

Identification and Ranking of Factors Affecting Government Investment in Iranian Ports within the Framework of the Blue Economy: A Fuzzy Delphi Approach

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ABSTRACT

Government investment in ports, as one of the main pillars of maritime transport infrastructure development, plays a vital role in strengthening economic growth and enhancing the country's position in the blue economy. The aim of this study is to identify and prioritize the factors influencing government investment in Iranian ports within the framework of the blue economy. To this end, the Fuzzy Delphi method was employed, and data were collected and analyzed based on the opinions of experts in the fields of economics and maritime transport. The results revealed ten key factors influencing government investment in ports, among which "government revenue status" and "its financial capacity with an emphasis on dependence on oil and tax resources" play the most critical roles. Other influential factors include the volume of maritime trade and global demand, the quality and extent of domestic transport infrastructure, government economic policies, the geographical location of ports, the intensity of regional competition, the level of technology and automation, security and safety requirements, the level of foreign investment attraction, and attention to environmental sustainability. The findings indicate that government investment in ports, in addition to macroeconomic variables, is also affected by institutional, regional, and environmental factors. Accordingly, strengthening the government's financial sustainability, developing transport networks, leveraging geopolitical advantages, and enhancing technological capabilities can pave the way for the sustainable development of Iranian ports and their more effective contribution to the realization of blue economy objectives.

1. Introduction

Seas and coastal areas have always been recognized as one of the most important foundations of economic, social, and environmental development worldwide. International statistics indicate that today more than one-third of the world's population lives within 60 kilometers of the coasts, and over two-thirds of the world's major cities are located in coastal regions. In

addition, more than one percent of the global active population is directly employed, and about three percent are indirectly engaged in sea-related economic sectors. The contribution of the ocean economy to global GDP is estimated at about 2.5 percent, while nearly 80 percent of international trade is carried out through maritime routes. These figures clearly demonstrate that the sea functions as a driving engine of the global economy, playing a key role in growth,

job creation, and international economic interactions [1].

Iran, with over 5,800 kilometers of coastline along the Persian Gulf, the Sea of Oman, and the Caspian Sea, possesses enormous potential in the field of the blue economy. Despite this unique geopolitical position—which makes Iran a strategic bridge between Asia and Europe and a central passageway for international North–South and East–West corridors—the country’s share of the maritime economy remains far below its potential. While more than 90 percent of Iran’s foreign trade is conducted by sea, only about 10 percent of its population resides in coastal areas. In leading maritime economies such as China and Vietnam, the share of the marine-based economy in GDP ranges between 20 and 50 percent, whereas in Iran this share is estimated at only around 10 percent. According to available statistics, Iran accounts for roughly 1 percent of the global maritime economy excluding oil and gas resources, and about 2.5 percent when these resources are included. These figures clearly indicate that the vast majority of Iran’s aquatic and marine capacities have yet to be utilized [2].

Beyond trade and transport, the blue economy encompasses diverse dimensions such as fisheries, marine tourism, renewable energy, aquaculture, the use of saline water in agriculture, and seawater desalination. Estimates in the European Union show that in 2014 alone, more than 3.36 million people were employed in these sectors. Moreover, each direct job created in the blue economy generates, on average, four additional indirect jobs in other sectors. This enormous potential for employment and value creation has made the blue economy one of the key drivers of sustainable development across the world. In Iran, however, coastal exploitation has been largely limited to port and military facilities, leaving a significant portion of coastal capacities—about 95 percent—underutilized [3].

At the same time, Iran is located within the global arid belt and faces severe freshwater resource limitations. Under such conditions, the use of seawater for agriculture, the cultivation of salt-tolerant plants, and the development of marine-based industries can serve as fundamental strategies for employment generation, food security, and diversification of the national economy. In many countries, seawater desalination as well as the cultivation of algae and halophytes have already become important sources of exports. Thus, a stronger focus on the blue economy could help Iran

transition away from a single-product, oil-dependent economy [2].

Despite these capacities, multiple challenges hinder the development of Iran’s maritime economy. The shortage of modern port infrastructure, the aging of the maritime transport fleet, the lack of advanced logistics technologies, and intensifying regional competition are among the most significant obstacles. In this context, government investment in ports emerges as one of the most effective tools to overcome these challenges and leverage existing opportunities. Such investments not only enhance transport infrastructure and port facilities but also create the necessary conditions for attracting private and foreign investment, thereby paving the way for sustainable development and strengthening Iran’s position in the global blue economy [2].

Accordingly, this study employs the Fuzzy Delphi method to identify and prioritize the factors influencing government investment in Iranian ports, aiming to provide a comprehensive picture of the economic, institutional, technological, regional, and environmental elements that determine such investments, and to propose policy recommendations for improvement in this domain.

2. Theoretical Framework and Literature Review

2.1. Theoretical Framework

2.1.1. History and Concepts of the Blue Economy

The concept of the blue economy emerged in the 1990s in response to global concerns about sustainable development. Its turning point was the United Nations Conference on Environment and Development in 1992, which emphasized the protection of marine resources. In subsequent decades, meetings such as the Johannesburg Summit (2002) and the Rio+20 Conference (2012) highlighted the role of ocean-based economies in poverty reduction and environmental protection. Since 2009, the concept has been incorporated into policy discussions and gradually attracted the attention of institutions such as the U.S. Congress, the World Bank, and the United Nations. Gunter Pauli played a significant role in developing this idea through his book *The Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs*. Furthermore, Goal 14 of the United Nations Sustainable Development Goals (SDGs) is specifically dedicated to the sustainable use of oceans. In recent years, the European Union, the African Union, and small island developing states have embraced the blue economy as a key

strategy for resilience and economic growth [4, 5, 6, 7, 8].

