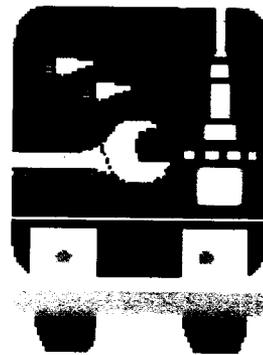


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REPAIR TIME STANDARDS FOR TRANSIT VEHICLES

FINAL REPORT
SEPTEMBER 24, 2002



Submitted by: Grisselle Centeno, Ph. D.
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FDOT Project BC137-RPW032
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ABSTRACT

This report summarizes the main findings and activities of the first phase of the Repair Time Standard project for Transit Vehicles. A team of two faculty from the Center of Urban Transportation Research (CUTR), one faculty from the Industrial and Management Systems Engineering Department (IMSE), two graduate students and one undergraduate student from IMSE conducted an analysis of the brake system procedure in three different locations: Lynx – Orlando, Palm Tran – West Palm and Hartline – Tampa. The study was conducted from September 2001 to August 2002. This report describes in detail the procedure followed by the maintenance technicians for changing the brakes of the buses. Ideas and recommendations for improvement are also provided.

Acknowledgements

Special thanks go to all the technicians across the locations that participated in this study, the in-site coordinators: Ricky Sonny, Peter Spencer and Bill Slover, and to Robert Westbrook for initiating and supporting this effort.

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1.0 INTRODUCTION AND SCOPE

Today, most U.S. businesses and industries are, by necessity, restructuring themselves in order to operate more effectively in an increasingly competitive world. The public service sector is not an exception. Fundamental tools required to increase productivity include: methods, time study standards and work design. This study incorporates principles of industrial engineering and work measurement to establish time standards for transit vehicles. Time standards define the time necessary for a qualified worker, working at a pace ordinarily used, under capable supervision, and experiencing normal fatigue and delays, to do a defined amount of work following the prescribed method.

According to the literature, 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, 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.

The objective of this study is to establish accurate repair time standards for transit vehicles in Florida public transit systems. This project develops standards in order to minimize the time required to perform tasks, continually improve reliability of services and to conserve resources and minimum costs by specifying direct/indirect materials of tools to provide repair service.

This report has been organized as follows: Section two describes the brake system and the processes involved in completing a brake job. In section three the Time Study method is described and considerations while conducting the Time Study are provided. How the standards were established is described in section four. The database development and its description are presented in section five. Finally, recommendations and conclusions drawn from the research and a look into future possibilities for the Transit Sector are given in section six.

2.0 BRAKE SYSTEM DESCRIPTION

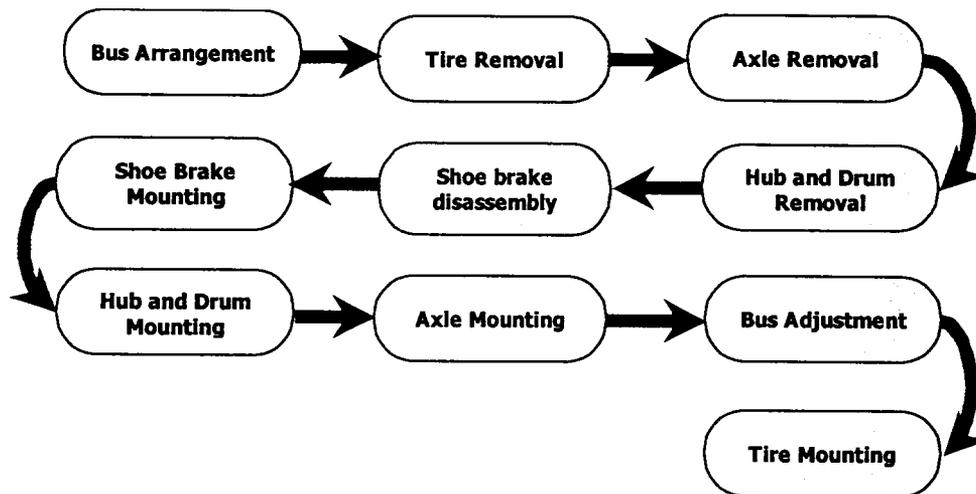
During the exploratory phase of this project the steering committee, comprised of members of the Florida Maintenance Training Advisory Committee, guided the Time Standard Team to start the analysis with the Brake System. Three locations were invited to participate in the study. These facilities were: Lynx in Orlando, Palm Tran in West Palm, and Hartline in Tampa. A description of the components related to the brake system is shown in Table 1.

Table 1: Description of Participating Centers

	Lynx – Orlando	Hartline - Tampa
Total number of active buses	245	196
Average number of brake jobs per month	46	9
Active Brake Technicians	68	2
Total Brake Technicians	74	8

The Brake System Operation was divided into 10 processes: bus arrangement, the removal of the tire, axel, hub and drum, disassembly of the shoe brake, shoe mounting, hub and drum mounting, axle mounting, bus adjustment and tire mounting. For the sequence of the process see Figure 1.

Figure 1: Brake Processes



For ease of data collection, these processes were divided into groups of motions known as elements. Before this was done, the analysts watched the technicians for several cycles. The total number of elements is around 260. Elements include: remove wheel nuts, remove the outer tire, move tire at side, tool set up, etc. Refer to Appendix 1 for a complete list of elements.

3.0 THE TIME STUDY

Before a valid time study could be conducted four fundamental requirements were addressed. First, *because of the many interests and reactions associated with the time study, it is essential that there be full understanding between the supervisor, employee, and time study analyst.* This project was strongly supported by supervisors, maintenance directors and employees. Everyone was informed of the purpose of the study and the analysts were always welcomed to the facilities.

Second, *the analyst should be honest, tactful, patient and enthusiastic. He/she should ensure that the correct method is being used and should accurately record the times taken.* The analysts that participated in this study possessed these qualifications. As a result, a good relationship was established between the analysts and both the technicians and supervisors.

Third, *the technicians must be thoroughly acquainted with the processes.* All the technicians that agreed to participate had vast experience doing brake jobs. Although some variability existed regarding the elements, the sequence and completion of each process was very similar.

Fourth, *the technicians should assist the analyst in breaking the job down into elements, and work at a steady normal pace.* Technicians assisted the analysts while dividing the job into elements. Most of the technicians worked at a normal pace while being observed, however, since time study directly affects the pocketbooks of workers it was evident that some were technicians worked below normal. Observations were adjusted with a performance factor in order to standardize the data.

3.1 Number Of Observations

Determining how many cycles to study to conduct statistical methods were used. Since time study is a sampling procedure, averages of samples (\bar{x}) drawn from a normal distribution of observations are distributed normally about the population mean (μ). The following formula was used to determine the number of cycles to observe:

$$n = \left(\frac{St_{\alpha/2, v}}{k\bar{x}} \right)^2 = \left(\frac{1131.44 * 4.303}{0.1 * 14950.3} \right)^2 = 10.6048 \cong 11$$

a 90% confident level ($1 - \alpha$) was used an a 10% probability of error (k). The mean (\bar{x}) and standard deviation (s) used were obtained from the 4 readings taken. The total number of cycles required for the 260 elements was computed to be 10.6 observations. To ensure the required confidence, it was rounded up to 11.

3.2 Data Collection

A summary of the first seven observations taken at Lynx is shown in Table 2. The eleven observations were taken as follows:

Lynx – 9 observations (Rear Brakes)
 Hartline – 1 observation (Rear Brakes)
 Palmtran – 2 observations (Front Brakes)

While collecting the data the following inconsistencies were observed:

1. Element differences: although every technician followed the same process to complete the brake job, each technician had a unique method of working on the elements of each process. For example, a technician will remove the tire and the axel for one side of the bus and then for the other side. Another technician preferred to remove both tires first and then the axels. Due to these variations

the collection of data was more difficult than having a standardized process. However, it allowed us to identifying a combination of best practices from the various styles. Our study recommends a standard process that is based on all the best practices observed and the minimum time required.

2. Facility Layout: Each participating facility had a different work-floor layout; hence travel times varied significantly depending on the layout. Thus, when we designed the new processes, only time taken for actual work elements was considered, and allowances were provided for travel times. This makes the standards independent of the facility, yet effective.
3. Equipment: Equipment used by the different facilities varied slightly. For example, one facility used forklifts to transport new hub and drums to the mechanic and take away the old ones. It was observed that this considerably saved travel time wherein the mechanic had to take the old ones to the rework bay and return with the new one using a trolley.

