what reason, and how long, and (i) other data necessary due to local operating conditions;

5. Systematic maintenance planning for preventive and periodic maintenance based on the data collection and analysis proposed in guideline 4;

6. Specific maintenance personnel assigned to inspection and repair of transit vehicles; and

7. Minimum training requirements and competency qualification for maintenance personnel.

Clearly, in light of the present economic conditions in public transit, the proposed guidelines must be accompanied by the proper direction and level of assistance from the appropriate local and state agencies. Guidelines 2, 3, 4, and 6 can be implemented by the operating properties with minimal disruption and outside assistance. The remaining three guidelines--1, 5, and 7--will require a certain amount of assistance for implementation. Such an effort is now being undertaken as an extension of this research by the Public Transportation Division (PTD) of the Virginia Department of Highways and Transportation. The implementation of guideline 1 will be assisted by the current actions of PTD, in conjunction with the Virginia Association of Public Transportation Officials, to develop a transit information exchange program and management seminar series at the state level to deal with maintenance. Guideline 5 is being supported by the efforts of PTD to initiate a vehicle maintenance management information system study effort and demonstration program at a medium-sized property. Once developed and implemented, this system will be made available to the other transit operations within the state. Finally, guideline 7 is being supported by the ongoing efforts PTD is sponsoring to define and refine the possible alternatives for providing training assistance programs in transit bus maintenance to all Virginia operating properties. These actions will give the transit operators the assistance they need to combat external factors that affect maintenance performance and provide accountability for capital funding grants.

ACKNOWLEDGMENT

We are grateful to the public transit systems in Virginia that cooperated in this study. Special acknowledgment is made of the assistance given by the transit maintenance management personnel, who also provided valuable insights concerning their maintenance operations.

Acknowledgment is due M.D. Kidd for his support of this project, helpful suggestions, and review of the draft of this paper. The interest, support, and guidance of R.N. Robertson during the study and preparation of this report are also sincerely appreciated.

Sincere appreciation is expressed to Jan Kennedy and Jean Vanderberry for typing and Harry Craft for patient and skillful editing.

The study was financed with highway planning and research funds administered by the Federal Highway Administration. The opinions, findings, and conclusions expressed in this paper are ours and not necessarily those of the sponsoring agencies.

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Publication of this paper sponsored by Steering Committee for Workshop on Bus Maintenance.

Louisiana's Equipment Replacement Dilemma

G.L. RAY

The Louisiana Department of Transportation and Development is currently in the second year of a three-year equipment improvement program. The Legislature approved the program based on an economic analysis that indicated that a 20 percent annual savings was possible. Net savings will accrue after a four-year period as a result of increasing capital investment to reduce the cost of equipment operations, assuming the economic predictions are used. An accumulated unit cost curve is maintained on each individual machine and, along with repair limits, is used to identify the critical repair that makes an equipment unit uneconomical. This critical repair concept is the basis for identifying the optimum time to replace each unit. The method has accurately predicted the optimum replacement point in 96 percent of the cases and allows for ranking of replacement needs in priority order so that available funds can be used most effectively. Although this concept is economically sound, there are many obstacles in the path to implementation. Implementation has been difficult at the field level because of the dilemma surrounding replacement decisions. Since an average one-year lead time is required to obtain new equipment, replacement equipment is not normally available at the time of failure. Managers are rarely able to retire a unit and await replacement. This dilemma is compounded by the buildup of a replacement backlog over a period of many years. Of a 7500-unit equipment fleet, almost 3500 units are beyond the economic replacement point, which further complicates the manager's dilemma. For this program to succeed, the field manager must thoroughly understand the dilemma posed by the replacement decision and be willing to support the computer-assisted projections based on faith in the statistical accuracy of the system.

In Louisiana, management control of the equipment fleet of the Louisiana Department of Transportation and Development is exercised by the Division of Maintenance and Field Operations. Central control of the statewide fleet is the responsibility of the director of maintenance and field operations, who delegates routine decisionmaking authority to the chief maintenance and operations engineer. Service facilities are located in nine Department of Transportation and Development districts under the direction of a district administrator. Planning, budgeting, systems development, experimental programs, and other centralized functions are directed by the maintenance systems engineer, who reports to the chief maintenance and operations engineer. Equipment acquisition, disposal, specification development, replacement control, and budget control are performed by the equipment engineer, who reports to the maintenance systems engineer. Parts are supplied by contractor-operated parts stores located in each major repair facility. Equipment is assigned to an individual or an organizational unit, and cost is distributed via a rental rate as use is reported. New equipment is purchased through a central fund controlled by the equipment engineer. All replacement funds are budgeted centrally by using projected needs identified by the equipment management system. Zero-based budgeting techniques are used to evaluate budget alternatives and communicate these alternatives to the Legislature.

