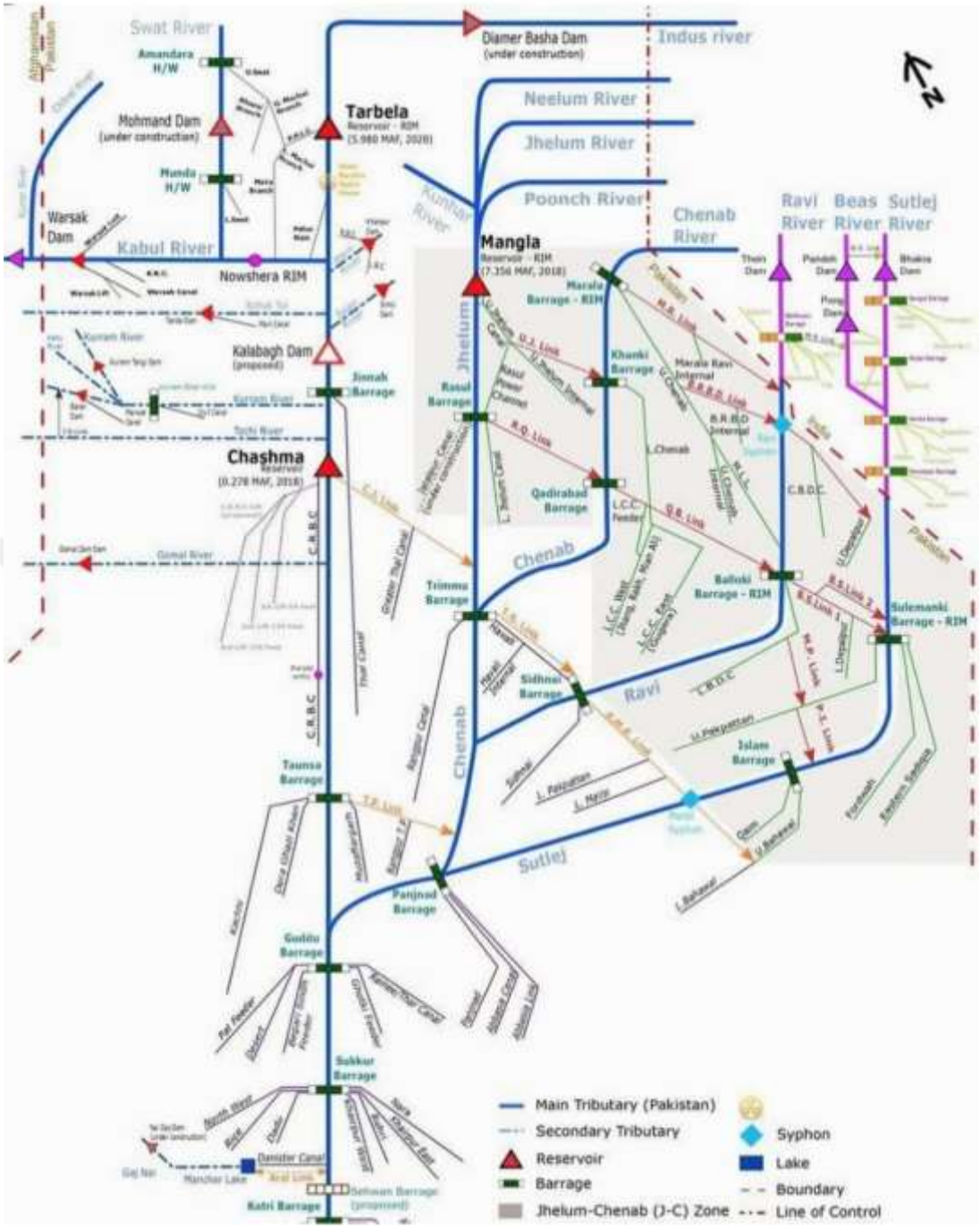

Figure 4.14: Schematic diagram of the Indus Basin Irrigation System

Source: Ahmad et al., (2022)

