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A Framework to Select the Best Strategy for Iran's Entry into the Repair and Maintenance Market of Oil Drilling Rigs

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Abstract

The oil and gas service industry revenue is projected to rise to $350 billion in 2020, and a major part of such services belong to repair and maintenance (R&M) of the drilling rigs. Therefore, with regard to the number of jack-up rigs in Iran and the Persian Gulf, the R&M and improvement of these types of rigs become particularly important, especially due to the high lifespan of these rigs, which increases the time frequency of basic repairs. Nevertheless, Iran is suffering from lack of management and knowledge in the field of project resource management in this industry. Therefore, knowing the strategies and effective criteria for this industry is essential. In this paper, 15 criteria affecting the selection of R&M strategy were determined through interviews with experts, and the effect of each criterion on each alternative (seven strategies) was studied, and the most appropriate R&M strategy was then selected through analytic hierarchy process (AHP). The results show that the best strategy for Iran's entry into the R&M market is to perform all basic repairs of the rig, followed by license and joint venture. Finally, the best strategy was applied at R&M of Sina1 rig, comparing the results with those for Iranian rigs such as Modarres and Rajaei, the repairs of which were carried out in foreign yards, indicates the low cost of domestic repairs and the economic justification.

Keywords: Strategy; Repair And Maintenance; Drilling Rig; AHP; Effective Criteria.

1. Introduction

Based on Figure 1, the number of jack-up rigs more than 40 years old has rapidly increased, and it can thus be concluded that the fleet of jack-ups in the world is getting old with a need for repair and maintenance. In other words, the R&M market will be better by the day due to the increased time frequency of basic repairs [1].

Figure 2 indicates three peaks of frequency of jack-up rigs construction in 1982, 2009 and 2015. Also, Figure 2 shows that with cyclical behavior, improvement in the business of basic repairs is expected in certain years [1]. Due to the large part of the operations in the land workshop, the rig repairs often require a large workspace and guiding rails. The provision of the required infrastructure in the land is costly; so, it is suggested to use low-volume equipment and lower energy consumption [2].

Drilling rigs are one of the most important pieces of drilling industry equipment. Drilling equipment regularly needs R&M and system upgrade. Each rig usually requires R&M between five and 10 years after getting started which increases efficiency of drilling operations and the life span of drilling equipment. Neglecting oil rig repairs can lead to irrecoverable incidents. The incidents happened in Mexico bay, causing complete destruction of the rig, the loss of platform forces and irreparable environmental damage, and Asalouye can be exemplified [3]. Considering several years of foreign sanctions and multiplying the cost of importing drilling equipment and machinery, R&M of drilling rigs is of

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considerable importance, and any interruptions and limitations in the drilling process will bring severe economic losses to the Iranian economy [4].

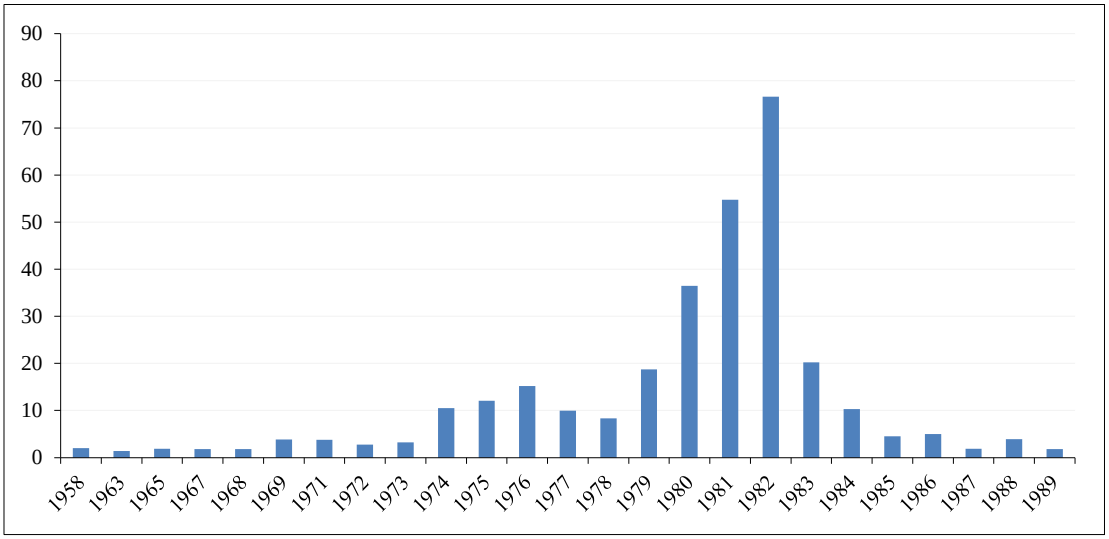

Figure 1. The number of jack-up rigs more than 40 years old

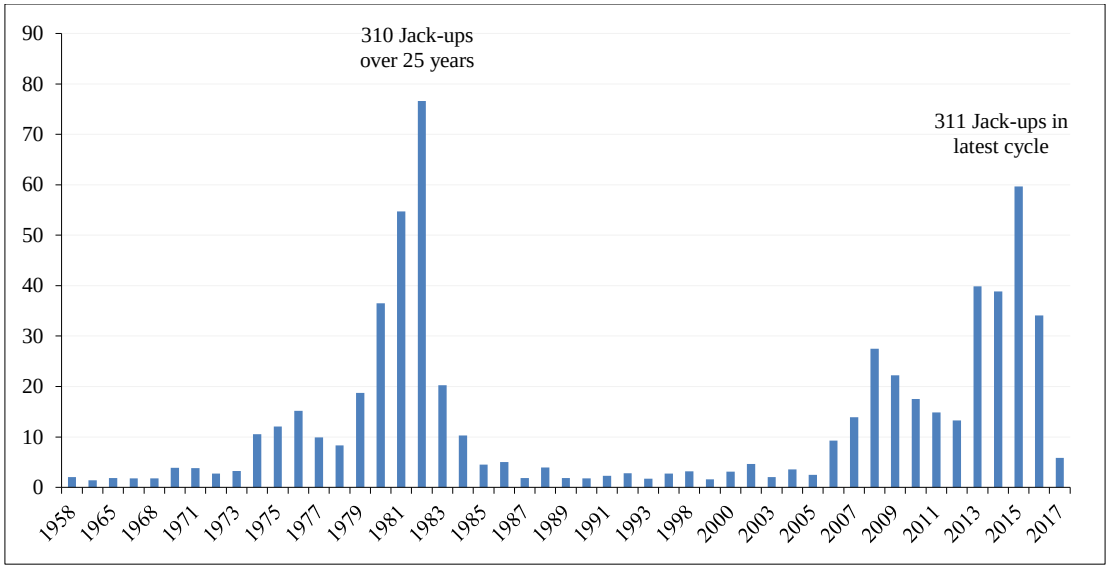

Figure 2. Frequency of jack-up rigs construction

Iran is an oil-rich country which a large part of its oil reserves locate in Fars bay and it should be used oil rigs to extract them. Most of the rigs used in Iran's oil industry are jack-ups, a kind of floating rigs which is employed for digging exploratory wells [4, 5]. However, R&M of jack-up rigs does not have much history in Iran and was mostly performed by foreign countries. But this industry is developing in Iran. For example, in 2014, R&M of Sina1 rig leaded to millions of dollars in saving currency. It is clear that Iran's entry into the R&M market of oil drilling rigs without an appropriate strategy can cause confusion, waste of cost and time, and even personal injuries.

Studies on the selection of strategy for basic repair and maintenance have much higher inherent complexity than studies of infrastructure construction [6]. The highly important and considerable point resulting from this method is that such studies, in addition to clarifying the overall discussed context, would establish a basis for more accurate and realistic analysis and, finally, result in standardization of the implementation processes for such projects, a path that is highly considered in the world class of the industry.

Accordingly, one of the defects that can be seen in the drilling industry, especially in the offshore section, is the weakness of Iranian domestic companies for not having a proper strategy for R&M, improvement, or construction of the rigs. Currently, there is high potential in Iran regarding operational yard, dry dock, improvement, and reconstruction of rigs, but due to the lack of experience of domestic companies and their incapability of obtaining the required approvals after repairs, the rigs' owners prefer to rely on the Arab states of the Persian Gulf for R&M of rigs. This shows that Iran is suffering from a management weakness and lack of knowledge of project resource management in the industry. Therefore, knowing strategies and effective criteria in this industry such as a need for infrastructure, technical capacity,

expert human resources, and available facilities, appropriate distance between target markets and rig repair facilities, and sanctions are essential for the success and growth of this industry in Iran. Therefore, in this research, three problems are considered: 1) Identification and classification of effective criteria for the selection of jack-up R&M strategy; 2) Selection and classification of R&M strategies of the jack-up drilling rigs based on identified criteria; and 3) Application of the selected strategy in a case study to measure the results.

