became increasingly concerned with productivity in terms of ton miles and similar measurements. The equipment managers, on the other hand, tended to concentrate on technical aspects of equipment. At the lower end of the equipment and highway maintenance hierarchies, many equipment operators believe equipment downtime is caused by improper equipment selection and poor maintenance, whereas many other mechanics believe that downtime is caused by operator carelessness and abuse. Most administrators in the highway maintenance field have had all too many opportunities to attempt to resolve personnel difficulties arising from these two points of view.

This controversy has undoubtedly existed since equipment operation and maintenance were first separated, but as long as fleets were expanding and new equipment was frequently purchased it did not have a particularly serious effect on work or employee efficiency. Since the early 1970s, however, when inflation started increasing faster than revenues, competition for the highway dollar has become greater. Equipment costs started increasing faster than the general inflationary trend, replacement programs slowed, and average equipment downtime started to increase. The equipment-using side of agencies became more conscious of unit costs and improving production by using large amounts of equipment but for shorter periods of time. There are equipment costs, however, that occur regardless of use, and hourly rates of use rose rapidly. Fewer dollars, higher charges, and more downtime could only result in worsening relations and increasing turmoil between the highway maintenance personnel and the equipment specialists.

The disagreements that naturally arise between two segments of an organization that have different goals and only one source of insufficient funding cannot be eliminated, but they can be greatly reduced by a logical approach to the problems that create the disparity of opinion. In this case, only a businesslike, precise, well-designed, and responsive equipment management system will suffice. All costs of equipment must be collected without exception; and, based on these costs, rental or use rates that are fully auditable and justifiable to everyone must be established. These rates should be dual in nature, and charges should be made based on daily possession of equipment for fixed costs such as depreciation and insurance. No possession charge should be made for equipment that is inoperable or unavailable for use, and consequential costs should be absorbed by the equipment section. On the other hand, maintenance managers who are working with correctly structured budgets and who are charged realistic rates for possession of equipment will have ample incentive to ensure that they have no more equipment than necessary. The operation portion of the rate must also be precise and accurately reflect true costs. Obviously, collecting and assigning all costs and correctly recording all use require that joint decisions be made by equipment managers and maintenance managers as part of the development of an effective equipment management system. This cooperative effort is a major step in reducing the effect of the adversary relationship of the two sides.

Not only will improved relationships and better efficiency result from a soundly designed equipment management system, but also direct and sizable financial benefits will accrue to the parent organization. As an example, one only needs to compare the fuel cost per hour between the bestand poorest-operated and maintained equipment to realize the possible savings to an agency that employs properly trained drivers operating correctly maintained equipment.

In summary, the common ground between the equipment manager and the maintenance manager is concerted action to hold down equipment costs, but only a correctly constructed and operated use-rental rate system will suffice as a tool. In addition, each manager must be assigned responsibility for work performed by his or her organization and funds budgeted for its performance.

Publication of this paper sponsored by Committee on Maintenance Equipment.

Development of Parts and Materials Inventory System

DOUG NIELSEN

The Parts and Materials Inventory Subsystem (PMIS), one of four interrelated subsystems in the equipment management system under development by the Arkansas State Highway and Transportation Department (ASHTD), is described. The established user objectives of PMIS are to (a) maintain parts inventory balances, (b) support established fill-rate objectives, (c) set efficient limits on stock levels, (d) control stock replenishment actions, and (e) evaluate inventory management performance. Additional desired features include interdistrict checking to locate a needed item stocked elsewhere in the state and error-free distribution records for accounting. Due to various inadequacies in the existing method of numbering stock, new numbering schemes were devised for all inventory items and stockpile locations. All stock items and locations were then converted to the new numbers. The PMIS design specifies on-line computer terminals in each district stockroom to process normal accounting transactions and meet user needs. Inventory transaction information is input at the district and subjected to detailed editing to ensure data integrity. Balancing and editing routines permit all error correction to be made at the data source. Various stock management reports are provided in on-line and batch modes for district and Central Headquarters. PMIS operations were tested in two ASHTD districts. Prearations are under way for statewide implementation.

