

Benefits to Bus Operators of Introducing a Comprehensive Life Cycle Costing System: A Practical Application

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Life cycle costing is an explicit method for evaluating the total cost of an asset over its whole life. It is most useful for equipment whose past purchase costs are comparable in real terms to the acquisition price. The application of life cycle costing to bus fleet purchase, replacement, and maintenance costing leads to more efficient resource control and investment management decisions. An overview of the life cycle costing system is applied to a bus fleet and the inputs needed and outputs available are listed. The technique is applied to a commuter bus company. The application of cross sectional and time series analysis to a partial data base demonstrates how robust results can be obtained from limited information, leading to the identification of significant cost savings in both operating and purchasing decisions.

Life cycle costing (LCC) analysis is an explicit method for evaluating purchase options, taking into account the major costs of an asset over its whole life. These costs consist not only of the initial price but also of the costs of owning, operating, and maintaining the equipment. The concept was initially developed some 20 years ago for equipment procurement decisions at the U.S. Department of Defense.

The application of LCC to investment decisions should lead to efficient purchasing and maximum value for money in the broadest sense. Almost by definition, the technique is most useful for equipment the post-purchase costs of which are comparable in magnitude to their acquisition price. Motor vehicles are ideal subjects for this kind of analysis because they contain a large number of moving parts that interact in a complex manner over a number of years. Whenever they are used, they consume fuel, lubricants, and tires, and the moving parts are subject to wear, which in most cases will require repair and eventual replacement. Vehicle maintenance incurs expensive and often skilled labor as well as the purchase of replacement parts from the manufacturer.

Depending on the life of the vehicle and the scale of the post-purchase costs, differences in the initial price of competitors' vehicles might be small compared with differences in the life cycle cost. In addition, the initial prices and the LCCs may not be correlated or may even be negatively correlated; that is, the vehicle with the lowest purchase price is the most expensive to maintain, and vice versa. Intuitively, this relation suggests reasonable grounds for paying a higher price for a better quality, more enduring product. This potential tradeoff makes LCC an essential part of the investment decision.

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A great deal of literature (e.g., 1–18) already exists on the subject of life cycle costing, some referring directly to LCC and some addressing the concept by implication through, for example, management information systems, vehicle maintenance efficiency, and vehicle operating costs.

Figure 1 shows a simplified cost structure over a vehicle life. The sum of the two crossing curves shows high costs in the early years because of the high initial capital cost, and in the later years because of high maintenance costs. In between, the total annual costs reach a minimum whose position is determined by the relative positions of the capital and maintenance cost curves.

The position of the capital curve is determined by the initial purchase price and the resale values annualized over the vehicle life; a lower purchase price would shift the whole curve down and to the left. Similarly, a reduction in maintenance costs would shift that curve down and to the right. Both of these examples would result in a lower minimum life cycle cost (at different vehicle ages) and would therefore be of interest to a purchaser of vehicles.

LCC analysis is invaluable for making purchase decisions, but for other reasons as well. The methods and data requirements of LCC embrace a wide range of operating practices, accounting conventions, costing systems, and vehicle replacement policies. As these change over time, which they tend to do with the increasing need to monitor costs and with the introduction of computer-based data systems, there will be a general increase in organizational efficiency.

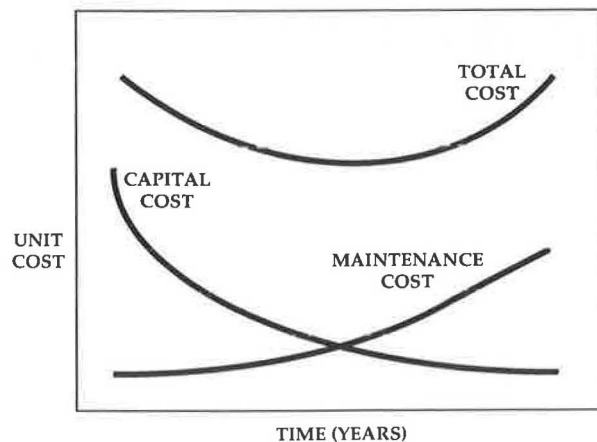


FIGURE 1 Simplified LCC structure.

A LIFE CYCLE SYSTEM FOR ONGOING PLANNING AND MONITORING OF THE VEHICLE FLEET

The key feature of a comprehensive LCC system is the information provided by the vehicle operating cost data base. This should be an ongoing, continuously updated, cumulative costing system, providing a level of information that can be used to monitor in detail current vehicle operating costs on a component basis. The system can then be used to determine the lifetime performance both of individual vehicles and vehicle types on different route types and sectors.