5. FINDINGS

The analysis of sustainable infrastructure projects in Pakistan, including RBOD-1 & 3, Mangla Watershed Program, Tarbela Watershed Program, Billion Tsunami Tree Project, Darawat Dam Project, Dasu Hydro Power Project, Diamer Bhasha Dam Project, and Kurram Tangi Dam Project, reveals several key findings related to sustainable development in the country. These findings address the research questions concerning factors hindering progress, benefits of sustainable projects, and how Pakistan achieves sustainability through project implementation. Resource Constraints: One of the primary challenges facing sustainable projects in Pakistan is the limitation of resources, particularly financial and technical resources. Large-scale infrastructure projects like the Diamer Bhasha Dam and Dasu Hydro Power Project require substantial financial investments, which can strain the national budget. The complex nature of these projects often necessitates international funding and expertise, which can lead to delays in implementation due to lengthy negotiation and approval processes. Technical expertise is another critical resource that is often in short supply. Projects such as RBOD-1 & 3 and the watershed programs require specialized knowledge in areas like hydrology, environmental engineering, and sustainable land management. The scarcity of local experts in these fields can hinder project progress and increase reliance on international consultants, potentially increasing costs and reducing knowledge transfer to local communities. Institutional and Bureaucratic Challenges: The implementation of sustainable projects in Pakistan is often hampered by institutional inefficiencies and bureaucratic hurdles. Projects like the Billion Tsunami Tree Project and large-scale dam constructions involve multiple government agencies, each with its own procedures and priorities. This can lead to coordination issues, delays in decision-making, and sometimes conflicting approaches to project management. Furthermore, the lack of a streamlined approval process for large-scale sustainable projects can result in significant delays. For instance, projects like the Diamer Bhasha Dam have faced prolonged periods of planning and approval before actual construction could begin. These delays not only increase project costs but also postpone the realization of benefits for local

communities and the nation as a whole. Environmental and Social Complexities: Sustainable infrastructure projects, particularly large dams and watershed management programs, often face complex environmental and social challenges. The construction of dams like Kurram Tangi and Diamer Bhasha involves the displacement of local communities and significant changes to local ecosystems. Balancing the needs of development with environmental conservation and community rights can be a delicate and time-consuming process. The Billion Tsunami Tree Project, while aimed at environmental improvement, also faces challenges in terms of land use conflicts and ensuring the long-term survival of planted trees. These environmental and social complexities require careful planning, stakeholder engagement, and ongoing management, which can slow down project implementation and increase costs. Enhanced Water Resource Management: A significant benefit of the analyzed projects is improved water resource management. Dams like Darawat, Kurram Tangi, and Diamer Bhasha play crucial roles in water storage, flood control, and regulated water supply for irrigation. These projects help address Pakistan's water scarcity issues, particularly in arid and semi-arid regions. The RBOD-1 & 3 projects contribute to better drainage management, reducing waterlogging and salinity in agricultural lands. This improvement in water management leads to increased agricultural productivity, food security, and economic stability for farming communities. The Mangla and Tarbela Watershed Programs demonstrate the benefits of integrated watershed management. These programs help in reducing soil erosion, improving water quality, and enhancing the overall health of river ecosystems. The long-term benefits include extended lifespans of water infrastructure, reduced siltation in reservoirs, and improved water availability for various uses. Clean Energy Production: Hydropower projects like Dasu and Diamer Bhasha represent significant steps towards clean energy production in Pakistan. These projects have the potential to substantially increase the country's renewable energy capacity, reducing reliance on fossil fuels and decreasing greenhouse gas emissions. The benefits extend beyond environmental considerations to include energy security, reduced energy import costs, and potential for economic growth through increased industrial capacity. Environmental Conservation and Climate Change Mitigation: The Billion Tsunami Tree Project stands out as a major initiative for environmental conservation and climate change mitigation. Large-scale afforestation efforts contribute to carbon sequestration, biodiversity conservation,

