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Optimal Repair Time of Municipal Transit Vehicle's Clutches

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ABSTRACT

The criticality of maintenance planning in maintenance operations and by extension fleet management cannot be over-emphasized. Time study offers the much needed organizational growth in terms of effective labour utilization, methods improvement, wage calculation, task assignment and employee welfare by analyzing maintenance operations into elements that make up the entire repair work. A typical fleet management company is faced with repairing on routine the clutches of its fleet. A time study was conducted by carrying out analysis of a video recording of the repairs of the clutches of a case study municipal transport fleet. The analysis revealed that the current repair process has 15 major repair process, 124 elemental procedures of work of which; 56 were Operation; 17 were Inspection; 29 were Transportation; 0 were Storage and 22 were Delay. The current repair process sees a clutch repair to be completed in 3:34hours. However, a clutch repair process was proposed. The proposed method has 18 major repair elements, 130 elemental procedures of which; 70 is Operation; 18 is Inspection; 27 is Transportation; 4 Storage and 11 Delays. The proposed method was seen to be completed in 3:11hours and far lesser delays and increased inspection which enhance the quality of repair work. A time study of the current repair process revealed that tool and spares procurement occupied the chunk of the delays in the current repair process, it further revealed that the gearbox disassembly process amounts to greater time, energy and man-hour wastage hence, a gantry was proposed to be mounted on the bus walkway to aid the lifting-off of the gearbox. On tool and spares procurement, tools and spares were proposed to be procured firsthand before the actual repair work is commenced. This would reduce the "to and fro" movement to the store. The proposed method also factored ergonomics into its sequence of repairs by allowing rest time for fatigue, personal, standing and basic allowances as against the current process where breaks can be taken at technician's wish.

Keywords: *Optimal Repair Time, Time Study, Maintenance Productivity, Municipal Transit Vehicle, Clutch.*

1. INTRODUCTION

Today, most multinational businesses and industries are, by necessity, restructuring themselves in order to operate more effectively in an increasingly competitive world. The public service sector is however not an exception. Fundamental tools required to increase productivity include: methods, time study standards and work design. Work measurement is a term widely used in industry which covers several different ways of finding out how long a job should take to complete. Standard times are used by industries for manpower planning, estimating labor costs and calculating the productivity of workers, scheduling, budgeting and designing tasks allocated to people. A great number of research activities, with a base in task analysis, have been developed during last years with the aim of integrating methods and techniques from engineering and ergonomics in order to estimate the time needed to perform a task in a planned but not yet existing product or workplace.

For organizations that operate without standards a 60% performance is typical. When time standards are established, performance improves to an average of 85%, a 42% increase (Niebel and Freivalds, 1999). Establishing time standards is a step in the systematic development of new work-centers and the improvements in methods used in existing work-centers. Areas such as planning, control, training, and scheduling are closely related to standards functions. To operate effectively, all of these areas depend on time and operational procedures.

Code of ethics in engineering practice stressed the importance of adherence to standards in carrying out any engineering tasks; Standards such as the routine/sequence of a repair work or the sequence of manufacturing. As most organizations are striving to be world class, having a time standard for their repair and maintenance work will give them a strong footing to compete and will align them to the latest trends such as the idea of lean manufacturing and methods engineering. The idea of lean manufacturing is to eradicate process (es) that does/do not contribute to the economics and profitability of the firm. Time of course is crucial to either a manufacturing or servicing company as time is used as a reference to set targets; as quality is reigns supreme so is the timeliness of maintenance. This research work however seeks to adopt the idea of lean manufacturing and methods engineering by identifying all elemental procedures in a clutch repair exercise, eliminating time wasting and fruitless elements and developing a standard repair time for such activity to be carried out while taking cognizance of the levels of skills of technicians, facility layout, available tools and other inconsistencies while giving room for allowances incumbent on such activities according to the principles of ergonomics and work study.