In April 1979, the Arkansas State Highway and Transportation Department (ASHTD) entered into a contract with the Federal Highway Administration (FHWA) to test and evaluate an equipment management system (EMS) based on an EMS Manual developed by a consulting firm under another FHWA contract. Since an EMS must be tailored to the particular needs of the user, ASHTD was authorized to make whatever changes in the Manual recommendations it deemed necessary to accomplish this task. The contract term is three years, and FHWA is funding approximately 25 percent of the total cost.

An interdepartmental project team was formed within ASHTD to plan and carry out implementation of the EMS and monitor progress. The team is composed of representatives from the Fiscal Services Division, Computer Services Division, and Equipment and Procurement Division. Advising the project team are personnel from the Maintenance Division, several districts, and the Internal Audit Section.

Several functions must be dealt with in an EMS to achieve desired equipment use. This involves various equipment-related activities, such as acquisition, assignment, daily use, preventive maintenance, repair, and eventual removal from use and disposal. In addition, the consumption of various resources, such as labor, parts, fuel, and outside services, must be considered.

EMS SUBSYSTEMS

To meet the information requirements to manage this multifaceted operation, the ASHTD EMS is composed of four interdependent subsystems. These subsystems are being developed and implemented on a priority basis determined by ASHTD's existing systems and areas of most pressing need. Each of these individual systems is briefly examined below in the chosen order of development.

Parts and Materials Inventory System

The Parts and Materials Inventory System (PMIS) will maintain a file of all equipment parts and other materials stocked throughout ASHTD together with balances on hand at each stocking point. The system will periodically analyze parts use, recommend stock levels and reorder quantities, and produce stock replenishment notifications when stock balances fall below established levels. PMIS will relay parts and materials cost data to two other EMS subsystems: the Equipment Maintenance and Operations Cost System and the Equipment Cost Accounting System.

Equipment Maintenance and Operations Cost System

The Equipment Maintenance and Operations Cost System (EMOCS) will collect all direct equipment ownership (purchase cost, depreciation, etc.), maintenance (labor, parts, etc.), and operations (fuel, oil, etc.) cost data and maintain histories of charges to each unit in the equipment inventory. To permit computation and reporting of per-mile and per-hour costs, the system will also maintain current levels of equipment use.

Data necessary for most of the analytical reports required by equipment managers at all levels will be stored by EMOCS. Cost analyses for equipment replacement decisions, preventive maintenance program evaluation, and repair shop staffing and resource allocation will be generated by this system.

Incorporated into this system will be the primary means for controlling scheduled repair and inspections, nonscheduled maintenance, and repair backlogs. It will record actions taken to expedite parts and repairs for units that have been out of commission for long periods. The system will provide control of equipment downtime and responsibilities related to equipment maintenance.

EMOCS will draw charges for parts issued to equipment from PMIS. In addition, it will collect equipment cost data, such as depreciation, from the Equipment Cost Accounting System and, in turn, will supply data for allocating indirect and overhead costs to the Cost Accounting System.

Equipment Cost Accounting System

The Equipment Cost Accounting System (ECAS) will provide an interface between existing accounting systems and the cost collection and analysis systems developed specifically for equipment management purposes. It will permit the collection of all indirect, overhead, and administrative costs related to equipment ownership, operation, and maintenance and will distribute them to equipment classes for budgeting and cost-reporting purposes.

This system will collect direct costs obtained through EMOCS and data to allocate indirect overhead costs. It will thus provide the means for developing and charging comprehensive equipment rental rates, developing program budgets, and reporting actual cost performance against these budgets. Finally, this system will feed necessary expenditure data to inventory and depreciation accounts.

Equipment Control System

The Equipment Control System (ECS) will maintain a master inventory of all equipment in the complement and provide the means to record changes in the inventory and in equipment assignments. Equipment unit records will include significant descriptive data on equipment units, current assignments and location, and current and recent levels of use. The system will generate reports that show equipment assignments and analyses of equipment use.