REPLACEMENT COSTS

Equipment costs can be subdivided into two general groups: fixed costs and variable costs. Variable costs can be further subdivided into those costs that are proportional to use and those costs that compound with use. Variable costs that are proportional to use should not affect the replacement decision if the challenging machine can be expected to experience similar costs (1). Expenditures for tires, tubes, batteries, blades, fuel, and lubricants are examples. Costs that influence the replacement decision are those costs that compound with use, such as repair parts, repair labor, contract work, and reliability costs. Fixed costs are incurred regardless of the amount of use. Depreciation has a fixed-cost component and a variable-cost component but tends to be predominantly fixed. Depreciation was considered a fixed cost for this analysis because a variable-cost relation could not be established for many types of equipment. These categories of expenditures are used in the replacement model described in this paper.

Reliability costs require additional explanation. As a machine ages and repairs become more frequent, one expects downtime to increase. If downtime costs can be adequately defined and measured, the loss of a machine's reliability as it ages can be included in the replacement analysis. Downtime in the field is extremely difficult to measure and account for because equipment-related delays do not necessarily cause delays to planned maintenance activities. The disruptive effect of equipment downtime can often be countered by supervisor action, including preplanning of alternative activities, use of substitute equipment, and use of alternative procedures. Downtime in the shop, however, can be accurately measured and a cost penalty applied for inclusion in the replacement analysis. If it can be assumed that enough second-line units are available to mitigate the effect of downtime, the cost of shop downtime becomes defined by the cost of maintaining second-line equipment. This is the procedure used in Louisiana to inject this consideration into the replacement analysis.

The cost of depreciation also requires some elaboration. Many different depreciation formulations are used by industry. These formulations are usually selected based on the tax strategy of the individual organization. Because a government agency does not have a tax strategy to consider, it was felt that a depreciation schedule that predicted actual cash value should be the method of choice. Actual cash value was determined by studying various "blue books" and guides that reflect market trends. Once a depreciation curve was constructed for each equipment type, this curve was compared with the results of departmental auctions. Since these results are only available for the latter portion of a machine's life, the relation derived from market studies was forced through the average sales point to describe a curve that would approximately predict actual cash value to the Department. Once depreciation was determined in this manner, these costs, along with the costs outlined above, were used to develop a replacement methodology.

REPLACEMENT METHODOLOGY

Since all replacement models require assumptions about the future, the perfect replacement formulation has not yet been devised. Considerable effort has been expended to establish a practical replacement criterion for departmental equipment that effectively weighs the economics of replacement. Initially, the work focused on the evaluation of different replacement concepts. Two basic approaches were studied from the viewpoint of simplicity and accuracy: a group replacement policy and an individual replacement policy. An individual evaluation of equipment resulted in a projection of minimum cost that was more accurate than a group evaluation by a factor of approximately 19 percent. This factor was developed by simulating the use of various replacement criteria on a sample of wheel tractors that had been retained longer than 15 years. The sample average minimum cost was computed and used to evaluate each simulated policy. The group replacement policy produced a minimum cost that was 19 percent greater than the minimum cost produced by the best individual replacement policy. A simple criterion for replacement was also found to be as effective as more complicated models in view of the economic parameters facing the Department (2).

The accumulated unit cost criterion described in several textbooks on replacement theory proved to be an effective method of dealing with a wide variety of equipment types (3). Accumulated unit cost curves were computed by dividing the lifetime sum of those costs known to compound with use by the lifetime summed use and monitoring this computation annually. This concept provided a simple technique for individually evaluating each equipment unit. The accumulated unit cost curve also allowed for predicting repair limits simply by projecting the following year's use. The selected replacement criterion is shown in Figures 1 and 2, which depict a series of accumulated cost curves for a continuing chain of like replacements. The theory is explained by two alternatives, A and B. Alternative A, replacement at the actual minimum cost point, results in three replacements over 6000 h of use at points A1, A2, and A3. Alternative B, replacement after the actual minimum cost point, results in two replacements over 6000 h of use at points B1 and B2. The accumulated unit cost of alternative A, TA, is \$1.31/h. The accumulated unit cost of alternative B, TB, is \$1.32/h. It can be seen from Figures 1 and 2 that minimum total cost for a continuing chain of replacements occurs at the minimum accumulated unit cost for each machine.

At the completion of the conceptual design phase, three basic assumptions were made: (a) Interest and inflation would be considered at the fleet level, (b) the "challenging" machine would have essentially the same cost pattern as the "defending" machine, and (c) technical obsolescence is insignificant in most instances. In practice, interest is irrelevant at the individual unit level because the objective of the analysis is to minimize the total cost of equipment operation. A present-cash-flow analysis is used in Louisiana at the equipment unit level and has proved to be simple, effective, and easily understood. Since inflation and interest tend to be

Figure 1. Accumulated unit cost replacement model, alternative A: replacement at minimum cost point.