Automobile servicing and maintenance companies use largely manual but semi-automatic machines in carrying out their major functions of repairs and overhauling, where most of their work processes are done manually by their workers. Lack of standardized procedure and optimal time for repair works can be said to be responsible for inefficiencies and a shortfall in productivity particular to servicing/maintenance operations. It affords engineering managers to either indiscriminately specify shorter repair times, hence creating a time constraint making the technicians in a haste to complete the task ahead of them. Thereby making them skip some essential sections of the repair work or make the managers over stretch the time for a repair work and in this case afford the technicians a liberty of time and hence so much time will be expended thereby reducing effectiveness in labor utilization. This research work seeks to determine how time and motion studies affect productivity in the clutch repair process and in addition to determine how the establishment of work and time standards improves the quality and reliability of automobile transmission system. The optimal repair time to be developed will be such-that the constraint of time and wastage shall be eliminated whereby technicians shall be able to carry out a clutch repair in a standardized sequence in an optimal time.

The main goal of this paper is to determine the optimal repair time for the repair of municipal transit vehicle clutches. In pursuing this goal, the following objectives are sought for;

i. To establish accurate repair time standards for municipal transit vehicle clutches.
ii. To eradicate/merge non-productive elemental sequence in the repairs of clutches.
iii. Improving the work process in terms of service time, number of process and production layout by proposing a new work process for clutch repairs.

2. REVIEW OF PAST WORK IN WORK STUDY, METHOD STUDY AND WORK MEASUREMENT

Abdul and Aliza, (2004) carried out a research to improve production capabilities for Small Medium Enterprise (SME) industry. Their research focused on SME, which produce chili sauce. They applied the principle of Time and Motion technique to improve work process at SME, they identified the problems in the production work process and improved it in terms of production time, number of process and production layout by proposing an efficient work process to SME. Their research used systematic observation; process chart and stopwatch time study as research methodology. Stat Fit and Pro Model Software were used for data testing and develop new work process. The improvement of work process was executed by eliminating and combining of work process, which reduces production time, number of process and space utilization. The research concentrated on 3 parameters namely; number of processes, the production time and the production layout. From their study, they concluded that the production process can be improved based on the 3 parameters highlighted. With the combination of work process and time measurement and the changes of production layout, the current work process was improved. The modifications were made by eliminating the wasted time and reduction of the work contents. A comparison of the proposed and the existing work processes were made, it was found out that the best improvement towards this problem was made. These improvements was successful to achieve the project goals and objectives, which the improvements was included the processes, production layout, economy in human effort and the reduction of unnecessary fatigue.

Muhamad and Law, (2002) made a study on work improvement in a car manufacturing company. They identified problems at the metal finish line and proposed a recommendation to improve the efficiency of the current situation. Based on their observations and the collected data, online work-in-progress (WIP) was identified as a major problem and this was said to be caused by insufficient movements due to material handlings and unbalanced workload. They incorporated Method improvement technique to determine the best method of carrying out tasks in order to eliminate the unnecessary movements. Then, line-balancing technique was used to minimize the idle time at every station or the percentage of line balance loss (LBL). *Witness* simulation package was used to verify the results that were obtained from the generated line-balancing alternatives. One effective alternative was chosen based on the results obtained from the simulation and cost justification. Then, a proper planning was also suggested to maximize the resource utilization at the metal finish line. Simulation results showed that productivity increased about three times higher than the current situation. However, the results were obtained based on several assumptions that were made in the analysis.

Oke (2006) presented a case study in the development and application of a time study model in an aluminum manufacturing plant involved in the production of kettles, frying pans, and cooking pots of diverse categories. He asserted that the three products have similar production processes, then, the production process was broken down into jobs and tasks by the use of differential calculus. He highlighted the kettle production process to consist of several major activities including stamping and oiling, press forming, trimming, spinning, degreasing, polishing, labeling, wiping and wrapping, spout holing and bumping, inspection, riveting, and packing. The study's most important finding was that the time of producing a unit of product is directly proportional to the number of production stages involved and the time spent at each stage. This was represented by some structural equations, which were said to be the characteristics of the system studied. The limitations of the study lie in the variability of the major components of the system. The model did not incorporate some variables which may influence decisions made based on the computation of time for which the model may be used.

