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ENHANCING MACHINERY REPAIR MANAGEMENT IN ROAD CONSTRUCTION

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บทคัดย่อ

งานซ่อมบำรุงเครื่องจักรหนักที่ล่าช้ากว่ากำหนดอาจส่งผลให้งานก่อสร้างถนนล่าช้าไปด้วย งานวิจัยนี้จึงมีวัตถุประสงค์เพื่อเพิ่มประสิทธิภาพในการบริหารงานซ่อมเครื่องจักรกลหนักในงานก่อสร้างถนน โดยใช้แนวทางการบริหารโครงการ เครื่องมือหลักได้แก่ วิธีสายงานวิกฤติ (CPM) แผนภูมิแกนต์และเส้นโค้งตัว S การดำเนินการวิจัยมีขั้นตอนดังนี้ 1) รวบรวมข้อมูลการเสียของเครื่องจักรและสาเหตุเพื่อกำหนดวิธีการซ่อมแซมและเวลามาตรฐานในการซ่อม 2) สร้างระบบฐานข้อมูลเพื่ออำนวยความสะดวกในการจัดทำแผนการซ่อม 3) วิเคราะห์กิจกรรมเครือข่ายการซ่อมด้วย CPM 4) สร้างแผนภูมิแกนต์เพื่อนำเสนอแผนสำหรับแต่ละโครงการซ่อม 5) ดำเนินการควบคุมและติดตามความคืบหน้าด้วย S-curve 6) หากพบว่าการซ่อมแซมล่าช้ากว่าที่วางแผนไว้จะมีมาตรการเร่งรัด หลังจากการปรับปรุงหนึ่งปีแล้วทำการประเมินผลได้ว่าสามารถกำจัดเวลาที่ไม่มีประสิทธิภาพลง ส่งผลให้เวลาหยุดทำงานเพื่อซ่อมลดลง เช่น การหยุดซ่อมของระบบตัวถังลดลงจาก 75 วันเหลือ 16 วัน (78.67%) การหยุดซ่อมของระบบเครื่องยนต์ลดลงจาก 122 วันเหลือ 54 วัน (55.74%) โดยสรุปได้พบว่าเมื่อนำการบริหารโครงการมาประยุกต์ใช้กับงานซ่อมแซมแล้วเวลาหยุดทำงานเพื่อซ่อมลดลงได้ 23.33% ถึง 55.74%

คำสำคัญ: การบริหารงานซ่อมบำรุงเครื่องจักร; งานก่อสร้างถนน; การบริหารโครงการ

ABSTRACT

The delay in repairing heavy machinery may result in the slow completion of road construction. The objective of this research was to apply the project management approach to the management of heavy machinery repair work in road construction. The main tools were Critical Path Method (CPM), Gantt chart, and S-curve. The study was conducted with the following procedures: 1) collecting the data on failures and causes to determine the repair methods and standard time of repairs, 2) building a database system to facilitate the creation of repair plans, 3) analyzing the repair network activities with CPM, 4) creating Gantt charts to present a plan for each repair, 5) conducting control and monitoring progress by S-curve, 6) if the repair was found to be delayed than planned, countermeasures were required to be following the repair plan. After one year of improvement, the results were evaluated, indicating that inefficient time was eliminated, resulting in reduced downtime e.g. downtime of body system reduced from 75 days to 16, days (78.67%), downtime of engine system reduced from 122 days to 54 days (55.74%). In summary, it would find that when applying the project management to repair work, downtime could be reduced 23.33% to 55.74%

KEYWORDS: Machinery Repair Management; Road Construction; Project Management

1. Statement of problem

The road construction industry contributes significantly to a country's physical, economic, and social prosperity. To respond to the current highly competitive condition, the construction industry must change its corporate strategy, such as having skilled staff to handle projects efficiently, including effective technology and equipment [1-3].

One of the road construction problems in Thailand, small and medium contractors have encountered financial and budget constraints, indicating that before the start of construction projects, new machines could not be prepared. These small and medium contractors' traditional machinery procurement approach was to purchase used machinery [4]. That may be one of the causes of operational failures that occur unexpectedly. Besides, untrained machine operators and not well-done machine servicing habits contributed to unexpected machinery failures [5]. Figure 1 shows an example of a heavy machine and road construction project in Thailand and Figure 2 illustrates machine failure types of the medium contractor in road construction in this research. There were systems of the engine, hydraulic, power transmission, suspension, electricity, body, backhoe, and others. The results showed that the most frequently failed system was the suspension system (32%) with the longest time to repair at 43 days, followed by the electricity system (20%) and the power transmission system (19%) with the longest time to repair at 63 and 41 days, respectively. The time spent to repair included inefficient time, thus causing downtime to be longer than usual, for example, delayed purchase of spare parts led to a delay in receiving spare parts. Machine repair could be done when spare parts were available. A short description of each type of failure is shown in Table 1.

The construction contractor in this study commonly used reactive maintenance or run-to-fail, resulting in severe damage such as engine piston deformation due to engine overheating. The machine would then be unable to function, and repairs would take a long time due to damage to other components. Moreover, it also lacked repair preparation, power, and monitoring. The repair took a longer time than it should. As a result, road building projects were delayed [6], and the majority of machinery repair was done without any planning, controlling, or monitoring.