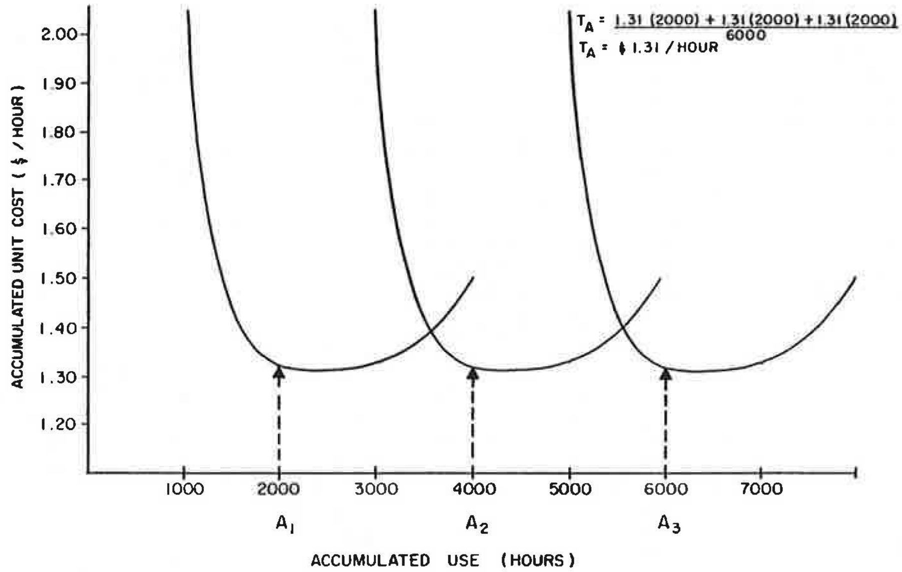
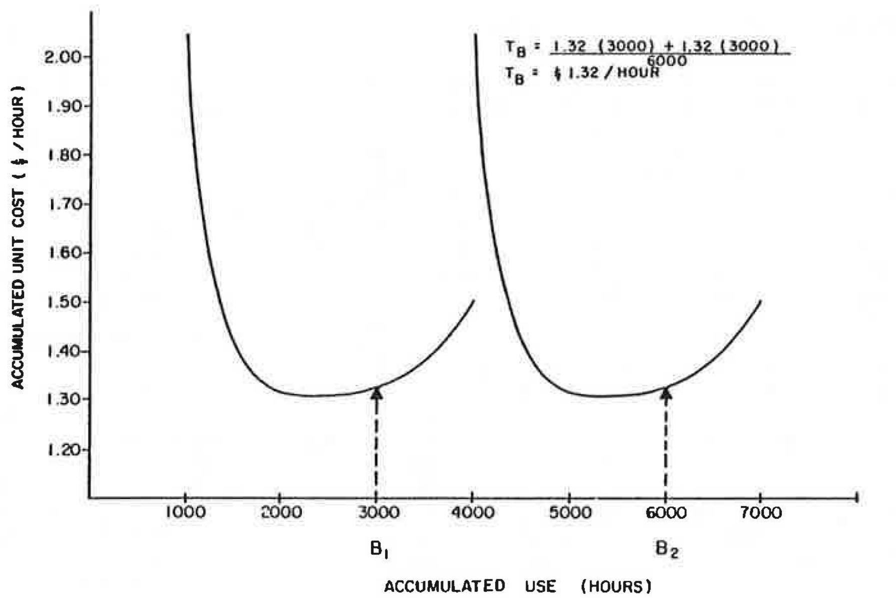


Figure 2. Accumulated unit cost replacement model, alternative B: replacement after minimum cost point.



additive factors, inflation is usually considered in the selection of an interest rate. Inflation is predictable from historical trends and has been included throughout this paper. If an appropriate interest rate can be determined, it will be included at the fleet level. The assumption that the challenging machine will have a cost pattern similar to that of the defending machine (disregarding technical obsolescence) is as good as any other assumption that involves events five or more years in the future. In practice, cost curves are extremely variable between successive replacements and this variance cannot be predicted with certainty. The cost pattern is consistent, however, in that a single minimum point is usually observed over the life of the unit. Technical obsolescence is a significant factor in the electronics industry, but dump trucks and construction equipment are not developing as rapidly. There are exceptions, but they can easily be handled as the need arises. When technical obsolescence was an issue, a complete reevaluation of an entire activity was required rather than a simple comparison of equipment alternatives.

The principal weakness of the accumulated cost method was that the minimum cost point had to be exceeded before it could be identified. Repair limits helped to solve this problem (4, p. 337). Repair limits allow one to evaluate the replacement decision at any time prior to the minimum cost point by defining the annual cost that would cause the accumulated cost curve to reach its minimum juncture. The following equation was used to compute repair limits:

$$\text{Annual repair limit} = (\text{lifetime accumulated cost rate} \times \text{projected annual use}) - \text{projected annual depreciation} \quad (1)$$

Once repair limits were determined for each unit, equipment could be evaluated at the time of each repair to determine whether the repair could economically be made. This allowed for evaluation of replacement prior to a significant repair expenditure.

