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| Research Article

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Planning and Scheduling Maintenance Operations at the Haditha Hydroelectric Station in Iraq

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Abstract: The process of planning and scheduling maintenance activities in any production and service organization is of vital importance because it helps the organization to complete maintenance work according to the specified time or before it to be reflected in the continuity of production operations. Anbar Governorate in Iraq, and to achieve this goal, the station was visited on the ground for a period of 15 days in order to collect data and information related to planning and scheduling maintenance operations. Instead of 259 days, the project will be completed by 63%, according to the BART analysis, but according to the simulation system, the work period of 172 will be completed by 99.9%. The study also showed many conclusions and proposals that are compatible with the nature of the station's work.

Keywords: maintenance planning, maintenance scheduling, PERT method.

Introduction: Maintenance operations are considered as a very important process to ensure the continuity and continuity of equipment and devices, as well as their role in providing the highest levels of efficiency and productivity. Emergency and corrective maintenance. In addition, the process of planning and scheduling maintenance operations depends on estimating the cost, time, and spare parts required to carry out maintenance. This contributes to improving the efficiency of equipment and devices, improving productivity, and reducing costs resulting from maintenance operations and emergency stops. This work enhances confidence in Equipment quality.

From this standpoint, planning and scheduling maintenance operations at hydroelectric stations in Iraq in general, and the Haditha station in Anbar Governorate in particular, is considered one of the very vital tasks to ensure the continuity of operating the stations with high efficiency and effectiveness, and among the reasons that make planning and scheduling maintenance operations at hydroelectric stations in Iraq very important It is the equipment and devices exceeding their productive or operational life, which may lead to the occurrence of breakdowns and stoppages more frequently, so the operations necessary for preventive maintenance must be determined regularly and scheduled in a way that ensures a balance between maintenance needs and the continuity of production operations, as well as determining the appropriate periods for conducting corrective maintenance and planning them properly Regularly, in order to avoid stopping the hydroelectric station and ensuring its effective operation. The tasks and works required for maintenance must also be identified and resources must be specified to implement them correctly.

In addition, emergency maintenance plans must be developed and well planned to deal with sudden emergencies, in order to reduce damages and improve the station's response to these cases. In light of this, the current study is divided into several axes:

The first axis: the methodology of the study

First: The problem of the study: Hydroelectric stations in Iraq suffer from problems in planning and scheduling maintenance operations, and this affects the efficiency of operating the stations and increases the possibility of malfunctions in electrical appliances, which causes interruption of productivity and reduces the possibility of providing electricity to the areas surrounding the station, and this negatively affects On the daily life of the people, and the most important reasons behind this problem are:

- The lack of sufficient technical expertise among the workers at the station to identify faults and implement preventive and corrective maintenance.
- Lack of material and human resources, which makes it difficult to establish regular and effective maintenance schedules.
- Failure to provide spare parts and equipment required for maintenance, which affects maintenance schedules and increases unplanned downtime.

Materials and Methods

At the forefront of solving this problem is the use of the (PERT) method, as well as the use of operations scheduling according to the first-in, first-served method, because of the effective role of these two methods in developing plans and scheduling maintenance operations in a manner that ensures the completion of maintenance work as quickly as possible, and this is done by providing the necessary technical training for workers At the plant and provide the necessary resources to schedule preventive and corrective maintenance, and provide financial support for the modernization and development of hydroelectric plants in Iraq.

Second: Study Objective: The study mainly aims to develop plans for scheduling maintenance operations at the hydroelectric stations that operate in Iraq, and from this goal we diagnose the most important obstacles that prevent the success of plans and scheduling maintenance in Iraqi stations in general and Haditha station in particular, and addressing them based on the two sides of the study Theoretical and practical.

Third: Methodology, Hypothesis, and Study: The study adopted the analytical quantitative approach, and the study relied on one hypothesis: There is an effect of the planning and scheduling process in determining and reducing maintenance times at the study sample station.

