Czech University of Life Sciences Prague

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Bachelor Thesis

Environmental and Economic Impact of the Panama Canal Expansion

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BACHELOR THESIS ASSIGNMENT

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Economics and Management

Thesis title

Environmental and Economic impact of the Panama Canal Expansion

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Objectives of thesis

The objective of this thesis is to comprehensively investigate and analyze the environmental and economic impacts of the Panama Canal Expansion, with a focus on evaluating the long-term consequences and sustainability implications. This research aims to provide a nuanced understanding of the complex interplay between economic development and environmental conservation in the context of this significant infrastructure project. Through a rigorous examination of data and case studies, the study seeks to elucidate the trade-offs, synergies, and potential solutions that emerge at the intersection of economic growth and environmental stewardship, ultimately contributing to a more informed and balanced perspective on the Panama Canal Expansion's effects on both ecological and economic systems.

Methodology

This thesis employs a mixed-methods research design to assess the environmental and economic impacts of the Panama Canal Expansion. It combines both quantitative and qualitative data collection methods to achieve a comprehensive understanding of the subject.

The construction of the Panama Canal commenced in 2016 following a triumphant national referendum. The Panama Canal Authority is the sole entity entrusted with the management, operation, preservation, upkeep, and enhancement of the Panama Canal, along with its associated activities, in strict adherence to existing constitutional and legal provisions. Its primary objective is to ensure the secure, uninterrupted, efficient, and profitable functioning of the canal. This institution provides me with the convenience of accessing monthly and yearly reports, enabling me to acquire comprehensive information regarding the project's advancement, as well as its environmental and economic implications, up until its completion.

The proposed extent of the thesis

40 pages

Keywords

Panama Canal Expansion, Environmental impact, Economic impact, Infrastructure development, Shipping industry, Biodiversity conservation, Water resources management, Carbon emissions, Economic growth, Employment opportunities, Sustainable development, Environmental regulations, Climate change adaptation, Socio-economic benefits, International trade routes

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Declaration

I declare that I have worked on my bachelor thesis titled "Environmental and Economic Impact of the Panama Canal Expansion" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on date of submission _____

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First of all, I want to thank God for giving me the opportunity to start this journey in this country and accompany me in every stage of my life.

Likewise, I am grateful to my family and friends for supporting me and believing in me, knowing that with effort, dedication, and discipline, all things can be achieved.

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Environmental and Economic Impact of the Panama Canal Expansion

Abstract

The Panama Canal has long been recognized for its significant impact on global trade and the economy, serving as a vital link between two oceans and facilitating commercial activity. Despite being one of the smallest countries in the world, Panama has experienced remarkable economic growth, fueled by the success of the Canal and its strategic location.

Under Panamanian administration since 2000, the Canal has undergone substantial changes to meet the evolving demands of international maritime transport. These changes were driven by shifts in global maritime activity and the need to enhance the Canal's operational capacity.

This thesis delves into the economic impact of the Panama Canal expansion project, examining its feasibility, costs, benefits, and effects on global trade and competition. The literature review explores the historical significance of international trade and transportation, highlighting the role of the Panama Canal in facilitating global commerce.

The practical analysis includes a cost-benefit assessment based on data from the Panama Canal Authority, evaluating construction costs and projected revenues.
Overall, the Panama Canal expansion project represents a significant milestone in the history of global trade and has the potential to further bolster Panama's economic growth and international standing.

Keywords: Panama Canal Expansion, Economic Impact, Carbon emissions, Employment opportunities, Sustainable development, Climate change, Shipping industry, International Trade routes, Infrastructure development, Water resources management.

Environmentální a ekonomický dopad rozšíření Panamského průplavu

Abstrakt

Panamský průplav je dlouhodobě uznáván pro svůj významný dopad na globální obchod a ekonomiku, sloužící jako klíčové spojení mezi dvěma oceány a usnadňující obchodní činnost. Přestože je Panama jednou z nejmenších zemí na světě, zažila pozoruhodný ekonomický růst, podporovaný úspěchem průplavu a jeho strategickou polohou.

Od roku 2000 je průplav spravován Panamskou vládou a prošel významnými změnami, aby vyhověl se měnícím se požadavkům mezinárodní námořní dopravy. Tyto změny byly motivovány posuny v globální námořní činnosti a potřebou zvýšení operační kapacity průplavu.

Tato práce se zabývá ekonomickým dopadem rozšíření Panamského průplavu, zkoumající jeho proveditelnost, náklady, výhody a dopady na globální obchod a konkurenci. Přehled literatury zkoumá historický význam mezinárodního obchodu a dopravy, zdůrazňuje roli Panamského průplavu při usnadňování globálního obchodu.

Praktická analýza zahrnuje hodnocení nákladů a přínosů založené na datech od Panamské průplavové autority, posuzující stavební náklady a předpokládané příjmy.

Celkově rozšíření Panamského průplavu představuje významný milník v historii globálního obchodu a má potenciál dále posílit ekonomický růst Panamy a její mezinárodní postavení.

Klíčová slova: Rozšíření Panamského průplavu, ekonomický dopad, emise uhlíku, příležitosti k zaměstnání, udržitelný rozvoj, změna klimatu, lodní dopravní průmysl, mezinárodní obchodní trasy, rozvoj infrastruktury, řízení vodních zdrojů.

3. Table of content

1. Introduction

The completion of the construction of the Panama Canal in 1914 represented the realization of the project to connect the Atlantic and Pacific oceans through the shortest route, a goal sought for centuries. Its operation was a historic milestone in global transportation and marked a crucial point in the commercial exchange between nations worldwide.
The Panama Canal has efficiently maintained uninterrupted operations for the past 109 years, implementing continuous maintenance and updates to its infrastructure and waterway to meet the standards demanded by the world's merchant fleet.

Regrettably, due to technological advancements and the modernization of large vessels, the capacity of the canal became inadequate. Consequently, the Panamanian government chose to pursue expansion, a decision ratified through a referendum on October 22, 2006, resulting in a favorable outcome for the project. This marked the commencement of one of the most pivotal endeavors in Panama's history, considering the canal's contribution of 5.8% to the GDP and its pivotal role in facilitating 6% of global trade transportation. It stands as a cornerstone of the nation's economy, necessitating efforts to prevent the canal from becoming obsolete.
The expansion plan of the Panama Canal includes the construction of two sets of three-level locks, one on the Pacific side and another on the Atlantic side. Each set includes water reuse basins. It also involves widening and deepening the existing navigation channels of Gatun Lake and the sea entrances on the Pacific and Atlantic sides, as well as deepening the Culebra Cut. To connect the Pacific locks with the Culebra Cut, a dry excavation of a new 6.1 km-long access channel will be carried out. After its opening on June 26, 2016, the Expanded Canal not only exceeded transit expectations but also solidified its position as an environmental leader in the maritime industry. This was achieved by prioritizing water conservation and contributing to the reduction of CO2 emissions, thanks to shorter travel distances and increased cargo capacity for its customers. Furthermore, it has propelled the development of global maritime trade, creating numerous opportunities for connectivity and exchange among countries and markets. These aspects will be discussed in more detail throughout this work.