Since the Department could not fund the capital outlay requirements identified by the equipment management system without first developing a capital budget program, some method of priority of replacement had to be devised in order to make good decisions concerning the best use of scarce replacement funds. To accomplish this, the cost of having failed to replace at the optimum point was termed the retention cost. Retention cost is computed by subtracting the minimum cost rate from the current cost rate and multiplying the result by the accumulated use. The retention cost represents the total cost of having kept the unit from the minimum cost point to the present. This may be thought of as the cost error that results from having failed to replace at the optimum point. The fleet objective was to minimize the error--i.e., the retention cost--within the limits of replacement funds. A ratio of retention cost to predicted replacement cost was used to establish replacement priority. The higher ratio indicated a greater reduction of retention cost per available capital outlay dollar and placed that unit at a higher priority rank in relation to other units. Table 1 illustrates the priority disposal listing, which identifies units with similar replacement priority.

EVALUATION OF REPLACEMENT METHODOLOGY

In order to evaluate this system, a feedback measurement was required along with a performance standard. FY 1974 data were used to evaluate the accuracy of the selected replacement criterion and the effectiveness of current procedures on a fleetwide basis. Table 2 summarizes the pertinent information. The accuracy of the replacement model was measured by the error frequency. This was the number of times an equipment unit failed to produce a single universal minimum cost similar to that shown in Figures 1 and 2. Out of 2133 cases, this occurred in 91 instances, or 4 percent of the time. The cost error was even less than 4 percent because the cost curve tends to be relatively insensitive in the area of the minimum. Individual units were analyzed from the 91 errors found, and many of these errors were determined to result from severely curtailed patterns of use near the end of depreciated life. It was concluded that the selected model was a good approximation to an economic fleet replacement criterion. The accumulated equipment cost curve did, in fact, produce a universal minimum in the vast majority of cases. The idea that a recent high repair cost dictates retention of the unit until the repair cost is "recovered" is invalid 96 percent of the time if the minimum point has been reached.

Replacement or disposal of equipment should reduce the cost of routine equipment operations. Since current procedures could be evaluated by looking at cost errors due to improper replacement timing, the individual equipment cost curve was used to evaluate all active equipment. When an individual cost curve was increasing, the minimum point was obtained and the cost of having failed to replace at the minimum point was computed. The minimum point cannot be determined 100 percent of the time, but evaluation of the error could serve as a yardstick for comparison of present practice with alternative approaches. From Table 2, 35 percent of the listed equipment was replaced in FY 1974 but only 12 percent of the cost error was eliminated. These statistics indicate that an improved replacement model could result in considerable savings to the Department.

Some appreciation of the effectiveness of the replacement analysis can also be gained by studying Table 3. The FY 1979 cost of equipment identified for replacement in FY 1978 but retained due to inadequate replacement funding is given in relation to the cost of all other units. The retained units identified for replacement in 1978 amount to 35 percent of active units in 1979 but account for 56 percent of the repair parts costs and 59 percent of the downtime costs.

LOUISIANA'S CURRENT REPLACEMENT POLICY

In 1978, a departmentwide equipment management policy was published. The following points illustrate the principal objectives of this policy:

1. Departmental policy was defined as "to replace equipment on an economically sound basis."
2. The disposal list produced by the equipment management system would serve as the principal vehicle for identification of end of economic service life.
3. The district administrator or section head would ensure that all equipment on the list was reviewed and equipment that would no longer be replaced was deleted. Equipment remaining on this list would be placed on order.
4. As new equipment was received, the highest-priority unit of that type would be replaced. If the district administrator or section head felt that the analysis was in error, he or she could challenge the analysis by providing correct information or improved data (repair estimates).

This policy was an attempt to focus management attention on the facts and figures related to equipment replacement rather than rely on a totally subjective analysis. Although this policy is still in effect, the dilemma surrounding the replacement decision has resulted in marginal implementation.

REPLACEMENT DECISION

As previously noted, the replacement decision must be made when technical improvements dictate the acquisition of new equipment or when old equipment fails due to declining performance or excessive maintenance. Historically, technical evolution of most transportation maintenance equipment has been slow and deliberate; thus, technical obsolescence should be evaluated case by case. Replacement under conditions of declining performance and/or excessive maintenance was deemed worthy of analysis by computer-oriented processes so that timely decisions could be made.