Literature Review

The second axis: the theoretical framework

First: Maintenance planning: It is the process of setting an integrated schedule for all maintenance activities for each piece of equipment. The maintenance plan must be integrated with the production plan. This integration is very important because production and maintenance are directly related. Any malfunction in the operation of the machine leads to disruption production and leads to additional costs due to downtime, loss of production, and low productivity and quality (Ashayeria and Selen, 2012,1), and is defined as a process that includes a series of decisions regarding the type of maintenance work, and the time of maintenance procedures to reduce total maintenance costs and maximize the condition of machinery and equipment, It is a tool for decision support by relying on mathematical models to facilitate predictions of equipment condition and treatment in order to efficiently maximize the quality of equipment work (Jaafaru & Agbelie, 2022, 2), and it requires the following two steps to develop the required schedules: First:

developing a master plan for all maintenance work that must be To be done annually, and the main structure of this plan depends on the number of existing machines, and the length of time periods during which periodic inspection must take place on them. The second: dividing this plan into the weeks or days that make up the year, so that the industrial departments have an idea of what maintenance work is. Which will take place in its departments during the coming weeks, and thus they will have enough time to re-plan the maintenance operations in it (Abdulamir, 2010, 52).

Second: Scheduling maintenance of electrical stations: It is to create an annual maintenance plan for electric power equipment while maintaining stability to ensure a continuous flow of energy by preparing a list of equipment that needs maintenance or replacement, with the aim of creating an ideal maintenance plan (Popovic, et. al, 2022, 1) Or it is determining the time to stop the generation units for preventive maintenance in order to maintain the reliability of the system and reduce the general operating costs, as the scheduling of the maintenance of the electrical stations depends on several steps: (Froger, et. Al. 2016, 4):

Results and Discussion

1. Maintenance tasks: maintenance window (probable time for maintenance), sequence, spacing, and overlapping tasks.
2. Generation units: the highest or lowest levels of production.
3. Manpower: Availability of manpower for each working period, and determining the requirements of workers to carry out maintenance tasks.
4. Resources: their availability per period, requirements, and consumption through maintenance tasks.
5. Network: transmission line capacity, voltage
6. Demand: meeting the energy demand.
7. Reliability: The minimum reserve required by period, and risk levels.

Third: The PERT method: (PERT) PERT was initially created by the US Navy in the late 1950s. It was first used in the experimental ballistic missile development project and there were thousands of contractors involved. Sometimes people classify and put PERT and CPM together. Although CPM shares some characteristics with PERT, PERT has a different focus, while CPM defines project duration planning in a deterministic manner, i.e. all duration is known as a lead, whereas PERT treats the duration of activities as a random variable trial with expected completion values ((Nafkha, 2016, 545) (Milojevic, et. al, 2022, 1126), that the project appraisal and review technique (PERT) uses projected activity time to overcome uncertainty related to activity work time, based on three estimates of estimated time (Prabowo and Anhar , 2020, 6):

1- The most probable time: The most appropriate time to complete an activity is the most frequent time if the activity is repeated several times

2- Optimism time: the shortest possible time

3- Pessimism time: the longest time an event may take.

The PERT method can also be used to be available to assist the maintenance project manager in carrying out their responsibilities, and among their responsibilities is to develop plans and schedule maintenance activities, as the maintenance activity provides unique opportunities for the maintenance department within a relatively short period of time, as well as enables it to maintain The continuity of machinery and equipment to work without interruption, in addition to that, the best way to ensure the success of any type of maintenance project depends on advance planning by adopting the trial and error technique, and this would direct managers to decide on maintenance activities to reduce the total cost and prevent the machines from stopping work and completion Maintenance work on time (Elmabrouk and Aljiebali, 2012, 290). The use of the BERT method in planning and scheduling maintenance operations in hydroelectric stations is useful because it helps to determine the time taken to complete various tasks, identify potential risks, and improve the efficiency and effectiveness of maintenance operations. It also helps to provide information Accurate and detailed for project management and maintenance teams that can be used to make the right decisions and improve maintenance operations in general (Jonsson, 2015, 1).

