NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

# 4 Synthesis of Transit Practice

# Allocation of Time for Transit Bus Maintenance Functions

TRANSPORTATION RESEARCH BOARD
National Research Council

## TRANSPORTATION RESEARCH BOARD EXECUTIVE COMMITTEE 1984



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# 4 Synthesis of Transit Practice

# Allocation of Time for Transit Bus Maintenance Functions

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## NATIONAL COOPERATIVE TRANSIT RESEARCH & DEVELOPMENT PROGRAM

Administrators, engineers, and many others in the transit industry are faced with a multitude of complex problems that range between local, regional, and national in their prevalence. How they might be solved is open to a variety of approaches; however, it is an established fact that a highly effective approach to problems of widespread commonality is one in which operating agencies join cooperatively to support, both in financial and other participatory respects, systematic research that is well designed, practically oriented, and carried out by highly competent researchers. As problems grow rapidly in number and escalate in complexity, the value of an orderly, high-quality cooperative endeavor likewise escalates.

Recognizing this in light of the many needs of the transit industry at large, the Urban Mass Transportation Administration, U.S. Department of Transportation, got under way in 1980 the National Cooperative Transit Research & Development Program (NCTRP). This is an objective national program that provides a mechanism by which UMTA's principal client groups across the nation can join cooperatively in an attempt to solve near-term public transportation problems through applied research, development, test, and evaluation. The client groups thereby have a channel through which they can directly influence a portion of UMTA's annual activities in transit technology development and deployment. Although present funding of the NCTRP is entirely from UMTA's Section 6 funds, the planning leading to inception of the Program envisioned that UMTA's client groups would join ultimately in providing additional support, thereby enabling the Program to address a large number of problems each year.

The NCTRP operates by means of agreements between UMTA as the sponsor and (1) the National Research Council as the Primary Technical Contractor (PTC) responsible for administrative and technical services, (2) the American Public Transit Association, responsible for operation of a Technical Steering Group (TSG) comprised of representatives of transit operators, local government officials, State DOT officials, and officials from UMTA's Office of Technical Assistance, and (3) the Urban Consortium for Technology Initiatives/Public Technology, Inc., responsible for providing the local government officials for the Technical Steering Group.

Research Programs for the NCTRP are developed annually by the Technical Steering Group, which identifies key problems, ranks them in order of priority, and establishes programs of projects for UMTA approval. Once approved, they are referred to the National Research Council for acceptance and administration through the Transportation Research Board.

Research projects addressing the problems referred from UMTA are defined by panels of experts established by the Board to provide technical guidance and counsel in the problem areas. The projects are advertised widely for proposals, and qualified agencies are selected on the basis of research plans offering the greatest probabilities of success. The research is carried out by these agencies under contract to the National Research Council, and administration and surveillance of the contract work are the responsibilities of the National Research Council and Board.

The needs for transit research are many, and the National Cooperative Transit Research & Development Program is a mechanism for deriving timely solutions for transportation problems of mutual concern to many responsible groups. In doing so, the Program operates complementary to, rather than as a substitute for or duplicate of, other transit research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, or the Urban Mass Transportation Administration, U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical committee according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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## PREFACE

A vast storehouse of information exists on nearly every subject of concern to the transit industry. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire transit community, the Urban Mass Transportation Administration of the U.S. Department of Transportation has, through the mechanism of the National Cooperative Transit Research & Development Program, authorized the Transportation Research Board to undertake a series of studies to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

## FOREWORD

*By Staff*
*Transportation Research Board*

This synthesis will be useful to administrators, maintenance managers, and others in the transit industry concerned with establishing standards for maintenance work on transit coaches. Detailed information is presented on practices currently used for allocating employee time to specific, major maintenance tasks.

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Administrators, engineers, and researchers are continually faced with problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the problem. In an effort to correct this situation, NCTRP Project 60-1, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCTRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific problems or sets of closely related problems.

Work standards are used by bus agencies as objectively based criteria for measuring the quantity of maintenance work performed. Much relevant information has been produced in the field of industrial engineering on subjects such as: time and motion, performance measurement, standards establishment, worker productivity, and maintenance training. This report of the Transportation Research Board includes a summary of relevant information, a detailed description of two well-documented programs currently in use in Chicago and Seattle, and an outline of a process that might be used by agencies in establishing a work standards program.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researcher in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

## CONTENTS

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Information on current practice was provided by many transit agencies. Their cooperation and assistance were most helpful.

# ALLOCATION OF TIME FOR TRANSIT BUS MAINTENANCE FUNCTIONS


## SUMMARY

This synthesis reviews information on use of standard maintenance job times (i.e., work standards) for transit bus maintenance. Work standards means a set of objectively based criteria for measuring the adequacy of work performed.

A study of the literature revealed little published material on work standards specifically related to the transit industry, with the exception of reports on programs in Chicago and Seattle. However, a survey of transit agencies in the United States and Canada indicated that 20 of 50 agencies responding use some form of work standards.

Most work standards programs cover the full array of hardware systems found on the buses operated (e.g., electrical system, brakes, engine, etc.). The types of work typically standardized are inspection, preventive maintenance, corrective maintenance, and unit repair.

The maintenance function given the least attention thus far has been troubleshooting. Some programs contain time targets for troubleshooters, but no agency was found to be using error rates for that purpose.

Computer technology is starting to be used to support work standards programs, but chiefly for processing current performance data. With regard to the matter of capturing performance data at its source, little automation has taken place. For the most part, technicians still must make pencil entries on paper documents. A notable exception is the Chicago Transit Authority.

Generally, time-oriented work standards are based on the implicit assumption that each job is done properly. This assumption must be verified frequently as part of quality control. Otherwise, technicians are tempted to take short cuts to be sure of meeting the time standards. Verification may include checking the work itself, checking the effects of the work downstream, and requiring that the work be guided by detailed job instructions.

Work standards are most often based on in-house historical data, augmented by data obtained from external sources (i.e., from other agencies). The use of external data carries certain risks because jobs with the same title are not always defined in the same way from one maintenance organization to another. However, there are other risks involved when standards are based on in-house historical data. Even so, time-and-motion study—the classic method in other industries—is seldom used to set standards in the transit industry.

Work standards are used by agencies chiefly to identify problem areas. Standards are quite useful for "management by exception." The second leading use of standards

is to help establish work schedules. Personnel matters represent the third kind of application. Standards data provide quantitative evidence for use in cases where individual performance is well below expectations. Where labor unions regard such evidence as credible, it can be cited in support of the necessary personnel actions.

The work standards programs of the Chicago Tranist Authority and Metro Transit of Seattle have the most extensive documentation.

The goal of the Chicago program was to increase productivity through improved work methods and firm time standards. The program covers the work of mechanics in both garage and shop repair operations. Chicago used methods analysis to optimize the jobs and wrote detailed job instructions to ensure that the new procedures would be followed. Time standards were developed based on multiple observations of the work. The program is highly computerized, even to the point of data entry by job. The agency reports that mechanic productivity has improved by about 30 percent, relative to the original estimates of foremen.

The Seattle program was initiated to increase the effectiveness of management control. The program covered 150 mechanical activities and certain other functions, including servicing, inspection, hostling, and supervision. Seattle used very simple job instructions and made no attempt to optimize the work. Time standards were addressed separately for the four groups. Data were collected by means of periodic sampling, continuous observation, and paper simulation. Only the data processing and report preparation parts are computerized. The individual job performance data are still recorded manually. The agency states that the program has yielded a significant improvement in management control. No gains in productivity have been reported.

As an aid to agencies wishing to set up programs of their own, a process is described for establishing work standards in bus maintenance. The process entails nine steps:

1. Identify and define all jobs to be covered.
2. Describe types of standards to be used.
3. Establish data handling system.
4. Collect data and create reports.
5. Evaluate job performance.
6. Improve job performance.
7. Establish time standards.
8. Establish accuracy standards.
9. Update work standards.

Job definition ensures clear boundaries between jobs, thus preventing later confusion about job identity and content. Describing types of standards to be used lays the groundwork for the rules to be adopted on data handling. Types of standards available include measures of both speed and accuracy.

A system for data handling must provide for documenting vehicle operations and maintenance actions, and must define rules for recording specific transactions. Collecting data and creating reports are the actions enabled by the preceding three steps. The primary data come from the technicians doing the work. The system must provide ways to ensure that such data are valid.

Performance evaluation is enabled by the reports created, wherein actuals are compared with provisional standards. Performance evaluation results in supervisory judgments of relative adequacy and the targeting of jobs on which work improvement may be desired.

Improving job performance involves the removal of task elements and other factors that waste time or invite errors. It also includes the provision of effective job instructions, in printed form. Finally, it requires that the technician follow the job instructions as written.

Establishing time standards means making several observations, recording the respective elapsed times, and averaging the time values according to specific rules. Time standards also must take into account the nonproductive periods that affect every job.

Establishing accuracy standards means determining allowable error rates, for the various types of errors committed for a job, as a percentage of the number of times a like job was performed. Allowable error rates may be set by supervisory judgment.

Works standards must be kept current if they are to retain their credibility. Erroneous values should be corrected promptly. Changes in work method should lead to reconsideration of pertinent standards and updating where necessary. The updating process should be applied carefully and under controlled conditions.

CHAPTER ONE

# MAINTENANCE WORK STANDARDS AS CURRENTLY APPLIED

A literature search and a direct-mail survey were used to gather information on maintenance work standards as employed by bus agencies in the mass transit industry. As used herein, the term "work standards" is defined as a set of objectively based criteria for measuring the adequacy of work performed.

The literature search, which took place primarily at the Institute of Transportation Studies on the Irvine campus of the University of California, disclosed that very little has been accomplished to date in establishing maintenance work standards in the mass transit industry. Reports were found on only two major programs: one in Chicago and one in Seattle.

Conversely, a great deal has been written on the subject of work standards from a generic viewpoint. Such practices as methods design, time-and-motion study, performance measurement, and standards establishment have been in common use throughout industry for many years. They are well represented in the literature of industrial engineering.

There are additional reports on topics that could be generally related to work standards. Those topics include worker productivity, maintenance training, and data-collection methods. One subject is relatively new to the field. It concerns methods of measuring maintenance errors.

A survey form was mailed to 87 bus agencies in the United States and Canada. Of the 50 agencies that returned the form, 20 reported that they use work standards. Those 20 programs were explored, producing the following picture of current application.

## CHARACTERISTICS OF SURVEY SAMPLE

The 87 agencies addressed by the survey were selected by the Transportation Research Board; the only limitation was that agencies operating fewer than 70 buses were not included.