Figure 1 Heavy machine and road construction project in Thailand

As mentioned above, the repair management did not use a plan for any repairs, inputs for the planning process were neglected, it implied that there was no diagnosis of any repairs, resulting in the inability to determine the time when the repair should be completed and the repair time could be uncontrolled. It was believed that it was impossible to handle repairs efficiently and the time to repair (MTTR) was excessive. Also, there were related problems, including no supervision of machine repair, no information available for planning, etc., in line with several papers that confirmed that planning and control were the key factors of the success of maintenance management projects [7-8].

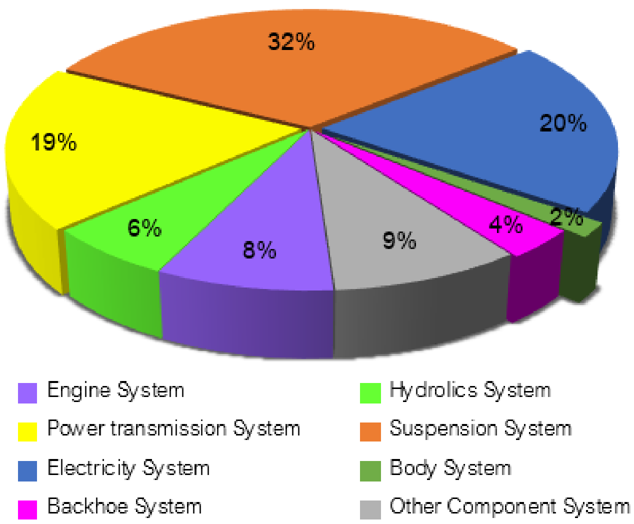


Figure 2 Frequency of heavy machinery repairs (during January to October in 2018)

Table 1 Types of failures and description

No.	Types of failure	Abnormalities and repair activities
1	Engine System	water entering the engine, repair, overhaul,
2	Hydraulic System	hydraulic cylinder leaks, broken hydraulic line s
3	Power transmission System	leaky radiator. repair gear, clutch, pump, shaft, etc.
4	Suspension System	repair steering, brakes, tires, etc.
5	Electrical Control System	repair air conditioner, electrical control systems.
6	Body System	Bodypaint and collision repair
7	Backhoe System	repair backhoe system
8	Other Component Systems	repair cylinder, seal, overhaul, etc., (excluding items 1 through 7).

To achieve effective management, project management has been widely used including used in road construction project management. However, project management is not widely used in maintenance because in the perspectives of project leaders and engineers, and foremen, project management is very complicated to be used for any repairs [9]. Demirkesen and Ozorhon commented that an efficient team would have a positive effect on efficient construction project management [3]. In this research. the management of road construction machinery repair project management was interested. Therefore, building a collaboration of the personnel in the repair project management was important to achieve success.

Project management is used in highly successful construction projects to manage risks and uncertainties [10] that can lead to project delays because project management can be applied from planning to the implementation process in resource management, manpower management, and the ability of the organization under the operations. Furthermore, progress is controlled and monitored regularly, with steps to endorse or revise activities to ensure they are carried out as scheduled. [3, 9].

In this research, project management was applied to maintenance management with a focus on machine repair planning and control. The project management tools selected included the Critical Path Method (CPM), Gantt chart, and S-curve.

2. Project management tools for a repair project

2.1 CPM

CPM is a useful management method for project planning and scheduling, as well as cost reduction and resource allocation. It can be used to find a critical path for a construction project, even though these strategies were applied to several maintenance programs [11-14]. CPM is considered an assistive tool in the analysis, the scope of the repair project, the activities to be carried out, critical activity path were cleared including project duration and expenditures.

2.2 Gantt chart

Henry L. Gantt developed the Gantt chart method in 1917 to help people schedule their time. Individual tasks that start and finish at various times are replaced with rectangular bars. A building project was used as an example of using a Gantt chart [15]. A project scheduling phase is often included as a sub-element of planning. The Gantt chart is common to provide information on project schedules and progress [15]. In this study, a Gantt chart was employed to demonstrate a project schedule.

2.3 S-curve

The S-curve is a graph that depicts the progress of a project using an S-shaped curve. The percentage of activity development is represented on the vertical axis of the S-curve, while the length of the activities is represented on the horizontal axis. The S-curve is used in applications that display growth, such as living organisms, market growth, and innovation growth, as well as in project management in construction. When it is discovered that the output does not go according to the plan, it would be able to change the plan or remedy it to work to meet the goals quickly.

Typically, the construction management project's S-curve is divided into three phases, (a) Early phase: is site planning, which takes a long time and has a less steep curve, (b) Middle phase: the curve steepens as the work continues over a shorter time, (c) End of the project: It was the point at which the work was finished. This study used the S-curve of a project for the monitoring and tracking of the machine repair project (Figure 3).

