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A System Dynamics Modeling Approach to Influences on Iran's Oil Export Growth

Fatemeh Anghaei *[1], Mohammad Rabiei [2]

[1] Ph.D. in Industrial Engineering with a specialization in Large-Scale Systems Analysis, University of Eyvanekey, Semnan, Iran

Fatemeh.anghaei@eyc.ac.ir

[2] Ph.D. in Information Technology in Industrial Engineering, Assistant Professor and Faculty Member of the Electrical and Computer Engineering Department, University of Eyvanekey, Semnan, Iran;

Mohammad.rabiei@uniud.it

* Corresponding author: Fatemeh Anghaei

Abstract

The Persian Gulf serves as a critical global oil transportation route, connecting the Middle East with other continents, underscoring its pivotal role in ensuring global energy supply. Considering the recent regional tensions and sanctions, this research using a dynamic systems method, deals with a dynamic model to investigate the dynamics and security of maritime transport in the Persian Gulf region. It further explores how the geopolitical positioning of the Persian Gulf influences the attraction of foreign investment and the development of Iran's oil exports. In the course of this research, equations pertinent to the model have been formulated within the Vensim software environment. Extensive simulations were conducted to investigate various scenarios and implement policies as part of the model scenarios. And finally, the recommended solutions include: strengthening regional and international cooperation, diversifying transportation routes, encouraging foreign investment, utilizing and developing innovative security technologies, enhancing training and awareness of security forces, and developing a strong security system to enhance the management of oil transportation security, address security challenges and sanctions, attract foreign investment, and consequently strengthen Iran's oil exports.

Keywords System dynamics, Maritime transportation security, Geopolitics of the Persian Gulf, Foreign investment, Expansion of Iran's oil exports.

1. Introduction

Security, in the sense safeguarding society, its core values, and its institutions against internal and external threats, is a vital concept that directly impacts the survival of governments, civic systems, and the way of life of individuals in the community and endangers their existence. It is under the umbrella of security that the expansion of bilateral and multilateral economic and trade relations between countries in international economic organizations increases mutual interdependence, leading to national security and preventing conflicts and violence among economically interdependent nations."(Karimi, 1389).

Trade serves as the primary catalyst for economic growth, and trade and economic growth have a bilateral relationship, meaning that in addition to the role of trade in economic activity, economic growth itself leads to the development of trade. It goes without saying that without transportation, trade cannot take place, and having an appropriate international transportation at a reasonable cost is an essential element for growth and development. In this context, maritime transport constitutes the most important form of international transportation. The significance of the role of maritime transport in world trade can be understood by the fact that more than 19% of global industrial transportation is carried out by sea. Transport by sea is the most cost-effective form of transportation in terms of ton-miles. economic advantage becomes even more pronounced as distances increase".

Given Iran's location in the volatile Middle East, it is imperative to harness its geopolitical and geoeconomic potential effectively and optimize the utilization of its abundant oil and natural gas resources. This includes establishing energy transit routes to vital consumption centers, notably the Indian subcontinent, China, the European Union, and bolstering relationships with neighboring countries, particularly energy-rich nations in landlocked Central Asia. This strategy is aimed at overcoming the signs of insecurity, linking the destinies of these regions to Iran's strategic transit position, upgrading the depth of North's geopolitical connectivity

to the South's (the Persian Gulf) geopolitical depth. .Furthermore, it involves forging regional alliances and strategic partnerships in the energy sector to counter the constraints imposed by sanctions and Western political pressures, which aim to isolate Iran. In doing so, Iran seeks to not only enhance its national security and interests but also elevate its geopolitical and geoeconomic significance at the regional and even international levels.

2. Statement of the problem

Maritime transportation security plays a pivotal role in influencing foreign investment and the increase in Iran's oil production and exports. .As one of the member countries of the Organization of the Petroleum Exporting Countries (OPEC), Iran relies heavily on revenue generated from oil production and exports.

The security of maritime transportation has a direct and crucial impact on increasing foreign investment and enhancing Iran's oil production and exports. .Given Iran's substantial reliance on maritime transport for delivering oil to global markets, ensuring the security of this mode of transportation is of paramount importance. Below, we examine the primary impacts of maritime transportation security on these two factors:

1. Attracting foreign investment: Foreign investors require assurance of maritime transportation security when considering investments in the oil and gas industry. The existence of a secure and stable maritime transportation chain enhances investors' confidence in Iran and encourages them to invest in this industry. .These investments can facilitate technological advancements, infrastructure development, and bolster Iran's oil production and export capabilities .
2. Increasing oil production and exports: Maritime transportation security plays a vital role in the growth of oil production and exports. By creating a secure and stable platform for oil transportation, Iran can increase its production and enhance its oil exports to global markets. This, in turn, can result in increased oil revenue, economic growth, and the creation of job opportunities in the oil industry and related sectors".

In general, maritime transportation security can result in increased attraction of foreign investment, increased oil production, expanded exports,and improved national economy. Therefore, paying attention to maritime transportation security and establishing a sustainable and reliable transportation chain for Iran's oil is of paramount importance.

3. Theoretical framework and research background

3.1. Theoretical background

- **Oil Exports and the Safety of Oil Product Transportation**

Reducing human and financial damages, enhancing the reliability and safety of transportation systems for hazardous materials and oil products represents a primary objective in the contemporary oil industry. , Within this category of oil products, including natural gas, gasoline, kerosene, and others, the significant portion transportation risks by the transportation system is borne by the National Oil Product Distribution Company, and neglecting this aspect can have potentially dangerous consequences for the environment and human beings.

There are two methods for oil exports, one is delivery at the origin while the other is delivery at the destination. When the importing country receives the oil at the origin, the oil tanker is dispatched to Iranian ports, and all expenses including transportation, insurance, and ancillary costs tare the responsibility of the recipient. Under this method, once the oil or gas condensates are delivered, the originating country is relieved of any further obligations,, and the transaction is considered complete.

The other type of oil export is delivery at the destination, and some countries stipulate that the oil must be received at the ports of the destination country.

Iran has extensive experience in destination delivery. Particularly during the period of sanctions against Iran. when other nations were unable to send their vessels to Iranian ports and transport Iranian oil, the destination delivery method was employed. In this approach, all responsibilities, including those associated with risks from the moment the oil enters the tanker until the unloading process at the destination country's ports is completed, rest with the exporting country. Under this method, all incurred expenses are calculated and received based on the prevailing oil prices.

The geopolitics of the Persian Gulf is highly significant due to the critical geographical position of the Gulf and its rich oil and gas resources. The Persian Gulf region is one of the world's most important oil sources, with countries such as Iran, Saudi Arabia, Iraq, Qatar, and the United Arab Emirates situated in this area. ,Consequently, ensuring security, safeguarding national interests, and maintaining the political and economic stability of these countries in the Persian Gulf is crucial for these nations.