and soil stabilization. This project not only helps in combating climate change but also in restoring degraded landscapes and enhancing ecosystem services. The watershed management programs and dam projects also contribute to environmental conservation by regulating river flows, reducing flood risks, and creating habitats for aquatic and terrestrial species. These ecological benefits are crucial for long-term environmental sustainability and resilience against climate change impacts. Socio-Economic Development: Sustainable infrastructure projects in Pakistan have significant socio-economic benefits. The construction and operation of large dams and watershed management projects create employment opportunities, both during the construction phase and in long-term operation and maintenance. For instance, the Dasu Hydro Power Project and Diamer Bhasha Dam are expected to generate thousands of jobs, contributing to local economic development. Improved water management and increased agricultural productivity resulting from these projects lead to enhanced food security and rural livelihoods. The availability of clean, renewable energy supports industrial growth and economic diversification. Moreover, projects like the Billion Tsunami Tree Project create green jobs in forestry and environmental conservation sectors. Integrated Approach to Resource Management: Pakistan's approach to achieving sustainability through these projects is characterized by an integrated resource management strategy. The combination of large dam projects, watershed management programs, and afforestation initiatives demonstrates a holistic approach to addressing water, energy, and environmental challenges. For example, the Mangla and Tarbela Watershed Programs complement the water storage and hydropower generation functions of the dams by focusing on upstream conservation. This integrated approach ensures that the benefits of water infrastructure are sustained over the long term by addressing issues like soil erosion and sedimentation at their source. The RBOD projects further illustrate this integrated approach by addressing drainage issues that affect agricultural productivity and environmental health. By managing excess water and salinity, these projects contribute to the overall sustainability of water resources and agricultural systems in the region. Balancing Development and Conservation: The analyzed projects reveal efforts to balance development needs with environmental conservation. While large infrastructure projects like dams are crucial for energy and water security, there is also a focus on environmental mitigation measures. Environmental impact assessments and management plans are integral parts of these

projects, aiming to minimize negative impacts and enhance positive outcomes for local ecosystems. The Billion Tsunami Tree Project exemplifies this balance, addressing both environmental conservation and socio-economic development. By focusing on large-scale afforestation, the project contributes to climate change mitigation while also creating economic opportunities in green sectors. Stakeholder Engagement and Community Participation: A key aspect of achieving sustainability in these projects is the emphasis on stakeholder engagement and community participation. Projects like the Billion Tsunami Tree Project and watershed management programs involve local communities in planning and implementation. This participatory approach not only ensures that local needs and knowledge are incorporated but also builds a sense of ownership and long-term commitment to project success. For large dam projects, community engagement is crucial in addressing resettlement issues and ensuring that affected populations benefit from the development. The success and sustainability of these projects largely depend on how well they integrate community needs and concerns into project design and implementation. Leveraging International Partnerships: Pakistan's approach to sustainable project implementation involves leveraging international partnerships for financing, technical expertise, and knowledge transfer. Projects like the Dasu Hydro Power Project and Diamer Bhasha Dam involve collaborations with international financial institutions and development agencies. These partnerships not only provide necessary resources but also bring in global best practices in sustainable infrastructure development. International collaborations also play a role in capacity building, helping to address the technical expertise gap that often hinders sustainable project implementation in developing countries. By engaging with international partners, Pakistan is working towards building domestic capabilities in sustainable project management and implementation. Long-term Planning and Adaptive Management: The analysis of these projects indicates a shift towards long-term planning and adaptive management in sustainable development initiatives. The watershed management programs and afforestation projects, in particular, demonstrate an understanding of the need for sustained efforts over extended periods to achieve meaningful results. Adaptive management strategies are evident in how projects are designed to respond to changing environmental conditions and emerging challenges. For instance, the watershed programs incorporate climate change considerations, recognizing the need to build resilience in water management

systems. A clear trend in Pakistan's approach to sustainability is the focus on renewable energy development and enhancing climate resilience. The hydropower projects represent a significant investment in clean energy infrastructure, aligning with global efforts to transition away from fossil fuels. Projects like the Billion Tsunami Tree Project and watershed management initiatives directly contribute to climate change mitigation and adaptation. By enhancing forest cover and improving water resource management, these projects help build resilience against climate-related risks such as floods, droughts, and soil erosion.