Table 2: Summary of Observations

Time for the Work Elements								
	Observations (Minutes)							Average
	#1	#2	#3	#4	#5	#6	#7	
Bus arrangement	6.17	5.30	6.52	5.00	5.67	4.90	7.42	5.85
Tire removal	33.03	17.25	24.45	22.03	11.00	15.22	16.73	19.96
Axel removal	29.43	28.17	19.92	15.17	13.73	11.63	20.12	19.74
Hub and Drum removal	15.23	34.33	36.28	28.17	15.83	19.23	15.63	23.53
Shoe brake disassembly	45.40	32.18	24.12	28.33	34.87	28.10	43.07	33.72
Shoe brake mounting	43.33	49.95	29.87	30.42	85.38	45.72	44.28	46.99
Hub and Drum mounting	27.45	44.35	33.52	30.00	30.02	42.37	28.63	33.76
Axle mounting	32.97	30.37	19.58	16.83	21.25	32.45	32.85	26.61
Bus arrangement	3.58	6.50	3.42	4.17	4.50	5.78	4.67	4.66
Tire mounting	19.73	15.00	30.12	18.33	20.58	25.58	20.32	21.38
Total Time (minutes)	256.33	263.4	227.78	198.45	242.83	230.98	233.72	236.2143
Total Time (hours)	4.2722	4.39	3.7964	3.3075	4.0472	3.8497	3.8953	3.936905

3.3 Technician Performance Rating

The skill and effort of the technician will directly impact the actual time required to perform each element of the study. When different technicians are observed a variability factor is introduced. Even when the same technician is observed, performance might vary from time to time. For that reason, it will be necessary to adjust upwards to normal the time of the good technician and the time of the poor technician downwards

Since most of the technicians always followed the same pace from beginning to end, it is customary to apply one rating to the entire study. Therefore, the analyst assigned a fair and impartial performance rating to each study. In the performance rating the observer

evaluates the technician's effectiveness in terms of a normal technician performing the same task. For example if a technician performs below normal a performance rate of 90% to 95% will be assigned to that technician. If the technician works much faster than normal then a 105% to 110% will be assigned.

3.4 Allowances

Due to the interruptions that can take place on a daily basis, no technician can maintain an average pace every minute of the working day. There are three classes of interruptions for which extra time must be provided. These are: *personal interruptions* such as going for a drink or to the restroom; *fatigue* which can affect even the strongest individual and *unavoidable* delays such as supervisor interruptions or tool breakage. The main purpose of the allowances is to add enough time to the normal operation time to enable the average worker to meet the established standards when performing at normal rate. These allowances are meant to give flexibility and justified rest to the technician and thus ensure smooth and efficient working. The total allowance assigned for this study is 15%. Justification to this allowance follows.

Type of Allowance	Percent added to Normal Time
Personal	5
Basic Fatigue	4
Standing	2
Intermittent Loud Noise	2
Tediousness	2
TOTAL	15 %

1. Personal Allowance: This includes those cessations in work necessary for maintaining the general well being of the employee.
2. Basic Fatigue Allowance: The basic fatigue allowance is a constant to account for the energy expended to carry out the work and to reduce monotony.
3. Standing Allowance: This allowance generally accounts for the energy utilized in standing and gives flexibility and rest to the technician for standing continuously.
4. Intermittent Loud Sound Allowance: This allowance generally accounts for the sound made by the equipments used. For instance the noise made by the air gun.
5. Tediousness Allowance: This allowance is generally applied to elements that involve repeated use of certain parts of the body.

NOTE: The allowances established may vary depending upon the working and atmospheric conditions. It may also vary due to the facility layout.

4.0 ESTABLISHING TIME STANDARDS

Setting Time Standards involves two complementary procedures: operation analysis and work measurement. Operation analysis is the primary technique for reducing the work involved; it studies all productive and nonproductive elements of an operation, and ensures the elimination of unnecessary movement on the part of material or operatives and substitution of good methods for poor ones. Work measurement is concerned with investigation, reduction and subsequently elimination of ineffective time, which is time during which no effective work is being performed.

Before the standards were established, an extensive and thorough analysis and review of each element was conducted. Elements were classified into five categories:

○	Operation
◻	Transport
◻	Inspections
D	Delays
▽	Storage

The current process has approximately a total of 260 elements. From these a total of 156 elements were classified as operations, 60 elements were classified as transport, 12 inspections, and on average 16 delays per brake job. The complete flow process chart of the current method is shown in Appendix 1.

It is important to mention that a couple of readings for the front brakes were collected at Palm-Tran in West Palm. We have seen that the repair of the front brake takes lesser time than that of the Rear Brake. The elements in the front brakes are merely a subset of the rear brake. For instance, the front brakes do not have the axle removal process as they do not have the axle assembly in the front wheels. The flow process chart of the current process for front brakes can be seen in the Appendix 2.

After evaluating the actual process elements were reduced from 260 to 241. Refer to Appendix 3 for the flow process chart and time standards for the proposed method. In the proposed method a total of 201 elements are operations. Only a total of 36 elements are classified as transport, which reduces the original transport by nearly 30%. Inspections were reduced from 13 to 4. Delays, which constituted nearly 10% of the total time, were eliminated. Elimination of the delays was possible because most of them were caused by missing essential tools required to perform the brake job. Due to a recommendation for a setup of tools before beginning the brake system job, the delays were eliminated.

The total proposed time to complete each brake job is of **2.98** hours. This is 30 % less than what the current process takes. The time reduction is justified by following reasons:

1. All the processes and elements are standardized that eliminates redundant operations and other inconsistencies.
2. The travel time is reduced due to division of the complete braking system into processes and then following each process in a sequence.
3. The frequency of the equipment set up is reduced causing reduction in the delays

It is also important to emphasize that the time standards developed are realistic and feasible. This is supported by:

1. Actual readings: The standards are developed using actual data for the time required to complete work elements and tasks.
2. Normal pace: All the time suggested is to be performed at normal working pace, i.e., with no speed increment.
3. Processes: The standard times' are reduced because of alterations made to processes, instead of changing the work tasks themselves.
4. Worker habits: Worker habit changes, like speaking to colleagues or conferring with others while borrowing tools, have been reduced by altering the processes i.e., making them interact less frequently. Otherwise, work and basic processes of the jobs have not been altered. So, the workers will not have a problem migrating to the standards.
5. Facility layout: All the standards are based on flexible facility design, with no changes to it. Thus these standards can be implemented widely and effectively.
6. Other considerations: The approach used gives the time that is actually taken by the technicians to do the job, i.e., times are not based on the theoretic study. These are the actual time taken by the technician to do the brake job.

4.1 Benefits of the Time Standards

Establishing repair time standards for transit vehicles will be beneficial for:

- *Evaluating actual performance and productivity* – it provides a basis to compare actual vs. the planned use of resources. For example, if a time standard for axle removal should take half hour, and it takes one hour, then productivity will decrease and cost will increase.
- *Determining the need for training* – standards are based on the performance of a qualified worker, so management will be able to train employees to acquire the necessary skills to meet the established standard through periodic company-wide training programs.
- *Balancing the work among the crew* – standards will allow determining the optimum number of workers required completing an operation, it will also help to coordinate the allocation of tasks and assignment of jobs. Consequently, workforce utilization will increase, and unaccounted time and redundancy will decrease.

- *Comparing methods* – standards are set based on good methods performed in a efficient manner, so it allows to determine if actual practices need to be improved or modified.
- *Scheduling* – standards allow the allocation of workers for single activities and determines which personnel are available to perform unscheduled repairs or maintenance backlog. In addition, standards provide managers a better understanding of where and how all the resources are applied.
- *Assessing the need for labor and equipment requirements* – when an operation is performed repetitively, the cost visibility provided by labor standards permits detailed cost evaluation and control that can result in significant savings to the company. For example, when standards are used for repair activities for the braking system, a supervisor can review the progress of a mechanic to determine whether more time, personnel or equipment is needed for the repair action. Also, if we consider specific operations such as shoe cutting, and since the work elements are known, we can allocate a worker who is more experienced in that area instead trying somebody who may take longer time to complete the task.
- *Establishing preventive maintenance activities* – most preventive maintenance (PM) activities involve routine systems, component and mechanism checks. The majority of these activities, when broken down into their elements, correspond to the elements of standards developed for production and repair activities and may be used for establishing best processes for PM.
- *Benchmarking* – this is a popular tool for assessing financial and operational efficiencies of an organization. In benchmarking, the processes of the organization conducting the study are compared with another facility. In such a scenario, operational Time Standards provide a very good parameter for comparison.

4.2 Current Method vs. Proposed Method

A general comparison between the current method and the recommended/proposed method is shown in **Table 3**.

