Management and Production Engineering Review
Volume 12 • Number 1 • March 2021 • pp. 108–118
DOI: 10.24425/mper.2021.136876

Integration of the TRIZ Matrix and ANP to Select the Reactive Maintenance Tactics Using the Meta-Synthesis Approach

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Received:10 August 2020
Acepted: 08 February 2021

Abstract
So far, numerous studies have been published on the selection of appropriate maintenance tactics based on some factors affecting them such as time, cost, and risk. This paper aims to develop the TRIZ contradiction matrix by explaining the dimensions and components of each of the following Reactive maintenance tactics. The related findings of previous studies were analyzed by adopting "Rousseau and Sandoski" seven-step method to identify and extract the relationships between TRIZ principles and Reactive maintenance tactics. Thereafter, 5 Reactive maintenance tactics were replaced TRIZ's 40 principles in the TRIZ contradiction matrix. Finally, the ANP method were used to extract and prioritize the appropriate Reactive maintenance tactics. The proposed matrix in this research was used in the desalination section of one of the oil companies to select on the appropriate Reactive maintenance tactics. The results of this research is useful for managers and maintenance specialists of units in making decisions to provide appropriate Reactive maintenance tactics for the desired equipment.

Keywords
Reactive Maintenance Tactics, TRIZ contradiction matrix, Meta-synthesis Method, ANP.

Introduction

Today, with the rapid development of technology and the expansion of industrial automation, the volume of investment in machinery and physical assets of organizations has grown exponentially. Therefore, maintenance plays an important role in keeping reliability, availability, quality of products, risk reduction, efficiency, and security of equipment. Therefore, the proper selection of maintenance and repair tactics has a special place in the industry. So far, many researches have been done on the selection of the maintenance and repair tactics and prioritization of these tactics based on the factors affecting them. The distinction of this study from other similar studies is to model the TRIZ contradiction matrix in order to resolve the contradictions of the factors affecting the selection of maintenance and repair tactics, prioritizing and selecting the appropriate maintenance, especially Reactive maintenance tactics.

In literature is provided a research on the analysis and prioritization of maintenance and repair techniques (Labib, 2004). There is presented the hierarchical analysis method and the use of DMG matrix. The proposed DMG matrix has two failure frequency and failure time parameters, based on which maintenance and repair techniques where considered within the matrix cells. To use this matrix the data were collected on the failure frequency parameter and the failure time of each equipment (Labib, 2004).

In reference (Khazraei and Deuse, 2011) are examined and compared American, German, Australian, and European maintenance strategies in a study entitled Strategic Maintenance Classification. In this paper, the strengths and weaknesses of these strategies are analyzed in terms of structure, implementation, economic, political issues, and finally, the classification structure of the various types of maintenance that incorporate the principles of strategy science are introduced as the most complete maintenance techniques (Khazraei and Deuse, 2011).

In reference (Shahin and Pourhamidi, 2011) is presented a matrix similar to the TRIZ contradiction matrix to design services quality. This matrix has 12 ver-

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tical houses and 12 horizontal houses. In this matrix, 39 Altshuller parameters have been changed to 12 production parameters. The final matrix has been used as a case study in the hospitality industry (Shahin and Pourhamidi, 2011).

Matrix similar to the TRIZ contradiction matrix can be used to improve the use of Kansei engineering. In this case matrix has 8 vertical and 8 horizontal houses (Shahin et al., 2013). In this matrix, 39 Altshuler parameters have been changed to 8 Kansei engineering parameters. In this study, qualitative methods have been used for comparisons and analysis.

In a study entitled *Asset Management and Maintenance System Strategy Selection* (Fraser, 2014) is pointed important role of asset management in asset reliability and security and the use of a system to control maintenance performance. The paper proposes identifying and describing various maintenance models and systems available to facility managers. In this study, out of 37 maintenance management models, 4 tactics including Total Productive Maintenance (TPM), Condition-Based Maintenance (CBM), Reliability Centered Maintenance (RCM), Corrective Maintenance (CM) were selected (Fraser, 2014).