The third axis: the field side

First: Description of maintenance works: The Haditha hydroelectric station is one of the electric stations in Iraq that operates under the pressure of water resources. Periodic maintenance work every year, the maintenance work for the year 2022 is shown in Table (1), where the maintenance team at the station carries out (15) maintenance work for different activities, as these works take approximately (363) days throughout the year, and there are days For holidays and events estimated at (93) days during which work stops, in addition to the days of necessary stops as a result of lack of availability of materials or other circumstances, which are estimated at (11) days, and thus the total net work days are (259) days, which means that within 259 days maintenance plans are implemented. in all its details during the year.

Table (1) Description of maintenance work, total working days, days off, stoppages, and net time at the station

no	work orders	Total time in days	days off	Days of necessary downtime	net maintenance time	Subsequent activity	previous activity
1	**Unit one**	40	13	5	22	A	
2	**Unit two**	44	-	6	38	B	A
3	**Unit three**	28	8	0	20	C	A
4	**Unit four**	10	4	0	6	D	B
5	**First main transformer (B1)**	3	-	0	3	E	A
6	**transformer maintenance (11)**	11	2	0	9	F	A
7	**Rainwater drainage system maintenance**	10	2	0	8	G	D
8	**Second main transformer (B2)**	64	18	0	46	H	G
9	**Left and right irrigation port**	10	4	0	6	I	C,E
10	**Transformer maintenance and firefighting A1 + E1**	10	4	0	6	J	F
11	**Maintenance of service transformers from T1 to T15**	39	9	0	30	K	I,J
12	**River level gantry crane maintenance**	33	10	0	23	L	K,G
13	**Maintenance of the gantry crane at the level of the dam body**	44	13	0	31	M	H,L
14	**Maintenance of the gantry crane in the machinery hall**	13	4	0	9	N	M
15	**Final checks**	4	2	0	2	O	N
	Total	363	93	11	259		

Second: Choosing the Business Network: Based on the results of Table (1), the researcher cooperated with the maintenance team at the station, the study sample, considering the net time of (259) days as the potential time, as well as the previous and subsequent activities were arranged according to the important and most important, and then the time was distributed to Three types (optimistic time - potential time - pessimistic time), and in light of this, the Bert method was chosen to analyze and plan maintenance work based on the program (WinQSB) because it is the most appropriate method for the study sample on the one hand, in addition to not applying the Bert method in such activities in The station is the study sample on the other hand, and this is the opportunity to test the ability of this method to help the maintenance team to complete their work before the specified time.

Table (2): The order of the previous and subsequent activities, and the optimistic, probabilistic, and pessimistic times