When analyzing the geopolitics of the Persian Gulf, a multitude of factors come into play. These include the

influence of external forces, regional conflicts, control of natural resources, political and economic sway, the role of military forces, safeguarding the security of the Strait of Hormuz, government and international policies, the impact of sanctions, and adherence to international laws.

As a result, the geopolitics of the Persian Gulf focuses on examining the dynamics, interactions, and power relations in the Persian Gulf region and its impact on the security, policies, and economy of the region.

Security in the Persian Gulf stands as a primary objective for Iran, a strategically positioned nation in the region. Given its extensive coastline and substantial borders along the Persian Gulf, Iran places a particular emphasis on ensuring security. Here are some key aspects of Iran's efforts to secure the Persian Gulf:

- Maritime Security: Iran is dedicated to preserving maritime security in the Persian Gulf and the Strait of Hormuz, ensuring the free passage of ships and vessels while preventing threats like drug trafficking and maritime terrorism.
- Traffic Management: Iran employs maritime traffic management systems to continuously monitor ship movements in the Persian Gulf.
- Military Strengthening: Iran has bolstered its military forces in the Persian Gulf, deploying naval, air, and ground units to maintain regional security.
- Regional Cooperation: Iran actively cooperates with neighboring Persian Gulf states and other regional countries to enhance security .
- Defense Capability Development: Iran focuses on increasing self-sufficiency by enhancing its defense capabilities to secure the Persian Gulf .
- Preserving Independence and Integrity: Iran's primary goal in securing the Persian Gulf is to safeguard the independence and integrity of the region. The security of the Persian Gulf is vital for Iran's commercial, economic, and political interests and defense strength to achieve this objective.
- Global Trade and Persian Gulf Security: Maritime transportation security in the Persian Gulf is a critical concern for global trade and Iran's oil industry. The Persian Gulf serves as a pivotal route for global oil transportation, facilitating trade between various countries, including China. Therefore, maintaining security in this region holds significant importance (Aizhu & Lawler, 2022).

Oil transportation in the Persian Gulf has a significant impact on the global oil market. The Persian Gulf is recognized as one of the major sources of oil production and exports worldwide, constituting a considerable percentage of global oil trade. Consequently, changes in oil transportation and any security threats or disruptions in this region can have a significant impact on the global oil market.

The cessation or limitation of oil transportation in the Persian Gulf, whether due to regional tensions, sanctions, security concerns, or technical and infrastructural issues, can result in a reduction of oil supply in the global market. This, in turn, has the potential to lead to increased oil prices and substantial fluctuations in the global oil market.

Moreover, as a key route for oil exports from the Middle East to other regions of the world, any disruptions or delays in oil transportation in the Persian Gulf may create fluctuations in global oil supply and demand. This can have implications for oil prices and energy supply for countries and companies reliant on oil.

Oil transportation in the Persian Gulf has a direct impact on the movement of oil tankers and the overall oil transport process.. Any delays, issues, or security threats in oil transportation can lead to reduced oil dispatch and a decrease in the ability to meet the global market demands.

Therefore, oil transportation in the Persian Gulf has significant implications for the global oil market and prices, supply and demand, energy supply, and energy security. Factors such as regional tensions, sanctions, security threats, and infrastructural issues can become significant roles in shaping the global oil market. (Gholami, R., Gholami, S., & Abdekhodaee, A., 2019)

- **Ensuring security in the Persian Gulf**

Ensuring security in the Persian Gulf by Iran can have diverse impacts on the development of oil exports. The Persian Gulf is one of the key routes for global oil exports, and a significant percentage of global oil production is located in this region. Below, I examine some of the impacts of Persian Gulf security by Iran on the development of oil exports:

-Maintaining oil trade security: If security in the Persian Gulf is preserved, the conditions for oil exports from this region to other countries will improve. Oil transportation through this region should proceed without tensions and security threats to ensure sustainable oil trade.

-International confidence: Preserving security in the Persian Gulf by Iran can foster international confidence

in oil exports from this region. International trust can attract investment and enhance commercial cooperation.

-Oil price stability: The security of the Persian Gulf has a direct impact on oil prices. If tensions and security threats in this region decrease, oil prices become more stable, and unforeseen risks in the global market are reduced.

-International relations: Maintaining security in the Persian Gulf by Iran can have an influential impact on international relations. This can lead to the strengthening of economic and political relationships with other countries, which can also contribute to the development of oil exports.

- Investment in the oil industry: Ensuring security in the Persian Gulf by Iran can attract investors to the oil industry. This can aid in infrastructure development, improved oil extraction and production technologies, increased production capacity, and consequently, the development of oil exports. (Gholami, R., Gholami, S., & Abdekhodaee, A., 2019)

In recent years, the significance of energy security has drawn a lot of attention. Politicians are continuously concerned about the rising need for oil on a worldwide scale, the safety issue, the cost of energy supply and transmission, and the ability to supply energy from risky and unreliable regions of the world. For developing economies like China, this issue is crucial. (Karimimakhsous, Nazanin , 2023)

Energy security and its future for China have become a significant and at the same time concerning issue due to the country's recent economic growth, an accelerating increase in the country's energy demand, and the limited and insufficient domestic energy resources. Because any disruption in the energy flow might seriously impede China's economic progress and undermine the continuation of political and economic dominance.

- **The demand of China for oil from the Persian Gulf and Iran.**

Iran is crucial in this regard as the world's second-largest owner of gas resources and third-largest owner of oil resources. China may benefit from the country's dominance over the Strait of Hormuz and unique geographic location in ensuring energy security. Additionally, the long-term international sanctions have practically eliminated the possibility of the presence of Western oil companies in the country's oil industry, while China's participation has been given more room to operate. Iran actually depends on China for the sale of its resources, and China sees Iran as an unmissable chance to assure its energy security. (Karimimakhsous, Nazanin , 2023)

China, as one of Iran's largest oil customers and a country seeking to secure energy resources for its own needs, plays a significant role in ensuring maritime security in the Persian Gulf. Through investments in the ports and port infrastructures of this region, China has sought to guarantee the security of oil and other cargo transportation in the Persian Gulf. For instance, Chinese companies have invested in projects involving the construction and development of ports and the provision of navigational security in the Persian Gulf.

In 2018, China surpassed Russia to become Iran's top commercial partner. Despite Iran's heavy dependence on China as its primary trade partner, oil exports have played a key role in maintaining a favorable trade balance for the country (Conduit, Akbarzade, 2019).