Of the 50 agencies (45 U.S. and 5 Canadian) that responded to the survey, 20 (16 U.S. and 4 Canadian) reported that they use work standards. To check for any biases in the data, a comparison was made of the respondents versus the nonrespondents, using the statistical tables of the UMTA 1981 Section 15 Report.

Four variables were selected for the comparison, based on their relevance to maintenance logistics. Those variables were:

- Total administrative employees per vehicle
- Total revenue vehicles per maintenance employee
- Total vehicle miles per road call
- Size of fleet (buses only)

Administrative employees per vehicle gives an indication of the availability of manpower for activities such as setting up a standards program. Revenue vehicles per maintenance employee is a measure of maintenance efficiency. Vehicle miles per road call is a measure of maintenance effectiveness. Size of fleet reflects the magnitude of the workload at an agency.

Results of the comparison for the first three variables are presented in Table 1. The variable on size of fleet will be examined separately. Please note that the figures in Table 1 apply to U.S. agencies only. Canadian agencies are not covered by the Section 15 Report.

The data in Table 1 indicate that the two groups were highly similar with respect to all three variables. No significant differences could be found in any of the averages compared.

With regard to the data on fleet size, two comparisons were made among U.S. agencies: survey respondents versus nonrespondents, and respondents with standards versus respondents without standards. In neither case was the difference in median values found to be significant. What this suggests is that interest in standards is not concentrated primarily in the large agencies as one might expect. Standards are just as well represented among the smaller agencies.

As indicated above, these figures apply to U.S. agencies only. The level of interest shown by the Canadian agencies was considerably higher. Of the six Canadian agencies surveyed, five responded, and four of them (or 80 percent) reported they were using standards. That contrasts vividly with U.S. totals showing that standards were being used by 16 of 45 responding agencies (or 35 percent).

## DISCUSSION OF SURVEY RESULTS

The remainder of this chapter concerns the 20 U.S. and Canadian agencies that reported they were using standards. Those agencies are identified as follows:

Broward County Mass Transit, Fort Lauderdale
Chicago Transit Authority, Chicago

TABLE 1

CHARACTERISTICS OF SURVEY SAMPLE

| Comparison Variable | Average per Agency[a] Respondents (45) | Average per Agency[a] Non-respondents (36) |
|---|---|---|
| Total Administrative Employees per vehicle | 0.18 | 0.15 |
| Total Revenue Vehicles per Maintenance Employee | 2.06 | 2.54 |
| Total Vehicle Miles per Road Call | 2,585 | 2,554 |

[a]U.S. agencies only.

Central New York RTA, Syracuse
Des Moines Metro Transit, Des Moines
Edmonton Transit, Edmonton
Golden Gate Bus Transit, San Rafael
Gray Coach Lines, Toronto
Lane Country Transit District, Eugene
Madison Metro Transit, Madison
Metro Transit, Seattle
MTL, Inc., Honolulu
New Jersey Transit, New Jersey
NYCTA, New York
Pacific Coach Lines, Victoria
Phoenix Transit System, Phoenix
Pioneer Valley Transit, Springfield
Rhode Island PTA, Rhode Island
Southern California RTD, Los Angeles
Toronto Transit, Toronto
VIA Metropolitan Transit, San Antonio

Two of these agencies (Chicago Transit Authority and Metro Transit of Seattle) provided extensive documentation of their programs. Their programs are highlighted in Chapter Two. The account presented in this chapter concerns the 20 agencies as a group, based on their responses to the survey and associated telephone interviews. The purpose of this chapter is to show the general characteristics of work standards as applied in bus maintenance today.

## DESCRIPTION OF STANDARDS IN USE

Survey questions pertaining to program description involved the kinds of measures used to express work standards, and the means employed for collecting and processing job performance data.

### Kinds of Measures Used

As expected, the most frequently used measure for expressing work standards was time. Only a small proportion of the 20 agencies indicated a preference for other measures. Among them were Golden Gate Bus Transit, Pacific Coach Lines, and Pioneer Valley Transit Authority. Those agencies pointed out that, while a reasonable degree of speed was expected, they were more interested in work quality, as measured by such indicators as miles between road calls and frequency of service interruptions.

### Methods of Handling Data

Once a work standards program is established, data must be handled at two points. One involves data collection from the mechanic. The other involves data processing, leading to reports of various kinds. Nearly all of the 20 agencies are collecting data from the mechanic manually. Only the Chicago Transit Authority has thus far automated that function. On the other hand, more than half the agencies have either automated or plan to automate the data processing function.

An illustration of a report produced by a standards program data processing system is presented to Figure 1. The report shows actual work times for an individual mechanic in a particular calendar period, along with average work times for all mechanics, against which to compare the actual performance.

## AREAS COVERED BY STANDARDS

The "areas" referred to by the survey questions consisted of types of equipment and types of work covered by maintenance standards.

### Types of Equipment

Nearly all agencies said their standards apply to the following:

- Air conditioning
- Transmissions
- Brakes
- Engine
- Electrical
- Air system

The lone exception was air conditioning, which was typically omitted by agencies located in the northern-most latitudes.

### Types of Work

With respect to the types of work covered by standards programs, the activities most frequently cited were inspection, preventive maintenance, unit repair, and corrective maintenance.

The survey did not ask the level of detail of the equipment hierarchy covered by the standards. However, interviews with some of the respondents disclosed that at least two different strategies may be employed. One strategy is to focus at the system level, (e.g., electrical); the other strategy is to focus at the unit level within the system (e.g., alternator).

## DIAGNOSTIC STANDARDS

The final area of coverage considered by the survey was diagnostic work. Some respondents indicated that they have accumulated standards data on the time consumed by their troubleshooters. However, agencies (including those emphasizing work quality instead of speed) have not developed definitive measures of a mechanic's accuracy in troubleshooting. Their data processing systems have not yet been equipped with programs to analyze work records and compute individual error rates.

The same observation (as above) may be made about the function of inspection. The common approach is to measure inspection performance in terms of time. However, inspection is similar to troubleshooting in that it is a diagnostic process. Errors in inspection often are not detected until later, usually through the same means as indicated above for troubleshooting. Thus, inspection represents another candidate for performance measurement in terms of work accuracy.

DATE- 1/31/83 MECHANIC TIME REPORT PAGE- 41 MSS101
DES MOINES METROPOLITAN TRANSIT AUTHORITY

NUMBER- [illegible] NAME- [illegible]

| WORK DESCRIPTION | VEH | WO NO | DATE | HRS | COST | AVG HRS ALL MECH THIS MECH | AVG COST ALL MECH THIS MECH |
|---|---|---|---|---|---|---|---|
| 08 ELECTRICAL | 110 | 22289 | 1/06/83 | .62 | 6.03 | | |
| 08 ELECTRICAL | 127 | 22261 | 1/05/83 | .50 | 4.86 | | |
| 08 ELECTRICAL | 140 | 22259 | 1/05/83 | .10 | .97 | | |
| 08 ELECTRICAL | 142 | 22276 | 1/06/83 | 2.04 | 19.83 | | |
| 08 ELECTRICAL | 143 | 22257 | 1/05/83 | .26 | 2.53 | | |
| 08 ELECTRICAL | 143 | 22309 | 1/07/83 | .18 | 1.75 | | |
| 08 ELECTRICAL | 160 | 22283 | 1/06/83 | .76 | 7.39 | | |
| 08 ELECTRICAL | 172 | 22228 | 1/04/83 | 1.02 | 9.91 | | |
| 08 ELECTRICAL | 173 | 22311 | 1/07/83 | .13 | 1.26 | | |
| 08 ELECTRICAL | 180 | 22230 | 1/04/83 | 1.33 | 12.93 | | |
| 08 ELECTRICAL | 513 | 22290 | 1/06/83 | .80 | 7.78 | | |
| 08 ELECTRICAL | 705 | 22258 | 1/05/83 | .76 | 7.39 | | |
| | | | | ----- | ------ | 2.18 | 21.61 |
| | | TOTAL | | 8.50 | 82.63 | .70 | 6.88 |
| 09 ENGINE | 105 | 22206 | 1/03/83 | 2.98 | 28.97 | | |
| 09 ENGINE | 129 | 22451 | 1/14/83 | 63.55 | 617.69 | | |
| 09 ENGINE | 136 | 22284 | 1/06/83 | .46 | 4.47 | | |
| 09 ENGINE | 155 | 22287 | 1/06/83 | .48 | 4.67 | | |
| | | | | ----- | ------ | 17.21 | 170.23 |
| | | TOTAL | | 67.47 | 655.80 | 16.86 | 163.95 |
| 11 FUEL | 177 | 22335 | 1/10/83 | .64 | 6.22 | | |
| | | | | ----- | ------ | 2.38 | 22.81 |
| | | TOTAL | | .64 | 6.22 | .64 | 6.22 |
| 12 AIR SUSPENSION | 133 | 22278 | 1/06/83 | .71 | 6.90 | | |
| 12 AIR SUSPENSION | 166 | 22212 | 1/03/83 | .70 | 6.80 | | |
| | | | | ----- | ------ | 3.75 | 36.55 |
| | | TOTAL | | 1.41 | 13.70 | .70 | 6.85 |
| 13 TRANSMISSION | 156 | 22321 | 1/10/83 | 2.33 | 22.65 | | |
| | | | | ----- | ------ | 5.90 | 60.20 |
| | | TOTAL | | 2.33 | 22.65 | 2.33 | 22.65 |

*Average for all mechanics* (upper figures) / *Average for this mechanic* (lower figures)

FIGURE 1 Report on mechanic work time data (Des Moines RTA).

#### CONTROL OF WORK QUALITY

The subject of work accuracy (as opposed to work speed) introduces the notion of quality control. The penalties of inaccurate work in maintenance far outweigh those of work that is merely slower than average. Thus, there is good reason to control the *quality* of maintenance as well as the speed. Work standards based primarily on time introduce an additional reason to monitor accuracy; that is, to keep the time data meaningful.

The above view was well expressed by H. Chaput, General Manager, OC Transpo, Ottawa, in a presentation to the First National Mass Transit Institute Seminar in 1980. After initiating a standards program, the managers of Maintenance Operations recognized that some mechanics would take short cuts to avoid exceeding standard times. If they could do so without restraint, not only would the risk of error be increased, but the resulting time data, while accurate, would become essentially invalid. The question was how best could short cuts be prevented?

The strategy selected by Ottawa was to track the *effects* of the mechanics' work, including such things as defects found during inspection, defects reported by drivers, bus changes and pull-ins, repeat work, and components failing prematurely. All such incidents were logged and reported back to the foremen. The foremen were then required to determine specific causes, one category of which was "poor workmanship." Because this process was repeated continuously and reports were posted for reading by garage personnel, mechanics were motivated to keep up the quality of their work and thereby avoid attracting unfavorable attention.