In reference (Goossens and Basten, 2015) AHP is used to select maintenance strategies for see ship systems. The authors selected three different groups in the industry, including shipbuilders, operators and manufacturers of core equipment in choosing the optimal maintenance strategy (Goossens and Basten, 2015). The ship system utilized three strategies of corrective maintenance, time-based maintenance and status-based maintenance. The first level consisted of 2 decision criteria; the second level consisted of 8 and the third level comprised 29 criteria. Status-based maintenance was selected.

According to (Alrabghi and Tiwari, 2015) the goal of the maintenance system as reducing sudden failure, reducing total costs, increasing profits, revenue and accessibility, and they divided the Maintenance system into a variety of Preventive Maintenance (PM), CM, and CBM that are a subset of the prophylactic net (Alrabghi and Tiwari, 2015).

37 maintenance-related guidelines with qualitative TRIZ principles were compared in (Vaneker and van Diepen, 2016), then extracted ideas and principles as a process road map to solve the problem at a minimum time (Vaneker and van Diepen, 2016).

ELECTRE as a multi-criteria decision-making method was used in (Trojan and Marçal, 2017) to prioritize traditional classifications of maintenance tactics based on criteria such as action planning, costs, critical points, and available resources (Trojan and Marçal, 2017).

An approach that was able to integrate performance and maintenance strategies to adapt existing data to equipment failures and regular preventive measures was proposed in (Seecharan et al., 2018).

A model aimed at optimizing and reducing the overall cost of long-term maintenance of complex systems was presented in (Martinod et al., 2018). The proposed model is based on two optimization approaches and a cost model for complex multi-component systems consisting of preventive and corrective maintenance using reliability analysis. It also includes a clustering approach for maintenance actions aimed at reducing the total maintenance costs of a complex system (Martinod et al., 2018).

Referring to (Seiti et al., 2019) many quantitative models cannot be used since basic information is low in identifying the likelihood of equipment failure,. Also due to the dynamic nature of maintenance and the presence of unforeseen factors, reducing equipment reliability as well as the difficulty of scheduling maintenance occurred. For this purpose, a fuzzy model has been developed taking into account the reliability criteria and taking into account the positive and negative risks and errors in using effective factors to plan maintenance in a given period of time (Seiti et al., 2019).

Meta-synthesis was used in (Mortazavi et al., 2020) to extract the components affecting maintenance strategy selection and identified through the seven steps and classified in 26 concepts and 59 codes. Organizations which intend to apply maintenance strategies can gain a better insight about benefits of using Altshuller's parameters in TRIZ matrix (Mortazavi et al., 2020).

In many studies are selected and prioritized maintenance tactics using different methods, but no comprehensive research has been conducted through qualitative (meta-synthesis) studies. In this study, the relationship between Reactive maintenance tactics and the TRIZ principles have been considered. Therefore, this study differs from other similar studies by modeling the TRIZ contradiction matrix in order to resolve the contradictions of factors affecting the selection of maintenance tactics, prioritizing and selecting appropriate Reactive maintenance tactics. The reason for comparing Reactive maintenance tactics with the 40 TRIZ principles can be attributed to the comprehensiveness of these principles. Given that the TRIZ principles identified and extracted by Altshuler are sufficiently comprehensive to identify improvement features and adverse outcomes, and can also be applied to solve all issues, so the TRIZ contradiction matrix can be extended to select a new matrix that incorporates these 40 tactics instead of the 40 TRIZ principles for choosing Reactive maintenance tactics.

Research background

Appropriate selection of maintenance tactics in the industry, considering the factors and conditions affecting each equipment, as well as the competitive environment and customer need for a higher quality and cheaper product, necessitates the use of innovative approaches.

Reactive maintenance tactics

The tactics associated with Reactive maintenance policies extracted from the research (Khazraei and Deuse, 2011), which include the following 5 tactics.