Computer repair limits normally provide the first decision point related to replacement or retirement of a unit. Significant repair estimates cause shop personnel to consult repair-limit listings or computer terminals at district offices to determine whether limits are being exceeded. Once it has been determined that the proposed repair will exceed the established limit, several factors must be considered. Operational commitments will often mandate that the repair be performed regardless of economic considerations. Excessive acquisition lag time may also dictate a decision to repair. Ideally, the decision to repair a unit that is expected to exceed the repair limit should be reviewed fleetwide so that statewide priorities can be reconsidered.

Tables 4 and 5 compare units that were evaluated in FY 1981 based on current condition with units on the disposal list. The results show that the challenger units effectively displaced the defending units, assumed a higher priority on the disposal list, and were retired from operation. This evaluation normally takes place when new equipment is

Table 1. FY 1981 equipment priority disposal listing.

Rank	Equipment No.	Description	Age (years) Current	Age (years) Minimum	Rate Current	Rate Minimum	Cost ($) Retention	Cost ($) Replacement
366	130-343	Pickup	7	4	0.068	0.026	5 223	6 874
367	231-708	Sickle bar mower	6	3	7.974	5.035	6 686	8 803
368	262-107	Wheel tractor	15	7	1.867	0.384	7 551	9 944
369	130-035	Pickup	6	4	0.159	0.089	5 209	6 874
370	233-533	Slope mower (5 ft)	7	4	7.420	4.043	10 506	13 896
371	266-252	Backhoe/loader	11	8	17.236	5.420	14 664	19 398
		Dump truck						
372	140-818	Light	6	3	2.479	1.209	7 821	10 399
373	150-301	Medium	6	3	1.828	0.846	7 820	10 399
374	150-216	Medium	9	4	1.258	0.613	7 810	10 399

Table 2. FY 1974 equipment replacement analysis.

Equipment Series	No. of Units Requiring Disposal	Error Frequency	No. of Listed Units Actually Disposed Of	Retention Cost Reduction ($)	No. of Units Ordered	Potential Retention Cost Reduction ($)
Passenger	470	24	90	38 916.37	361	177 297.57
Hauling	599	16	115	83 518.62	180	486 431.49
Processing	260	15	8	6 568.92	24	242 827.23
Earthwork	180	5	11	33 238.73	21	473 165.04
Mowing	624	31	59	67 495.15	166	604 007.93
Total	2133	91	283	229 737.79	752	1 983 729.26

Note: Number replaced = 752/2133 = 35 percent; cost reduction = $229 738/$1 983 729 = 12 percent; expected error = 91/2133 = 4 percent.

Table 3. Evaluation of equipment replacement prediction.

District	Continued Economic Operation Predicted in FY 1978: Parts ($)	Downtime ($)	No. of Units	Replacement or Disposal Predicted in FY 1978: Parts ($)	Downtime ($)	No. of Units	Replacement Predicted Versus Total (%): Units	Parts	Downtime
02	68 000	269 000	275	63 000	317 000	159	36.6	48.3	54.0
03	144 000	172 000	437	233 000	379 000	308	41.3	61.8	68.8
04	180 000	111 000	482	198 000	133 000	246	33.8	52.4	54.5
05	109 000	217 000	487	114 000	214 000	199	29.0	51.1	49.7
07	125 000	90 000	456	153 000	178 000	247	35.1	55.0	66.4
08	109 000	164 000	454	160 000	227 000	229	33.5	59.5	58.1
58	77 000	49 000	324	111 000	66 000	190	37.0	59.0	57.4
61	115 000	107 000	406	220 000	174 000	288	41.5	65.7	61.9
62	144 000	251 000	395	210 000	444 000	248	38.6	59.3	63.9
41	75 000	120 000	313	68 000	144 000	146	31.8	47.6	54.6
Total	1 146 000	1 550 000	4029	1 530 000	2 276 000	2260	35.9	57.2	59.5
Department total	1 243 000	1 653 000	4409	1 568 000	2 335 000	2364	34.9	55.8	58.6

received but should be performed when repair limits are exceeded. Currently, the large backlog of uneconomical equipment prevents successful application of the procedure.

The procedure for physical acquisition and disposal represents one aspect of the replacement dilemma. The time interval between selection of the type of equipment to be ordered for replacement and the physical disposal of a unit is approximately one year. This means that prediction of the future is necessary in order to identify equipment to be ordered. Although the equipment management system has proved effective for this purpose, it is difficult for field personnel to ignore the current condition of equipment and make this projection based on statistics. Poor current condition usually causes managers to order a replacement unit. During the delivery period, extensive repairs may be needed due to the pressure of operational commitments. When the replacement unit is received, another unit in poor current condition is selected for retirement. This is not necessarily an economic decision and means that replacement planning and execution are based on current condition rather than on economics. Although the long-range economic factors more accurately predict total downtime and interruption to operations, this is not immediately visible unless one believes in the effectiveness of statistical analysis and prediction. Most field personnel are not trained in these sciences and are reluctant to believe these predictions on faith alone.