Use summaries will be produced to permit the development of rental rate charges. Input from the ASHTD Maintenance Management System will permit maintenance-crew equipment needs to be evaluated and complements to be established. The equipment planning component of the ASHTD Construction Management System will be used to establish Construction Division equipment needs.

Several equipment control procedures already existed in some form within ASHTD operational procedures prior to EMS development. Most of these, however, were not dependent on or coordinated with other equipment programs; they were complete units in themselves. EMS will collect and update these elements and expand into other areas to form one cohesive, interrelated system.

PMIS

For the sake of internal organization and distribution of the workload in the ASHTD Computer Services Division, two project leaders were designated to coordinate the design and programming of various EMS phases: one for PMIS and the other for the remaining three subsystems.

Due to user concern over the inadequacies of the existing inventory system, PMIS was given the highest development priority. The bulk of our development work to date has been on this subsystem, and it is the primary focus of this paper.

The initial task of PMIS development was to get the users of data from the subsystem to list the objectives that they felt PMIS should address. The basic objectives of PMIS were to

1. Maintain parts inventory balances,
2. Support established fill-rate objectives,
3. Set efficient limits on stock levels,
4. Control stock replenishment actions, and
5. Evaluate inventory management performance.

Additional desired features included

1. Interdistrict checking, which provides a method for determining whether any district stocks a part another district needs and whether they actually have any on hand;
2. Capability for establishing and showing reorder points for stock when a minimum level is reached; and
3. Error-free distribution records for accounting.

The capability of interdistrict checking and maintaining stock at an optimum level will reduce repair backlogs and equipment downtime and increase labor productivity and use of shop space. Interdistrict checking and centralized stocking will free the districts from stocking slow-moving, high-cost items. Error-free distribution will improve the integrity of equipment history and, by means of the various equipment management reports, point out problem areas that need attention.

The old automated inventory system was set up 15 years ago for equipment parts. Maintenance materials were maintained on a manual perpetual index-card system. The numbers in the old system were assigned consecutively without attention to grouping of related items. This permitted duplication of numbers. The ASHTD number had no particular significance other than uniform length and format.

One of the requirements of the new inventory system was to devise a new numbering scheme that would accurately identify parts and provide consistency. The numbering scheme chosen consists of eight numerical characters. The first two numbers designate the major group, the second two designate the subgroup, and the last four digits are the sequence number for that item.

The major group identifies the major category of use: e.g., 01--Road Surface Material, 07--Safety and First Aid Supplies. In equipment parts, the major group is a variation of the rental code given to each class of vehicles:

30 Passenger Type and Light Utility Vehicles
41 Crawler Tractors
45 Expendable Supplies (tires, batteries, etc.)

The subgroup further specifies the area of use:

01 Air Induction System
07 Engine
15 Suspension System

For example, disc brake pads for a 1981 Oldsmobile Cutlass are numbered 30180695: The number 30 designates the major group, Passenger Type Vehicles; 18 indicates the subgroup, Wheel and Brake System; and item number 0695 specifies the particular item.

In order to provide a method of isolating various types of stock, a uniform stockpile location numbering scheme was devised. The stockpile location numbers also provide the districts with a means to control stock at the various levels of responsibility. Area foremen are responsible for stock in their counties; the storeroom supervisor is in charge of the parts warehouse, the sign room, and the district yard and can isolate various stock items by the location numbers.

All stock locations throughout each district are identified by a two-digit location number. The following numbers were preassigned for stock maintained at the district headquarters:

01 Parts Storeroom
02 Parts Warehouse
03 Sign Storeroom
04 Salt Storeroom
05 District Storeroom
06-09 Other discretionary stock locations at district headquarters

Sequences of 10 two-digit numbers are assigned to locate stockpiles in each county. The first number in the sequence designates the area headquarters yard in that county. For example, Crittenden County is assigned stockpile location numbers 10-19 in district 1, and 10 designates the Crittenden County area yard. The storeroom supervisor in each district is responsible for keeping up with the stockpile location numbers.