At least two other methods have been used by agencies interested in high-quality work. One is having worked checked before it leaves the shop. This approach has the twin advantages of preventing serious aftereffects and permitting quick feedback to the mechanics making the errors. The other method is detailed job instructions. Such instructions take the guesswork out of unfamiliar jobs and help the mechanics apply the procedure found to be best by the analysts or experts who set up the standards program.

Some agencies are firmly convinced that detailed job instructions are essential to maintenance operations. The Chicago Transit Authority; OC Transpo, Ottawa; and Gray Coach Lines state that view explicitly in their program documentation. The Detroit Department of Transportation (D-DOT) has been exploring the detailed instruction medium as part of a major research project.

## MEANS OF ESTABLISHING STANDARDS

Survey questions in this category dealt with the procedures used to establish the standards for the various jobs covered. Examples of such procedures might be time-and-motion study, analysis of historical data, and sampling methods.

Respondents indicated that they relied most heavily on historical data, as derived from the experience of their supervisors and past records of work orders.

Time-and-motion study was named in only a small proportion of the cases. Time-and-motion study requires a relatively intense analytical effort and is most likely to be used when outside consultants are brought in. Such was the case at Chicago, Seattle, and New York.

Most agencies check external sources for time standards data that might be useful. Results of that strategy have been mixed, principally because organizations tend to vary in the way they identify and define jobs. The problem is illustrated by an incident described by MTL, Inc. In search of guidance for its standards on engine rebuild, MTL asked six independent contractors on the west coast to quote their flat-rate times on 10 jobs. Results are presented in Figure 2. There is a marked variation in the values shown and it is difficult to believe the contractors were all thinking of the same elements of work.

One remedy for excessive variation in job time estimates is a more explicit definition of the work represented. An example of such a detailed definition is shown in Figure 3.

Some agencies make a special effort to coordinate their pro-

| | | FLAT RATE HOURS QUOTED BY SIX CONTRACTORS | | | | | |
|---|---|---|---|---|---|---|---|
| | JOB | A | B | C | D | E | F |
| 8V | Remove Engine and Cradle | 3.5 | 3* | 8 | 4 | 8 | 4 |
| 6V | Remove Engine and Cradle | 3.5 | 3* | 8 | 4 | 8 | 4 |
| | * 1 hour if muffler forward of bulkhead | | | | | | |
| 8V | Strip Engine to Bare Block | 4 | 5 | 16 | 14 | 35 | 6 |
| 6V | Strip Engine to Bare Block | 3.5 | 4.5 | 16 | 13 | 34 | 6 |
| 8V | Rebuild Engine, Liners, Pistons, Crankshaft, Cams & Gear Train - Short Block | 9 | 10 | 28 | 25 | 20 | 10 |
| 6V | Rebuild Engine, Liners, Pistons, Crankshaft, Cams & Gear Train - Short Block | 8 | 9 | 26 | 24 | 19 | 10 |
| 8V | Short Block to Complete Engine Heads, Pan, Alternator, Fan Drive, Transmission, Etc. | 25 | 28 | 40 | 35 | 50 | 30 |
| 6V | Short Block to Complete Engine Heads, Pan, Alternator, Fan Drive, Transmission, Etc. | 22 | 26 | 38 | 33 | 49 | 30 |
| 8V | Replace Engine | 5.5 | 8 | 16 | | 8 | 8 |
| 6V | Replace Engine | 5.5 | 8 | 16 | | 8 | 8 |

FIGURE 2 Variation in flat-rate hours quoted by six contractors (data furnished by MTL, Inc., Honolulu).

OPERATION DESCRIPTION

WITH ENGINE REMOVED

TIME TO PERFORM OPERATION IN HOURS AND TENTHS

| OPER. NO. | BASIC ENGINE | ENGINE SERIES | ENG. REM. |
|---|---|---|---|
| 1.60-00 | Cylinder Kit - R & R One | | |
| | This operation is to R & R one cylinder kit on either bank of a "V" engine or one cylinder kit on an inline engine. | | |
| | INCLUDES: - R & R (1) cylinder head | 2-53 | 4.4 |
| | (1.20-00), oil pan (4.70-00), | 3-53 | 5.0 |
| | R & R rings, clean ring grooves and | 4-53 | 5.6 |
| | replace rings, hone or clean up | 6V53 | 5.1 |
| | block bores, measure liner height | 8V53 | 5.6 |
| | and liner bores, and liner O.D. | 2-71 | 4.4 |
| | for proper liner to block fit. | 3-71 | 5.0 |
| | | 4-71 | 5.2 |
| | DOES NOT INCLUDE: - Block Boring | 6-71 | 5.3 |
| | (1.00-02), replacement of | 6V71 | 5.1 |
| | connecting rod or piston pin | 8V71 | 5.2 |
| | bushings in trunk type pistons, or R & R | 12V71 | 7.0 |
| | of oil pump (4.10-00). | 16V71 | 6.2 |
| | | 6V92 | 5.3 |
| | | 8V92 | 5.8 |
| | | 16V92 | |
| | | 12V149 | 5.5 |
| | | 16V149 | 5.6 |

FIGURE 3 Good definition of job data (Edmonton Transit).

grams with external sources known to have merit. Such is the case with the Chicago Transit Authority and the Southern California RTD. Samples of their respective job identifiers are shown in Figure 4. The similarity between the two lists is very close.

Another application of external reference data is being tried in New York. The NYCTA has put some jobs up for bid by outside contractors. The labor union has agreed to compete with such bids. Assuming the problem of variability can be overcome by good definition of the jobs being bid, the resulting performance times are expected to differ considerably from standards based entirely on historical data.

## USES MADE OF WORK STANDARDS

In those industries where work standards have been taken most seriously, the chief applications tend to be profit oriented. One such use is to support wage incentive programs. Other uses include cost estimating and production scheduling.

Although agencies in the mass transit industry are interested in improved productivity, the use of work standards toward that end is not yet very highly developed. For example, none of the survey respondents reported having a wage-incentive program.

The three major uses of work standards by bus agencies are to identify problem areas, establish work schedules, and to help with personnel matters.

### Identification of Problem Areas

The leading use of work standards among the agencies surveyed was to identify problem areas. Once a body of performance and standards data is accumulated, it can be summarized in many ways (by coach, by garage, etc.). Visual comparisons between standard and actual values permit fast recognition of mismatches, each of which represents a candidate for further investigation.

The kinds of problems generally uncovered in such cases might involve the need for special training, changes in work method, or different work assignments. Following the installation of a particular remedy, performance and standards data may be used in the same way to track results.

### Establishing Work Schedules

The second leading use of work standards concerns work scheduling, and to a lesser extent, determining staffing levels.

| | | |
|---|---|---|
| 2200 | 01:24 | FUEL & EXHAUST |
| 2201 | | |
| 2202 | | |
| 2203 | | |
| 2204 | | |
| 2205 | | |
| 2206 | | |
| 2207 | | |
| 2208 | 00:48 | OUT OF FUEL (ROADCALL) |
| 2209 | 01:00 | ACCELERATOR AIR RESERVOIR |
| 2210 | 01:30 | ACCELERATOR INTERLOCK |
| 2211 | 02:05 | ACCELERATOR CABLE |
| 2212 | 01:00 | ACCELERATOR LINKAGE & PEDAL |
| 2213 | 05:00 | BRACKETS, FUEL TANK |
| 2214 | | |
| 2216 | 01:00 | EXHAUST MANIFOLD |
| 2217 | 03:30 | FUEL DILUTION |
| 2218 | 02:00 | FUEL INJECTOR RACK |
| 2219 | | |
| 2220 | 01:00 | EXHAUST PIPES, FITTINGS & MOUNTINGS |
| 2221 | 01:00 | FUEL FILTER BRACKET |
| 2222 | | FUELING |
| 2223 | 00:30 | FUEL LINE CHECK VAVLE |
| 2224 | 00:35 | FUEL FILTERS |
| 2225 | 01:00 | FUEL TANK FILLER NECK |
| 2226 | | |
| 2227 | 02:00 | FUEL INJECTORS, ONE BANK |
| 2228 | 01:00 | FUEL LINES & FITTINGS |
| 2229 | 01:00 | FUEL PRESSURE SWITCH |
| 2230 | 01:54 | FUEL PUMP |
| 2231 | 04:15 | FUEL TANK ASSEMBLY |
| 2232 | 01:00 | MUFFLER |
| 2233 | 00:30 | FUEL TANK FILLER CAP |
| 2234 | | |
| 2235 | 00:18 | PRIMARY FUEL FILTER |
| 2236 | 00:30 | THROTTLE CONTROL CYLINDER, SLAVE |
| 2237 | 01:00 | TRANSMITTES, 720 |
| 2238 | 02:00 | "Y" PIPE |

(a)

| 2200 FUEL & EXHAUST SYSTEM | | PROPOSED TIME STANDARDS |
|---|---|---|
| 2210 | ACCELERATOR INTERLOCK | 2 hrs. |
| 2211 | ACCELERATOR CABLE | 00 * |
| 2212 | ACCELERATOR LINKAGE & PEDAL | 1 hr. |
| 2213 | BRACKETS, FUEL TANK | 5 hrs. |
| 2214 | DRAIN FUEL TANK | 2 hrs. |
| 2215 | FUEL ROD (S) | 1 hr. |
| 2216 | EXHAUST MANIFOLD/GASKET | 1 hr. |
| 2217 | FUEL DILUTION (PRESSURE TEST SYSTEM) | 2 hrs. |
| 2218 | FUEL INJECTOR RACK | 2 hrs. |
| 2219 | FUEL INJECTION PUMP | 00 * |
| 2220 | EXHAUST SYSTEM SUPPORT HARDWARE | 1 hr. |
| 2221 | FUEL FILTER BRACKET | 1 hr. |
| 2222 | FUELING | 00 * |
| 2223 | FUEL LINE CHECK VALVE | 1 hr. |
| 2224 | FUEL FILTERS | 1 hr. |

*Time value not yet determined.

(b)

FIGURE 4 Two sets of job identifiers with close similarity.

Agencies reported that they could plan their work better on the basis of their standards than they could based on individual judgments of how long it should take to accomplish particular jobs. Such visibility has improved management control over the repetitive jobs, such as inspection, servicing, and unit repair. In this respect, maintenance is becoming more and more like a conventional production operation. A large percentage of the workload will always be subject to the random effects of equipment failure. But, at the same time, a growing proportion of the work can be scheduled, and agencies are using standards and computers to exploit that opportunity.