Table 3: Current vs. Proposed Method

	Current method	Proposed method
Wheel removal	Two methods exists: <ol style="list-style-type: none"> 1. Wheel removal method (removing entire wheel assembly and transporting it to the rework bay) 2. Tire removal method (disassembly of each tire at the working area) 	Tire removal method (disassembly of each tire at the working area)
Set up	There is a considerable amount of set up time required due to the use of the overhead crane	The set up time is reduced as the operation is carried out at the working area.
Tool procurement	Searching of tools and attachment delays the operation by nearly 10-15 minutes	As all the required tools are arranged in the set up the tool procurement delay is eliminated
Part procurement	Due to frequent procurement of the parts as and when needed the process is nearly delayed by 25-30 minutes	As all the parts required are arranged in the set up there is considerable reduction of time in traveling. The saved time between tool and part procurement recommendation is reduced by 30-35 minutes
Human habits (e.g., frequent interaction among technicians)	This causes delay and interruption in the work due to frequent visits to the part bay	The human habits are not affected by the proposed method but due to less frequent visit to the part bay the delay and interruption caused by the human habits are reduced
Delays due to interruptions	Technicians may be distracted due to difficulty in locating the tools and new parts	The proposed standard method allows the technician to work continuously with minimum distractions
Facility Design	Current practices depend on the facility layout, consequently traveling time are closely related	Recommendations are applicable to any facility regardless of its design that makes the method robust and portable
Operation Standardization	Many of the elements are repeated due to lack of standardization	Elements are organized in such way that redundancy of operations is minimized
Tediousness	The tediousness caused to the technician increases as the total time taken to do the job is more as compared to the standard time	The tediousness caused to the technician decreases as the operation is standardized and the total time to complete the job is reduced

All the proposed alternatives were considered when establishing the time standard.

4.3 Quality Assessment

One of the concerns of the managers is the quality assessment of the job performed following the proposed time standards. As mentioned earlier, time standards have been established considering that the technician will be working at a normal pace. However, several ideas to address this concern are listed next.

- Job sampling: To conduct sampling of the jobs is a supervised inspection of various jobs selected at random. Due to the nature of the jobs, number of jobs sampled should be around one in five. Ideally, every job would have to be checked for quality, although this task would involve additional labor and time.
- Certification program: Another way to reduce “comebacks” is by making a certification program, wherein a checklist is made for every job type, and the vehicle overall, to check functionality and quality. The overall bus certification would indicate the health of the machine, and workers can use the system checklists after they finish working on every job. This would mean the same worker can assure all quality norms specified in the checklist, and supervisors can do sampling less frequently.
- The database could also be configured to track “comebacks” without much difficulty. It would store information about all the buses and jobs performed on them, and every time a comeback occurs, an entry would be made using interactive forms. This would allow a manager at any given time view the comebacks at a glance, and identify further training/problem areas to ensure better work quality.

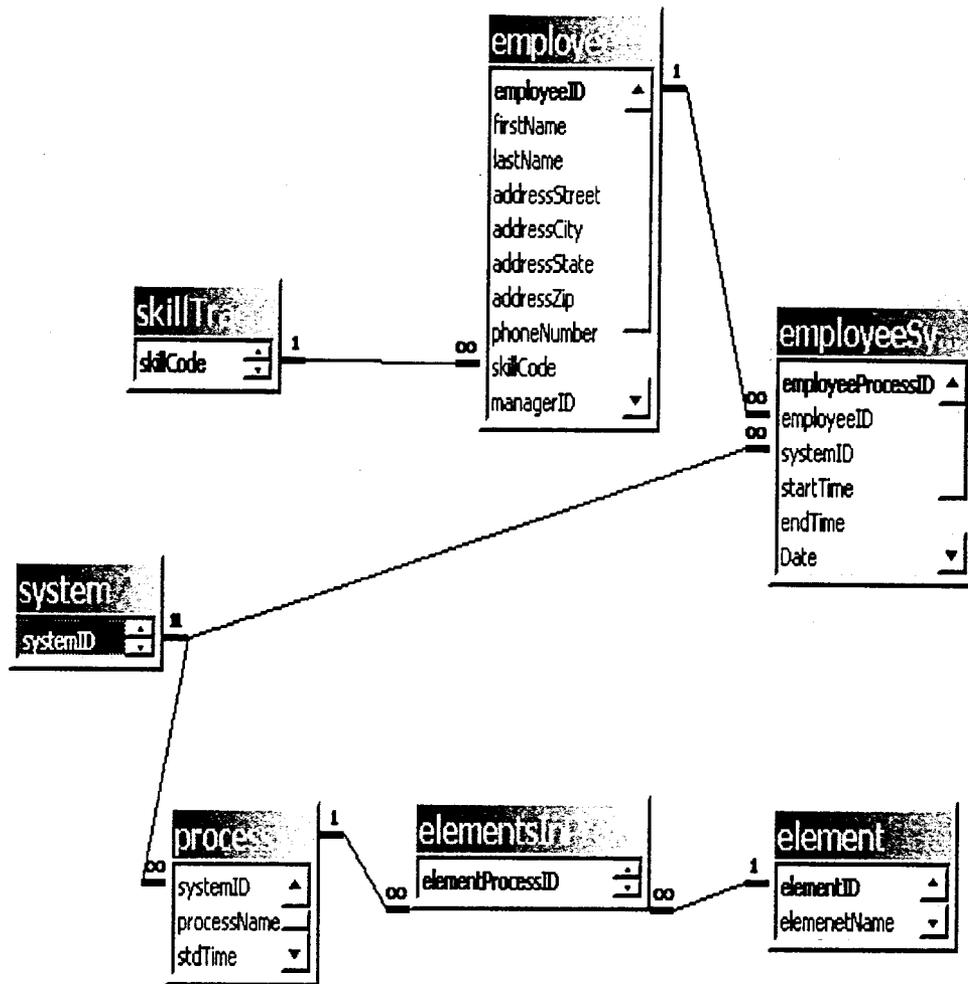
5.0 DATABASE

A database that provides information on the time standards for the repair of the braking systems has been developed. The database shows the work elements required to do the repair jobs on the transit vehicles along with the standard time required to do the job. It is intended to help the managers to evaluate the relative productivity or the combined productivity of all employees. In addition, it allows managers to schedule specific tasks to employees and to obtain an estimate of ending time of those tasks according to the standards previously determined. A Users’ Manual was developed to help a layman learn to understand and operate the database with ease, and generate customized reports for viewing, please refer to it for more details.

5.1 E-R Diagram

All the tables within the database are connected to one another in some way, such that the data can be viewed using the reports in any manner. The relationships are shown in the Entity – Relationship Diagram (Figure 2). Explanation of each table is covered in the data dictionary.

Figure 2: E-R Diagram



5.2 Requirements

To use the Transit database, minimum system requirements are:

- Intel Pentium processor, AMD Duron or equivalent (500 MHz system speed)
- 64 MB RAM
- At least 50 MB of free hard disk space (8 GB HDD preferred)
- Microsoft Office 2000, Professional edition.
- Microsoft Windows 2000 operating system
- CD ROM (16x preferred)

5.3 Reports

Three reports can be generated by the database: the Work Flow Report, the Work Log Report and the Performance Level Report. A description of each report is provided in the following sections.

5.3.1 Work Flow

As shown in Figure 3, this report shows at a glance the processes involved in a brake job, their standard times and a brief description of the processes. This can be handed to a worker along with the flow chart provided with the database to use as a guideline. The Management can also add/edit processes through the forms, and all changes will automatically be reflected in the Reports.

Figure 3: Work Flow Report

Work Flow			
System Name brakes			
Process Name	Std Time	Minutes	Description
Bus Arrangement	5		Raise bus and back up brakes
Remove Tires	8		Remove RHS and LHS wheels
Axle Removal	10		Removing axles on either side with assembly
Drum Disassembly	15		Dissambling the drums
Mount Shoe Brake	21		Mounting the shoe brake
Mount Hub And Drum	18		Mounting the hub and drum on either side
Mount Axle	15		Mounting the axle assembly back on either side
Bus adjustment	14		Receding the brakes
Tire Mounting	24		Mounting wheels on both sides back
Grand Total	130		

5.3.2 Work Log

The Work Log Report (Figure 4) shows a job was performed by which employee and on what date. It also provides a comparison between technicians and standard times and keeps track of worker performance. Ultimately, this report can be used for performance evaluation, identifying training needs and assessing scientific grounds for promotion of employees.

Figure 4: Work Log Report

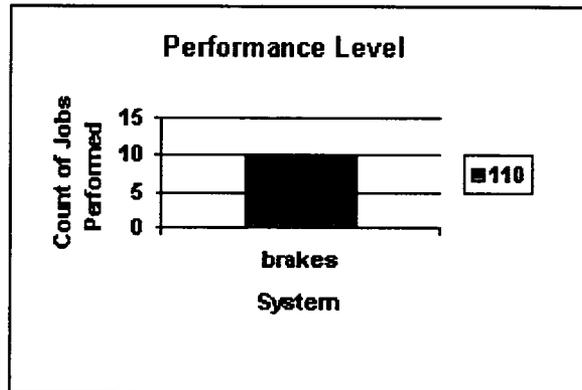
Work Log

First Name	Last Name	Job Type	Std Time	Operator Time	Date
Raj	Chaudhary	brakes	300	32	8/29/2002
		brakes	300	333	7/31/2002
		brakes	300	340	7/31/2002
		brakes	300	265	7/31/2002
		brakes	300	753	9/1/2002
Vik	Bhide	brakes	300	410	8/12/2002
		brakes	300	285	8/12/2002
		brakes	300	340	8/12/2002
		brakes	300	245	8/12/2002
		brakes	300	30	9/15/2002

5.3.3 Performance Level:

This is a graphical report (Figure 5) and shows at a glance the number of jobs worked on, and the average performance level for the jobs. This will allow management to find out the preparedness of the facility to do brake jobs.