Throughout history, the sea has always been one of the fundamental pillars of human civilization's economic activities—both as a rich source of food supply and as a strategic route for the transport of goods and intercontinental trade. This vital and enduring role is evident across all historical periods and provides the foundation for the emergence of modern concepts such as the blue economy. In recent years, the term has gained a central position in global policymaking and has evolved into a concept associated with the sustainable exploitation of marine resources, grounded in the protection of oceans and coastal areas within the framework of sustainable development goals. The main objective of this approach is to achieve economic growth, improve quality of life, strengthen social inclusion, and generate employment without compromising the environmental sustainability of marine resources. Since these resources are limited and vulnerable to degradation due to human activities, scientific research into the blue economy often requires attention to overlapping and related concepts. Lee et al. (2020) note that “the blue economy has been interpreted in various ways and is often used interchangeably with terms such as ‘ocean economy’ or ‘marine economy’ without clear distinctions.” Other studies also demonstrate that terms such as Ocean Economy (OE), Marine Economy (ME), and Blue Growth (BG) have been used synonymously or complementarily [9].

2.1.2. Dimensions of the Blue Economy

In contemporary research, the blue economy is generally considered a multidimensional concept encompassing six main dimensions. Each dimension is based on principles and practices aimed at ensuring the sustainable use of ocean resources for the benefit of both present and future generations [10, 11].

- **Economic Dimension**

The economic dimension of the blue economy addresses economic growth and development within the framework of sustainability. It covers a wide range of activities, including fisheries, aquaculture, marine biotechnology, coastal and marine tourism, maritime transport, and renewable energy. The principles of this dimension focus on creating value from marine resources, fostering innovation, and developing sustainable

business models that support local communities.

- **Social Dimension**

The social dimension ensures the equitable distribution of benefits derived from marine resources among all stakeholders. It encompasses issues such as human rights, labor standards, gender equality, and community development. Its principles emphasize participation, engagement with local communities, and consideration of the social impacts of economic activities.

- **Environmental Dimension**

The environmental dimension addresses the protection of the health and integrity of marine ecosystems. It includes biodiversity conservation, climate change mitigation and adaptation, pollution prevention, and ecosystem-based management. Its principles ensure that economic activities do not undermine the ecological sustainability of marine resources.

- **Technological Dimension**

This dimension focuses on the development and application of innovative technologies to support sustainable ocean-based economic activities. It spans areas such as marine robotics, sensors, artificial intelligence, renewable energy technologies, and biotechnology. The principles emphasize innovation, technology transfer and dissemination, and the responsible use of emerging technologies.

- **Cultural Dimension**

The cultural dimension highlights the recognition and preservation of cultural heritage and traditional knowledge related to ocean resources. It covers activities such as traditional fishing, seafaring, storytelling, and cultural tourism. Its principles focus on respecting cultural diversity, acknowledging cultural aspects of marine resources, and promoting cultural exchange and cooperation.

- **Governance Dimension**

The governance dimension concerns the establishment of effective governance

mechanisms for the sustainable management of ocean resources. It involves institutional frameworks, policy coordination, and stakeholder participation. The principles emphasize transparent, participatory, and accountable governance structures that support the sustainable use of ocean resources.

3.1.2. The Role of the Blue Economy in the Global Economy

According to the UNCTAD (2024) report, ocean-related economic activities have grown at a faster pace than other sectors globally. The Ocean Economy Index increased by approximately 2.5 times between 1995 and 2020, surpassing the global average growth rate. This expansion has been primarily driven by the development of trade and innovation in this domain.

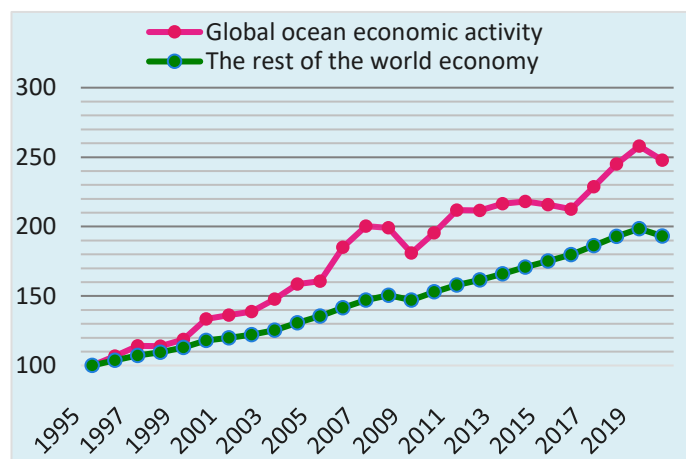


Chart 1. Growth of the Ocean Economy Compared to the Global Economy (1995–2020) [12]

In 2023, the volume of global trade in marine goods and services reached record levels of USD 899 billion and USD 1.3 trillion, respectively, highlighting the growing importance of ocean-related activities for coastal and island nations. The fisheries sector alone currently supports the livelihoods of about 600 million people, predominantly in developing countries.

