e-Bangi Faculty of Social Sciences and Humanities Universiti Kebangsaan Malaysia
Journal of Social Sciences and Humanities

eISSN: 1823-884x

Volume 22, Issue 3, DOI: https://doi.org/10.17576/ebangi.2025.2203.50

Article

Connecting the World through Canals:An Analysis of Water Infrastructure in Diplomacy, Economic Relations, and Sustainable Development

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Received: 01 June 2025
Accepted: 22 August 2025

Abstract: Canals have long been a crucial component in the development of world civilisations, functioning not only as water infrastructure but also as symbols of diplomacy, economic power, and sustainable development that transcend geopolitical boundaries. This article examines the strategic role of canals in linking global societies, strengthening international trade, and fostering cultural exchange from both historical and contemporary perspectives. Employing a qualitative approach, the study underscores the significance of waterways such as the Suez Canal, the Panama Canal, the Kra Canal and others, as both physical and symbolic conduits that facilitate social, economic, and political integration. The findings reveal that canals have accelerated global mobility, shaped major maritime trade networks, and acted as instruments of economic diplomacy. Nevertheless, persistent challenges including geopolitical rivalries, uneven distribution of economic benefits, and ecological vulnerabilities continue to constrain the potential of canals as catalysts for global cohesion. This article argues for enhanced ecological monitoring and the establishment of a more inclusive framework for international cooperation to mitigate these challenges. By situating canals within the context of climate change and sustainable development, it advances a new perspective on water infrastructure as a critical element of global integration, capable of supporting social, economic, and ecological interconnectedness at the international level, thereby making a significant contribution to the academic literature.

Keywords: Canal; water infrastructure; diplomacy; economy; sustainable development

Introduction

In examining the role of canals in shaping a global network, one striking reality is that these infrastructures are not merely physical channels for trade or irrigation but also symbols of diplomacy, economic relations, and sustainable development that transcend geopolitical boundaries. Canals have long played an important role in the history of human civilisation, serving as routes that connect peoples and regions while stimulating

economic growth, trade, and cultural exchange (Abdullah, 2025). From the Grand Canal in China, which has linked the northern and southern parts of the country since the Sui Dynasty, to the Corinth Canal in Greece, which reduces maritime travel distances in the Mediterranean, canals have become enduring symbols of innovation and human resilience in adapting to geographical constraints (Hopper, 1955; Yan, 2021). Yet behind these benefits, canals also expose gaps in resource management, economic justice, and geopolitical tensions. The Suez and Panama Canals exemplify how water infrastructure has been deployed to strengthen the economic and political positions of major powers. The Suez Canal, connecting the Mediterranean Sea and the Red Sea, is not only a vital route for European and Asian trade but has also sparked conflicts over its control. The Suez Crisis of 1956 illustrated its strategic significance, as Egypt asserted sovereignty over the canal and resisted Western dominance (Boughton, 2001). Similarly, the Panama Canal, linking the Atlantic and Pacific Oceans, dramatically reduced the cost and time of international maritime travel but simultaneously served as a symbol of U.S. hegemony until its transfer to Panama in 1999 (Conniff, 2012).

The role of canals, however, extends beyond global trade routes. In regional contexts, they often constitute the backbone of economic and social development. In Japan, the Fuchu Irrigation Canal functions to reduce flooding while enhancing logistical efficiency (Okazaki & Saito, 1989). In India, the Indira Gandhi Canal has transformed the arid landscapes of Rajasthan, sustained agriculture and stabilising local livelihoods (Gardiner, 1987). Canal construction, however, frequently raises ecological concerns that necessitate careful management to balance development with sustainability. Moreover, canals contribute significantly to regional integration and diplomacy. The Kiel Canal in Germany, which connects the North Sea and the Baltic Sea, plays a vital role in uniting the economy of Northern Europe (Heine, 2014). More recently, proposed projects such as the Nicaraguan Canal have aimed to rival the Panama Canal, underscoring the persistent centrality of water infrastructure in international relations and global economic development (Keasbey, 1896; Yip & Wong, 2015). Yet, widespread criticisms regarding ecological and social consequences demonstrate that canals represent not only instruments of development but also contested arenas where economic imperatives confront environmental responsibility.