Grisselle et al. (2002) conducted a research to find the repair time standard for the brakes of transit vehicles using a case study. Their report described in details the procedure followed by the maintenance technicians for changing the brakes of the buses. As typical to all time studies, the major repair sequence was analyzed and every elemental procedure involved in the repair work was listed. They identified about 261 elemental procedures involved in the repair of transit vehicles and further determined the standard time it would take to complete each of the procedures. The highlight of their study is the inclusion of allowances such as tediousness allowance, fatigue allowance, personal allowance, standing allowance and intermittent sound noise allowance. The adopted 15% of the actual repair time for all the allowances is stated and presented in Table 1 below.

Table 1: Types of allowance and associated percentage of normal time (Grisselle et al. (2002)

Type Of Allowance	Percentage of Normal Time
Personal	5
Basic Fatigue	4
Standing	2
Intermittent Loud Noise	2
Tediousness	2
Total	15%

Comparisons of standard and operator times were made on different dates by different time study experts on brake repairs. Their recommendations include the use of forklift and cranes to ease work-handling and transportation as well as workshop layout. It was believed that the implementation of these recommendations will bridge the gap between the standard time determined and the operator time. The operator time was found out to be not lesser than 20% of standard time and can be far greater than 100% of normal.

The assembly activities were recorded by Sony handy camera and the video is uploaded in the Timer Pro software. The assembly activities were split into elements and time for respective work elements are recorded, analyzed, and established. The summary of their research is as presented in Table 2 below. It was established that 338sec was the standard time required to carry piston assembly. Liner, loop, “U” and “T” layouts were considered in their research an the most cost effective layout was chosen. Their research can be likened to a minimization model to reduce cost and improve producitivity.

Noriah et al. (2012) conducted a case study research at a local car seat polyurethane (p/u) injection manufacturing company by extensively exploiting the work study methods and techniques during the on-site studies. Two fundamental approaches in work study namely method study and work measurement were employed in the research studies. Their paper discusses on the application of the work measurement technique in establishing a benchmark time for producing the car seat p/u injection line of the case study subject.

3. CLUTCH REPAIR PROCESS

The repair sequence for a clutch of an automobile can be understood by considering figure 1 below. The process starts with the disassembly of the propeller shaft/drive shaft from the U joint securing it to the gearbox to removing the gearbox to access the clutch and further to the flywheel.

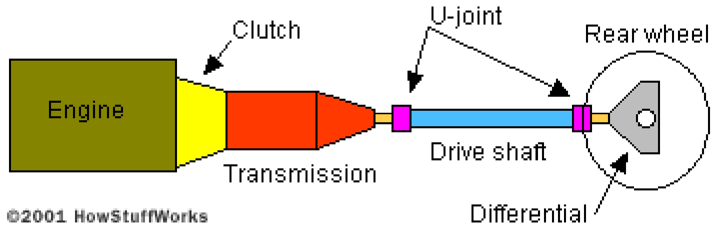
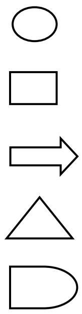


Figure 1: Automobile Transmission System (HowStuffWorks, 2001).

A case-study clutch repair activity is taped, watched, analyzed and categorized under major processes. These major processes are then reviewed and durations are attached to respective activity. The video coverage was done with the consent of the technicians but so much effort was put into not distracting them.

The major processes involved in clutch repairs are as represented in Table 2 below. Each major elemental procedure is then further analyzed into sub-elemental procedures making up each major process.
An extensive thorough analysis of each elemental procedure is further done to categorize them appropriately. Grisselle et al. (2002) classified repair process elements into five categories to capture all elemental procedures involved. The categorization is as follows:



Operation

Inspection

Transportation

Storage

Delay

These categorizations are adopted for the clutch repair process under study and they are represented in table 2. Summary of the current repair process and process categorization are presented in Tables 3 and 4.