The overall purpose of this research is to determine the appropriate strategy for jack-up rig repair. The present research is performed on Iranian rigs established in the Persian Gulf, but the results can be useful for other places that use jack-up rigs for extraction.

2. Literature Review

In 1937, Brown & Root Company built a wooden deck at a distance of 1.6 km from the coast at a depth of 4.3 meters. The construction of wooden platforms continued until 1940, with the development of operations suspended as a result of World War II [7]. This type of deck is used in Mexico bay, Maracinio Lake, Persian Gulf, Nigeria, and California beach.

The fixed platform installation become common in the Persian Gulf since 1955, and the first fixed platform was installed in Iran's waters in 1964. Currently there are nearly 135 fixed platforms in the Persian Gulf belonging to Iran. The platforms installed in the Persian Gulf are designed to deal with weaker waves and storms compared to those in the Gulf of Mexico [8].

Apart from thousands of indirect jobs, it is estimated that between 1000 and 3500 people are directly working in this industry in the United States. The jack-up construction industry has annual revenue of about $360 million for US. There are many specialized companies operating in the United States that provide employment and obtain proper profits. The largest underground water drilling capacity for US is in the Gulf of Mexico. However, it is expected that shallow drilling in the Gulf of Mexico is reduced, and that the capital in this area thus transfers to other areas in the world such as the Persian Gulf [9].

Apergis et al. (2017) reviewed the characteristics of service centers with appropriate performance, operational centers, and products based on price. Their findings showed how an appropriate strategy for platform services and operational centers interacts with the price of goods and services. The access to good service and timely response for repairs also increases the production level and prolongs rig life, and thereby will increase profitability. The exploration and production (E&P) companies have faced problems, such as increase in time, total cost, and operating costs, and also lack of capital [10].

The success of service supply and optimal use of existing facilities require a proper strategy. The strategy determined for R&M should ensure maximum use of minimum facilities, so that the cost of opportunity can be minimized. In order to achieve this goal, an optimization and simulation method can be used to provide the expected solutions and performance measurement for command as well as statistical data. Among the appropriate methods to achieve this goal, the decision-making and neural networks techniques should be mentioned [11].

Mikkelsen & Lange (2017), by studying the potential displacement of oil drilling rigs and their conversion into public places, have concluded that in case of proper maintenance and design of the drilling rigs, they can be used in urban facilities after the end of the exploitation period. Considering the reuse issues in R&M strategy is one of the important criteria [12].

Based on these results, it can be predicted that the future of this market requires organizing and accurate information for decision-makers. The future analysis, present situation prediction, higher inspection and control, review of market structure aspects, and definition of econometric models will be integral activities in the jack-up R&M market, and those companies that define an appropriate strategy based on the abovementioned items will be best able to compete. In order to determine an appropriate strategy, a systematic and appropriate decision-making method is essential [13]. One of the best decision-making methods is AHP. Different researchers have used this method to date for decision-making infrastructure projects [14].

Cheung et al. (2001) applied AHP for project delivery system selection. They chose and described eight criteria for weighting via defining some six possible project delivery systems as the possible alternatives for project delivery. The more points a system could earn through the AHP method and questionnaire weighting, it would be selected as the optimal method [15].

Al Khalil (2002) suggested a model for selecting the optimal delivery system based on an analytic hierarchy that defined 12 effective factors and categorized them into three main groups of the project characteristics. Then, by choosing from among the possible Design-Build, Design-Bid-Build, and construction management methods, he made the final selection. Al Khalil believed that AHP was a suitable decision making tool for owners to select a project delivery method due to its ability to incorporate "tangible and intangible factors" and the possibility of breaking down the problem into AHP hierarchies [16].

Mafakheri et al. (2007) preferred AHP over other methods of decision making and developed a list of criteria which were used by owners when evaluating delivery methods [17].

Wang et al. (2009) used a combination of Fuzzy hierarchical TOPSIS method for choosing the supplier and concluded that they would be unsuccessful for modeling uncertainties of the projects [18].

Zavadskas et al. (2013) used AHP and strengths, weaknesses, opportunities and threats (SWOT) analyses to develop a method for project management, which makes its selection based on the current method and also possible techniques for the future. After weighting the criteria, these criteria were classified using permutation according to their priorities [19].

Today, oil companies no longer dig and extract the oil themselves, but service companies provide such services to them [20]. This is why the service companies have grown. As a result, these companies have become leading innovators in this field and have developed various technologies such as horizontal, directional and hydraulic fracturing drilling [21]. The field of services in such industries is very broad; R&M services, equipment supply, equipment transport, and even management services such as project and construction management and personnel supply are numbered among the services of this type of industry. In other words, there are no boundaries for the activity area of the service companies, and they are active in upstream, midstream, and downstream industries, except for the main activities of oil companies.

According to First Research, Inc. titled "Oil & Gas Field Services." published in Market Research website in June 2015, the oil and gas service industry generates revenue of $200 billion worldwide, and based on Mordor Intelligence prediction it will reach $350 billion in 2020. Meanwhile, the United States with 7500 companies provides total revenue of $100 billion. According to reports from this institute, the demand for this sector depends on the prices of oil and gas. The profitability of the companies is determined by technical expertise and performance of activities. According to the authors, the large companies compete through a wide range of services, and small companies compete through having expertise in a particular sector or providing services to a particular geographical area [22].

Micro Market Monitor in its 2015 report has examined the service market for oilfield services in the Middle East through 2019. This report divides the service market in the Middle East into nine sectors: 1) Middle East Drilling Services Market; 2) Middle East Coiled Tubing Services Market; 3) Middle East Drilling Fluids Market; 4) Middle East Oil Country Tubular Goods Market; 5) Middle East Oilfield Equipment Rental Market; 6) Middle East Pressure Pumping Services Market; 7) Middle East Well Completion Market; 8) Middle East Well Intervention Market; and 9) Middle East Wireline Services Market

According to this report, the market is associated with a 4.2% growth rate from 2014 to 2015, which is the largest market sector in the Middle East. The drilling services sector with 86.3% is done by jack-up rigs [1]. The jack-up rigs have been part of the offshore drilling industry since 1978. The main purpose of this type of rig is to provide a moving, installable, and stable substrate for drilling operations in the sea. The jack-up rigs have become more complete over time and found a wider performance. The primary rigs were capable of drilling to a depth of 250 feet of water, but today, they are also capable of drilling to a depth of 625 feet of water (300-foot rigs are appropriate for drilling in the Persian Gulf) [23].

Modeling and selecting the R&M strategy of industrial structures such as drilling rigs play a major role in reducing the lifecycle cost of such facilities [24]. Different factors such as material type, transportation distance and consumed energy are effective on life span of a structure [25], but the most important discussion on R&M rigs is the maintenance of structure, especially its legs [26]. Along with a complete database, an appropriate strategy for selecting the R&M method of infrastructure leads to better management and maintenance and much higher added value than the routes that were built without a system-based strategy because it has maximized the life cycle, and all the facility branches have a specific location with no need for trial and error [27].

The common type of rig has various structural components including the rig, mast, and infrastructure, which are steel-frame structures. The mast is a removable tower that can be assembled as a set, and should be able to resist against action loads such as those resulting from dead line, fast line, the weight of tubes, wind, or earthquakes. Masts are divided into three categories based on the rising method: slingshot, swing up and one step.

The lack of a suitable strategy for R&M of drilling rigs caused irreparable mortal and financial losses, examples of which took place in the Gulf of Mexico and the Persian Gulf [28]. The jack-up drilling rigs are widely used in the Persian Gulf. These rigs belong to Chinese, Hindi, Norwegian, and some Iranian companies, which include a wide range of various types of jack-up rigs. Iran currently has 32 jack-up rigs in the Persian Gulf [29].

Every 3 to 10 years (every 5 years, based on the studies), the jack-up rigs have a need for wharf, inspections, and basic repairs. The jack-up rigs have various main components, which are generally divided into two categories: 1) rig structure components such as hull, leg and jacking system; and 2) components that are installed for drilling operations, including various drilling systems such as mud circulation systems. From the beginning, the R&M of components were the concern of rig-owning companies, which have become more important as they have become more complex and more developed [2, 26].