2. Objectives and Methodology

2.1.1 Objectives

The main objective of this thesis is comprehensively investigate and analyze the environmental and economic impacts of the Panama Canal Expansion, with a focus on evaluation the long-term consequences, sustainability implications, the economic and social growth and overall impact, including a thorough assessment of the cost-benefit aspect of the project.

The following are specific objectives:

- Analyze the role of the Panama Canal in the context of regional GDP.
- Examine the influence of the Panama Canal on maritime transportation and international trade.
- Evaluate the costs and benefits of the project.
- Describe and comprehend the impact of the expansion on the Panamanian economy.
- Describe and comprehend the environmental impact caused by the expansion.
- Analyze changes in biodiversity and ecosystems.
- Assess the generation of jobs.

These objectives will provide us with a deeper understanding of the importance of this mega project.

2.2.1 Methodology

In order to recognize the geographical context discussed in the thesis, it is crucial to define Panama as a distinct region in Latin America. It is a nation that connects the world with its interoceanic canal through two oceans, offering a shorter and safer route that supports environmental conservation. However, when creating indicators, institutions such as the Panama Canal Authority (ACP) and other related organizations assisted us in acquiring reliable and concrete data on the Panama Canal expansion project and its impact.

The thesis is structured into two main sections: theoretical and practical. The theoretical part is developed based on an extensive literature review that covers the beginnings of this megastructure since 1914, when its operations began. This literature review covers topics related to environmental development, commercial indicators of international maritime trade, and the efficiency of the expansion project over the last 14 years.

The Panama Canal Authority (ACP) is an autonomous public institution of the Republic of Panama, responsible for all matters related to the operations of the Panama Canal and its vision. The information it provides to the public is well-structured, which has facilitated the research methodology for this thesis with both quantitative and qualitative data.

The Panama Canal expansion project involves a comprehensive analysis of costs and benefits to inform decision-making. An exploratory study is conducted to examine trends in various indicators such as trade volume, maritime traffic patterns, economic development, environmental impact, and infrastructure investment. This study plays a crucial role in guiding the cost-benefit analysis of the project by providing insights into potential costs and benefits associated with the expansion. For instance, it may reveal the economic growth and development in the region. Additionally, it identifies potential environmental impacts and infrastructure investment requirements. The cost-benefit analysis conducted in the practical part of the thesis utilizes estimates of costs and revenues associated with the canal's construction and operation. Results such as Net Present Value and Internal Rate of Return are generated under two scenarios: In the first scenario, it is assumed that the project would be expanded, while in the second scenario, it is assumed that the project would not be expanded.
These results highlight the measurable monetary benefits of the expansion project during and after its completion.

4. Literature Review

3.1 Historical context of the Panama Canal.

The Isthmus of Panama, measuring just 50 km at its narrowest point, has stood as a strategic focal point for international trade for centuries, owing to its unique geographical position.

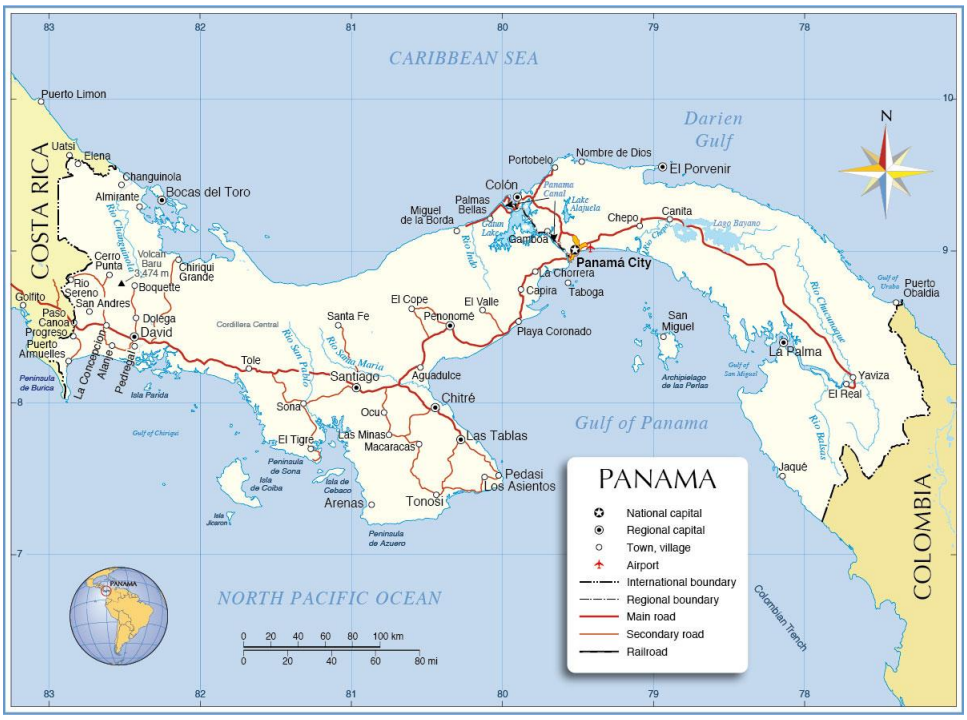


Figure 1: Panama Map

Source: canal de Panamá (2023)

The concept of constructing a canal to link the Pacific and Atlantic Oceans originated in the 15th century, as monarchs from Spain, England, Portugal, and Scotland contemplated this ambitious prospect. The formalization of this idea occurred in 1534 through a decree issued by Emperor Charles V, mandating the development of plans to establish a route to the Pacific along the Chagres River. This marked the inaugural study conducted for the construction of a canal in Panama.

The year 1850 witnessed the commencement of the construction of the transisthmian railroad, prompted by the California Gold Rush, aiming to facilitate the movement of settlers along the Panama route. By 1855, the railroad had been successfully completed, spanning a distance of 75 km from Colón on the Atlantic coast to Panama on the Pacific.

In 1880, France took the lead in constructing a sea-level canal in Panama, appointing the renowned builder of the Suez Canal, Ferdinand de Lesseps, as the project's head. However, adverse tropical climatic conditions and diseases resulting from excavations compelled the French to withdraw from the undertaking.

Shortly thereafter, the United States acquired the rights to the Panama Canal project and its properties for 40 million dollars, taking on the challenge of completing this monumental endeavor.

3.1.1 The Construction of the Panama Canal and it's challenges

The French Canal

It took more than three hundred years before the first attempt to construct the canal began. In 1876, the Geographical Society of Paris established a committee to encourage international cooperation in conducting studies that would fill gaps in the geographical knowledge of the Central American area with the goal of building an interoceanic canal. Presided over by Ferdinand de Lesseps, the committee, a limited company called Société Civile Internationale du Canal Interocéanique de Darién, commissioned Lieutenant of the French Navy, Lucien N. B. Wyse, to explore the Isthmus.

Wyse examined two potential paths in Panama: the San Blas route and the route from Limón Bay to Panama City, which aligns with the current Canal route. Opting for the latter, his intention was to construct a sea-level canal, closely following the Panama Railroad and necessitating a 7,720-meter tunnel through the Continental Divide in Culebra. Wyse brokered an agreement with the Colombian government in Bogotá, referred to as the Wyse Concession, granting Société Civile the exclusive authority to construct an interoceanic canal in Panama.

