Research Report 1360

Maintenance Training and Performance: A Computer-Based Management Information System

Douglas J. Bobko and John F. Hayes

Training and Simulation Technical Area
Training Research Laboratory

U. S. Army
Research Institute for the Behavioral and Social Sciences

January 1984

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A computer-based maintenance training and performance management information system was developed. This system, called the Maintenance Performance System (MPS), is designed to monitor the daily technical activities of maintenance personnel, identify maintenance performance strengths and deficiencies on an individual and unit level basis, and guide training managers to available training resources. MPS was installed and made operational in a divisional maintenance battalion. The need for and use of MPS by training managers at the unit level was observed. Also, practical and potential value of MPS data was analyzed.

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FOREWORD

The Army Research Institute for the Behavioral and Social Sciences has been conducting research into improved techniques for the management and delivery of technical training for maintenance personnel in the unit environment.

This research was stimulated by the continuing difficulties that operational units experience in developing, retaining and managing sufficient numbers of trained mechanics. Work to date has resulted in the development of a computer-supported system for tracking and managing mechanics' proficiency development. This system is called the Maintenance Performance System.

This report by the Training and Simulation Technical Area of the Training Research Laboratory describes how information accumulated by the Maintenance Performance System can be analyzed to provide both immediate performance feedback as well as establish long term trend data on maintenance efficiency. Such information can be of value not only to unit training managers but to personnel and equipment planners as well.

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MAINTENANCE TRAINING AND PERFORMANCE:
A COMPUTER-BASED MANAGEMENT INFORMATION SYSTEM

EXECUTIVE SUMMARY

Requirement:

To improve the management and delivery of on-the-job technical maintenance training.

Procedure:

A computer-based maintenance training and performance management information system was developed. This system, called the Maintenance Performance System (MPS), is designed to monitor the daily technical activities of maintenance personnel, identify maintenance performance strengths and deficiencies on an individual and unit level basis, and guide training managers to available training resources.

MPS was installed and made operational in a divisional maintenance battalion. The need for and use of MPS by training managers at the unit level was observed. Also, the practical and potential value of MPS data was analyzed.

Findings:

MPS succeeded in routinely providing unique and valuable maintenance performance and training data; moreover, the cost of supporting the system was found to be acceptable to the units. The most significant use of MPS has been to guide job assignments.

Utilization of Findings:

At the unit level, MPS can help break the pattern of incorrect task performance due to lack of supervision and feedback on performance. On a larger scale, the MPS longitudinal data base can be used to target Army-wide skill deficiencies and fine-tune institutional training curricula, to pinpoint areas in which training materials need to be developed or improved, to establish more reliable and comprehensive performance standards, to aid in the design of hardware, and to estimate future manning requirements.

MAINTENANCE TRAINING AND PERFORMANCE:
A COMPUTER-BASED MANAGEMENT INFORMATION SYSTEM

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MAINTENENCE TRAINING AND PERFORMANCE:
A COMPUTER-BASED MANAGEMENT INFORMATION SYSTEM

Introduction

The US Army Research Institute (ARI) has designed, developed, and field-tested a computer-based management information system which monitors the daily technical activities of maintenance personnel. The primary goal of this system, called the Maintenance Performance System (MPS), is to improve the management and delivery of on-the-job technical training of mechanics. To accomplish this, MPS provides unit level supervisors with current information about the experience and performance of maintenance personnel, and guides supervisors toward selection of appropriate training materials. The structure and operation of MPS is in many ways analogous to existing and planned Army-wide maintenance reporting systems (such as the Maintenance Control System or the Standard Army Maintenance System). However, MPS differs from these reporting systems in one important respect: MPS is designed to monitor the status of personnel, not hardware.

Does a need exist within the Army for a system that monitors the daily technical activity and performance of people? Can such a system be effectively implemented with minimal drain on existing unit resources? What kinds of information can such a system generate and of what value is this information? In turn, each of these questions is addressed below and, where appropriate, maintenance training and performance data from an operational MPS are reported.