Obviously, Iran has high competitive ability in the R&M market for drilling rigs in terms of appropriate geographic location, depth, proper slope, topography, equipment arrival time to drilling sites, and proximity to equipment production sites, and the biggest existing weakness could be the lack of a proper strategy based on effective criteria.

2.1. Repair and Maintenance Strategy

Porter introduces three strategic bases that are called generic strategies, including leadership in costs, product differentiation, and focus on specific customer groups [30]. The Center for Properties and Facilities of the University of Helsinki analysis showed that the most important questions to be answered for R&M of a structure include 1) What types of tools and information are required for facility management and R&M personnel? 2) How is design data delivered in a project? 3) How do designers and managers find integration facilities and R&M information systems? [31].

For major repairs of oil-drilling rigs, a large space and fixed guiding railways are required, which leads to a failure in R&M operations for small- and medium-scaled marine systems because of the high and inevitable production, transport, and installation costs, and the pollution produced in the environment will be considerable. Therefore, providing the required infrastructure on land is costly, and a new type of R&M is needed using low-volume equipment and lower energy consumption [2, 26].

2.2. Analytical Hierarchy Process

A diverse array of methods can be used for selecting the best strategy for Iran's entry into the R&M market. These methods are divided into two main groups in various procedures in the field of multi-trait models in literature including non-compensatory models and compensatory models. In Non-Compensatory models exchange between the criteria is not valid: the disadvantage of a measure is not compensated by the advantage of the other criteria. Instead, any measure is singly proposed and comparisons are done based on measure to measure; whereas in compensatory models exchange between the criteria is valid. It means a change (probably small) in a measure can be countervailed by an opposite change in another criterion (or other criteria) [32].

Multi-attribute decision making (MADM) methods are one of operation research parts having a rapid growth in the past two decades. A number of tangible alternatives are ranked based on multiple criteria from the best to the worst by these methods. This approach considers theory and methodology of complex issues in management, business, engineering and other fields of human activities [33].

In this research, numerous different factors affecting the proper strategy selection have turned the research problem into a multi-criteria problem. The criteria for a multi-criteria problem can be divided into two categories: The profit-oriented criteria that must be maximized, and the cost-oriented criteria that must be minimized. In this case, the ideal solution maximizes all the profit-oriented criteria and minimizes all the cost-oriented criteria. There is usually no such solution; therefore, a solution must be found that is feasible or justified, but the immediate topic of multi-criteria decision making (MCDM) models is how to obtain the best solution. MCDM methods are divided into two main groups: Multiple objective decision making (MODM) and Multiple attribute decision making (MADM) [34].

In MADM models, the objective is to select the best alternative from the available alternatives. In a general definition, MADM refers to certain preferential decisions such as evaluating, prioritizing, or selecting one of the available categorized alternatives by multiple and often opposite individuals [35]. The analytic hierarchy process (AHP) makes possible the simultaneous combination of qualitative with quantitative criteria [36].

In considering the simple and yet comprehensive nature of this process, it has been welcomed by leaders and different users in the scientific community. The AHP process makes the combination of qualitative criteria along with quantitative criteria simultaneously possible. This process is based on paired or pair-wise comparisons of the alternatives and criteria of decision making. For such a comparison, information from each of the decision makers is required. This makes the decision maker able to focus only on comparing two criteria regardless of any external influence or interference. Moreover, the pair-wise comparison provides valuable information for investigating the problem under study and makes the decision making process rational because the participants compare just two factors and need not pay any attention to the other ones. Having examined the information provided in the filled questionnaires, accuracy of the information should be checked with an Incompatibility Rate (IR) that should be less than 0.1, which is calculated by SPSS software [36].

3. Research Method

3.1. Data Gathering and Analysis

The field studies and research carried out on different constraints and needs associated with existing tools and strategies for R&M of oil rigs show a lack of an appropriate process for decision-making. The lack of sufficient information to evaluate and select an appropriate strategy becomes obvious in terms of R&M for these rigs. Therefore, in order to develop the proposed model based on the adoption of knowledge, the experts in this field were consulted through structured and semi-structured interviews, and for development and implementation of the selected method, the

results were used in the Sina1 drilling rig, which is highly useful in confirming the supplementary information associated with the objectives of this research.

3.2. Survey Tool

The first step in the preliminary study was a semi-structured questionnaire containing 30 questions for identifying the criteria, which was based on the findings of the background analysis and examining the important issues and values for each question, while the primary criteria were examined through questions and answers, and simple data analysis was also carried out through review and categorization.

The purpose of the semi-structured questionnaire format was to avoid the repetitive responses to questions and more flexibility to elicit more reliable responses from subjects. In order to avoid restricting the subjects, the option "other" was also given in the questionnaire, through which the subjects could provide other viewpoints not found in the questionnaire. For this purpose, to collect qualitative information and to gain a better understanding of knowledge on the subjects of the questionnaire, the participants were asked to provide their answers by reason. The questionnaire was divided into three parts, including questions associated with the title of the research, description of the subject, and individual questions. In the section of individual questions, the participants were first asked to provide personal information, including occupation and experience in R&M. This showed their levels of knowledge and experience on the studied topic. Figure 3 shows the position of interviews in the research method.

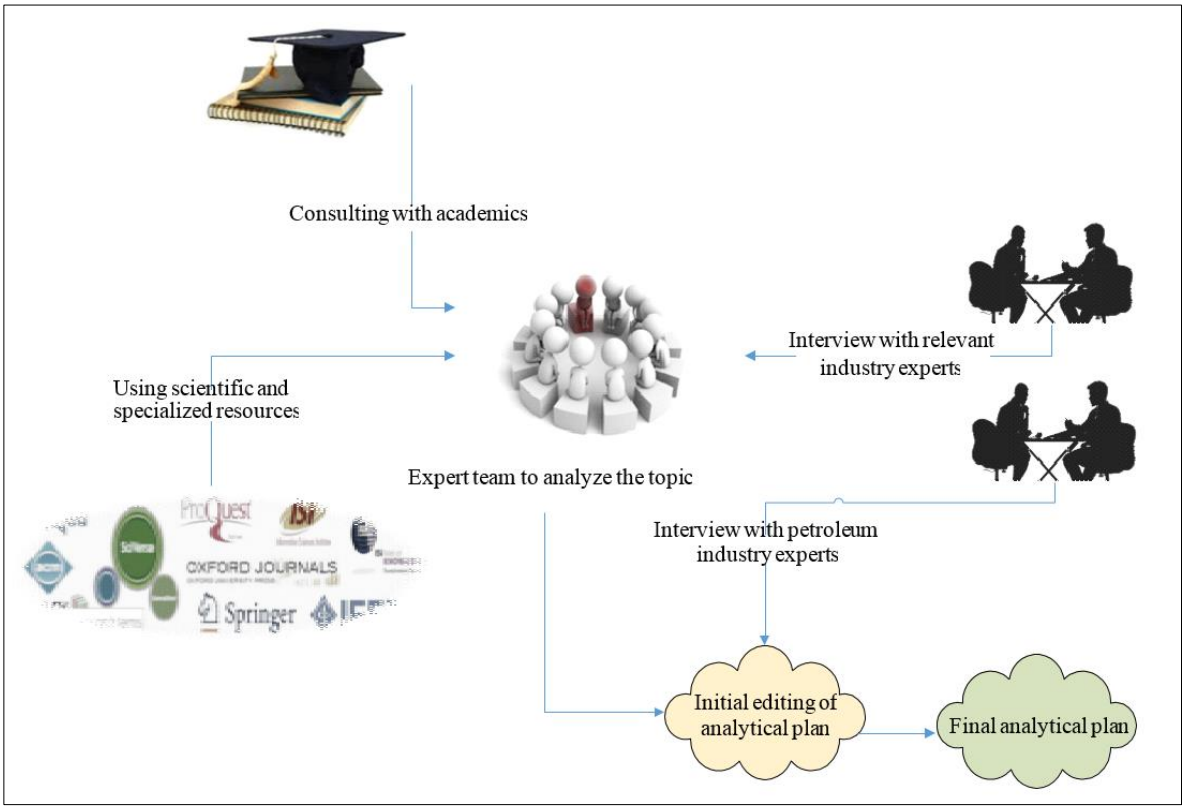

Figure 3. The position of performed interviews in the project of strategies and criteria analyses about R&M improvement of drilling rigs

According to the usefulness of the findings and resource constraints in terms of cost and time, as well as the effect of other factors such as access, work progress follow-up, and information completing speed, three cases of email, in person and phone interviews were used for data generation, validation, and evaluation. The main objectives of this questionnaire include 1) Strengthening validation and classification of effective criteria on reconstruction of drilling rigs; 2) Measuring effect of each of the criteria on determining R&M strategies; and 3) Obtaining additional information that might improve the selection of R&M strategy for decision-makers.