1. Immediate reactive maintenance (IRM). It is a reactive maintenance tactic in which a corrective or prospective (i.e. opportunistic) maintenance activity is taken place right after a machinery breakdown or a failure happens. This requires great effort in a sense that all the necessary resources have to be employed in an urgent manner to vanish or overcome the problem. This is feasible for cost or production effective machinery breakdowns or failure events which cause the production process stopped or highly disturbed.
2. Scheduled reactive maintenance (SRM). Based on this tactic when a failure happens, the necessary reactive activities are planned and then scheduled to be employed in a definite time period. This helps utilizing of the necessary resources in a more flexible and efficient way, although the tactic can be considered for machinery failures of lower risk (e.g. financial or operational risks) that do not disturb the production process with high relentlessness.
3. Deferred reactive maintenance (DRM). This tactic involves reactive maintenance activities which are postponed or deferred to another unscheduled time or the earliest possible time of availability of resources. It is used when the risk or effect of the machinery failure is very low or at the time that for any reason the required resources that are need to maintain or repair are not available at all.
4. Failure-based maintenance (FBM). This maintenance tactic is the simplest reactive maintenance activity and one where the machinery is left unmaintained until one or more failure modes have been observed and it is carried out only after a breakdown. This tactic is effective when number of equipment is few, equipment are very simple and repair does not need many resources, and sudden failure does not cause severe safety or environmental hazards.
5. Operate to failure (OTF). A tactic in which there is no attempt or effort to reduce the number of failures. Maintenance is done only when machine(s) is broken down. However, engineering resources are used to shorten repair time presumably.

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Do not use abbreviations in the title or heads unless they are unavoidable.

The principles of TRIZ

Contradiction means two characteristics with contradictory or opposite characteristics. If there is a conflict between the two features of one system, which means that a positive change in one feature (e.g. increasing the quality of one product) results in a negative change in another (e.g. increase in product price) then the system is inconsistent. TRIZ's knowledge states that the problem of invention is accompanied by some kind of contradiction, and that problem solving occurs when that contradiction is resolved.

One of the most important roles of TRIZ is to identify and analyze contradictions and provide solutions to them (Trinico, 1998). Given that TRIZ's knowledge is based on the concept of inconsistencies, TRIZ offers innovative and creative solutions to the problem at hand. Therefore, applying this knowledge to resolve the inconsistencies among the factors influencing the appropriate selection of Reactive maintenance tactics is suggested by this study. In addition, the resulting new matrix will be called the "Matrix of Reactive Maintenance".

Meta-synthesis

A meta-synthesis similar to meta-analysis is performed to integrate several studies to generate comprehensive and interpretive findings. In comparison with the quantitative meta-analytic approach that relies on quantitative data from subject literature and statistical approaches, the meta-synthesis focuses on qualitative studies, returning to translating qualitative studies into one another and deep understanding of the researcher. Therefore, meta-synthesis is a type of qualitative study that explores information and findings extracted from other qualitative studies related or similar to the subject, and by providing a systematic approach to researchers, explores new and fundamental metaphors and themes by combining different qualitative studies. Meta-synthesis requires the researcher to conduct a deep and precise review, and to combine the findings of relevant qualitative researches. By reviewing the findings of the main research articles, researchers identify and create words that represent a more comprehensive representation of the phenomenon under investigation.

Research methodology and finding

In order to create the contradiction matrix of TRIZ Reactive maintenance, the steps in Fig. 1 will be sequenced, respectively. The method chosen for this study is the use of Rousseau's and Sandusky's (2007) meta-synthesis method, which consists of seven steps. Subsequently, meta-synthesis steps have been performed in order to identify and compare Reactive maintenance tactics with the TRIZ principles. In the following, the steps of the research are described in details. The applicability of the proposed TRIZ reactive maintenance contradiction matrix is done in the desalination department of the National Oil Company of Iran to select the best appropriate reactive maintenance tactics. This company is located in the city of Ahvaz. The Company used maintenance and overhaul in order to perform maintenance on the desalination unit due to the inability to remove the equipment. Due to the lack of readiness of the unit in the past two periods, no maintenance has been performed and the reliability of the system has fallen sharply. Research experts include maintenance specialists, management in Oil Company and professors in this field as shown in Table 1.

