A game-theoretical approach to solve the oil price problem using the NSGA-II model

Special Subject 2

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Contents

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Abstract The oil is a critical and essential product of the global system that directly affects global activities. However, the erratic change in oil price has become an extremely noticeable concern that needs to be solved to limit the impact on the costs of other industries as well as people's lives in society. To make an attempt in solving this problem, we are trying to apply a negotiation model in which each oil firm does its best to achieve the broadest possible share so that game theory and Nash equilibrium can easily shed light on this problem (Bratvold & Koch, 2011). In this paper, we will examine the oil price problem by using game theory and applying the NSGA-II model to tackle the problem. The NSGA-II model enables us to solve conflicts between multiple objectives and also analyze price changes, and in this particular case, NSGA-II will be used to deal with all the non-linearities while considering real-world circumstances. The experiment that we demonstrated will show how effective it is to apply this model to deal with the price conflict in the oil industry, thereby yielding the most optimal balance between the stakeholders, which could be a promising solution.

Keywords: Game Theory; Oil Price; NSGA-II model.

1 Introduction

It can be said that the scarcity, limitation, and high demand for oil - one of the world's most valuable industries in terms of dollar worth is considered the main reason that makes oil prices become an extremely crucial and challenging facet for every country all over the world (Camerer,2002). In reality, we have various crude oil streams that come from multiple geographical places and are delivered into the markets, each with its own features in terms of quality and price. Crude oil standards provide a pricing reference for specific products produced in a particular location, such as WTI, which is regarded as the benchmark price for the oil that is produced in the United States, whereas the Brent price is a global criterion for the oil that is produced in the countries in the North Sea (Seljom & Rosenberg, 2011). The oil industry is defined as a rapidly changing business environment controlled by corporate partnerships that go hand in hand with severe government restrictions (Popescu, 2011). In addition, Araujo and Leoneti (2018) showed that each factor involved in the exploration of oil and gas resources wants to achieve different benefits. That is the cause of the conflict between the factors. These conflicts appear in the market, within the country, or among competing companies. Furthermore, oil prices are constantly fluctuating due to the impact of all kinds of social problems or even the intervention of the oil companies themselves. petroleum companies because of the large and extremely dynamic market.

To find and create equilibration among government, enterprise, and people, we decided to apply game theory with the purpose of finding equilibration in the equation of the problem, including all oil countries. By definition, game theory is a branch of mathematical modeling concerned with the study of complicated interactions between entities and enables the prediction of events or behavior of one person or a specific group (Chang et al., 2013). In the cost problem of the oil industry, game theory can be considered as an essential factor in solving its application in reality. When confronted with these scenarios, Nash equilibrium has always been the concept that goes parallel with game theory to ensure that there will be no incentive for players to deviate by offering the most optimal solution (Burguillo,2017). Besides, to be able to solve this problem, we chose to use the NSGA-II model to ensure benefits for all players. The NSGA-II model is built and applied to find the best score and decision for the player thanks to the renowned for sorting at high speed. This model can also help in picking the oil price data in the short-term and medium-term, which could be extremely useful in finding the solution to balance oil prices (IEA, 2020). To enhance the logic and validate the model's accuracy, we use additional Nash equilibrium to increase the accuracy and find the most effective results where all players give the best options regardless of the opponent's choice (IEA, 2020).

When the petroleum market becomes volatile, the world economy may become inchoate whether the industries, production, and transportation that depend on oil simultaneously lose control, causing people to panic and leading to the collapse of the global economy. Therefore, given the apparent significance of oil prices to the global economy as analyzed, a series of experimental papers have been published that examine the most essential variables that explain oil price behavior in a quantitative and analytical manner [2,4]. However, much of this research has been published for many years with old statistics while the oil economy is steeply changing. The differences between these two factors can lead to the lack of many new cases when applying previously studied methods. In order to describe clearly what empirical problems will be solved in our study, we have experimentally tested on a wide range of subjects, ranging from the comparison of rising and falling gasoline prices over the years, considering the changes in the world political situation, giving completely accurate data. This method will certainly increase the objectivity of the research results. When comparing and contrasting conclusions from other studies: although this comparison may differ as the study uncovers something new, new perspectives on other causes of past conflict, and this proposed comparison also ensures multidimensionality in our review.

