

## ACHIEVEMENTS OF THE MAINTENANCE MIS

The Birmingham-Jefferson County Transit Authority has been using this maintenance MIS for approximately a year. During that year, it has become apparent that data-processing efforts can be readily implemented at transit operating properties. The maintenance personnel in Birmingham have become quite familiar with the reporting requirements, and these requirements have had little adverse impact on daily work activities. In addition, the data-processing system has provided the type of information necessary for supervisory and management control of maintenance activities. Specific records on individual work performance, as well as detailed maintenance records for each bus, are available for analysis. Specifically, it would appear that labor productivity in the maintenance department has increased significantly as a result of these data-processing efforts. During a recent nine-month period, overtime has been reduced to one-third that of the similar period of the prior year. This productivity has improved not only

because the employee is aware of the monitoring capability but also because of the additional training that has been focused on many employees. Evidence of results can be seen in the FY 1980 budget; maintenance costs were reduced to little more than 96 percent of the prior year's cost over a similar nine-month period, whereas other operating functions continued to experience double-digit inflationary increases.

Maintenance is a significant area of cost incurrence in the public transit industry. As transit operations continue to expand, further management attention must be directed to maintenance problems. In Birmingham, experience with data processing and analysis of maintenance labor requirements has yielded some tangible benefits. It is hoped that, by means of further analysis and review, additional cost savings can be identified and implemented.

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## Work Sampling as a Performance Measure for Maintenance Functions

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The way in which two work-sampling studies were used as tools for objectively measuring activity levels in transit-vehicle maintenance shops is discussed. Positions ranging from utility worker to foreworker were sampled in four shops to determine how time was utilized, i.e., productively or nonproductively. The results of the studies are summarized and their implications examined. Improvements were found as a consequence of recommendations implemented after the first study; however, foreworker control over the work force was found to be insufficient in both studies. Increases in essentially nonproductive activities were attributed to decreased work load, and the issue of sufficient work load raised the possibility of adjustment of staffing levels. The data compiled from the work-sampling study were used to estimate the potential for reducing staff through attrition and transfer.

Managers in transit agencies today are vitally concerned with the effective use of their employees. Underutilized employees mean lower operating efficiency and, therefore, higher costs. Although they are not usually involved in direct labor supervision, managers are responsible for providing the necessary control to ensure that workers are fully productive and that costs are kept down. However, determination of the amount and type of control to apply requires that managers get accurate information on the work being done and on the effort being applied. Often the issue is how to evaluate fairly the feedback given by different supervisors and foreworkers on the performance levels of their employees. The question for managers, then, is how to objectively determine the amount of productive time that exists for various position classifications, shifts, and shops.

One prevalent method of objectively measuring productive time is a work-sampling study. The advantages of using work sampling for measuring people's activities are that

1. It is a widely accepted, low-cost, work-study technique;

2. Many positions or machines can be analyzed at the same time by one analyst;

3. People who have little technical background are able to do the actual sampling; and

4. Observations can be made over a long period of time so as to compensate for variations in the work performed.

One of the objectives of this paper is to familiarize the reader with the procedure of performing a work-sampling study. The other is to present an example of how work sampling can be used as a performance measure in maintenance shops.

### STUDY OBJECTIVES, DESIGN, AND IMPLEMENTATION

As in any study, there are some basic steps a person must follow to successfully complete the analysis. The following description of the studies conducted at San Francisco's Bay Area Rapid Transit (BART) will outline the seven steps that constitute a work-sampling study.

#### Discover the Need for a Study

In 1976, BART was experiencing a car-availability problem. Shop management felt that the low number of cars released to revenue service was caused by low productive time in the shops. Since BART was planning to expand service, it was imperative that the car count be increased. Therefore, shop management decided that an objective work study should be conducted by the industrial engineering group that had just been formed within BART.

#### Define the Objectives

The purpose of performing the work sampling studies



Table 1. Work-sampling results.