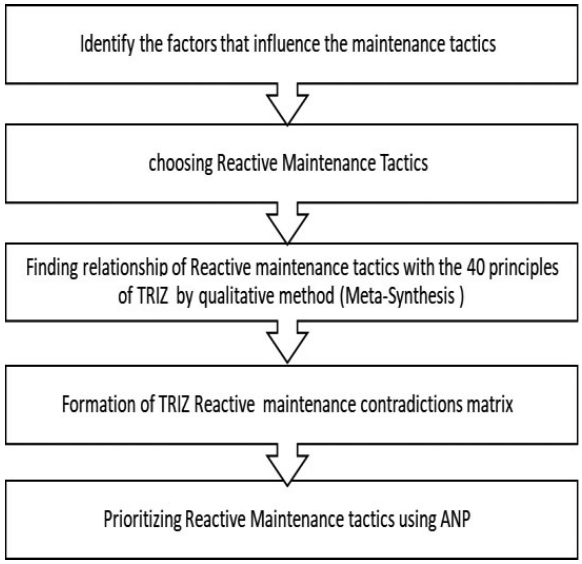

Fig. 1. Steps to make TRIZ's Reactive Maintenance contradiction matrix

Identifying and selecting the factors that influence maintenance tactics

According to the proposed algorithm, it is necessary to identify the factors influencing the selection of maintenance tactics. For this purpose, the TRIZ contradiction matrix parameters that are effective in selecting maintenance tactics are identified and selected. Out of 39 Altshuler parameters, 26 parameters are selected for this purpose (Table 2) (Mortazavi et al, 2020).

Table 1
The Mographic characteristics of experts

Experts	work experience/ years	Gender	Degree of education	Organizational position
1	21	Maintenance and repair	Master degree of Management	Maintenance and Repair Manager
2	22	Maintenance and repair/ production	Bachelor	Production Deputy
3	25	Industrial Management	Ph.D degree of Management	Head of Maintenance and Repairs
4	20	Maintenance and repair/ production	Master degree of Management	Head of Maintenance and Repairs
5	11	Maintenance and repair	Bachelor	Maintenance and repair expert
6	13	Maintenance and repair	Bachelor	Maintenance and repair expert
8	14	Industrial Management	PhD. degree of Management	Faculty member/Professor
9	23	Production and operations	PhD degree of Industrial Engineering	Technical manager
10	18	Production and operations	Bachelor/s Master and PhD degree of Management	Faculty member/Maintenance and repair manager

Table 2
The factors affecting maintenance tactics

Altshuller's Parameters	Parameter Numer	ROW	Altshuller's Parameters	Parameter Number	ROW
Loss of information	24	14	Speed	9	1
Waste of time	25	15	Tension pressure	11	2
Amount of substance	26	16	Shape	12	3
Reliability	27	17	Stability of object	13	4
Harmful factors acting on object	30	18	Strength	14	5
Harmful side effects	31	19	Durability of moving object	15	6
Convenience of use	33	20	Durability of non-moving object	16	7
Reparability	34	21	Temperature	17	8
Adaptability	35	22	Energy spent by moving object	19	9
Complexity of device	36	23	Energy spent by non-moving object	20	10
Complexity of control	37	24	Power	21	11
Level of automation	38	25	Waste of energy	22	12
Productivity	39	26	Waste of substance	23	13

Selection of reactive maintenance tactics

In this study, the tactics associated with Reactive maintenance policies extracted from the basic research (Khazraei and Deuse, 2011), which include the following 5 tactics.

Finding the relationship of reactive maintenance tactics to the 40 principles of TRIZ by qualitative method (meta-synthesis)

As mentioned before, Reactive maintenance tactics are used to compare and analyze qualitative data and find out the relevance of these tactics to the 40 TRIZ principles through a meta-synthesis approach.

Step 1: Set up the research question

The first step in the meta-synthesis approach is to ask questions that the researcher intends to answer in the process of doing his research.

The questions of this research are as follows:

1. Find out the relevance of Reactive maintenance tactics and TRIZ principles
2. What are the studied communities and time constraints to identify the relevance of Reactive maintenance tactics and TRIZ principles?
3. How do the Reactive maintenance and contradiction matrix arise?