#### Helping with Personnel Matters

The third use of work standards reported by the survey respondents was to help with personnel matters. Of the three categories offered on the questionnaire (personnel selection, personnel promotion/transfer, and personnel discipline/termination) the results of the questionnaire indicated that the third category was used much more extensively than the first two categories.

Standards data make it possible now to accumulate quantitative evidence in situations where individual performance is well below expectations. To the extent that labor unions consider that evidence credible, it can be cited in support of the necessary personnel actions. Agencies making use of the standards in this way agreed that the perception of everyone concerned regarding data credibility is strongly influenced by the care with which the program is established and the fairness with which the rules are applied.

The opposite situation was explored by MTL, Inc. What happens to the employee who is found to be performing better than the work standard? Experience at MTL has been that some employees will continue to show high productivity, while others will slow down, possibly because of peer pressure. Unfortunately, it is sometimes difficult to reward excellent performance on a direct basis. Therefore, MTL has had to rely on other forms of encouragement, such as acknowledgment of work well done. An important point to note is that "high performers" can be quickly recognized by a good standards program. It is therefore essential for agencies to establish effective ways of dealing with that condition.

## STANDARDS DOCUMENTATION

Most of the agencies using work standards do not have their programs documented in a formal way. Several agencies possess partial documentation but prefer not to release it. Other agencies are quite willing to share their knowledge and achievements. Those most helpful were the Chicago Transit Authority; Metro Transit of Seattle; MTL, Inc. of Honolulu; Des Moines Metro Transit; and Southern California RTD. The information they provided became the primary sources for this chapter and Chapter Two.

CHAPTER TWO

# TWO DOCUMENTED WORK STANDARDS PROGRAMS

There is extensive documentation concerning maintenance work standards programs at the Chicago Transit Authority and the Metro Transit of Seattle. This documentation furnishes valuable guidance for other agencies interested in establishing programs of their own. Thus, the programs of Chicago and Seattle are examined here in some detail.

## CHICAGO PROGRAM

The goal of the Chicago program was to increase productivity through improved work methods. Within that framework, there were two objectives. One was to discover and apply the optimum procedure for each job studied. The other was to establish time standards based on those procedures.

### Jobs Covered

The Chicago program covered parts replacement and servicing on more than 300 hardware items at 10 bus garages. Both garage and shop repair operations were included. Only the work of mechanics was covered. Hostlers and supervisors, for example, were not studied.

### Description of Jobs Covered

In the Chicago program, each job was described in considerable detail. Descriptions covered job code and title, hardware identification, work location, materials and tools required, safety provisions, and step-by-step procedures for performing the work. Descriptions were documented on Vehicle Service Bulletins, as shown in Figure 5.

### Treatment of Jobs Covered

At Chicago, each job was subjected to change as the time standards were being developed. The purpose of the change was to "optimize" the job. Jobs were analyzed to determine the most efficient work method. The analysis covered other aspects of the work as well, including tools, support equipment, parts handling, and even work space design. The work method finally selected was documented and preserved as part of the standard. Bulletins were distributed containing the detailed job descriptions.

### Time Standard Development

The standard for each job at Chicago was based on three continuous observations of three different mechanics, at three different garages.

Each observation resulted in a measurement of performance time plus avoidable and unavoidable delays. Delay times were then subtracted to produce raw performance times.

Raw performance times were inspected for the presence of extreme values. A value was regarded as extreme if it was not within 33 percent of the others for the same job. Extreme values were discarded. Standards were obtained by averaging the observed times and then taking into account a number of other factors.

The other factors taken into account consisted of supporting tasks, personal needs, and average efficiency. Supporting tasks included obtaining and returning tools and materials, and moving vehicles to and from work points. Average efficiency reflected the physical characteristics of the work place.

These factors were quantified in terms of constants and percentage allowances, based on a separate series of analyses. Pertinent values are:

Performance Constants
- Obtaining and returning tools and materials (6 min)
- Moving vehicles to and from work points (12 min)

Special Allowance
- Personal needs (12.5%)
- Average efficiency factor (12.5%)

A standard time for a job thus equalled the average of three observed times (less avoidable and unavoidable delays), plus the performance constants, plus the allowances.

Vehicle Service Bulletin

AS-7-143-A
Bulletin No.

SUBJECT Engine, Starter, Replacement

STANDARD HOURS 2.0

VEHICLE 1-5, 6-9, 21-25, 300-449
1000-1524, 7-00-7944, 9000-9599

JOB. NO. 4092-868-1

WORK LOCATION Flat, Pit

| MATERIAL | LOT. NO. | QUANTITY |
|---|---|---|
| Gasket, Exhaust Manifold | 8321509 | 1 |
| Gasket, Starter | 8251500 | 1 |
| Starter | 8750001 | 1 |
| SPECIAL TOOLS | LOT. NO. | QUANTITY |
| Sling, (Nylon) | 1751603 | 1 |
| Torque Wrench, 1/2" Drive, 0-50 ft.-lbs. | 1731901 | 1 |

NOTE: SAFETY IS PART OF THE JOB -- Exercise all CTA established safety rules relating to the use of tools, materials, equipment and personal safety in the performance of these procedures.

PROCEDURE

Job on, obtain bus and position work site, obtain necessary tools and materials.

1. Open battery compartment door and disconnect negative ground battery cable(s).
2. Raise rear settee seat onto prop. Remove engine access cover panels.
3. Remove nuts and washers that secure exhaust manifold to right bank cylinder head. Remove exhaust pipe clamp and lift out exhaust manifold.
4. Disconnect wiring harness from starter terminals, remove harness hold down clamp from starter and remove negative ground wire from engine block.
5. Secure sling around the starter, then remove three (3) nuts and washers which attach starter to engine. Carefully remove starter through access opening under rear settee seat.
6. Clean gasketed surface and install new gasket.
7. Using the sling to support the new starter, carefully lower the starter into position on engine through access opening under rear settee seat. Install three (3) washers and nuts which attach starter to engine. Be sure to secure firmly.
8. Mount harness hold down clamp on starter. Connect negative ground wire to engine block and replace wiring harness on starter terminals with washers and nuts.
9. Remove exhaust manifold gasket, clean gasketed surfaces and install a new gasket.
10. Position exhaust manifold to right bank cylinder head and secure with washers and nuts. Torque to 30-35 foot-pounds.
11. Replace and tighten exhaust pipe clamp.
12. Connect negative ground battery cable(s).
13. Check starter by starting bus. (If starter does not operate properly, see foreman for further instructions.)
14. Replace and secure firmly engine compartment access panels. Lower and secure rear settee seat.
15. Close battery compartment door. Clean work area, return tools and material to their proper place. Tag defective starter with the appropriate Unit Identification Tag.

FIGURE 5 Sample job description for mechanic (Vehicle Maintenance System, Chicago Transit Authority).

**Standard Time Data**

A sampling of standard times for mechanics at Chicago is shown in Figure 6. There are two points of special interest. One is that a distinction is made between "Estimated Standard" and "Established Standard." An established standard is one substantiated by a time study. An estimated standard is one that has not yet been studied. The second point of interest is that the standard is applied to the equipment item irrespective of the maintenance function(s) performed. All such functions are meant to be covered by the same time value.

The maintenance function does not enter the data base until later, when the mechanic applies a job completion code. Job completion codes are identified in Figure 7.

**Performance Monitoring**

After standards were established, a system was developed to check actual performance times and compare them continuously with the standard times.

The Chicago program is highly computerized. Mechanics enter data into the system through IBM 2797 Data Entry Units. Mechanic identification, date, and garage data are transmitted automatically when the mechanic inserts an encoded plastic card. Job and coach identities are keyed in by the mechanics whenever they "job on" and "job off."

Time computations and other processing operations are performed by an IBM 370 processor. Output reports may be on hard copy and/or IBM 3275 Visual Display Terminals.

**** MASTER LISTING OF ALL VMSJOBS AND ****
**** APPROPRIATE ACCT PAYROLL FUNCTION ****

2/22/83

| VMS JOB# | ESTM STAN | ESTB STAN | VMSJOB# DESCRIPTION AS LISTED IN DATA BASE | FUNC | |
|---|---|---|---|---|---|
| 1100 | 01:42 | | AIR CONDITIONING & HEATING | 4023 | JOB |
| 1101 | 01:00 | | A/C BATTERIES, 70 | 4023 | JOB |
| 1102 | 00:30 | | A/C BATTERY CABLES, 70 | 4023 | JOB |
| 1103 | | | | | JOB |
| 1104 | | | | | JOB |
| 1105 | | | | | JOB |
| 1106 | | | | | JOB |
| 1107 | | | | | JOB |
| 1108 | | | | | JOB |
| 1109 | | 01:00 | A/C ACC DRIVE PULLEY & SEAL | | JOB |
| 1110 | 01:54 | | A/C CLUTCH ASSY. | 4023 | JOB |
| 1111 | 01:30 | | A/C COND. COIL, EVAP COIL & HTR CORE CLEANING | 4023 | JOB |
| 1112 | | | | | |
| 1113 | 01:00 | | A/C COMP. ALIGNMENT MOUNTS | 4023 | JOB |
| 1114 | 00:18 | | A/C COMP CLUTCH CONT. CYL. | 4023 | JOB |
| 1115 | | | A/C COMP. CLUTCH SPRING | 4023 | JOB |
| 1116 | 02:00 | | A/C CONDENSER COIL | 4023 | JOB |
| 1117 | 00:30 | | A/C CONDENSER FAN BLADE | 4023 | JOB |
| 1118 | | | | | |
| 1119 | 02:00 | | A/C CONTROL BOX | 4023 | JOB |
| 1120 | 01:30 | | A/C CONTROLS & WIRING | 4023 | JOB |
| 1121 | | 01:30 | A/C DISCHARGE LINE | 4023 | JOB |
| 1122 | 02:00 | | A/C EVAPORATOR COIL | 4023 | JOB |
| 1123 | | 03:30 | A/C EXPANSION VALVE | 4023 | JOB |
| 1124 | | | | | |
| 1125 | 00:30 | | A/C 25 PSI OIL PRESSURE SWITCH | | JOB |
| 1126 | | 01:00 | A/C GENERATOR BELT | 4023 | JOB |
| 1127 | | 00:30 | A/C GENERATOR BRUSHES | 4023 | JOB |
| 1128 | | 00:54 | A/C PROPLR SHFT ASSY. | 4023 | JOB |
| 1129 | 00:30 | | A/C HI-LO PRESSURE SWITCH | 4023 | JOB |
| 1130 | 01:00 | | A/C REFRIGERANT | 4023 | JOB |
| 1131 | 02:00 | | A/C REFR RECVR TANK | 4023 | JOB |
| 1132 | 00:30 | | A/C SOLENOID, CLTCH CONTROL | 4023 | JOB |
| 1133 | 00:30 | | A/C ENGINE STARTER, 70 | 4027 | JOB |
| 1134 | | | | | |
| 1135 | 03:00 | | A/C SOLENIOD VALVE, PRES RELIEF, 70 | 4023 | JOB |
| 1136 | 01:00 | | CONE SCREEN - HTR WIRE | 4020 | JOB |
| 1137 | | | | | JOB |
| 1138 | 3:30 | | DEFROSTER HEATER ASSY. | 4020 | JOB |
| 1139 | | 00:30 | DEHYDRATOR STRAINER | 4020 | JOB |
| 1140 | | | | | |
| 1141 | | | | | |
| 1142 | 01:00 | | GRADUSTAT, HEATING SYS. | 4020 | JOB |
| 1143 | | | FILTERS, UNDER FLOOR | 4020 | JOB |
| 1144 | | | | | JOB |