Therefore, the main aim of our research is to deliberate how game theory combined with the NSGA-II model solves the oil price problem. Putting all the information into consideration, it is clear that the primary goal is to provide a decent visualization of the strategy. for a variety of contexts. These strategic interactions have the potential to influence the choice processes of all oil firms, combined with the governments and people who are involved in the oil industry. Therefore, the remaining portion of this paper is structured as follows: (iii) Describing the oil price problem in detail, and giving an example that demonstrates the NSGA-II model's ability to solve the cost problem of oil; (iv) Methodological procedures for applying mathematical assumptions of game theory in calculating the cost of oil in the industry; (v) The results that turn out after applying the NSGA-II model; (vi) Evaluation of the experimental results; (vii) We provide a summary of our work and also our comments for future views in this field.

2 Literature Review

The conflict and cooperation between these multiple agents have been researched and confirmed that the above actions can be modeled using game theory (Maskin, 2011). As it can be seen, by applying game theory, the suitable approach for each participant would be dictated after calculating and analyzing all of the related circumstances (Niazi & Hussain, 2011). However, in the actual world, agents or organizations are constantly disagreeing on whether to spend more investment or take more risks than others, which leads to many complex situations (Ozkan et al., 2016). In the cost problem of the oil industry, game theory can be considered as an essential factor in solving its application in reality. When confronted with these scenarios, Nash equilibrium has always been the concept that goes parallel with game theory to ensure that there will be no incentive for players to deviate by offering the most optimal solution (Losáñez, 2018). These strategic circumstances in an attempt to find out the maximized option are normally dissected in the game theory approach (Pravleen, 2022), and the methods can be any of the NSGA-II algorithms.

Higher oil prices bring many clear and worrisome consequences, including higher energy expenses for consumers and businesses, increased inflation, and a greater trade imbalance (Kolaczkowski, 2022). However, even downward volatility has negative sequels, increasing disincentives for conservation, efficiency, and renewable energy expenditures (Frank & Reidar, 2011). This is a two-way street as far as our reliance on petroleum products in all ways such as transportation, chemicals, and manufacturing implies that fluctuations in oil prices can also impact the rate of economic growth (Popescu, 2020). The rate of inflation and hyperinflation are affected which is the reason for the expensiveness of gasoline, which can also lead to an increase in inflation that is harmful to the total GDP of the world (Myerson, 1991). When applying Game theory model to the oil price challenges, the difficulty is to keep the game's key aspects while simplifying it enough so that it can be examined (Igor, 2019). In settings of risk, uncertainty, and unpredictability, game-theoretic and living lab techniques may be strong decision-making tools. Therefore, there must be involved increasingly effectively in the research and development of innovation systems (Losáñez, 2018). Game theory would be well suited to explain fluctuations in oil prices during periods of low prices and price wars (Hoi, 2016).

Each research paper analyses separate and different problems, but in general, they all use algorithms to solve real-world problems. The table below summarizes the elements of the above publications:

Authors	Publications	Factors
Camerer et al	Research in behavioral game theory: Thinking, Learning, and Teaching.	Using parameterization to weaken assumptions about game theory's rationality to better fit empirical data.
Kang et al	Description and Application Research of the Multiple Regression Model Optimization Algorithm	Using the multiplicative model can predict to be greatly reduced. The model is made to forecast future real estate prices to good effect.
Ozkan-Canbolat et al	Research and analyze the evolution of game theory.	The game theory here is to analyze the decisions that affect the decisions of others.
Prableen Bajpai	The world is still heavily dependent on crude oil, that is why there are a number of factors that affect oil prices.	The two main factors affecting the demand for crude oil are transportation and population growth.

Table 1: Some highlight publications and their factors

In general, the above studies have analyzed and pointed out the factors and ways to solve the oil problem by algorithms, but if analyzed deeply, they still have gaps in the analysis process. Most of the research papers focus on analyzing the conflict between factors in practice, but little mention is made of what it will mean for those factors after solving the problem.

In this study, we used the NSGA-II model to conduct a new solution that can address the aforementioned price issues by incorporating crisis information into the model. Besides, applying game theory in this context also helps visualize the obstacles that the world's oil industry is facing. In light of the aforesaid factors, it can be said that this paper's main purpose is to discuss the implementation of making the right decision by applying game theory combined with the use of the NSGA-II model. Three distinguishing characteristics of NSGA-II, one of the most prominent multi-objective optimization algorithms, include a fast sorting approach, a quick populated position estimation technique, and a rapidly congested comparison function (Yusliza et al., 2011). During the project execution, we tested the relevance and effectiveness of some algorithms related to NSGA-II with these problems based on the game theory model, and they returned a detailed pay-off function that can give an optimal answer for dealing with each specific case in oil price with the participation of all parties.