The evolution of canals also reflects broader technological transformations and human innovation. The Amsterdam–Rhine Canal in the Netherlands, for example, represents modern engineering designed to enhance trade between the German hinterland and international ports in the Netherlands. This canal strengthens the regional economy while symbolising advancements in water resource management (Van der Veen, 1985). In Egypt, the Toshka Canal project seeks to divert Nile waters to vast desert areas, illustrating how canals can reshape economic and social landscapes (Malterre-Barthes, 2016). Similarly, the proposed Iran–Russia Canal, intended to connect the Caspian Sea with the Indian Ocean, demonstrates how canals may be employed to reorganise geopolitical dynamics. This initiative has sparked debates about its potential impact on established routes such as the Suez Canal and on the world's reliance on strategic chokepoints (Kameneva et al., 2018). In such cases, canals emerge not merely as infrastructure but as instruments that challenge and recalibrate the balance of global power.

Beyond economic and political functions, canals also carry significant cultural dimensions. In Venice, Italy, canals form an intrinsic part of the city's identity, sustaining tourism and local economies (Van Der Borg, 2017). The Rideau Canal in Canada, initially constructed for military purposes, has since been designated a UNESCO World Heritage Site and a major tourist destination (Donohoe, 2012). These examples illustrate that canals are not only practical infrastructures but also cultural symbols with deep societal resonance. Nevertheless, the potential of canals as catalysts for unity is constrained by persistent challenges in management. Issues such as water pollution, limited international cooperation, and inadequate adaptation to climate change threaten their effectiveness in advancing social and economic integration.

This study therefore investigates the role of canals as strategic elements that transcend their function as transport routes. It examines how canals contribute to global integration through three principal dimensions: diplomacy, economy, and sustainable development. By analysing historical and contemporary examples, the study also identifies the challenges faced by canal infrastructure in the modern era, including geopolitical rivalries, ecological sustainability, and inequalities in the distribution of benefits. In doing so, the article offers a fresh perspective on the role of canals in international relations and contributes to academic debates on

sustainable water infrastructure. It further proposes recommendations aimed at ensuring that the benefits of canals are shared more equitably. By foregrounding the strategic significance of canals within the global context, this study seeks to inform the development of fairer and more sustainable policies for water infrastructure governance.

Literature Review

This literature review examines the role of canals as strategic elements in geopolitical relations, economic development, and sustainable governance. Existing scholarship has discussed the significance of canals such as the Suez Canal, the Panama Canal, the Istanbul Canal and others in reshaping maritime trade routes, improving logistical efficiency, and supporting regional economic growth. However, there remains a substantial gap in understanding the imbalance of economic benefits, the challenges of sustainable management, and the more complex geopolitical consequences within the context of contemporary global transformations, including climate change and increasing pressure on water resources. This study seeks to address this gap by examining the economic, ecological, and geopolitical dimensions of canals in both historical and contemporary contexts.

For example, research on the Suez Canal has focused primarily on its importance as a strategic route connecting Europe and Asia. Studies such as Piquet (2004) have shown that the canal not only played a central role in international trade but also became a symbol of geopolitical dominance for major powers such as Britain and France prior to its nationalisation by Egypt in 1956. Yet, much of this scholarship neglects a deeper analysis of how geopolitical conflicts and post-nationalisation economic pressures have affected local communities and ecosystems surrounding the canal. This study adopts a more holistic approach by incorporating social and ecological dimensions in order to capture the broader impact of canals on both local societies and global geopolitics.