Figure 5: Performance Level Report



For more details related to the database please refer to the Database User's Manual.

6.0 CONCLUSIONS AND RECOMMENDATIONS

At the conclusion of this phase, a wealth of information has been compiled and documented regarding the brake system. A critical review of the numerous observations and a thorough analysis of the data have been conducted. A database system has been developed and requirements necessary to support this service have been described.

Tests of recommended procedures are still being validated. Although the recommended procedure has been tested once, the total time recorded was 2 hours and 59 minutes. This time included three small breaks of nearly 8 minutes each. The principal finding of the work to date is that the establishment of *accurate and consistent* standards improves execution of the procedures required to complete a brake job. We expect to extend this study to other systems such as transmission, a/c, etc. with the guidance of the advisory committee and the support of FDOT.

In examining the brake process from a top-down or systematic perspective, the Time Standard Team identified several common problems that are best characterized as:

- Lack of consistent and accurate procedures among technicians and facilities.
- Lack of proper set up.
- Lack of proper arrangement of tools and parts.

The primary recommendation is the implementation of the standards and process suggested by this study are shown in Appendix 3. Some recommendations were also provided in section 4 (Current vs. Proposed Method). Further recommendations follow:

1. Sequential workflow: Each process specified should be finished completely before starting the next process. Working on two processes simultaneously may affect the efficiency of both. For instance, while removing the left side wheel, it is more time-efficient to set up the air gun and remove both wheels on the left side and then move to the other side.
2. Forklifts: An arrangement can be made to transport the new shoe brake and hub & drum assembly to the working place and the old ones back to the rework bay using a forklift operated by an additional technician for about 2 minutes, there would be considerable reduction in the total job time. Approximately 12- 15 minutes were allocated to this task during the time study.
3. Set up times: The set up should be done before starting the job. That is, the required tools should be procured and kept handy for the brake job before the work order is obtained and time for job is measured. This includes air guns, tool trolley, tire dolly, cleaning bath, trolleys and all other required tools. Also, procurement of all parts that need to be replaced according to FDOT/USDOT specifications must be done when the work order is taken so it is not necessary to visit the materials station frequently. This considerably reduces travel time. Refer to Appendix 4, the recommended setup.
4. Ergonomic Position: It is recommended that while working on the brake job, the bus should be lifted up to waist-height. It has been observed that this position is most convenient and puts the least strain on the back, as the worker has to bend less. This also enhances work efficiency.
5. Lighting: The shop floor should be well lit, especially during the evening shift, so that the use of flashlights by mechanics is minimized.

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Appendix 1
Current Flow Process Chart – Rear Brakes

CURRENT FLOW PROCESS CHART

DATE:03/07/2002

PART DESCRIPTION: Braking System of the transit vehicle

OPERATION DESCRIPTION: Repair time for for the braking systems

SUMMARY	OPERATION NO	TIME MINUTES
○ OPERATIONS	177	156
⇨ TRANSPORT	55	60
□ INSPECTIONS	12	7
D DELAYS	16	22
▽ STORAGES	0	0
TOTAL ELEMENTS	260	245

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
	○	⇨	□	D	▽	
BUS ADJUSTMENT						
Adjustment of the bus on the hydraulic lifter	●	⇨	□	D	▽	240
Inspect for the alignment	○	⇨	■	D	▽	45
Backing the brakes	●	⇨	□	D	▽	30
Inspect for backing	○	⇨	■	D	▽	30
Lowering on the jack	●	⇨	□	D	▽	25
AXLE REMOVAL						
Get tool trolley(big)	○	⇨	□	D	▽	150
Get tool trolley (small)	○	⇨	□	D	▽	66
Getting air gun (tool)	○	⇨	□	D	▽	60
Tool set up for the air gun	●	⇨	□	D	▽	45
Remove axle nuts (* 10)	●	⇨	□	D	▽	30
Travel between nuts (* 9)	●	⇨	□	D	▽	18
Idle time	○	⇨	□	●	▽	180
Removing lock washers and dowel pins (manual)	●	⇨	□	D	▽	30
Idle time	○	⇨	□	●	▽	180

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
Preparing for repair (putting on glasses and collecting hammer)	●	→	□	D	▽	120
Bang with the hammer	●	→	□	D	▽	25
Remove dowel pins	●	→	□	D	▽	120
Shift the cap forward to drain the oil	●	→	□	D	▽	20
Wait for oil to drain	●	→	□	D	▽	60
Getting oil and maintenance tools	●	→	□	D	▽	150
Removing the axle	●	→	□	D	▽	10
Idle time	○	→	□	●	▽	120
Tool procurement	○	→	□	D	▽	180
Remove axle seals and gaskets	●	→	□	D	▽	45
Travel to other side	○	→	□	D	▽	35
Remove axle bolts (* 10)	●	→	□	D	▽	30
Travel between bolts (* 9)	●	→	□	D	▽	18
Removing lockwashers (manual)	●	→	□	D	▽	30
Bang with the hammer	●	→	□	D	▽	25
Remove dowel pins	●	→	□	D	▽	120
Shift the cap forward to drain the oil	●	→	□	D	▽	20
Wait for oil to drain	●	→	□	D	▽	60
Removing the axle	●	→	□	D	▽	10
Remove axle seals and gaskets	●	→	□	D	▽	45
TIRE REMOVAL						
Preparation of air gun	●	→	□	D	▽	20
Remove hexagonal nut	●	→	□	D	▽	21
Remove the locking pin	●	→	□	D	▽	12
Remove the other hexagonal nut	●	→	□	D	▽	15
Travel to other side	●	→	□	D	▽	16
Remove hexagonal nut	●	→	□	D	▽	15

WORK ELEMENTS	OPERATION					TIME (Sec.)
	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	
Remove the locking pin	●	→	□	D	▽	10
Remove the other hexagonal nut	●	→	□	D	▽	15
Travel	●	→	□	D	▽	20
Delay	●	→	□	D	▽	60
Get the hydraulic lifter	○	→	□	D	▽	20
Placing hydraulic lifter to remove wheel	●	→	□	D	▽	15
Remove wheel assembly	●	→	□	D	▽	30
Move the wheel to the side	○	→	□	D	▽	20
Move the hydraulic lifter to the other side	○	→	□	D	▽	60
Placing hydraulic lifter to remove wheel	●	→	□	D	▽	15
Remove wheel assembly	●	→	□	D	▽	30
Move the tire to the side	○	→	□	D	▽	40
Transport the tire to the rework bay	○	→	□	D	▽	60
Adjust crane and accessories	●	→	□	D	▽	90
Move wheel	○	→	□	D	▽	150
Arrange for the new parts (bearing)	○	→	□	D	▽	180
HUB AND DRUM REMOVAL						
Adjust the crane to lift the hub and shoe drum assembly	○	→	□	D	▽	60
Bring shoe brake from rework bay	○	→	□	D	▽	30
Tool procurement	○	→	□	D	▽	240
Move wheel to rework bay	○	→	□	D	▽	30
Remove grease from wheel	●	→	□	D	▽	25
Idle time	○	→	□	●	▽	30
Push the wheel to the horizontal position	●	→	□	D	▽	5
Set up (change gloves)	●	→	□	D	▽	30
Remove nut	●	→	□	D	▽	60
Travel between nuts	●	→	□	D	▽	18
Arrange the crane to lift the wheel (upper)	●	→	□	D	▽	45