Despite this remarkable economic growth, the blue economy also faces significant environmental challenges, some of the most critical of which include [13]:

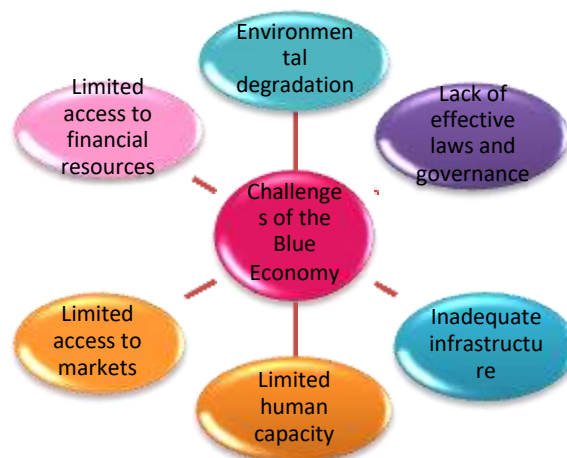


Figure 1. Challenges of the Blue Economy [13]



4-1-2. The Blue Economy within the Framework of Sustainable Development

The importance of oceans for sustainable development has been widely emphasized by the international community through instruments such as Agenda 21, the Johannesburg Plan of Implementation, the Rio+20 Outcome Documents, and the 2030 Sustainable Development Goals (SDGs). Among these, the United Nations Convention on the Law of the Sea (UNCLOS) of 1982 and its implementing agreements have established the international legal framework governing ocean-related activities, playing a strategic role in fostering global cooperation. In global literature, the Blue Economy has been introduced as a novel framework for sustainable economic development that integrates three main pillars: economic growth, environmental protection, and social equity [14].

This concept emphasizes high efficiency, low carbon emissions, and ecological cleanliness, focusing on the optimal use of marine natural resources within ecological limits and seeking to decouple development from environmental degradation. The Blue Economy

refers to resource-based development that aims to enhance human well-being and achieve social justice while simultaneously reducing poverty, environmental risks, and ecological constraints. It is closely aligned with the principles of the Green Economy and traces its origins to the United Nations Conference on Sustainable Development, where the idea of an “ocean economy” or “blue economy” was first articulated as a means to decouple socio-economic growth from environmental harm [15].

Broadly, the Blue Economy highlights the sustainable use of oceans and related resources for economic development while preserving ecosystems. It is defined as an ocean-based economic model that leverages green infrastructure, advanced technology, innovative financial mechanisms, and enabling institutional regulations to achieve ocean and coastal conservation goals while enhancing their contribution to sustainable development. These contributions include improving human well-being, reducing environmental risks, and addressing ecological deficits [16].

The Blue Economy has been explicitly recognized as the core subject of Sustainable Development Goal 14 (SDG 14) — “Life Below Water”, which calls on countries to conserve, sustainably use, and develop marine and ocean resources. Furthermore, it is directly or indirectly linked to at least ten other SDGs out of the seventeen, which are listed below.

Figure 2. Sustainable Development Goals Related to the Blue Economy

In a more comprehensive report by the United Nations, the potential linkage between the Blue Economy, sustainable development, and economic growth has also been recognized within the framework of the UN 2030 Agenda for Sustainable Development. In particular, the concepts of “Blue Growth” and a “Green Economy in a Blue World” are aligned and mutually reinforcing, strengthening the achievement of one of the United Nations Sustainable Development Goals — SDG 14, which focuses on the conservation and sustainable use of oceans and marine resources for sustainable development.

5-1-2. Government Investment in Ports

Government investment refers to the allocation of financial resources by the state for the creation, development, and operation of public infrastructure, which directly or indirectly contributes to economic growth [17]. In the port sector, government investment includes the construction and improvement of port infrastructure, development of terminals,

transportation equipment, and enhancement of logistics systems [1⁸]. Investment in economic infrastructure, particularly ports, has been identified as a key driver of economic growth. According to endogenous growth theory, investment in infrastructure that increases productivity can lead to sustainable economic growth because such investments generate positive externalities that improve the efficiency of the overall economy [1⁹].

Aschauer, in his theory of public infrastructure, also demonstrates that government investment in physical infrastructure — including maritime transport and ports — plays a significant role in boosting productivity and GDP [1⁹]. Ports, as critical nodes in global supply chains and international trade, facilitate the flow of goods, reduce transportation costs, and attract private investment [1⁹]. Therefore, government investment in ports, especially in developing economies, can indirectly stimulate exports, improve the trade balance, and ultimately support economic growth [1⁹].

Economic literature emphasizes the critical role of transportation. Adam Smith (1776) argued that: “Through waterborne transport, a broader market (compared to land-based transport alone) is opened to all types of industries, allowing industries to grow and develop by leveraging navigable rivers and coasts.” Button (2010) notes that classical economists believed transportation has a positive effect on economic development, whereby increased production can be directly linked to improved transport systems. Rosenstein-Rodan (1943) highlighted that investment in transport infrastructure is one of the main avenues for realizing the Big Push theory. A broader perspective by Anderson and Sturmquist claims that all major transitions in European economic systems began with, or were at least accompanied by, changes in transportation and communication infrastructure. Efficient transport lowers movement costs, enabling many activities to access wider markets and benefit from economies of scale. Similarly, Owen (1964) argued that expanding domestic markets through advanced transport services is a prerequisite for national economic development. Moreover, most developed countries are reliant on international trade due to geographic, economic, and historical reasons, making the improvement of trade a necessary condition for growth. From this viewpoint, providing efficient port facilities can contribute significantly to development.

The impact of a port as a critical transport infrastructure on regional economic growth can be analyzed from two perspectives. The first considers the various effects of

a port on the regional economy during different stages, from construction to full operation. The second examines potential interactions between the port and the regional economy from a macro perspective. Specifically, from the first perspective, transport infrastructure can have different effects at different operational stages. Button (2010) categorizes these effects into four types:

- **Primary effect:** The initial additive effect stems from income generated during the construction of facilities and has a multiplicative nature. Its magnitude depends on the proportion of this income absorbed by the local economy.
- **Secondary effect:** Once a transport infrastructure becomes operational, income is injected into the local economy through directly employed staff and activities utilizing the facilities. This income subsequently generates multiplier effects on the regional economy.
- **Tertiary effect:** The third additive effect, often highlighted in development economics, relates to economic activity attracted to the region due to the infrastructure, as well as successive ripple effects resulting from income injection. These regional economic effects can be sustainable.
- **Final effect:** While the tertiary effect is frequently emphasized, an efficient infrastructure can substantially shift the regional production function upward, fundamentally transforming the regional economy. For example, islands in the Caribbean and Mediterranean, whose economies were traditionally based on fishing and agriculture, have fully transitioned to tourism-driven economies following the construction of major airports [۲۲].