3 Oil Problem Description

3.1 Problem description

Petroleum and energy resources had long been seen as valuable goods, but they have also been associated with the possibility of crisis because of the opposing interests of numerous entities involved in their growth, including generating and supplying countries around the world (Felipe & Alexandre, 2018). As a matter of fact, the irregular change in oil prices can lead to several problems as well as straightforwardly affect every related individual. Normally, there is always a certain conflict between oil firms in the oil industry when it comes to economics, and each firm tends to obtain the most beneficial portion whereas leaving the others with the least advantageous one (Kolaczkowski, 2022). To be more detailed, the change in each country's oil production and export activity has a significant effect on the world oil price in particular and the oil revenue of other countries in general.

For example, based on the Energy Information Administration's aspect, we discover five distinct key elements affecting the crude oil prices in general: market prices (Brent oil and WTI oil), oil balance (the balance between import and export oil activities and oil storages - the amount of oil that is used to distribute and backup), financial markets (participants and future contract transactions), supply, and the world demand for oil. In general, if one of these elements fluctuates, the world oil price and the countries' profit on oil will be strongly affected. Hence, a change in the strategy of an oil-supplying country can create knock-on effects on other countries as well as directly cause the constant rise and fall of oil prices in the market if there is no agreement with the oil-supplying countries. Overall, the inconsistency in the strategy of each country can be considered the main cause of long-lasting conflicts in the relationship between these oil countries.

To deal with the above conflict, we have already mentioned multiple solutions that have been proposed by other researchers in section 2. For instance, Araujo and Leoneta - they use a game theory approach and some simple strategic games (2x2) to solve the decision-making problem in the oil industry (Araujo & Leoneti, 2018). Besides, Youngho and his partners make an attempt to investigate the alternative options for changing the international oil market by building game-theoretical models featuring the main players: Russia and Qatar, which export oil to Europe and Asia-Pacific, respectively (Youngho et al., 2021).However, a regular burden for these solutions is the constant changes in oil prices due to conflicts in the strategies of countries to get the best profit for themselves. This obstacle could lead to instability in all activities using this fuel source in society, such as inflationary, detrimental to the global economy, and so on. In this case, the application of game theory and NSGA-II can be useful as they are expected to solve the oil price problem by predicting the future oil price in a short time and then based on it to find out the most optimal way for each oil firm in producing and exporting oil plans with the expectation that it can balance and minimize the change in the price of oil.

Example

An analysis of how game theory can give out the optimal solution for the change of oil price written by Richie and his partners will be a superb one for our problem. In this example, the authors believe that we have to know what is happening behind the scenes of oil change in the middle of the COVID-19 pandemic in order to solve the dropping oil price problem. Based on the analysis, we can see that the author uses the Russian and Saudi Arabia war prices to show the downside of non-cooperate as it is the main cause that leads to the drop in oil prices since both countries are large oil exporters and the demand for oil is severely reduced (Ma et al., 2021). As a result, the effects that should have occurred in the oil market were lessened, according to their findings. Market participants were able to notice and incorporate market developments and modify their expectations (Ma et al., 2021).

In the below example of this oil market throughout the COVID-19 epidemic, we have two key participants - Russia and Saudi Arabia with the following features:

1. Saudi Arabia: has considerable raw material potential and advanced technological gear.
2. Russia: culminating in an oil market conflict due to the conflict between a huge amount of oil production and a small number of oil exports..

Based on the analyzed information we mentioned above, table 2 is created to give us a closer look at the real Russia and Saudi Arabia data of oil production, oil export, and revenue over the 2 years following the COVID-19 pandemic:

	Oil production (mbpd)	**Oil export (mbpd)**	**Brent oil price (USD/bbl)**
Saudi Arab	9.08	6.431	53.6
Russia	9.562	4.654	53.6

Table 2: The average amount of oil production and oil export, revenue, and oil price of Russia and Saudi Arab (3/2020 - 3/2022))

In two years (3/2020 - 3/2022), the difference between the amount of oil produced and the amount of oil sold is very large, so it is easy to see the problem each country was facing at that time is finding ways to compensate, or more specifically, finding the answer for the question about what action should they take to guarantee the most profit.