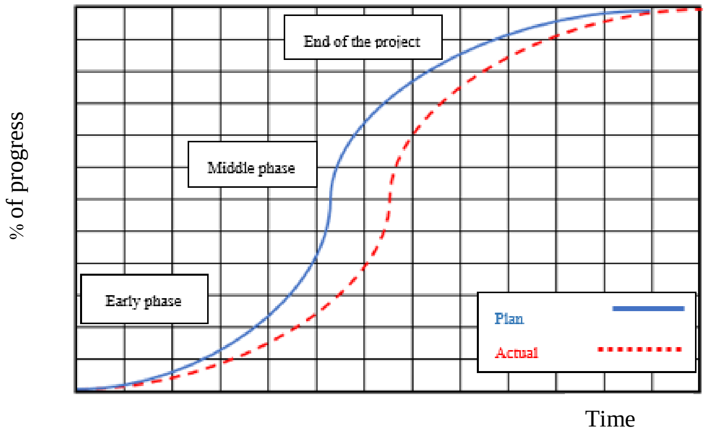


Figure 3 S-curve of project

3. Research methodology

Figure 4 illustrates the procedures of the research method. A participatory approach [6] was used in this research to facilitate the teamwork's meeting for repair projects more efficiently, which consisted of 1) a project construction executive who conducted a repair project meeting, 2) a repair technician who determined a repair method, 3) a procurement officer as key informants regarding spare parts, such as price, lead time, and coordinate with an external provider, 4) civil engineer who supervised the construction work also participated.

Effective teamwork had a positive effect on project management efficiency [3, 10, 16] as well as maintenance projects of road construction management. Teamwork who participated in the meeting of the repair project considered the statistics of machine failure, causes of breakdowns, and determined the repair process and repair time. The CPM and Gantt chart was used for the analysis of repair activities of the repair project.

Next, a database system was created for use in repair planning. The repair history was stored in the database. It was analyzed to obtain repair activities for the CPM and a roadmap was generated with Gantt charts. Figure 5 shows the structure of the database system and does not clarify the specifics of how to construct the system here. The database system, on the other hand, would be critical in integrating CMMS in the organization for future growth [17].

With an actual S-curve, the teamwork could monitor and track the progress of each repair project until the repair plan has been implemented. When it was discovered that the actual S-Curve did not match the planned S-curve, the cause had to be investigated, and steps had to be taken to meet the repair project's deadline.

The assessment of performance was the next step. In this study, downtime (ineffective time and Mean Time To Repair) was used as the indicator. Ineffective time and MTTR should begin to decrease as repair management improves, increasing availability. The use of MTTR has been addressed in maintenance research [18-19]

$$MTTR = \sum_{i=1}^{N} \frac{T_i}{N} \quad , \qquad (1)$$

Ti is the time it takes to repair,

N is the number of times the machine is broken.

From Figure 5, the "Machine" table in the database shows the machine's code and machine type code, for example, AF is a type of machine and has machine codes, such as AF03 AF04 AF05, and so on. The "MachineType" table shows the machine type code and machine type description. The " Part" table shows various parts of each machine and components. The " ComponentSystem" table consists of a group of parts of a machine, including Engine, hydraulic, transmission, suspension, chassis, electrical system, excavator arm, and other components. "Machine_Maintenance" table shows the relationship between each machine and its parts, work order number, repair date, and repair method. The " Part_Maintenance" table shows the relationship between repair projects with various parts of each machine that need to be repaired. The "Project" table shows the repair project code and description of that project. The " Maintenance" table shows repairs, such as Adjust, Clean, Check, Inspection, Tightening, Replacement. "Project_Procedure" shows the repair sequence for each project, project code, along repair times according to the CPM. The order of repairs uses symbols A, B, C,… respectively. Also, symbols M1, M2, M3,… for other activities e.g. M1 = purchasing spare parts.

4. Results

The following are examples of research findings. Figure 7 depicts nine network activities in the CPM and Gantt chart for the body repair of ten-wheel truck no.18. with a critical path of A, M1, and an optimistic time of 8 days. S-curve was used to monitor the project's progress as soon as it was implemented. As a result, it was determined that the repair activities had been delayed since the beginning of the repair project. The countermeasure was taken, but they were unable to catch the plan. This might be because the traditional time used in repair project planning was impracticable.

Figure 8 depicts the loader No. 2 overhaul project, which has a critical path of A, M1 and a plan optimistic time of 47 days. It was found that it was progressing only eighty percent at the end of 47 days. The work was completed at 122 days. Figure 9 states the FT-07 with a critical path of A, M1, and B, and of 18 days. At the end of the project time. It could operate ninety percent. It could be seen that the beginning of the project in the S-curve was still in the plan. But from the middle to the end of the project, the work began later than the plan. Some workpieces had been sent to repair at another repair shop, which was not in the plan. After that, these workpieces were returned to the main workshop.

Figure 10 depicts a project for repairing the loader's transmission system, which has a critical path of A, B, C, M2, D, E, M3 and an optimistic time of 15 days. Due to a faulty purchase of spare parts, the work began later than plan. Figure 11 depicts the hydraulic system repair project of grader No.02, which has an optimistic time of 8 days. The S-curve indicating that the actual repair schedule was delayed due to the late arrival of spare parts. Figure 12 depicts the air conditioning repair project for the excavaroe no. 25, which had a critical path, an optimistic time, and a tracking S-curve. The project began later than plan due to a shortage of repair technicians.