Why a Training Management Information System is Needed

As a result of the Army's shift to a more decentralized individual skill training philosophy, lower organizational units are given greater responsibility for the achievement of training goals. In fact, the initial and refresher training of individual soldiers in their Military Occupational Specialty (MOS) technical tasks is now largely accomplished at the company or squad level (US Government Accounting Office, 1981). Moreover, this training is performance oriented and targeted to specific tasks and task standards found in each Soldier's Manual. The effectiveness of this training strategy is a primary factor in the Army's ability to achieve and maintain combat readiness.

Several recent reports have suggested that, in practice, soldiers are not being adequately trained at the unit level in the performance of their MOS technical tasks (see US General Accounting Office, 1981, for a review). This lack of adequate training is often reflected in poor performance of technical tasks, especially for equipment maintenance specialties. Kern and Hayes (in press), for example, reported that 22%-71% of mechanics had one or more serious uncorrected errors remaining in the equipment upon completion of their maintenance task; also, 60% of the mechanics either failed to perform the check-out procedure or did so incorrectly. Buchan and Knutson (1977) reported that the frequency of false-removal (removal and replacing a part which is misdiagnosed as faulty) is about 30%. Dressel and Shields (1979) found a similar frequency of false-removal, and estimated that as much as 30% of the total repair cost is attributable to false-removal. Poor performance of technical tasks is a phenomenon not only within the Army, but within the other services as well (Orlansky and String, 1981).

When ARI first began its maintenance performance research, the anticipated approach was the development of more effective training programs and training strategies. However, it quickly became apparent that a more fundamental research and development effort had to be undertaken first. ARI found that, at the unit level, there is no official mechanism for recognizing or supporting the accomplishment of training. In short, unit level training managers have little in the way of resources to pinpoint performance deficiencies and to develop unit training programs. Current Army reporting systems are biased toward the status of equipment and provide little information about the skill and performance of individuals.

To address this underlying, systemic problem in the management and delivery of maintenance training, ARI developed the Maintenance Performance System. MPS is a computer-based maintenance performance management information system which provides to training supervisors quantitative measures of who needs to be trained, what tasks need to be trained, and how training can be accomplished. This information is designed and presented so that opportunities for training can be easily recognized and taken advantage of within the context of a unit's available resources and constraints. Examples of MPS information output are given in the third section of this report.

Scope of System Operation and System Support Requirements

MPS is designed for use in a divisional maintenance battalion (although in principle it can be employed as well in other technical or combat areas). MPS currently tracks ten MOSs and almost all of the equipment serviced by the two forward support companies of a divisional maintenance battalion. The MOSs include the high density MOSs of 63H (track vehicle mechanics), 63W (wheel vehicle mechanics), and 45K (tank turret mechanics). For a detailed description of MPS, see Harper (1981).

Technical MOS supervisors routinely feed information into the system with two simple MPS forms. One form is used to record the names of mechanics and the work-hours each mechanic contributed to a job; next to each name the supervisor checks "GO" or "NO GO" depending on the performance of the individual. The second form is used as necessary by supervisors to record successful completion by personnel of special training or performance-based tests (such as the Army's Skill Qualification Test). Because the use of these forms has been integrated into normal shop routine, data entry for MPS does not interfere with regular maintenance activities. Based on observations to date, supervisors spend no more than ten minutes per week completing these forms.

Day to day operation of the MPS computer system is accomplished by a junior enlisted clerk in grade E2 or E3. The clerk is responsible for collecting the MPS input forms, entering the data on these forms into the computer, printing computer-generated reports, and distributing the reports. An IBM 5120 micro-computer is used to store MPS data and to generate the MPS reports. The clerk's MPS duties require about 25-30 hours per week.

The computer programs which allow data entry, data analysis, and report generation have been carefully prepared so that very little training is required to perform the duties of the MPS clerk. Most of the training can be accomplished with a computer-driven lesson in which the trainee "walks-through" the operation and use of the computer.

MPS Training and Performance Data Output

MPS has been fully operational for about one year at a divisional maintenance battalion. The data presented and described below were generated from the information collected during the first eight months of MPS operation. Also included in these reports are two weeks of data from one company of this maintenance battalion that participated in the National Training Center exercises.

Although the following information reflects real field data from an operational system, it is important to note that the data are meant to be primarily illustrative. The sample of figures and charts below was selected because it best represents the scope, uniqueness, and potential utility of information provided by MPS -- information which is not available from any other source.