3.3. Characteristics of Respondents

According to Figure 4, a questionnaire was distributed to all stakeholders associated with geographic, social, economic, and various goals regarding the effective criteria in choosing the best R&M alternatives for rigs. Figure 4 shows the research community composition. Simple random sampling technique was employed to select respondents.

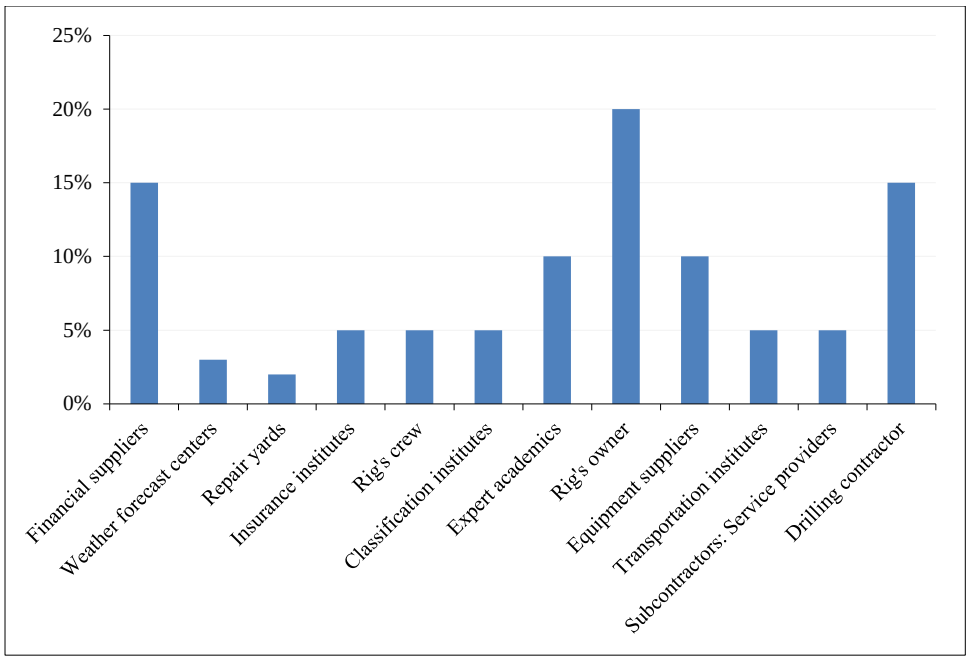

Figure 4. The research community composition

The analysis showed that 65% of the research community believes that by effecting some changes in strategies and creating an appropriate infrastructure, Iran can perform all R&M services for the rigs in its shipyards. Even in case of changes in the strategy, 20% believes that full repair is not possible in the shipyards of Iran while 15% believes that with the same situation, this is possible with no need for change, and only by developing the infrastructure can Iran become one of the main R&M service providers in the region.

When asked to what extent a suitable strategy is effective to turn Iran into the main shipyard of repairs, 51% and 34% considered the strategy to be very important or important, respectively, and 15% believed that with regard to existing infrastructure, strategy is not effective in turning Iran into the repair yard for oil rigs.

With regard to the question of whether previous decision-makers have considered the essential factors in determining R&M strategies, 33% of respondents indicated that previous experience from older projects was effective in determining the choice of strategy, while 47% believed that the choice of strategy is no affected by the key factors, and key factors were not considered; 20% believed that the factors used in the past to choose a strategy were not the correct factors.

Consequently, the analysis showed that most decision-makers rarely consider effective factors comprehensively when choosing a strategy.

3.4. Sample Size Estimation

To estimate the number of interviewees, the Levy and Lemeshow [37] sampling model was employed. It is worth noting that estimating main population through other sampling methods does not differ significantly with this formula. The following formula shows how sample size was estimated:

$$n \geq \frac{Z^2 N V_X^2}{(N-1)\varepsilon^2 + Z^2 V_X^2} \quad (1)$$

In this formula:

$$V_X = \frac{S_X}{\overline{X}} \quad (2)$$

n= sample size, Z= confidence level, N=population size, V_x= coefficient of variation, S_x= Standard deviation, $\overline{X}$ = average, ε = coefficient of error (in this survey equals 0.08)

$S_x = 0.66$, $\overline{X} = 2.77$, $V_x = 0.24$, Z = 1.96, N = 150

Hence the sample size has determined: $n \geq 28.2$

With regard to the confidence interval for collecting questionnaires, 36 questionnaires were distributed. At last, 30 questionnaires were returned and analyzed.

3.5. Decision Analysis through AHP

Invented by Thomas L. Saaty in the 1970s, the AHP method is one of the most famous multipurpose decision-making techniques. This method is employed when a decision action is faced with more than one alternative and criteria. AHP enables us to combine qualitative criteria and quantitative criteria simultaneously. AHP is based on paired comparison or one by one comparison of alternatives and criteria for decision making. For such a comparison we need to collect information from decision makers. This makes it possible for decision makers to focus only on comparing two criteria regardless of any external influence or interference. Moreover, one by one comparison provides valuable information for investigating the problems and leads to a rational decision making process, because the respondent compares only two factors but pays no attention to the other one [38].

It can be said that analytic hierarchy is one of the most comprehensive systems for multi-criteria decision making and has the ability to formulate problems in terms of qualitative and quantitative criteria that is based on paired comparisons which provide the possibility for sensitivity analysis on criteria and sub-criteria. Also this process demonstrates the compatibility or incompatibility rate of the decision: one of the most important features of this technique in multi-criteria decision making that is based on axiom principles [39].

MADM is a method by which a decision-maker would evaluate the classification of a finite number of alternatives measured by variables or features. AHP, a subset of MADM, has seven main stages, including 1) Defining the objective: selecting the best strategy for Iran's entry into the R&M market of oil drilling rigs; 2) Identifying alternatives for rating: determining eight strategies; 3) Identifying effective criteria: determining 15 criteria affecting R&M strategy selection for drilling rigs; 4) Investigating the impact of criteria on alternatives: pairwise comparison of criteria and strategies; 5) Determining relative weight: determining the weight of effective criteria; 6) Ranking criteria based on their weights: rating criteria with respect to obtained weights; and 7) Selecting the best alternative: determining the strategies' weights and selecting the superior strategy.

3.6. Determining Alternatives (Strategies) and Criteria

In this research, the R&M strategies of drilling rigs (alternatives) were divided into eight main categories to determine the best strategy with regard to the specified criteria through two original questionnaires. Hence, 15 criteria were determined regarding choice of R&M strategy through interviews with experts (questionnaires 1), and the effect of each criterion was determined for each alternative (questionnaires 2). Finally, the most appropriate strategy was selected through AHP. In this survey the reliability of the questionnaires was calculated by SPSS software through Cronbach's Alpha method. The method returned a score of 0.92, which indicates the questionnaire is reliable. In questionnaire 1, the criteria's quantities importance within the research scope was determined according to the following numerical scale table (See Table 1).

Table 1. Preferences (Oral Judgment)

Importance	Score
Extreme importance	9
Very strong and demonstrated importance	7
Strong importance	5
Moderate importance of one over another	3
Equal importance	1
Intermediate values between adjacent scale values	2 ,4 ,6 ,8

The results of the first questionnaire, i.e. expert views for identified criteria, were surveyed and 15 criteria affecting R&M strategies selection for drilling rigs, listed below, were identified: Existence or ability to create infrastructure (C1); Potential competition with competitors (C2); Ability to providing the required initial investment (C3); Specialized forces (C4); Better risk-sharing (C5); Domestic demand of country (C6); Technical and managerial knowledge (C7); Ability to attract required knowledge and technology (C8); Compliance with domestic and international laws (political, legal, etc.) (C9); Compliance with characteristics of domestic business space (C10); Profitability to investment volume (C11); Employing previous experience (C12); Foreign market of costumers (C13); Reduced controversy (C14); and Environmental protection (C15).

The Alternatives (strategies) which are considered in this study to select the best R&M strategies of drilling rigs are: Performing all major repairs of rig (A1); Performing repairs under the license of international companies (A2); R&M contracting through joint venture with foreign companies (A3); Providing technical, engineering, management, and software services (A4); Manufacturing and supplying components for repair of rigs (A5); Purchasing stock of foreign companies or their ownership (A6); Transferring all R&M services to foreign companies (A7); and Providing transport services to the yards in the area (A8).