In this game, we give some characteristics of players, such as *oil balance* (measured in units: million barrels/day), which includes objects like *oil production, oil exports*, and *oil inventories*. In addition, there are other characteristics that need to be mentioned, which are *spot price* (measured in units: dollars/barrel) and *demand* (measured in units: million barrels per day). With these characteristics, we come up with two different strategies: *cooperation* and *competition,* which are analyzed clearly within the characteristic table below

Property	**Characteristics**	**Strategy**
Players (Producing and exporting countries)	*Oil balance* (million barrels/day) *Oil production*: the amount of oil a player produces. *Oil inventories*: the amount of oil that players hold back in order to process other plans (special case/back-up plan). *Oil price* (dollars/barrel): the price of oil at a specific time. *World demand* (million barrels/day) *Production cost*	Raise oil price: High demand, low production. Low demand, low production (coop) Reduce oil price: Low demand, high production High demand, low production (competition). High demand, high production (competition). Low demand, low production (competition). Remain oil price: High demand, high production (coop) Low demand, low production (coop)
Special Player (Importing countries	*Oil price* (dollars/barrel): the price that special player sells for retailers *Storage costs* include: warehouse rent, machinery, and equipment rental fees, factory depreciation, electricity bills, cost of labor, materials, and operating costs to preserve and rotate inventory.) *Anticipatory stocks*: stock retained in preparation for predicted customer needs. *Investment* (dollar/barrel)	-*Oil inventories:* Increase the amount of *oil anticipatory* if predict *oil price* high Reduce *oil anticipatory* if predict *oil price* low by reducing the *investment* on *oil production* importing.

Table 3: Players' characteristics and strategies

The ability to predict these changes in oil prices based on oil product volumes, oil demand, and oil export prices allows economic actors such as companies to adapt to future market changes. and provide decision-makers with the precise information they need to know. are used to select the optimal decision for them. The predictability of this change is expressed in the form of the following formula: Competition case:

$$u_i = 0.76 * (95.86 * (12.85 * 52.12 + 13.23 * 49.56 + 12.48 * 46.19 + 14.19 * 47.67))+$$

*0.24 *(94.97*(10.84 *48.87 + 12.04*47.56 + 11.98*45.97 + 12.33*51.78) = 168057.05*

Cooperative case:

$$u_i = 0.5 * (95.86 * (9.83 * 52.12 + 10.14 * 49.56 + 11.48 * 46.19 + 10.19 * 51.78))+$$

*0.5 *(94.97*(9.83 *52.12 + 10.14*49.56 + 11.48*46.19 + 10.19*51.78) = 152334,3*

After applying our dataset into the model, we have the below result:

Strategy	Competition	Cooperative
Payoff result	168057.05	152334.3

Table 4: Players' strategies a result

As we can see clearly from Table 4 above, in some cases, the strategy of dominating the oil market, Russia and Saudi Arabia are willing to reduce prices and betray the cooperation to dominate the oil market. Under the COVID-19 circumstances, Russia unilaterally changed and switched to its dominant strategy with lower and more competitive prices. This forced the Saudi Arab to shift to their dominant strategy to avoid backlog losses by accepting low margins. In this case, Russia and Saudi Arab have an unbalanced output when they try to compete with each other, which is 168057.05 and 152334.3, respectively. The reason for this situation is the difference in export prices and the amount of oil production in each country.

However, Russia and Saudi Arab will need to cooperate and jointly give out the same price as well as the specific oil production level to achieve the best profit, which means both of these countries can reach the Nash equilibrium point if they decide to make alliances and set an agreement with each other.

4 Game model

4.1 Game-theoretical model

The Unified Game-based model is a model built based on a general structure for incomplete-information, cooperative, and non zero-sum games (Nash, 2020). a unique member is formed with perks that differ from those of the other competitors. This particular player is considered as a party who shows the benefit of all players. Simultaneously, the tactics of each participant will be represented by a characteristic vector. Therefore, by combining three factors: special players, normal players, and the set of player strategies, the formula of the Unified Game-based model is described as follows:

As introduced in Section 1, we applied this model to the Oil Problem. There are only 3 players in this game (oil firms, government, citizens) in which the government and citizens are the special players. Therefore, this game can be described as follows:

$$G = < \{P_0 , P\}, \{S_0, S_i\}, \{u_0, u_i\}, R^c > \tag{1}$$

In which,

G: is our game in strategic form.

P_0: is the unique member who has distinct interest from the rest of the players , can be a party who shows the benefit of all players or a referee in the game.
$S_0 = \{S_{0a}, ..., S_j, ..., S_{0M_0}\}$: is a unique player's set of tactics, and $M_0$is the total of the special contributor options.
$u_0 = S_0 \to R$: is the measure of payoff for the unique contributor.
$P\ \{P_1, P_2, ..., P_i, ..., P_M\}$: is the series of basic individuals. M is the quantity of regular participants.
$S_i = \{S_{iA}, S_{iB}, ..., S_{ik}, ..., S_{iM_i}\}$: represents the series of approaches for regular participant i, M_i is the number of options for regular member i i
u_i: $S_i \to R$: shows the measure of the payoff for member i i
R^c: vector space representing the set C of the problems' conflicts.