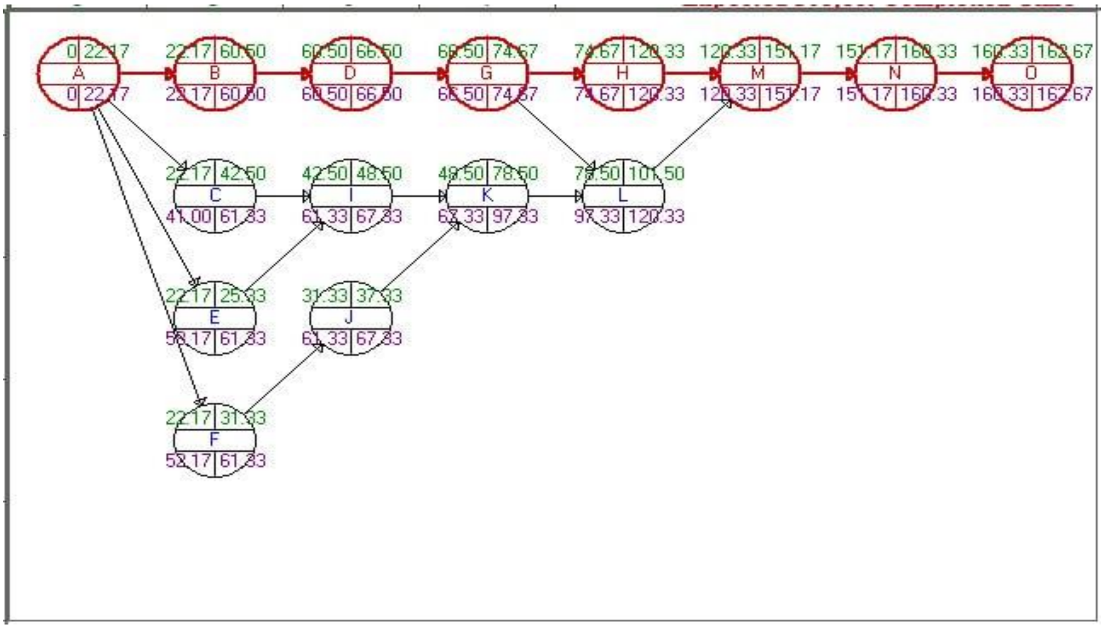
orders	Subsequent activity	previous activity	optimistic time	probabilistic time	pessimistic time
1	A		19	22	26
2	B	A	34	38	44
3	C	A	18	20	24
4	D	B	4	6	8
5	E	A	2	3	5
6	F	A	7	9	12
7	G	D	6	8	11
8	H	G	40	46	50
9	I	C,E	4	6	8
10	J	F	3	6	9
11	K	I,J	26	30	34
12	L	K,G	20	23	26
13	M	H,L	26	31	35
14	N	M	7	9	12
15	O	N	1	2	5
total			217	259	309

Third: Data Analysis: On the basis of the results of Table (2), all previous and subsequent activities and all times (optimism - probability - pessimism) were entered into the (WINQSB) program. After the analysis was conducted in the program, the results in Table (3) show that there are One critical path includes activities (A - B - D - G - H - M - N - O), as the total number of working days according to this path was 162 days, while the total number of planned days was 259 days, which indicates that the possibility of completing The project rate is (63%), and this percentage is acceptable, but modest. The station management must provide sufficient human and material resources to complete the project as quickly as possible and at a higher rate, as well as clarifying the early and late start and end times, the excess time and the standard deviation.

Table (3) Critical path and times for activities, early and late start and end, overtime and standard deviation

04-20-2023 03:58:47	Activity Name	On Critical Path	Activity Mean Time	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Slack (LS-ES)	Activity Time Distribution	Standard Deviation
1	A	Yes	22.1667	0	22.1667	0	22.1667	0	3-Time estimate	1.1667
2	B	Yes	38.3333	22.1667	60.5	22.1667	60.5	0	3-Time estimate	1.6667
3	C	no	20.3333	22.1667	42.5	41.0000	61.3333	18.8333	3-Time estimate	1
4	D	Yes	6	60.5	66.5	60.5	66.5	0	3-Time estimate	0.6667
5	E	no	3.1667	22.1667	25.3333	58.1667	61.3333	36.0000	3-Time estimate	0.5
6	F	no	9.1667	22.1667	31.3333	52.1667	61.3333	30.0000	3-Time estimate	0.8333
7	G	Yes	8.1667	66.5	74.6667	66.5	74.6667	0	3-Time estimate	0.8333
8	H	Yes	45.6667	74.6667	120.3333	74.6667	120.3333	0	3-Time estimate	1.6667
9	I	no	6	42.5	48.5	61.3333	67.3333	18.8333	3-Time estimate	0.6667
10	J	no	6	31.3333	37.3333	61.3333	67.3333	30.0000	3-Time estimate	1
11	K	no	30	48.5	78.5	67.3333	97.3333	18.8333	3-Time estimate	1.3333
12	L	no	23	78.5	101.5	97.3333	120.3333	18.8333	3-Time estimate	1
13	M	Yes	30.8333	120.3333	151.1667	120.3333	151.1667	0	3-Time estimate	1.5
14	N	Yes	9.1667	151.1667	160.3333	151.1667	160.3333	0	3-Time estimate	0.8333
15	O	Yes	2.3333	160.3333	162.6667	160.3333	162.6667	0	3-Time estimate	0.6667
	Project	Completion	Time	=	162.67	days				
	Number of	Critical	Path(s)	=	1					

