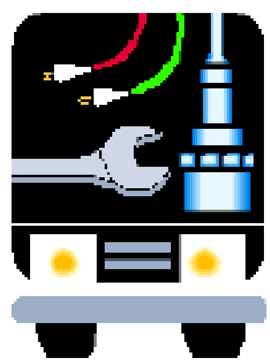
REPAIR TIME STANDARDS FOR TRANSIT VEHICLES

FINAL REPORT
SEPTEMBER 24, 2002



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FDOT Project BC137-RPW032
CUTR Account 2117-473-LO

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NCTR-506-01 NCTR-473-05		

4. Title and Subtitle	5. Report Date
Repair Time Standards for Transit Vehicles	September 2002
	6. Performing Organization Code
7. Author(s) Grisselle Centeno	8. Performing Organization Report No.
9. Performing Organization Name and Address National Center for Transit Research (NCTR) University of South Florida 4202 E Fowler Av, CUT 100, Tampa, FL 33620-5375	10. Work Unit No. 11. Contract or Grant No. DTRS98-G-0032
12. Sponsoring Agency Name and Address Office of Research and Special Programs U.S. Department of Transportation, Washington, D.C. 20590 Florida Department of Transportation 605 Suwannee Street, MS 26, Tallahassee, FL 32399	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes
Supported by a grant from the Florida Department of Transportation and the U.S. Department of Transportation

16. Abstract
Under contract with the Florida Department of Transportation (FDOT), the Center for Urban Transportation Research (CUTR) was asked to develop repair time standards for transit vehicles. This report identifies the process used to define the standards and identifies the actual time standards developed for each of the tasks associated with repairs.

17. Key Words	18. Distribution Statement
Repair Time Standards	Available to the public through the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, 703-487-465, and through the NCTR website at http://www.nctr.usf.edu

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	49	

Form DOT F 1700.7 (8-69)

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.

PROJECT TEAM

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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

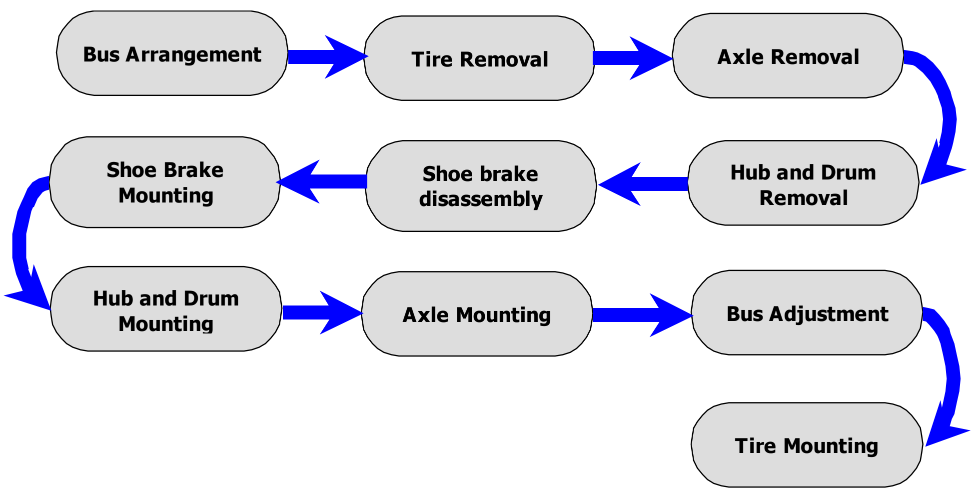
During the exploratory phase of this project the steering committee, comprised of members of the Florida Maintenance Training Advisory Committee, guided the Time Standard Team to start the analysis with the Brake System. Three locations were invited to participate in the study. These facilities were: 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:

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

a 90% confident level (1- α) 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 where 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 essentials 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: 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.