Once all requirements and desired features of PMIS were defined and the item and stockpile location numbering schemes were complete, the team began the process of designing the system of programs necessary to meet user needs. The design specified on-line computer terminals in each of the district stockrooms to provide the system's two primary functions:

1. Processing the normal accounting transactions for issues, receipts, and adjustments while maintaining proper inventory balances and
2. Analyzing parts use and generating stock management information.

As transactions take place, the data are posted on forms that serve as source documents from which the information is keyed into the terminal. The actual keying of the data on the terminal is a new experience for the stockroom personnel. The speed of entry, compared with centralized data entry, has decreased somewhat, but the accuracy of the input data has increased. The timeliness of the data has increased tremendously since the time lost by mailing transactions and corrections has been eliminated.

There are screens for each type of stock transaction: issue, receipt, and direct (outside purchase). For each transaction type, there are separate panels for distribution to tag equipment; county, route, and section; job and federal aid project number; special projects; buildings; rest areas; bridges; resident engineers; and no distribution (used for stock adjustments and nondistributive administrative charges). Each panel has space only for that specific information.

These 19 separate panels were provided so that the data could be entered easily and user exit programs could perform detailed edits on each specific type of distribution. The specialization of these programs ensures data accuracy without a great degree of complexity in the program code.

As the transaction is transmitted, the central computer edits the data for accuracy and returns any errors. Incorrect fields are highlighted, and an error message is shown on the last line of the screen. After each correction, the data are again edited in entirety for errors to prevent any previously correct information from being changed in error. These edits force the user to enter the data as correctly as possible at its source, the district office. Corrections are made by the people who can check the information sources for corrections.

After the district sends a page of data, the page total is entered. The computer will then tally item numbers (called the hash total), quantities, and money for the page. If any of the totals vary, the entire page of data is returned to the district as out of balance. District personnel must then check to see whether all transactions were sent and the correct amounts were entered.

Two media are used to supply information to the various levels of users: on-line and batch. When the amount of data is small and specific and response time is critical, on-line terminal inquiries are used. When details or large volumes of data have to be processed, batch reports are used. As hardware improvements are made and program expertise improves, more applications may be changed from batch to on-line or to a variation of remote job entry.

For the benefit of stock management at the district level, there are screens for description inquiry and detail inquiry. The description inquiry screen displays the item description, specification, manufacturer name and number, old inventory part number, expenditure object, unit of measure, rental code, and cross reference. The detail inquiry screen displays the item description; stockpile number; manufacturer number and name; unit of measure; bin location; on-order quantity, requisition number, and requisition date; last date issued; last date received; requisition number; minimum and maximum stock levels; review point; quantity on hand; unit price; and total dollar value on hand.

Some of the batch reports provided for the districts are as follows:

1. The Consigned Stock List lists all items stocked by each budget in order of stockpile location. Since the area foremen are responsible for the verification of the quantities on hand, a report without quantity and money, with space for these entries, is provided on the last day of each month. The foreman's actual counts are then verified to a run with quantity and money supplied to the districts at the close of the month.
2. The Inventory Listing by Bin Location lists the item number, manufacturer number and name, description, unit of measure, object, bin location, quantity on hand, unit price, and dollars on hand in the bin order in which they are stocked in that particular stockroom. Variations of this program give the district or audit the ability to specify blank quantity and money for auditing, listings for certain aisles or bins for spot verifications, or certain stock locations for checking all stock in that area.
3. There are several microfiche catalogs of the description file: (a) catalog by item number, (b) catalog by manufacturer, (c) catalog by description, and (d) catalog by old ASHTD part number (for conversion only).