Challenges in Implementation and Lessons Learned: The analysis of these projects also reveals ongoing challenges and lessons learned in implementing sustainable infrastructure in Pakistan. Issues such as project delays, cost overruns, and environmental concerns in large dam projects highlight the complexities involved in sustainable development.

These challenges underscore the need for:

- Improved project planning and management practices
- Enhanced coordination among various government agencies and stakeholders
- Stronger environmental and social safeguards in project implementation
- Continued focus on building domestic technical and managerial capacity

The experiences from these projects provide valuable insights for future sustainable development initiatives in Pakistan and other developing countries facing similar challenges. The analysis of sustainable infrastructure projects in Pakistan reveals a multifaceted approach to achieving sustainability. While facing significant challenges in terms of resource constraints, institutional inefficiencies, and complex environmental and social issues, Pakistan is making strides in implementing projects that contribute to water security, clean energy production, and environmental conservation. The benefits of these projects extend beyond immediate infrastructure development to include long-term impacts on resource management, climate resilience, and socio-economic development. The integrated approach to resource management, focus on balancing development with conservation, and efforts to engage stakeholders and leverage international partnerships demonstrate Pakistan's commitment to sustainable development. However, the challenges faced in implementing these projects highlight the need for continued improvements in

project planning, management, and capacity building. As Pakistan continues to pursue sustainable infrastructure development, the lessons learned from these projects will be crucial in shaping future initiatives and policies. The experiences from these projects offer valuable insights not only for Pakistan but also for other developing nations grappling with similar sustainability challenges. They underscore the importance of holistic planning, stakeholder engagement, and adaptive management in achieving sustainable development goals in the face of resource constraints and environmental challenges.

The following table (Table 4) summarizes the key sustainability aspects, achievements, challenges, and long-term implications of the major infrastructure projects analyzed in this study.

Table 5.1: Comparative Analysis of Sustainable Infrastructure Projects of Pakistan

Project Name	**Sustainability Components**	**Key Achievements**	**Challenges**	**Long-Term Potential / Impacts**
RBOD-I & RBOD-III	Water management, protection of agricultural land, environmental restoration	Prevention of saline water intrusion, improved agricultural productivity	Funding constraints, lack of comprehensive social impact assessments	Improved food security and rural ecosystem resilience
Mangla Watershed Program	Soil erosion control, watershed conservation, climate adaptation	Sedimentation reduction, reforestation initiatives	Limited community engagement, weak institutional coordination	Enhanced water security and sustainable land management
Tarbela Watershed Program	Soil and water conservation, ecosystem rehabilitation	Strategic watershed planning, improved soil quality	Absence of long-term monitoring mechanisms	Supporting hydropower sustainability and biodiversity recovery
Billion Tree Tsunami	Reforestation, carbon sequestration, biodiversity restoration	Global recognition, contribution to climate goals	Verification and inconsistent reporting in some regions	Climate resilience, carbon offsetting, rural employment generation

Table 5.1: (Cont.) Comparative Analysis of Sustainable Infrastructure Projects of Pakistan

Project Name	Sustainability Components	Key Achievements	Challenges	Long-Term Potential / Impacts
Darawat Dam Project	Water storage, irrigation, environmental and economic sustainability	Agricultural productivity, employment opportunities	Risk of displacement, insufficient social impact planning	Strengthened food systems and local economic growth
Dasu Hydropower Project	Renewable energy, social development, environmental compliance	Increased energy generation capacity, attraction of foreign investment	Resettlement concerns, limited stakeholder consultations	National energy security and clean energy transition
Diamer Bhasha Dam	Hydropower, water security, environmental mitigation measures	Boost in water and energy supply	High costs, population displacement, regional tensions	Strategic water reservoir and long-term energy reliability
Kurram Tangi Dam	Agricultural support, energy access, climate adaptation, compliance with international sustainability standards	Socioeconomic uplift, irrigation and energy co-benefits	Delays in project phases, climate adaptation plans needing improvement	Integrated rural development with food–water–energy security