FIGURE 6 Sampling of time standards for mechanic (Vehicle Maintenance System, Chicago Transit Authority).

| WITHOUT DIAGNOSIS | | WITH DIAGNOSIS | |
|---|---|---|---|
| 11 | Adjusted/tightened | 21 | Adjusted/tightened |
| 12 | Cleaned/lubricated | 22 | Checked and found okay |
| 13 | Added fluid/checked for leaks | 23 | Cleaned/lubricated |
| 14 | Repaired | 24 | Repaired |
| 15 | Replaced | 25 | Replaced |
| 16 | Other | 26 | Added fluid/checked for leaks |
| | | 27 | Other |

FIGURE 7 Job completion codes used by mechanic (Vehicle Maintenance System, Chicago Transit Authority).

The Chicago data processing system tracks other maintenance performance variables as well, including coach status, coach history, road calls, parts consumption, and many others. However, the key factors pertinent to a time-standards program are mechanic, job and coach identification, and job time.

#### Program Administration

The Chicago program was started in the early 1970s by the Methods and Standards Group within the Maintenance Department. Outside help in analyzing the jobs and setting standards was obtained from the Department of Systems Engineering at the University of Illinois at Chicago. Internal help in performance monitoring was obtained from the CTA Data Center. The bulk of the work involved in analyzing the jobs and setting standards was performed by Industrial Engineering students from the university. Continuous cooperation was given by CTA upper management, CTA supervisors, and the labor union.

Chicago reports that the part of the program most difficult to implement was that of optimizing and documenting the jobs. Observation schedules were hard to arrange because of the random nature of job occurrence. In addition, the work of writing the necessary procedures was labor intensive, thus entailing costs higher than experienced elsewhere in the program. Even so, Chicago believes the procedures were essential.

The program is still in operation, now in the performance monitoring stage. Information on the software system used for that purpose is not available in the Chicago report.

#### Program Results

The agency regards its program as very successful. Mechanic productivity has improved by about 30 percent, relative to the original estimates of foremen. The improvement in some cases exceeded 50 percent. Much of the gain is attributed by CTA to the changes made in methods and the provision of written instructions. Job scheduling also has experienced improvement.

### SEATTLE PROGRAM

The Seattle program was initiated to increase productivity through management control. The need for measurement was recognized as a key factor. In the words of the Seattle report, "without measurement, management can only guess at the causes and cures of inefficiency. With measurement, guesses are replaced by facts." Thus, the program was designed to incorporate a system of measurement, with benefits expected to follow when managers used facts to increase their control of the work.

#### Jobs Covered

The Seattle program covered 150 maintenance activities and certain other functions at the East Maintenance Base in Bellevue. The maintenance activities were those performed by mechanics. The other functions covered included servicing, inspection, hostling, and supervision.

#### Description of Jobs Covered

At Seattle, jobs were described very simply. Mechanic job descriptions were limited to job code and title, and the identification of associated tasks, such as steam cleaning and road testing. An example of such a description is shown in Figure 8.

The job description for inspection was presented in somewhat greater detail, including the objects of inspection and, in some cases, the physical characteristics of concern. An example of an inspection job description is shown in Figure 9. The hostler and supervisor job description simply listed the activities involved.

#### Treatment of Jobs Covered

At Seattle, job modification was attempted only to a limited degree. Mechanic, service, hostler, and supervisor jobs were not changed at all. The work of inspection was changed but only enough to ensure that it would be done the same way each time. Optimization was not an objective of the Seattle program.

#### Time Standard Development

Time standards at Seattle were addressed separately for mechanics, service workers, inspectors, hostlers, and supervisors.

*Mechanical Standards*

Mechanics were observed by means of periodic sampling, a method that permits the observer to collect data on several

| JOB CODE | JOB DESCRIPTION |
|---|---|
| 15-435 | Replace/Repair Surge Tank |
| | Replace or repair surge tank.<br>Get parts.<br>Hostle coaches, paperwork.<br>Steam cleaning.<br>Road testing. |

FIGURE 8 Sample job description for mechanic (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

```
TYPE C INSPECTION ACTIVITIES

Road Test (Brakes, Steering, Power, etc.)
Farebox (Seal, Cylometer, Telltale)
Fire Extinguisher (Seal and Pressure)
Swipes & Washer
Alarms & Gauges (Generator, Oil Pressures, Low Air,
  Backup Warning, Buzzer)
Check Horn, Heater Blower, Wheel Chair Lift & Kneeling
Check Sander
Engine Fire Alarm
Doors (Operation, Interlock, Sensitive Edge)
Flares & Reflectors
Wheel Blocks & Sand Buckets
Interior Cleanliness & Damage
Destination Signs
Lights
Lube Door Engine, Shafts & Linkage
Check for Exterior Damage
Visual Inspection (Air, Oil, Coolant Leaks, Missing
  Parts)
Fluid Levels (Engine Oil, Turbine, Power Steering)
Mufflers & Tailpipes
Check Fan Hub for Looseness
Drain Throttle Air Tanks (1100's)
Check Air Compressor Filters (500's)
Emergency Stop Action
Check Low Water Warning
Top Off Kyser Fluid in Shutter filter & Engine
Adjust Clutch & Shaft Lever Arms (200's & 700's)
Turbine Scavenger Filter (Clean, Check for Metal)
Fan Bevel Gear Oil Level(500's)
Inspect Undercarriage for Broken, Worn, or Loose Parts
Drain Air Tanks
Brakes (Adjust, Check Pins, Linings & Hi-Cams)
Air Leaks (Brakes, Axles, Lines)
Mufflers & Tailpipes (Articulated)
```

FIGURE 9 Sample job description for inspector (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

mechanics simultaneously. Mechanic activities were observed at five-minute intervals, starting at the beginning of designated jobs. Activities observed included all uses of time, even those not specifically job related. Detail logs were kept for each mechanic. Detail logs were then integrated, showing total time spent per job and per other identified activity. Standards were obtained by averaging the observed job times and then taking into account the other identified activities.

The other identified activities included supporting tasks and overhead. Supporting tasks included hostling coaches, steam cleaning, and road testing. Supporting tasks were quantified in terms of constants. Pertinent values are:

- Hostling coaches and paperwork (0.100 hr)
- Steam cleaning (0.093 hr)
- Road testing (0.105 hr)

The task of getting parts was treated as intrinsic to each job rather than as a supporting task. It was therefore timed separately and not quantified as a constant.

Overhead included 23 activities found to be associated with, but not a direct part of the jobs under study. Overhead was computed on a percentage basis. The elements contributing to the mechanical overhead rate, and the computations underlying it are shown in Figure 10.

A standard time for a job thus equalled the average of the observed times, plus pertinent supporting task times, plus overhead.

*Servicing Standards*

Servicing was found to consist of the activities listed below:

1. Drive from fueling bay.
   Park coach.
   Walk to next coach.
   Check tires, oil level, water level, turbo level, and power steering.
   Drive to service building.
2. Possible delay outside of service building.
3. Wash coach.
4. Possible delay within service building after washing.
5. Fuel coach.
   Sweep coach.
   Add fluids as required.

The primary activities (1, 3, and 5) were studied by continuous observation over a period of 17,000 minutes. An average performance time was computed for each element per activity.

| OVERHEAD FACTOR | MINUTES |
|---|---|
| Talk to Supervisor | 901.50 |
| Cleanup | 706.70 |
| Personal Time | 351.70 |
| Time Card | 140.00 |
| Talk to Coworker | 570.00 |
| Search for Parts | 5.00 |
| Watch Over Office | 5.00 |
| Transit Pass Pictures | 40.00 |
| Search for Parts Man | 2.00 |
| Search for Supervisor | 11.50 |
| Soap Hands | 50.00 |
| Building and Equipment Repairs | 30.00 |
| Charged Cleanup | 30.00 |
| Look at Toolbox | 5.00 |
| Fill In for Foreman | 250.00 |
| Allowable Standby Time | 50.00 |
| Search for Coworker | 30.00 |
| Open Doors for Ventilation | 5.00 |
| Miscellaneous Welding | 10.00 |
| Battery Shop | 105.00 |
| Look at History Card | 5.00 |
| Fill Out Bad Order (New) | 5.00 |
| Sharpen Tools | 5.00 |
| Total Minutes of Overhead Items Observed: | 3313.40 |
| Total Minutes of Nonoverhead (Job-Related) Items Observed: | 17,077.00 |
| Overhead as a Percentage of Job-Related Minutes: | $\frac{3,313.40}{17,077.00} = 19.4$ |

FIGURE 10 Computation of overhead rate in mechanical area (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

The delay activities (2 and 4) were not easily handled by continuous observation, because they were influenced by too many combinations of working conditions, such as number of service people working and number of washers in operation. Delay times had to be estimated by a process of paper simulation.

The paper simulation was a fairly complex process. The service activities were simulated by using a table of random numbers to select working conditions. Delays were caused by specific working conditions, e.g., both wash bays busy. The time for the work activities (e.g., wash coach) determined the length of any specific delay.

The average times for the primary activities were combined with the average delay times to create a series of standards pertinent to the various sets of working conditions. A fixed overhead rate was applied in each case.

The elements contributing to the servicing overhead rate, and the computation underlying it are shown in Figure 11.

### *Inspection Standards*

Several different types of inspection sequences were defined. Each type consisted of a listing of the features to be checked and, in some cases, the characteristics to be checked for. Each feature was subjected to continuous observation until a firm time average was produced.

That time reflected the fact that most of the features were available for inspection on all the coaches. For those features not present in all the buses, a slight reduction was made in the corresponding time value. That reduction was equal to the proportion of the coaches not possessing the object feature.

The total of the feature averages (including those reduced in magnitude) represented the total hours of inspection per coach, per type of inspection.