In the case of the Panama Canal, previous literature, including Maurer and Yu (2010), has explored the technological transformations and diplomatic negotiations that accompanied the transfer of control from the United States to Panama. These works highlight how the canal's expansion and the adoption of new technologies, such as logistics automation, enhanced maritime efficiency and increased national revenue for the host country. Nevertheless, a significant gap remains concerning the unequal distribution of economic benefits, particularly the social consequences for indigenous populations who were displaced during the canal's construction and subsequent expansion. This study underscores the need to examine how the canal can be managed sustainably in order to mitigate inequality and ensure a more equitable distribution of its benefits.

The proposed Kra Canal in Thailand has also attracted scholarly attention, though much of the literature has concentrated on its economic potential while neglecting geopolitical and ecological risks. Studies such as Duangjai and Sulong (2012) emphasise how the Kra Canal could alleviate congestion in the Malacca Strait and strengthen Thailand's role in international trade. However, issues such as potential disputes with neighbouring countries, particularly Singapore, and the environmental implications for regional marine ecosystems remain under-analysed. This study addresses this gap by considering multilateral approaches that could prevent regional tensions and safeguard environmental sustainability.

The overarching gap in the literature lies in the absence of an integrative approach that brings together historical, economic, geopolitical, and ecological perspectives. Most previous studies have examined these dimensions in isolation, focusing on trade, geopolitics, or technological aspects, without adequately exploring their interconnections. This study aims to overcome this limitation by employing an interdisciplinary framework to provide a more comprehensive understanding of the strategic role of canals. It is expected to make an important contribution by proposing a sustainable framework for canal governance that responds effectively to contemporary global challenges.

Methodology

This study employs a qualitative approach that integrates theoretical analysis, case studies, and international comparisons to examine the strategic role of canals in global trade, diplomacy, and sustainable development. World-systems theory serves as the primary analytical framework, enabling the study to assess how canals

operate within global economic and political structures, reflecting hierarchies of power and imbalances in the distribution of economic benefits (Chirot & Hall, 1982). This framework also facilitates an exploration of the relationship between structural global transformations, such as the expansion of international trade and the challenges of climate change, and the evolving role of canals as instruments of integration.

Data collection was conducted through a comprehensive review of secondary literature and case study analysis. The literature provided historical data on canal development, as well as insights into their roles in global trade and the ecological and geopolitical challenges they confront. The data were analysed through three main methods: thematic analysis, international comparisons, and a theory and empirical approach. Thematic analysis was used to identify core themes including economic integration, geopolitical management, and ecological sustainability. International comparisons were employed to examine similarities and differences across canals, allowing lessons to be drawn for future canal development. The theory and empirical approach combined world-systems theory with empirical data, linking theoretical insights with real-world cases to produce a more comprehensive and policy-relevant understanding.

This methodological framework ensures that the study is able to answer the central question of how canals continue to function as instruments of economic integration, diplomacy, and sustainable development in the contemporary global order. It also aims to make a substantive contribution to the academic literature by bridging theoretical debates with empirical realities and by advancing a more holistic understanding of water infrastructure in international relations.

The Findings and Discussion

1. Canals as Global Connectors in Historical and Contemporary Contexts

We find that canals have long served as vital connectors in trade and international relations, playing a strategic role that extends beyond their physical function as transport channels. From antiquity to the present, canals such as the Grand Canal in China, the Suez Canal in Egypt, and the Panama Canal in Central America have formed a global network that supports economic integration, diplomacy, and cultural exchange. In addition, Southeast Asia also has canals that play a significant role in the regional context, demonstrating the global importance of canals across multiple dimensions (Sulong, 2012).

The Grand Canal in China is one of the earliest examples of how canals can act as vital connectors in the formation of civilisation. Since its construction during the Sui Dynasty in the 7th century, the Grand Canal has played a central role in uniting northern and southern China. It facilitated the transportation of agricultural products, particularly grain from productive regions to metropolitan centres such as Beijing, thereby reinforcing both economic and political stability. It also served as a channel for cultural exchange, enabling the circulation of technologies and ideas across regions. Today, the Grand Canal functions not only as an economic artery but also as a symbol of cultural heritage that continues to shape China's national identity (Yan, 2021).