Step 2: Content review

In this study, different databases and journals and search engines were investigated between 2000 and 2020 as seen in Table 3, Table 4 and Table 5, respectively. Various keywords were used to search the research articles. As a result of searching and searching different databases, journals and search engines and using keywords, 150 valid and relevant articles were found as seen in Fig. 2.

Table 3
Searched sources

Sources	Row	Sources	Row
Emerald	6	Science Direct	1
SCOPUS	7	IEEE	2
WOS	8	Springer	3
ISC Journal	9	Taylor&Francis	4

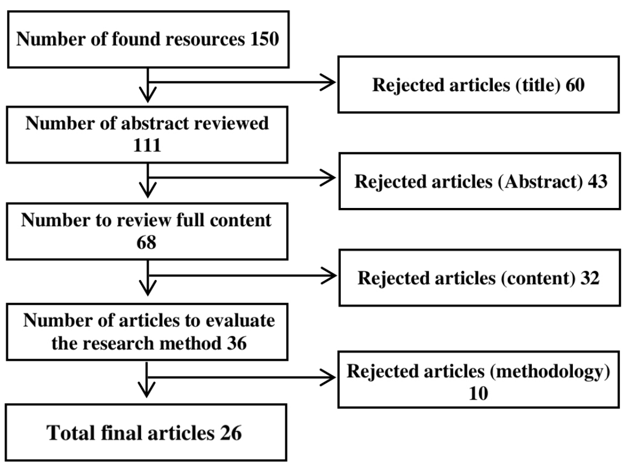

Fig. 2. The process of search and selection of appropriate articles

Table 4
Reviewed journals

Row	Reviewed journals	Row	Reviewed journals
1	Computers & Industrial Engineering	11	Loss Prevention in the Process Industries
2	Industrial Management	12	Hazardous Materials
3	Production Economics	13	Modern Processes in Manufacturing and Production
4	Reliability Engineering and System Safety	14	Computational Design and Engineering
5	Operational Research	15	Process Mechanical Engineering
6	Intelligent Manufacturing	16	Advanced Manufacturing Technology
7	Production Research	17	Engineering Applications of Artificial Intelligence
8	Computer Integrated Manufacturing	18	Statistical Planning and Inference
9	Modeling, Simulation, and Scientific Computing	19	the Operations Research Society of Japan
10	Operations Management	20	Quality in Maintenance Engineering

Table 5
Key words

Row	Words searched	Row	Words searched
1	Reactive Maintenance Strategy	6	Maintenance Policy Assessment
2	Maintenance Policy	7	Maintainability Evaluation Model
3	Maintenance Management System	8	Maintenance Optimization Model
4	Scheduling Maintenance Activity	9	TRIZ
5	Repair and Overhaul (MRO) Strategies		

Step 3: Searching and selecting the right articles

In order to select the appropriate articles based on the algorithm observed in Fig. 2, various parameters such as title, abstract, content, accessibility, and quality of the research method were evaluated.

Step 4: Results extraction

Article information is categorized by reference to each article, including the author's name and surname, along with the year of publication of the article and the coordinating components stated in each article.

Step 5: Analyzing and integrating qualitative findings

As can be seen in Table 6, the themes associated with each of the maintenance tactics are identified first by reviewing the content and previous studies. Then, by considering the concept of each of these themes and placing them against each of the 40 TRIZ coded principles, the relationship between Reactive maintenance tactics and TRIZ principles is extracted in Table 7.

As seen in Table 7, based on the analysis, with the help of the content analysis method on the selected 150 articles, out of the 40 TRIZ principles, 14 principles are associated with 5 maintenance tactics and 5 Reactive maintenance tactics. Moreover, the final extracted codes associated with each category and concept is shown in Table 7.

Step 6: Control the extraction codes

Maintenance experts' opinions have been used to control extraction concepts as seen in Table 8. Kappa Cohen's index as seen in Table 9 is used to evaluate the degree of agreement between the ratings. The kappa index is used only for variables whose level of measurement is the same and the number of classes is equal. The kappa index value fluctuates between zero and one. The closer the value of this measure to the number one, the greater the agreement among the ratings, but when the value of kappa is closer to zero, there is less agreement between the two ratings. Due to the smaller value of significant number than 0.05, the error of the extracted codes is rejected. So it can be argued that code extraction has good reliability.