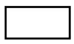
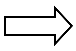
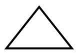
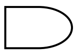
Table 2: Summary of the Current Clutch Repair Process

S/N	Major repair procedures	Time for the work elements(sec)	Operation	Inspection	Transportation	Storage	Delay	Total number of elements
1	Bus parking	465	1	3	1	0	1	6
2	Open engine hood	605	1	0	0	0	1	2
3	Disengage battery terminals	23	3	0	1	0	1	5
4	Propeller disassembly	310	1	0	2	0	1	4
5	Gearbox disassembly	2431	10	0	7	0	9	26
6	Clutch disassembly from engine	680	2	1	1	0	1	5
7	Flywheel disassembly from engine	972	1	2	2	0	1	6
8	Mount flywheel to engine	1112	2	1	2	0	2	7
9	Mount clutch to engine	1748	10	1	2	0	1	14
10	Mount gearbox to engine input shaft	2458	14	2	4	0	3	23
11	Mount propeller to gearbox	273	3	1	2	0	0	6
12	Inspect and retighten all bolts	92	0	4	0	0	0	4
13	Return battery terminals	62	2	1	2	0	0	5
14	House keeping	173	4	0	0	0	1	5
15	Examine clutch pedal and test-drive	626	2	1	3	0	0	6
	Total elemental procedure		**56**	**17**	**29**	**0**	**22**	**124**

Table 3: Summary of Major Repair Process

Major repair process	Number of elemental procedure	Time taken (seconds)
Bus Parking	6	465
Open Engine Hood	2	605
Disengage Battery Terminals	5	23
Propeller Disassembly	4	310
Gearbox Disassembly	26	2431
Clutch Disassembly From Engine	5	680
Flywheel Disassembly From Engine	6	972
Mount Flywheel To Engine	7	1112
Mount Clutch To Engine	14	1748
Mount Gearbox To Engine Input Shaft	23	2458
Mount Propeller To Gearbox	6	273
Inspect And Retighten All Bolts	4	92
Return Battery Terminals	5	62
House Keeping	5	173
Examine Clutch Pedal And Test-Drive	6	626
Total Elemental Procedure	**124**	
Total Time In Hours	**12030 sec**	
Total Time In Hours	**3.34hrs**	

Table 4: Process Categorization Summary

Process Categorizations		Number of Elemental Procedure
Operation		**56**
Inspection		**17**
Transportation		**29**
Storage		**0**
Delay		**22**

4. RESULTS OF TIME STUDY OF PROPOSED CLUTCH REPAIR PROCESS

Having carried out a time study of the current clutch repair process in existence in the case study in the last section, this section proposes an optimal and a more effective and efficient clutch repair process. The proposed repair process is based on expert opinions and recommendations as well as by an informed understanding of the nature of the repair work in consonance with time study principles whilst factoring ergonomics to play a decisive role.

As against 15 major procedures identified in the current repair process, the proposed method identifies the following repair processes;

1. Parking the bus
2. Transmission inspection & troubleshooting
3. Open engine hood
4. Tool procurement
5. Spares procurement
6. Electrical isolation and cable disconnection
7. Propeller disassembly
8. Gearbox disassembly
9. Clutch disassembly from engine
10. Flywheel disassembly from engine
11. Mounting flywheel to engine
12. Mounting clutch to engine
13. Mounting gearbox to engine input shaft
14. Mounting propeller to gearbox
15. Reassembly inspection
16. Electrical cables reconnection
17. House keeping
18. Examining transmission and test-driving

Analytical analysis and the time-study of the elemental procedures of respective major repair elements are presented in table 5. Tables 6 and 7 presented the summary of major repair processes of the proposed procedures and summary process categorization of the proposed procedures respectively.