In Iran, given its strategic geographical position along international corridors, port investment can act as a driver of economic growth [۲۳]. Ports, as gateways for the import and export of goods and passengers, play a crucial role in developing a sea-based economy. Their efficiency and productivity are directly linked to the quality of equipment and infrastructure. Ports facilitate trade, reduce transport costs, boost exports and imports, and create employment.

Governments typically invest in areas where the private sector shows less inclination due to high costs or low returns. In Iran, the government has played a significant role in port development by financing port infrastructure and providing facilities to the private sector [۲۴]. Such investments not only support international trade but also generate employment, attract foreign investment, and increase foreign exchange earnings [۲۵]. In recent years, the Iranian government has developed multiple plans for port development; for instance, the expansion of Shahid Rajaei Port through public investment and private sector participation represents a key project in this area [۲۶]. However, challenges such as economic sanctions, limited financial resources, and managerial weaknesses have negatively affected the effectiveness of these investments.

2-2. Literature Review

In this section, domestic studies are first reviewed, followed by international research, to provide a comprehensive overview of previous scholarly efforts.

• Domestic Studies

Salarvand et al. (2024) conducted a study titled “Factors Affecting the Components of the Blue Economy and Their Impact on Sustainable Economic Growth” using the ARDL model. They found that key components of the blue economy, including total fisheries production, agricultural value-added, forestry and fisheries, coastal tourism, maritime transport, and trade value-added, have a significant positive impact on Iran’s economic growth. In contrast, government investment in ports did not show a significant effect, likely due to insufficient efficiency or the delayed return on such investments [۲۴].

Bik-Mohammadi, Bazzazan, and Khoshdil (2024), in the article “Conceptual Framework of Marine Advancement,” defined the concept of *marine advancement* across five main dimensions: economic, socio-cultural, environmental, scientific-technological, and security, based on sea-centered governance. The study emphasized the role of this discourse in guiding national policymaking in maritime affairs [۲۵].

Hasanvand and Salarvand (2024), in a research titled “A Review of the Role of the Marine Economy in the Development of Selected Countries,” examined the experiences of leading countries such as Norway, China, the European Union, Australia, the United States, and small island nations. They explored challenges arising from climate change, environmental

pollution, and financial constraints. Their findings indicate that despite serious challenges, significant opportunities exist in the development of marine renewable energy, sustainable fisheries, and marine tourism, which can serve as tools for sustainable economic growth [٢٦].

Khamr and Khodestan (2024), in a study titled “Sea-Oriented Economy of Bandar Abbas Coastal Areas,” demonstrated that a sea-based economy, by diversifying economic activities, can strengthen regional growth and reduce dependency on oil-based economic activities. Additionally, the study highlighted that neglecting the culture of maritime utilization poses a significant barrier to sustainable development [٢٧].

Elmi et al. (2023) investigated the impact of port development on the economic growth of host regions using data from six provinces — Sistan and Baluchestan, Khuzestan, Bushehr, Hormozgan, Gilan, and Mazandaran — for the period 2005–2017. The results showed that port operational capacity, human development, initial economic growth rate, employment, government investment in ports, government current budget, wages, technology, production structure, and urbanization had significant positive effects, whereas transportation costs had a significant negative impact on provincial economic output [٢٨].

Hoseinpour and Tabaeizadeh (2022), in their study “Examining the Causal and Structural Relationship between Port Development and Economic Growth: A Cross-Country Study,” addressed the debate on the diminishing role of ports in economic development. They analyzed the impact of ports on production and economic growth across 122 countries from 2004 to 2021. The study employed Dumitrescu-Hurlin causality tests for heterogeneous panels, along with various panel regression estimations. The liner shipping connectivity index was used as a measure of port development. Results indicate that a bidirectional causal relationship between port development and economic growth cannot be rejected. Regression analyses further revealed that port development continues to have a significant impact on countries’ economic growth [٢٩].

In another study, Hoseinpour (2022) in “Measuring the Spillover Effects of Ports on Economic Growth in Iran: A Spatial Econometric Analysis” measured the spillover effects of ports on economic growth in Iran using spatial econometrics for 23 non-coastal and 7 coastal provinces during 2005–2013. The results

showed that over the nine-year period, port performance positively affected the GDP of coastal provinces; however, spillover effects on non-coastal areas were negative, indicating that an increase in port performance in a specific region tends to reduce GDP in other regions [٣٠].

Saidi and Moradpour (2013) examined the role of ports in the country’s economic development process. They argued that Iranian ports have the potential to shift from a warehouse-based system to an order-based system, in which ports play a more active role in the transportation chain. Additionally, Ehsanifar (2015) investigated the impact of implementing a transit enhancement strategy via Chabahar Port on local development. The study found a significant positive relationship between employment generation, social security, and transit activities [٣١].

• International Studies

A study conducted by Danio et al. (2025) examined the role of the blue economy in strengthening Indonesia’s economic growth, emphasizing the importance of sustainable management of marine resources. The research particularly focused on sectors of the blue economy with high potential for innovation and economic growth, including marine biotechnology, which contributes to the development of new products and technologies. Additionally, environmentally friendly maritime transport helps reduce the ecological impacts of shipping and supports broader sustainability goals. The study underscores the need to integrate sustainable practices across different marine sectors to balance economic growth with environmental conservation [٣٢].