Three time elements were then added to the base total, to create the final standard. Two were supporting tasks and one was overhead. The supporting tasks were quantified in terms of constants and overhead was computed on a percentage basis. Pertinent values are listed below:

Supporting Tasks
- Time to get coach and return (0.0781 hr)
- Time for writeup (0.0833 hr)

Overhead
- (Same as shown in Figure 11) (10%)

### *Hostlers and Supervisors*

The standards for hostlers and supervisors were developed in a different manner than for mechanics, inspectors, and service workers. Both positions were continuously observed and time logged for the various work activities. However, the time values were not averaged per activity. They were instead converted into proportions of the total time worked.

## Standard Time Data

Samplings of Seattle time standards are displayed in the figures that follow. In each case, the Seattle term "Target Hours" may be equated to standard time.

Figure 12 concerns mechanical standards. The target hours shown include both supporting tasks and overhead.

Figure 13 concerns servicing standards. The target values shown are driven by the particular combination of working conditions that apply. The overhead rate is 10 percent in all cases.

Figure 14 concerns inspection standards. Note that the standards (target hours) are adjusted downward for each inspection feature that does not appear on all the buses.

Figure 15 concerns hostler standards. Activity time is represented by proportions of the total instead of by absolute values.

Figure 16 concerns supervisory standards. Activity time is represented by proportions of the total instead of by absolute values.

| ACTIVITY | MINUTES |
|---|---|
| Time Spent on Miscellaneous tasks Not Related to Fueling and Exterior Washing of Coaches | 30.00 |
| Personal Time, Fatigue, Cleanup | 120.00 |
| Breakdowns & Unsanitary Coaches | 30.00 |
| Talk to Supervisor or Co-worker | 30.00 |
| Total Overhead Time Per Night | 210.00 |
| Total Minutes Spent Fueling and Washing @ 5 Full-Time, 1 Part-Time Service Worker | 2295.00 |
| Total Time Servicing Coaches Equals: 2295 - 210 = | 2085.00 |
| Overhead as a Percentage of Service Time Equals: $\frac{210}{2085} \times 100 =$ | 10.0% |

FIGURE 11 Computation of overhead rate in service area (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

| JOB CODE | JOB DESCRIPTION | TARGET HOURS |
|---|---|---|
| 01- | Air System - General | 1.2 |
| 01-90 | Replace Air Compressor | 2.7 |
| 01-95 | Adjust Air Regulator | .5 |
| 01-99 | Replace/Repair Spitter Valve | .4 |
| 01-187 | Replace/Tighten Line | .5 |
| 01-400 | Tighten Bolts or Clamps in Air System | .5 |
| 01-401 | Replace Compressor Base Gasket | 1.5 |
| 01-402 | Replace/Repair Air Dryer | 1.0 |
| 01-403 | Replace Air Compressor Air Governor | .8 |
| 02- | Axle/Differential - General | 1.7 |
| 02-100 | Replace Partial Axle | .6 |
| 02-101 | Replace Differential | 6.0 |
| 02-107 | Replace U-Joints | 2.0 |
| 02-202 | Replace Differential Gasket | 6.0 |
| 02-400 | Tighten Bolts (Axle or Differential) | .6 |
| 02-405 | Replace Axle Seal in Wheel | 3.5 |
| 02-406 | Replace/Repair Axle Plate | 1.1 |
| 02-407 | Replace/Adjust Wheel Bearing | 1.7 |
| 02-XXX | Replace King Pin Grease Fitting | .3 |
| 03- | Body/Chassis - General | .6 |
| 03-250 | Replace Chassis Bracket | .7 |
| 03-408 | Fill Window Washer | .3 |
| 03-409 | Repair/Secure Body Panel | .6 |
| 04- | Electrical System - General | .7 |
| 04-113 | Replace Bulb | .2 |
| 04-117 | Adjust Headlamp | .6 |
| 04-118 | Replace Headlamp | .3 |
| 04-122 | Repair Wiring or Connector | 1.0 |
| 04-124 | Replace/Repair Switch | .6 |
| 04-169 | Repair/Clean Plugs or Sockets | .8 |
| 04-247 | Replace Sender | .7 |
| 04-254 | Replace/Repair Relay | .5 |
| 04-410 | Replace Light Ballast | .7 |
| 04-411 | Replace/Repair Buzzer or Bell | .4 |
| 04-412 | Replace/Repair Gauge or Meter | 1.0 |
| 04-457 | Replace Light Fixture | .6 |
| 04-462 | Reset Switch or Circuit Breaker | .2 |

FIGURE 12 Sample of time standards for mechanic jobs (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

CONDITIONS:

3-Person Crew Working Simultaneously
Both Wash Bays Functioning
Non-Articulated Coaches Only
Washing Every Coach

| ACTIVITY | TARGET HOURS |
|---|---|
| Travel from fueling bay to pickup the next coach. | .030 |
| Check oil, tires, water and turbine-fluid. | .017 |
| Travel from parking area to service building. | .030 |
| Delay outside of service building | .002 |
| Wash cycle. | .066 |
| Delay between wash cycle and fuel cycle. | .002 |
| Fuel coach and sweep interior. | .068 |
| Total Manhours Per Coach: | .215 |
| Net Manhours, Including 10% Overhead: | .237 |
| Percent of coaches both washed and fueled: | 100% |
| Percent of coaches fueled, not washed: | 0% |

FIGURE 13 Sample time standard for servicing (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

INSPECTION

TYPE C INSPECTION

| Activity Description | Target Hours | Proportion of Coaches | Adjusted Target |
|---|---|---|---|
| Road Test (Brakes, Steering, Power, etc) | .1313 | 1.000 | .1313 |
| Farebox (Seal, Cyclometer, Telltale) | .0096 | 1.000 | .0096 |
| Fire Extinguisher (Seal and Pressure) | .0439 | 1.000 | .0439 |
| Swipes & Washer | .0205 | 1.000 | .0205 |
| Alarms & Guages (Generator, Oil Pressure, Low Air, Backup Warning, Buzzer) | .0056 | 1.000 | .0056 |
| Check Horn, Heater Blower, Wheel Chair Lift & Kneeling | .0154 | 1.000 | .0154 |
| Check Sander | .0208 | .628 | .0130 |
| Engine Fire Alarm | .0833 | .628 | .0523 |
| Doors (Operation, Interlock, Sensitive Edge) | .0376 | 1.000 | .0376 |
| Flares & Reflectors | .0101 | 1.000 | .0101 |
| Wheel Blocks & Sand Buckets | .0056 | 1.000 | .0056 |
| Interior Cleanliness & Damage | .0098 | 1.000 | .0098 |
| Destination Signs | .0044 | 1.000 | .0044 |
| Lights | .0317 | 1.000 | .0317 |
| Lube Door Engine, Shafts & Linkage | .0188 | 1.000 | .0188 |
| Check for Exterior Damage | .0229 | 1.000 | .0229 |
| Visual Inspection (Air, Oil & Coolant Leaks, Missing Parts) | .0582 | 1.000 | .0582 |
| Fluid Levels (Engine Oil, Turbine, Power Steering) | .0604 | 1.000 | .0604 |
| Mufflers & Tailpipes | .0245 | 1.000 | .0245 |
| Check Fan Hub for Looseness | .0049 | 1.000 | .0049 |
| Drain Throttle Air Tanks (1100's) | .0458 | .628 | .0288 |
| Check Air Compressor Filters (500's) | None | None | None |
| Emergency Stop Action | .0156 | 1.000 | .0156 |
| Check Low Water Warning | .0042 | 1.000 | .0042 |
| Top Off Kyser Fluid in Shutter Filter & Engine. | .0333 | .327 | .0109 |
| Adjust Clutch & Shaft Lever Arms (200's & 700's) | .2625 | .096 | .0252 |
| Turbine Scavenger Filter (Clean, Check for Metal | None | None | None |
| Fan Bevel Gear Oil Level (500's) | None | None | None |
| Inspect Undercarriage for broken, Worn, or Loose Parts. | .0319 | 1.000 | .0319 |
| Drain Air Tanks | .0250 | 1.000 | .0250 |
| Brakes (Adjust, Check Pins, Linings & Hi-Cams) | .0286 | 1.000 | .0286 |
| Air Leaks (Brakes, Axles, Lines) | .0377 | 1.000 | .0377 |
| Mufflers & Tailpipes (Articulated) | None | None | None |
| Total Hours Per Type C Inspection: (Continued) | | | .7884 |

FIGURE 14 Sample time standard for inspection (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

### Performance Monitoring

At Seattle, after the standards were established, a system was developed to check actual performance times and compare them with the standard times.

The Seattle program is partially supported by a data processing system. The front end is still manual. Mechanics enter data into the system through daily time sheets, with personnel identification, date, and garage already printed. Job and coach identity are pencilled in at the start of a job. Elapsed time is pencilled in at the finish of a job. The daily time sheets are then audited by a clerk and turned over to data processing.

A computer produces various summary reports for use by the foreman of each shift. Such reports show individual mechanic performance per job, in terms of actual-versus-standard time. Corresponding source records and reports are generated for inspectors and servicemen, in addition to the mechanics. The Seattle records processing system tracks other maintenance performance variables as well, including coach status, coach history, and road calls. However, the key factors pertinent to a time-standards program are worker, job and coach identification, and job time.

### Program Administration

The Seattle program was started in the late 1970s. Outside help was obtained from two sources. J.W. Cowley was selected to establish the labor standards and Arthur Andersen designed the reporting system. A high level of cooperation was provided by upper management, supervision, and the various supporting

| ACTIVITY | PERCENTAGE OF WORKING TIME |
|---|---|
| Signout | 13 |
| Prior Day logging to Bus History Cards | 10 |
| Telephone | 9 |
| Trips to Pick up Bad Orders | 7 |
| Telephone Dispatch Office | 6 |
| Coach Changes | 4 |
| Keep Record of all Coach Locations | 3 |
| Time Slips | 3 |
| Unit Reports (to Computer) | 3 |
| Setup for Yard Check | 3 |
| Inspection Planning | 3 |
| Tripper Sheet | 3 |
| Evaluate Time Slips | 3 |
| Conversation with Supervisor | 3 |
| Prepare Trouble Calls | 3 |
| Compile Outgoing Mail | 2 |
| Yard Check | 2 |
| Coordinate Coach Changes | 2 |
| Prepare SIMS Inspection Report | 2 |
| Organize Computer Slips for Bad Orders & Trouble Calls | 2 |
| Prepare Out of Service Report | 2 |
| Log Brake Work | 2 |
| Conversation with Drivers | 2 |
| Conversation with Mechanics & Service Workers | 2 |
| Coordinate Road Calls | 2 |
| Coordinate Radio Service | 1 |
| Mileage Envelope | 1 |
| Compile Night Service Activity | 1 |
| Coding | 1 |

FIGURE 15 Proportion of work time per hostler activity (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

| ACTIVITY | PERCENTAGE OF WORKING TIME |
|---|---|
| Discussing Work with Mechanics | 24 |
| Paperwork | 24 |
| Discussing Work with Service Workers | 15 |
| Personal Time, Non-Working | 11 |
| Discussing Work with Other Supervisors | 10 |
| Telephone | 4 |
| Inspection of Coaches | 3 |
| Trips to Pick up Bad Orders | 3 |
| Get Parts | 2 |
| Assist with Mechanical Work | 1 |
| Other | 1 |

FIGURE 16 Proportion of work time per supervisor activity (Maintenance Labor Performance Monitoring System, Metro Transit, Seattle).

organizations. A positive interface was maintained with the labor union.

