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Improving the Performance of Gas Extraction by Reducing the Shutdown Time Using an RCA-based Approach–A Case Study

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ABSTRACT

To continue gas production at the South Zagros Oil and Gas Production Company, which is the understudied case, several factors for reducing the stoppage of production are faced. This indicates that the root cause analysis (RCA) of the equipment related to gas production (control panels) is required since it has been widely adopted as a central method to learn from mistakes and mitigate hazards. Using an efficient and effective method in RCA, one can determine the cause of the failures. Thus, this study aims to apply an appropriate RCA-based approach to reduce the failure factors and subsequently improve the performance of gas extraction in the understudied context. After reviewing the records of the past research, and according to the Ministry of Petroleum Implementation, the root cause failure phases of the equipment (control panels) were systematically carried out. Initially, the RCA team consisted of specialized experts in the region. After collecting the required data, the group began the research process and discovered the physical, human, and unknown causes using the logical tree method and the PROACT approach. Once the hypotheses have been validated, the root causes of equipment failures are ultimately identified. The analytical team has come up with solutions and then prioritization of them in the final stage. The findings revealed that identifying and overcoming the root causes of equipment failure will save on the organization's facilities and costs, and subsequently sustainable production of gas that is particularly susceptible to various problems.

Keywords:
Root causes analysis; PROACT method; Logical tree; Wellhead control panel; Oil and gas production sustainability

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1. Introduction

The oil and gas industry has been a major contributor to the global economy for decades; however, the industry has been facing challenges in recent years due to the depletion of conventional oil and gas reserves, increasing environmental concerns, and the emergence of alternative energy sources. To address these challenges, the industry has been focusing on improving the performance of gas extraction; thus, such industries must improve their performance to address current challenges

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and transition toward sustainable development [12]. One way to achieve this is through the adoption of effective tools and innovative practices [13,36].

Root cause analysis (RCA) serves as a valuable tool for identifying and addressing underlying causes to enhance performance, safety, and environmental stewardship in the industry. According to Jayswal *et al.,* [15], this methodology is able to help the designers focus the attention on the most important fundamental causes, discover opportunities for sustainability improvement and provide critical guidance to design for sustainability. RCA is a structured process to identify the cause and effect relationships in an organization with the aim of preventing the repetition of failure or reduction of its effects [13]. Due to many influential factors, the complex nature and specific delicacies existing in industrial processes provide solutions to prevent the repetition of many unpleasant incidents. This requires technical and expert inspections and an efficient and technical standard method. One of the most standard and genuine methods in this field is the use of RCA [31].

Nowadays, the RCA method is an integrated part of various industries such as aerospace, nuclear, oil and gas, electricity and telecommunications, and mining. In oil and gas companies, a frequently used approach to learn from previous disruptions is to perform RCA [2,25]. This is a process of investigation aimed at understanding the reasons behind a disturbance by identifying its underlying causes, or "root causes." [24]. After identifying the root causes, appropriate countermeasures can be proposed and implemented to eliminate them. This process guarantees that the production system won't be disrupted by the same issue in the future. If it does happen again, its impact will be reduced to a minimum [3]. This process could offer insights for creating more resilient and sustainable production systems, with a focus on enhancing operational efficiency [5,8]. Despite their best efforts, companies often face production disruptions during their day-to-day operations. It's not uncommon for them to experience up to a hundred such disruptions in a single day [31]. It is highly probable that a considerable amount of these disruptions have been encountered previously [30]. It appears that there is a requirement to enhance the RCA process. Taking this step could assist manufacturing companies in increasing their capacity to acquire knowledge from past disruptions and ultimately result in the creation of more robust and environmentally-friendly production systems [13,16].