As we mentioned before, our cooperative game includes three main elements: (1) a series of N countries, (2) a series of possible choices for each of these countries, and (3) the series of pay-off functions. The main players in our research are the oil countries that can affect oil prices by producing and selling oil around the world. The Unified Game-Based model is defined as follows:

$$G = < \{P_0, P\}, \{S_0, S_i\}, \{u_0, u_i\}, R^c > \qquad (2)$$

In which,
G : presents the oil problem game in a strategical formality.
P_0: is the importing country.
$S_0 = \{S_{0a}, S_{0b}, ..., S_{0k}, ..., S_{0M_0}\}$: presents the series of strategies of importing countries.
u_0: is the payoff function of an importing country.
$P = \{P_1, P_2, ..., P_i, ..., P_N\}$: the series of all players (oil-producing and oil-exporting countries) that have conflicts in strategy formulation with other participants.
$S_i = \{S_{ij1}, S_{ij2}, ..., S_{ik}, ..., S_{iM_i}\}$: the series of approaches for country j and u_i: is the measure of payoff of country j
R^c: vector space representing the set C of the oil problems' conflicts.

The strategies of importing countries;

- $S_0 = \{s_{01}, ...\ s_{0j}, ...\ s_{0M_0}\}$:
- M_0 is the volume of oil import.
- S_{0j} is a structure containing information related to the amount of oil to be imported: demand, inventories, oil wholesale prices, and time.

The strategies of producing countries;

- $S_i = \{s_{i1}, ...\ s_{ij}, ...\ s_{iM_i}\}$:

- M_i is the amount of oil required for production.
- S_{ij} is player i's strategy with strategy based on special player's strategy including information related to the amount of oil to be produced: demand, world oil price, production cost, time, inventories.

Special player pay-off function

Assume that the profit after oil distribution in the country of a particular player at time *t* is A calculated by total sales of importing country is *imp_profit(t)*, the cost of importing oil is *pr(t)* and the total storage cost is *st(t)* which is described as following:

$$A = total\_sales(a) \ - pr(a) - \ st(a) \tag{3}$$

We find that the total oil sales of an importing country can be calculated by using the oil wholesale price combined with the oil demand, which is already predicted within t time frame plus with the needed oil volume of importing country i. Based on these factors, we have the below formula:

$$total\_sales(a) = \ price(a). \sum_{i=1}^{l} \sum_{j=1}^{m} \left(\widehat{E(a)}_i . \ ant\_stock(a)_j + vol(a)_{ij} \right) \tag{4}$$

In which:

- l is the number of storages
- m_i is the total of retailers of importing country i
- $ant\_stock(t)_j$: anticipatory stock of retailer j over time *(a)*.
- $\hat{E}(t)_i$ is predicted oil demand of importing country i over time (a)
- $price(t)$: the global price of oil in over an amount of time (wholesale price)
- $volume(a)_{ij}$ volume of oil distribution for retailer *j* of importing country i over time *(a)*

Besides, we can use the amount of imported oil combined with the predicted oil price in order to find out the the imported oil cost, or in another word, the investment formula which is described as:

$$pr(a) = \hat{P}(a). \sum_{i=1}^{l} pur\_(a)_i \tag{5}$$

Where:

- $pur\_(a)_i$: represents the purchased oil of importing country *a*

And the last contribution to formula A is *st(t),* or storage cost. This factor can be calculated basing on two different circumstances:

$$st(t) = \sum_{i=1}^{l} (pur\_(a)_i + \ ant\_stock(a)_i) - \sum_{j\ =\ 1}^{m_i} vol(a)_{ij}) + \sum_{i=1}^{l} \sum_{j=1}^{m_i} (volume(a)_{ij} + ant_{stock(t)_i} - \hat{d}(a)_{ij}\ ) \tag{6}$$

In which:

- $ant\_stock(t)_i$ is the anticipatory stock of importing country i over time *(t)*.