5.1 Addressing the Research Questions

5.1.1 RQ1: Factors hindering the progress of sustainable projects

The analysis identifies several major factors that impede the progress of sustainable infrastructure projects in Pakistan:

Resource Limitations: Financial and technical resource constraints are among the most prominent barriers. Projects such as the Diamer Bhasha Dam and Dasu Hydropower Project require substantial capital investment and specialized technical expertise. The reliance on international funding sources and foreign consultants leads to delays, increased costs, and limited local capacity development.

Institutional and Bureaucratic Challenges: Inefficiencies within governmental institutions and bureaucratic delays significantly hinder project execution. Coordination across multiple agencies often results in fragmented decision-making and conflicting priorities. Projects like the Billion Tree Tsunami and major dam constructions faced setbacks due to the absence of a streamlined approval process and weak inter-agency coordination.

Environmental and Social Complexities: Projects involving large-scale physical interventions, such as dams and watershed management programs, often encounter environmental and social resistance. Displacement of communities, ecosystem disruption, and land use conflicts complicate project implementation. These issues require extensive planning, consultations, and mitigation measures, which often extend timelines and inflate costs.

Weak Community Involvement and Oversight: In projects like the Mangla and Tarbela watershed programs, limited community engagement and inadequate monitoring mechanisms reduced the overall effectiveness and long-term sustainability of interventions.

5.1.2 RQ2: Benefits of sustainable projects

Despite various challenges, sustainable infrastructure projects in Pakistan have demonstrated significant benefits:

Enhanced Water Resource Management: Projects such as the Darawat Dam, Diamer Bhasha Dam, and Kurram Tangi Dam have contributed to improved water storage capacity, flood control, and irrigation support. The RBOD-I and RBOD-III drainage systems have helped reduce waterlogging and salinity, leading to improved agricultural productivity.

Clean Energy Generation: Hydropower projects like Dasu and Diamer Bhasha represent progress toward renewable energy goals. These initiatives contribute to energy security, reduce reliance on imported fossil fuels, and support long-term economic development.

Environmental Conservation and Climate Mitigation: The Billion Tree Tsunami project has contributed to carbon sequestration, biodiversity conservation,

and land rehabilitation. Watershed programs have reduced soil erosion, improved water quality, and supported the ecological health of river basins.

Socio-Economic Development: Infrastructure development has created employment opportunities, both in construction and maintenance phases. Projects have stimulated rural economies through improved irrigation, energy access, and job creation. The Billion Tree Tsunami has generated green employment in forestry and land management sectors.

5.1.3 RQ3: Achieving sustainability through project implementation

Pakistan's approach to sustainability is characterized by several strategic elements:

Integrated Resource Management: The simultaneous implementation of dam projects, watershed conservation programs, and large-scale afforestation reflects an integrated approach to managing water, energy, and environmental resources. Projects such as the Tarbela and Mangla watershed programs support dam operations by reducing sedimentation and extending reservoir life.

Development-Conservation Balance: Efforts have been made to align infrastructure development with environmental protection. Environmental assessments, management plans, and conservation strategies are incorporated into project planning to minimize adverse effects and enhance sustainability.

Community Participation: Projects involving reforestation and watershed management have adopted participatory approaches, engaging local communities in planning and execution. This not only increases acceptance but also enhances long-term project effectiveness through local stewardship.

International Collaboration: Engagement with international financial institutions and development partners has facilitated access to funding, technical expertise, and best practices. Projects such as the Dasu Hydropower and Diamer Bhasha Dam have benefited from these partnerships, which also support capacity building in project management and sustainability practices.

Long-Term and Adaptive Planning: Several projects demonstrate a shift toward long-term planning and adaptive management. By incorporating climate projections and focusing on resilience, particularly in watershed and forestry

projects, Pakistan is aligning its infrastructure development with broader environmental sustainability goals.