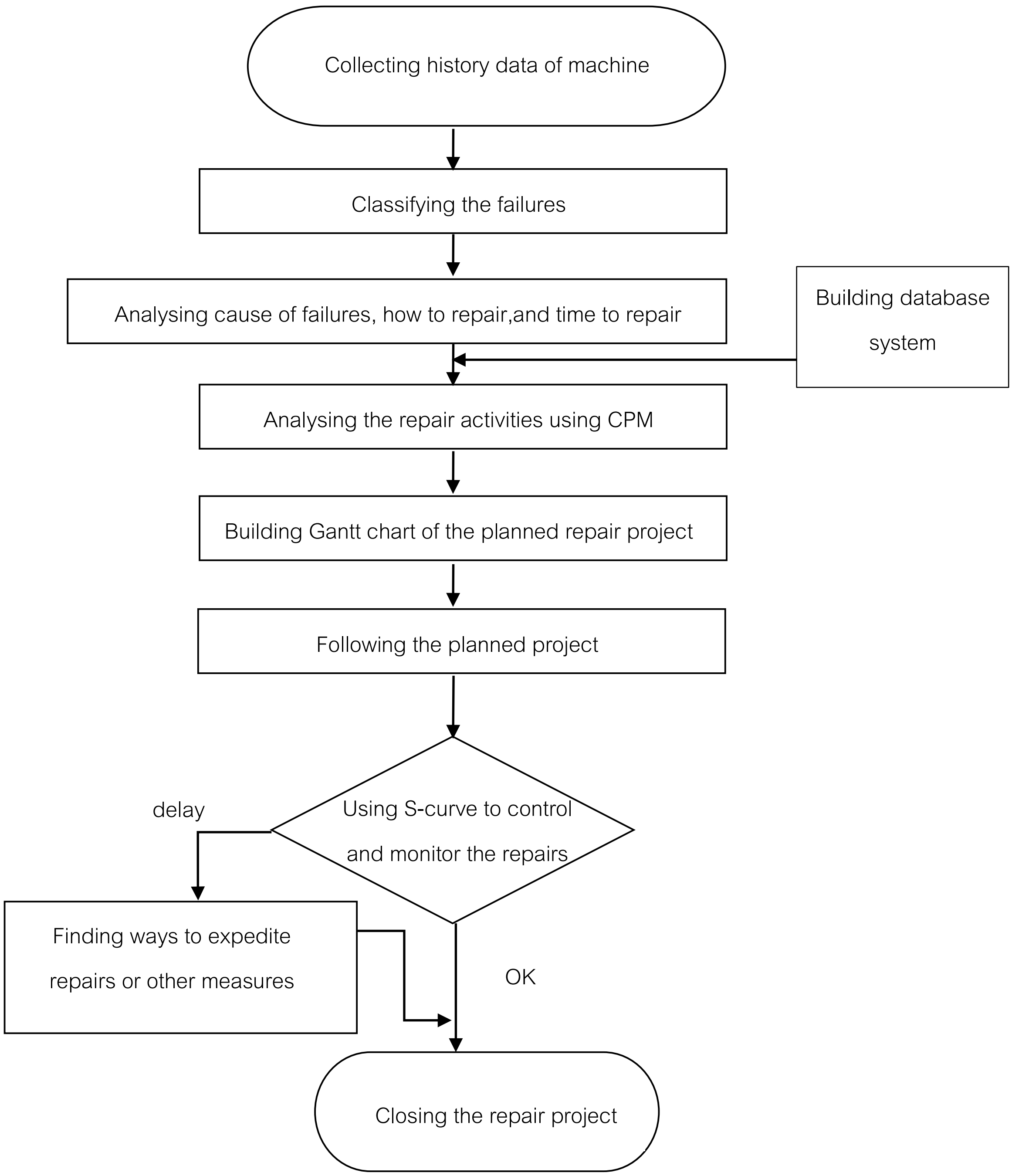


Figure 4 Procedure of the study

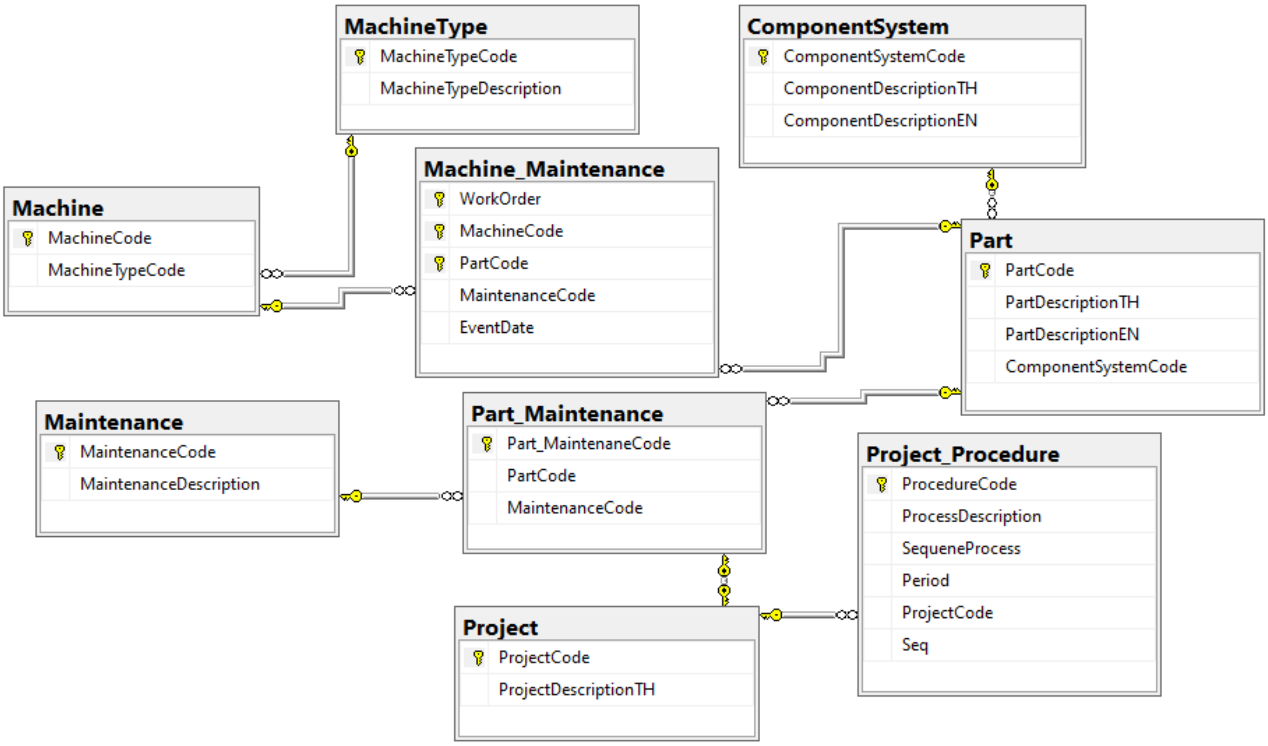
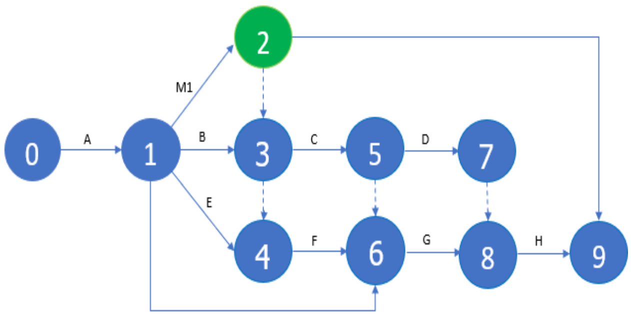


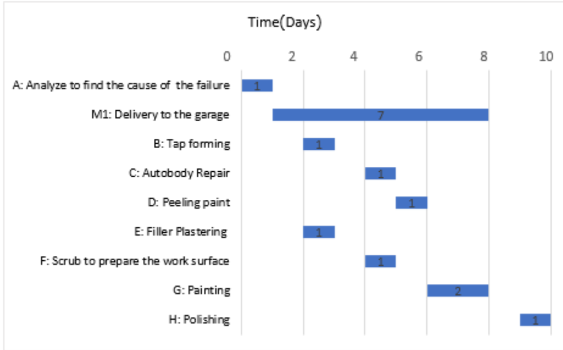
Figure 5 Database Structure

ProcedureCode	ProcessDescription	SequeneProcess	Period	ProjectCode	Seq
A	Analyze to find the cause of the failure	-	1.0	P002	1
M1	Delivery to the garage	A	7.0	P002	2
B	Tap forming	A	1.0	P002	3
C	Autobody Repair	A,B	1.0	P002	4
D	Peeling paint	A,B,C	1.0	P002	5
E	Filler Plastering	A	1.0	P002	6
F	Scrub to prepare the work surface	A,E	1.0	P002	7
G	Painting	A,F	1.0	P002	8
H	Polishing	A,F,G	1.0	P002	9

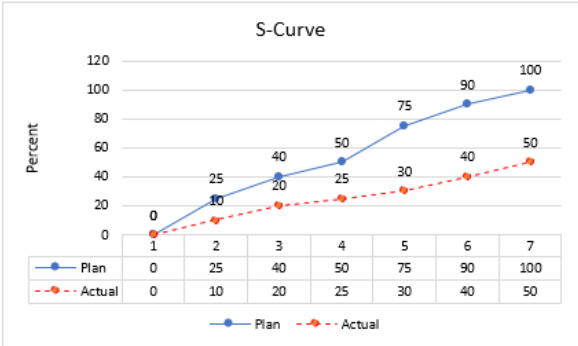
Figure 6 Record in the "Project_Procedure" database