In fact, the reason is the volatile oil market, a huge amount of oil inventories are not uncertain of price increase or decrease. Moreover, as the price of oil changes over time, the market value of oil inventories changes accordingly. If the price of oil tends to increase, rising oil inventories is a wise decision to achieve higher profits in the near future. While cutting down on inventory volume is the opposite, it is recommended if oil prices are trending down. Therefore, if the price predicts the future *(pr(a+1)>pr(a)),* special players will tend to buy a high amount of oil to store at *a* then put it on the market at *a+1*. The above action creates another source of profit and is called arbitrage benefit maximization. Suppose this profit is B, we have

$$B = (\hat{P}(a\ +\ 1)\ - \hat{P}\ (a)) \sum_{i=1}^{l} pur\_(a)_i \tag{7}$$

In overall, we have the importing country's payoff is:

$$u_0 = B - A \tag{8}$$

Normal player pay-off function

The profits of oil-producing and exporting countries depend on the amount of oil produced, customer demand at time *t*, and the selling price of oil. Therefore, the payoff function of oil-producing and exporting countries will be calculated as follows:

$$u_i = E(t) \sum_{i\ =\ 1}^{M_0} \sum_{j\ =\ 1}^{M_i} (S_{ij}.(\sum_{i\ =\ 1}^{C_i} p(t)_i) \tag{9}$$

In which:

- M_0 is the volume of oil imported.
- M_i is the oil production of exporting country i.
- S_{ij} : the status of whether there is a production cut or not
- C_i is the production cost of exporting country i (in which C_i= *Cost of factory overheads + Direct labor cost + Direct material cost)*
- *E(t)* is oil demand of importing country j over time (t)

- *p(t)* is oil price of exporting country i over time (t)

We can calculate the oil demand by basing on the cross elasticity of demand.

$$E_X^D = \frac{\%\ Q_D}{\%X} \tag{10}$$

In which:

E is the elasticity of demand with respect to the variable X.

Q_D is the quantity demanded.

X is the variable that affects the quantity demanded.

The fitness function is the below equation.

According to the pay-off function of each player we have proposed, the adaptive function for our problem can be calculated and the result can be seen as an evaluation in considering which solution is better (in our case, if the result is higher, the solution is worse:

$$u_{all} = |u_0 - \sum_{i=1}^{N} u_i| \tag{11}$$

4.2 Nash equilibrium and Nikaido Isoda function

Based on the aforementioned information in cases 2 and 3, we can tell that Nash equilibrium is the model used to solve the conflict between many players. In other words, Nash model has its ability to be seen as a main aspect to the method to the crisis in profit between oil countries. According to the Thomas-Killman model, there are five conflict resolution options. However, collaboration is mentioned as the best one as it also shares the same idea as game theory and Nash equilibrium, which means its purpose is to form alliances and make them work together to come up with a solution that pleases all involved parties. In fact, the Nash equilibrium needs to satisfy additional constraints, which means, in this case, finding the Nash equilibrium based on the Nikaido Isoda function has the form of a multi-objective optimization problem (Ngoc, 2020). The Nikaido-Isoda function defines the Nash equilibrium of the project management conflict problem described by the Unified Game-based model of the following form:

$$f(x^*,\ x) = f(S^*,\ S) = \sum_{j=1}^{n} [-\left(u_j\left(s_j,\ s_{-j}^*\right)\right) + \left(u_j\left(s_j^*,\ s_{-j}^*\right)\right]\right) \geq\ 0 \tag{12}$$

It can prove the use of nash equilibrium in conflict problems in oil field operations as follows: (i) if the multi-objective evolutionary optimization algorithms converge in the case when the fitness value of the algorithm after a finite number of iterations changes only within less than a predetermined value , when that will find the Nash equilibrium satisfying the formula, (ii) The conflict in the oil field is suitable for a linear programming problem with many objective functions (multi-objectives). From (i) (ii) it is shown that the collision in the oil field can be convergent and both Nash equilibriums exist. The conflict subproblems in project management have the same characteristics as those introduced, also exist in Nash equilibrium, and can be found through multi-objective optimization algorithms.

5 Algorithm with NE

5.1 Explained why this algorithm can be used in solving the problem

As far as we can see the NSGA-II algorithm and its comprehensive implementation process, this algorithm has proven to be one of the most effective ways to improve many references. A succinct summary of NSGA-II is as follows: for aptitude tests, NSGA-II employs unrestricted sorting overall. Number 1 is given to all people who are not dominated by others (Murugan, 2009) Front number 2 is assigned to all people who are dominated only by people from front number 1 and so on. The choice is made by competition between two people. If two people are in different nodes, the person with the lowest number of fronts is selected. The person with the greatest distance from the population from the same point will be chosen. This means that more fitness is given to people who are on the sparsely populated front. Every time parents appear and a new person (children) is created. Both parents and children are competing for the next meeting. The following issues could arise when facing non-linearities parallel to complicated interactions using the conventional method plus gradient-based techniques, which is the reason why there is the existence of evolutionary algorithms (Petrowski, 2017)

As far as oil prices are concerned, there is an expectation for anticipated nations to work in concert and then come to a mutually advantageous arrangement. Thus, we apply these algorithms in order to seek the most suitable option for our players in terms of benefit, which is the oil price in our case. In other words, we try to find out the profit maximization for each player.