The South Zagros Company is one of the upstream companies in the oil and gas industry in Iran, which supplies gas to Bandar Abbas gas refinery. All refinery processes will be disrupted if the gas is shut off. The selected tool for RCA is Wellhead Control Panels. This tool plays a vital role in gas production facilities. All wells in the area have safety valves, which are responsible for the opening and shutting of the valves. If the safety of the wells collapses, the equipment automatically shuts off the production of gas and prevents possible casualties. The main problem is when there are unsafety conditions. If an error occurs in the internal circuit of a control panel, the equipment will be out of service and will cause the gas to shut off. In this case, we face many failures and incidents. One of the most critical tasks of the top managers in the industry is to preserve and protect the national capital. Hence, an in-depth view of failures and incidents is a necessity. The RCA analysis will help identify the root causes of the problem; however, it requires the use of the right mechanism to implement it [2,31]. Therefore, the principle of the failure of the equipment associated with gas production is fundamental to perpetuating the gas production in South Zagros Oil and Gas Production Company. By using efficient and effective RCA methods, it is possible to figure out the causes of the failure. Finding the root causes of equipment failure increases reliability and reduces gas production with fewer risks. Thus, this research is aimed at identifying the existing methods in root cause failure analysis; choosing the appropriate method to determine the failure of the equipment; implementing the selected method for equipping and studying the causes of failure; and providing an effective solution to reduce equipment failure and reduce production stop times.

To meet the research objectives, this article is organized as follows: Section 2 provides an overview of the literature; Section 3 presents the research methodology to clarify the procedures and methods utilized; Section 4 discusses empirical findings contributed by the analyses in the understudied scope; and finally, Section 5 outlines conclusion and recommendations.

2. An Overview of the Literature

The main reason for the inspection and reporting of the causes of casualties is the ability to identify necessary corrective actions to prevent the recurrence of casualties, as a result, to protect the health and safety of the community, workers and the environment [33]. Root cause analysis (RCA) is a problem-solving method that became popular with the implementation of the Toyota production system and the lean manufacturing approach, which assists manufacturing companies in their continuous improvement processes, particularly in areas such as production cost, productivity, quality, and maintenance [1,10,20]. RCA is an investigative process that takes place after a production disturbance occurs. Its main objective is to identify the root causes of the issue and implement corrective actions [3,24]. The root causes are the fundamental and underlying reasons behind a disturbance [28]. To fully get rid of a disturbance and prevent it from happening again, it's important to address the root causes and eliminate them instead of just dealing with the immediate and visible symptoms [27].

The process of RCA is usually carried out by a team comprising individuals from varied fields of expertise [24, 28]. During the process of conducting RCA, groups may utilize various tools and methods to identify the root causes. Some commonly used techniques include the Five Whys, Fishbone Diagrams, Cause and Effect Analysis, Fault Tree Analysis, and Six Sigma [9,14,23,27]. In manufacturing companies, RCA can be conducted in various ways and with different phases. However, the process typically involves four phases: (1) identifying the problem, (2) collecting data, (3) identifying the root causes, and (4) identifying and implementing countermeasures [13,21,36].

Experiences in the industry show that each adverse event has an average of 10 to 14 cause and effect relationships, which are modeled in a specific way to occur. This eliminates the common delusion based on the fact that an error results in a final undesirable outcome [2,18]. Based on [18], all the adverse events and outcomes have a root in physical, human, and unknown fields. *Physical roots* – these roots occur very soon due to the presence or absence of errors and are the first physical consequence as a result of human decision-making errors. The physical roots are tangible. *Human roots* – these roots are decision-making errors and occur in both the planning and execution stages of a task. Plans can be adequate or inadequate, and actions (behavior) can be intentional or unintentional. Human roots are related to the presence or absence of human beings. *Unknown roots* – these roots are organizational systems that have been defective. These systems are support systems (i.e., procedures, training, incentive systems, purchasing habits, etc.) that are usually created to help the workforce make better decisions. The hidden roots are meant to express the decision-making process of humans.