Step 7: Presenting the findings

From Table 7, the result of comparing Reactive maintenance tactics with the TRIZ principles using the meta-synthesis method are shown in Table 10.

Table 6
Extracted the theme of each Reactive maintenance tactic

Abbreviation	Maintenance tactic	Abbreviation brief description	Theme
A	Immediate reactive maintenance (IRM)	Maintenance is immediately done after a machinery breakdown. All the necessary resources have to be available right after a failure happens.	Immediately- breakdown-
B	Scheduled reactive maintenance (SRM)	Maintenance is planned and scheduled when a machine is broken down. This provides a more flexible and efficient use of resources.	planned and scheduled-flexible
C	Deferred reactive maintenance (DRM)	Maintenance is postponed or deferred for a brokendown machine due to lack or unavailability of resources in case of an unimportant failure.	postponed or deferred
D	Failure-based maintenance (FBM)	Maintenance is undertaken when one or more failure modes of un-maintained machinery have been observed, thus after a breakdown.	Observed one or more failure modes
E	Operate to failure (OTF)	Maintenance is done when a machine is failed. There is no endeavor to trim down the number of failures.	Overall

Table 7
Relationship between TRIZ principles and Reactive maintenance tactics

Maintenance Tactic	Theme	Code	TRIZ principles related	Referance
Immediate reactive maintenance (IRM)	Immediately-breakdown-	Taking out – Dynamism – Periodic action – Continuity of useful action – Rushing through – Blessing in disguise (harm to benefit)	2-15-19-20-21-22	(Minou et al., 2016; Kumar and Maiti, 2012; (Minou et al., 2016; Kumar and Maiti, 2012; Zio and Compare, 2013; Tan, 1995; Alrabghi et al., 2013; Manzini et al., 2009; Wang et al., 2019)
Scheduled reactive maintenance (SRM)	planned and scheduled-flexible	Preliminary anti-action – Preliminary action – Beforehand cushioning	9-10-11	(Minou et al., 2016; Kumar and Maiti, 2012; Gan et al., 2015; Zio and Compare, 2013; Arunraj and Maiti, 2010; Glarner and Alsyouf, 2007; Gento, 2004; Mobley, 2002; Peng and Zhu, 2017; Kang and Subramaniam, 2018; Martinod et al., 2018)
Deferred reactive maintenance (DRM)	postponed or deferred	Partial or excessive action – Intermediary – Cheap disposable	16-24-27	(Minou et al., 2016; Kumar and Maiti, 2012; Gan et al., 2015; Zio and Compare, 2013; Peng and Zhu, 2017; Kang and Subramaniam, 2018)
Failure-based maintenance (FBM)	Observed one or more failure modes	Cheap disposable – Universality	6-27	(Minou et al., 2016; Kumar and Maiti, 2012; Gan et al., 2015; Zio and Compare, 2013; Nakagawa and Mizutani, 2009; Kader et al., 2015; Wang et al., 2011; Briš, 2018; Alsyouf, 2004; Glarner and Alsyouf, 2007; Alrabghi and Tiwari, 2015; Manzini et al., 2009; Abdi and Taghipour, 2019; Peng and Zhu, 2017)
Operate to failure (OTF)	Overhall	Merging or combining – Universality – Dynamism	5-6-15	(Minou et al., 2016; Kumar and Maiti, 2012; Gan et al., 2015; Zio and Compare, 2013; Nakagawa and Mizutani, 2009; Kader et al., 2015; Wang et al., 2011; Briš, 2018; Alsyouf, 2004; Glarner and Alsyouf, 2007; Manzini et al., 2009; Arunraj and Maiti, 2010; Alrabghi and Tiwari, 2015)

Table 8
The result of the Kappa agreement (Experts' answer)

		Diagnostician 2		Total
		0	1	
Diagnostician 1	0	0	0	0
	1	1	4	
Total		1	4	5

Table 9
Cohen's kappa coefficient

	Amount	Statistically significant
Cohen's kappa coefficient	0.75	0.05
Diagnostician	5	