In Central America, the Panama Canal has long been a crucial connector between the Atlantic and Pacific Oceans. This canal accelerated maritime trade by significantly reducing costs and travel times. Although its early twentieth-century construction was marked by United States dominance, the transfer of control to Panama in 1999 demonstrated how sovereignty over strategic assets can eventually be recognised for smaller states (Haskin, 1913; Conniff, 2012). The expansion of the Panama Canal in 2016, which enabled the passage of larger container vessels, further illustrates the importance of technological innovation in maintaining the relevance of waterway infrastructure in an increasingly complex global trade system (Park, Richardson & Park, 2020).

Beyond these major waterways, Southeast Asia possesses canals that play important roles in regional trade and development. The Lat Pho Canal in Thailand, constructed to mitigate flooding in Bangkok, has also enhanced trade logistics (Tanabe, 1977). This canal supports the domestic economy while reinforcing Thailand's position in regional commerce. Meanwhile, the proposed Kra Canal, intended to link the Indian and Pacific Oceans, has become a subject of intense debate (Monika et al., 2020). If realised, the project could ease congestion in the Strait of Malacca and significantly reshape global maritime trade routes. Yet ecological

and geopolitical concerns, including opposition from neighbouring countries such as Singapore, underscore the complex considerations surrounding canal development in Southeast Asia.

In Malaysia, the Wan Mat Saman Canal in Kedah and the Sanglang Road Canal in Perlis serve as important connectors in rural contexts, underpinning local economies tied to rice production. These canals have historically provided irrigation for paddy fields and contributed to economic stability for farming communities (Abdullah & Mohd Noor, 2020; Abdullah et al., 2023). However, water pollution and inefficient management have reduced their effectiveness, mirroring challenges faced by many canals in developing countries (Petah Wazzan, 2019). Beyond economics, canals also function as cultural and social symbols. In Venice, Italy, canals are at the centre of urban life, sustaining both the local economy and global tourism (Cowan, 2008). Similarly, in Southeast Asia, the Bangkok Noi Canal has become integral to Bangkok's cultural and historical landscape, shaping community identity and facilitating cultural exchange, particularly through traditional practices such as floating markets (Suphaphorn, 2015).

Modern challenges further complicate the role of canals, particularly in light of climate change and increased maritime traffic. The Suez and Panama Canals, for instance, are under pressure to expand and adapt in order to accommodate rising global trade demands (Ahmed et al., 2018). In Southeast Asia, the proposed Kra Canal has sparked ecological concerns regarding threats to marine biodiversity and potential alterations to surrounding ecosystems (Ramadhan & Prakoso, 2024). Effective international cooperation and sustainable management are therefore essential to ensure that canals continue to serve their strategic purposes without compromising environmental sustainability. At the same time, new canal projects such as the Istanbul Canal and the proposed Nicaragua Canal highlight the enduring prioritisation of water infrastructure in global planning. While these projects promise significant economic returns, they also raise social and environmental concerns. The Istanbul Canal, intended to ease congestion in the Bosphorus Strait, has been criticised for its potential to destabilise the Black Sea ecosystem (Kalinov, 2019). Similarly, the Nicaragua Canal project has triggered protests from local communities due to fears of displacement and land loss (Fairchild, 2018). In conclusion, canals worldwide embody a unique dual role as physical connectors, symbols of cultural identity, and instruments of economic diplomacy. Despite challenges such as unequal distribution of benefits and ecological risks, canals remain critical elements in sustaining global trade and shaping international relations.