To this end, Nelms [26] introduced the domino theory to investigate the causes of failure, which is divided into four categories: physical causes, human causes, unknown causes, and root causes. The result of this study is that the main causes of failure occur in the fourth layer (the root causes), and in most cases, the maintenance engineers do not go beyond the first layer. Vinnem *et al.,* [34] analyzed the root causes of leaks in offshore oilfield facilities. In this study, all causes of leakage between 2008 and 2014 were reported. Antony Harison *et al.,* [4] analyzed the root causes in the failure of wind turbine blades. In the research, various methods such as visual, stereomicroscopic, and metallographic tests were performed, but based on chemical analysis and hard tests there was no evidence of failure. After analyzing the results obtained from the different methods, several holes existed in the edges of the blades containing chlorine. As a result of these holes, cracks were formed in the thinner parts of the blades. The presence of chlorine and silicon in these cavities showed that the cavities were formed due to corrosion and the failure of the blades were the outcomes of corrosion fatigue. Scolnick *et al.,* [29] used root cause failure analysis to resolve the operational errors in the separation of deep wells, especially in the Gulf of Mexico in offshore areas. The method used in the study was such that they conducted a detailed analysis of the problems leading to cement failures by the analytical team. A team of engineering and operational personnel conducted the analysis for a period of 3 months. The team identified the key indicators needed for analysis and developed a tool for monitoring, tracking and adjusting operations based on variations in these indicators. The result of the above research indicates that transferring the knowledge to the drilling team, resulted in the successfully division of the region. In general, according to Viveros *et al.,* [35], the RCA process sometimes lacks a systematic approach for defining countermeasures and assessing their effectiveness. This can result in ineffective countermeasures being implemented, failing to eliminate root causes. To improve the process, it should be made more efficient and effective in defining and implementing actions that prevent the recurrence of disturbance.

Practitioners are still facing challenges in conducting root cause analyses efficiently and effectively. However, the literature on this subject appears to be scattered. It is necessary to publish materials that summarize the present research and make the information more easily accessible to practitioners, while also providing academics with details on further developments.

3. Methods

3.1 Examining and Identifying Various RCA methods

Considering the variety and number of RCA methods, the discussion in this context is very vast. Thus, in this section, an overview of the most important RCA methods is firstly presented based on Doggett [6] and Gano [7] since understanding different RCA methods helps select the appropriate method for analysis.

Change analysis–This method identifies and systematically analyzes any changes that may have occurred in the development of the problem. If the change is the cause of the problem, the tool will check what has changed from previous situations and what effect the change has on the event. From the name of the analysis, it is clear that it looks at the deviation from the optimal situation. Therefore, for the proper use of this tool, two things need to be specific: Optimal situation - Deviated state from optimal. By comparing these two situations, changes can be seen, and then each change is considered as the probable event to be examined.

Barrier analysis–The barrier analysis is based on the "risk identification" science, which may affect a target (personnel, equipment, or environment) due to potential risks, and therefore should protect them from the possible risks. Obstacles (physical and organizational) are used to preserve a specific target within the designated range. The use of obstacles is irrespective of the risks. Obstacles are usually designed within systems or are planned within specific activities to protect individuals, equipment and the environment [19]. The purpose of barrier analysis is to identify the barriers that are lost or distorted from the optimal situation. This analysis can also identify obstacles that have worked well and prevented the occurrence of accidents.

Event and Causal Factors Analysis–This chart begins with the questions "What? How? Why?" and focuses on them, during the study of root causes, which is continued and updated. This is done by describing the problems and causes. This tool helps to identify what is known and what is necessary to know in historical order, thus paving the way for further research. Moreover, an "event" is defined as a cause or situation at a given time point relative to the problem that is considered. In addition, the term "conditions" is a reason that influences the chain of events.

Cause and effect analysis–This method identifies the root causes of an incident or event by examining the cause and effect relationships. This is done through repeated questioning "What has happened and why?” To implement this method, one must start from the end. Therefore, it should take into account the latest failure or undesirable event and, accordingly, over time, return to discover the root cause. This is a method for researching and exploring the details of cause and effect relationships by creating a virtual image of all possible ways that can create undesirable conditions. By this method, a model for reconstructing the event can be created in the form of a logical tree analytical diagram also known as a fishbone diagram. This tree depicts all possible mechanisms of failure through scientific research and approves or rejects mechanisms until the initial failure mechanism is defined and determined. This method is recommended for events related to equipment.

5 Whys method–This technique is a question-based technique that looks at the causes and effects of a particular problem, and its ultimate aim is to identify the root cause of failures of an event. The procedure for this methodology is a five-time sequencing question, "Why?” The root causes discovered in this way are followed by a set of sentences with the phrase "so". The investigator must continue to ask the question to go beyond the scope of the review or to determine whether the failure is fixed outside the organization's control. It should be understood that while some analytical processes emphasize the root causes of a certain number of questions, this method repeats the question "Why?" until the discovery of the root cause. This method can be repeated more than 5 times.