Table 10
The Reactive Maintenance Contradictions Matrix

Undesired Result (Contradiction) / Feature to Change		9 Speed	11 Tension pressure	12 Shape	13 Stability of object	14 Strength	15 Durability of moving object	16 Durability of non-moving object	17 Temperature	19 Energy spent by moving object	20 Energy spent by non-moving object	21 Power	22 Waste of energy	23 Waste of substance
9	Speed		ED	AE			AE		A	AE		A	A	B
11	Tension pressure	ED		ABE	A	B	ACD		A	CB		B	A	B
12	Shape	AE	ABE			B	B		A	ADE		ADE		E
13	Stability of object	AE	A	A		ABE	CBD			A	CD	CD	ADE	A
14	Strength		B	B			CD		B	ABCD		B		
15	Durability of moving object	E	ACD			BCD			A	DE		AB		CD
16	Durability of non-moving object								A			C		CD
17	Temperature	A	A	A		AB	A	A		AE		A	A	
19	Energy spent by moving object	AE		A	AC	ABE	ED		AC			ADE	ACE	CE
20	Energy spent by non-moving object				CD									CD
21	Power	AE	AB	A	AE	B	AB	C	A	ACDE			B	CD
22	Waste of energy	C			AED				A					ACD
23	Waste of substance	B	B	E	A		CD	CD	A	CE	CD	CD	ACD	
24	Loss of information						B	B				AB	AB	
25	Waste of time			B	AED		AB	ABC	A	A		ABED	BE	B
26	Amount of substance		B		AED	B	B			C				BCDE
27	Reliability	AB	ABC	CB		B	A	CDE	B	ABCD		AB	B	B
30	Harmful factors acting on object	A	A	A	C		AE		A	CDE	AB	A	A	A
31	Harmful side effects		ACD		CD	AE	AE	ACDE	AC	ADE	A	A	A	B
33	Convenience of use		A	AE				C	CD	C		AB	A	ACD
34	Repairability	B		A	A	AB	BCD		B	ACE		ABE	AE	ACD
35	Adaptability	B	C	AE		ED		ACDE	ACD	A		A	AE	ABE
36	Complexity of device	B	A	AE	A	A	ABE		A	ACD		A	AB	B
37	Complexity of control	C		CD	AB	ACDE	A	CDE	CD		AC	ABC	AE	BCDE
38	Level of automation	B		AE			BDE		A	A		ACD		BE
39	Productivity		B	B	A	B	AB	ABC	AB	AB		AB	B	B

Formation of reactive maintenance contradiction matrix

Table 10 in two sections have been prepared to show the TRIZ Reactive maintenance contradictions Matrix.

Prioritizing reactive maintenance tactics using ANP

In the following, the Reactive tactics are modeled based on the factors influencing them using the ANP method. For this purpose, factors influencing the selection of maintenance tactics (Table 1) are used as decision criteria and Reactive maintenance tactics as options. The pairwise comparison matrix have been applied to show the relationships between factors based on the views of selected experts. The readers are referred to (Shahanipour et al., 2020) for more details on the ANP method. Super Decisions software is used to perform the calculations.

Each of the Reactive maintenance tactics is prioritized according to the factors influencing the choice of these tactics. The results can be seen in Table 11. It is noted that all related data have been gained through interview with experts as shown in Table 1.

Table 11
The Reactive Maintenance Contradictions Matrix

Abbreviation	Maintenance Tactic	LPI	RAI	Rate
A	Immediate reactive maintenance (IRM)	0.1898	0.3193	1
B	Scheduled reactive maintenance (SRM)	0.0974	0.1639	2
C	Deferred reactive maintenance (DRM)	0.0868	0.1460	3
D	Failure-based maintenance (FBM)	0.0615	0.1035	4
E	Operate to failure (OTF)	0.0400	0.0673	5

With the help of the TRIZ Reactive maintenance contradiction matrix, the reliability parameter is considered as an improvement factor as well as the time loss parameter as an undesirable result. Table 11 illustrates the tactics extracted from the matrix of Reactive maintenance contradiction resulting from the collision of each of the parameters introduced in the row and column. The result is shown the use of IRM of Reactive maintenance tactics as seen in Table 12.