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
Remove nut from the wheel (inner)	●	→	□	D	▽	30
Travel between nuts	●	→	□	D	▽	18
Arrange to lift the wheel (inner)	●	→	□	D	▽	50
Lift the wheel and put it on the new hub and drum assembly	○	→	□	D	▽	75
Put nuts (manual)	●	→	□	D	▽	50
Travel between the nuts	●	→	□	D	▽	27
Tighten the nut mechanically	●	→	□	D	▽	40
Travel between the nut	●	→	□	D	▽	18
Lift the other wheel and place it on the assembly	○	→	□	D	▽	60
Semi tight the nut (manual)	●	→	□	D	▽	40
Travel between the nuts	●	→	□	D	▽	27
Tighten the nut mechanically	●	→	□	D	▽	40
Travel between the nuts	●	→	□	D	▽	27
Idle time	○	→	□	●	▽	30
Move the old hub and drum assembly	○	→	□	D	▽	70
Clean the surface	●	→	□	D	▽	30
Lift the wheel by crane (vertical position)	●	→	□	D	▽	75
Take the wheel to the bus	○	→	□	D	▽	45
Move the other side wheel to the rework bay	○	→	□	D	▽	20
2 nd SIDE WHEEL						
Adjust the crane to lift the other new hub and shoe drum assembly	●	→	□	D	▽	60
Bring shoe lining	○	→	□	D	▽	30
Fix rubber of hub and drum	●	→	□	D	▽	5
Move the wheel	○	→	□	D	▽	15
Remove the grease from the wheel	●	→	□	D	▽	30
Dispose the grease	○	→	□	D	▽	15
Clean the gloves	●	→	□	D	▽	40
Push the wheel to the horizontal position	●	→	□	D	▽	5
Remove nut	●	→	□	D	▽	30

WORK ELEMENTS						TIME (Sec.)
	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	
Travel between nuts	●	→	□	D	▽	18
Arrange to lift the wheel (upper) and lift	●	→	□	D	▽	45
Remove nut from the wheel (inner)	●	→	□	D	▽	30
Travel between nuts	●	→	□	D	▽	18
Arrange to lift the wheel (inner)	●	→	□	D	▽	60
Lift the wheel and put it on the new hub and drum assembly	○	→	□	D	▽	90
Put bolts (manual)	●	→	□	D	▽	50
Travel between the nuts	●	→	□	D	▽	27
Tighten the nut mechanically	●	→	□	D	▽	40
Lift the other wheel and place it on the assembly	○	→	□	D	▽	70
Semi tight the nut (manual)	●	→	□	D	▽	40
Travel between the nuts	●	→	□	D	▽	18
Tighten the nut mechanically	●	→	□	D	▽	85
Idle time	○	→	□	●	▽	25
Move the old hub to the side	○	→	□	D	▽	45
Clean the surface	●	→	□	D	▽	20
SHOE BRAKE DISASSEMBLY						
Lift the arrangement in the bus to assemble shoe lining	●	→	□	D	▽	24
Inspect	○	→	■	D	▽	20
Get tool and wear a mask	○	→	□	D	▽	45
Get tool (hammer)	○	→	□	D	▽	30
Loosening 2 bolts	●	→	□	D	▽	30
Hammering to remove the shoe lining	●	→	□	D	▽	10
Removing the nuts with air gun to remove shoe lining	●	→	□	D	▽	180
Travel to the other shoe lining	○	→	□	D	▽	60
Inspect	○	→	■	D	▽	10
Loosening 2 bolts	●	→	□	D	▽	30
Hammering to remove the shoe lining	●	→	□	D	▽	10

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
Removing the nuts with air gun to remove shoe lining	●	→	□	D	▽	270
Inspect the shoe lining	○	→	■	D	▽	10
Spraying oil (both sides)	●	→	□	D	▽	60
S-CAM						
Getting sprays and paper for cleaning	○	→	□	D	▽	120
Cleaning the Scam assembly	●	→	□	D	▽	240
<i>BREAK</i>	○	→	□	●	▽	
Clean the scam assembly (other side)	●	→	□	D	▽	300
Putting grease in the groove	●	→	□	D	▽	180
Tool arrangement	○	→	□	D	▽	50
Cleaning and greasing on the other side	●	→	□	D	▽	180
Idle time	○	→	□	●	▽	20
Putting the tool back	○	→	□	D	▽	60
Cleaning the assembly	●	→	□	D	▽	30
Travel to Disposing oil	○	→	□	D	▽	35
Cleaning the gloves and preparation	●	→	□	D	▽	60
Travel	○	→	□	D	▽	40
Hammering to remove the wiper seal	●	→	□	D	▽	30
Travel to get wiper seal	○	→	□	D	▽	20
Replace with new seal wiper and tighten with hammer	●	→	□	D	▽	60
Cleaning the assembly	●	→	□	D	▽	60
Hammering to remove the wiper seal (other side)	●	→	□	D	▽	30
Replacing with new seal wiper and tighten with hammer	●	→	□	D	▽	90
Cleaning the assembly	●	→	□	D	▽	35
Idle time	○	→	□	●	▽	30
Remove ear cover and gloves	●	→	□	D	▽	85
Apply grease on the 2 nut assembly	●	→	□	D	▽	25
Apply grease on the shoe liner	●	→	□	D	▽	30
Apply grease on the 2 nut assembly (other side)	●	→	□	D	▽	30

WORK ELEMENTS						TIME (Sec.)
	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	
Apply grease on the shoe liner	●	→	□	D	▽	35
Keep the tools and grease	○	→	□	D	▽	30
Idle time	○	→	□	●	▽	30
SHOE BRAKE MOUNTING						
Mounting the shoe liner	●	→	□	D	▽	25
Travel to get the spray	○	→	□	D	▽	30
Assembly of nut and bolt (manual) *2	●	→	□	D	▽	50
Check for alignment	○	→	■	D	▽	60
Idle time	○	→	□	●	▽	100
Get retractor spring	○	→	□	D	▽	60
Mounting retractor spring	●	→	□	D	▽	300
Inspecting	○	→	■	D	▽	20
Raise the Scam	●	→	□	D	▽	15
Put the cam bolts	●	→	□	D	▽	25
Tighten the nut assembly (* 2)	●	→	□	D	▽	10
Inspect and maintenance	○	→	■	D	▽	80
OTHER SIDE						
Mounting the shoe liner	●	→	□	D	▽	40
Assembly of nut (manual) *2	●	→	□	D	▽	40
Check for alignment	○	→	■	D	▽	60
Travel	○	→	□	D	▽	20
Mounting retractor spring	●	→	□	D	▽	280
Inspection	○	→	■	D	▽	20
Put the rollers	●	→	□	D	▽	25
Tighten the nut assembly (* 2)	●	→	□	D	▽	10
Inspect and maintenance	○	→	■	D	▽	60
Rearranging	●	→	□	D	▽	120
Cleaning	●	→	□	D	▽	60

WORK ELEMENTS	OPERATION					TIME (Sec.)
	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	
Part procurement	○	➡	□	D	▽	120
Get grease from rework bay	○	➡	□	D	▽	120
Apply grease on hub and drum assembly	●	➡	□	D	▽	40
Apply grease on wheel axle	●	➡	□	D	▽	15
Get grease from rework bay	○	➡	□	D	▽	120
Apply grease on hub and drum assembly	●	➡	□	D	▽	45
Apply grease on wheel axle	●	➡	□	D	▽	35
Idle time	○	➡	□	●	▽	60
Cleaning floor area	●	➡	□	D	▽	120
Clean axle clamping accessories (ball bearing)	●	➡	□	D	▽	120
Clean axle clamping accessories (ball bearing)	●	➡	□	D	▽	120
Mount axle seal and bush	●	➡	□	D	▽	10
Mount seal wiper	●	➡	□	D	▽	15
Apply grease	●	➡	□	D	▽	15
Tool procurement	○	➡	□	D	▽	90
Mount axle seal and bush (other side)	●	➡	□	D	▽	10
Mount wiper	●	➡	□	D	▽	20
Apply grease	●	➡	□	D	▽	15
TIRE MOUNTING						
Move and fit the wheel (hydraulic lifter)	○	➡	□	D	▽	180
Put ball bearing	●	➡	□	D	▽	5
Fitting hexagonal nut (manual)	●	➡	□	D	▽	30
Remove the hydraulic tool and move to other side	○	➡	□	D	▽	60
Move and fit the wheel (hydraulic lifter)	●	➡	□	D	▽	165
Put ball bearing	●	➡	□	D	▽	5
Fitting hexagonal nut (manual)	●	➡	□	D	▽	27
Remove the hydraulic lifter and move it aside	○	➡	□	D	▽	50
Idle time	○	➡	□	●	▽	140

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
AXLE MOUNTING						
Axle Mounting	●	→	□	D	▽	12
Cleaning axle head	●	→	□	D	▽	70
Cleaning axle head (other side)	●	→	□	D	▽	120
Idle time	○	→	□	●	▽	180
Check the tire alignment (manual)	○	→	■	D	▽	15
Travel	○	→	□	D	▽	35
WHEEL ADJUSTMENT WITH AXLE MOUNTING						
Raising the bus	●	→	□	D	▽	25
Travel	○	→	□	D	▽	40
Fill air bags to raise the bus over the wheel to adjust the wheel	●	→	□	D	▽	40
Idle time	○	→	□	●	▽	130
Mounting and torching the bearing	●	→	□	D	▽	75
Further tightening	●	→	□	D	▽	25
Mounting the locking device	●	→	□	D	▽	10
Get new part (hexagonal nut)	○	→	□	D	▽	240
Mounting hexagonal nut	●	→	□	D	▽	15
Travel	○	→	□	D	▽	20
Tool set up	●	→	□	D	▽	60
Tightening of hexagonal nut	●	→	□	D	▽	15
Mounting bush	●	→	□	D	▽	15
Mounting axle	●	→	□	D	▽	20
Mounting ring nut	●	→	□	D	▽	35
Hammering ring nut	●	→	□	D	▽	20
Travel	○	→	□	D	▽	35
Tool set up	●	→	□	D	▽	60
Assembling the nut and bolt (manual)	●	→	□	D	▽	30
Travel between the nut	●	→	□	D	▽	18