Regarding China's investment in Iran's oil industry, the country, as a major industrial power with high energy demands, is keen on securing oil resources. China has long acted as one of Iran's largest oil customers and has strengthened its direct investments and technical cooperation in Iran's oil industry through long-term oil contracts..Notably, companies such as China National Petroleum Corporation (CNPC) and Sinopec, two of the largest Chinese oil companies, have made significant investments in various oil projects in Iran. These investments encompass activities such as oil and gas extraction, oil field development, refinery operations, and the development of oil industry infrastructure in Iran.

However, the connection between China's investment in Iran's oil and maritime security in the Persian Gulf should be considered as a separate issue. While China's investment in Iran's oil may not have a direct short- term impact on maritime security, in the long term, it can strengthen economic and commercial relations between the two countries and contribute to ensuring maritime security in the Persian Gulf.

It is paramount that all nations involved in the region actively consider cooperation and interaction for the preservation of maritime security in the Persian Gulf. Collaborative regional and international programs can promote economic and political interactions in the area while strengthening maritime security. Additionally, transparency and adherence to international standards in maritime security are of utmost importance. China stands as one of Iran's major oil customers, and the oil trade between the two countries holds substantial

importance.Given the economic sanctions against Iran, China has played a significant role in increasing Iran's oil exports as one of the countries that continue to trade with Iran. This is due to the existing oil agreements between the two countries and China's dependence on energy resources to meet its own needs.

Therefore, as one of Iran's main oil customers, China is striving to maintain and increase Iran's oil exports. This was particularly evident during the period of international sanctions imposed by the United States and some European countries, which China disregarded, increasing Iran's oil exports and resisting the sanctions.

On the other hand, some of Iran's oil resources are owned by Chinese companies, which has led China to have a commercial approach to Iran's oil. These companies have invested in oil projects in Iran and benefit from the oil produced in these projects.

- **The main impacts of oil transportation in the Persian Gulf.**

The principal impacts of oil transportationin the Persian Gulf are as follows:

- Impact on oil supply: The Persian Gulf, as one of the main centers of global oil production, affects global oil supply. .Any alterations in oil movements within this region can result in an increase or decrease in the global oil supply
- Impact on oil prices: The supply of oil from the Persian Gulf is considered one of the main determinants of oil prices in the global market. Any changes in oil movements and related issues can lead to fluctuations in oil prices and significant impacts on the global oil market.
- Impact on energy supply: The Persian Gulf's role as a significant source of global oil production makes it a key determinant of oil prices in the global market. If oil movements in the Persian Gulf are halted or restricted, energy supply for countries may be affected, and their energy needs may be compromised.
- Impact on energy security: Due to the high volume of oil tanker traffic and oil transportation, the Persian Gulf is considered a vital route for global energy transportation. Any security threats in this region can jeopardize global energy supply security and cause fluctuations in the global oil market.
- Impact on economic growth: In oil-producing countries in the Persian Gulf, oil is one of the main factors driving economic growth. Movements in oil transportation and changes in supply and demand can have significant impacts on the economic growth of these countries.

Overall, changes in oil movements in the Persian Gulf can have significant impacts on the global oil market, prices, energy supply, and energy security and consequently have a global impact.

3.2. Experimental background

In this section, we will explore articles that have focused on the dynamics and security of maritime transportation in the Persian Gulf region, as well as the impact of the geopolitical position of the Persian Gulf on attracting foreign investment and the development of Iran's oil exports.

Notteboom & Rodrigue. (2018). The book "Ports and Networks: Strategies, Operations and Perspectives" delves into the examination of strategies, operations, and perspectives related to ports and transportation networks. This comprehensive book provides an analysis of management and operational issues and challenges in the field of ports and transportation networks.

Overall, the content of this book includes the following:

-Port strategies: Reviewing the managerial strategies of ports and their impact on the development and competitiveness of ports compared to other global ports and ceremonies.

-Port operations: Investigating operational issues in ports, including the physical organization of ports, loading and unloading facilities, cargo handling, and intra-port transportation.

-Transportation networks: Analyzing multimodal transportation networks and their connection to ports, development strategies for transportation networks, and the role of ports in these networks.

-Challenges and future perspectives: Examining current and future challenges in the field of ports and transportation networks, including global trade changes, technology, environmental factors, and climate changes.

This book serves as a reliable and comprehensive resource in the field of port and transportation network management, facilitating study and consultation for industry enthusiasts.

Jun U. Shepard & Lincoln F. Pratson. (2020). They stated that Persian Gulf Countries (PGC) are collectively the world’s largest exporter of fuels. The vast majority of these fuels are shipped via maritime routes and require transit through the Strait of Hormuz. As such, the Strait of Hormuz is considered the most important chokepoint for the global energy economy. This study examines the effect of maritime piracy through this chokepoint on exports of specific fuels from each PGC. We classify piracy as a soft restriction in the Strait; the effect of a such a restriction depends on the risk sensitivities of the trading countries and the type of fuel being traded. We

use a two-stage least squares regression to first estimate the impact of piracy attacks on tanker traffic through the Strait, and then estimate the risk that the restriction would pose to energy exports. The first stage of the analysis reveals that tanker transit declines two years after piracy attacks.

Seaport, C & Cariou, P. (2021). They examine the impact of globalization and internationalization processes on the maritime transportation industry and regional sustainability. The analysis of these impacts can include the examination of changes in trade patterns, the role of transportation in the development of regions, the environmental impacts of maritime transportation, and the associated social and economic issues.

Karimimakhsous, Nazanin. (2023). In a research titled "IRAN'S ROLE IN CHINA'S ENERGY SUPPLY She expressed "China's influence in the Middle East has drawn increased attention recently. The Persian Gulf's strategic importance is mostly due to the region's massive oil and gas resources. As the second largest economy in the world, China is actively pursuing its economic, political, and geopolitical interests in the area. Iran has huge oil and gas reserves but cannot sell them because of severe international sanctions. However, despite additional restrictions, China continues to be Iran's main oil customer and commercial partner. The purpose of this article is to examine the importance of Iran's energy resources in providing China's energy security. This article analyses this position by examining the relations between the two countries after China's industrial revolution.

Satnam Singh Saini & et al. (2023). They stated that we reflect on the significance of our research in the broader context of intelligent transportation systems and their potential impact on society. The findings of this study underscore the transformative power of intelligent transportation systems (ITS) in revolutionizing the safety and security landscape of transportation networks. Through a meticulous examination of data, real-world scenarios, and comprehensive analysis, we have unveiled compelling evidence of the substantial benefits conferred by the integration of intelligent features in to transportation in frastructure. Summary of Findings Our research has brought to light aseries of compelling findings: Enhanced Safety and SecurityOne of the fundamental pillars of our investigation was the examination of how ITS contributes to safety and security within the transportation ecosystem.