6. CONCLUSION

The journey toward sustainable infrastructure in Pakistan, as explored in this thesis, reveals a complex landscape of progress, challenges, and future opportunities. Pakistan's commitment to sustainability is evident in its infrastructure projects, which are designed not only to meet the nation's immediate development needs but also to contribute to a more sustainable and resilient future. However, the path to achieving true sustainability is multifaceted, requiring a comprehensive approach that goes beyond environmental considerations to include social, economic, and technological dimensions. Sustainability has become a critical aspect of modern infrastructure development. The global shift towards sustainable practices, driven by initiatives like the Sustainable Development Goals (SDGs) and the Paris Agreement, underscores the importance of integrating sustainability into all aspects of development (United Nations, 2016). In Pakistan, where environmental challenges such as increasing temperatures, floods, smog, and heatwaves are becoming more severe, sustainable infrastructure is not just an option but a necessity. The adoption of sustainable practices in infrastructure projects can mitigate these environmental impacts, enhance the quality of life, and contribute to long-term economic stability. Countries like India and China have made significant strides in integrating sustainability into their infrastructure projects, providing valuable lessons for Pakistan. India's solar panels on water canals and China's smart cities initiatives demonstrate how innovative approaches can address both energy needs and environmental challenges. These examples highlight the potential for sustainable infrastructure to drive progress in developing nations, provided there is a commitment to innovation and long-term planning. Pakistan, with its unique set of challenges, can benefit from these global examples by adapting similar strategies to its context. The need for sustainable infrastructure in Pakistan is driven by several pressing factors. The country is increasingly vulnerable to environmental challenges, including rising temperatures, frequent floods, smog, and extreme heatwaves. These issues not only threaten the environment but also pose significant risks to public health, economic stability, and overall quality of life. Sustainable infrastructure projects offer a viable solution to

these challenges by promoting efficient resource utilization, reducing environmental degradation, and enhancing the resilience of communities. By addressing these issues through sustainable infrastructure, Pakistan can move towards a more secure and prosperous future. The findings indicate that resource constraints, inefficiencies, and a lack of technical expertise are significant barriers to the successful implementation of sustainable projects in Pakistan. Limited financial resources and insufficient infrastructure impede the progress of these projects, while inefficiencies in project management and execution further exacerbate these challenges. Additionally, the scarcity of technical expertise in sustainable practices limits the ability to design and implement projects that meet international sustainability standards. Despite the challenges, sustainable infrastructure projects in Pakistan offer numerous benefits. These projects optimize the utilization of resources, leading to significant cost reductions and prolonged longevity of infrastructure assets. By prioritizing sustainability, these projects help to conserve natural resources, reduce environmental impacts, and create a more sustainable and resilient infrastructure. Moreover, sustainable projects contribute to economic development by creating jobs, fostering innovation, and enhancing the quality of life for communities. Achieving sustainability in Pakistan requires a multi-faceted approach that includes reducing land degradation, increasing water availability, and promoting community involvement. The successful implementation of sustainable projects depends on the adoption of innovative materials, effective management practices, and strong policy frameworks. By integrating these elements into infrastructure projects, Pakistan can enhance the sustainability of its infrastructure and ensure that it meets the needs of both current and future generations. The analysis of key infrastructure projects in Pakistan provides insights into the country's progress toward sustainability. The Right Bank Outfall Drain (RBOD-1 & 3) projects, Mangla and Tarbela Watershed Programs, and various dam projects such as the Diamer Bhasha Dam and Dasu Hydro Power Project demonstrate the country's commitment to integrating sustainability into its development plans. These projects highlight the importance of comprehensive planning, the use of advanced technologies, and community involvement in achieving sustainability outcomes. For example, the Billion Tree Tsunami Project showcases Pakistan's efforts to combat deforestation and enhance environmental sustainability. The project not only contributes to carbon sequestration but also helps to protect biodiversity and promote sustainable land use. Similarly, the