He et al. (2025), in the article “The Role of the Blue Economy and Green Economy in Economic Growth: Evidence from Pakistan,” empirically examined the impact of blue economy and green economy factors on Pakistan’s economic growth during 1990–2019. The findings indicate that both blue economy and green economy components have significant positive effects on Pakistan’s economic growth. These results highlight the importance of leveraging marine resources and renewable capacities in macroeconomic policymaking, providing empirical support for enhancing Pakistan’s economic performance through sustainable development [٣٣].

Khan and Iman (2024), in the article “Systematic Assessment of Blue Economy Potential: Strategies for Developing International Trade in Bangladesh within the Indo-Pacific Region,” analyzed the structural

capacities, key stakeholders, policies, technological advancements, investment trends, and trade in various blue economy sectors in Bangladesh. The study concluded that the blue economy offers substantial potential for economic growth, social progress, and environmental sustainability in the region; however, challenges such as regulatory complexities, inadequate infrastructure, and environmental damages require serious attention and coordinated actions among governments, private sectors, and development organizations [۳۴].

Sarker et al. (2018) investigated the realization of blue economy development in Bangladesh by examining economic value as well as opportunities and challenges faced by the country's marine areas. They collected data and engaged in discussions with stakeholders in an exploratory study aimed at achieving sustainable water-based economic development [۳۵].

Rahman (2017) studied the blue economy in the Bay of Bengal and identified the Bay as a strategic and economic actor for Bangladesh. The research suggests that, through effective regional and oceanic development efforts, the Bay can generate significant economic, security, and environmental benefits for the country [۳۶].

Park and Seo (2016) examined the impact of ports on regional economies in South Korea. Their estimates indicated that the depreciation rate had no significant effect on port performance or GDP; however, physical capital had a significant positive effect. Specifically, a 1% increase in the ratio of physical capital to revenue resulted in a 0.1185% increase in port output [۳۷].

Shan et al. (2014) explored the economic effects of port cities, finding that port activities had a significant positive impact on urban economic growth. A 1% increase in port activity was associated with a 0.065% increase in the city's economic growth [۳۸].

Bottasso et al. (2014) studied the impact of port activities on local development. Their results indicated a direct effect (the impact of a port's performance on the GDP of the same port) of 0.003, meaning that a 10% increase in port performance led to an average 0.03% increase in the port's GDP [۳۹].

3. Research Methodology

In this section, the data analysis approach is presented according to the mixed-method research design, distinguishing between the qualitative and quantitative components. In the first phase, the qualitative section

utilized content analysis with the aid of Atlas.ti software. Using an open coding approach, interviews conducted with experts were analyzed to identify the factors influencing government investment in ports. In the second phase, the fuzzy Delphi method was employed to achieve consensus on the identified factors.

3-1. Fuzzy Delphi Approach

The fuzzy Delphi method, an extension of the classical Delphi in management science, was first proposed by Kaufman and Gupta [۴۰]. The Delphi method is one of the most effective techniques for converging expert opinions. Through a structured, multi-stage process using questionnaires, the method collects expert opinions, provides feedback, and iteratively repeats the process until consensus is reached. This method is particularly valuable for decision-making and achieving consensus on objectives or parameters that are not clearly defined. A key feature of this method is that it provides a flexible framework, addressing many challenges related to lack of precision or clarity. In essence, Delphi is a systematic approach for eliciting expert opinions on a specific topic or question [۴۱].

The fuzzy Delphi method represents a robust, group-based process. It is particularly applied when complete or certain knowledge is unavailable, aiming to achieve group consensus among experts. In this method, experts' opinions are expressed as precise numbers, while they rely on subjective judgment, reflecting the inherent uncertainty of the situation. The probabilistic nature of this uncertainty aligns with fuzzy sets; therefore, it is preferable to collect data in natural language from experts and analyze them using fuzzy sets [۴۲]. Consequently, the integration of the traditional Delphi approach with fuzzy set theory was proposed. In this method, membership functions are used to represent experts' opinions. In practice, the fuzzy Delphi method structures group communication in such a way that participants can challenge the issue at hand. Implementing this structured communication requires feedback on individuals, evaluation of group judgment, opportunities for revising viewpoints, and a degree of anonymity [۴۳]. The main objective of the fuzzy Delphi method is to achieve the most reliable group consensus among experts on a specific topic, which is accomplished through repeated questionnaires and feedback [۴۴]. The implementation stages of this approach are illustrated in Figure 3.

Figure 3. Implementation Algorithm of the Fuzzy Delphi Approach [۴۵]

The main advantage of the Fuzzy Delphi method compared to the traditional Delphi is that it allows for a stage dedicated to summarizing and screening variables within the indicator screening process. Therefore, the steps of the Delphi method are as follows:

- Identifying an appropriate range for fuzzification of verbal expressions
- Fuzzy aggregation of the fuzzified values
- Defuzzification of the values
- Selecting the threshold intensity and screening the criteria

In implementing the Fuzzy Delphi method for screening, it is first necessary to develop a suitable fuzzy scale for fuzzifying respondents' verbal expressions. Methods for developing fuzzy scales can be applied for this purpose, or common fuzzy scales can be used. For example, a triangular fuzzy scale for a five-point Likert scale to indicate the importance of indicators is as follows:

Table 1: Triangular fuzzy numbers equivalent to a 5 degree Likert spectrum

very much	Much	medium	little	very little
(0, 0, 0.25)	(0, 0.25, 0.5)	(0.25, 0.5, 0.75)	(0.5, 0.75, 1)	(0.75, 1, 1)

Since in the fuzzy Delphi method, the diverse characteristics of individuals influence their subjective interpretations of qualitative variables, defining the

range of these qualitative variables ensures that experts respond to the questions with a shared mindset. These variables are defined as triangular fuzzy numbers, as shown in the figure below.