a) Network activities

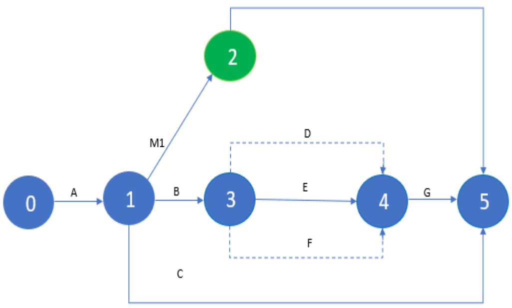


b) Gantt chart

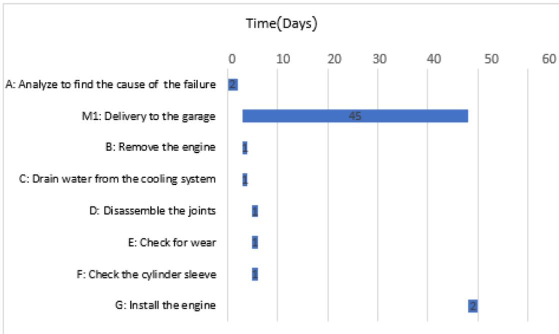


c) S-curve

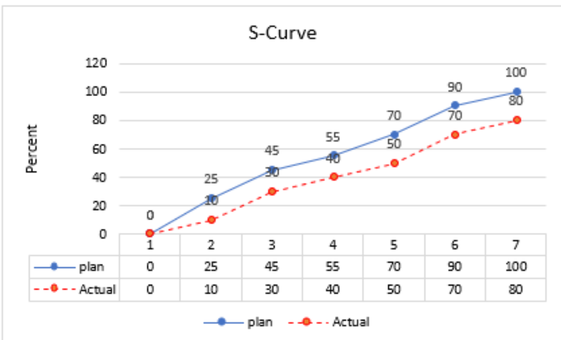
Figure 7 Body system repair project of ten-wheel truck no.18



a) Network activities

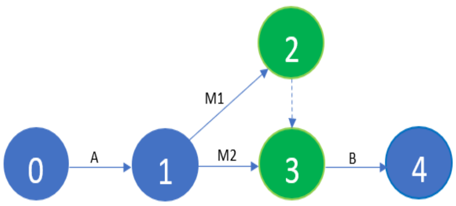


b) Gantt chart

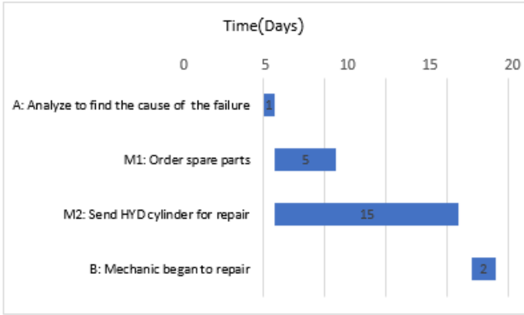


c) S-curve

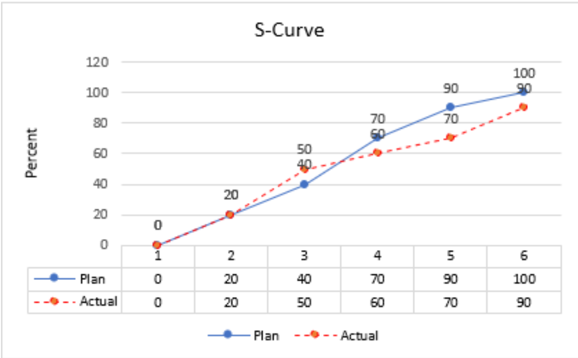
Figure 8 Engine system overhaul project of loader No. 2



a) Network activities

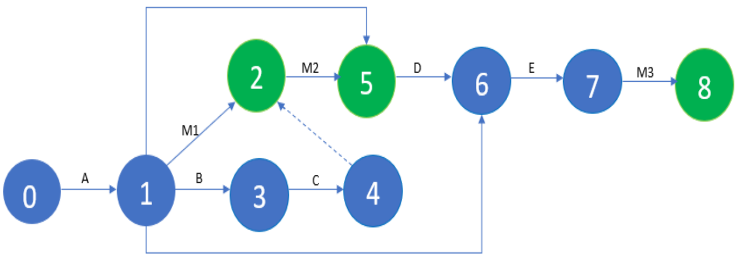


b Gantt chart

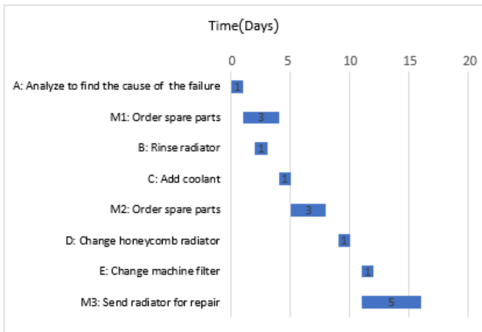


c) S-curve

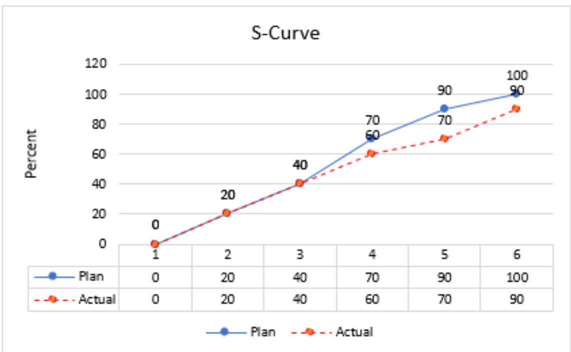
Figure 9 Suspension system repair project of FT 07