The International Congress on the Studies of the Interoceanic Canal (Congrès International d'Etudes du Canal Interocéanique) took place in Paris on May 15, 1879. In this congress, 14 alternatives for building the canal were analyzed, and it was approved to construct a sea-level canal between Limón Bay and Panama Bay without locks, financed by bonds totaling 400 million francs, although only 300 million could be raised. The Universal Interoceanic Canal Company of Panama, formed by the French, commenced work in 1880. However, in 1889, the company went bankrupt due to mismanagement, financial problems, collapses in excavations, and diseases such as malaria and yellow fever, severely impacting the workforce and causing a financial crisis in France. (Panama Canal Authority (ACP))

The project is executed by the United States

After experiencing the defeat as Panama witnessed the failure of the project led by the French, crushing the idea of achieving an Inter-Oceanic canal connecting the world, Panama appeared draped in defeat. The second Walker Commission, the Isthmian Canal Commission of the United States from 1899-1902, ordered by President McKinley, favored the route through Nicaragua, along with the popular and official sectors of the United States. Nicaragua seemed like a new slate for the U.S. project to build a canal, while Panama was considered a lost cause.

The canal was deemed essential, crucial, and irreplaceable for the United States' role as a dominant global power, given its control over both neighboring oceans. Following President McKinley's assassination, Theodore Roosevelt assumed the presidency. Roosevelt viewed a canal under U.S. control as imperative for the country's interests.

As the Americans became the new stakeholders in the project, the Canal through Nicaragua remained more attractive to the Walker Commission. The intervention of the Compagnie Nouvelle, assigning a new value of 40 million dollars to its properties in Panama, influenced the change in perspective. The House of Representatives approved the Hepburn Act in favor of Nicaragua, but after a meeting with the Walker Commission, Roosevelt expressed his desire to accept the French offer and submit a unanimous supplementary report favoring the route through Panama, resulting in a change of decision by the Commission.

Senator Mark Hanna was also in favor of the Panama route for technical reasons already provided in the technical reports. The waterway through Panama would be shorter, more direct, require less transit time, fewer locks, have better ports, already had a railway, and its operation would be cheaper. Finally, after much discussion, on June 19, 1902, the Senate vote favored the canal route through Panama by a margin of only eight votes.

After the U.S. government approved the project, negotiations with Colombia began to build the canal in the Colombian province of Panama. However, Colombia rejected the proposal.

President Roosevelt, impatient to build the canal, supported the independence movement in Panama. He was willing to stage a military show by sending battleships to both sides of the Isthmus. This led to Panama declaring its independence from Colombia on November 3, 1903.

The new agreement was sent to Panama for ratification. This granted the United States the perpetual concession of the canal for the development of a canal zone 10 miles wide, 5 miles on each side of the Canal line, over which it would exercise its own sovereignty.

At the start of the project, the Americans had the advantage of learning from the mistakes of the French. For example, to reduce deaths from diseases such as malaria and yellow fever, they brought a team of doctors led by Dr. Gorgas, reducing such cases by half.

During the tenure of Chief Engineer John F. Stevens, who led the project from July 1, 1905, to April 1, 1907, numerous challenges requiring immediate solutions were encountered. Extensive planning was conducted to address the shortage of housing and food supplies, as Panama's development level was insufficient to support the growing canal workforce. A complete overhaul of the Panama Railroad, deemed crucial for Canal construction, was carried out, and equipment and infrastructure were significantly improved. Furthermore, the workforce tripled within six months under Stevens' leadership, leading to the construction of entire communities with facilities such as housing, dining areas, hospitals, and schools. Stevens implemented an innovative system for excavation and disposal of rocks and soil in the Canal, utilizing an efficient system of coordinated trains and steam shovels at different levels in the Cut.

While the United States was building the Canal, the majority of workers were directly employed rather than through contractors, except for special projects such as the construction of a lock gate, which required workers with specific expertise. At one point, the McClintic-Marshall Company, responsible for building the gates, had over 5,000 men working on that particular project. The workforce reached its peak on March 26, 1913, with a total of 44,733 men working, excluding those who were sick, on vacation, or absent for other reasons. If these workers were included, an additional 20 percent would have been added to the total number at any given period.

Until July 1, 1914, a total of 238,845,587 cubic yards of material had been excavated during the American construction of the Panama Canal. Adding the 30,000,000 cubic yards excavated by the French, an approximate total of 268,000,000 cubic yards was reached. This volume was more than four times the original estimate for the sea-level canal proposed by de Lesseps. The success of the Panama Canal construction is largely attributed to Roosevelt, and this assertion has rarely been questioned.

The official opening of the Panama Canal took place on August 15, 1914. The construction of the Panama Canal cost approximately $375,000,000 for the Americans, including the $10,000,000 paid to Panama and the $40,000,000 paid to the French company. This project was the most expensive in the history of the United States at that time, and the additional fortifications cost around $12,000,000.

What is remarkable is that the final cost of the Canal turned out to be $23,000,000 less than the estimate made in 1907, despite challenges such as landslides and changes in the design for a wider canal.

Figure 2: August 15, 1914- Opening of the Panama Canal

Source: canal de Panamá (2023)

Even more impressive is that this vast and complex project concluded without scandals or corruption, which is uncommon in efforts of this magnitude, and significant issues did not arise in the years following its completion. Of course, this success was not without a human cost in lost lives.

In his book "The Path Between the Seas," David McCullough describes the creation of the Panama Canal as one of humanity's supreme achievements. He considers it the culmination of a heroic dream spanning over four hundred years and more than twenty years of phenomenal efforts and sacrifices. McCullough emphasizes the considerable challenges faced in conquering the fifty miles between the oceans, underscoring that no tonnage or toll statistics can fully convey the greatness of this accomplishment. Furthermore, he highlights that beyond its logistical function, the canal is an expression of an ancient human desire to unite what has been divided and to bring people together, regarding it as a work of civilization.

3.2 Maritime Transportation and International Trade

Maritime transportation serves as a cornerstone of the global economy, playing an essential role in facilitating the movement of goods, passengers, and commodities via ships and vessels across oceans, seas, rivers, and other water bodies.

Over 90% of global trade by volume and 70% by value is transported by sea, making maritime transportation the most cost-effective and efficient mode for transporting large quantities of goods over

long distances. It provides access to international markets, enabling countries to participate in global trade and benefit from comparative advantages in production resources.

It encompasses various types of vessels, including container ships, bulk carriers, tankers, cruise ships, and specialized vessels for specific cargo types such as LNG carriers or roll-on/roll-off (Ro-Ro) ships. Ports and terminals serve as crucial nodes in the maritime transportation network, where cargo is loaded, unloaded, and transferred between different modes of transportation.

Maritime transportation supports economic growth, job creation, and industrial development, particularly in coastal regions and countries with extensive maritime infrastructure.

Environmental concerns

Maritime transportation contributes to air and water pollution, greenhouse gas emissions, and degradation of marine ecosystems. Efforts to mitigate these impacts include the adoption of cleaner fuels, technological innovations, and regulatory measures such as the International Maritime Organization's (IMO) sulfur cap regulations.