The program is still in operation; now in the performance monitoring stage. Detailed information on both the labor standards and the manual reporting system is available in the Seattle report.

**Program Results**

The agency is pleased with the results of its program. A significant improvement has been achieved in management control, which was the primary objective. Gains in productivity have not been reported.

CHAPTER THREE

# A PROCESS FOR ESTABLISHING WORK STANDARDS

The information in this chapter is presented as an aid to agencies wishing to set up their own standards programs. The process described here is consistent with the methods found in the literature on industrial engineering. However, the present process has been adjusted to fit the needs of maintenance work in the mass transit industry. The process is expressed in nine broad steps:

1. Identify and define all jobs to be covered.
2. Describe types of standards to be used.
3. Establish data-handling system.
4. Collect data and create reports.
5. Evaluate job performance.
6. Improve job performance.
7. Establish time standards.
8. Establish accuracy standards.
9. Update work standards.

## IDENTIFY AND DEFINE ALL JOBS TO BE COVERED (STEP 1)

The purpose of this step is to document the total set of jobs and to establish clear boundaries between them. Unless this is done properly, there will be a risk of confusion among participants regarding the intended contents of many jobs. As used here, the term "job" means a specific maintenance function applied to a specific piece of equipment. An example would be *Replace Generator.*

An effective tool for identifying and defining jobs is a two-dimensional matrix (Fig. 17). The columns of the matrix are labeled at the top to show the various maintenance functions, such as troubleshoot, test, inspect, service, replace, adjust, and so on. Maintenance is unique in this respect. This same list of functions always applies, regardless of the kind of equipment involved.

The rows of the matrix are labeled at the left to show all the units within a given system. A matrix normally is prepared for each system of each coach model under investigation.

For the sake of clarity in dealing with these matters, the following definitions are employed concerning level of equipment detail:

**System** is a group of hardware items designed to perform a definite purpose in the operations of the bus. An example would be the electrical system. All bus models are divided into a small number of established and familiar systems.

**Units** are the major hardware items that make up systems. A well-known unit within the electrical system would be the generator. As a rule, units are designed to be replaced on the bus and repaired elsewhere.

**Components** are the detail parts that make up units. An example of a component on the generator would be a mounting bolt. A component may also be classed as a unit, if designed for on-bus replacement. An example of a component of that type would be a brush in the generator.

In each matrix, the open cells are used to collect entries denoting the relevance of the maintenance functions to the respective hardware items. Each hardware item is cycled against every maintenance function to see if the function applies. A check mark indicates YES. A blank cell indicates NO. This process ensures that all possibilities are considered.

The checked cells are then used to identify and define jobs, each cell contributing a hardware name and a maintenance function. A given cell might represent a complete job, as occurred in the example given earlier *(Replace Generator).* Another cell may represent only part of a job, as for example, *Test Generator. Test Generator* might be one of several functions comprising the job *Troubleshoot Electrical System.* When all the cells have been accounted for in this manner, the jobs covered by that matrix will have been identified and defined.

Each job may then be given an official title, with constituent functions documented clearly, for use whenever needed. A job-numbering scheme may also be employed.

## DESCRIBE TYPES OF STANDARDS TO BE USED (STEP 2)

Two types of standards may be used in evaluating work performance. One concerns work speed and the other concerns work accuracy. Although standards programs have historically dwelled on speed alone, the reality is that both aspects of performance deserve attention. The penalties of inaccurate work in maintenance may far outweigh those of work that is merely

MAINTENANCE FUNCTIONS

| EQUIPMENT | TROUBLESHOOT | CHECK/TEST | REMOVE | INSTALL | DISASSEMBLE | ASSEMBLE | ADJUST | INSPECT | SERVICE | OVERHAUL |
|---|---|---|---|---|---|---|---|---|---|---|
| BATTERIES | ✓ | | | | | | | ✓ | ✓ | |
| BATTERY CARRIERS | | | | | | | | | ✓ | |
| BATTERY MASTER SWITCH | | | | | | | | | ✓ | |
| BATTERY CABLES | | | | | | | | ✓ | | |
| GENERATOR | | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | |
| DIODES | | ✓ ✓ | ✓ | ✓ | | | | | | |
| VOLTAGE REGULATOR | ✓ | | ✓ | | | | ✓ | ✓ | | |
| PCBs | | ✓ | ✓ | ✓ | | | | ✓ | | |
| STARTER MOTOR COMPONENTS | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ |
| ETC... | | | | | | | | | | |

FIGURE 17 Sample equipment by maintenance functions matrix.

slower than average. Some jobs, in fact, are uniquely sensitive to inaccuracy. It is important, therefore, to have both speed and accuracy represented when setting up a work standards program.

Speed, of course, is the easier of the two to deal with because measurements of work time are so readily available. When planning to collect time samples, it is necessary to recognize the existence of different *kinds* of time components in addition to the primary component for each job. One example would be paperwork. Another would be hostling coaches. A third would be overhead. Each component represents a small amount of time demanded of the worker whenever the job is performed. It is vital that the specific treatment of such components be defined before the establishment of the data-handling system.

With regard to accuracy, a "most common" measure has not yet been adopted by the transit industry maintenance community. However, there are several familiar candidates, all based on the concept of worker reliability (i.e., relative absence of error). One is by direct observation, wherein work is checked by a follow-up inspector. This is a practice widely used in aircraft maintenance.

Another is by tracking certain kinds of maintenance events, such as repeat complaints, reports of equipment damage, and reports on parts replaced. The feasibility of this approach has been established by recent studies for the Navy.

The Navy studies focus on three types of maintenance errors, Type I, Type II, and Type d. A Type I error occurs when the technician replaces a good unit while attempting to isolate a fault during troubleshooting. A Type II error occurs when the technician fails to recognize a malfunction during system checkout. A Type d error occurs when the technician damages the equipment during maintenance. In the Navy maintenance data system, records are created enabling such transactions to be identified and counted. It is thus possible to compute error rates by unit within system, throughout an aircraft.

The Navy method of measuring maintenance error appears directly applicable to the transit industry, wherever a data processing system is available to support it. As was indicated earlier for time measures, if error measures are to be included in a standards program, then those measures must be defined before the establishment of the data-handling system.

## ESTABLISH DATA-HANDLING SYSTEM (STEP 3)

The data-handling system for a work standards program consists of the provisions for documenting vehicle operations and maintenance actions; the rules for recording specific transactions; the rules for treating transaction records; and provisions for auditing source documents and checking completed jobs.

Provisions for documenting vehicle operations and maintenance action generally are represented by paper forms or computerized data-entry devices. The kinds of information to be covered would depend on the decisions made in Step 2. Typical elements might include date, vehicle identity, system identity, technician identity, reported complaint, job identity, minutes to complete job, damage detected, and results of tests on replaced parts.

Rules for recording specific transactions would include definitions and entry codes where applicable. Closely associated with these rules would be provisions for auditing source documents and checking completed jobs. Both the audits and the checks could be scheduled on a sampling basis for purposes of economy. However, they should be made highly visible so as to influence technician behavior in the desired direction.

Rules for treating transaction records would include the specific ways of combining data elements to form usable outputs. An example would be the formula for computing the overhead value applicable to the elapsed maintenance time on a given job. Another example would be the algorithm used to identify a Type II error following system checkout. As suggested above, the outputs of all record treatment must be *usable.* That means the reports to be prepared for management should be designed with great care.

### COLLECT DATA AND CREATE REPORTS (STEP 4)

The three steps just described constitute a plan for measuring maintenance job performance. In Step 4, that plan is executed.

The primary data collected come from the technicians themselves. As they do the work, they create records. When the records are processed, they enable the preparation of reports denoting actual performance per job. Those reports provide managers with a basis for evaluating the performance. It is that evaluation that leads eventually to the adoption of standards.

At this stage of the process the key factor is data validity. Without validity, the data have little meaning and, in fact, could be highly misleading. The foundation for data validity is provided by good planning in Steps 1, 2, and 3. In Step 4, constant vigilance is needed to ensure that those plans are carried out as intended.

One source of data weakness is the procedure used to process data and create reports. This procedure should be closely monitored and revised promptly when problems appear. Such revisions are important not only as they affect the reports themselves but also as they affect upstream data collection. Wherever collection is made difficult in any way, data quality is almost certain to decline.

The major influencers of data quality are the technicians who generate the source documents. For a variety of reasons, some entirely innocent, the technicians can make incorrect entries that affect the data base. They can also compromise the maintenance program itself by taking shortcuts to get the work done faster. It is essential that controls be used to prevent both kinds of discrepancies.

One way to reduce mistakes in the source documents is to audit records before they enter the data-processing system. Auditing enables the early detection of errors in coding and questionable entries in performance time. Another way to reduce such mistakes is to provide good instruction for the technicians on the subject of source-document preparation.

The problem of shortcuts can be handled in two ways. One is to have the work checked on a random basis. The other is to assure the technicians that work quality is just as important as work speed.

Where the standards program is designed to measure technician errors as well as time, two maintenance activities may be conducted that might be new in some agencies. One is the testing of units replaced while troubleshooting. The other is the recording of damage evidence discovered while working on the equipment.

Unit testing can be performed as an off-line function. Records must be kept identifying units and unit (good/bad) status. Such records enable the measurement of Type I errors (i.e., replacing a good unit).

Recording damage evidence is a coding task done in parallel with other work. It may refer either to the current job or to equipment worked on earlier by someone else. It employs a preestablished listing of damage codes from which the technician may choose the one that best fits.

Records of unit test and equipment damage can be made on the form designed to record the primary flow of maintenance actions. Provisions must be made for unit test and equipment damage data in the data-processing system.

### EVALUATE JOB PERFORMANCE (STEP 5)

The reports resulting from Step 4 provide measurements of performance as actually experienced. However, the values shown do not yet represent standards.