Failure Mode & Effects analysis–This is a systematic process through which all possible failure modes and their associated effects are identified. It can be used in processes but its common practice to use this method for technical applications. This analysis involves reviewing schematics, engineering designs, and operational routines to identify the basic errors at the lowest level, and eventually identify their effects at the highest level. In this analysis, failure modes can be prioritized based on the effects and outcomes, the frequency of occurrence, and their identification. This will cause a number of failures that are of less importance to be removed from the list of failures that need to be managed in the system.

Pareto analysis–This method is a statistical approach to problem-solving, which uses a database of issues and problems and identifies some of the predetermined factors that occur in the system. This method is based on the Pareto principle, which is also known as the 80-20 rule. This analysis has the purpose to allocate resources to the most common and important factors. Although this analysis is not properly used in many cases, Pareto can be used to determine where to begin the RCA.

Table 1 shows the comparison of the RCA methods discussed. By studying the different RCA methods, one can conclude that the logic tree method is a very suitable method to analyze the root cause failures of the equipment, which provides all of our research needs. Among the reasons for choosing this method, one can point out a graphical representation of cause and effect relationships, which was referred to as complex analysis such as progressive failure analysis (case study). By studying the successful implementation of the PROACT-based RCA method, it is realized that the key tool in this model is the logic tree [17,22]. All of the above contents were shared with a few technical experts in the company, and they all selected the logic tree method for the study. Therefore, in this study, the chosen method for analyzing RCA is the methodology of the logic tree with a PROACT approach.

Table 1
Comparison of RCM Methods

method RCA	Application	Problem definition	Definition of known causes	Determining the path from causes to the root cause	Providing Evidence and Documentation	Description of the recurrence of the occurrence of solutions by applying solutions	Ease of tracking reports	Score
Events and casual factors	Method	Yes	Restricted	No	No	No	No	1.5
Change Analysis	Tools	Yes	No	No	No	No	No	1
Barrier analysis	Tools	Yes	No	No	No	No	No	1
Whys 5	Method	Yes	No	Yes	No	No	No	2
Pareto	Tools	Yes	No	No	No	No	No	1
Cause and effect analysis	Method	Restricted	No	No	No	No	No	0.5
logical tree	Method	Yes	Yes	Yes	No	Yes	No	4
Failure Mode & Effects Analysis	Tools	Yes	No	Restricted	No	Restricted	No	2

(Comparison criteria)

4. Findings and Discussion

The goal of solving RCA problems with the PROACT approach is to identify the root causes of the repeating events. In other words, this approach looks for the root causes of the events and prevents them from repeating. The logical tree PROACT is a proprietary tool designed specifically for use in RCA. A logical tree is a special case of cause and effect relationships that uses a certain sequential pattern to produce an undesirable output. These cause and effect relationships are based on solid evidence and documents. The data adds value to the process of analysis, not the expert who is talking loudly in the meeting room. The power of this equipment is so strong that it can be relied on even in judicial trials [18]. The PROACT model is an expert-based model in which the validity of the results depends critically on experts, and if implemented well, there will be successful results in the organization.

After selecting the appropriate method with the target equipment, root causes analysis should be implemented systematically [17,22]. For this purpose, the executive method approved by the Ministry of Oil is used [32], as explained below.

4.1 Process Input

Due to the variety of different models of equipment associated with gas production, the failure of the equipment that is repeated more frequently has to be checked to make the range of our studies smaller. At the end of the analysis, the results can be generalized to all models. In general, the mismatches are reported by three methods such as periodic review of repair records, assessing key performance indicators and direct reporting of mismatches entering the process. In this section, we select the process input after reviewing the periodic review of the maintenance records through the risk assessment method. In Table 2, the approximate RPN is calculated for all control panels. Therefore, the failure of Phase 2 gas wells of the region was chosen as the first priority to implement RCA, due to the high RPN value. For each of the control panel models based on equipment failure records, the number of MTBF1 is calculated in a period of one year, where the probability number is obtained. The diagnosis and intensity numbers are scored based on an agreement by the members of the RCA along with the instructions.

Table 2
Calculating the RPN number for each of the Control panel models.