Individual Skill History

The Individual Skill History (See Figure 1 for an abbreviated example) identifies each mechanic by name and primary MOS, and shows their skill credit standing listed by specific tasks on equipment items. Tasks specific to each equipment are shown on the left column. On the right side, the number of skill credits is shown on a scale ranging from one to seven. A star symbol (*) indicates that the repairman has gained credit from either on-the-job training, other special training, or from demonstrated acceptable performance on the task.

Skill credits are most often accumulated when a mechanic receives a "GO" on either of the two MPS data input forms described above. In Figure 1, Mechanic 1, MOS 63H, is shown as having four skill credits (i.e., training experiences) in replacing the engine and transmission on the M60 tank. However, only one skill credit was given on Task 5, replacing the turbocharger.

The primary value of the Individual Skill History is as an accurate and up-to-date skill record and graphic indicator of a mechanic's standing on all required technical tasks. When repair jobs arrive in the shop, supervisors use the Individual Skill History for job assignments. For example, the mechanic who is inexperienced in replacing turbochargers can be assigned to

INDIVIDUAL SKILL HISTORY

NAME: Mechanic 1

MILITARY OCCUPATIONAL SPECIALITY: Automotive Mechanic

	NUMBER OF CREDITS						
EQUIPMENT/TASK	1	2	3	4	5	6	7
M60 TANK							
1 Replace Engine/Transmission	*	*	*	*			
2 Replace Fuel Injection Nozzle	*	*	*	*			
3 Replace Fuel Injection Pump	*	*	*	*			
4 Replace Fuel Tank	*	*	*	*			
5 Replace Turbocharger	*						

Figure 1. An abbreviated Individual Skill History for an automotive mechanic.

that task when the opportunity arises. Alternatively, when a repair task needs to be performed quickly, the Individual Skill History serves to identify the most experienced personnel.

Training Requirements Summary

The Training Requirements Summary (Figure 2) is designed to indicate to unit training managers and trainers what job exposure is needed, what training needs to be developed, and which personnel require the training. The column under Names lists those personnel who require training to meet requirements of their primary MOS and paygrade. For the Equipment/Tasks column, the table is organized vertically so that the closer an equipment is placed to the top of the listing, the higher the priority that is required for training on this equipment and related repair tasks. Based on the Individual Skill History information described above, a computer algorithm generates the names and Equipment/Tasks training priorities for a given unit. Notice, for example, that Mechanic 1 is listed in the Training Requirements Summary as needing training in replacing the turbocharger of the M60 tank (Task 5).

The extreme right-hand column of the Training Requirements Summary includes a training reference. The reference number in this column keys the user to a page number in an MPS booklet which contains detailed training resource information arranged by task and equipment. Figure 3 shows page B79 from this MPS training resource booklet. Here, marks in the boxes show that fourteen sources of training materials are available for Task 5, replacing the turbocharger.

The Training Requirements Summary is the single most important record for the unit-level training manager. It is an objective statement of training requirements listed by task, equipment, and priority, for each individual according to his performance and experience. The computer will maintain this history and update it as each task is performed, training is received, or performance is demonstrated.

Training Opportunity Utilization

The Training Opportunity Utilization information provides a measure of the extent of on-the-job training that occurs in the maintenance shop. This measure is a ratio of the number of available on-the-job training opportunities (i.e., the total number of repair jobs which enter the maintenance shop) to the number of utilized on-the-job training opportunities.

Figure 4 shows the training opportunity utilization for two different MOSs, automotive mechanic and armament mechanic. In the automotive mechanic shop section, for example, 250 repair jobs were received by the shop and were potentially available for on-the-job training purposes. As indicated by the shaded area of the column, about 52 jobs (or about 21%) of these 250 were actually utilized for on-the-job training. In other words, inexperienced mechanics were assigned to work on 21% of incoming jobs -- the remaining jobs were performed by experienced personnel.

Across the nine MOSs tracked by MPS, the utilization of training opportunities ranges from 11% to 21%. Based on experience with maintenance shop operations and other MPS data, it appears that a training opportunity

TRAINING REQUIREMENTS SUMMARY

NAMES/MOS	EQUIPMENT/TASKS	TRAINING REFERENCE
	M60 TANK	
Mechanic 1 (63H)	5 Replace Turbocharger	B79
Mechanic 2 (63H)		
Mechanic 3 (63H)		
Mechanic 2 (63H)	1 Replace Engine/Transmission	B79
Mechanic 3 (63H)	3 Replace Fuel Injection Pump	B79

Figure 2. An abbreviated Trianing Requirements Summary for automotive mechanics.