The maritime industry is at a critical juncture, facing the challenge of reducing carbon emissions amidst economic and geopolitical complexities. Over the past decade, emissions have surged by 20%, reaching 3% of the global total, with projections suggesting a potential 130% increase by 2050 without intervention. Aging vessels, with an average age of 22.2 years as of early 2023, present additional challenges, as many are unsuitable for retrofitting or decommissioning. Despite the urgent need for decarbonization, securing multibillion-dollar investments is challenging, compounded by uncertainties about transition strategies. While alternative fuels show promise, their adoption remains limited, with fossil fuels still dominating 98.8% of the fleet. Another complicating factor is the issue of responsibility for the transition. While major flag states like Liberia, Panama, and the Marshall Islands, which contribute significantly to shipping emissions, are tasked with enforcing new green standards, the primary responsibility for investing in alternative fuels, bunkering infrastructure, and eco-friendly vessels falls on shipowners, ports, and the energy sector.

Navigating this intricate network of economic, regulatory, and environmental challenges presents the industry's most pressing dilemma. Decisions on decarbonization measures ultimately rest with the International Maritime Organization (IMO) and its member states. (UNCTAD, 2023)

4.2.1 Shipping routes

Refer to predetermined pathways or courses utilized by maritime vessels to traverse the global oceans and seas, linking various ports and destinations. These routes undergo meticulous planning to enhance

efficiency, safety, and economic viability in maritime transport operations. Integral to the facilitation of international trade, shipping routes serve as the structural framework for the conveyance of goods and commodities across continents and regions. Their configuration is shaped by diverse factors including geographical characteristics, meteorological conditions, navigational risks, trade dynamics, and regulatory frameworks. Typically, major shipping routes are firmly established and routinely utilized by vessels for the conveyance of cargo, passengers, and other maritime activities.

Figure 3 Main Maritime Shipping Routes and Chokepoints

Source: Port Economics, Management and Policy (2020)

Key shipping routes include:

- Trans-Pacific Route: Connecting Asia (particularly China, Japan, and South Korea) with North and South America.
- Trans-Atlantic Route: Linking North America (primarily the United States and Canada) with Europe.
- Intra-Asian Routes: Serving trade within the Asia-Pacific region, including routes between East Asia, Southeast Asia, and South Asia.
- Asia-Europe Route: Connecting major ports in Asia (e.g., China, Singapore) with Europe (e.g., Rotterdam, Hamburg).

Major maritime chokepoints, such as the Panama Canal (Europe-UK), Suez Canal (Asia-US), Strait of Malacca (Intra-Asia), and Strait of Hormuz, play critical roles in facilitating shipping routes and global trade flows.

In conclusion, international trade between continents heavily depends on the efficiency of shipping routes to facilitate the transportation of goods and commodities worldwide. These routes interconnect key trading centers, fostering the exchange of goods and thereby playing a crucial role in promoting global economic growth and development.

4.2.2 Regulations and Customs

The maritime sector is governed by an extensive array of regulatory frameworks and customs protocols that oversee diverse facets of maritime activities, commerce, and safety. These regulatory measures and customs protocols are established by governmental entities, international bodies, and maritime industry associations with the primary objectives of safeguarding vessel integrity, preserving marine ecosystems, and fostering the seamless flow of global trade. Here is a comprehensive overview of several pivotal dimensions of maritime regulatory frameworks and customs practices:

- ***Safety Regulation:*** Safety regulations in the maritime industry are aimed at ensuring the safety of vessels, crew, passengers, and cargo. They cover areas such as ship construction standards, equipment requirements, navigation rules, and emergency procedures.

  Key international regulations in this regard include the International Maritime Organization's (IMO), Which is an agency of the United Nations (UN). This organization enhance and uphold global maritime safety and security standards; Preserve marine biodiversity and ecological integrity through the prevention of ship-related pollution, thereby supporting the industry's transition to sustainability; Foster innovation within the maritime sector; Ensure full compliance with international conventions by all participating nations through the alignment of national legislation.

  Safety of Life at Sea (SOLAS) Convention: The SOLAS Convention is one of the most important international treaties concerning maritime safety, established by the International Maritime Organization (IMO). Its primary objective is to ensure the safety of merchant ships, their passengers, and crews at sea.
- ***Environmental Regulations:*** The marine environment holds significant importance within the purview of the International Maritime Organization (IMO), owing to the pivotal role of shipping in global trade and its consequential impact on marine ecosystems. Despite being recognized as the least environmentally damaging mode of transport relative to its productivity, the mitigation of pollution stemming from maritime activities has emerged as a central tenet of IMO's agenda since its establishment. Initially conceived with a primary focus on maritime

safety, the organization has since broadened its scope to encompass an array of pollution prevention and control initiatives. Notably, IMO has ratified an extensive array of conventions and protocols designed to tackle diverse manifestations of marine pollution, encompassing oil contamination, chemical discharges, waste management, sewage treatment, atmospheric emissions, and the translocation of invasive species via ships' ballast water. The Marine Environment Protection Committee (MEPC) and its ancillary bodies serve as pivotal platforms for the formulation and execution of these regulatory frameworks. Moreover, IMO extends support to developing nations through its Integrated Technical Cooperation Program (ITCP), aimed at bolstering their capacity to adhere to environmental mandates, thereby facilitating sustainable socio-economic progress and bolstering marine ecosystem preservation on a global scale.

- ***Security Regulations:*** Security regulations aim to enhance maritime security and prevent acts of terrorism, piracy, and other unlawful activities at sea. The International Ship and Port Facility Security (ISPS) Code, adopted by the IMO, establishes standards for the security of ships and port facilities, including requirements for security plans, access control, and security drills.

  Piracy and armed robbery against ships have been prominent concerns for the International Maritime Organization (IMO) since the early 1980s, with particular attention given to regions such as the South China Sea, the Straits of Malacca and Singapore, and more recently, the coast of Somalia, the Gulf of Aden, and the wider Indian Ocean. In response, the IMO has developed and implemented various antipiracy measures in collaboration with the shipping industry, leading to a reduction in the negative impact of piracy worldwide. Information on piracy incidents is accessible through the IMO's Piracy and Armed Robbery module within the Global Integrated Shipping Information System (GISIS), contingent on registration. Additionally, IMO offers support to Member States in developing national or regional measures to combat piracy and other illicit maritime activities upon request. Examples include the Djibouti Code of Conduct for the Western Indian Ocean and the Gulf of Aden, as well as the Code of Conduct for the Gulf of Guinea region in West and Central Africa.

  Through these endeavors, IMO strives to promote sustainable development and security within the maritime domain.

- ***Customs Procedures:*** Customs procedures in maritime transportation encompass the comprehensive regulatory framework and operational protocols governing the movement of goods across international borders via maritime vessels. These procedures are indispensable

for fostering smooth trade operations and ensuring adherence to regulatory requirements. Fundamental elements of these procedures comprise meticulous documentation, timely submission of customs declarations prior to vessel arrival, rigorous cargo inspections aimed at ensuring compliance with import regulations, meticulous assessment and collection of import duties and taxes, issuance of clearance processes by competent customs authorities, and the enforcement of security measures delineated in international frameworks such as the International Ship and Port Facility Security (ISPS) Code to deter illicit activities. Effective collaboration and coordination among customs authorities, maritime operators, and pertinent stakeholders are imperative for facilitating seamless cargo transit across borders while upholding the integrity of regulatory standards and security protocols.