4. Ranking Criteria and Determining the Superior Strategy

It is clear that each strategy has specific strengths and weaknesses. Therefore, at the time of selecting the best strategy, the owner should explore a method that brings highest value for money spent. To achieve this, first, the employer must carefully identify various approaches to strategies and their specifications and then determine the project's requirements and available capabilities.

In the second questionnaire, the expert respondents choose a number between 1 and 9 for the criteria in each strategy with regard to the paired comparison. In this stage after collecting the second questionnaire, the score of each strategy was determined and arranged in descending order based on their top score. An example of a completed questionnaire can be seen in Table 2, which compares 15 criteria to select the most appropriate R&M strategy for drilling rigs. "Potential competition with competitors (C2)", for instance, is a little more important than "ability to attract required knowledge and technology (C8)", hence number 3 is entered into the table. Another example is the pairwise comparison between "specialized forces (C4)" and "better risk-sharing (C5)" that shows C4 is a little more important than C5, so ½ is entered into the table. This is how Table 2 should be filled. Ultimately, the Inconsistency Ratio (IR) of the questionnaire is found to be 0.08, which is less than 0.1 and therefore reliable.

Table 2. An example of a completed questionnaire

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15
C1	1	2	2	5	4	6	5	4	8	9	9	5	4	9	9
C2		1	2	6	2	4	2	3	5	4	9	3	5	9	9
C3			1	5	2	1.5	2	5	7	5	6	5	4	7	9
C4				1	½	½	½	1.5	4	2	3	5	4	4.5	8
C5					1	2	4	5	6	9	8	5	6	6	6
C6						1	2	2	4	7	9	3	5	6	5
C7							1	2	7	6	5	6	3	7	8
C8								1	5	3	5	6	4	7	9
C9									1	½	2	2	2	2	2
C10										1	2	2	2	5	5
C11											1	2	2	2	4
C12												1	2	3	2
C13													1	2	5
C14														1	2
C15															1

At this stage of the investigation, the importance of the effective criteria on the selection of the most appropriate R&M strategy for drilling rigs is obtained using the AHP method and Expert Choice software, based on obtained weights. After applying the ideal synthesis, the weights of criteria are divided into the weights of alternatives and thus the sum of relative weight of each alternative for each criterion equals the weight of that alternative. The numbers in the Figure 5 show the rank of each alternative. It is clear that "performing all major repairs of rig" (A1) has received the highest score (0.333).

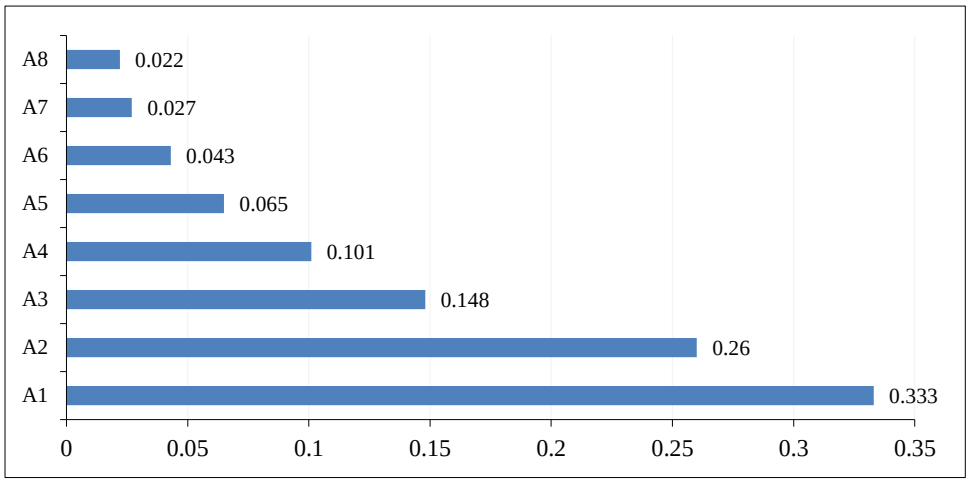

Figure 5. The rank of the strategies (alternatives)

Figure 6 shows the importance of criteria affecting the selection of the most appropriate R&M strategy for drilling rigs based on obtained weights. Obviously, "existence or ability to create infrastructure" (C1) obtained the most score (0.211) and identified as the most effective criteria.

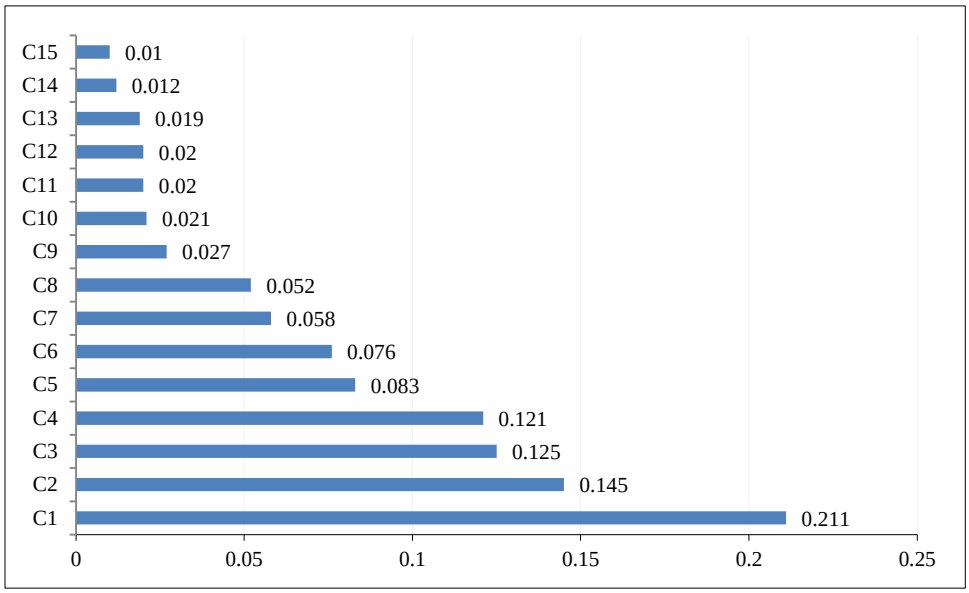

Figure 6. The rank of the effective criteria

5. Data analysis

Most drilling rigs in Iranian gas and oil fields are sent to the states of the Persian Gulf, which costs a lot of money. On the other hand, the repair of several drilling rigs such as Sina1 inside the country indicates the domestic ability of Iran with respect to this industry. Hence, providing a proper strategy for domestic repairs is essential, which will in turn increase the capability of Iran to repair the rigs and even provide technical services to other countries.

5.1. Performing all Major Repairs of Rig (A1)

The results of this research indicate that the most suitable strategy for entering the R&M market for drilling rigs is "performing all major repairs of rig" (A1) with obtained score of 0.333. Regarding the valuable experience obtained from repair projects carried out in Iran, as well as the problems in dispatching the rig to foreign countries (such as lack of permission for rig departure from the yard before full payment); in case of several other repair projects in the country, the domestic capability in this market will be strengthened, and Iranian contractors will be able to compete with foreign rivals, at least on the Iranian rigs. It can be said that with regard to the facilities, geographic location, and effective criteria, Iran could turn into the major yard for R&M oil rigs for Iranian platforms, but under these conditions, it should be noted how the existing infrastructure can be exploited. Therefore, the division of labor and specialization are required to avoid wasting resources. For example, a large yard such as ISOICO focuses on service and repair of the rig. The resources, infrastructure, and facilities must also be integrated, and coordination between companies that can provide R&M services is required; this coordination needs a leader to provide an opportunity to collaborate with other companies and develop a strategy, and on that basis the tasks of each company are explained. The components and equipment of the drilling rig can be supplied by China, and most of the components required for rigs, even the American ones, can be provided by China. The United Arab Emirates is also considered for supplying equipment and having large warehouses and inventory, which are given to the consumers quickly. In some technical activities such as welding in certain conditions, the Indian forces have high potential, and providing these forces for some complicated repair works for rigs is not so difficult. The Indians have also highly valuable experience in the field of offshore oil and gas activities, and hiring them as consultants for repair and modernization of rigs is very effective for communicating with foreign suppliers, as well as proper management of the project.