It is possible at this time to contrast the actuals with provisional standards based on supervisory judgment and/or data obtained from other agencies. An alternative is to allow the standards to evolve more gradually, as further actuals become available.

Meanwhile, successive reports provide a data base enabling evaluation of performance on the full array of jobs. Because performance is expressed in quantitative terms, it is possible to make judgments of relative adequacy by examining the time and error values.

Low (and stable) time values suggest that the corresponding jobs are under control and that those values might serve well as standards. High (and stable) time or error values, or values lacking in stability, suggest that the corresponding jobs should be investigated for the purpose of improving performance. Before that, it is generally unwise to use those values as standards.

This evaluation step represents a key component in any standards program. First, it pinpoints the areas where significant improvement may be desired. Second, it enables an advance estimate of the *value* of each suggested improvement. And third, it facilitates (later) remeasurement showing the degree of success achieved for each attempted improvement.

### IMPROVE JOB PERFORMANCE (STEP 6)

Given a job on which significant improvement in performance is desired, it is usually necessary to mount a special effort to achieve that improvement, before the establishment of performance standards. Although it is theoretically possible to have technicians discover the most efficient work method by themselves, that approach frequently fails in maintenance. One reason may be that most jobs do not repeat themselves often enough to expose their sources of inefficiency. The best available method therefore will become evident only after a period of concentrated study.

The classic approach to discovering the best available work method, for use in a standards program, is time-and-motion analysis. As described in the literature on industrial engineering, time-and-motion analysis proceeds in three phases: streamline the job, describe the job in writing and require technicians to perform it that way, and take time measurements under the revised work conditions. The first two of these phases will be described here. The third phase will be addressed in Step 7.

The streamlining of the job entails the specific enumeration of job tasks and steps, and the observation of the physical actions required by each. The analyst looks for task elements that appear to place a heavy load on the technician, in terms of skill or strength or time consumption. The job is then revised in various ways to reduce that load. Steps may be re-sequenced or eliminated. New tools or materials may be prescribed. Even a job location might be changed (for example, from coach to bench).

For most jobs, the analysis leading to streamlining is based on direct observations, sometimes with the aid of a videotape recorder. For jobs such as troubleshooting, additional information is needed. Such information is obtained through system analysis focusing attention on the relationships between hardware units and on the various indications available to the technician. This enables the construction of checkout routines and symptom-cause tables. When these factors have been agreed on, the work of streamlining the job of troubleshooting can proceed in a manner similar to other jobs.

After a job has been streamlined, it is described in writing and given to the technician for consistent execution. This phase is called job standardization. Job standardization is an important step in developing time standards. If it is not done properly, individual variations will creep in and upset the basis for time measurements. This tendency is especially evident when experienced technicians are asked to abandon a method they have become accustomed to over a long period. It should be clearly shown that the standardized job is superior to past practices.

A large amount of energy is sometimes needed to produce the desired change in behavior. When seriously seeking that objective, it is wise to give great care to the written description of the job. To the extent the procedure is documented clearly and accurately, it eliminates a major source of variation in job performance. Thereafter, the controls exercised by supervisors can be concentrated on getting the technicians to follow the procedure as written.

Toward this end, every maintenance instruction should have the following characteristics. It should (a) state the conditions that must prevail before the work can be started, (b) identify all the tools, equipment, and materials needed, (c) show job location(s), (d) describe all major activities and constituent steps, and (e) show all decision points and the action path to follow in each case. Instructions prepared in this manner provide the same direction to both the technician and the observer when establishing time standards.

### ESTABLISH TIME STANDARDS (STEP 7)

When the method has been made as efficient as is economically justified and standardized, the job is ready for the third phase of time-and-motion analysis, time study. Time study consists of a series of timed observations of actual performance, plus certain adjustments to the data to allow for other variables.

In preparation for the time study, the job is subdivided into elements suitable for separate observation and timing. Where the job has been properly documented (as described in Step 6), subdividing the job should be relatively simple. The elements to be observed are selected groups of detail steps.

On some jobs, the elements observed will be all the steps documented. On other jobs, complete observation may not be necessary. That is, it may be possible to substitute time values obtained on equivalent elements from other jobs or from elsewhere on the job under study. Where a job contains alternative paths, as in checkout and troubleshooting, all paths must be accounted for. The decision on how to combine the various time values is made later in the process.

Several observations are made of each element marked for measurement. The number of observations is generally a compromise between the need for accuracy and the need for minimum observation cost. Many analysts recommend at least three observations. Observation times (including those obtained from other sources) are averaged for each element.

Before the averages of elements are combined to form a job average, they are treated in two ways. The purpose of the first treatment is to stabilize the observed averages. The purpose of the second is to provide allowances for nonproductive periods.

Averages are stabilized by a process known as leveling. Leveling takes into account the proficiency of the technician at following the prescribed procedure, the degree of effort he or she appears to be applying, and the work conditions affecting performance of the job. The analyst performs leveling while making time observations. He or she uses an established rating scheme to quantify the three leveling factors and adds the obtained values to 1.0 to produce a final leveling factor.

The final leveling factor is in effect the amount (in percent) actual performance times are above or below the *average* level, where average is taken to mean normal, steady, but unhurried performance that could reasonably be expected from anyone qualified for the work. The average performance time is obtained by multiplying the final leveling factor by the elemental averages, and summing the products across the job.

It is at this point that provision is made for the various kinds of legitimate nonproductive periods that affect every job. Such periods include time taken for personal needs, time spent on activities common to many jobs (such as hostling), delays beyond the control of the technician, and others. The normal method of dealing with legitimate nonproductive periods is to define and measure them, and then specify corresponding time allowances to cover them.

The final phase of developing time standards is to put all the pieces together for each job. Each element is timed, averaged, and leveled. Elements are combined in various groups to reflect alternative paths through the job. Allowances are made for nonproductive time periods. The net result is a standard time for the job.

### ESTABLISH ACCURACY STANDARDS (STEP 8)

As used here, the term "accuracy standards" refers to allowable error rates on various jobs. As indicated earlier, three kinds of errors may be tracked in maintenance. A Type d error is one that results in hardware damage. A Type I error means the wrong item was replaced in attempting to remedy a fault. A Type II error means a particular fault could not be isolated.

The data collection system must be set to accumulate specific occurrences of each kind of error, by job, by technician, within a given time period. That combination establishes one aspect of a performance measure. The data-handling system must then contrast those data with the total number of like jobs performed by the same technician, within the same time period. From that may be computed a series of percentages representing error rates for that technician. Error rates for a given job may then be compared across several technicians. Allowable error rates may be set by supervisory judgment. Allowable error rates equate to accuracy standards.

### UPDATE WORK STANDARDS (STEP 9)

After new standards have been established, they must be applied seriously and kept current. This is important for two reasons. One is to maintain credibility and the other is to take advantage of every opportunity to improve productivity.

Credibility is weakened whenever the technicians sense that the standards are being ignored by supervisors, or are not being kept up-to-date. One aspect of the latter condition is the presence of specific standards known to be in error. Credibility is strengthened when technicians see supervisors using the standards and when errors are corrected quickly.

Opportunities to improve productivity may be welcomed by the technicians as well as by supervisors, especially where the environment motivates people to take pride in doing a good job. Improved productivity may come from several sources: the technicians themselves could develop more efficient work methods, new tools or equipment could be introduced, or work practices could be revised. Each instance should be regarded as an opportunity to bring pertinent work standards under reconsideration.

The updating process should not be applied arbitrarily. That would be detrimental to employee morale. Changes should be made with respect for those most likely to be affected, and always for good reasons. One way to handle the updating function is to set up a formal change procedure, with a particular person in charge and provision for consultation with the technicians, before change approval.

CHAPTER FOUR

# GENERAL RECOMMENDATIONS

The mass transit industry is moving gradually in the direction of maintenance work standards. Not only are many programs already in existence but interest in the topic is quite widespread. This interest is due partly to the expanding availability of computer technology and partly to growth in management recognition of the importance of maintenance. The recommendations presented here are intended for use by all agencies but especially those that have not yet established their own work standards.

1. Approach work standards on an organized, formal basis. Treat it as a program that will require a considerable amount of initial effort. Give the program strong management support and recognize that the work may involve a number of specialized skills not normally held by transit agency personnel. Among those skills are job description documentation, methods analysis, and data-base development. Outside help may be necessary.

2. Plan to establish standards for work accuracy as well as work speed. Measure accuracy in terms of error rate, by mechanic and by job. Studies done with the Navy's maintenance records indicate that reduction of work errors offers a higher potential return on investment than reduction of work time. This is important to agencies seeking improvements in maintenance productivity.

3. Take particular care in identifying and defining the jobs to which standards are to be applied. Job definitions represent the foundation for everything else in the program. Document job definitions by hardware system within vehicle model. To do this effectively, apply the matrix approach summarized in Chapter Four. Coordinate with other agencies to make job definitions common across many organizations.

4. As the planned features of the standards program become visible, describe in detail the data-handling system that will be needed. Recognize that the processing demands of time measurement will not be the same as the demands of error measurement. Coordinate with other agencies to develop a data-handling system common across many organizations.

5. Treat all initial standards (both work time and work error) as provisional. Look for ways to change the constituent values, on behalf of improved productivity. Do not rely too heavily on historical data. Historical data tend to reside in the upper region of the performance time distribution. Basing standards on such data is safe but possibly wasteful. Productivity improvements are more likely to occur when some effort is spent attempting to streamline the jobs before setting the standards.

6. To streamline a job, examine it in depth by some form of methods analysis. Do not expect the technician to discover a better method. After selecting the desired method, document it in a form that is usable on the job. Then, insist that the job be performed as prescribed. This approach has the effect of reducing errors as well as time to perform.

7. Do not attempt to streamline all jobs. Concentrate on the high drivers, the ones that appear to be causing the biggest drain on productivity. These jobs will be indicated by initial reports showing performance actuals. High and stable values, or values lacking in stability, suggest that the corresponding jobs should be investigated.

8. Include in the standards program some provision for quality control. Verifying that work is done correctly has the

effect of validating the time standards. Without such verification, technicians may be tempted to take shortcuts just to meet time standards. Shortcuts often produce negative downstream effects.

9. After establishing a set of standards, keep them up to date. That is, correct them immediately whenever an error is found in the data, and adjust them whenever the conditions of work change on a particular job. Introduction of a new tool, for example, should prompt reconsideration of a work standard. Above all, do not allow the standards to fall into disuse by supervisors. That condition would weaken the credibility of the standards.

10. Establish a forum for the exchange of information on work standards and associated practices. Such a mechanism could save a large amount of wasted time and expense, particularly with regard to the issues cited here as having potential for treatment on a common basis.

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