4. Methodology

The dynamic system is a modeling approach used to examine and analyze the complexities of dynamic systems over time. Here, I will discuss how this method is used to investigate the impact of maritime transportation security on attracting foreign investment and increasing Iran's oil exports:

1) Phase One: Problem Definition
   Objective: Identifying key factors and setting modeling objectives.
   Result: Identifying why foreign investment has decreased and how this issue relates to oil exports.
2) Phase Two: Conceptual Model Construction
   Objective: Creating a flowchart that illustrates all the factors, flows, and feedback loops.
   Result: An initial map of how maritime transportation security affects foreign investment attraction and the increase in Iran's oil exports.
3) Phase Three: Model Formulation
   Objective: Transforming the conceptual model into a mathematical model using differential equations.
   Result: An executable model capable of simulation and prediction.
4) Phase Four: Testing and Parameter Determination
   Objective: Ensuring the model's accuracy using real-world data.
   Result: Model adjustments and improvements for greater precision.
5) Phase Five: Simulation
   Objective: Utilizing the model to simulate various scenarios for increasing foreign investment in Iran's oil industry.
   Result: Insights and forecasts regarding the impacts of maritime transportation security on attracting foreign investment and increasing Iran's oil exports.
6) Phase Six: Analysis and Result Extraction
   Objective: Examining simulation results and extracting useful insights.
   Result: Recommendations and strategies for addressing the negative impacts of sanctions or leveraging opportunities more effectively. (Sterman, 2000)

Using this process, the impacts of maritime transportation security on attracting foreign investment and increasing Iran's oil exports can be scientifically and systematically examined. This approach enables decision-makers to take a long-term perspective on the issue and devise better strategies to address challenges and leverage opportunities.

5. Research Methodology

The current research is practical and aims to discover new knowledge that directly impacts the targeted process. Also, the current research is considered a "cross-sectional" type of research since it examines data related to a period of time. The method used in this research is an analytical survey. In order to collect a combination of information, library and research methods have been used. The library method will be used to study the literature of the subject and review the research history. Then, with other methods, information and surveys are collected, and finally, the collected data is subsequently subjected to thorough validation and verification using specialized software tools such as Vensim.

5.1. Variables

In this research, the variables can be categorized into three main types:

- Accumulation Variables (3): These variables represent quantities that accumulate over time, capturing the build-up or stock of certain elements within the system.
- Flow Variables (4): These variables represent the rates of change or flows of specific elements within the system, indicating how quantities move or change over time.
- Auxiliary Variables (11): These variables serve as additional factors or parameters that influence the dynamics of the system but do not fit directly into the accumulation or flow categories.

The quantification and simulation of these variables have been carried out using Vensim software, enabling a comprehensive analysis of their interplay within the system.

6. Data analysis

6.1. A causal loop diagram

In the field of system dynamics, we use various graphical tools to understand the structure of the system, such as causal-loop diagrams and stock-flow diagrams (Sterman, 2000). Causal-loop diagrams are an important tool for illustrating the feedback structure of systems. With a long history in scientific work and increasing promotion in the business world, these diagrams are considered the best choice in the following cases:

-Rapid access to a hypothesis about the causes of dynamics -Deduction and understanding of individuals' or groups' mental models

-Connecting important feedback that you believe is influential in the occurrence of the problem (Sterman, 2000)

The process of Drawing loops and conceptual connections between variables is one of the most important stages in building dynamic system models. In this section, based on what has been described earlier, we present the causal loop diagrams .illustrating the dynamics of the oil export system in Figure 1.

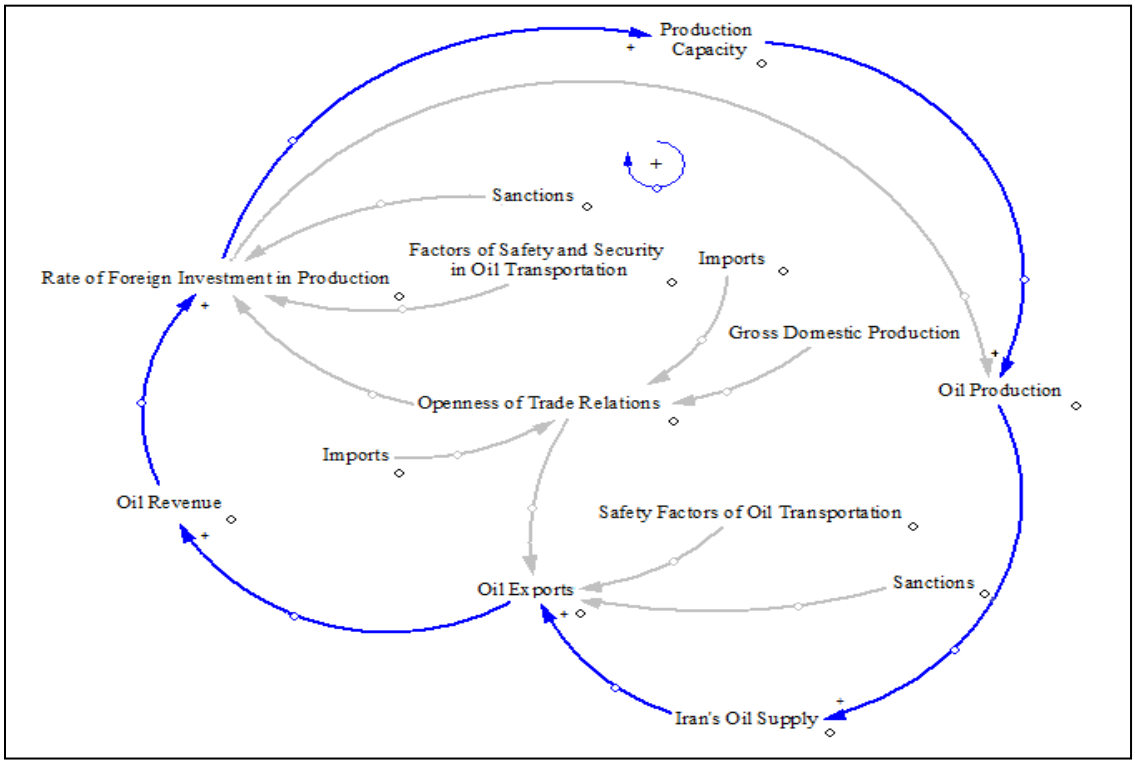


Figure 1: Causal diagram illustrating the impact of maritime transportation security and the geopolitical influence of the Persian Gulf on the increase in foreign investment and the development of oil exports in Iran.