TRAINING MATERIALS

TRAINING MATERIALS FOR MPS TASKS—MOS 63H

TASKS BY EQUIPMENT

TASKS BY EQUIPMENT	FM 9-63H/CM	FM 9-63H1/2	TM 9-2300-257-20	TM 9-2300-257-34	TM 9-2300-378-35/1	TM 9-2350-215-20	TM 9-2350-222-20	TM 9-2350-257-34/1	TM 9-2520-223-34	TM 9-2520-236-34	TM 9-2520-254-34	TM 9-2815-200-35	TM 9-2815-205-34	TM 9-2815-220-34
M60 Family														
1 Replace engine/transmission (split pack)	●	●			●	●	●	●	●			●		●
2 Replace fuel injector nozzle	●	●			●	●	●	●				●		●
3 Replace fuel injector pump	●	●			●	●	●	●				●		●
4 Replace fuel tank					●	●	●	●						
5 Replace turbocharger	●	●			●	●	●	●						
M113 Family														
1 Replace engine/transmission/transfer (split pack)	●	●	●	●						●			●	
2 Replace cylinder head			●	●									●	
3 Replace fuel injector nozzle			●	●									●	
4 Adjust fuel injector rack control			●	●									●	
5 Adjust governor			●	●									●	
6 Replace engine air blower			●	●									●	

TASKS BY EQUIPMENT	TEC 610-091-6259	TEC 610-091-6260	TEC 610-091-6262	TEC 610-091-6263	TEC 610-091-6264	TEC 610-091-6265	TEC 610-091-6267	TEC 610-091-6268	TEC 610-091-6269	TEC 610-091-6270	TEC 611-091-6103	TEC 611-091-6104	TEC 611-091-6105	TEC 611-091-6106
M60 Family														
1 Replace engine/transmission (split pack)		●	●				●				●	●	●	●
2 Replace fuel injector nozzle	●			●	●	●		●		●				
3 Replace fuel injector pump	●			●	●			●						
4 Replace fuel tank														
5 Replace turbocharger	●		●	●	●									
M113 Family														
1 Replace engine/transmission/transfer (split pack)		●	●				●							
2 Replace cylinder head														
3 Replace fuel injector nozzle	●			●	●	●		●						
4 Adjust fuel injector rack control	●			●	●			●		●				
5 Adjust governor									●					
6 Replace engine air blower	●													

TASKS BY EQUIPMENT	COR. CRS. ODO402	COR. CRS. ODO403	COR. CRS. ODO412	COR. CRS. ODO420	COR. CRS. ODO531	COR. CRS. ODO607	COR. CRS. ODO729	SPAS 610-091-9060-Y	SPAS 610-091-9061-V	SPAS 610-091-9061-Y	SPAS 610-091-9062-H	SPAS 610-091-9063-H	SPAS 610-091-9066-H
M60 Family													
1 Replace engine/transmission (split pack)	●		●	●	●	●	●	●	●	●	●	●	●
2 Replace fuel injector nozzle	●	●						●	●	●			
3 Replace fuel injector pump	●	●						●	●	●			
4 Replace fuel tank								●	●	●			
5 Replace turbocharger					●			●	●	●			
M113 Family													
1 Replace engine/transmission/transfer (split pack)	●		●	●	●	●	●						
2 Replace cylinder head	●												
3 Replace fuel injector nozzle	●	●											
4 Adjust fuel injector rack control	●	●											
5 Adjust governor													
6 Replace engine air blower					●								

page B-79

Figure 3. MPS Training Resource Booklet, page B-79.