Based on the data of Table (3), this data has been embodied into a graphical chart representing the business network (Bert method). Figure (1) shows the results of the critical path of maintenance operations in the study sample station. This diagram will help the station management to carry out its work as quickly as possible. Without procrastination or delay, as a method applied for the first time to maintenance operations at the station.



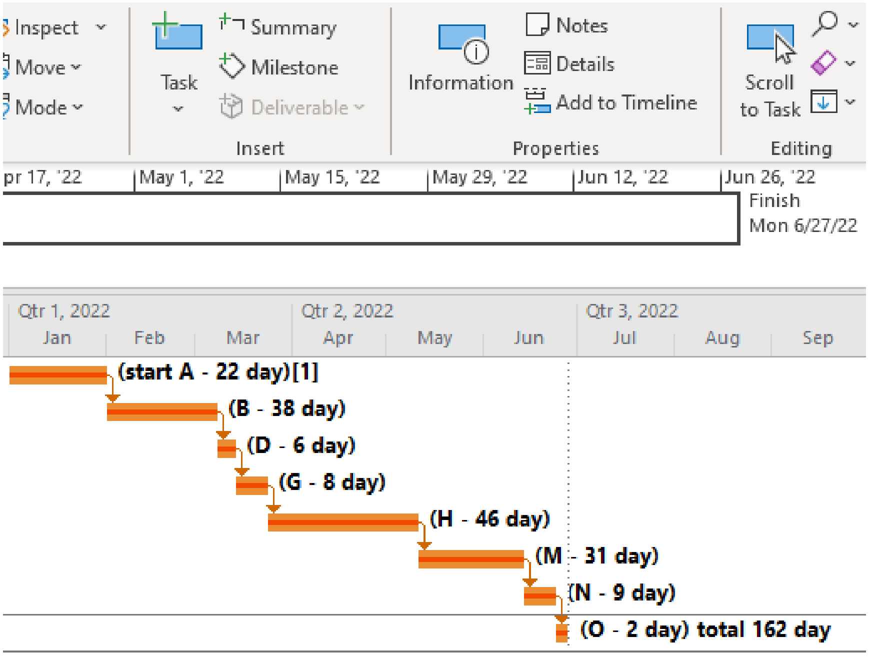
The above diagram (1) gives us a clear summary of the critical path of the activities, as shown in Table (4), as it becomes clear that the total critical path of all activities (8) is accomplished during a period of 162.67 days, with a standard deviation of (3.38).

Table (4) shows the number of activities along the critical path, their completion time, and the standard deviation

04-25-2023	Critical Path 1
1	A
2	B
3	D
4	G
5	H
6	M
7	N
8	O
Completion Time	162.67
Std. Dev.	3.38

Fourth: Gantt Chart: After completing the calculations of the completion time of the maintenance operations using the PERT method, it was necessary to use another method to calculate the project completion time to compare the results, as the project management program was used to find the completion time of the maintenance operations. This program is one of the scientific programs that works with high accuracy and is easy to use and is characterized by the speed of obtaining the final results, in addition to that it has the ability to absorb changes that arise in the project, including times and costs, as data for maintenance activities was entered, which included the time required for each activity, And the time sequence, and the relationship between the activities, and it was concluded that the time required to complete the maintenance project is 162 days, which is completely identical to the front and back accounts that were calculated by the program

(WINQSB) and whose results are shown in Table (3), as well as determining the critical path as shown in Figure (2).