Consider the data on dump truck 140-818 given in Table 6. As one can see, the accumulated unit cost of this unit started out high and continued to decrease until a minimum point was reached, at which time the influence of repairs and downtime caused the accumulated cost curve to increase. The repair limit was exceeded in FY 1978, and the unit was placed on the disposal run and given a priority of 1397 of 2692 units. The following year, another repair required the expenditure of $746 for parts and moved the unit up to priority 1118 of 2681 units. The next year, a repair parts expenditure of

$4329 was required, and the unit leaped to priority 372 of 3250 units. If this dump truck could have been replaced at the time optimum replacement was identified, more than $5000 in parts cost alone could have been saved. Short-sighted analysis of current condition by field personnel is responsible for many similar cases.

Although some types of equipment tend to occupy high priorities on the disposal listing, each unit is analyzed based on its performance history. For example, mowing machines tend to have high priority levels while passenger vehicles tend to have low priority levels. This is because mowers usually have higher operating costs, higher downtime costs, and lower capital costs than automobiles. The priority analysis provides an objective method of ranking replacement need. This presents another dilemma.

Field personnel have been conditioned over the years to replace equipment groups each year. One year mowing machines are selected, the next year dump trucks, and so on. Evaluation of the facts indicates that this is a fallacious procedure. Mowing machines do not all fail in one year and dump trucks in another year. Grouping replacement in this manner builds in problems for the future. The field manager must learn to believe in the effectiveness of statistical analysis rather than in past procedure.

There are other problem areas that are related to the equipment shop. The "sunk cost syndrome" causes shop personnel to attempt to retain equipment well beyond its economic life because of previous repairs. There is a tendency to try to recover the cost of the last repair. When costs begin to compound, this thinking results in sending good money after bad, as Table 6 indicates. In order to effectively manage second-line equipment, pools must be established that require management effort for control. This adds management difficulty at the field level. It is much easier to distribute all equipment to the first-level supervisor and not worry about equipment pools and the scheduling problems associated with them.

Many equipment users suffer from an "in-case" disease. This is the desire to retain equipment in case it is ever needed. Since the fleet, unlike personnel, does not naturally decrease in size if no action is taken, machines will remain in the field and deteriorate. Finally, there is a natural tendency for equipment users to want to replace units that are awaiting repair without regard for the economics of this decision. The increased downtime that results produces greater user delays and higher costs than would be experienced if the economic model were used. These problems must be resolved by support from top management and training of field personnel.

Table 4. Evaluation of current condition: both challenging and defending units on disposal list.

Item	Defending Unit[a]	Challenging Unit[b]	
		Before Failure	After Failure
Repair estimate ($)	0	0	7 859
Priority	1.1	0.90	2.57
Rank	261	364	50A
Age (years)	10	6	6
Retention cost ($)	11 520	9 322	15 581
Total use (h)	12 013	4 610	5 378
Total cost ($)	17 431	18 963	26 822
Replacement cost ($)	11 950	11 950	11 950

[a]1971 International 1600 dump truck 140-512.
[b]1976 International 1600 dump truck 140-908.

Table 5. Evaluation of current condition: defending unit on disposal list.

Item	Defending Unit[a]	Challenging Unit[b]	
		Before Failure	After Failure
Repair limit ($)	0	465	465
Repair estimate ($)	0	0	1195
Priority	0.10	NA	0.11
Rank	2578	NA	2435A
Age (years)	10	10	10
Retention cost ($)	875	NA	1045
Total use (miles)	53 282	76 909	84 600
Total cost ($)	6 227	6 043	7 238
Replacement cost ($)	11 700	11 700	11 700

[a]1972 Dodge D200 0.75-ton pickup 132-418.
[b]1971 Dodge D200 0.75-ton pickup 132-364.

FUTURE PLANS

Department management is currently supporting the concepts advocated during development of the equipment management system. There are plans to meet with district administrators and conduct training sessions by using data available at the computer terminals and case-by-case analysis in an attempt to convince field managers of the effectiveness of the system.

The equipment that will be retained in FY 1982, in order to replace equipment that was lower on the priority list, has been identified. The districts have submitted plans for reducing the cost of this equipment. It is hoped that next year the predictions made by field personnel concerning these specific equipment units can be compared with the predictions made by the management system to help convince those in doubt that the accumulated cost economic model is a reliable prediction tool.

The expenditure of $250 000 to develop an equipment management system allowed the Department to present the alternatives given in Table 7 to the 1979 session of the Louisiana Legislature. The active fleet consisted of approximately 7400 numbered equipment units with the exception of marine units, aircraft, and units not suited to quantitative analysis. The equipment management system revealed that 2500 units, one-third of the fleet, with a current replacement cost of more than $36

Table 6. Cost history of a dump truck.