a) Network activities

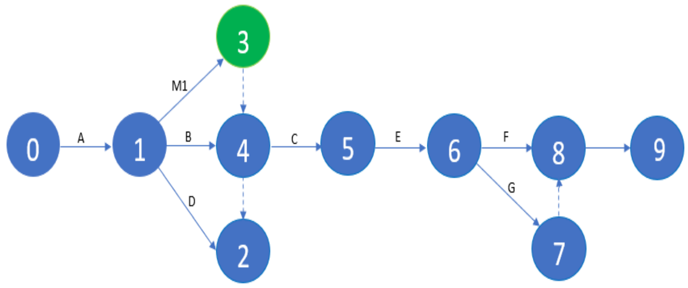


b) Gantt chart

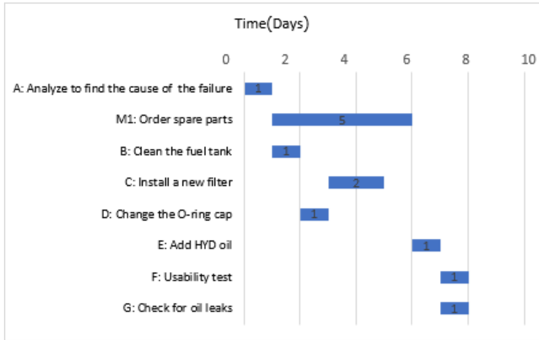


c) S-Curve

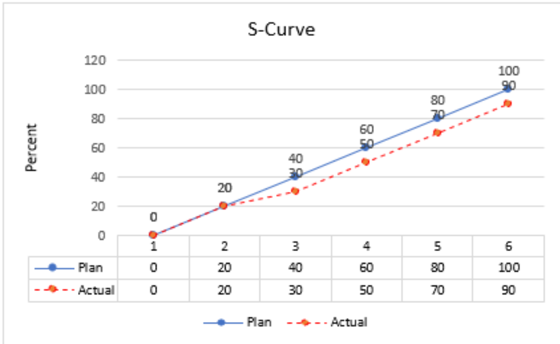
Figure 10 Transmission system project of loader no.5



a) Network activities

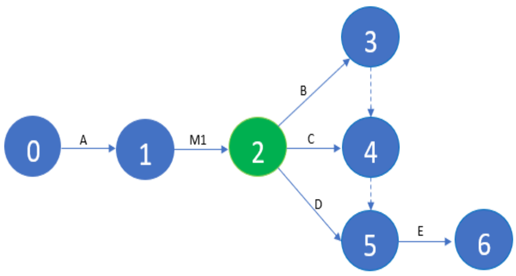


b) Gantt chart

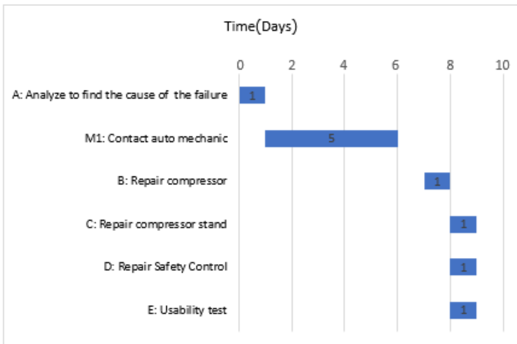


c) S-Curve

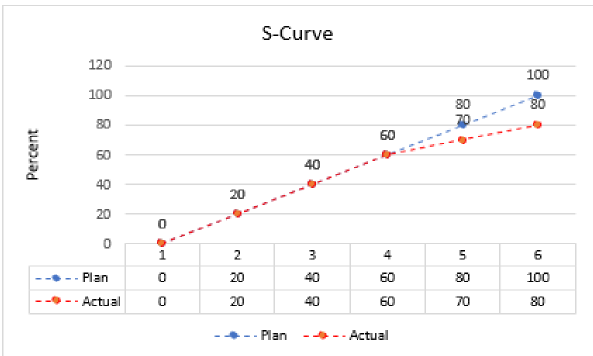
Figure 11 Hydraulic system repair project of grader no.2