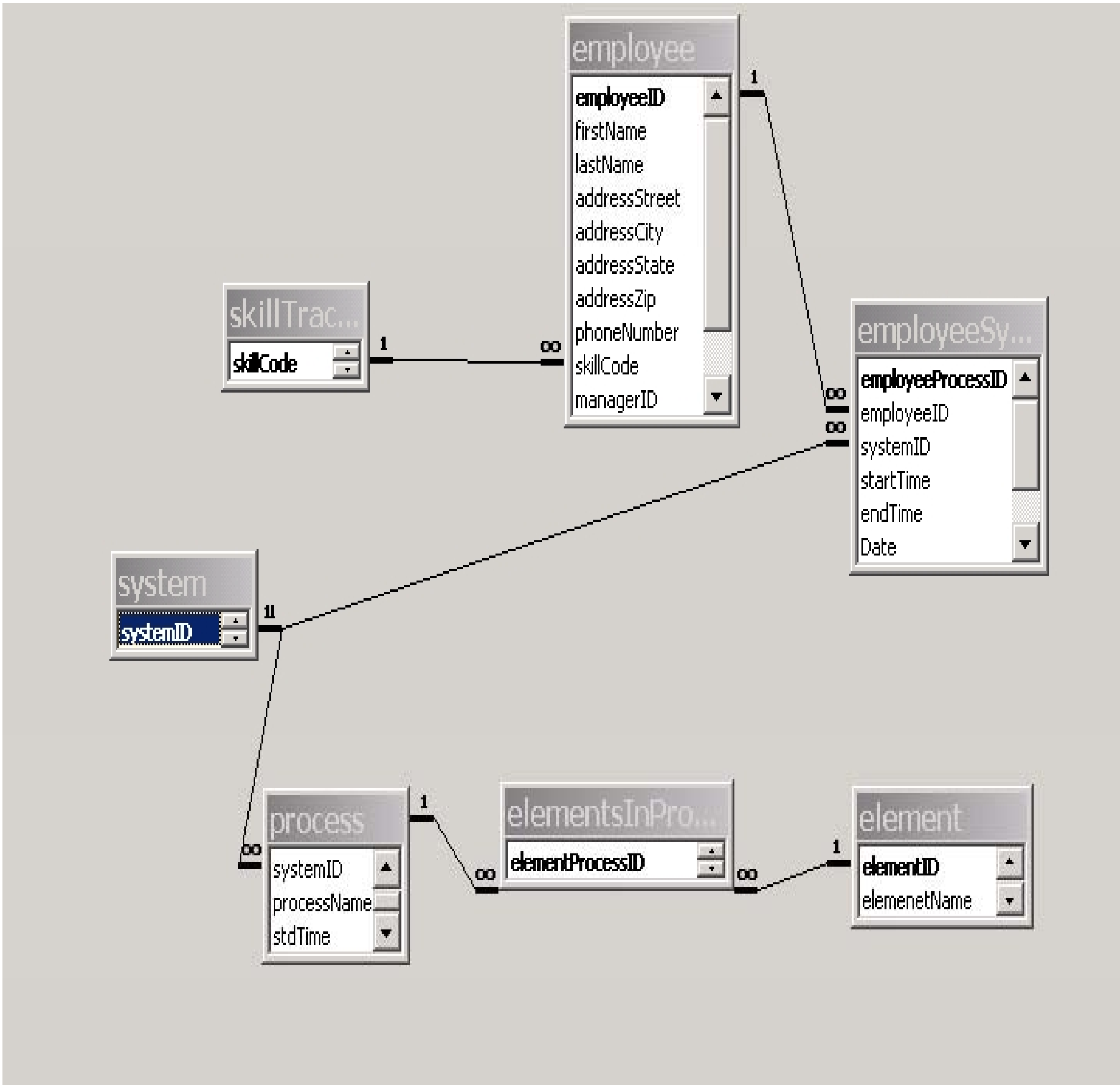
5.0 DATABASE

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

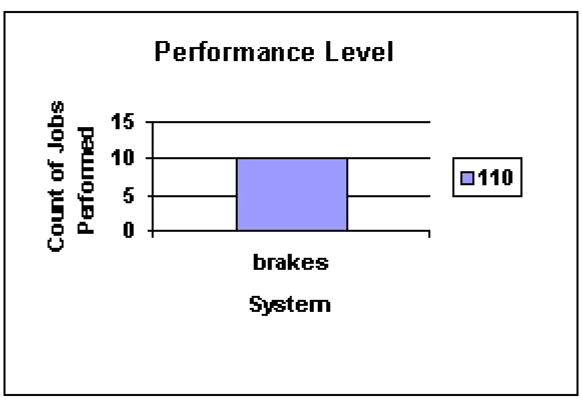
Work Log

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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