5.2 Explained how this algorithm can find Nash equilibrium

In this article, we will handle the NSGA-II to discover the Nash equilibrium for our proposed problem. The main problem with game theory is that project managers later found Nash equilibrium, which provides a neutral solution to the conflict between risks, or a “win-win” situation, and "Methods between players with strategy N" before using a genetic algorithm. In this game, we identify all input factors for conflicting risk responses in the project network. It includes information on the model, risks, and risk response functions. They are carried out by a genetic algorithm to solve this problem. Hence the uncertainty they are completely resolved, and unnecessary risks are controlled to achieve optimal performance to manage the project (Thang, 2018)

In this study, after the onset of oil countries, other countries are classified based on a lack of control over each front. The first front in the current market is completely unruly, and the second front is dominated and led only by individuals from the first front. Each person on each front receives a rank (suitability) based on the values or front to which they belong to. (Panda, 2010)

5.2.1 Settings

We always start with the lower settings for population density, generational rate, then mutation frequency. Crossover ratios begin to decline over time, while the generational rate and the density of total population affect how speedily the program runs. Additionally, I enjoy determining which generation has reached the highest fitness value. We have depicted and analyzed all of our necessary settings for the problem below:

Population density	100
Generational choice	Elitist choice
Number of generations	500
Mutation probability	0.3
Parental preference	Binary game
Crossover	SPX , p = 0.75
The total number of loops	30
Rules for ordering	Distance among people plus ranking

Table 4: Players' strategies a result

The core problem that we presented in this research has been found to be a relatively thorough solution. In more detail, we have applied the NSGA-II algorithm since it is specifically used for optimization with several targets. In the end, we believe that after all of these techniques, which we have denoted above, the algorithm could give out the most precise results.

Besides, the suggested technique, known as NSGA-II, is based on the idea of retaining variety in the population mixture and does not call for span adjustment (Kannan et al., 2009). Uncoordinated categorization and focus separation are two distinct and specialized processes that NGSA-II possesses in comparison to the conventional genetic operators (Haitham & Kalyanmoy, 2014). Therefore, we applied it to be able to optimize thoroughly, positively, and with the least amount of error when we started the payoff function, bringing our crude oil price prediction algorithm to the most favorable final results.

Therefore, in our problem, there will be quite complicated parameters. They need to be explained in more details as follows:

- *storage(t)* is an almost fixed variable, and the amount of oil contained in it will rarely change. It only changes when there is a reason or a problem that suddenly arises, and after a while, the inventory returns to its fixed number. And it will remain constant until it needs to be brought out for use.

- $ant\_stock(t)_j$ is anticipatory stocks of retailer j over time *(t)*: stock retained in preparation for predicted customer needs.

  There are 2 parameters that are very confusing in our special player pay-off function (formula (4)), which are $\hat{E}(t)_i$ and $vol(t)_{ij}$

- $\hat{E}(t)_i$ is simply a basic parameter that shows what percentage of user demand is based on the rate at which gasoline is sold from gas stations and from which it can be calculated. Determine the amount of oil that needs to be exported for distribution to retailers j over time (t)

- $vol(t)_{ij}$ is the amount of oil that needs to be imported for distribution to retailers j over time (t)

  In formula (9) we have:

- M_i is the amount of oil produced by country i in time t .

- C_i is the cost of producing crude oil of country i (where Ci = Factory overhead + Direct labor cost + Direct material cost and some other costs)

In general, we can use NSGA-II to addressed the proposed oil benefit optimization model within seven stages:

No.	**Stages**	**Action**
1	Initialization	Generate the preliminary population P_d (d = 0) with N individuals representing potential approaches.
2	Fitness evaluation	Determine the fitness values of all persons *i = 1,...,N* in term of an objective (u_i in Eq. 9)
3	Nondominated sorting	Prescribe a fitness rate to a possible option depending on its nondomination level (K. Deb et. al., 2002).
4	Binary tournament selection	Based on fitness level, two dissimilar people are coincidentally picked from the group *Pd* above then compared in terms of fitness level. The higher one is considered a parent. This process will be repeated until there are N parents that have been selected.
5	Genetic operator	Main loop of NSGA-II algorithm.
6	Generation evolution	To ensure elitism, the N highest-ranking individuals are chosen as the new generation P_{d+1}.
7	Reproduction	Repeat until the maximum is reached.