2. Geopolitical Dimensions and Power Conflicts in Canal Control

We found that canals not only serve as trade routes but also function as geopolitical tools that reflect power struggles at the global level. As strategic assets, canals often become arenas of conflict, negotiation, and renegotiation, reflecting the economic interests, sovereignty, and political stability of the states that control them. Key historical and contemporary examples, such as the Suez Crisis in 1956, the Panama Canal dispute in 2025, and the geopolitical tensions surrounding the Istanbul Canal, demonstrate how water infrastructure plays an important role in shaping the dynamics of global power. In Southeast Asia, the proposal to construct the Kra Canal is a symbol of how canals continue to remain at the centre of strategic debate in the region.

The Suez Crisis in 1956 was a turning point in the geopolitical history of canals. The nationalisation of the Suez Canal by President Gamal Abdel Nasser of Egypt triggered a major conflict involving Britain, France, and Israel. This nationalisation was perceived as Egypt's effort to reclaim economic and political sovereignty over a strategic asset long dominated by colonial powers. Although the tripartite attack sought to restore Western control, diplomatic pressure from the United States and the Soviet Union forced their withdrawal. This episode underscored the potential of canals to become flashpoints of major power conflict, where diplomacy and international pressure decisively shaped outcomes (Smith, 2016).

The Panama Canal provides a different perspective, illustrating how canal control can become a symbol of sovereignty for smaller states. Built by the United States in the early twentieth century, it remained under American control for almost a century. During this time, Panama experienced intense social and political pressure to regain authority over the canal as a marker of national sovereignty. The 1999 transfer of control, following the Torrijos–Carter Agreement, demonstrated how prolonged diplomatic negotiation can resolve such disputes. However, the process was not free of challenges, including tensions over negotiations and concerns about the fair distribution of canal revenues within Panama (Conniff, 2012).

In the contemporary period, the Panama Canal remains a centre of strategic rivalry. A 2025 statement by U.S. President Donald Trump suggesting that the United States should "take back" the canal illustrates how great powers continue to perceive such infrastructure as strategic assets requiring control (Atlantic Council Experts, 2025). This reflects a continuity of American interventionist policy in Panama, including the 1989 invasion and the debates surrounding the 1999 handover (Priestley, 2004). While Panama has official sovereignty, the United States continues to justify its influence through narratives of security and national interest. At the same time, Washington has accused China of expanding its influence in Panama through Hong Kong–based companies operating major ports at the canal's ends. Although Panamanian authorities deny Chinese interference, these claims highlight how Sino-American rivalry translates into economic and strategic competition in Latin America. The Panamanian government's audit of ports and utilities can be seen as an attempt to reduce U.S. pressure, but it may also reshape Panama's international trade and investment relations. This situation raises broader questions about the sovereignty of small states under great power pressure. While Panama seeks to uphold autonomy, political realities show that smaller countries are often forced to negotiate under unequal conditions, affecting not only domestic sovereignty but also regional stability in Latin America.

The Istanbul Canal in Turkey provides another example of canals as geopolitical tools. Designed to ease congestion in the Bosphorus Strait, the project is expected to enhance Turkey's trade capacity and strengthen its role as a global logistics hub (Sen et al., 2022). Yet, it has also sparked ecological concerns regarding the stability of the Black Sea and heightened diplomatic sensitivities with Russia and other neighbouring states. This case demonstrates how canal development combines economic opportunity with complex geopolitical considerations. In Southeast Asia, the proposed Kra Canal in Thailand remains central to strategic debates. If built, it would link the Indian and Pacific Oceans, reducing dependence on the Strait of Malacca. While the project promises significant economic gains for Thailand, including increased revenue from trade and logistics, it also raises geopolitical concerns. Singapore, which relies heavily on the Malacca Strait, perceives the project as a potential threat to its strategic position (Ho, 2020; Rezani, 2025). Additional issues such as population displacement, threats to marine ecosystems, and possible disputes with neighbouring countries add layers of complexity to the project's viability.