Programs for district bookkeeping and fiscal services are as follows:

1. The Inventory Transaction List by Type and Date lists all transactions for each budget by type (receipt, issues, direct) and by date and page.
2. All receipts and directs by requisition number and category are listed in the Inventory Stock Received Journal, which replaces the previous manual posting of this bookkeeping journal.
3. The Inventory Stock Issue Journal carries actions by date for six categories of expense and eliminates the manual posting and tabulations required in the past to prepare this bookkeeping journal.
4. The Out-of-District Equipment Upkeep and Stock Transfers report lists the transaction data for stock charges made to budgets or tag vehicles from other than the originating budget.
5. The Inventory Detail Tab by Budget report lists all stock for each budget and gives a total of both quantity and dollar value on hand.

Programs for procurement and stock-level control are as follows:

1. The Stock Below Minimum report shows all stock items in a district for which the quantity on hand is below their specified minimum.
2. The Stock Above Maximum report shows stock above maximum.
3. The Inventory Stock Activity by Quantity report shows the total quantity used for each item number by district.
4. The Inventory Stock Activity by Dollars report lists the total dollar amount of all issues by item number and district.

There are screens for adding, changing, or deleting parts numbers, descriptions, manufacturer names and numbers, or unit of measure. All of these functions are performed by one individual, the inventory coordinator, located at the Central Headquarters.

As development of the EMS progresses and after a reasonable transaction history file is built, parts use will be used to provide guidelines for establishing fill rates, limits on stock levels, and replenishment activities.

Once PMIS development was complete, it was decided to test the system in a pilot district. Restricting operation of the new system to a small representative group would allow the project team to fine tune the system and more easily address any problems that arose. Actual user feedback could then be incorporated. All operational problems could be resolved before statewide implementation. District 6 at Little Rock was chosen for the initial pilot test because of its proximity to the Central Headquarters. District 7 at Hope was later added as an extension of the pilot testing.

The conversion to the new PMIS was divided into two segments: maintenance stock and equipment repair parts. The old maintenance stock system consisted of a manual index-card file that had the unnumbered items in alphabetic description order. There was lack of uniformity in the actual descriptions and in the semantics used for the same items. However, the card system did provide the capability to verify quantities on hand, unit prices, last issue, last receipt, or last several transactions, since the retrieval of one stock card put all this information in the hands of the stockroom personnel.

Due to this lack of uniformity, the manual task of numbering maintenance stock was very tedious and time consuming: It took about 16 h to number a district's 1500 maintenance items. There was some skepticism among the users about the currentness of data. The old automated Parts Inventory System was a batch system and, due to the time delays in mailing, manual coding, and verification, the actual inventory balances were not reported until 15-20 days after the end of a month. To verify balances on hand, the districts had to reconcile the latest inventory run and the in-transit transactions. In these respects, the maintenance index-card system outperformed the old automated system. Skepticism concerning data accuracy and apprehension as to how central office management might control a district's stock were two of the greatest obstacles the design team had to combat in persuading the users to accept PMIS.

The conversion of the old automated equipment parts system to PMIS was an easier task. Although considerable effort had been expended to eliminate duplicates in the old system prior to conversion, additional duplicates were discovered at conversion. Still, cross-matching was fast and uniform since a number did exist.

The cleaning, purging, and identification of duplicates in the old system took several employee hours. Then the identification of the group and subgroup for each old number became a time-consuming task for several specialized employees using various reference manuals before some parts could be specifically identified. Once a new number had been assigned to all items, catalogs by manufacturer number and description were checked for duplication.

The actual match of a district's stock was merely a sequential match of the old inventory to the new inventory file. Once a match was found, the new item number was issued with the quantity on hand and inventory dollars to create the new inventory file. The user only supplied the bin number by old part number.

After the district's file had been converted, runs were prepared in new number order, old number order, bin order, and manufacturer number order, and all new PMIS catalogs were supplied.

Since the old system was not up to date with the inventory balances, 100 percent audits were made of the quantities on hand. The new system supplies the report used for auditing in bin number order. This report actually reduces the physical count time from about 7 h with the old procedures to 3 h with the new.

The ASHTD Internal Audit Section completed a review of PMIS design documentation and operational procedures. The final report indicated that auditability and control are adequate.