No	Failure title	Diagnosis	Contingency	Intensity	RPN (S*O*D)
1	Control panels for phase 1 gas wells	6	2 or 3	6	72 to 108
2	Control panels for phase 2 gas wells	6	5 or 6	6	180 to 216
3	Control panels for new wells of the region	6	2 or 3	6	72 to 108

4.2 Determining the Members of the RCA Team

In the next step, the members of the RCA committee should be determined. This board consists of the experts in the region. The members are experts in the operation department, the head of the operation directorate, the instrumentation unit, and the head of the department of instrumentation.

4.3 Define the Problem

The most important step in RCA is defining the problem. The mismatch is a "temporary gas cut-off". The members of the analytical committee were formed by meeting and making an agreement on the "issue of non-compliance". Finally, the problem was defined as follows: What is the root cause that led to the failure of the wells of phase 2, which caused a temporary disruption to the gas production process? In terms of mismatch, the control panel failure is called the primary effect and by finding the subsequent effects, the root causes of the inconsistency are eventually discovered.

4.4 Cause and Effects Analysis and Evidence Review

According to the chosen method (logical tree method), the analysis begins with the RCA team. By gathering the required data, we must perform the analytical process for the failure, and ultimately tackle the cause or root causes to resolve the problem [18].

4.5 Data Collection

The required data are collected in different ways such as interviews with those related to the hypothesis and technical maps associated with equipment, inspection at the site of the equipment failure, and inspection of equipment failures.

4.6 Event Selection

The event is one of the most important components of the logical tree since the subsequent levels or the remaining stages of the analysis process are formed based on that. The event is the first box to be drawn in the logic tree. This house is based on facts and not on hypothetical events.

After discussions with the RCA team, the sudden interruption of gas production was ultimately selected as an incident. In the event selection, we are looking for the negative effects and failure conditions, not the failure itself. In other words, the failure of the equipment in normal conditions does not provide an incentive for root cause analysis, but rather the effects and conditions resulting in the discontinuation of the gas production.

4.7 Drawing a Schematic Diagram

The RCA team discussed the issues related to the events. The most basic question raised in relation to these conditions is to understand “how and in what way the event has happened in the past”. According to the agency's observation, the “control panel out of service” detects the state of the above event. Now, to form a second level, we describe cases that can be indicated by “controlling the control panel service”. By setting up an RCA meeting and exchanging ideas in this regard, two issues were presented as a cause at the next level, as shown in Figure 1. The problem is, in fact, the control panel exit service. The two opinions expressed are in fact hypothesized and unproven. Two modes can be considered for every equipment. Hence, there must be a mechanism for validating the hypothesis.