Southeast Asia also faces challenges relating to canal sustainability and management. For example, the Wan Mat Saman Canal in Kedah, Malaysia, once central to socio-economic transformation, now suffers from pollution and poor maintenance (Petah Wazzan, 2019). This reflects a wider governance problem in protecting historical canals as national assets. Despite Kedah Chief Minister Sanusi Md Nor's emphasis on water disputes with Penang, little attention has been given to conserving the Wan Mat Saman Canal, even though Perlis also benefits from Kedah's water supply without compensation (Abdullah, 2024; Abdullah et al., 2024). This neglect highlights how mismanagement of canals undermines both socio-economic stability and cultural heritage.

More broadly, canals continue to serve as instruments of power projection. Control over canals such as Suez and Panama provide states with strategic leverage in international negotiations. However, such control does not guarantee stability. On the contrary, uneven or unilateral control often provokes tensions, as seen in the Suez Crisis and in Panama's protests prior to the handover. In Southeast Asia, potential conflicts over the Kra Canal suggest the need for strong diplomatic frameworks to prevent escalation. From our analysis, it is clear that canals are not merely waterways but strategic sites where power, sovereignty, and global stability intersect. To ensure that the benefits of canals are equitably shared, and that conflict is minimised, international cooperation involving all stakeholders is essential. In this sense, canals represent not only physical infrastructure but also enduring symbols of global power dynamics.

3. The Economic Impact of Canals: Strategic Routes and Unequal Benefits

We found that canals, as strategic routes, play a crucial role in supporting global trade and accelerating economic growth. Canals such as the Suez Canal, the Panama Canal, and those in Southeast Asia not only shorten travel times but also reduce logistics costs, making them critical assets in international trade networks. However, the economic benefits of these canals are often unequally distributed, creating imbalances that raise questions about economic justice and the allocation of revenues. The Suez Canal is one of the clearest

examples of the economic importance of canals in global trade. Since its opening in 1869, the canal has served as a vital route between Europe and Asia, including the transport of oil from the Middle East to global markets. By shortening maritime travel by thousands of kilometres, the Suez Canal has become a highly profitable economic artery for Egypt, generating substantial annual revenue from transit fees (Huber, 2013). Yet, this income has not always benefited the Egyptian population directly, particularly during periods of colonial domination by Britain and France. The Suez Crisis of 1956, when Egypt asserted control over the canal, symbolised the efforts of postcolonial states to claim greater economic benefits from strategic assets located within their territory (Marston, 1988). Today, the Suez Canal continues to be a major source of revenue for Egypt, but high maintenance costs, expansion projects, and geopolitical threats such as regional conflicts add significant complexity to its economic management (Soffer, 2023).

The Panama Canal similarly highlights how unequal economic benefits can arise when smaller states depend on major powers to construct and operate canal infrastructure. For almost a century under United States control, Panama received only a fraction of the revenues generated, despite the canal lying within its territory. Protests and sustained diplomatic pressure eventually led to the transfer of control in 1999, allowing Panama to enjoy greater returns from canal operations (Conniff, 2012). Nevertheless, challenges remain, including debates over how canal revenues should be invested for national development. The expansion of the Panama Canal in 2016, which increased capacity for larger vessels, reaffirmed its global strategic value (Pagano et al., 2016). Yet this expansion has also intensified pressure on surrounding infrastructure and ecosystems, reflecting hidden costs that are rarely borne equally by all stakeholders.

In Southeast Asia, canals play important roles in regional economies. The Khlong Lat Pho Canal in Thailand, initially constructed to mitigate flooding in Bangkok, also improved logistics efficiency and strengthened domestic trade (Tanabe, 1977). At the same time, the proposal to construct the Kra Canal has generated significant debate about regional economic imbalances. If built, it could ease congestion in the Strait of Malacca and create new trade opportunities, bringing substantial benefits to Thailand. However, neighbouring states such as Malaysia, which rely heavily on the Malacca Strait, could suffer adverse economic impacts. This raises broader questions about how canal revenues and benefits should be shared equitably within the region (Abdul Rahman, 2013; Abdul Rahman et al., 2016).