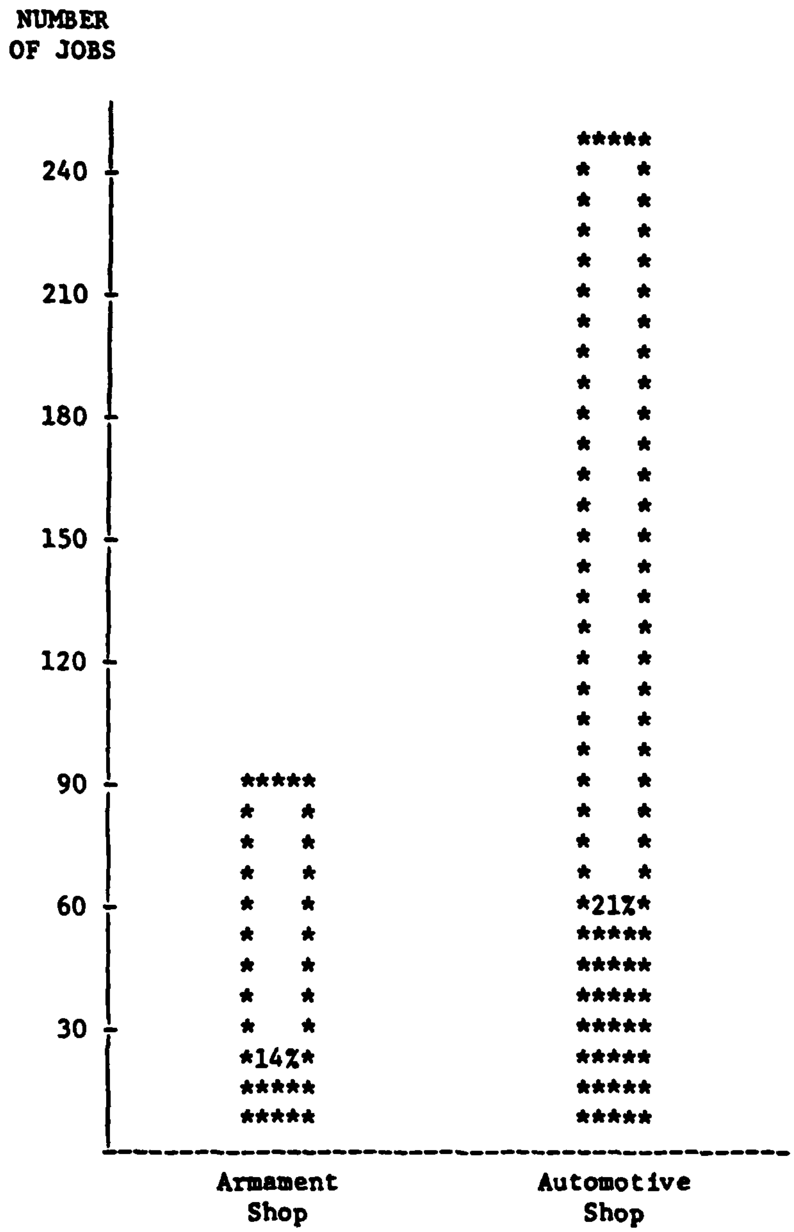

Figure 4. Training opportunity utilization for two MOSs.

utilization rate of about 20% is as high as can be expected given the number of personnel available to the unit and the unit's mission requirement. This finding suggests that increased attention be given to off-line, special training programs: given the constraints on a unit's resources, on-the-job training by itself cannot produce mechanics who are well-practiced in all of their MOS technical tasks.

On-the-Job Training Assignment

Figure 5 indicates the extent to which training managers effectively distribute job assignments among inexperienced personnel. It is here in the assignment of personnel to jobs that training managers can have the most effect on technical skill training. In the automotive mechanic shop, for example, about 70% of the total number of inexperienced mechanics (n=31) received some type of on-the-job training over the course of eight months.

Across all the MOSs monitored by MPS, the percent of inexperienced mechanics receiving on-the-job training ranges from 30% to 100%, i.e., there is about a three-fold difference in the effective use of incoming jobs for the training of inexperienced personnel. This finding clearly indicates that the management of on-the-job training can be improved through more effective job assignments. Although the opportunities for the conduct of on-the-job training may be constrained by factors beyond the control of unit level managers, MPS reports can help training managers use these opportunities more effectively.