a) Network activities

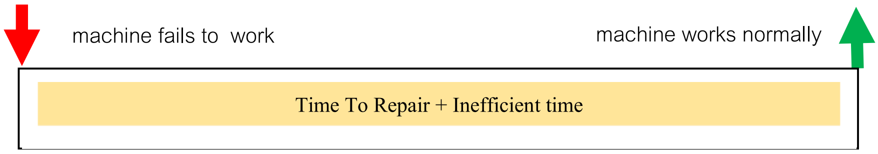


b) Gantt chart

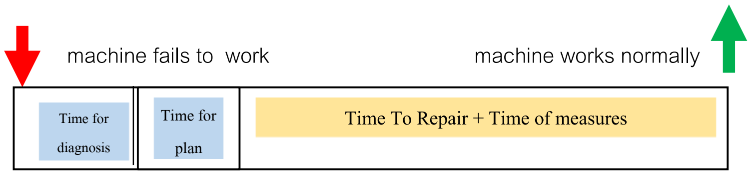


c) S-Curve

Figure 12 Electrical system repair project of excavator no. 25



a) prior



b) after implementing project management

Figure 13 Comparison of Downtime

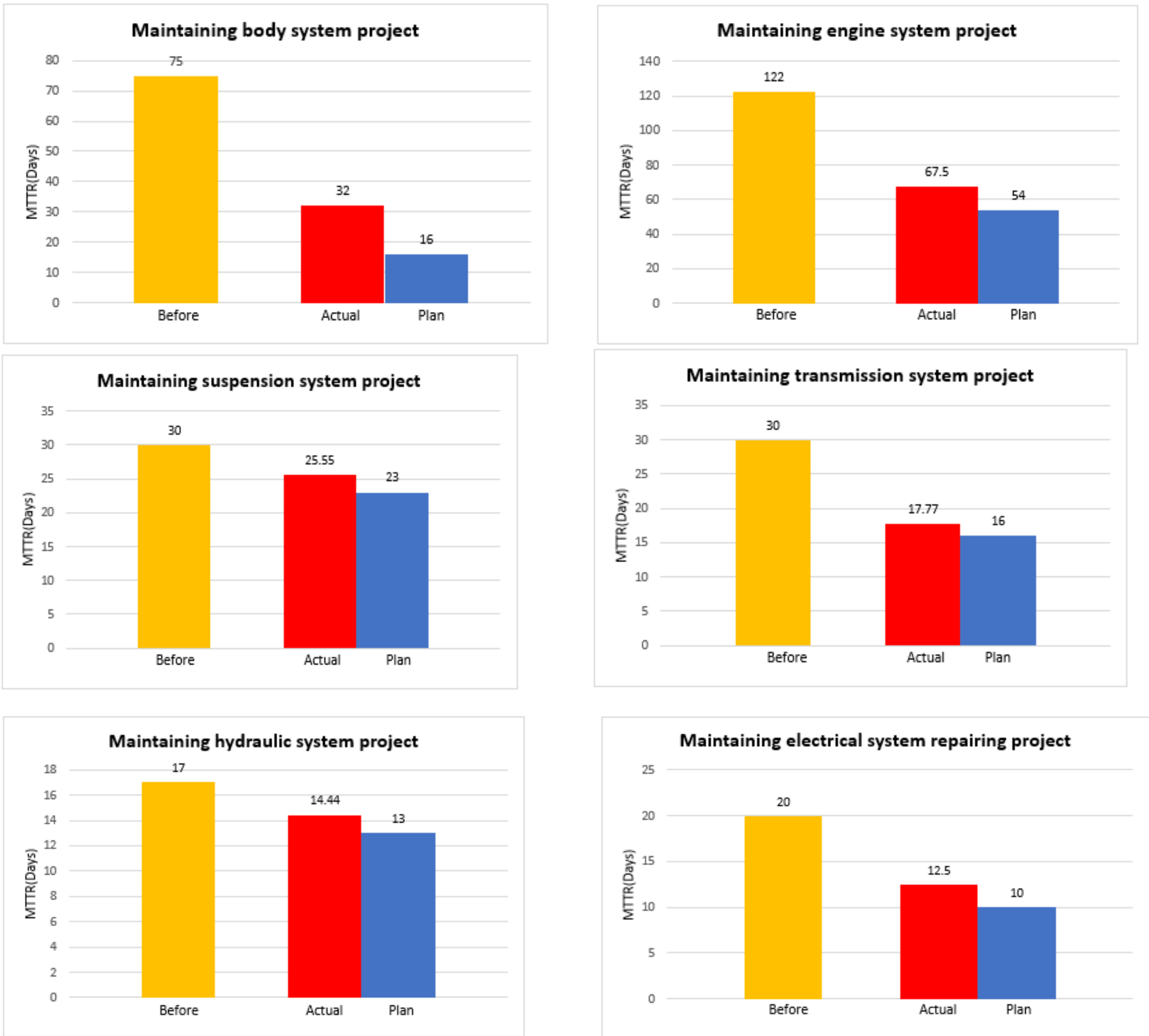


Figure 14 Results of the repair projects

5. Conclusion

In conclusion, the Critical Path Method (CPM) was used to assess the best repair times for each repair project and schedule plans, used Gantt charts to show the sequence of repair activities, and the S-curve was used to monitor and track the process. If the repair project was delayed, it could be known quickly so that measures to accelerate or mitigate the delay.

When project management was applied to a repair project, downtime included time to repair plus time of diagnosis, time for a repair project plan, and time for countermeasures. Finally, it would find that when using the project management with repair work, downtime would be reduced (Figure 13). Figure 14 states the successful results, the body system downtime reduced from 75 days to 16 days (78.67%), the engine system downtime reduced from 122 days to 54 days (55.74%), and the suspension system downtime reduced from 30 days to 23, days (23.33%), the transmission system downtime reduced from 30 days to 16, days (46.67 %), the hydraulic system downtime reduced from 17 days to 13, days (23.53 %), the electrical system downtime reduced from 20 days to 10 days (50 %), respectively.

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