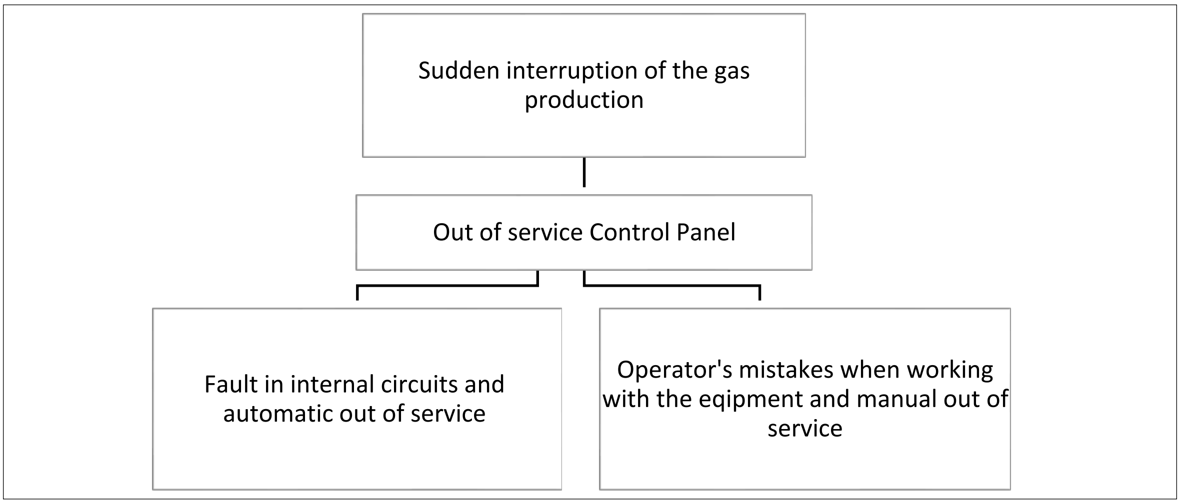


Fig. 1. Logic tree with consideration of two hypotheses for the event occurring

4.8 Hypotheses and Validating the Hypotheses

Here the facts are accepted and to hypothesize we must continue the route, and for each of the steps mentioned in the preceding steps, the question of “how could this event happen " should be put forward. Asking questions in this way pushes the mind toward answers that are more likely to find reality out of them. Based on the answer to this question, we turn to the data collected through the P5 approach and by using them, we confirm or reject the assumptions. The hypothesis that is approved correctly with valid data is converted into a fact. For each hypothesis proposed by the RCA team, a validation report must be issued in accordance with Table 3 to ensure that the hypothesis is rejected or approved [18]. Based on the collected data, one can reject or confirm a hypothesis.

Table 3
Validation of the hypothesis

Hypothesis	Validation method	Supervisor	Completion date	Result	Degree of confidence
Operator’s errors	Interview with an expert, and to examine the documents installed on the equipment.	Dr. Zarei	14/2/2020	The operator’s performance has no effect on the resulting errors.	-

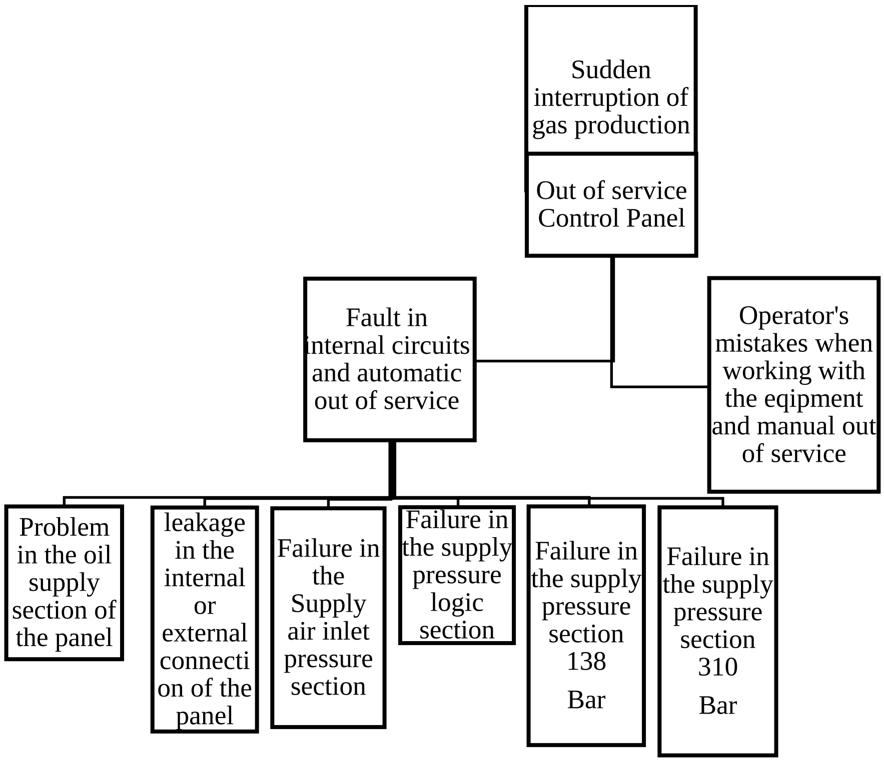
To evaluate the validity of the test and the accuracy of the result, we use a scale called confidence degree. The value of this scale is between 0 to 5 degrees. If we consider the confidence degree of hypothesis 0, undoubtedly and with 100 % confidence, it can be said that based on the data collected the hypothesis is not correct. On the contrary, the degree of confidence 5 means that based on the data collected data and the tests conducted the hypothesis is correct with 100 % confidence. The numbers between 0 and 5 are in fact gray numbers and are used when full certainty cannot be discussed in relation to the authenticity of the hypothesis. The closer the confidence number to 5, the more reliable our confidence will be in the validity of the hypothesis. It is observed in the above table that the degree of confidence intended for the hypothesis is zero. Therefore, the hypothesis is completely rejected and goes back to the other hypothesis, namely, "We automatically withdraw equipment". We continue the hypothesis process in the same way, i.e., for the confirmed hypothesis at each stage, we propose new hypotheses and consider their validity.