3.3 Economic Impact of the expansion

The National Institute of Statistics and Census (INEC), operating under the Government Accountability Office of Panama, categorizes national production into various economic activity categories known as economic branches. For instance, animal breeding and agriculture fall under the Agriculture, Livestock, Hunting, and Forestry branch, while cement and food manufacturing are included in the Manufacturing Industries branch. The three most significant branches in Panama's production belong to the tertiary or service sector, encompassing Trade, Construction, and Transportation, Storage, and Communications, with Trade being the most prominent in terms of GDP contribution.

Activities managed by the Panama Canal Authority fall within the Transportation, Storage, and Communications branch. In 2017, Canal-related activities alone generated revenues exceeding two billion dollars, significantly surpassing the combined revenues of agriculture and fishing. This underscores the Canal's importance to the Panamanian economy.

These initial observations on Panama's production structure and its sectors are crucial for understanding the economic activities driving growth, which is the primary focus of this thesis.

The economic impact of the Panama Canal expansion has been substantial, with several key effects. Doubling the Canal's capacity through the expansion has allowed larger ships, known as Neopanamax vessels, to transit through the waterway, resulting in a significant increase in transported goods and benefiting global trade.

Additionally, during the most active construction period, the Panama Canal Authority (ACP) projected that the project would generate over 7,000 direct jobs and between 35,000 and 40,000 indirect jobs. It was also highlighted that the canal expansion, by enabling a greater concentration of services and

activities, could lead to the creation of between 150,000 and 250,000 new jobs in the country. (ACP-expansion-proposal.pdf, 2006)

For a better understanding, I have compared the Panama Canal's contribution to the national treasury in the year 2016, which marked the inauguration of the project, with the year 2023, representing the current year. Through this comparison, we can observe that, despite the global conflicts that have impacted the global economy, the contribution of the Panama Canal to the country's economy has increased.

Figure 4 Expanded Panama Canal

Source: Canal de Panamá (2023)

In the fiscal year 2016, which marked the inauguration of the expanded Panama Canal, it generated a total economic impact of B/.2,411 million on the country's economy. This included direct contributions to the National Treasury amounting to B/.1,013 million, indirect contributions to other state entities totaling B/.198 million, and general contributions to the economy amounting to B/.1,200 million. Direct contributions to the National Treasury encompassed surplus payments, net tonnage dues, and fees for public services. (ACP, ACP, 2016)

By the end of the fiscal year 2023, despite the economic impact of the conflict between Russia and Ukraine, and transit restrictions due to low levels of Lake Gatun caused by the El Niño phenomenon, the Canal contributed to the national treasure B/. 2,544 million and to the economy with direct and indirect economic contributions totaling B/.3,630 million. (ACP, ACP, 2023)

Figure 5: Panamanian President and Executives of the ACP

Source: Ministry of Presidential Affairs (2023)

It is important to highlight that, according to studies conducted on the Canal's impact on the country's economy, a multiplier effect of these contributions has been observed. For the fiscal year 2023, it is estimated that this multiplier effect will be an additional 1.3%, bringing the Canal's total contribution to 5.8% of GDP.

3.4 Environmental Impact

During the planning phase of the Panama Canal expansion project, one of the most significant aspects was assessing its environmental feasibility. Comprehensive Environmental Impact Studies were conducted to identify and understand the potential effects of the works, as well as the necessary mitigation measures. In this process, the collaboration of the National Environmental Authority (ANAM), a government entity dedicated exclusively to environmental protection and conservation, was enlisted.

One of the main advantages was that the expansion project would be carried out on an existing structure, which would avoid a significant environmental impact due to the changes the project would require.

The environmental impact of the Panama Canal expansion and environmental planning in response to global climate change are critical topics that must be considered in every project development. In the case of the construction of the third set of locks, this was no exception. Although unavoidable impacts are inherent in projects of this magnitude, measures were implemented to reduce, mitigate, and compensate for these impacts.

Environmental Conservation Measures Implemented During Panama Canal Expansion: Air quality was a significant consideration during the execution of the project, given its status as one of Panama's largest undertakings. Dust reduction equipment, such as conveyor belts and water spraying systems, was employed to minimize airborne particles. To prevent water contamination, workshops were equipped with water and oil separators to ensure these elements remained separate and did not pollute nearby waterways. Measures to protect the soil included the installation of smooth surfaces or plastics across all project sites, considering the heavy truck traffic involved in the expansion works. Wildlife preservation efforts involved the rescue of over 6,000 animals, primarily mammals, facilitated by nighttime cameras and traps manned by teams of biologists and veterinarians. Environmental strategies also featured water recycling tanks to save up to 60% of water usage and the responsible disposal of excavation materials in a designated area, repurposing a former shooting range used by the US Department of Defense. This approach emphasized resource optimization and minimal impact on surrounding areas.

Tree Felling: More than 600 hectares of forests were cleared, leading the Panama Canal Authority (ACP) to compensate the government, specifically the Ministry of Environment (MiAmbiente), with over 4 million dollars and commit to reforesting double the affected areas. To date, over 2.8 million dollars have been invested in these reforestation projects, which are conducted following the standards established by MiAmbiente. This entity also identifies the areas requiring reforestation and sets the parameters for the plan, which the ACP implements.

Water Quality: A strategy was implemented to treat and protect the watersheds near the work areas. Water was directed to settling tanks where it was allowed to settle, and then the sediment was removed to prevent contamination of the watersheds. Additionally, the new structures include water treatment plants and oil separators, and it is ensured that no wastewater is discharged.

Climate Change: The expansion of the Panama Canal will not only facilitate the passage of large vessels but will also help combat climate change. This is because transporting a larger amount of cargo

on a single vessel reduces fuel usage per unit. In other words, the cargo that previously would have required multiple ships to transport can now be carried by a single one.

Relocation: With the construction of the new passage for ships through the Isthmus, it is planned to raise the level of Lake Gatun to its maximum operational level. This required conducting surveys to determine if it was necessary to relocate families that might be at risk. A team of environmental specialists from the ACP carried out this task, and only three families at potential risk were identified. Discussions were initiated with each of these families, who accepted relocation but with conditions. They requested to remain in their current locations within the Lagartera Grande community. The exact points within the community where these families resided were identified, and then the acquisition of land and construction of new homes proceeded.