With the increase in oil exports, the revenues derived from exports will increase, leading to an enhanced motivation for foreign investment in the country. Given that the production trend in the oil industry requires investment and the use of modern equipment, the oil industry in Iran will also follow an increased production and extraction capacity as a result of increased foreign investment. This situation is depicted in Figure 1.

Maritime transportation security plays a vital role in the growth of oil production and exports. Foreign investors seeking to invest in Iran's oil industry require assurance of maritime transportation security. By establishing a secure and stable platform for oil transportation, Iran can increase its production and boost its oil exports to global markets. The existence of a secure and stable maritime transportation chain enhances investors' confidence in Iran and encourages them to invest in the industry. These investments can improve technologies, infrastructures, production capacity, and enhance Iran's oil exports.

6.2. Stock and Flow diagram

- **Description of stock and flow diagram**

In the previous section, the causal structure of the model was explained to provide a deep understanding of the system and the reinforcing and control loops within it. The causal diagram is a very useful tool for illustrating the interdependencies between variables and depicting the feedback processes of the system. By utilizing it, one can draw a mental model of the system. In this section, the state-flow model of the system, which represents the system's status and can be mathematically formulated using equations, will be explained. The state-flow model can serve as the basis for decision-making. The state-flow diagram used in this study is presented in Figure 2.

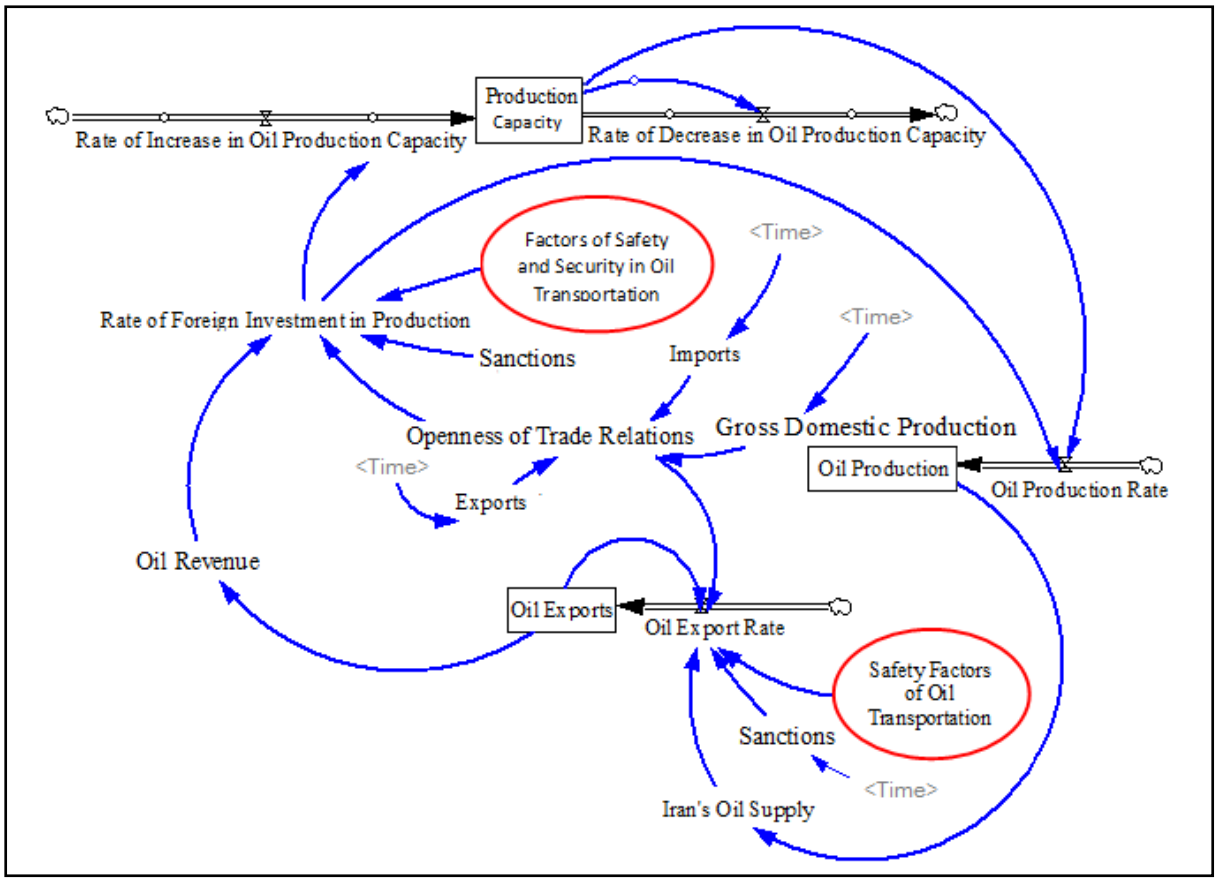


Figure 2: State-flow diagram depicting the influence of maritime transportation security and the geopolitical influence of the Persian Gulf on the increase in foreign investment and the development of oil exports in Iran.

As shown in Figure 2, the stock-flow diagram of this study consists of 3 stock variables, 4 flow variables, and 11 auxiliary variables and has been quantified and simulated using the Vensim software. Equations 1 to 3 represent the relationships used in the stock-flow model.

1) Oil Production = ∫ Oil Production Rate
2) Oil Exports = ∫ Oil Exports Rate
3) Oil Production Capacity = ∫ Oil Production Increase Rate - Oil Production Decrease Rate

Given the importance of increasing oil exports, this question has been a focus from the beginning of this research: What is the impact of maritime transportation security and the geopolitical position of the Persian Gulf on the increase in foreign investment and the development of oil exports in Iran? To address this question, we have meticulously constructed and evaluated a system dynamics model, incorporating data spanning from 2005 to 2022.

7. Validation of the model

7.1. Model test

Model testing is a crucial step in system dynamics modeling. Before utilizing the model for analysis, it is necessary to assess its validity through one or more methods .

7.2. Structure validation test

The purpose of the structure validation test is to determine the conformity of the model's structure with the relevant descriptive knowledge of the system and to examine the logical consistency of the decision rules in shaping the behavior of the variables, as well as the correctness of the model's equation structure. Since in this study, the equations related to the model have been formulated in the Vensim software environment, the correctness of the model's equation structure has been confirmed by the software. This is illustrated in Figure 3.