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
Tighten the nut mechanically	●	→	□	D	▽	50
Travel between the nut assembly	●	→	□	D	▽	18
Travel	○	→	□	D	▽	40
Cleaning and spraying the wheel cap	●	→	□	D	▽	360
Tool set up	●	→	□	D	▽	120
Idle time	○	→	□	●	▽	30
Check the tire alignment (manual)	○	→	■	D	▽	15
Fill air bags to raise the bus over the wheel to adjust the wheel	●	→	□	D	▽	35
Travel	○	→	□	D	▽	20
Mounting and torquing the bearing	●	→	□	D	▽	60
Further tightening	●	→	□	D	▽	30
Mounting the locking device	●	→	□	D	▽	20
Get new part (hexagonal nut)	○	→	□	D	▽	120
Mounting hexagonal nut	●	→	□	D	▽	10
Tightening of hexagonal nut	●	→	□	D	▽	15
Mounting bush	●	→	□	D	▽	15
Mounting axle	●	→	□	D	▽	25
Mounting ring nut	●	→	□	D	▽	30
Hammering ring nut	●	→	□	D	▽	30
Assembling the nut and bolt (manual)	●	→	□	D	▽	30
Travel between the nut	●	→	□	D	▽	18
Idle time	○	→	□	●	▽	20
Tighten the nut mechanically	●	→	□	D	▽	50
Travel between the nut assembly	●	→	□	D	▽	18
Cleaning and spraying the wheel cap	●	→	□	D	▽	360
Travel	○	→	□	D	▽	45
Fix a odometer	●	→	□	D	▽	16
Travel	○	→	□	D	▽	30
Unback the brakes	●	→	□	D	▽	35

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME (Sec.)
BUS ADJUSTMENT						
Lower the bus	●	⇨	□	D	▽	30
Remove the jack	●	⇨	□	D	▽	20
Keep the tool back to the place	●	⇨	□	D	▽	100

TOTAL TIME = 14691 SECONDS
TOTAL TIME = 244.85 SECONDS
TOTAL TIME = 4.08 HOURS

Appendix 2
Current Flow Process Chart - Front Brakes

CURRENT FLOW PROCESS CHART (FRONT BRAKE)

DATE:03/07/2002

PART DESCRIPTION:Front Braking System of the transit vehicle

OPERATION DESCRIPTION: Repair time for the braking systems

SUMMARY	OPERATION NO	TIME MINUTES
○ OPERATIONS	88	117
⇨ TRANSPORT	5	5
□ INSPECTIONS	1	1
D DELAYS	1	2
▽ STORAGES	0	0
TOTAL ELEMENTS	95	117.45

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
BUS ADJUSTMENT						
Raise bus	●	⇨	□	D	▽	120
Adjust workstation	●	⇨	□	D	▽	35
Check Brakes	○	⇨	■	D	▽	60
Confer with Supervisor	●	⇨	□	●	▽	120
Backing brakes	●	⇨	□	D	▽	60
Lowering bus	●	⇨	□	D	▽	30
TIRE REMOVAL						
Get tools and set up	○	⇨	□	D	▽	60
Remove nut caps (new)	●	⇨	□	D	▽	30
Remove nut caps (new) other side	●	⇨	□	D	▽	30
Remove nuts	●	⇨	□	D	▽	32
Remove wheel and place	○	⇨	□	D	▽	10
Remove nuts	●	⇨	□	D	▽	35
Remove and place wheel	○	⇨	□	D	▽	10

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Remove drum assembly (hammer and remove)	●	→	□	D	▽	60
Remove drum assembly (hammer and remove) other side	●	→	□	D	▽	35
Raise bus	●	→	□	D	▽	60
Get tools	○	→	□	D	▽	15
Backing brakes	●	→	□	D	▽	20
Remove hub's inner nut	●	→	□	D	▽	25
Remove hub cap	●	→	□	D	▽	60
Drain oil	●	→	□	D	▽	60
REMOVE HUB AND DRUM						
Set tool	●	→	□	D	▽	50
Remove Hexagonal nut	●	→	□	D	▽	10
Remove washer	●	→	□	D	▽	10
Remove bearings	●	→	□	D	▽	20
Remove hub cover (big with wheel nuts)	●	→	□	D	▽	15
Remove anchor pin	●	→	□	D	▽	35
Remove locks screw	●	→	□	D	▽	20
Remove roller 1	●	→	□	D	▽	10
Remove roller 2 (got stuck)	●	→	□	D	▽	60
Remove shoes	●	→	□	D	▽	30
Inspect s-cam assembly	●	→	□	D	▽	90
SHOE BRAKE MOUNTING						
Insert shoes	●	→	□	D	▽	60
Insert anchor locking pins	●	→	□	D	▽	60
Insert new springs	●	→	□	D	▽	180
Insert new rollers	●	→	□	D	▽	30
Put Anchor pin lock nut	●	→	□	D	▽	180
Remove old oil seal	●	→	□	D	▽	45

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Remove and inspect bearings	●	→	□	D	▽	60
Change oil seal	●	→	□	D	▽	330
MOUNT HUB AND DRUM						
Insert hub	●	→	□	D	▽	60
Insert hexagonal nut & washer and gasket	●	→	□	D	▽	255
Cleaning	●	→	□	D	▽	60
Insert hub cap	●	→	□	D	▽	180
Press fit, clean, grease anchor pin	●	→	□	D	▽	60
Fill oil in the hub	●	→	□	D	▽	540
Adjustment of spring misalignment	●	→	□	D	▽	120
Remove old drum, bring new one and place in slot	●	→	□	D	▽	60
Set tool	●	→	□	D	▽	120
Coffee Break						
HUB AND DRUM REMOVAL						
Tool preparation	●	→	□	D	▽	120
Remove hub nuts	●	→	□	D	▽	60
Remove hub cap & drain oil	●	→	□	D	▽	60
Remove Hexagonal nut	●	→	□	D	▽	35
Remove gasket and washers	●	→	□	D	▽	60
Remove hub	●	→	□	D	▽	30
Clean	●	→	□	D	▽	15
Backing brakes	●	→	□	D	▽	45
Remove anchor pin lock screw	●	→	□	D	▽	30
Remove anchor pin rollers and get tools	●	→	□	D	▽	120
Remove shoes and springs	●	→	□	D	▽	120
Dispose old parts and clean assembly	○	→	□	D	▽	190

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
SHOE BRAKE AND DRUM MOUNTING						
Insert new shoes	●	→	□	D	▽	120
Insert spring	●	→	□	D	▽	120
Insert rollers	●	→	□	D	▽	30
Wind locking screw	●	→	□	D	▽	120
Insert hexagonal nut & washer and gasket	●	→	□	D	▽	210
Insert hexagonal nut	●	→	□	D	▽	60
Gasket stock scraped out	●	→	□	D	▽	360
Insert hub cap (and torquing)	●	→	□	D	▽	180
Clean assembly	●	→	□	D	▽	60
Oil parts	●	→	□	D	▽	60
Fill oil	●	→	□	D	▽	540
Get tools and clean area	●	→	□	D	▽	180
Insert drum	●	→	□	D	▽	60
BUS ADJUSTMENT						
Lower bus	●	→	□	D	▽	30
Insert wheel in place	●	→	□	D	▽	160
Tighten nuts	●	→	□	D	▽	120
Put nut caps	●	→	□	D	▽	35

TOTAL TIME = 7047 SECONDS
TOTAL TIME = 117.45 MINUTES
TOTAL TIME = 1.95 HOURS

Appendix 3
Proposed Flow Process Chart

PROPOSED FLOW PROCESS CHART

DATE: 7/08/02

PART DESCRIPTION: Braking System of the transit vehicle

OPERATION DESCRIPTION: Repair time for the braking systems

	SUMMARY	TOTAL	TIME
		NO.	MINUTES
○	OPERATIONS	201	155
➡	TRANSPORT	36	24
□	INSPECTIONS	4	1
D	DELAYS	0	0
▽	STORAGES	0	0

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
BUS ARRANGEMENT						
Adjust the bus on the hydraulic lifter	●	➡	□	D	▽	45
Raise the bus	●	➡	□	D	▽	91
Inspect for alignment	○	➡	■	D	▽	39
Get tools for brakes backing	●	➡	□	D	▽	23
Backing the brakes	●	➡	□	D	▽	70
Replace tools	●	➡	□	D	▽	10
Lower the bus	●	➡	□	D	▽	31
TIRE REMOVAL						
LEFT SIDE						
Get tool (Air Gun)	●	➡	□	D	▽	57
Tool set up (Air Gun)	●	➡	□	D	▽	45
Remove wheel nuts (*10)	●	➡	□	D	▽	61