Water Usage: During fiscal year 2023, a total of 220 million cubic meters (Mm3) of water were saved in the Panamax locks, with 42 Mm3 (19%) saved in the Gatun locks and 178 Mm3 (81%) in the Pedro Miguel locks. This volume is equivalent to a water level decrease in the Gatun reservoir of approximately 1.84 feet (0.56 meters). The average water usage per transit for a Panamax vessel was 0.163 Mm3, representing 78% of one lockage equivalent (EE). Neopanamax vessels required an average of 0.3745 Mm3 of water per transit, with 48% of this volume (0.1809 Mm3) consumed for maintaining the water quality of the Gatun reservoir (CCA). The water volume deficit of 574 Mm3 (18 m3/s) to meet water demand was covered by the Gatun and Alhajuela reservoirs. The daily average salinity in the navigation channel of the Gatun reservoir during fiscal year 2023 was 0.2262 practical salinity units (ups). Precipitation over the Panama Canal Watershed (PCW) for fiscal year 2023 was 1,998 mm, which was 25% below the historical average of 2,659 mm. This 661 mm deficit was the driest recorded in the period from 1951 to 2023.

Drought Impact: In 2023, there was 30% less rainfall than usual, leading to the storage of only 50% of the water needed to meet the demands during the 2024 dry season. Historical records indicate that this is the second driest year in the past 73 years.

The total capacity of both reservoirs is 1,857 cubic hectometers (hm3), with 558 hm3 corresponding to Alhajuela and 1,299 hm3 to Gatun. However, in 2023, only approximately 900 hm3 were stored, with just over 500 hm3 in Alhajuela reaching capacity and the remaining 400 hm3 in Gatun.

Several factors contributed to the dramatic level of the reservoirs. Firstly, there was an early start to the 2023 dry season, which extended beyond the usual period, lasting a total of five and a half months,

very close to the longest dry season on record in the Panama Canal Watershed (CHCP), which lasted six months.

Additionally, on June 8, the National Oceanic and Atmospheric Administration (NOAA) declared the onset of an El Niño event, exacerbating the reservoir situation due to the lack of rainfall associated with this phenomenon. In six of the last 10 years, rainfall in the Basin has been below the historical average, including the second, third, sixth, and seventh driest years since measurements began in 1950. These events have significant repercussions on the CHCP, where aquifers (natural underground formations where water is stored) often do not have enough time to recover before another drought occurs, resulting in a significant impact on the river flow into the reservoirs. The Panama Canal closely monitors the development of this drought and has implemented permanent water-saving measures in operations over the past year. Usually, such measures are only implemented during the dry season. However, this year it has been necessary to maintain them continuously.

The main measures implemented include:

- Cross-locking in the Pedro Miguel and Gatun locks.
- Use of water-saving tubs in the newpanamax locks.
- Draft restrictions and restrictions on the number of daily transits.
- Short chamber lockings in the panamax locks when vessel dimensions are allowed.
- Minimization of direction changes in the Gatun locks.
- Monitoring and elimination of water leaks in valves and gates
- Suspension of special locking's (only carried out for operational needs).
- Suspension of hydraulic assistance during locking's
- Minimization of hydrogeneration.

In essence, the drought at the Panama Canal is having a notable impact on global shipping, highlighting the urgency of tackling climate change issues within trade routes and transportation systems.

CO2 Neutral

Carbon dioxide (CO2) is the primary greenhouse gas emitted by human activities. In 2022, global CO2 emissions reached a historic high, surpassing 40 billion metric tons, posing a significant global challenge. Maritime transport, according to the International Maritime Organization (IMO), accounts for approximately 950 million metric tons of CO2, representing about 2% of global emissions.

Efforts to reduce emissions in the maritime sector are underway, with both shipping companies and ports striving to enhance operational efficiency and environmental friendliness.

The Panama Canal aims to achieve carbon neutrality by 2030 and has initiated several measures to transition towards a greener operation. This includes introducing four electric cars in a pilot project to gather data for shifting the fleet away from fossil fuels. Additionally, the Canal's decarbonization plan involves adopting alternative fuels for tugs and launches, replacing electricity production with photovoltaic plants, utilizing hydraulic energy, and ensuring environmental responsibility in all projects.

Through environmental programs in the watershed, the Panama Canal contributes to making it one of the three countries globally considered carbon negative. This is achieved as its forests absorb more carbon than the emissions it produces.

Recognizing the urgency of climate change, the Panama Canal has made significant strides in reducing emissions and achieving decarbonization. Its strategic location provides a shorter route for ships, aiding in emissions reduction.

Since 2016, the Canal has intensified its efforts by promoting environmentally friendly transits, such as through the Green Connection Environmental Recognition Program. In 2021, the Canal introduced the CO2 Emissions Reduction Dashboard, which publishes monthly data on emissions saved by ships transiting through the waterway compared to alternative routes. Recent enhancements to this tool aim to improve accuracy by using geo-referenced data and fuel type information.

In 2022, emissions savings reached 12,941,323 metric tons of CO2 equivalent, compared to the most likely alternative route, contributing to an overall reduction of approximately 50 million metric tons of CO2 emissions over the past four years.

5. Practical Part

4.1 Initial Cost Projection

The expansion proposal unveiled in 2006 indicated that constructing the third set of locks was expected to cost approximately $5.25 billion. The estimated cost underwent a thorough analysis process involving renowned international specialists. In the midst of the global economic recession, prominent international financial institutions, comprising the European Investment Bank, the Japan Bank for International Cooperation, the Inter-American Development Bank, the International Finance

Corporation, and the Andean Development Corporation, extended their support to the project by disbursing loans totaling $2.3 billion to facilitate its expansion.

Table 1: Financing of the Panama Canal Expansion Project

European Investment Bank (EIB)	500M
Japan Bank for International Cooperation (JBIC)	800M
Inter-American Development Bank (IDB)	400M
International Finance Corporation (IFC)	300M
Andean Development Corporation (CAF)	300M
Subtotal	**2300M**
ACP (Panama Canal Authority)	**2950M**
Total	**5250M**

The projected expenditure for the construction covers both direct and indirect costs. Direct costs include expenses related to design, construction activities, testing, environmental mitigation, and commissioning, with administrative expenses also falling under this category. Additionally, the estimate incorporates provisions for contingencies to address potential risks and unforeseen events such as accidents, design changes, price hikes, and possible delays. This contingency allocation is considered adequate and suitable for a project at its conceptual design stage. Furthermore, the estimated project cost factors in the impact of inflation during the construction period.

Table 2: Projected Cost of the Panama Canal Expansion Project

Project Elements	Projected Investment Value (Million)
New Locks	
Atlantic Locks	1110
Pacific Locks	1030
Contingency for New Locks	590
Total for the New Locks	**2730**
Water Saving Basins	
Atlantic Water Saving Basins	270
Pacific Water Saving Basins	210
Contingency for Water Saving Basins	140

Total for Water Saving Basins	**620**
Access Channels for New Locks	
Atlantic Access Channels (Dredging)	70
Pacific Access Channels (Dry Excavation)	400
Pacific Access Channels (Dredging)	180
Contingency for Access Channels	170
Total for New Locks Access Channels	**820**
Existing Navigation Channel Improvement	
Deepening and Widening of Atlantic Entrance	30
Widening of the Gatun Lake Channels	90
Deepening and Widening of Pacific Entrance	120
Contingency for Existing Channel Improvement	50
Total for Navigational Channel improvements	**290**
Water Supply Improvements	
Increase the Maximum Level of Gatun Lake to 27.1m (89') PLD	30
Deepening of the Navigational Channels to 9.1m(30') PLD	150
Contingency for Water Supply Improvements	80
Total Water Supply Improvement	**260**
Inflation During the Construction Period	**530**
Total Investment	**5250**

The primary expense within the program pertains to building the two new lock facilities, one on the Atlantic side and the other on the Pacific side. The estimated costs for each facility are approximately $1,110 million and $1,030 million respectively, with an additional provision of $590 million allocated for potential contingencies during their construction. (ACP Proposal)

The new lock facilities, along with their water reutilization basins and contingencies, are estimated to cost $3,350 million, with $1,110 million allocated for the Atlantic side and $1,030 million for the Pacific side. Water reutilization basins for the lock facilities will cost approximately $270 million for the Atlantic side and $210 million for the Pacific side, with an additional $140 million provision for contingencies.