Frequency of Job/Task Occurrence

The frequency of occurrence for automotive repair tasks for the M60 tank is given in Figure 6. The data reveal that some critical tasks (e.g., replacement of the fuel tank and turbocharger) do not occur often in the normal garrison environment and hence there is little opportunity for on-the-job training on these tasks. MPS data reveal similar results in most other MOSs. That is to say, there are a small number of repair tasks that occur very frequently and a larger number of tasks which occur infrequently or not at all.

The job frequency data raise several interesting questions. If some repair jobs do not occur in the garrison environment, how will repairmen be trained to perform the tasks? Should the institutional-setting Advanced Individual Training (AIT) courses focus on the infrequently performed tasks or ones that are most likely to be encountered in the field? How critical are the repair tasks which occur infrequently, and are they likely to be repairs which are found in combat situations? ARI is now examining the MPS job frequency data in order to determine if there are more effective ways to partition training between school and unit environments.

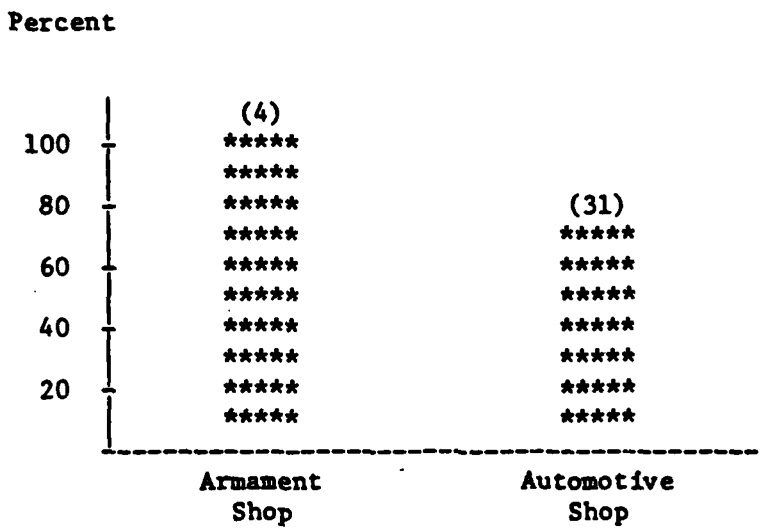

Figure 5. On-the-job training assignments for two MOSs.