However, due to the large number of foreign rivals in the Persian Gulf region, it can be concluded that competition for customers from other rival companies is rare. Even the foreign rig owners in the waters of Iran often do not rely on Iranian yards for repair because the owners of these rigs have good communication with foreign yards. The foreign companies, especially UAE companies, have proven experience and background in terms of knowledge, structure, and management. Each of these yards has created a good trust and background for their customers, and the history of operational and repair information of the repaired or upgraded rigs leads them to have consistent repeat customers.

5.2. R&M Contracting through Joint Venture with Foreign Companies (A3)

According to the results of this research, "performing repairs under the license of international companies" (A2) and "R&M contracting through joint venture with foreign companies" (A3) have the second and third priorities, respectively.

One of the shortcuts to reach regional and even global markets is to use the experienced foreign consultants, licenses, or partnerships, and in the case of lifting sanctions and having good relations with advanced countries, European partners in this regard will quickly develop their domestic consulting engineer companies and achieve a larger share of the R&M market. In order to begin partnership with foreign parties, confidence-building plays an important role that requires long-term communication with the other party. After confidence- building and meeting the interests of the other party, technology can be gradually transferred from the foreign party into the country.

In conclusion, it can be said that establishing yards, infrastructure, technology, and knowledge required for repairing jack-ups and floating rigs and investment in this sector is a necessity for Iran. Due to the advantages in Iran, this is certainly an economic industry. In order to improve this industry, the productivity of existing facilities should be managed by the companies with this capacity in a consortium, and working alone should be avoided. The foreign experts and internationally experienced companies should be used in partnerships. In the end, it should not be expected that ideal conditions of productivity and economy will be achieved in a short period, but also this requires time and cost.

To get started in this industry, paying attention to the advantages and abilities of Iran in terms of the repair of body, structure, and legs of rigs is necessary. First, it is better to focus on providing these services for rig owners. The light and medium repairs (repairs lasting less than three months with a cost below $10 million) or meeting the requirements of classification inspections can be considered as a business strategy, especially in the early years of entering the rig repair market. As noted above, the affordable light and medium-scaled repair projects can be justified at least for annual classification inspections, even in a recession, and there is high demand for such projects. Therefore, success in this industry rests on linking the three sides of the attention triangle to the advantages and abilities of the country, attracting participation foreign experts and companies and entering a high-demand service market.

6. Case Study of Repair and Maintenance of Sina1 Rig

It is necessary to investigate the factors affecting the economic costs of jack-up repairs for accurate planning in order to meet the desired goals. The economic evaluation of major jack-up repairs in the oil industry section is highly important for planning, as well as developing strategies and recommendations. Comparing the cost of major repairs inside and outside the country can be a suitable measure of the economic evaluation of such projects inside and outside the country, which has been addressed in this study. In addition, the cost of repair and transport of jack-ups in another country is considerable, and also there are companies in Iran that are highly capable of working in the engineering, procurement, and construction sectors. The strategy defined in this research (A1) was used in the R&M of Sina1, which was a jack-up, leading to the following results.

Successfully performing major repairs of Sina1 rig is a noticeable lesson learned in terms of Iran's entry into the R&M market of oil drilling rigs. Therefore, the necessity of this research is more and more evident, considering the need for strategic planning for the entry into and intelligent presence in the market of major repairs and also the vital role of a strategy as one of the stages of strategic planning. One of the research limitations was lack of resources explaining detailed service costs to achieve more accurate results. In addition, studying resources and websites could not provide much information related to costs. It seems this kind of information is considered confidential. So the cost of repairing rigs is presented in general. The stakeholders of the upgrade and renovation project of Sina1 rig are listed in Table 3:

Table 3. The stakeholders of the upgrade and renovation project of Sina1 rig

Stakeholder Company	Stakeholders in Sina1 Project
Drilling contractor (or his representative)	PetroGohar Co.
Subcontractor	Andishe & Omran Mohit Co.
Rig's owner (or his representative)	Sepanir
Classification institute	Iranian classification institute.
Insurance institute	Dana insurance Co.
Repair yards	ISOICO
Reliable weather forecast institute	OujPajouhesh institute
Financial support	Sepanir

Sina1 drilling jack-up with a power of 2000 horsepower is among the leading drilling machines in drilling in several phases from the massive South Pars gas field. Drilling at a depth of 300 m is one of its features. This jack-up is the first drilling rig that has been repaired completely by Iranians at ISOICO.

The Iranian oil industry specialists were able to conduct basic repairs of the Sina1 drilling rig within seven months. The activities carried out in the project of major repairs of Sina1 drilling rig include thickness measurement, repair of main and gantry cranes, repair of diesel generators, inspection and repair of piping systems, design, production and installation of emergency and capacitive switchboards, and repair of rig legs.

The repairing cost of this rig was about $11 million. According to Figure 7, major costs include the cost of structural repairs, the cost of equipment repairs and miscellaneous expenses. Figure 8, 9 and 10 show the detail of these costs. The highest cost was incurred by repair of rig legs, which accounted for about 65% of structural repairs cost and 42% of the total cost, which was due to the purchase of expensive raw materials for this section. Another point in repair of rig legs was the repair time, which lasted about 4 months and could compete with outside of Iran with regard to the number of replaced braces. The coastal services with 13.9%, washing, NDT, painting legs with 9.3%, and repair and replacement of the EMD and CAT diesel generators with 6.7% after the repair cost of the rig legs, respectively, make up the largest share of the total cost of major repairs.