The two pilot districts have conducted periodic inventories of a percentage of their stock as prescribed by ASHTD policy. These partial inventories yielded the least variance ever achieved between actual and book figures in those districts. The pilot districts balanced their year-end inventory within a day of the end of the fiscal year whereas all other districts required about four weeks.

Authorization to proceed with statewide implementation of PMIS has been requested. That decision is being delayed pending legislative action on additional highway funding.

Publication of this paper sponsored by Committee on Maintenance Equipment.

Abridgment

Routine Maintenance of Highways in Member Countries of PIARC

HENRY DeLANNOY, ALAIN LABEAU, JEAN REICHERT, AND CLAUDE FRÉDÉRIC

The techniques currently used for routine road maintenance are described on the basis of data from the member countries of the Permanent International Association of Road Congresses (PIARC). The planning and control of these works are examined. Details are given regarding the established administrative structure (maintenance districts and maintenance centers) and personnel training. Finally, the financial management of road maintenance is dealt with from the point of view of maintenance costs and analytic accounting. The following areas of needed improvement are noted: greater cost-effectiveness of specific maintenance techniques, the development of more durable materials, the necessity of an overall maintenance strategy, and the continued improvement of analytic accounting.

In member countries of the Permanent International Association of Road Congresses (PIARC), as a result of advances in vehicle ownership and the development of road network equipment, the problems presented by road maintenance have required a total reorganization of the methods used. In Great Britain, the Marshall committee, taking this reorganization as a basis, studied organization and maintenance standards. In France, efforts were for a long time aimed at strengthening strategies for the national road network, while at the same time the Federal Republic of Germany achieved the highly mechanized organization of its motorway maintenance centers.

Nevertheless, it has been felt necessary to adopt a systematic and rational approach to the formulation of overall maintenance strategies. Although maintenance budgets have traditionally been drawn up on the basis of the budget for preceding years, it has now been confirmed that the establishment of these budgets with respect to levels to be achieved is desirable. Currently, the procedure used in most countries combines both approaches.

TECHNIQUES

As a result of the increase in traffic and the degree to which roads are equipped, it has proved to be necessary to work out maintenance techniques that are both more suitable and more economical. The improvements made in these techniques have to do chiefly with the increasing mechanization of works, which in turn is the result of more efficient plant better adapted to maintenance tasks and the use of improved materials.

Patching is in most countries the largest item in day-to-day pavement maintenance. Patching may be used to remedy local deficiencies of a pavement in good condition and also to maintain minimum service levels over a short period on a damaged pavement for which major repairs have been scheduled. Ways of mechanizing the process to the greatest extent possible are currently being studied.

The patching of flexible pavements consists of making emergency repairs of defects such as potholes, local depressions and cracks, or incipient peeling, by the following methods:

1. The means involved in temporary patching are very limited: cleaning with a brush, spreading with a shovel, and tamping with a rammer.
2. Permanent patching consists of removing the unstable material by cutting with a saw, filling the cut with a bituminous material, and completing the operation by laying a bituminous surfacing mix. Special bituminous mixes are being tested in the Federal Republic of Germany and in Finland.
3. The sealing of surface cracks is done with a coat or with a thin layer of hot-laid sheet asphalt.

As for the patching of rigid pavements, a current practice in a number of countries is the use of thin concrete layers for the repair of scaled and peeled surfaces.

The purpose of sealing the joints in cement concrete pavements is to prevent the infiltration of water into subjacent layers and to prevent aggregate from entering the joint. A distinction is made between (a) local repair, which is often carried out by government agencies and consists in cleaning the joint and applying a warm sealant, and (b) general repair, which is often executed by a specialized firm and consists of stripping the sealant out of the groove, cleaning the groove, and applying new sealant.

For sealing, three main types of materials are used: (a) hot-injected sealing compounds (most commonly used), (b) cold-injected mastics (used only for local maintenance), and (c) rubber (neoprene) compressible strips (used in new construction).