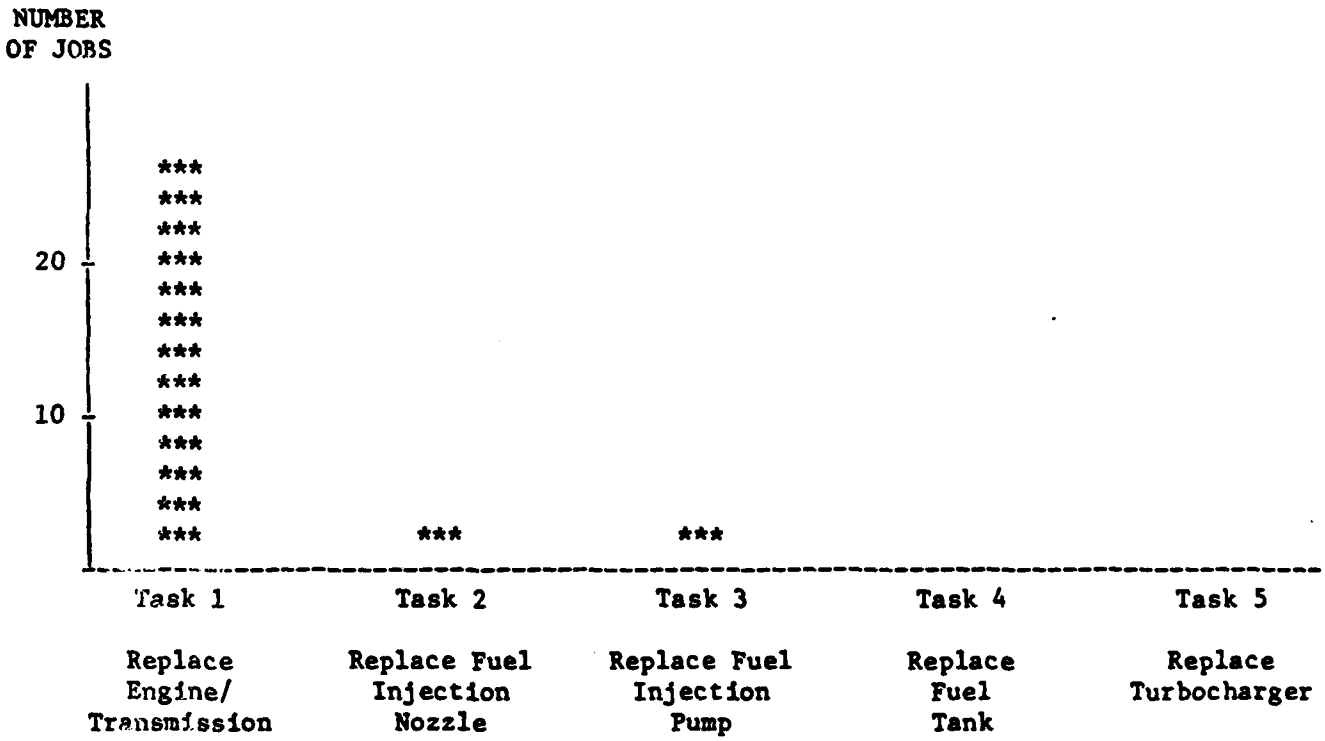

Figure 6. The frequency of automotive mechanic repair tasks for the M60 tank.

Mean Repair Time

Mean repair times (in days) for equipment serviced by automotive mechanics are presented in Figure 7. These repair times can be further broken down into repair times for specific tasks on each piece of equipment.

Repair times such as these have utility in the estimation of performance standards, system personnel requirements, logistical support requirements, and equipment design. Typically, the data required for these types of estimations are expensive and time-consuming. MPS, however, captures the data on a longitudinal basis in a simple and routine way.

National Training Center Data

Because one company being monitored by MPS participated in the National Training Center (NTC) exercises, it is possible to compare MPS data from the garrison environment with an environment more similar to that of a combat situation, e.g., the National Training Center. A sample of findings appears in Figures 8 and 9, which show mean repair time and mean team size, respectively.

Mean repair times (in days) across all equipment for two MOSs are shown in Figure 8 for both locales. The data suggest that repair times are consistently shorter at NTC than in garrison. This difference in repair time may reflect a difference between normal garrison operations and the NTC combat mode. Hence the team sizes at each locale were analyzed and are shown in Figure 9. Here, the results indicate that team size was smaller at NTC than in garrison. Therefore, team size (and by implication training mode) is identified as a factor affecting repair time. Comparisons such as these hold the potential for generating more accurate standards of repair time in combat, as well as generating estimates of unit level training costs within the garrison environment.

Data from NTC are also useful in another way. ARI is currently looking for differences between the kinds of repair tasks which occur in garrison and those which occur in combat situations. It is possible that some critical combat-related repair tasks do not get adequate on-the-job training in the garrison environment; the MPS data is being analyzed to determine whether this is so.

Summary and Discussion

The goal of MPS is to improve the delivery and conduct of technical training by providing relevant information to unit level training managers. The data shown above clearly demonstrate the usefulness and value of MPS in meeting this goal. Moreover, MPS is a milestone in that it represents the first operational military reporting system which provides information about the status of personnel rather than equipment. Reporting systems similar in scope and intent are now under development by the Navy and Air Force (these systems are, respectively, the Enlisted Personnel Individualized Career System and the Integrated Training System).

```
EQUIPMENT                                                 FREQUENCY
TYPE                                                      OF REPAIR

M109/M578      |****                                          4
M113           |*******                                      35
M60            |***********************                      30
M88            |***********                                   4
               L----+----+----+----+----+----
                    1    2    3    4    5

               MEAN REPAIR TIME (days)
```

Figure 7. Mean repair time (in days) grouped by type of equipment for automotive mechanics.