Activity	Location				Total
	Pit	Floor	Office	Unknown or Other	
Direct work (h)					
On car	250	100	0	0	350
On component	10	40	0	0	50
Other	150	105	5	0	260
Direction (h)					
Instruction	20	25	55	0	100
Clerical (h)	15	5	20	0	40
Other (h)					
Personal	60	40	25	0	125
Unknown	0	0	0	75	75
Total (h)					1000

Figure 2. Productive time for all employees.



them that they were not being personally evaluated.

Other decisions were made about the number of observers and their qualifications and about the times and places for making the observations.

Do the Sampling

The actual sampling was done over a two-month period. Four to eight observations of each shop employee's activity and location were recorded during each hour of the shift. Data were not collected during break and lunch periods. Samples were collected during the graveyard, day, and swing shifts at all four shops. More than 200 employees were sampled in the course of the study. The type of employees studied ranged from utility worker to foreworker.

Dissect and Compile the Data

One of the more laborious and time-consuming tasks in work sampling is to reduce the data to meaningful figures. To manually compile all the analyses desired in these studies would have taken a month or more. Fortunately, a computer program was developed to sort and compile the data. The program produced work profiles showing the breakdown for various categories, such as all employees, transit-vehicle mechanics, electronics technicians, foreworkers, all or individual shops, and all or individual shifts.

A simplified sample of a work profile is shown in Table 1. Columns for the percentage breakdown and the precision interval are not shown. Rows that

indicate the totals, percentage breakdown, and precision intervals for the locations could also be added.

Work activities were condensed into the two categories of productive and nonproductive functions. Graphs such as the one shown in Figure 2 were then prepared to aid in comparisons of the various shops, shifts, and job classifications for both the current study and the previous study. The graphs permit the quick identification of shops or shifts that had low productive time or that had undergone large changes.

Deduce and Describe Conclusions and Recommendations

Analyses of the data and observations made by the management engineers during the sampling provided the basis for several major conclusions and recommendations. These are discussed below.

RESULTS OF THE STUDIES

First Study

The first study identified three major problems that were impairing shop productivity:

1. Lack of foreworker control over work force,
2. Inadequate production planning, and
3. Inadequate job organization.

Foreworkers were observed spending excessive amounts of time in their offices and not enough time on the shop floor and in the pits where the work force was located. Thus, they were unable to effectively manage the workers' activities. Furthermore, in planning the work for the shift, foreworkers were not using the schedule produced by the Maintenance Control Division. Assignments were being planned after the start of the shift, and little planning was being done to set up the shop with work for the start of the next shift.

The foreworkers also had difficulty in keeping the shops busy for the entire shift. Car movements were not being coordinated effectively, and changes of assignments were not anticipated. These difficulties and others resulted in large amounts of nonproductive time, which meant that overall shop productivity was low.

The following key recommendations were developed by the study team in conjunction with shop management:

1. Provide better foreworker supervision--restructure the foreworkers' day so that a majority of their time is spent at the various work locations rather than idle in their offices.
2. Institute more effective shop scheduling--have the foreworkers adhere to the Maintenance Control Division's schedule and have them arrive prior to the start of shift to prepare assignments and coordinate the setting up of work in the shop.
3. Expedite shop car movements--have the foreworkers provide tighter planning and scheduling of high-railer car movements to ensure a steady flow of work into the shop.
4. Reduce shop idle time--institute a hiring freeze to counteract the large amounts of nonproductive time recorded in the shops and provide tighter management control over contract break periods, clean-up activities, and shift start.

As a result of the study, various changes were made. Offices of the fishbowl type were constructed on the floor of shops that did not have such a setup. In the heavy-repair shop, the foreworker's desk was moved from the general office to the middle

of the work bay, which enabled the foreworker to see almost all the employees in the shop from that position.

A hiring freeze was imposed on shop personnel. In addition, staff adjustments were made; electronics technicians (this position was found to have higher nonproductive time) from some of the less-productive shifts were moved to shifts that had more work. Shop management also had the meetings at the start of the shifts take place on the shop floors instead of in the lunch rooms.

The study was part of a successful effort by shop management to increase the average daily car count. The average daily car count went from fewer than 250 cars to more than 350 cars released per day. The improved car count enabled BART to expand to seven-day service.