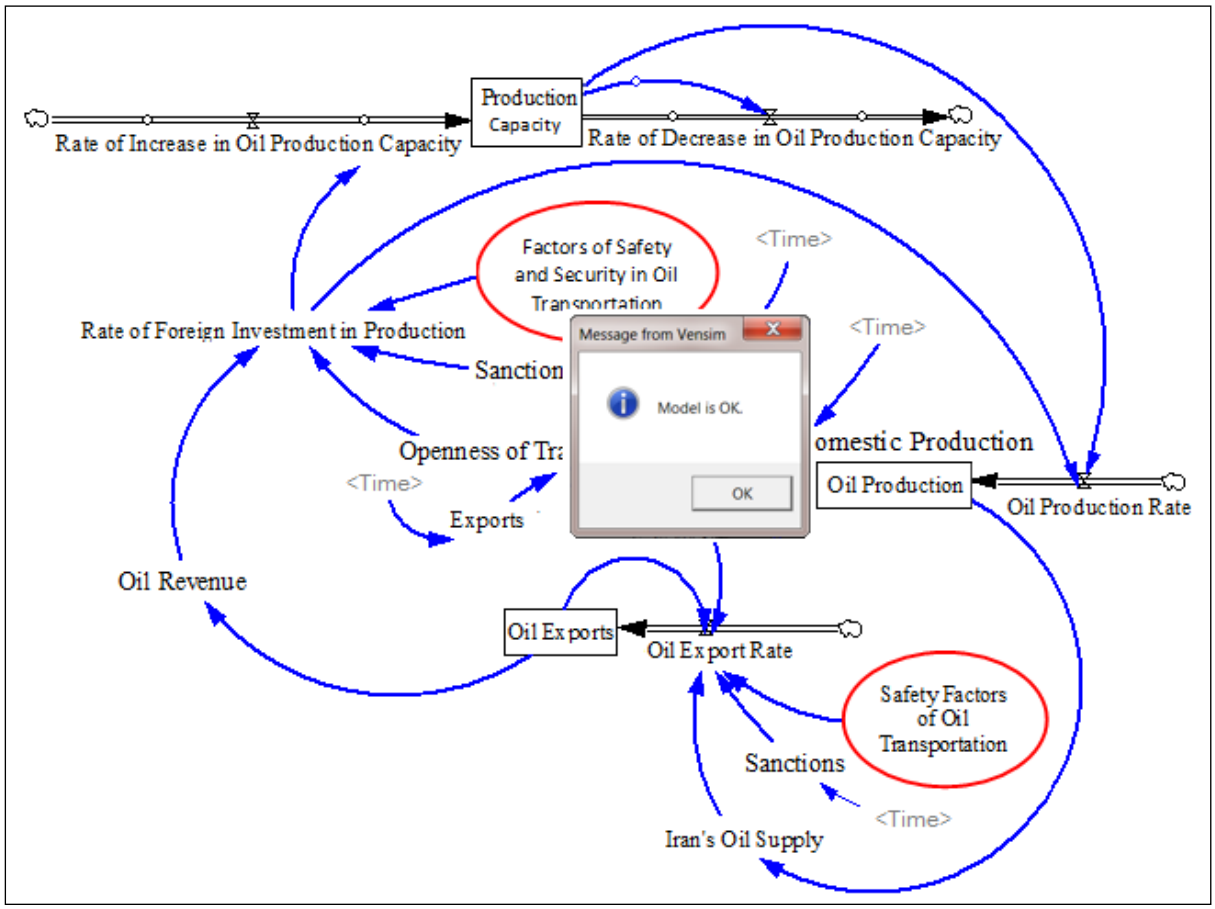
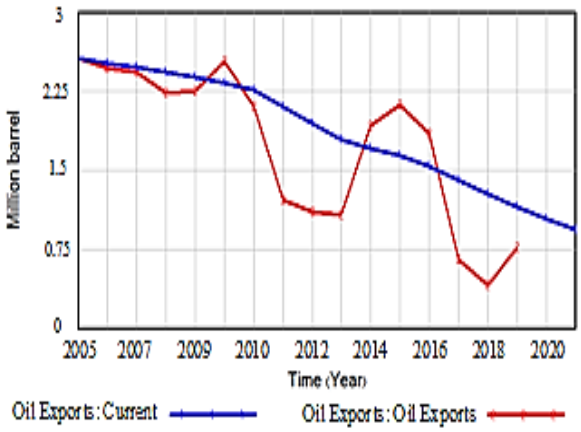


Figure 3: Model structure evaluation test

7.3. Behavioral Replication Test

One of the most critical tests available is behavioral replication, which involves comparing the model's results with historical data. This test assesses the model's ability to replicate historical data accurately. In Figure 4, the model's outputs were compared to real historical data. When the model's results closely match the historical data, it instills confidence in the model's accuracy and validates its utility for evaluation and future predictions.

As shown in Figure 4, the values obtained from the simulation of the Iran oil export system model have been compared with actual values of some key variables. In fact, the "Current" scenario represents the current state resulting from the simulation (blue lines), and the red lines represent the actual historical data values for each of the variables.



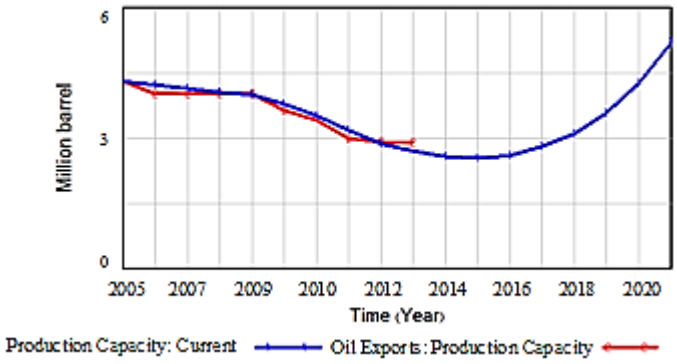
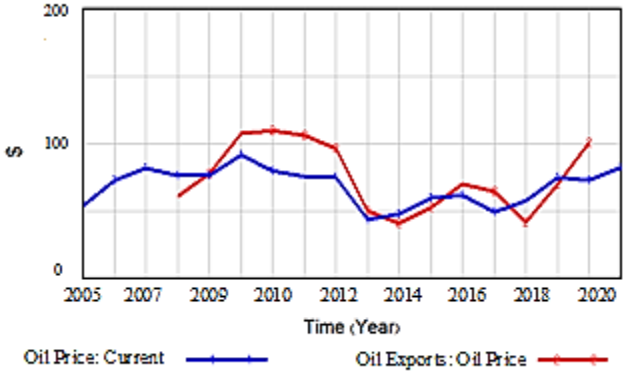


Figure 4: Behavioral Replication Test: Oil exports, price, production capacity.