The construction of new lock access channels is estimated at $820 million, including $400 million for dry excavations, $250 million for drilling, blasting, and dredging works, and a $170 million provision for contingencies. Improvements to existing navigational channels are estimated to cost $290 million, with $90 million for widening Gatun Lake's channels, $150 million for deepening and widening canal entrances, and a $50 million provision for contingencies.

Water supply improvements are estimated at $260 million, including $150 million for deepening navigational channels, $30 million for elevating Gatun Lake's operational level, and an additional $80 million for contingencies. Including an estimated $530 million for inflation during construction, the total estimated cost of the third set of locks project is $5,250 million.

The detailed cost analysis ensures a high level of confidence in its reliability. By incorporating adequate contingencies to address potential risks, uncertainties, and unforeseen events, the estimate is deemed robust and dependable. Consequently, there is a strong likelihood that the construction will be completed within or even below the estimated costs.

4.2. Projected Benefits

The expansion of the Canal is evidently financially viable. Considering the increase in its capacity, which will alleviate congestion, reduce transit times, and accommodate larger post-Panamax vessels.

Significant enhancements such as widening the Gaillard Cut, strengthening the locomotive fleet, and acquiring more robust tugs are expected to substantially decrease average transit times, facilitating faster passage through the canal.

The expected increase in daily transits and faster transit times is projected to stimulate growth in toll revenue, making the canal more economically feasible for international shippers and traders

From an economic perspective, the expansion initiative is anticipated to boost economic activity by attracting more trade traffic, thereby generating socio-economic benefits for Panamanian society.

The self-financed nature of the expansion, without government assistance, along with revenue forecasts indicating potential cost recovery within a decade and loan repayment in about eight years, underscores the project's financial independence.

In summary, the Panama Canal expansion project is positioned to strengthen global trade dynamics, drive economic growth, and ensure the canal's long-term financial viability, solidifying its competitiveness in the global market.

4.3. Cost Benefit Analysis

A cost-benefit analysis was conducted to assess the viability of proceeding with the expansion project. It's essential to highlight that the data used for this analysis was sourced from studies conducted by the Panama Canal Authority (ACP), supplemented by information from books, articles, and reports. To ensure accuracy, the analysis focused on two key components: net present value and internal rate of return. Furthermore, various factors were considered to evaluate the costs and benefits associated with the expansion project. Notably, the projections and calculations do not account for the impact of the COVID-19 pandemic from 2019 to 2021.

Timeline

The assessment extended from 2017 to 2036, encompassing the duration from the initiation of construction to the anticipated useful lifespan of the expansion initiative. This timeframe guaranteed that the enduring effects, which were predicted to be briefer than the project's total duration, were adequately addressed without needlessly prolonging the analysis.

Projected Net Benefits

The report outlines the expected net benefits for the expansion project based on two primary scenarios. In the first scenario, it was assumed that the project would be expanded. In the second scenario, the assumption was made that the project would not be expanded. In both cases, the initial investment in the project was combined with the anticipated costs throughout the project's lifespan. The resulting sums from this calculation were then deducted from the projected net benefits of the project to determine the net value of the Panama Canal expansion project.

Projected Cost:

The anticipated net benefits were calculated based on two distinct scenarios, as were the expected costs.

Discount Rate

To determine the Net Present Value (NPV) of the Panama Canal expansion project, URS Holdings Inc. constructed a discount rate. They opted for a 50-50 debt-equity ratio to reflect that only half of the project's funds would be borrowed, with the remaining coming from the ACP. The first part of the discount rate was computed using a reference rate of 6.5 percent, representing the yield of T-bills or

U.S. Treasury Bonds, and an inflation rate of two percent. This yielded a cost of debt (Kd) of approximately 4.4118 percent. For the equity portion, the average profitability of national capital from 1993 to 2004 was utilized, resulting in an opportunity cost of 9.9 percent for the ACP. Combining these factors, the discount rate for the project was calculated as 7.1559 percent. This discount rate was applied to all calculations conducted in the analysis. (du Plessix)

4.3.1 Financial Evaluation

This will demonstrate the potential private profitability resulting from the Panama Canal expansion project, taking into account previously mentioned economic indicators and evaluating its efficacy under two distinct scenarios: one involving the implementation of the expansion project and another where it is not pursued.

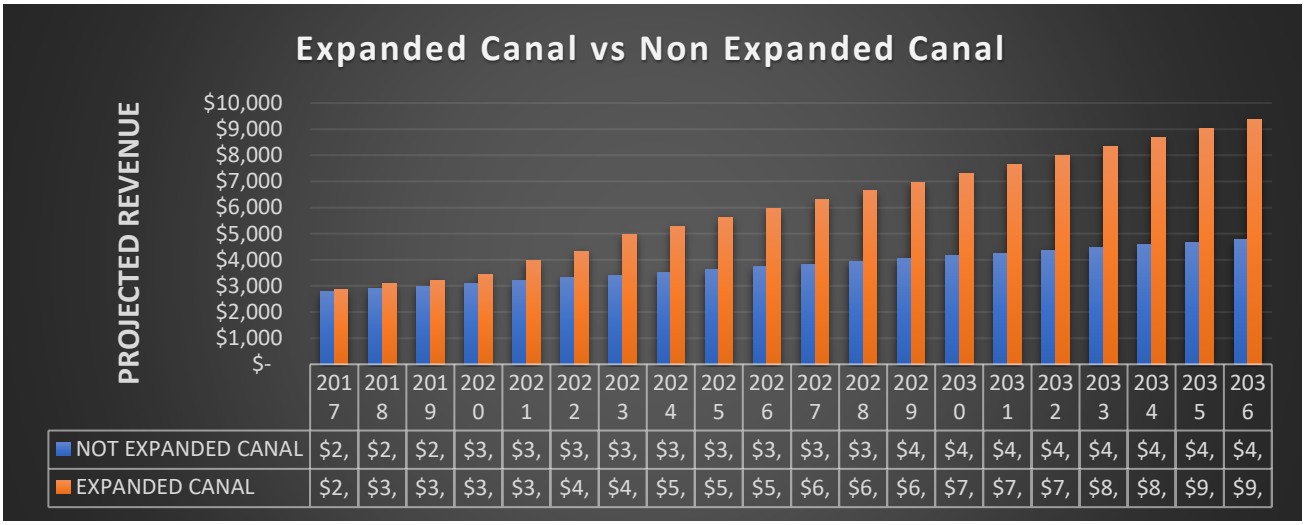
4.3.2 Net Present Value (NPV) of Economic and Social Aspects

The first scenario will provide insight into the operational dynamics of the canal under the condition of maintaining its current state but incorporating certain enhancements, as assessed through a forecast analysis. The timeline encompasses the period from 2017 to 2036.
The current value of the overall economic benefits total is referred to as current benefits, resulting in a sum of $75620 million. The total economic costs are $40743 million.