Table 6. Process of NSGA II execution

5.2.2 Pseudo Code

After sorting all individuals based on non-domination and assigning crowding distances, genetic procedures should be conducted (Juan et al., 2015).

Algorithm 1 Non-dominated Sorting Genetic Algorithm

Initialize a oil profit randomly

P_d **=** $(u_1,u_2,..)$ = non_domination_sort_mod (P_d)

for i=1, i>=0, i++ do

for each u_i P_d do

Level should be assigned using the Pareto-sort method.;

Determine crowing distance (u_i, i=0):

end for

while oil demand is less than oil production volume **do**

use selection

crossover (p = 0.75)

mutation to make a new strategy (p = 0.5)

create a new strategy in new U (p = 0.25)

end while

Combine P and U (for elitism).

Assess the above mixture base on level

return u_i;

end

5.2.3 Diagram of algorithm

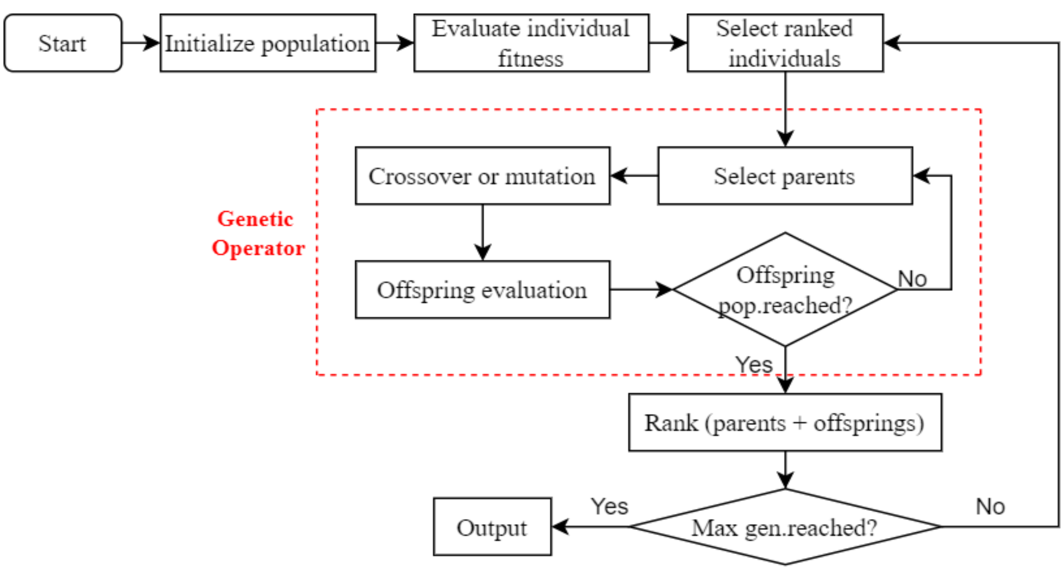

Figure 1: NSGA II execution diagram

Additionally, in order to make the pseudo-code to be more clear and easier, a detailed diagram of how the NSGA-II algorithm executes our model is shown in Figure 1. After that, basing on the diagram above combined with the proposed parameters, we create a pseudo-code for our model in attempt to prove and show the NSGA-II model is a suitable option for our case in more understandable way.

6 Conclusion

The oil issue is still one of the most important issues for some countries because it plays a very important role in our economy. Therefore, it is inevitable that conflicts arise due to the competition of the parties. When governments and businesses adjust prices, this creates an imbalance and affects the individuals involved. This is the main cause of long-standing conflicts. In which, the game theory model and Nash equilibrium give the optimal solution to this problem. Through this experiment, we present an approach to our cost difficulty in real-life oil industry by applying the optimal algorithms created using NSGA II. We present the conflicts that arise around changes in oil prices in detail. Based on the given NSGA II, we applied it to handle the existing predicaments. NSGA II is chosen to solve the model depending on the characteristics and properties of the proposed model. Then, based on the results of the experiment, we determine the optimal strategy for each specific situation and come up with some possible risks during the experiment. This study proves that the change of oil price can be predicted almost accurately. There is still some error, but it is not significant, the prediction results play an important role in making the method a suitable approach. All parties affected when oil prices change completely can use this model to minimize inadequacies as well as ensure benefits are as balanced as possible.

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