8. Sensitivity Analysis

After simulating and observing the behavior of all components of the model in the desired time frame, changes to the variables of interest in the model and their effects on the main variables under investigation are analyzed. Sensitivity analysis is mainly used to estimate some parameters in the model or to test certain structures in the system when the parameters are not very precise. The aim of sensitivity analysis is to assess how the model's outcomes are affected by variations in parameter values

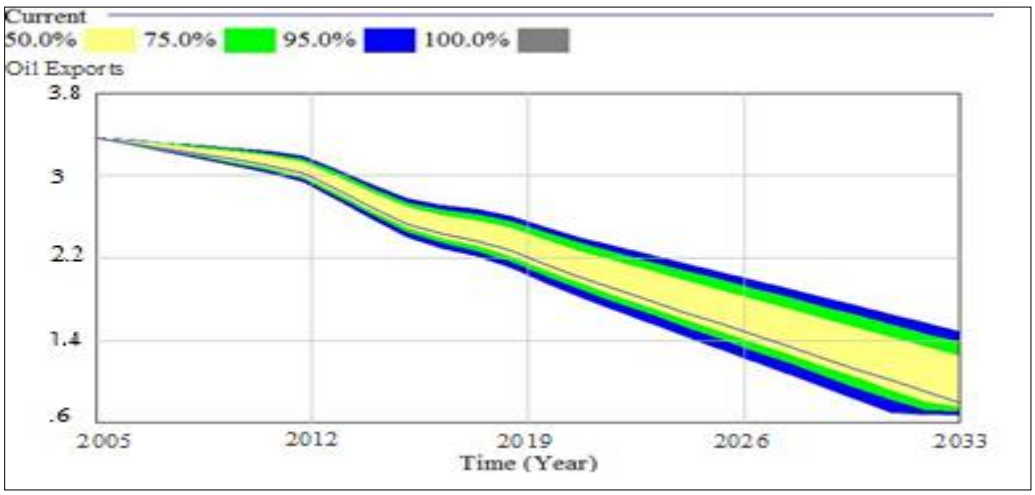


Figure 5, results of the model sensitivity analysis.

As shown in Figure 5, changes in maritime transportation security and the geopolitical influence of the Persian Gulf on increased foreign investment have a substantial impact on oil exports, which, as indicated, increases over time. In the absence of maritime safety and security, oil exports will face a significant decline, while an increase in maritime safety and security will lead to a considerable rise in oil exports.

9. Scenario planning

The oil industry is always faced with significant uncertainties. On one hand, there are technological uncertainties, such as the uncertainty in estimating investments leading to production growth and oil exports. On the other hand, there are geopolitical uncertainties in the system that can result in oil price fluctuations and investment changes.

Considering these factors, this study has developed five scenarios, which include:
Scenario 1: Increase in undiscovered remaining resources through foreign investment
Scenario 2: High global oil prices
Scenario 3: Low global oil prices
Scenario 4: Increase in foreign investment
Scenario 5: Decrease in foreign investment

In Scenario 1, an additional 100 billion barrels have been added to the initial amount of undiscovered remaining resources. Scenarios 2 and 3 are achieved by changing the slope of the global oil price variable. Scenario 4 considers an optimistic outlook on foreign investment, while Scenario 5 focuses on the examination of the decrease in foreign investment.

In Figure 6, the simulation results for various scenarios are shown for the oil production rate variable. In Scenario 2 (Graph 3), the presence of demand and an increase in oil prices have led to further capacity development and meeting the increased demand. In this scenario, the oil production rate has occurred at a higher volume and in a shorter timeframe compared to the baseline. According to the simulation results, since most of the foreign investment in the exploration and oil production sector is being utilized (due to certain sanctions) in the model, we do not observe significant changes in the production rate in Scenario 4 (Graph 5), although production has occurred at a higher volume and in a closer timeframe compared to the baseline. Additionally, the abundance of resources and consequently the increase in the exploration rate, which occurred in Scenario 1 (Graph 2), has only led to an increase in production volume at the time of the peak and has not affected the timing of its occurrence. Furthermore, the clear decrease in oil prices and the significant decline in production have resulted in a delayed peak in a lower volume.

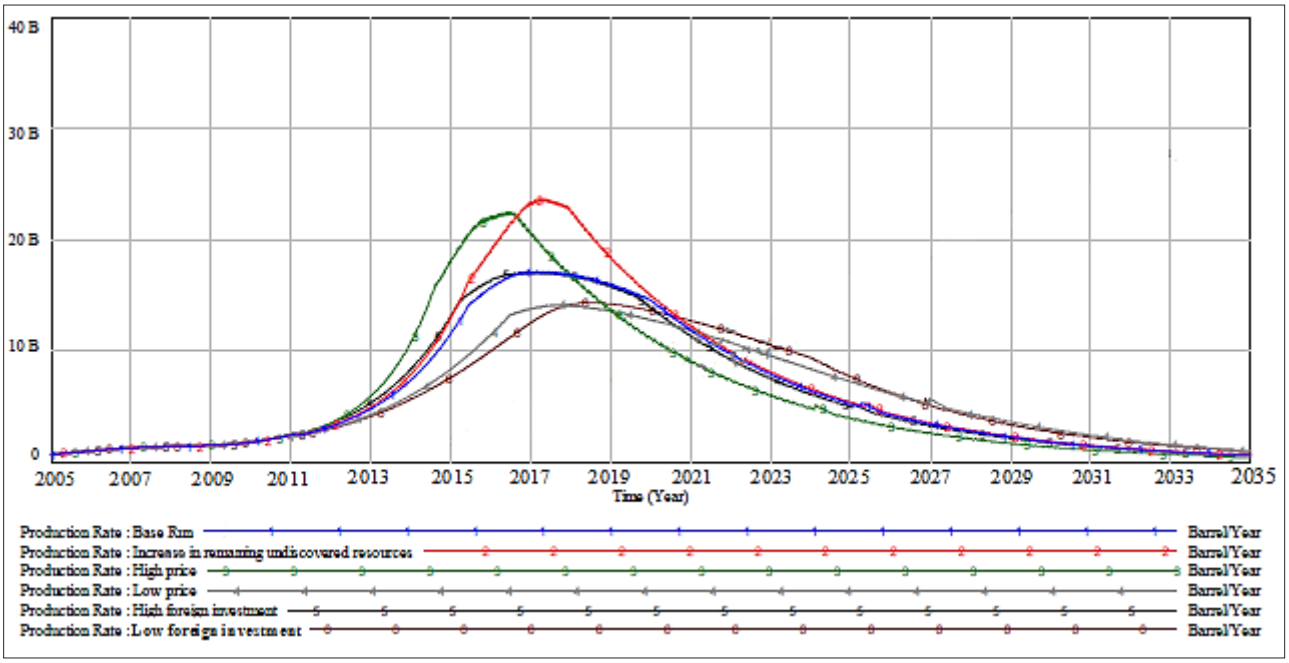


Figure 6: Scenario Analysis Results - Increase in Oil Production Rate

10. Conclusion

To address the security challenges and sanctions, strengthen the security of oil transportation, and attract foreign investment in the field of oil exports, the following strategies can be considered:

1. Strengthening regional cooperation: Establishing cooperation and interaction among Gulf countries in the field of oil transportation security can contribute to the security and stability of the region. . The establishment of a cooperative framework for sharing information, implementing joint security measures and exchanging best practices can play a pivotal role in strengthening security in the Persian Gulf.
2. Diversification of transportation routes: Diversifying oil transportation routes can help reduce dependence on a single route and decrease vulnerability to sanctions and security threats. Examining and developing non-maritime transportation routes, pipeline networks, and the use of innovative transportation methods such as smart oil tankers and modern technologies like satellite tracking and intelligent systems can improve oil transportation security.