4.9 The Process of Finding Root Causes

At this stage, we should first look for physical factors that lead to failure, then human factors and ultimately root causes. The analysis team will have to carry on until it reaches the root causes of the problem. Figure 2 shows the process of the hypothesis at the next level (level 3). Each hypothesis that is approved contains causative factors, which actually represent the next levels of the graph. At the third level, the “failure in the logic section" hypothesis is confirmed by the analysis team. Therefore, we must make assumptions that are shown in Figure 3. Similarly, other levels of the graph must be formed, finally reach the point that we can no longer make any hypotheses. The root causes found by the analysis team are

i. Root Cause 1: Pressure on the operational forces for repairing the equipment faster due to critical production conditions.
ii. Root Cause 2: Complex logic circuit structure.
iii. Root Cause 3: Restrictions on the purchase of spare parts.

At this stage, finding the root causes of failures ends, since none of the hypotheses can be broken into smaller hypotheses. By analyzing the root causes of failure and equipping them, the analysis team's work in the analysis section ends.



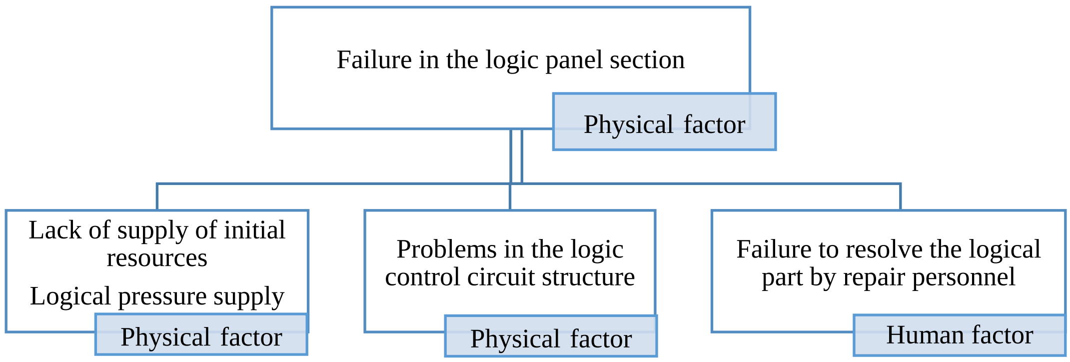


Fig. 3. Three factors considered by the analysis team for a third level hypothesis

4.10 Proposing a Solution

After finding the root causes, the analysis team should identify effective strategies and determine the best solution for the root causes of failures. *Proposing a solution for root cause 1*: The policy of the Ministry of Oil and the special conditions that exist in today`s oil and gas industry, creates huge pressures on the operational unit and top management of the organization to accelerate the equipment conditions in the production circuit. These pressures cause stress and the lack of precision of workers during work. Therefore, the pressure of the operational unit to repair the equipment faster can be considered one of the root causes of equipment failure, which should be followed by appropriate solutions. To reduce this pressure, we should seek to reduce the repair time of the equipment. One of the indicators used to identify the causes for the repair time of equipment is the M.D.T index. As shown in Table 4, rows 7, 5, and 8 are related to the net times taken to repair the equipment and are based on the MTTR index, and other items were stated as a waiting time to start or end of repair and re-start of production. Among the actions taken in the organization to reduce the timeout period are

i. Reducing the time of access to spare parts and tools required from the storage (at the time of equipment failure).
ii. Enhancing the skill of executive staff in work through training (during equipment failure).
iii. Enhancing the morale of the team in the executive staff (at the time of the equipment failure).
iv. Installing a troubleshooter card on equipment to reduce the troubleshooting time and determine the location of the incident with respect to item 3 of the above table (during the equipment failure).
v. Modifying the time interval of equipping preventive maintenance (during equipment activity).

Table 4
Effects on the MDT Index.