### Second Study

Observations made and data compiled during the second study showed that production planning and job organization had improved since the first study. Schedules produced by the Maintenance Control Division were being followed. Job assignments were being prepared by the foreworker prior to the start of the shift. The early arrival of the foreworkers also facilitated a smooth shift change and allowed for the prompt dispatching of work crews at the start of the shift. The amount of time on the high-railer had decreased and, generally, there was a steady flow of work through the shops.

At the same time, however, foreworkers' control over the work force was still insufficient, and the amount of nonproductive time for all employees in all shops had increased slightly. The foreworkers were again found to spend a large amount of time in their offices. One important exception was the heavy-repair shop. Having the desk out in the open on the shop floor seemed to increase the foreworkers' involvement with the employees. The nonproductive time for the heavy-repair shop employees was also found to have decreased.

Another area found to be hampering the effectiveness of the work force was the unavailability of parts. An investigation into the inventory operation revealed that parts were out of stock as a result of incorrect computer data on the number of parts available in the various storerooms. These incorrect data were caused by inaccurate or missing requisition slips, which stemmed from unattended storerooms and lack of supervision.

The following recommendations evolved from the second study.

1. Foreworkers should provide better control over the work force. Specifically, they should be more involved with the employees on the shop floors and in the pits, should give clear direction, and should improve motivation.

2. The amount of nonproductive time should be reduced to an acceptable level by pursuing one or both of two alternatives: First, employees should be enabled and encouraged to be fully productive during their shifts. This presupposes that there is sufficient work available to keep them occupied. If it is determined that there is an insufficient work load, then the second alternative, to reduce the work force through attrition and transfer, must be given serious consideration.

3. The inventory operation should be improved by establishing better control over the storerooms so as to ensure that information is completely and correctly submitted. This would require that the storeroom personnel be provided with closer supervision.

The issue of sufficient available work was raised because at several times during the study the shops ran out of work. This naturally led to an increased number of observations of workers being idle or performing nonproductive tasks. Shop personnel maintained that these were unusual situations. However, the data on improved car reliability and better maintenance procedures made it clear that the amount of work was decreasing. At the same time, other modification work was increasing. The question of appropriate staffing levels had to be addressed.

In recommending a reduction in staff, the study team used the data compiled from the work sampling to develop estimates of the potential number of employees that could be reduced. First, an achievable short-term goal for percentage of nonproductive time was established. This figure was subtracted from the actual percentage of nonproductive time found in each shop to ascertain the excess nonproductive time. This excess percentage was multiplied by the average attendance per shift during the study to determine the estimated excess staff. An example of such a staffing analysis is shown below. The analysis was done separately for transit-vehicle mechanics and for electronics technicians.

Shop	Average Number of Employees per Shop	Excess Non-productive Time (%)	Estimated Number of Excess Staff
A	15	10	1.5
B	18	15	2.7
C	22	8	1.8
Total	55		6.0

### CONCLUSIONS AND IMPLICATIONS

The work-sampling studies had provided BART management with definitive measures of the level of activity in the vehicle-maintenance shops. At the time of the first study, BART management felt that the low car availability was a result of low production time in the shops. The work-sampling study showed clearly that the percentage of nonproductive time was high. As objective data, the results of the study were a convincing basis for the corrective actions taken--the hiring freeze and foreworker training.

The second work-sampling study demonstrated that the activity level was again down, even though the car count remained high. Management was then required to consider the reduced amount of work available in the shops as a result of improved car reliability and better maintenance procedures. The study also brought to management's attention the problems in the inventory operation.

These work-sampling studies gave management information essential to the performance of the control and planning functions. Performing the studies on a periodic basis gave the studies an audit type of character that highlighted changes in activity levels for various shifts and job classifications. As can be seen from the experience at BART, work sampling is an effective tool for objectively measuring activity levels in maintenance shops.