The discount rate remains consistent throughout the entire period. As previously mentioned, the discount rate is maintained at 7.1559%.

In the second scenario, considering an expanded canal resulted in a notably favorable outcome for proponents of the project. The total benefits estimated between 2017 and 2036 amounted to $120990 million, while the total economic costs were $41997 million. Consequently,
The discount rate stays constant over the entire timeframe, as noted before, at 7.1559%.

The graph shows evidence that the expanded canal has demonstrated positive increases in its revenues since its opening and promises to continue contributing significant benefits to the Panamanian economy.



Graph 1: Revenue Comparison between the Expanded Canal and the Non-Expanded

Source: Canal de Panama (2023)

6. Results and Discussion

Scenario 1:

Operational dynamics were scrutinized within the existing framework of the canal, albeit with enhancements, covering the period from 2017to 2036. Current benefits were estimated at $75620 million, while total economic costs amounted to $40743 million.

Scenario 2:

Exploring the feasibility of an expanded canal, projecting total benefits of $120,990 million against total economic costs of $41,997 million, yielded favorable results.

Final results:

The cost and benefit analysis of the Panama Canal expansion project highlights several key findings. The Net Present Value (NPV) is calculated at $16,570 million, indicating a positive return on investment. This suggests that the project is expected to generate more value than the initial investment. Additionally, the Internal Rate of Return (IRR) of 9% signifies the annualized rate of return generated by the project, further supporting its financial viability. Despite an initial investment of $5,250 million, the project demonstrates profitability over time, as evidenced by the positive NPV

and IRR. Overall, these findings indicate that the Panama Canal expansion project is financially feasible and expected to yield positive returns, as indicated by the NPV and IRR metrics.

The expansion project has been largely successful from a financial standpoint, generating revenues that contribute to repaying project debts. Increased traffic and toll revenues resulting from the expanded canal have helped offset the initial investment costs. Furthermore, meticulous financial planning and management have ensured gradual repayment of project debts while maintaining the canal's operational efficiency and competitiveness. Amortization payments for the construction of the expansion project will be made over a period of ten years. Overall, the success of the Panama Canal expansion project is evident in its positive impact on trade, economic development, and financial sustainability. The project has not only expanded the capacity and capabilities of the canal but has also positioned Panama as a vital hub in global commerce.

Table 3: Cost-Benefit Calculation

Year	Revenue		Flow of Benefit		Economic cost		
	Expanded	Not expanded	Economic Benefit	Net economic benefits	Expanded	Not expanded	Difference
2017	$2,852	$2,783	$69	-$221	$1,593	$1,287	$306
2018	$3,108	$2,888	$219	-$126	$1,731	$1,366	$364
2019	$3,213	$2,993	$219	-$82	$1,766	$1,445	$321
2020	$3,443	$3,098	$344	$124	$1,705	$1,524	$180
2021	$3,958	$3,203	$755	$413	$1,773	$1,603	$170
2022	$4,322	$3,308	$1,014	$527	$1,897	$1,682	$215
2023	$4,968	$3,413	$1,554	$836	$1,958	$1,761	$196
2024	$5,277	$3,518	$1,758	$938	$1,967	$1,839	$127
2025	$5,617	$3,623	$1,993	$1,016	$2,018	$1,918	$99
2026	$5,957	$3,728	$2,228	$1,080	$2,069	$1,997	$71
2027	$6,297	$3,833	$2,463	$1,131	$2,120	$2,076	$44
2028	$6,637	$3,938	$2,698	$1,170	$2,172	$2,155	$16
2029	$6,977	$4,043	$2,933	$1,199	$2,223	$2,234	-$11
2030	$7,317	$4,148	$3,168	$1,218	$2,274	$2,313	-$38
2031	$7,657	$4,253	$3,403	$1,230	$2,325	$2,392	-$66
2032	$7,997	$4,358	$3,638	$1,235	$2,377	$2,471	-$93
2033	$8,337	$4,463	$3,873	$1,233	$2,428	$2,550	-$121
2034	$8,677	$4,568	$4,108	$1,227	$2,479	$2,628	-$149
2035	$9,017	$4,673	$4,343	$1,215	$2,531	$2,707	-$176
2036	$9,357	$4,778	$4,578	$1,200	$2,582	$2,786	-$204

NPV	**$16,570**
IRR	**9%**

7. Conclusion

The expansion of the Panama Canal has undoubtedly brought a significant economic and environmental impact to the region and to the international maritime trade

Economically, the increased capacity and efficiency of the canal has facilitated greater trade volumes and enhanced connectivity between global markets, bolstering Panama's position as a vital player in international commerce. The expansion has stimulated economic growth, job creation, and infrastructure development, driving prosperity not only for Panama but also for the broader Latin American region.

However, it's imperative to acknowledge the environmental consequences that have accompanied this development. While the expansion aimed to reduce carbon emissions and increase water efficiency through modernization, it also raised concerns about biodiversity loss, habitat destruction, and water management practices. Sustainable practices and environmental mitigation measures are crucial in lessening these impacts and ensuring the long-term health of the surrounding ecosystem.

The cost-benefit analysis has provided valuable insights into the project's financial viability and long-term sustainability. By weighing projected costs against anticipated benefits, policymakers can make informed decisions to optimize resources and maximize returns. The analysis underscores the importance of comprehensive planning, risk assessment, and stakeholder engagement in large-scale infrastructure projects such as the Panama Canal expansion.

The expansion of the Panama Canal represents a complex interplay between economic development, environmental stewardship, and strategic planning. While it has brought undeniable benefits to global trade and regional prosperity, it also underscores the need for responsible and sustainable infrastructure development to ensure a balance between economic growth and environmental conservation in the years to come.

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9. List of pictures, tables, graphs and abbreviations

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Appendix

Definitions and Formulas

Net present Value (NPV): is a financial tool assessing investment profitability by comparing present cash inflows and outflows, factoring in a discount rate. A positive NPV signals profit potential, while a negative NPV indicates possible financial loss.

$$NPV = \sum_{t=0}^{N} \frac{Bt - Ct}{(1 + r)^t}$$

Where:

Bt – benefit for year t of the project

Ct – cost for year t of the project

t – year corresponding to project life from 0 to n

0 – initial year of project, in which investment begins

r – discount rate or minimum acceptable discount rate (MADR)

Internal rate of return (IRR): The Internal Rate of Return (IRR) is a financial metric employed to gauge the profitability of an investment by determining the rate at which the net present value (NPV) of cash flows equals zero. It indicates the annualized return yielded by the investment and is utilized to evaluate the desirability of an investment prospect.

$$IRR = 0 = \sum_{t=0}^{N} \frac{Bt - Ct}{(1 + r)^t}$$