No	Activity description	Mean Down Time
1	Announcement of equipment failures by the operation unit to the repair department	Mean Wait Time
2	Issuing work permits and recruiting repairers to the position of the device	Mean Wait Time
3	Check, troubleshoot, and locate machine failure	Mean Wait Time
4	Get the required tools from the warehouse for the disassembly of the equipment	Mean Wait Time
5	Disassemble the equipment to access the machine's location	Repair Time
6	Receive material from the warehouse to replace the faulty parts of the machine	Mean Wait Time
7	Perform repairs and replace the faulty machine parts	Repair Time
8	Perform assembling operations after finishing the repair	Repair Time
9	Performing equipment reset operations	Mean Wait Time
10	Checking and verifying equipment repair	Mean Wait Time

Proposing a solution for root cause 2: One of the underlying causes that lead to failure is the complexity of the logic circuit structure. This was achieved through the logic tree developed by the analysis team. All experts believed that the logic circuit structure related to this equipment has many complications, and is not easy to troubleshoot and repair the equipment. This causes more time to spend on repairing the equipment. In addition, the reliability of the equipment is reduced, because the problem cannot be solved definitely. To deal with this cause, the analysis team achieved two strategies: the first solution is to replace the equipment with a more efficient and recent one. Since the equipment technology is from 50 years ago, the lifespan of the machine is somehow over, and the diagnosis of older systems is difficult. The second solution is to improve the structure of the equipment in the logic section. Since most part of the equipment is related to the logic section, then it is better to improve the section in a specialized way. It is noted that the initial plan for improving the logic circuit structure has long been proposed by one of the experts of the technical committee of the region.

Propose a mechanism for the root cause 3: The final underlying cause that leads to more failures is the absence of proper spare parts or poor-quality parts, which was achieved by analysis team through the logical tree. All repair staff have acknowledged that despite the large amount of time spent on repairing the equipment, the efficiency in the maintenance is not available, and at a short distance, the equipment will fail again. One reason could be the use of inappropriate spare parts or the use of parts that are similar to the original parts that do not have the necessary efficiency. In an interview with the purchasing officer, it became clear that two reasons caused a limitation in the purchase of the required equipment. Firstly, the equipment required to repair is not produced inside the country. Hence, it should be satisfied internally. Secondly, the company faces budget constraints each year and the higher-priced parts have many purchasing restrictions. To deal with the above cause, the analysis team achieved two strategies: the first solution is to negotiate via the Supply Authority of the region with the companies that supply foreign quality parts, thereby limiting the purchase restrictions of the spare parts. It also provides technical justification and costs to the company so that the issue of budget constraints is not problematic. The second strategy is to negotiate and communicate with other Ministry of Oil subsidiaries, which have the same equipment in the gas operation sector, for the spare parts that are required. It should be noted that in the storage of other subsidiaries of the oil company, which are similar to the target equipment, there are parts that are being purchased and unrequired. Therefore, these companies can fix a portion of the constraints.

5. Conclusions and Recommendations

In this section, we summarize the results we were looking for during the research process, as well as the results of improvements that will occur in the company and in relation to the equipment

i. Choosing the appropriate RCA approach and its systematic implementation to analyze the root causes of failures.
ii. Improving the performance of gas extraction by identifying the causes of failure.
iii. Increasing gas production by taking special measures.
iv. Reducing MTTR and increasing MTBF types of equipment.
v. Reducing maintenance costs.
vi. Reducing the pressure on the operator by repairing the equipment.
vii. Reducing work stress on the maintenance staff, by decreasing the amount of maintenance work.

5.1 Recommendations

It is suggested to other researchers to analyze the root causes for all kinds of equipment failures, as well as the types of incidents and sudden occurrences, to prevent them from recurrence. The logical tree with the PROACT approach is a very effective and efficient method that can be used for similar experiences implemented in the project and used for other research. However, this method is very comprehensive and complete and can be used in a variety of situations and conditions. However, there are many different methods in RCA analysis, which can be used by referring to them in other research. It is also suggested to other researchers to conduct the RCA analysis into the implementation phase of the strategy and assess its impacts on the results of the implementation in an entirely accurate manner.

5.2 Recommendations for the target company

It is recommended that the RCA implementation method be more integrated into the company's working areas and by familiarizing and training all staff with the RCA processes, the root cause failures can be removed. It is also proposed that the technical committee of RCA will be set up in all regions of the oil and gas company in the Southern Zagros region to implement root cause analysis in case of major failures and accidents.

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