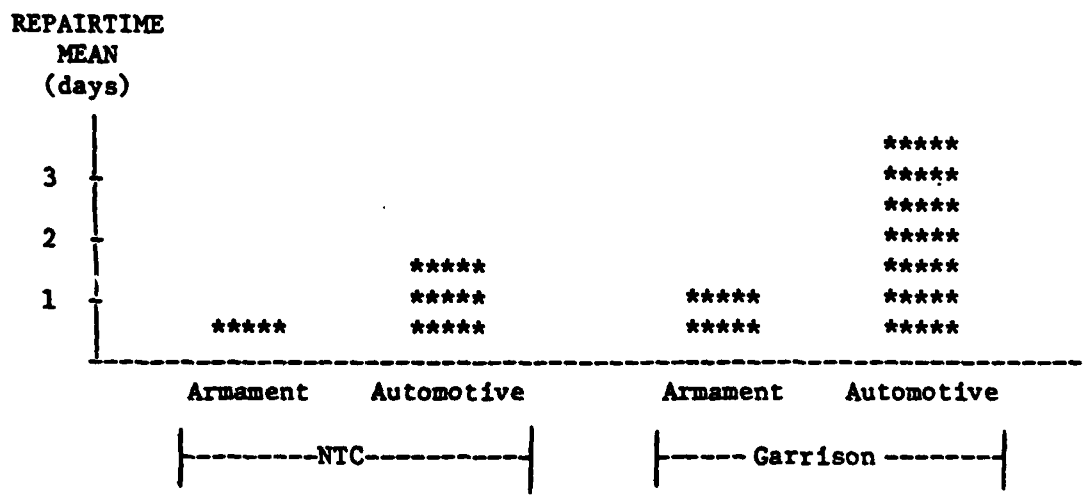

Figure 8. Mean repair time (in days) at National Training Center (NTC) and in garrison for two MOSs.

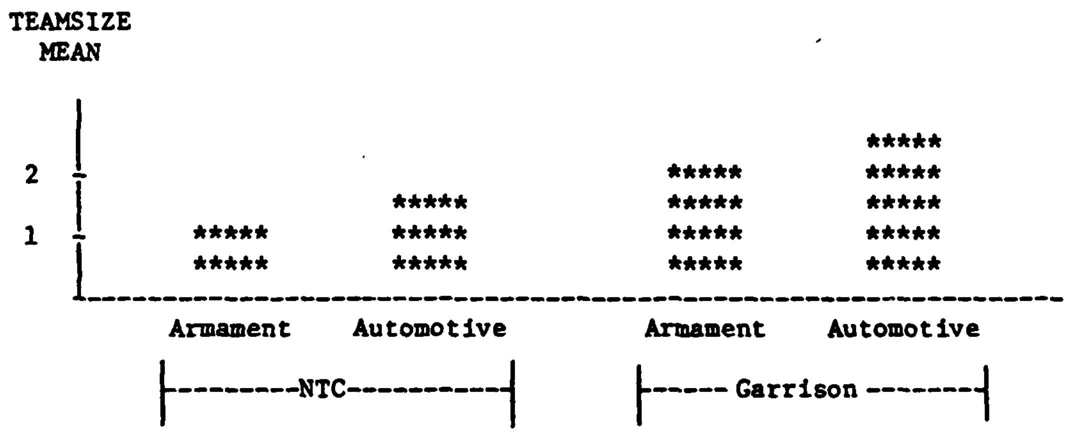

Figure 9. Mean team size at National Training Center (NTC) and in garrison for two MOSs.

One of the most important outcomes sought for MPS is to help break the pattern of early incorrect task performance by technicians because of lack of supervision and feedback on performance. MPS attempts to do this by identifying training requirements, highlighting early performance trials, and requiring overt task evaluation by supervisors. As MPS continues to provide high quality longitudinal performance data, ARI will seek to determine whether this is happening.

At present, ARI has found that the cost of operating MPS is acceptable to the units and that the MPS outputs are judged to be of considerable value. The most significant use of MPS to date has been to guide job assignments, especially for high density MOSs. With the information MPS provides, supervisors can readily identify who needs specific kinds of job experience; so that when mission requirements permit, proper use of the job environment for training and skill development can be achieved.

On a larger scale, MPS is regarded as the initial component in a total training system for the future. Current efforts are being directed toward extending MPS into computer-based training delivery. Based on MPS performance data, those tasks which need to be trained and matched better with the most appropriate training delivery system can be targeted. ARI has already developed several prototype computer-based maintenance trainers (see Johnson, Entwistle, and Gaddis, 1982; Johnson and Rouse, 1982) and is exploring the feasibility of a computer link between these devices and the MPS system. The promise of such a computer-based training management and delivery system is a reduction in both the training cost and training time.

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