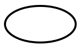
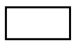
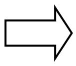
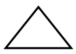
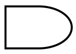
Table 5: Time-study summary of the Proposed Clutch Repair Process

S/N	Major repair procedures	Time for the work elements(sec)	Operation	Inspection	Transportation	Storage	Delay	Total numbers of elements
1	Parking the bus	225	1	0	1	0	0	2
2	Transmission inspection & troubleshooting	525	0	4	0	0	0	4
3	Open engine hood	5	1	0	0	0	1	2
4	Tool procurement	660	0	0	1	3	0	4
5	Spares procurement	600	0	0	2	1	0	3
6	Electrical isolation and cable disconnection	25	3	0	1	0	1	5
7	Propeller disassembly	310	2	0	1	0	1	4
8	Gearbox disassembly	1371	15	1	6	0	3	25
9	Clutch disassembly from engine	360	2	1	1	0	1	5
10	Flywheel disassembly from engine	785	1	2	1	0	1	5
11	Mounting flywheel to engine	335	4	1	0	0	0	5
12	Mounting clutch to engine	942	12	1	1	0	1	15
13	Mounting gearbox to engine input shaft	1254	19	2	4	0	1	26
14	Mounting propeller to gearbox	273	3	1	2	0	0	6
15	Reassembly inspection	80	0	3	0	0	0	3
16	Electrical cables reconnection	62	3	0	2	0	0	5
17	House keeping	173	3	0	1	0	1	5
18	Examining transmission and test-driving	650	1	2	3	0	0	6
	Total	**8635**	**70**	**18**	**27**	**4**	**11**	**130**

Table 6: Further Time-Study Summary of the Proposed Process

Major repair process	No. of elemental procedure	Time taken (sec)
Parking the bus	2	225
Transmission inspection & troubleshooting	4	525
Open engine hood	2	5
Tool procurement	4	660
Spares procurement	3	600
Electrical isolation and cable disconnection	5	25
Propeller disassembly	4	310
Gearbox disassembly	25	1371
Clutch disassembly from engine	5	360
Flywheel disassembly from engine	5	785
Mounting flywheel to engine	5	335
Mounting clutch to engine	15	942
Mounting gearbox to engine input shaft	26	1254
Mounting propeller to gearbox	6	273
Reassembly inspection	3	80
Electrical cables reconnection	5	62
House keeping	5	173
Examining transmission and test-driving	6	650
Total	**130**	**8635**

Table 7: Process Categorization Summary

Process Categorizations		Number of Elemental Procedure
Operation		70
Inspection		18
Transportation		27
Storage		4
Delay		11

As presented in table 1, Grisselle et al, (2002) identified 5 types of allowances during brake repairs and benchmarked a percentage of normal time for respective allowances. Since clutch repair operations exclude intermittent noise, this shall be left out in the computation of the total allowances thereby leaving Personal, Basic, Standing and tediousness allowances accumulating to 13%.

Computing total allowance;
Normal time = 8635seconds
Allowance = 13% of Normal time
= 13% * 8635
= 1122.55seconds
Total repair time therefore = Normal repair time + Allowance
= 8635 + 1122.55
= 9757.55sec (3hrs 11minutes)

5. DISCUSSION

The results of this time study were presented on Tables 6, 7, 8 and 9. However, contained in Table 10 below is at a glance comparison of the existing and proposed repair processes in terms of number of elemental procedures therein. Number of operations in the proposed repair process (70) is higher than that of the existing repair process (56) indicating that the time allocated for clutch repair in the proposed repair process is chiefly spent on actual productive work thereby ensuring optimal labour utilization on strictly productive tasks. Table 10 further reveals lesser delays and transportation and improved inspection.