3. Enhancing domestic capacity: The enhancement of domestic capacity in oil transportation security through training and preparing security forces, updating security equipment and technologies, strengthening navigation systems, and risk management can help improve oil transportation security in the Persian Gulf. Additionally, the development of the domestic industry in producing necessary security equipment and technologies can aid in attracting foreign investment and reducing dependence on imports.
4. Developing cooperation with international partners: Establishing cooperation with international partners in the field of oil transportation security can leverage their knowledge, experience, and resources. Building strong international relationships, signing agreements and contracts for cooperation in oil transportation security can facilitate security enhancement and attraction of foreign investments..
5. Diversification of revenue sources: To reduce dependence on oil exports and sanctions, diversifying the country's revenue sources can be beneficial. Developing other economic sectors such as tourism, industry, technology, and agriculture can help attract foreign investment and reduce reliance on oil exports.
6. Encouraging foreign investment: To create an environment conducive to attracting foreign investments in the oil industry and oil transportation, providing financial incentives, tax benefits, facilitating technology transfer, and establishing strategic partnerships with foreign companies are essential steps in achieving the stated objectives.
7. Utilizing innovative technologies: Leveraging cutting-edge technologies such as the Internet of Things (IoT), sensors, artificial intelligence (AI), and data analytics can contribute to improving oil transportation security and reducing security risks. These technologies can be effective in detecting and preventing adverse events such as theft, cyber threats, and natural disasters.
8. Enhancing education and awareness: Training and raising awareness among security forces, oil transportation personnel, and the relevant community about security incidents and preventive measures can emphasize the importance of oil transportation security. Conducting training courses, practical exercises, and enhancing public awareness can help reduce security risks and achieve the desired goals.
9. Developing a robust security system: Establishing a strong and comprehensive system for managing oil transportation security is crucial. This system should include security measures such as continuous monitoring, physical security, protection against natural and human-made incidents, risk management, and crisis planning. Additionally, there should be an effective reporting and communication system for prompt notification in the event of an incident.
10. Strengthening government-private sector cooperation: Active and continuous cooperation between the government and the private sector in oil transportation security is highly important. The government should formulate policies and laws that enable private companies to participate in oil transportation security. Mechanisms should also be established for collaboration in sharing information and experiences, exchanging security information, and coordinating against security threats.
11. Developing advanced security technologies: Leveraging advanced technologies in the field of oil transportation security can be highly effective. Research and development in smart systems, automation, robotics, the use of CCTV cameras and intelligent detection systems, the use of encryption technologies, and cybersecurity can help improve oil transportation security and increase attractiveness for foreign investors.
12. Encouragingproductdiversification: The development of the petro chemicalin dustry and the production of higher value-added products from crude oil can help reduce reliance on international oil markets and dependence on crude oil production and exports. Product diversification can contribute to income regulation and reducing the impacts of sanctions and oil price fluctuations.
13. Developing multi-modal transportation: Using multi-modal transportation methods such as railways, pipelines, maritime, and air transportation can contribute to the diversification and security of oil transportation. These methods can help reduce dependence on a specific transportation mode and consequently reduce vulnerability to security threats.
14. Strengthening international cooperation: Collaboration and coordination with other countries and organizations to enhance oil transportation security is crucial. This includes information, experience, and technology exchange, cooperation in training and capacity development, establishing interaction mechanisms and coordination in the event of security incidents and creating common international agreements and laws in the field of oil transportation security.

Ultimately, to achieve the aforementioned goals, it is necessary for governments and relevant organizations to actively and continuously collaborate in the development and implementation of joint security policies and programs and take necessary measures to protect oil transportation security.

11. suggestions

Given the security challenges and existing sanctions in the oil transportation sector, I propose the following suggestions to enhance security and optimize the management of this industry:

1. Development of security infrastructure: Building and developing robust security infrastructures, such as advanced surveillance facilities, Geographic Information Systems (GIS), tracking and monitoring systems, and databases related to security incidents and potential threats, is essential. These infrastructures can help in early detection of security incidents, preventing their occurrence, and optimal crisis management.
2. Training and awareness: Enhancing the level of awareness and training of individuals and personnel involved in the oil transportation sector in the field of security and safety practices is crucial. Regular and comprehensive training on identifying security threats, preventive behaviors, the use of safety equipment, and effective communication in the event of an incident should be provided continuously.
3. Collaboration with international organizations: Strengthening collaboration with international organizations related to oil transportation security, such as the International Energy Agency (IEA), the International Maritime Organization (IMO), and the Gulf Cooperation Council (GCC), is vital. This collaboration can aid in information exchange, coordination against security threats, and the establishment of international standards and regulations in the field of oil transportation security.
4. Utilization of advanced technologies: Leveraging advanced technologies such as artificial intelligence, the Internet of Things (IoT), data analytics, and encryption can help improve oil transportation security. Establishing smart systems for monitoring and controlling oil movement, offering and suggesting alert systems and threat detection, using robots and automated devices for hazardous missions, and developing advanced communication systems between various security forces, companies, and relevant organizations can also be effective.
5. Diversification of routes and transportation methods: Diversifying oil transportation routes and methods, such as using marine terminals, pipelines, railways, and road transportation, can help reduce security risks and increase flexibility. Increasing route diversity implies reducing dependency on a specific route and predictable focal points.
6. Development of government and private sector collaboration and interaction: Developing cooperation and interaction between the government and the private sector in the field of oil transportation security is of great importance. Creating appropriate mechanisms for information transfer, coordination against security threats, and defining the roles and responsibilities of both entities in security affairs can lead to significant improvements.
7. Crisis management: Proper preparedness and planning for managing crises and security incidents in the oil transportation sector are crucial. Establishing crisis teams and conducting exercises and simulations to ensure a rapid response in the event of security incidents are important measures.
8. Development of laws and regulations: Developing laws and regulations related to oil transportation security, creating security requirements and standards, and effectively implementing them can help ensure security and reduce security risks in the oil industry.

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