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Get tire dolly	●	⇨	□	⌒	▽	15
Remove the outer tire	●	⇨	□	⌒	▽	16
Move tire at side	●	⇨	□	⌒	▽	30
Tool set up (Air Gun)	●	⇨	□	⌒	▽	22
Remove Lug nuts (*10)	●	⇨	□	⌒	▽	49
Remove tire (Inner)	●	⇨	□	⌒	▽	18
Move tire at side	○	⇨	□	⌒	▽	28
Collect the nuts and the Lug nuts	●	⇨	□	⌒	▽	35
RIGHT SIDE						
Transportation of Tool trolley and tire dolly to other side	○	⇨	□	⌒	▽	25
Tool set up (Air Gun)	●	⇨	□	⌒	▽	25
Remove Wheel Nuts (*10)	●	⇨	□	⌒	▽	49
Remove the outer tire	●	⇨	□	⌒	▽	24
Move tire at side	○	⇨	□	⌒	▽	21
Tool set up (Air Gun)	●	⇨	□	⌒	▽	25
Remove Lug nuts (*10)	●	⇨	□	⌒	▽	54
Remove tire (Inner)	●	⇨	□	⌒	▽	17
Move tire at side	○	⇨	□	⌒	▽	25
Go to the Control	○	⇨	□	⌒	▽	9
Raise bus	●	⇨	□	⌒	▽	25
Collect the Lug nuts and other nuts	●	⇨	□	⌒	▽	35
AXLE REMOVAL						
RIGHT SIDE						
Get Tool (Air Gun)	●	⇨	□	⌒	▽	41
Tool set up (Air Gun)	●	⇨	□	⌒	▽	31
Remove Nut (*10)	●	⇨	□	⌒	▽	43

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Remove lock washers and dowel pins	●	→	□	D	▽	45
Get sledge hammer (safety glasses and ear pads may be inc)	●	→	□	D	▽	27
Hammer to remove Dowel pins	●	→	□	D	▽	170
Travel to get oil collector (* 2)	○	→	□	D	▽	52
Get Hammer	●	→	□	D	▽	66
Hammer to remove axle	●	→	□	D	▽	29
Shift the cap and place oil collector to collect oil	●	→	□	D	▽	25
LEFT SIDE						
Travel to other side with oil collector and tool trolley	○	→	□	D	▽	23
Remove Nut (*10)	●	→	□	D	▽	46
Remove the odometer	●	→	□	D	▽	14
Remove lock washers and dowel pins	●	→	□	D	▽	28
Hammer to remove dowel pins	●	→	□	D	▽	118
Get hammer	●	→	□	D	▽	20
Hammer to remove axle	●	→	□	D	▽	27
Shift the cap and place oil collector to collect oil	●	→	□	D	▽	19
Travel to other side	●	→	□	D	▽	11
Remove axle of right side	●	→	□	D	▽	12
Remove axle seal and gaskets	●	→	□	D	▽	39
Travel to other side	○	→	□	D	▽	10
Remove axle of left side	●	→	□	D	▽	12
Remove axle seal and gaskets	●	→	□	D	▽	29
Collect assembly	●	→	□	D	▽	35
HUB AND DRUM REMOVAL						
LEFT SIDE						
Travel to get attachment for removing the hexagonal nut	○	→	□	D	▽	40
Tool set up (Air Gun)	●	→	□	D	▽	24

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Remove Hexagonal nut	●	→	□	D	▽	48
Remove locking nut	●	→	□	D	▽	14
Remove 2nd Hexagonal nut	●	→	□	D	▽	14
Remove bearing	●	→	□	D	▽	15
RIGHT SIDE						
Travel to other side with air gun and tool trolley	○	→	□	D	▽	25
Tool set up (Air Gun)	●	→	□	D	▽	22
Remove Hexagonal nut	●	→	□	D	▽	18
Remove locking nut	●	→	□	D	▽	11
Remove 2nd Hexagonal nut	●	→	□	D	▽	14
Remove bearing	●	→	□	D	▽	12
Replace tools	●	→	□	D	▽	23
Get tools for backing brakes	●	→	□	D	▽	12
Backing brakes	●	→	□	D	▽	54
Travel to get Hydraulic lifter	○	→	□	D	▽	25
Remove drum assembly by adjusting hydraulic lifter	●	→	□	D	▽	67
Transport it to the rework bay for storage	○	→	□	D	▽	43
Travel to other side with the hydraulic lifter (left side)	○	→	□	D	▽	33
Remove drum assembly by adjusting hydraulic lifter	●	→	□	D	▽	43
Transport it to the rework bay for storage	○	→	□	D	▽	50
Replace the hydraulic lifter	●	→	□	D	▽	34
SHOE BRAKE DISASSEMBLY						
RIGHT SIDE						
Travel to control	○	→	□	D	▽	12
Make arrangement to fill air	●	→	□	D	▽	43
Fill air to lift the arrangement in the bus to dissemble shoe lining	●	→	□	D	▽	63

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Inspect shoe brake lining	○	→	■	D	▽	17
Air gun setup to remove shoe brake nut	●	→	□	D	▽	22
Remove shoe brake nut (* 2)	●	→	□	D	▽	28
Get hammer	●	→	□	D	▽	29
Remove anchor pin and dowel pin(may include hammering)	●	→	□	D	▽	30
Get tool to remove shoe brake roller	●	→	□	D	▽	15
Remove the shoe brake roller (* 2)	●	→	□	D	▽	21
Remove the return spring	●	→	□	D	▽	41
Remove shoe brake including hammering	●	→	□	D	▽	27
Transport shoe brakes to the rework bay	○	→	□	D	▽	29
Get hammer to remove wiper seal	●	→	□	D	▽	12
Remove inner wiper seal	●	→	□	D	▽	15
Remove outer wiper seal	●	→	□	D	▽	12
Get spray to clean the assembly	●	→	□	D	▽	15
Inspect the S cam and clean the assembly	●	→	■	D	▽	308
LEFT SIDE						
Travel to other side with tool trolley and air gun	○	→	□	D	▽	22
Remove shoe brake nut (* 2)	●	→	□	D	▽	26
Remove anchor pin and dowel pin (may include hammering)	●	→	□	D	▽	55
Travel to get tool to remove shoe brake roller	○	→	□	D	▽	16
Remove the shoe brake roller (* 2)	●	→	□	D	▽	43
Remove the return spring	●	→	□	D	▽	51
Remove shoe brake including hammering	●	→	□	D	▽	70
Transport shoe brakes to the rework bay	○	→	□	D	▽	36
Get hammer to remove wiper seal	●	→	□	D	▽	11
Remove inner wiper seal (includes hammering)	●	→	□	D	▽	22
Remove outer wiper seal	●	→	□	D	▽	11
Get spray to clean the assembly	●	→	□	D	▽	17

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Inspect the S cam and clean the assembly	●	→	■	D	▽	298
SHOE BRAKE MOUNTING						
LEFT SIDE						
Travel to the other side with the tool trolley	○	→	□	D	▽	19
Travel to get shoe brake from the rework bay	●	→	□	D	▽	28
Travel to get grease	○	→	□	D	▽	145
Change gloves	●	→	□	D	▽	46
Clean spindle	●	→	□	D	▽	54
Apply grease in nut assembly	●	→	□	D	▽	30
Mount the shoe brake on the hub shaft	●	→	□	D	▽	30
Mount Return spring	●	→	□	D	▽	77
Clean anchor pin	●	→	□	D	▽	26
Mount the anchor pin and dowel pin	●	→	□	D	▽	11
Mount the shoe brake nut (*2) manually	●	→	□	D	▽	34
Tool set up (Air Gun)	●	→	□	D	▽	24
Tighten the shoe brake nut	●	→	□	D	▽	15
Mount the shoe brake roller (* 2)	●	→	□	D	▽	37
Mount the inner wiper seal	●	→	□	D	▽	18
Tool set up (Air Gun)	●	→	□	D	▽	19
Tighten the wiper seal by hammer and an attachment	●	→	□	D	▽	47
Mount the outer wiper seal	●	→	□	D	▽	11
Tighten the wiper seal by hammer	●	→	□	D	▽	11
RIGHT SIDE						
Travel to other side with tool trolley and air gun	○	→	□	D	▽	23
Clean spindle	●	→	□	D	▽	119
Travel to get grease	○	→	□	D	▽	152
Change gloves	●	→	□	D	▽	46