Year	Parts Cost ($)	Depreciation ($)	Downtime Cost ($)	Use (h)	Accumulated Unit Cost ($)	Repair Limit ($)	Priority (no. of units)
1975	135	1918	NA	713	2.88	5328	-
1976	244	320	NA	1310	1.29	3712	-
1977	1083	266	NA	1258	1.21	1411	-
1978	1758	266	485	1075	1.48	1186	1397 of 2692
1979	746	266	1304	1201	1.58		1118 of 2681
1980	4329	213	1933	603	2.48		372 of 3250

Note: 1975 International 1600 dump truck 140-818 (initial cost = $5328).

Table 7. Predicted effect of funding alternatives.

Fiscal Year	No. of Units	Replacement Expenditures ($)	Operating Cost ($)	Replacement and Operating Cost ($)	Accumulated Total Cost ($)
Alternative 1: Five-Year Projections Assuming Funds at Present Levels					
1977/78	7441[a]	4 591 789[a]	13 466 682[a]	18 058 471[a]	
1978/79	7213[a]	4 958 497[a]	15 615 874[a]	20 574 371[a]	
1979/80	7213	4 855 358[a]	18 100 000	22 900 000	
1980/81	7213	5 500 000	21 000 000	26 500 000	26 500 000
1981/82	7213	6 050 000	24 350 000	30 400 000	56 900 000
1982/83	7213	6 660 000	28 250 000	34 910 000	91 810 000
1983/84	7213	7 320 000	32 770 000	40 090 000	131 900 000
1984/85	7213	8 050 000	38 010 000	46 060 000	177 960 000
Alternative 2: Five-Year Projections Assuming Funds at Requested Levels					
1977/78	7441[a]	4 591 789[a]	13 466 682[a]	18 058 471[a]	
1978/79	7213[a]	4 958 497[a]	15 615 874[a]	20 574 371[a]	
1979/80	7213	4 855 358[a]	18 100 000	22 960 000	
1980/81	7213	13 200 000	19 140 000	32 340 000	32 340 000
1981/82	6500	14 520 000	21 100 000	35 620 000	67 960 000
1982/83	6500	6 660 000	21 640 000	28 300 000	96 260 000
1983/84	6500	7 320 000	25 100 000	32 420 000	123 680 000
1984/85	6500	8 050 000	29 120 000	37 170 000	165 850 000

Note: Replacement expenditures after FY 1981/82 adjusted for increase from current level at 10 percent rate.
[a]Actual.

Table 8. Capital funding plan: six-year projections assuming funds at requested levels.

Fiscal Year	Category[a]	No. of Units[b]	Replacement Expenditures[c] ($)	Operating Cost ($)	Replacement and Operating Cost ($)	Accumulated Total Cost ($)
1978	Actual	7441	4 591 789	13 466 682	18 058 471	
1979	Actual	7213	4 958 497	15 615 874	20 574 371	
1980	Predicted	7213	4 855 358	18 100 000	22 900 000	
	Actual	7248	4 040 431	19 807 445	23 850 000	
1981	Predicted	7213	10 048 483	22 980 000	33 030 000	33 030 000
	Actual	7268	9 940 304	23 664 586	33 604 890	33 604 890
1982	Predicted	6850	11 053 000	25 730 000	36 780 000	69 810 000
	Actual					
1983	Predicted	6500	12 159 000	28 820 000	43 290 000	113 100 000
	Actual					
1984	Predicted	6500	7 320 000	31 130 000	38 450 000	151 550 000
	Actual					
1985	Predicted	6500	8 050 000	33 620 000	41 670 000	193 220 000
	Actual					
1986	Predicted	6500	8 860 000	39 000 000	47 860 000	241 080 000
	Actual					

[a]"Predicted" as of October 10, 1980, when fleet upgrading changed from a two-year to a three-year program.
[b]Includes active equipment only and excludes attachments such as dump bodies.
[c]Replacement expenditures after FY 1982/83 adjusted 10 percent/year for inflation over expected FY 1979/80 level of $5 million.

million, had exceeded economic service life. Units that should have been replaced were not replaced at the optimum time because of a lack of capital outlay funds and the absence of an accurate method for economic analysis of replacement needs. Correction of the existing replacement backlog required a coordinated approach to (a) increase capital expenditure for two years to upgrade the fleet and clean up the backlog and (b) remove from the fleet all equipment with such a low rate of use that retention was not justified. The capital acquisition part of the plan would require $13.2 million annually for two years (adjusted for inflation). After the second year, acquisition costs were expected to drop to current levels. The combined repair shop and operating cost savings, including the initial higher acquisition cost, would result in net savings over a four-year period. If replacement of equipment were continued on an optimum cycle, savings would continue to accrue. These savings were estimated at approximately $6 million/year once the backlog of high-cost equipment was eliminated.