Figure 4: Triangular fuzzy numbers equivalent to a 5 degree Likert spectrum

After selecting or developing an appropriate fuzzy scale, the experts' opinions are collected and recorded in fuzzy form. In the second step, these expert opinions must be aggregated. Various methods have been proposed for the fuzzy aggregation of expert opinions. If each expert's viewpoint is represented as a triangular fuzzy number (β, m, α) , the fuzzy average of n triangular fuzzy numbers is calculated as follows:

$$F_{AVE} = \frac{\sum \beta}{n} \quad \frac{\sum m}{n} \quad \frac{\sum \alpha}{n} \quad (1)$$

Other methods have also been employed for aggregating expert opinions instead of using the fuzzy average. In fact, these aggregation methods are empirical approaches proposed by various researchers [46].

4. Research Findings

4-1. Data Analysis Process Using the Fuzzy Delphi Approach

The influential factors identified through interviews and literature review were presented to the experts in the form of a questionnaire. Based on the defined linguistic variables and the provided options, the responses collected in the questionnaire were analyzed to obtain the fuzzy mean. The following formulas are used to calculate the fuzzy mean.

$$A_i = (a_1^{(i)}, a_2^{(i)}, a_3^{(i)}), i = 1, 2, 3, \dots, n$$

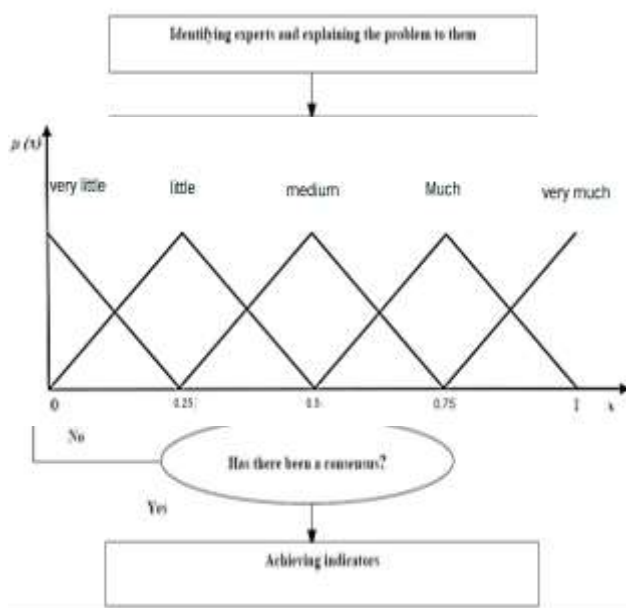
$$A_{ave} = (m_1, m_2, m_3) = \left(\frac{1}{n} \sum_{i=1}^n a_1^{(i)}, \frac{1}{n} \sum_{i=1}^n a_2^{(i)}, \frac{1}{n} \sum_{i=1}^n a_3^{(i)} \right) \quad (2)$$

In this relation, A_i represents the viewpoint of the i -th expert, and A_{ave} represents the mean of the experts' viewpoints.

After calculating the triangular fuzzy mean using the Minkowski formula, the defuzzified crisp numbers for each solution are computed.

Minkowski formula:

$$x = m + \frac{\beta - \alpha}{4} \quad (3)$$



In the fuzzy Delphi approach, since the questionnaire must be distributed to the experts at least twice, after analyzing the first-round questionnaire, it is redistributed for a second round among the experts and analyzed using the above formulas. After calculating the fuzzy mean in the second round, if the difference between the fuzzy means of the two rounds is less than 0.1, it indicates that the experts have reached a consensus on the factors.

For prioritizing the factors, the fuzzy mean from the second round is used, such that any factor with a higher fuzzy mean is assigned a higher priority.

In this context, to identify and determine the factors affecting government investment in ports, the experts on the research topic—whose descriptive statistics are presented in Table 2—were consulted for interviews and subsequently for completing the questionnaire.

Table 2. Frequency of respondents' type of relationship with the component

Type of Respondents' Relationship	Number (persons)
Active in the related component	9
Academic experts	14
Officials of relevant organizations	12
Total	35

Table 3. Frequency of respondents' education level regarding the component

Education Level	Number (persons)
Bachelor's degree	4
Master's degree	15
PhD	16
Total	35

Table 2, 3 illustrates the composition of experts who participated in the fuzzy Delphi process. In total, 35 experts with relevant expertise or experience in the component of government investment in ports were involved. The diversity in their educational background (from bachelor's to doctoral level) and the nature of their connection with the component (executive authorities, academic experts, and field practitioners) reflects a comprehensive approach in selecting the participants. This balanced composition provided the necessary foundation for achieving professional consensus and conducting an in-depth analysis of the factors influencing the component.

Following the semi-structured interviews with the experts and the coding of the obtained results, 10 key factors influencing government investment in ports were identified.

Table 4. Factors Identified as Influencing Government Investment in Ports through Interviews and

Volume of maritime trade and global demand	Government economic policies
Government revenue status	Port security and safety
Port technology and automation	Domestic transportation infrastructure
Attraction of foreign investment	Geographical location of the port
Regional competition	Environmental sustainability

After identifying the factors influencing government investment in ports, a fuzzy Delphi questionnaire was developed to reach theoretical consensus. In line with the rules of the fuzzy Delphi approach, the questionnaires were distributed in two rounds. Tables 5 and 6 present the results of the first-round distribution, while Tables 7 and 8 display the results of the second-round distribution.