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# Priority-Setting Method for Road Maintenance

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The Bureau of Indian Affairs (BIA) is responsible for maintaining approximately 25 500 miles of low-volume rural roads on the 179 Indian reservations. The BIA provides services to the Indian tribes through an agency organization that is located either on or near the reservation. The procedures described in this paper provide the BIA agency road engineer with a method for ranking the relative economic importance of the various routes within the reservation road network. This ranking provides a quantifiably supportable starting point for the tribal leaders to introduce the noneconomic considerations (i.e., the social needs and preferences of the tribes) to develop a maintenance priority listing that includes both economic and noneconomic considerations. A benefit-cost analysis approach is used. Input data currently available at BIA were identified and adapted to be used at the agency-tribal level without computer support. The method, described in the context of the BIA situation, is equally applicable to other activities involved with decision making about maintenance of low-volume rural road systems.

The Bureau of Indian Affairs (BIA) is responsible for maintaining approximately 25 500 miles of roads that are open to the public on the 179 Indian reservations. In 1978, this included 4777 miles of paved road, 3225 miles of gravel-surfaced road, and 17 546 miles of earth road (1).

The BIA provides services to the Indian tribes through an agency organization that is located either on or near the reservation. Usually a small maintenance section within the Branch of Roads at the BIA agency level maintains the roads on the one or more reservations that the agency serves. These maintenance sections consist of 8 to 10 persons and about the same number of pieces of (in most cases) antiquated, fully depreciated equipment. (For example, one agency road-maintenance section we visited in 1978 had a nine-person payroll, six road graders, one bulldozer, one oil distributor, one low-boy trailer, and one roller to maintain 948 miles of roads on 10 reservations.) In the practical sense, the agency road-maintenance section does the best it can with available resources to maintain the several hundred miles of roads within its responsibility. It not only must provide some semblance of scheduled maintenance to keep the roads open but must also be responsive to the changing day-to-day maintenance priorities specified by the tribal leaders. An agency road engineer, who heads a Branch of Roads, functions as the technical advisor to the tribes and is responsible to the agency superintendent for reservation road-construction and road-maintenance programs.

The agency road engineer works with the tribal governing body to establish road-maintenance priorities so that the highest level of service possible within funding limitations is provided. Since there are insufficient resources to provide optimum maintenance for all reservation roads, some trade-offs must be made. This is a two-step trade-off process. During the formal band analysis (described below), the tribal governing body

determines what portion of the banded funds allocated to the tribe will be devoted to road maintenance. At a later time it determines how the road-maintenance funds will be applied to the reservation network. To facilitate this two-step process, we proposed, as a part of a research project conducted by George Washington University for the BIA, a simplified priority-setting method for road maintenance that can be used at the agency level. This paper describes the general approach and illustrates the method in the BIA context.

For the past few years, the BIA has used a system known as band analysis as a tool to provide opportunity for the local tribes to affect the budgetary process. Priorities established by the tribes provide the basis for determining total funding levels and distribution of funds to the various programs at the BIA level. This system does not provide additional funds but, rather, gives tribes a chance to allocate money among programs within established funding limits. Road maintenance is a banded program. Road construction is not a banded program.

#### ECONOMIC BENEFITS AND COSTS OF ROAD MAINTENANCE

The principal economic benefit of road maintenance is the avoidance of increased user costs that will result if maintenance is not performed. The user costs consist of vehicle-running and travel-time costs that will increase as road condition deteriorates. Poorer road-surface condition means slower average vehicle-operating speeds that account, in large part, for the increased user costs.

If the construction of all roads were based solely on economic considerations, each road route could be required to justify its own maintenance based on economic benefits that result from the avoidance of increased vehicle-running and time costs. However, many rural roads in the United States, including BIA roads, have been constructed or surfaced based on social considerations and the stated preferences of the county or reservation population. For example, a road to a religious shrine used only once or twice a year might have been paved, even though traffic alone would not have justified such an expenditure for economic reasons. Thus there may be benefits other than reduced vehicle-running and time costs to be considered in the establishment of road-maintenance priorities. If a road that has been paved as a result of social considerations is not maintained, it could eventually deteriorate to the point that it is no longer passable.

If this occurs and if the original justification for paving the road is still valid, rehabilitation of the road will require a significant expenditure