Economic imbalances are also evident in the development of new canals such as the Istanbul Canal in Turkey and the proposed Nicaragua Canal. Both projects promise large economic gains for the host states, including transit revenues and job creation. Yet construction costs, ecological risks, and social dislocation are often unevenly distributed. The Istanbul Canal, for instance, has faced criticism for the potential damage it may cause to surrounding ecosystems. Here, the central question becomes how to balance economic benefits with social and environmental costs (Menteşe & Tezer, 2021).

We also observed that the unequal distribution of canal-related benefits frequently reflects underlying power dynamics between states that control canals and those dependent on them. In the cases of Suez and Panama, control provided certain states with disproportionate strategic and economic advantages, often at the expense of local populations or weaker actors. In Southeast Asia, the proposed Kra Canal reflects a similar dilemma, where potential benefits to Thailand could undermine the economic interests of its neighbours. Our analysis suggests that while canals remain indispensable to the global economy as strategic routes, persistent imbalances in the distribution of benefits continue to present a major challenge. Whether in routine operations or in planning new infrastructure, questions of economic justice and equitable distribution must be addressed within a cooperative framework that includes all stakeholders. Canals thus stand not only as symbols of economic integration but also as reflections of the inequalities and tensions inherent in the global political economy.

4. Ecological and Sustainability Challenges in Canal Development

The construction and operation of canals, while playing important roles in supporting global trade and irrigation, often have unavoidable negative impacts on the environment. Canals such as the Suez Canal, the Panama Canal, and the Wan Mat Saman Canal in Kedah, Malaysia, illustrate how this infrastructure provides significant benefits but simultaneously triggers ecological challenges that require serious attention. Water

pollution, ecosystem disruption, and biodiversity loss emerge as key issues closely linked to canal construction and maintenance, underscoring the urgent need for more sustainable approaches.

The Suez Canal, as the main strategic route connecting the Mediterranean Sea and the Red Sea, provides a clear example of ecological pressure resulting from intensive usage. Since its opening, it has played an essential role in accelerating trade between Europe and Asia. However, changes in water salinity caused by the mixing of two seas with distinct chemical compositions have facilitated the migration of invasive species such as lionfish and nomadic jellyfish, which threaten local ecosystems (Balzani et al., 2022). Moreover, the rise in shipping traffic has heightened the risk of oil spills and chemical discharges, negatively affecting marine biodiversity. Continuous investment in water quality monitoring technologies and the stricter enforcement of anti-pollution regulations are critical to reducing these impacts, though their effectiveness depends heavily on broader international cooperation (Mostafa, 2004; Özkanlısoy & Akkartal, 2022).

In Southeast Asia, the ecological challenges faced by the Wan Mat Saman Canal in Kedah highlight similar problems in the context of agricultural irrigation. Constructed in the nineteenth century, the canal became the backbone of Kedah's rice farming sector, consolidating the state's reputation as the "Rice Bowl of Malaysia" (Hill, 2012). Despite its benefits to local farmers, the use of chemical fertilisers and pesticides has degraded water quality. Sediment accumulation from soil erosion has further reduced irrigation efficiency, contributing to declining agricultural productivity. Restoration measures, such as the adoption of sustainable farming practices and regular canal maintenance, could mitigate environmental damage while preserving the canal's primary function (Petah Wazzan, 2019).

Contemporary projects such as the Istanbul Canal in Turkey demonstrate how ecological risks remain global concerns. Intended to reduce congestion in the Bosphorus Strait, the project has been criticised for its potential adverse effects on the ecosystems of the Black Sea and the Sea of Marmara (Baba, 2020). Projected changes in water flow could destabilise marine balances, while increased traffic is expected to heighten the risk of oil pollution (Sözer & Ozsoy, 2017). This case highlights the necessity of integrated planning, including comprehensive environmental impact assessments and the application of eco-friendly technologies in construction and operations.