Table 12
Part of Reactive maintenance contradictions matrix

Feature to Change \ Undesired Result (Contradiction)		25 Waste of time
27	Reliability	IRM

Discussion and conclusions

As mentioned earlier, the choice of maintenance and repair tactics is of particular importance in the industry and what further enhances the importance of these tactics is the need to understand the factors affecting the choice of Reactive maintenance tactics in different situations.

So far, many researches have been done on selecting maintenance tactics and prioritizing these tactics based on factors affecting them in different methods. But no research has been comprehensively conducted to identify the effective components in selecting maintenance tactics and categorizing these tactics and matrix presentations that can resolve the contradiction between these components in choosing the appropriate tactic, specially reactive ones.

In this study, Reactive maintenance tactics extracted from (Khazraei and Deuse, 2011) was selected as the most comprehensive classification of Reactive maintenance tactics. Then, the factors affecting the selection of maintenance tactics in comparison with the Altshuler parameters as well as the Reactive maintenance tactics compared to the TRIZ principles were grouped in a systematic meta-synthesis method, after analysis, they were placed against each of the Altshuler parameters.

The result of this research is the Matrix of Reactive Maintenance contradiction that incorporate Reactive maintenance tactics within each of its cells, and its rows and columns are effective factors in selecting these matrices. Reactive maintenance tactics have been prioritized by the ANP method based on the factors influencing the choice of these tactics to enhance the efficiency of this matrix and provide the appropriate tactics.

The results of this study considering the problem ahead help managers and specialists in the field of maintenance to resolve the contradiction between the factors affecting the selection of maintenance tactics as well as the appropriate selection of maintenance tactics in the shortest possible time.

Practical suggestions for the continuation of this research include the use of the meta-synthesis approach to find the relationship between maintenance tactics and 40 TRIZ principles based on other maintenance policies.

The result of this research is the formation of a matrix similar to the TRIZ contradiction matrix, which consists of 5 tactics of predetermined maintenance tactics in the cells of these matrices and the parameters affecting them. The findings and results of the research can be used. Explained as follow:

1. Provide tactics appropriate to resolving the contradictions and conflicts between the proposed parameters.
2. Identify and prioritize the factors affecting the selection of maintenance tactics using multi-criteria decision making methods.
3. Prioritize 9 maintenance tactics using multi-criteria decision making methods
4. Using the qualitative study method (meta-combination) in conducting research
5. This matrix helps managers and maintenance specialists of units in making decisions and providing appropriate tactics for the desired equipment.
6. This matrix increases the speed of decision-making and selection of appropriate tactics.
7. Spend less money to test and solve the problem ahead, because this matrix prevents the management mind from paying attention to the sub-answers that cause it to move away from the optimal answer.

The research limitation are as follows:

1. Time-consuming and tedious data mining operations the use of hyper-combined qualitative method was one of the limitations of this research.
2. The complexity and difficulty of conducting research in the field of data collection and analysis has led to limitations in measuring the opinions of experts and its analysis.
3. Among the limitations that this research faces, we can mention the relationship between the factors affecting the choice of net tactics and the Altshuler parameter, as well as finding the relationship between maintenance techniques and the principles of TRIZ. Spending time, great care and having comprehensive information in the field of each of the tools, principles and parameters.
4. The subject area of this research includes the review of all research conducted on maintenance-related tactics in order to achieve a matrix similar to the TRIZ contradiction matrix. Due to the fact that the volume of this type of research is very high, so this issue is an important and fundamental factor in the time consuming summary of this section.

For future research, topics related to data envelopment analysis can be used with methods related to meta-combination in order to optimize the output findings of this research. The use of fuzzy methods to prioritize maintenance tactics is also suggested. Due to the wide application of the TRIZ paradox matrix in problem solving, other TRIZ principles can be substituted for other management tools and tactics with the help of hybrid methods.

It is also suggested that in the industry, equipment that may malfunction for any reason be analyzed by the method of meta-synthesis and appropriate scenarios for maintenance and repair of each equipment according to the possibility of its operation to accelerate the decision with the help of matrices.

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