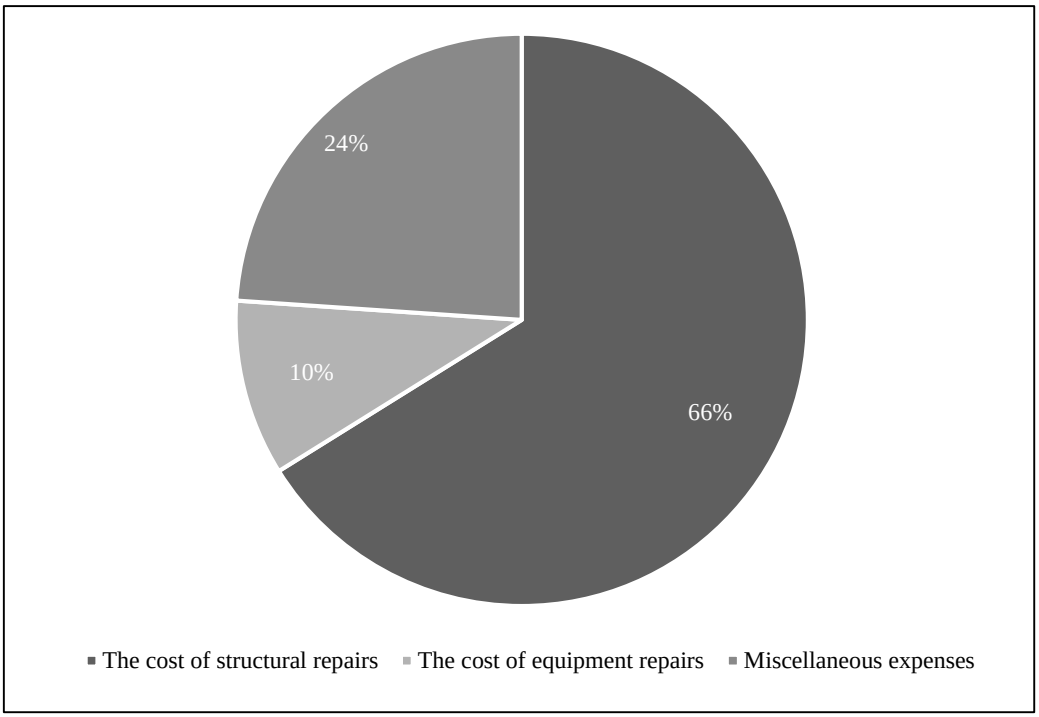

Figure 7. Main costs of major repairs in Sina1 rig repair

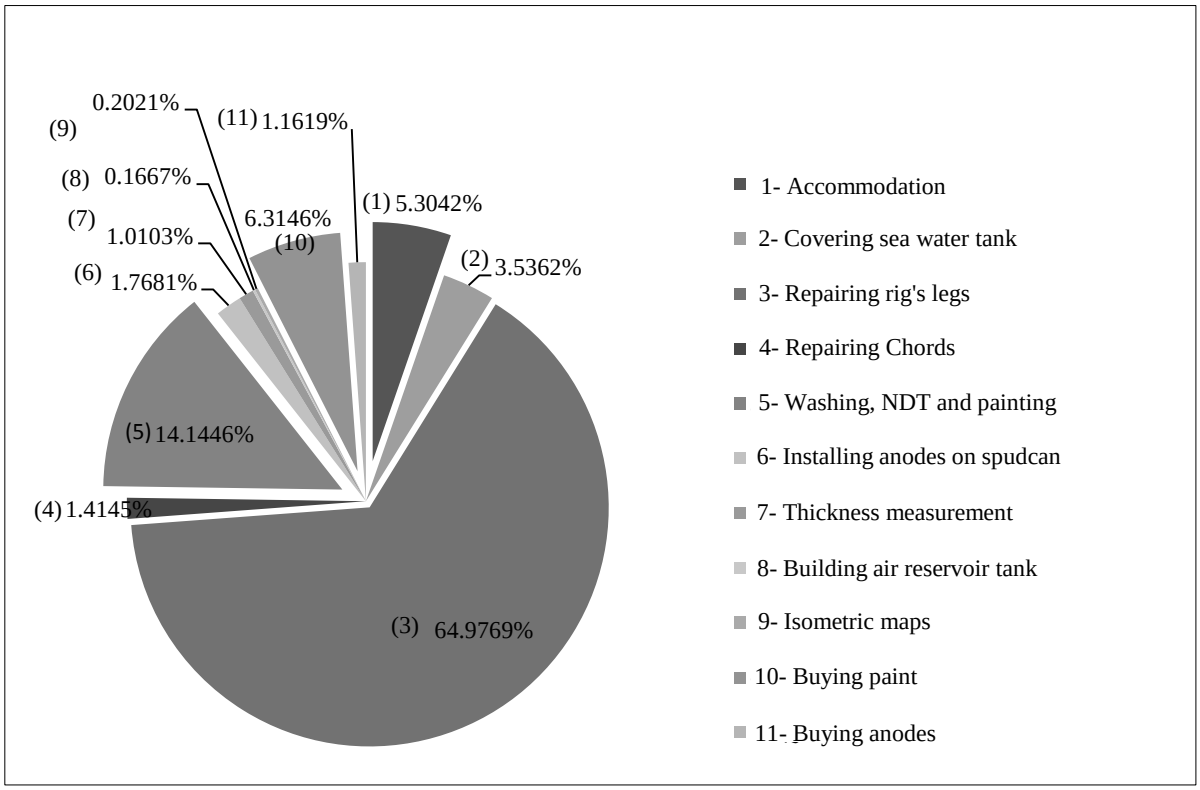

Figure 8. Details of structural repairs cost in Sina1 rig repair

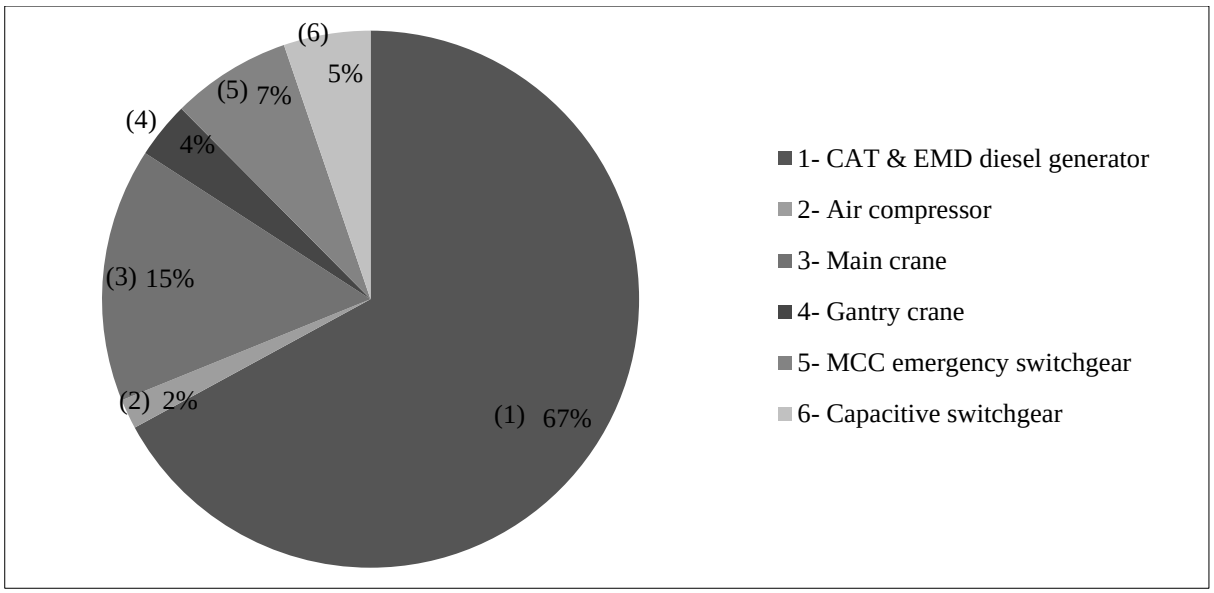

Figure 9. Details of equipment repairs cost in Sina1 rig repair

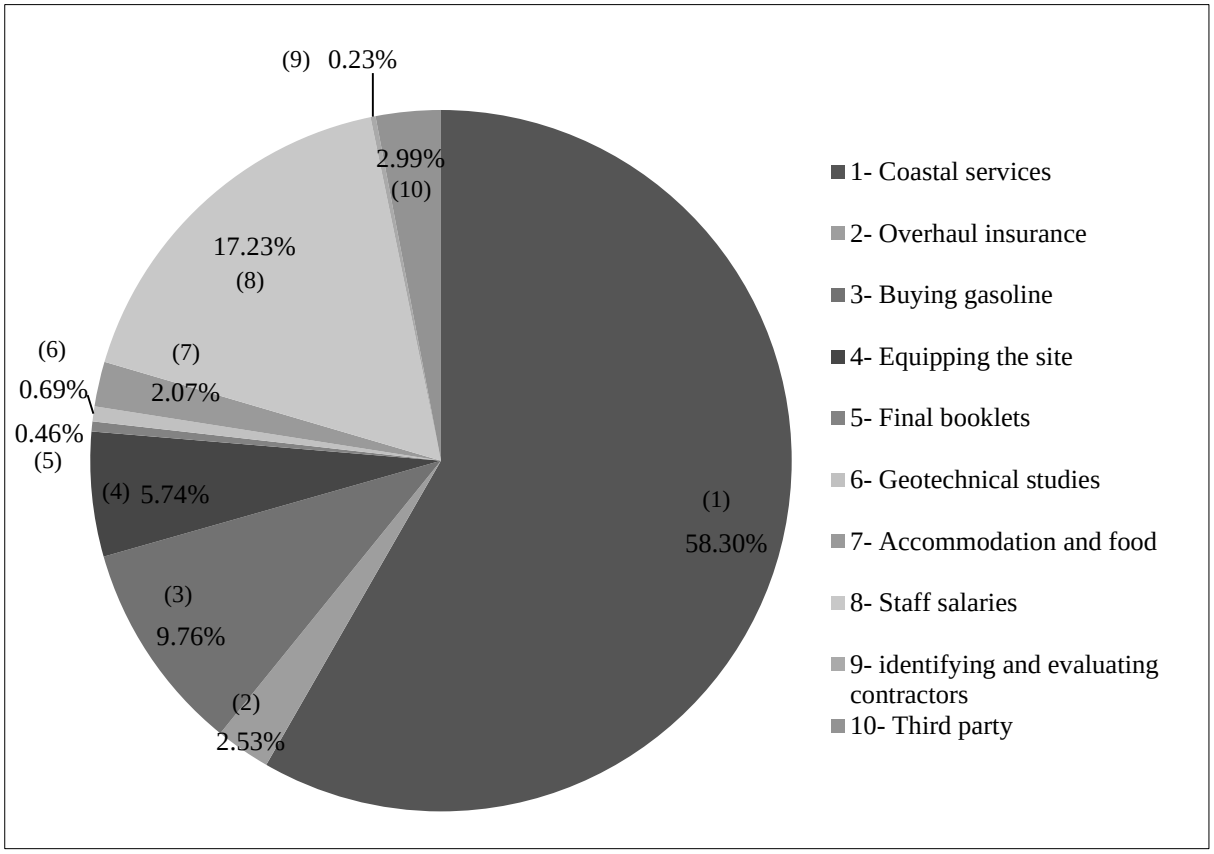

Figure 10. Details of miscellaneous expenses in Sina1 rig repair

The average cost of major repairs of a major Iranian jack-up outside Iran is 15% greater than repairs done in Iran. The average cost of major repairs of a necessary jack-up motor and a jack-up diesel generator had 30% and a jack-up compressor had 40% lower costs than yards in the Persian Gulf, which is also considerable. In addition, there are also other advantages such as guaranteed facilities and duration of repairs in this section inside the country, compared with yards of the Persian Gulf that have made these repairs quite competitive with those outside the country.