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Apply grease in nut assembly	●	⇨	□	D	▽	29
Mount the shoe brake on the hub shaft	●	⇨	□	D	▽	47
Mount Return spring	●	⇨	□	D	▽	60
Clean anchor pin	●	⇨	□	D	▽	26
Mount the anchor pin and dowel pin	●	⇨	□	D	▽	12
Mount the shoe brake nut (* 2) manually	●	⇨	□	D	▽	33
Tighten the shoe brake nut	●	⇨	□	D	▽	15
Mount the shoe brake roller (* 2) (may include adjustment)	●	⇨	□	D	▽	36
Mount the inner wiper seal	●	⇨	□	D	▽	16
Tighten the wiper seal by hammer and an attachment	●	⇨	□	D	▽	19
Mount the outer wiper seal	●	⇨	□	D	▽	10
Tighten the wiper seal by hammer	●	⇨	□	D	▽	12
HUB AND DRUM MOUNTING						
RIGHT SIDE						
Transport hub and drum (*2) on hydraulic lifter from the rework bay	○	⇨	□	D	▽	57
Mount hub and drum on the spindle	●	⇨	□	D	▽	123
Remove hydraulic lifter	●	⇨	□	D	▽	15
Travel to get grease	○	⇨	□	D	▽	132
Apply grease in hub and drum assembly	●	⇨	□	D	▽	49
Get bearing (*2)	●	⇨	□	D	▽	17
Apply grease on bearing	●	⇨	□	D	▽	30
Apply grease on axle shaft	●	⇨	□	D	▽	23
Mount bearing	●	⇨	□	D	▽	14
Clean gease	●	⇨	□	D	▽	23
Clean hexagonal nut	●	⇨	□	D	▽	30
Mount hexagonal nut manually	●	⇨	□	D	▽	19
Tool set up (Air Gun)	●	⇨	□	D	▽	22

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Tighten the hexagonal nut	●	→	□	D	▽	13
Tool set up (Air Gun)	●	→	□	D	▽	53
Torquing	●	→	□	D	▽	119
Clean locking pin	●	→	□	D	▽	16
Mount locking pin	●	→	□	D	▽	15
Clean hexagonal nut	●	→	□	D	▽	16
Mount other hexagonal nut	●	→	□	D	▽	15
Tighten the hexagonal nut	●	→	□	D	▽	14
Torquing for outer hexagonal nut	●	→	□	D	▽	88
LEFT SIDE						
Transport hub and drum on hydraulic lifter from the rework bay	○	→	□	D	▽	60
Mount hub and drum on the spindle	●	→	□	D	▽	117
Remove hydraulic lifter	●	→	□	D	▽	11
Travel to get grease	○	→	□	D	▽	131
Apply grease in hub and drum assembly	●	→	□	D	▽	59
Get bearing	●	→	□	D	▽	21
Apply grease on bearing	●	→	□	D	▽	24
Apply grease on axle shaft	●	→	□	D	▽	29
Mount bearing	●	→	□	D	▽	11
Clean grease	●	→	□	D	▽	70
Clean hexagonal nut	●	→	□	D	▽	15
Mount hexagonal nut manually	●	→	□	D	▽	26
Tool set up (Air Gun)	●	→	□	D	▽	25
Tighten the hexagonal nut by Air gun	●	→	□	D	▽	19
Tool set up (Air Gun)	●	→	□	D	▽	61
Torquing	●	→	□	D	▽	81
Clean locking pin	●	→	□	D	▽	15

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Mount locking pin	●	→	□	D	▽	16
Clean hexagonal nut	●	→	□	D	▽	14
Mount other hexagonal nut	●	→	□	D	▽	15
Tighten the hexagonal nut	●	→	□	D	▽	16
Tool set up (Air Gun)	●	→	□	D	▽	29
Torquing for outer hexagonal nut	●	→	□	D	▽	32
AXLE MOUNTING						
LEFT SIDE						
Travel to get axle seals and gaskets	○	→	□	D	▽	25
Mount axle seals and gaskets	●	→	□	D	▽	28
Clean the axle	●	→	□	D	▽	99
Mount axle and hammer to fit	●	→	□	D	▽	22
Mount lock washers, dowel pins manually	●	→	□	D	▽	58
Mount axle nut manually	●	→	□	D	▽	54
Tool set up (Air Gun)	●	→	□	D	▽	19
Tighten axle nut	●	→	□	D	▽	46
RIGHT SIDE						
Travel to other side with axle seals and gaskets and tool trolley	○	→	□	D	▽	21
Clean the axle shaft	●	→	□	D	▽	111
Mount axle seals and gaskets	●	→	□	D	▽	18
Mount axle and hammer to fit	●	→	□	D	▽	20
Mount lock washers, dowel pins manually	●	→	□	D	▽	86
Mount axle nut manually	●	→	□	D	▽	51
Mount Odometer	●	→	□	D	▽	16
Tighten axle nut	●	→	□	D	▽	51
BUS ADJUSTMENT						

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Travel to the control	○	➔	□	⊔	▽	9
Raising the bus	●	➔	□	⊔	▽	61
Get tool	●	➔	□	⊔	▽	13
Unbacking brakes	●	➔	□	⊔	▽	45
Front brake setting	●	➔	□	⊔	▽	34
Lowering bus	●	➔	□	⊔	▽	44
TIRE MOUNTING						
RIGHT SIDE						
Make arrangement for pneumatic pipe for filling air	●	➔	□	⊔	▽	31
Fill air	●	➔	□	⊔	▽	51
Transport inner tire to the bus usually from the side	○	➔	□	⊔	▽	20
Mount inner tire	●	➔	□	⊔	▽	44
Mount lug nut manually (* 10)	●	➔	□	⊔	▽	67
Tool set up (Air Gun)	●	➔	□	⊔	▽	21
Tighten the lug nut	●	➔	□	⊔	▽	56
Transport outer tire to the bus usually from the side	○	➔	□	⊔	▽	20
Mount outer tire	●	➔	□	⊔	▽	44
Mount wheel nuts manually (* 10)	●	➔	□	⊔	▽	57
Tool set up (Air Gun)	●	➔	□	⊔	▽	21
Tighten the wheel nuts	●	➔	□	⊔	▽	61
Get spray and cloth for cleaning	●	➔	□	⊔	▽	22
Clean the rim of the wheel	●	➔	□	⊔	▽	67
LEFT SIDE						
Travel to other side with tool trolley	○	➔	□	⊔	▽	16
Fill air	●	➔	□	⊔	▽	52
Transport inner tire to the bus usually from the side	○	➔	□	⊔	▽	24
Mount inner tire	●	➔	□	⊔	▽	40

WORK ELEMENTS	OPERATION	TRANSPORT	INSPECTION	DELAY	STORAGE	TIME
Mount lug nut manually (* 10)	●	→	□	D	▽	65
Tool set up (Air Gun)	●	→	□	D	▽	18
Tighten the lug nut	●	→	□	D	▽	53
Transport outer tire to the bus usually from the side	○	→	□	D	▽	30
Mount outer tire	●	→	□	D	▽	46
Mount wheel nuts manually (* 10)	●	→	□	D	▽	63
Tool set up (Air Gun)	●	→	□	D	▽	21
Tighten the wheel nuts	●	→	□	D	▽	71
Get spray and cloth for cleaning	●	→	□	D	▽	22
Clean the rim of the wheel	●	→	□	D	▽	62
Go to control	○	→	□	D	▽	8
Remove the air	●	→	□	D	▽	23
Lower the bus	●	→	□	D	▽	15
TOTAL NORMAL TIME (SECONDS)						9313.48
TOTAL NORMAL TIME (MINUTES)						155.22
TOTAL NORMAL TIME (HOURS)						2.59
ALLOWANCE (15%) SECONDS						1397.02
ALLOWANCE (15%) MINUTES						23.28
ALLOWANCE (15%) HOURS						0.39
TOTAL STANDARD TIME (SECONDS)						10710.51
TOTAL STANDARD TIME (MINUTES)						178.51
TOTAL STANDARD TIME (HOURS)						2.98

Appendix 4

Recommended Set-up

SET UP REQUIRED FOR THE TIME STUDY

1. The arrangement of the tool and the new parts that needs to be replaced by as per the specification of FDOT is to be done before starting the repair of the system.
 - a. The tools include the air gun, dowel pin pliers, sledge hammer, wiper seal tightening equipment.
 - b. The new parts include the wheel nuts, lug nuts, lock washers, dowel pins, axle seals, gaskets, axle nuts, wiper seals, shoe brake nuts, bearings, and other things depending on the replacement required.
2. The shoe lining should be assembled. The standard does not include the time required for cutting the shoe lining and assembling it.
3. The drum should be cut and set so as to be replacing the old one.
4. The lifting equipment should be located near the working area.