Fifth: Simulation of maintenance operations times: In order to help the station management implement maintenance operations quickly, as the total critical path reached 162.7 days, with a completion rate of 63%, and this is a very modest percentage. Therefore, simulations of maintenance operations times were performed. Data for maintenance operations was generated using the program (WINQSB) and it was repeated 1000 times, so the result of the simulation was that the total completion period of the project is 172 days with a completion rate of 99.9%. On the basis of that, we encourage the station management and the maintenance team to adopt the results of the simulation process because it is a tool that enables them to speed up the completion of maintenance operations, because it is better. From the adoption method, 162.7 days, at a rate of 63%.

04-25-2023	Completion Time From	To (included)	Frequency	%	Cumulative %
0	0	153.67	3	0.3000	0.3000
1	153.67	154.57	4	0.4000	0.7000
2	154.57	155.47	12	1.2000	1.9000
3	155.47	156.37	8	0.8000	2.7000
4	156.37	157.27	7	0.7000	3.4000
5	157.27	158.17	38	3.8000	7.2000
6	158.17	159.07	63	6.3000	13.5000
7	159.07	159.97	66	6.6000	20.1000
8	159.97	160.87	75	7.5000	27.6000
9	160.87	161.77	110	11.0000	38.6000
10	161.77	162.67	89	8.9000	47.5000
11	162.67	163.57	129	12.9000	60.4000
12	163.57	164.47	94	9.4000	69.8000
13	164.47	165.37	91	9.1000	78.9000
14	165.37	166.27	69	6.9000	85.8000
15	166.27	167.17	54	5.4000	91.2000
16	167.17	168.07	40	4.0000	95.2000
17	168.07	168.97	26	2.6000	97.8000
18	168.97	169.87	10	1.0000	98.8000
19	169.87	170.77	5	0.5000	99.3000
20	170.77	171.67	6	0.6000	99.9000
21	171.67	and over	1	0.1000	100.0000
	Total	Observations =	1000	Random Seed =	27437
	Average	Completion	Time =	162.75 days	
	Chance	to finish in	172 days	= 99.9000%	

Sixth: Scheduling the times of maintenance operations: Based on the results of the critical path in Table (3), a scheduling of maintenance operations was established according to the first-in, first-served method, as it was found that the processing time is (162) days, and this is consistent with the result of the critical path shown in Table (4). Also, orders along the critical path whose due time was consistent with the processing time, but these orders do not have an early time, but there is a late time, and this delay is not intentional, but indicates the waiting period until the work is executed, for example, order A is processed within 22 days and the due date 22 days, there is no early or late time because it is the first work, but work B needs 38 days to process, but it waits until work A is completed, so work B will wait at least 22 days, work G requires 6 days to complete it, but it waits until work B A is finished and so The work of G will wait at least 60 hours, and so on for the rest of the work until reaching 160 days. Thus, this delay is planned and not intended, which makes the works in the study sample station wait until the priority works are completed, and this indicates that the hydroelectric station does not have multiple and specialized maintenance teams This makes the maintenance process delayed, in addition to that, we confirm once again that the scheduling of operations is compatible with the results of the critical path plan through the following equation (Flow time - late time = 815 - 653 = 162 days) and this value gives us evidence of compatibility of the scheduling law with maintenance planning According to Bert's method, we will accept the hypothesis of the study.

Table (4) Scheduling of maintenance operations according to the first-in, first-served method

orders	processing time	Flow time	Due date	delivery time	early time	late time
A	22	22	22	22	0	0
B	38	60	38	60	0	22
D	6	66	6	66	0	60
G	8	74	8	74	0	66
H	46	120	46	120	0	74
M	31	151	31	151	0	120
N	9	160	9	160	0	151
O	2	162	2	162	0	160
total	162	815		815	0	653

Conclusions and suggestions

First: Conclusions: The study reached a number of conclusions, the most important of which are:

1- The results of data analysis according to the PERT method revealed that the total project completion period is estimated at 162 days instead of the 259 days set by the station management, with a completion rate of 63%, and this percentage is modestly acceptable and with a standard deviation of 3.38.