Climate change further compounds these ecological challenges. Rising global temperatures and shifting rainfall patterns have created imbalances in water flows in major canals such as the Suez and Panama. These uncertainties not only affect daily operations but also place stress on aquatic ecosystems that depend on stable water levels. Adaptation strategies such as constructing water reservoirs and improving flow management will be vital to maintaining canal functions under increasingly unpredictable climatic conditions (Abdullah et al., 2023).

A sustainable response requires the integration of advanced technologies, institutional resilience, and multi-stakeholder cooperation. Automated water quality monitoring, ship waste treatment systems, and robust enforcement of environmental laws represent essential measures. For example, recent initiatives in the Suez Canal to strengthen anti-pollution enforcement illustrate how regulatory frameworks combined with technological solutions can mitigate environmental pressures (Rodriguez-Diaz et al., 2024).

This analysis makes clear that ecological challenges associated with canal development and management demand immediate attention and integrated strategies. Ensuring that the economic benefits generated by canals are not achieved at the expense of environmental degradation is critical. Only by embedding sustainability into planning and governance can canals continue to play vital roles in facilitating global trade and irrigation while safeguarding ecosystems that are indispensable to both human well-being and natural resilience.

Conclusion

This study analyses the strategic role of canals in global trade, diplomacy, and sustainable development, focusing on their economic impact, geopolitical significance, and ecological sustainability. The main thesis advanced is that canals, as critical water infrastructure, embody the dynamics of power and cross-border challenges. While canals play a vital role in accelerating trade and supporting global economic growth, this

study demonstrates that imbalances in economic benefits, ecological risks, and geopolitical tensions remain persistent challenges that require innovative and collaborative solutions.

An examination of examples such as the Suez Canal, the Panama Canal, and the proposed Kra Canal demonstrates that canals function not only as physical routes for maritime navigation but also as instruments to consolidate or contest economic and political dominance at both global and regional levels. The case of the Suez Canal illustrates how its strategic role in connecting Europe and Asia has repeatedly made it a focal point of conflict and great power negotiation. Similarly, the transfer of control over the Panama Canal from the United States to Panama reflects the broader struggle of developing countries to assert economic sovereignty in the face of great power dominance. In Southeast Asia, debates surrounding the Kra Canal raise important questions about regional geopolitical balance, particularly in relation to strategic competition with the Strait of Malacca. Climate change adds a further dimension to the management of canals. Declining water levels, rising temperatures, and other ecological threats threaten to undermine the operational effectiveness of canals such as Suez and Panama. In this context, a multilateral framework that integrates data-driven monitoring and climate mitigation measures is becoming increasingly critical. The involvement of the International Maritime Organization (IMO) in promoting best practices in canal management illustrates the importance of global cooperation in addressing these challenges.

The study also underscores the need for more inclusive regional cooperation, particularly in Southeast Asia. For instance, the development of the Kra Canal requires careful negotiation between Thailand and neighbouring countries such as Singapore and Malaysia to ensure that its economic benefits do not exacerbate geopolitical tensions or undermine regional stability. Mechanisms such as ASEAN provide an important platform to foster dialogue and ensure that canal development reflects shared regional interests.

This study contributes to the academic literature by integrating technological, economic, and geopolitical perspectives to offer a more comprehensive understanding of the strategic role of canals at the global level. The findings suggest that the future of canals will depend on achieving a balance between economic development, ecological sustainability, and inclusive diplomatic cooperation. In this respect, the study not only provides an analysis of contemporary challenges but also proposes a pragmatic and innovative framework to ensure that the benefits of canals are sustained for future generations.

In conclusion, this study highlights the importance of canals as critical global connectors while emphasising that their future depends on how effectively international cooperation is mobilised to address contemporary challenges. By stressing the need for sustainable and inclusive approaches, it offers strategic guidance to ensure that canals continue to contribute to economic integration, geopolitical stability, and ecological resilience. In an increasingly complex global order, canals can remain symbols of progress, but only if they are managed with foresight and responsibility.

Acknowledgement:
This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

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