Table 5. Results of the First-Round Survey Responses on the Component of Government Investment in Ports

Variables	Very High	High	Medium	Low	Very Low
Volume of maritime trade and global demand	21	10	4	0	0
Government revenue status	22	11	2	0	0
Port technology and automation	20	8	4	3	0
Attraction of foreign investment	20	4	10	1	0
Regional competition	19	10	3	2	1
Government economic policies	22	7	4	2	0
Port security and safety	20	8	4	2	1
Domestic transportation infrastructure	20	10	5	0	0
Geographical location of the port	21	8	3	2	1
Environmental sustainability	20	8	2	3	2

Table 6. Experts' Average Views from the First-Round Survey on the Component

Variables	Defuzzified Average			Defuzzification
	α	m	β	
Volume of maritime trade and global demand	0.621	0.871	0.971	0.646
Government revenue status	0.643	0.893	0.986	0.666

Port technology and automation	0.571	0.821	0.929	0.598
Attraction of foreign investment	0.557	0.807	0.914	0.584
Regional competition	0.571	0.814	0.929	0.600
Government economic policies	0.600	0.850	0.943	0.623
Port security and safety	0.571	0.814	0.921	0.598
Domestic transportation infrastructure	0.607	0.857	0.964	0.634
Geographical location of the port	0.586	0.829	0.929	0.611
Environmental sustainability	0.557	0.793	0.900	0.584

Table 7. Results of the Second-Round Survey Responses

Variables	Very High	High	Medium	Low	Very Low
Volume of maritime trade and global demand	21	11	3	0	0
Government revenue status	22	11	2	0	0
Port technology and automation	20	8	5	2	0
Attraction of foreign investment	20	4	11	0	0
Regional competition	19	10	4	2	0
Government economic policies	22	7	5	1	0
Port security and safety	20	8	4	3	0
Domestic transportation infrastructure	20	10	5	0	0
Geographical location of the port	21	8	3	3	0
Environmental sustainability	20	8	3	3	1

Table 8. Experts' Average Opinions from the Second-Round Survey

Variables	Defuzzified Average			Defuzzification
	α	m	β	
Volume of maritime trade and global demand	0.629	0.879	0.979	0.654
Government revenue status	0.643	0.893	0.986	0.666
Port technology and automation	0.579	0.829	0.936	0.605
Attraction of foreign investment	0.564	0.814	0.921	0.591
Regional competition	0.579	0.829	0.943	0.607
Government economic policies	0.607	0.857	0.950	0.630
Port security and safety	0.571	0.821	0.929	0.598
Domestic transportation infrastructure	0.607	0.857	0.964	0.634
Geographical location of the port	0.586	0.836	0.936	0.611
Environmental sustainability	0.564	0.807	0.914	0.591

Based on the opinions provided in the first round and comparing them with the results of the second round, if the difference between the defuzzified fuzzy means in the two rounds is less than 0.1, the survey process is considered complete. The table below presents the differences between the results of the first and second rounds.

Table 9. Differences in Experts' Opinions between the First and Second Round Surveys

Variables	Defuzzified Fuzzy Mean – Round 2	Defuzzified Fuzzy Mean – Round 1	Difference between Round 1 & 2
Volume of maritime trade and global demand	0.654	0.646	0.007
Government revenue status	0.666	0.666	0.000
Port technology and automation	0.605	0.598	0.007
Attraction of foreign investment	0.591	0.584	0.007
Regional competition	0.607	0.600	0.007
Government economic policies	0.630	0.623	0.007
Port security and safety	0.598	0.598	0.000
Internal transportation infrastructure	0.634	0.634	0.000
Port geographical location	0.611	0.611	0.000
Environmental sustainability	0.591	0.584	0.007

To prioritize the factors affecting the component under study, the defuzzified fuzzy means from the second (final) round were used. Each factor with a higher defuzzified fuzzy mean is assigned a higher priority.

Table 10. Prioritization of Factors Affecting Public Investment in Ports

Influential Factors	Priority
Government Revenue Status	1
Volume of Maritime Trade and Global Demand	2
Internal Transportation Infrastructure	3
Government Economic Policies	4
Port Geographical Location	5
Regional Competition	6
Port Technology and Automation	7
Port Security and Safety	8
Attraction of Foreign Investment	9
Environmental Sustainability	10

The findings from applying the fuzzy Delphi method for the public investment in ports component indicate that 10 main factors, from the experts' perspective, are

influential in shaping, reinforcing, or constraining such investments. The analysis of these priorities shows that government investment in port infrastructure depends not only on the macroeconomic conditions of the country but also on regional, institutional, and even environmental factors.

At the top of the table, the government revenue status is identified as the most critical factor affecting public investment in ports. This highlights that the government's capacity to invest in port infrastructure heavily relies on public financial resources, including revenues from oil, taxes, and exports. In situations where the government faces budget deficits and declining sustainable revenues, the maritime transport and port sectors are deprioritized, and development projects are either halted or left incomplete.

Ranked second is the volume of maritime trade and global demand. Analysis of this factor indicates that governments often decide on investment based on the activity levels of ports and the volume of incoming and outgoing goods. When global demand for Iranian exports decreases or international trade restrictions intensify, the government's incentive to allocate financial resources to port development diminishes.

The third factor, internal transportation infrastructure, reflects the close linkage between port development and the efficiency of domestic transport networks. Poor connectivity of ports to roads, railways, industrial centers, or domestic consumption hubs reduces the effectiveness of any port investment, leading to lower government willingness to allocate funds to such ports.