2- The study plan (Bert method) concluded that there is one critical path, and this path includes the following activities (A - B - D - G - H - M - N - O).

3- The results of the simulation process increased the total project completion time to 172 days instead of 162 days, which makes the completion rate 99.9%. This is the desired percentage that helps the station management to complete maintenance operations as quickly as possible.

4- The results of the program (project management) Gantt chart show that the project completion period is 162 days, and it starts from the date 1/1 until 6/27/2022, and this corresponds to the outputs of Table (3).

5- The results of scheduling maintenance operations according to the first-in, first-served rule indicate that the total period for completing the project is 162 days, by comparing the difference between flow time and delay time.

Second: Recommendations: Based on the conclusions, the following recommendations were made:

1- The need for the station management to adopt modern scientific methods and ready-made computer programs for planning and scheduling operations in order to be able to set a schedule for preventive and corrective maintenance, based on an analysis of the previous performance of devices and equipment and anticipating possible malfunctions.

2- Work on the use of business networks CPM and PERT method because of its great role in shortening time and setting business priorities according to scheduling rules.

3- Forming multiple specialized work teams with experience in the field of maintenance in order to complete the work with the least possible time and effort, with high coordination with the maintenance teams.

4- There should be a clear strategy for preventive and corrective maintenance, and setting priorities based on the importance of devices and their impact on productivity.

5- Providing the necessary financial and human resources to implement maintenance plans, including training technicians and station workers on how to deal with devices and equipment, as well as providing spare parts and equipment necessary for maintenance, including storing and securing spare parts in case of need.

6- Using modern technologies in planning and scheduling maintenance, such as integrated maintenance management systems (CMMS), vibration analysis, and advanced techniques for fault diagnosis.

Sources

1. Safaa Abdel-Amir, 2010, Planning maintenance services and its role in increasing production (a case study in the Musayyib thermal power station), master's thesis, College of Administration and Economics, University of Karbala, Iraq.
2. Ashayeria, J. and Selen, Teelen, 2012, A production model and maintenance planning model for the process industry, https://core.ac.uk/download/pdf/7009038.pdf.
3. Elmabrouk, Omar and Aljiebali, Fardous, 2012, Crashing Project Activities Using Linear Programming Technique, Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management, Istanbul, Turkey, July 3 – 6, 2012.
4. Froger, Aur´elien and Gendreau, Michel and Jorge, Mendoza and Pinson, Eric and Rousseau, Louis-Martin, 2016, Maintenance scheduling in the electricity industry: a literature review, European Journal of Operational Research, 251(3).
5. Jaafaru, Hussaini and Agbelie, Bismark , 2022, Bridge Maintenance Planning Framework Using Machine Learning Multi-Criteria Decision Analysis and Evolutionary Optimization Models, journal of Automation in Construction, No.143.
6. Jonsson, Magnus Thor, 2015, Power Plant Maintenance Scheduling using Dependency Structure Matrix and Evolutionary Optimization, Proceedings of the World Congress on Engineering and Computer Science, Vol 2, October 21 - 23, 2015, San Francisco, USA.
7. Milojevic, Ivan and Krstic, Dalibor and Jovicic, Aleksandar, 2022, application of the pert method in the audit of business of agricultural enterprises, journal of Economics of Agriculture, No. 4, 2022, pp. 1125-1137, Belgrade.

8. Nafkha, Rafik, 2016, the pert method in estimating project duration, Information Systems in Management, Vol. 5 (4) 542−550.
9. Popovic, Louis and Cote, Alain and Gaha, Mohamed and Nguewouo, Franklin, 2022, Scheduling the Equipment Maintenance of an Electric Power Transmission Network Using Constraint Programming, 28th International Conference on Principles and Practice of Constraint Programming (CP 2022), Article No. 34; pp. 34:1–34:15.
10. Prabowo, Hugo and Anhar, Muhammad, 2020, optimization of project management at pt cipta ekatama nusantara using cpm – pert method in cendana sawangan regency housing development, Journal STEI Economic.