Although the capital outlay request was subsequently rejected because funds were lacking, the procedure was accepted as a step toward better government and more effective use of available equipment funds through better decisionmaking. The legislative dilemma has been to provide the "seed money" to cause savings to be realized. Initial investment in capital outlay for equipment to produce savings in later years represents a classic legislative problem. Better equipment management may produce lower cost, but it is not as readily visible to the voting public as are other competing capital outlay projects. The three-year term required to yield savings represents another problem for legislators, who may fail to return to bask in the success of this endeavor in the third year.

In FY 1981, the capital funding plan was modified by the Legislature to accomplish replacement over a three-year period instead of a two-year period (see Table 8). The first year of the plan was funded; this increased capital outlay funds by $5 million over the previous year. During the 1981 session, the second year of the plan was also funded. Funding of the remaining year will await evaluation of progress during the first two years of the program.

In spite of the many problems facing equipment managers, there is reason for optimism in Louisiana. The internal problem may be solved if the legislative problem can be overcome. The legislative problem appears to have been resolved by effectively communicating the benefits of sound equipment management to key decisionmakers. Resource management concepts have come to Louisiana with the objective of redesigning accounting and data processing systems so that users' needs for fast, reliable information can be addressed. A maintenance simulation model is being used to provide equipment managers at all levels with a means of evaluating equipment capacity and numbers with greater understanding and appreciation for the problems of operating personnel. Finally, inventory management with attendant equipment parts management potential is on the horizon and may be implemented as soon as the resource management effort is completed.

The Department believes that the issues have been faced squarely and an environment for improving equipment management has been developed. Support systems have been planned and programmed to provide the field manager with objective data on which to base fundamental equipment decisions. Flexibility has been built into the design to enable rapid response to improve concepts. The entire system has been tested and will work. It still remains to be seen whether field managers can actually produce the anticipated savings and effectively realize the potential created by this effort.

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Publication of this paper sponsored by Committee on Maintenance Equipment.

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Abridgment

Maintenance Managers Versus Equipment Managers: Their Adversary Relationship

MARTIN C. RISSEL

There is a natural adverse relationship between the highway maintenance hierarchy and the equipment procurement and maintenance hierarchy within the same highway agency as a result of the difference in their primary functions. Modern highway maintenance techniques require the use of substantial varieties and amounts of equipment. Due to declining availability of funds, maintenance managers are becoming increasingly cost conscious and more aware of all expenses contributing to total cost. Tighter control over activities has resulted in a decline in the per-unit use of equipment, and the income or transfer of funds to equipment sections has not kept up with depreciation. Slower replacement of older equipment has caused an increase in downtime due to equipment malfunction. As efforts are made to increase funding for equipment sections, maintenance managers perceive that they are receiving less service for more money. At the operational level, equipment operators believe that equipment downtime is caused by poor equipment selection and repair, and mechanics believe it is caused by operator carelessness and abuse. Recognition of the adversary relationship and its causes can result in increased efforts to design and implement effective equipment management systems that are responsive to change and track all equipment costs and use in a timely manner. In addition, the training programs used to introduce changes or make additions to equipment management systems can be far more effective if both the potential for resentment and the difference in viewpoints are taken into account.

The adversary relationship that tends to occur at essentially all levels of the highway operations-maintenance and equipment procurement-repair hierarchy is the natural result of the generally erratic evolutionary growth of most state highway agencies. When highway commissions or departments were first formed in the early 1900s, the fledgling highway industry was a very labor-intensive one. Federal legislation in 1921 established a federal-aid highway system, but the law also limited the mileage to 7 percent of a state's total public highway mileage. As a result, the various state legislatures assigned responsibility by law for highway construction and, therefore, maintenance in a bewildering array of combinations and permutations. Highway maintenance programs evolved from the abutter working off his taxes to a publicly paid highway patrolman maintaining "his" section of highway using his own equipment and assisted by a helper.

In addition to owner-operated, horse-drawn maintenance equipment and then trucks, $139 million worth of surplus military equipment was provided to states in 1920 as a result of federal legislation to assist them in highway construction and maintenance. As more highways became hard surfaced, the need for specialized equipment arose in the late 1920s and early 1930s with the advent of formal tar or resurfacing crews. Equipment operators working after hours with the assistance of their oilers, which was a usual practice at one time, could no longer supply the necessary upkeep and maintenance for this equipment, and so full-time mechanics became necessary. This evolutionary process produced a great array of management approaches by highway departments, but by the early 1950s most states had fairly well-established formal management relationships between highway equipment and highway maintenance organizations. During this same period, individual patrolmen were being assigned to patrol crews under the direction of a foreman, and private trucks were being replaced in increasing numbers by state trucks. Equipment operators were becoming less responsible for the care and upkeep of their equipment and more dependent on formal equipment management organizations and their mechanics.

In the 1960s, highway maintenance management systems were introduced and, concurrently, equipment maintenance management became more specialized and complex. As a result, highway maintenance managers