The current method sees a clutch repair operation to be carried out in 3:34Hrs. Despite time-lead, ergonomics and allowances of the technicians are not well factored. The efficiency and effectiveness of the technicians are not assured throughout the day for the daily task. Major repair elements are 15 in the current method. This reveals that the repair elements are muddled up which can ideally be further simplified. The current procedures reveal a whopping 22 individual delays amounting to serious time wastage. Due to frequent procurement of the parts as at when needed the repair time is further stretched. Another factor which stretch the repair time is human habits (e.g., incessant interaction among technicians, foul plays etc.). This causes delay and interruption in the work due to frequent visits to the inventory house. On material handling; an enormous amount of time is wasted during the assembly and disassembly of the gearbox due to its weight and constricted space. There are also delays due to interruptions**.** Technicians are distracted due to difficulty in locating the tools and new parts. The tediousness caused to the technician increases as a result of routine visits to the parts store and the laborious nature of some of the repair elements. The efficiency of the technicians drop after first of such repairs is carried out and their ability to perform at close to the same efficiency in other daily repair works is hampered. Also many of the elements are repeated due to lack of standardization.

Table 8: Comparison of Proposed and Existing Repair Process In Terms of Number of Elemental Procedures

Process Categorizations	Number Of Elemental Procedure For Existing Repair Process	Number Of Elemental Procedure For Proposed Repair Process
Operation	56	70
Inspection	17	18
Transportation	29	27
Storage	0	4
Delay	22	11

In the proposed method; the time study estimates a clutch repair work to be carried out in 3:11hrs. This represents a better process management and reflects the advantage of material handling and tool and part procurements. As well as factoring the allowances incumbent on this kind of repair work. The major repair elements of the proposed method of repair are 18, which reflects a further simplification of the repair process and reduces complexities. As all the required tools are procured firsthand before repair work is initiated, delays are reduced to 11 (Table 8). However, intermittent delays during repair work cannot be entirely eliminated owing to human nature and the nature of the job. Also as all the parts required are procured firsthand before repair work is initiated, time is further well managed and wastages associated to and fro movement for part procurement are eliminated**.** The human habits noticed in current method are not completely eliminated by this proposed method. However, it is reduced due to less frequent visit to the tool and part procurement store. On material handling**,** a mini gantry and chain-block was used. This makes the job less tedious and saves a great deal of time that contributed to delays in the current repair process. The proposed standard method allows the technician to work continuously with minimum distractions and lesser physical energy usage. The proposed method also reduces the tediousness caused to the technician decreases as the operation is standardized and alternative material handling tools are introduced. The efficiency (utilization of technicians) increases as the time study eliminates routine work, standardizes the process and eliminates far-reaching physical energy usage, hence preserving their energy for other daily tasks. Elements are organized in such a way that redundancy of operations is minimized.

6. CONCLUSION

The principle of Time study was adopted for a clutch repair task. The task was broken down into elemental procedures, critically reviewing each work elements, determining their duration in time domain, merging unproductive tasks and recommending improvements. The time study of the existing repair process revealed that there are; 15 major processes, a total of 124 elemental procedures of which 56 is operation, 17 is inspection, 29 is transportation and 22 is delays carried out in 3hrs 34mins. The proposed method however, identified that some processes cannot be merged, hence they were simplified into 18 major processes, 130 elemental procedures of which 70 is operation, 18 is inspection, 24 is transportation, 4 is storage and 11 is delay carried out in 3hrs 11mins with allowances of personal, basic fatigue, standing and tediousness all factored. The proposed method saw a reduction in numbers of delays and hence a shortened repair time.

The principal finding of this work is that the establishment of accurate and consistent standards improves execution of the procedures required to complete the task of a clutch repair and can be used as a bench mark in maintenance planning, wage calculation, efficiency measurement as well as in the training of technicians. The Time study of the current repair process revealed lack of standardized procedure, no formal allowances and a lot of delays that can be avoided. The current process sees clutch repair to be carried out in **3hrs 34 minutes.** However, a proposed repair process for a typical clutch repair operation for the brand of buses understudied can be carried out in **3hrs 11minutes**. The time covers all elements of the repair process with the ergonomics of the repair process factored to accommodate incumbent allowances. There is a 23minutes difference in duration between the current and the proposed repair process which qualifies for time saving and wage deployment. The proposed repair process is flexible enough to allow technicians to embark on other tasks even without taking further breaks as the method avoids tediousness and far lesser physical energy usage.

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