In Figure 11, the cost of major repairs of Sina1, which the proposed strategy in this research has used for its repairs, has been compared with costs of the repaired rigs outside of Iran and the global average for similar services, which indicates that costs are below the global average, indicating the success of these repairs in the country. It is also

noteworthy that the experience obtained from this rig inside the country will certainly lead to further reduced prices in major repairs for other rigs.

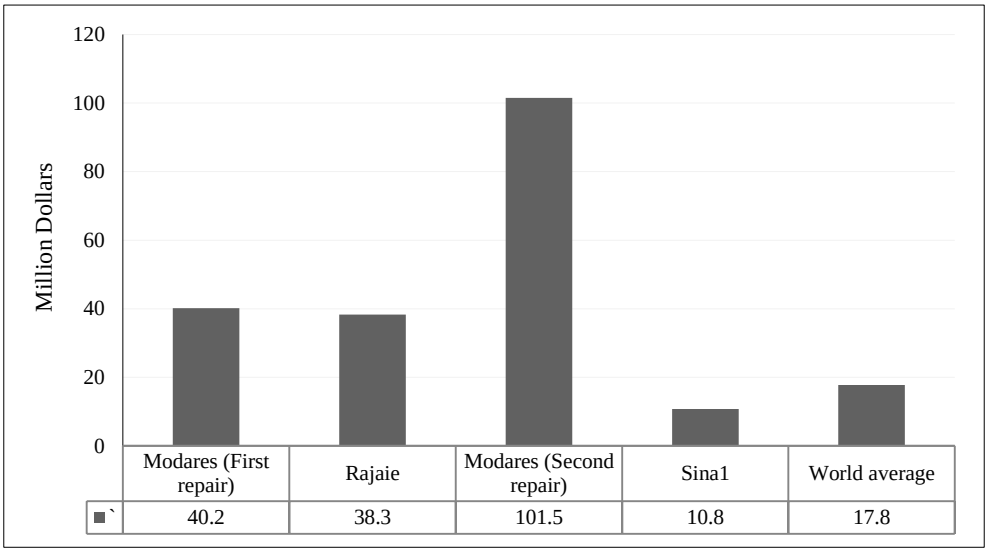

Figure 11. Comparison between the cost of major repairs in Sina1 rig and world average and Iranian repaired rigs in foreign yards

By comparing the major repairs in the repaired domestic rigs to foreign yards as well as repaired foreign rigs, it can be seen that the total cost of Sina1 was affordable in Iran, with much lower cost in proportion to the amount of work. The average cost of major repairs in foreign rigs is $17.8 million, while the major repairs of Sina1 rig is nearly $11 million, which was approximately 40% below the global average. A comparison between the repair cost of Sina1 with Iranian rigs such as Modarres and Rajaei, which have been carried out in foreign yards, also shows the low cost of repairs in Iran and its economic justification. In general, in order to compare the basic repairs of rigs, determining the working field of the rig is highly important.

Regarding the repair costs of main and emergency engines and generators, based on interviews carried out with industry experts and contractors involved in the Sina1, there are some significant points, as described below:

The average cost of supplying foreign components to domestic yards is 10-20% higher than foreign yards with respect to the issues of sanction and transfer costs, while the foreign yards demand higher profit regarding the sanction conditions.

Based on the experience of the repair of Sina1, various costs in the jack-up equipment repair was different based on the type of equipment; for example, the motor accounts for 15%, while human resources and other components account for 85% of the cost. The domination rate of domestic experts in repairing various parts of jack-up was very high, and Iranian experts can completely repair the jack-up in most cases, but there is no possibility for purchase and supply of all the jack-up components inside the country in its present situation.

The costs of labor and productivity are among the factors affecting the activity of the yards. The labor cost in the yards of the Persian Gulf is almost twice the labor cost in Iranian yards. Given the high cost of labor in the yards of the Persian Gulf, Iran has a significant advantage compared to the Arab states. However, it should be noted that the level of productivity in the Iranian yards is lower than in the yards of the region, the main cause of which is poor management and governmental affairs. Therefore, using the advantage of human resources and making the yards efficient, the R&M cost can be reduced so the industry can become more competitive. The cost of major repairs of the equipment inside the country is much lower than that of the yards of the Persian Gulf. For instance, comparing the average cost of major repairs of an emergency jack-up engine and a jack-up diesel generator inside the country was significant compared to the repairs in the yards of the Persian Gulf, and a difference in cost of 30% can be seen in both cases. The average cost of major repairs of a jack-up compressor is 40% lower than the yards in the Persian Gulf.

There are currently 140 drilling rigs in the Persian Gulf, 32 of which belong to Iranian companies. Due to the nature of the waters in this area and high activity of jack-up rigs in the Persian Gulf, these jack-ups require major repairs every five years, which have been carried out so far outside of Iran that, in addition to huge costs, it results in the dependence of the country. Due to the large of number of such rigs in Iran, localizing these repairs can save millions of dollars per year, and the major repairs of Sina1 offshore drilling rig is an example.

The major repairs in Iran create employment and strengthen domestic contractors, followed by importing currency into the country, contributing to the country's political relations, and many other interests. It should be noted that these

goals are in line with the resistance economy. The most important goals of repairs after competing with other countries also include increased technical engineering services, high added value and profitability, upgraded and increased ability of engineering and technical units, and as a result, the growth of this industry in terms of reputation, new technologies, and essential skills for the development of the country.

7. Conclusion

It is clear that each strategy for entering the R&M market of drilling rigs has advantages and disadvantages. Therefore, the employer should find a strategy that yields the highest value for the cost. Meeting this standard requires careful identification of various strategies for R&M of drilling rigs and the characteristics of each strategy, and then determining specific conditions in Iran and its existing capabilities.

In this regard, the most effective criteria for decision making to select the superior R&M strategy for drilling rigs were identified through questionnaires. Then, the reliability of questionnaire was calculated using Cronbach's Alpha and SPSS software, which yielded a parameter of 0.92 magnitudes. In the following, AHP methodology and Expert choice software were utilized to select the best R&M strategy for drilling rigs. The results are:

The rank of alternatives:

1. Performing all major repairs of rig (A1);
2. Performing repairs under the license of international companies (A2);
3. R&M contracting through joint venture with foreign companies (A3);
4. Providing technical, engineering, management, and software services (A4);
5. Manufacturing and supplying components for repair of rigs (A5);
6. Purchasing stock of foreign companies or their ownership (A6).
7. Transferring all R&M services to foreign companies (A7); and
8. Providing transport services to the yards in the area (A8);

The rank of identified criteria:

1. Existence or ability to create infrastructure (C1);
2. Potential competition with competitors (C2);
3. Ability to providing the required initial investment (C3);
4. Specialized forces (C4);
5. Better risk-sharing (C5);
6. Domestic demand of country (C6);
7. Technical and managerial knowledge (C7);
8. Ability to attract required knowledge and technology (C8);
9. Compliance with domestic and international laws (political, legal, etc.) (C9);
10. Compliance with characteristics of domestic business space (C10);
11. Profitability to investment volume (C11);
12. Employing previous experience (C12);
13. Foreign market of costumers (C13);
14. Reduced controversy (C14); and
15. Environmental protection (C15).

Finally, the superior criteria and strategies determined in this research were used in R&M of Sina1. Comparing the results with those for Iranian rigs such as Modarres and Rajaei, the repairs of which were carried out in foreign yards, yields the following results:

The total cost of Sina1 repair was affordable in Iran, with much lower cost in proportion to the amount of work and nearly 40% lower than the global average. Comparing the repair of Sina1 with those of Iranian rigs such as Modarres and Rajaei carried out in foreign yards indicates the low cost of domestic repairs and the economic justification.

According to studies, despite the fact that Iran has the most of the infrastructure required for R&M of the jack-up rigs, this infrastructure still needs to be completed. It is suggested that the research on the infrastructure required for optimal implementation of A1 strategy should be done based on cost-benefit theory. It is also suggested that by dividing the level of repairs based on the costs into 3 groups of small, medium, and large, an appropriate strategy should be determined with regard to the infrastructure of each group.

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9. Conflicts of Interest

The authors declare no conflict of interest.

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