Drawat Dam and Kurram Tangi Dam projects illustrate the potential of sustainable water management practices to address water scarcity and improve agricultural productivity. However, these projects also reveal the challenges of achieving sustainability in a developing nation. Issues such as resource constraints, limited technical expertise, and the need for continuous monitoring and evaluation are significant hurdles that must be addressed to ensure the long-term success of these initiatives. The objectives of this thesis were to explore the factors that hinder sustainable infrastructure development in Pakistan, to assess the benefits of such projects, and to identify strategies for achieving sustainability. The findings confirm that while Pakistan has made significant progress in integrating sustainability into its infrastructure projects, there are still considerable challenges that need to be addressed. The analysis of case studies underscores the importance of comprehensive planning, community involvement, and the adoption of innovative technologies in overcoming these challenges and achieving sustainability. One of the limitations of this study is the availability of complete and up-to-date information on the projects analysed. While the case studies provide valuable insights, the lack of detailed data on certain aspects of the projects limits the depth of the analysis. Future research should aim to gather more comprehensive data to provide a clearer understanding of the factors influencing sustainable infrastructure development in Pakistan. From a managerial perspective, the findings of this thesis have several implications. Project managers and policymakers in Pakistan must prioritize sustainability in infrastructure projects by adopting a holistic approach that considers environmental, social, and economic dimensions. This requires not only technical expertise and innovative solutions but also strong leadership and collaboration across sectors. By fostering a culture of sustainability, Pakistan can ensure that its infrastructure projects contribute to a more sustainable and resilient future. In conclusion, sustainable infrastructure is crucial for Pakistan's long-term development. While the country has made significant strides in integrating sustainability into its infrastructure projects, there is still much work to be done. Achieving true sustainability will require a comprehensive approach that addresses the environmental, social, and economic dimensions of development. By adopting innovative materials, effective management practices, and strong policy frameworks, Pakistan can enhance the sustainability of its infrastructure and ensure that it meets the needs of both current and future generations. As Pakistan continues to grow, it is imperative that future infrastructure

projects not only meet the immediate needs of the population but also contribute to a sustainable and resilient future.

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RESUME

Mouzam HAFIZ

COMPUTER SKILLS:

- Basic Knowledge of Computer
- MS Word
- MS Excel
- PowerPoint

PERSONAL SKILLS:

- Good Verbal & Non Verbal Skills
- Good communication Skills
- Exploring New things in the field of Engineering
- Able to work in Pressurize Environment.
- Motivated
- Hardworking

CARRER OBJECTIVES:

Exceptionally driven civil engineer with a background in on-time and cost-effective project delivery and a love for creative infrastructure solutions. aiming to use a dynamic engineering environment, strong technical abilities, and project management experience to support the design and development of significant and sustainable infrastructure projects.

WORK EXPERIENCE:

STC ENGINEERS & CONTRACTORS Pvt. Ltd. (2024)

(As a Project Manager Assistant) Sahiwal, Punjab Pakistan.

M/S AFZAL & BROTHERS CONSTRUCTION (2023)

(As a Trainee Engineer) Punjab Pakistan.

EDUCATION:

- *Gedik University Istanbul, Turkey* Masters in Engineering Management (Thesis) (2025) (Online Session)
- *University of Engineering & Technology, Lahore, Pakistan.* Civil Engineering (2022)
- Quaid-e-Azam College of Engineering & Technology, Sahiwal. *Punjab College Sahiwal, Punjab, Pakistan.* F.Sc (Pre-Engineering) (2018) Board of Intermediate & Secondary Education, Sahiwal.

CERTIFICATES :

STC ENGINEERS & CONTRACTORS Pvt. Ltd.

Certificate of Assistant Project Manager (2022-23)

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RESEARCH PROJECTS:

Rehabilitation & Upgrading of Branch Canals and Distributary System Covering,

Sahiwal Canal Division, Punjab, Pakistan. (2021) Thesis Research Report (Masters)

Sustainability Ecosystem of Infrastructure Development in Pakistan. (2025)