Government economic policies rank fourth. Governments that strategically prioritize the development of a maritime-based economy allocate more investment to ports. However, in situations of policy instability, frequent legal changes, lack of medium- and long-term planning, and poor coordination among economic institutions, the level of investment declines, and port projects often become victims of inconsistent decision-making.

Fifth is the geographical location of the port, emphasizing that ports situated in strategic positions—close to regional markets or international corridors—

receive more government investment. For example, Chabahar Port, located along the East-West corridor and capable of competing with southern Pakistani ports, enjoys higher priority.

Regional competition ranks sixth, highlighting competitive pressures from neighboring countries' ports such as those in the UAE, Oman, and Turkey, which, through substantial investment and advanced technology utilization, capture a larger share of regional maritime transport. This factor indicates that the government must increase investment in key ports to maintain its regional position and prevent monopoly by competitors.

The seventh factor, port technology and automation, points out that ports with lower technological levels typically require government support and investment for upgrades. While private sector participation in advanced technologies may face hesitations, the government's role in modernizing hardware and software infrastructure becomes more pronounced.

Port security and safety is ranked eighth. Ports lacking proper safety equipment, crisis management, maritime incident response, cargo and passenger security, and monitoring systems require governmental interventions to improve safety indicators. Poor security in ports can reduce the trust of traders and shipping companies, in addition to causing financial losses and public dissatisfaction.

Foreign investment attraction ranks ninth, showing that while this factor is complementary, it strengthens public investment in ports. Although it has a lower rank, in contexts of sanctions and restrictions on technology transfer and financial resources, the government's role in creating an enabling environment for international investment becomes increasingly important.

Finally, environmental sustainability ranks tenth. This relatively lower rank indicates that environmental concerns are not yet adequately considered in government financial decision-making for ports. While sustainable port development requires attention to environmental impacts, project assessments, and adherence to international standards, this component

still appears to be distant from the primary priorities of public investment in Iran's ports.

5. Conclusion

This study aimed to identify and prioritize the factors influencing public investment in ports in Iran. Using expert surveys and fuzzy analysis, the study identified and ranked the factors affecting public investment in port infrastructure.

The results of applying the fuzzy Delphi method indicate that government investment in ports is a multidimensional process influenced by a diverse range of economic, institutional, technological, regional, and environmental factors. The prioritization of these factors revealed that government revenue status ranks first, having the greatest impact on decisions regarding investment in port infrastructure. This finding highlights that, in an economy dependent on oil and tax revenues, financial stability and the government's ability to secure sustainable budgetary resources are prerequisites for any port investment. In other words, macroeconomic policies and the government's financial situation remain the main determinants of resource allocation to maritime transport, and without budgetary reforms and diversification of financial resources, sustainable port development cannot be expected.

Next in importance is the volume of maritime trade and global demand. This indicates that public investment is not only reliant on domestic capacities but also dependent on international trade conditions and the position of ports within the global supply chain. When exports decline or international trade restrictions or sanctions increase, the government's motivation and ability to allocate financial resources decrease. Conversely, when ports experience commercial growth, the pressure to upgrade capacities and expand infrastructure rises, making government investment more justifiable.

Another key finding is the ranking of domestic transportation infrastructure as the third most important factor. This underscores that ports alone cannot play a central role in development unless they are connected to efficient rail, road, and industrial networks. Weak

hinterland connectivity limits the return on port investments and reduces their economic and strategic justification from the government's perspective. Therefore, port development must proceed in tandem with improvements in domestic transport networks.

The fourth factor, government economic policies, also demonstrated that the degree of commitment and consistency in macroeconomic policymaking significantly shapes investment patterns. Governments that prioritize a maritime-based economy and implement coherent medium- and long-term plans have achieved more effective investments in ports. Conversely, frequent legal changes, institutional coordination failures, and policy instability have led to failed or halted investments.

Geographical and regional factors, such as port location and regional competition (ranked fifth and sixth), indicate that governments are strongly influenced by the geopolitical and commercial positioning of their ports. Ports like Chabahar, due to strategic location and competition with neighboring countries' ports, have received higher investment priority. These findings show that, in addition to domestic requirements, governments must respond to regional competitive pressures by increasing investment in key ports to secure their international standing.

From a technological perspective, port technology and automation (seventh) emerged as important. This shows that Iranian ports must modernize hardware and software to keep pace with global trends. With the private sector facing limitations and risks in this domain, the government's role in financing and guiding investments becomes more prominent, particularly in areas like automation, digitalization, and advanced equipment development.

Port safety and security (eighth) and foreign investment attraction (ninth) were also identified. These findings emphasize that the government should not only enhance safety indicators and build trust in ports but also provide the necessary environment for foreign investors. While foreign investment currently ranks lower, in the long term it can complement public investments and reduce financial pressure on the government.

Finally, environmental sustainability ranks tenth, indicating a gap between current policymaking and the requirements of sustainable development. Although environmental concerns are not yet a top government priority, neglecting this factor can have long-term negative consequences for ports and the blue economy. Integrating environmental considerations into port investment decisions is therefore essential.

Overall, the study shows that public investment in ports is not a simple financial decision but a complex process influenced by an intertwined set of factors. Macroeconomic conditions and government revenues, as well as geographical location, regional competition, technology levels, and environmental considerations, all directly or indirectly affect the scale and direction of investment. To achieve sustainable development in Iran's ports, a comprehensive, cross-sectoral approach is necessary, integrating economic policies, transport infrastructure, technological requirements, and environmental standards simultaneously.

From a practical perspective, this research provides guidance for policymakers, economic managers, and maritime transport planners. By identifying key factors and considering the prioritized list, they can design and implement more efficient and effective port investments. Attention to these factors can not only ensure the development of port infrastructure but also enhance Iran's position in the blue economy and global value chains.

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