Although individual organizations may have differing requirements as to how operating cost data should be assembled and presented, the basic framework is that presented in Table 1. The component parts of the framework include

- Vehicle purchase cost;
- Resale value;
- Annual miles run;
- Total miles run;
- Fuel consumed, quantity and cost;
- Oil and lubricants consumed, quantity and cost;
- Cost of spare parts (materials);
- Cost of major component replacement and major structural work;
- Number of labor hours, total and cost; and
- Tires consumed, quantity and cost.

The information is normally updated on a monthly basis, which in addition to giving cumulative costs, shows cost trends by component, and seasonal and usage variations.

TABLE 1 BASIC LCC FRAMEWORK

YEAR	CAPITAL COSTS		MAINTENANCE COSTS		MAJOR COMPONENTS AND STRUCTURE	OPERATING COSTS	
	purchase	resale	materials	labour		fuel	tires
1							
2							
3							
4							
5							
.							
.							
.							
.							
LAST YEAR							
TOTAL							

YEAR	ANNUAL COSTS	ANNUAL MILES RUN	CUMULATIVE ANNUAL COSTS	CUMULATIVE ANNUAL MILES	CUMULATIVE COST / MILE
1					
2					
3					
4					
5					
.					
.					
.					
.					
LAST YEAR					
TOTAL					

Additional information that can be added as required includes

- Time since major component change (e.g., engine or transmission);
- Time since major structural work;
- Availability (in days per month or year);
- Utilization (in hours per day, month, or year);
- Number of in-service breakdowns (per month or year); and
- Ratio of downtime to vehicle availability.

When the comprehensive data system is on stream, it is then available for use both in short-term monitoring of individual vehicles and longer term assessment of vehicle availability, usage, and replacement strategies.

1. *Short-Term Vehicle Monitoring.* Using the monthly records generated by the operating cost component, data files for each vehicle can be interrogated for changes in unit consumption rates that may indicate that problems are arising in certain areas. For example, an increase in fuel consumption per mile when there is no change in the operating conditions of the vehicle suggests there may be a fault in the engine; a reduction in the life of a brake component may suggest either a misassembly or poor quality brake material. The latter could have a significant fleet cost implication if not identified at an early stage.

2. *Longer Term Vehicle Assessments.* In order to carry out these assessments, it is necessary to compute the LCC for each type of vehicle operated by the company. To obtain a perfect LCC for an individual vehicle, it would be necessary to keep records of all costs incurred by the vehicle over its full life. In addition, price indices for each component would be required for each year to convert all historical costs to a common base year. In practice, the most convenient way to obtain the information required is to work within each individual bus type and use cross sectional data from vehicles of different ages within the type over a reduced time period to build the table. An advantage of this approach is that it avoids the problem of having to reconcile cost information from an extended period of time. Using the cross-sectional approach, the ideal situation is that in which the vehicle fleet is large enough to contain individual vehicles of every age, from new to retirement, so that the cost matrix can be built from a single year's data. In practice, this is unlikely to be the case, but it is usually possible to provide sufficient data for the matrix so that the missing years can be filled satisfactorily by interpolation.

With the data matrix complete and all historical costs converted to a base year, the LCC can now be computed. The first step is to discount all costs occurring afterwards back to Year 1.

Costs that will accrue in future years must have a discount factor applied to them to properly reflect their present value, because of the time value of money. Thus the present value of a sum of money due in the future is determined through the application of a discount factor reflecting the cost of money to the organization.

Using the discounted cost matrix, the costs are summed

over a given period of time and divided by the total number of miles run over the same period to give the average cost per mile of the period. This calculation is repeated for different time periods to find the time period over which the cost per mile is a minimum. This time period is the optimum life of the vehicle in economic terms and is the age at which the vehicle should be replaced.

With the LCC matrices available for each vehicle type currently in operation, it is possible to interrogate them to obtain information for long-term planning and monitoring purposes. Some major uses in this category include

- Monitoring the performance of individual buses against the fleet type average, to identify any units with consistently above or below average unit costs. Such units could be candidates for early retirement or extended use.
- Assessing the implications of future demand patterns on the ability of the current fleet to meet these demands. The need for additional capacity through early purchase of new buses or short-term hire from outside contractors can be assessed.
- Phasing in new bus purchases to match the economic timing to the availability of finance. It is often necessary to spread the purchase of replacement units over a number of years when a large number of vehicles reach retirement age at the same time.
- Deriving performance levels against which potential new vehicle suppliers can be asked to base their bids. Improvements in engine efficiency and structural life are two items that will have high cost and availability impacts.

Additional concerns will be identified as important by individual operators with different route systems and operating philosophies and constraints.

THE GO TRANSIT STUDY

In August 1987, GO Transit in Toronto initiated a preliminary LCC study of the GO Transit bus fleet, using a partial data base available from an upgraded data system that GO Transit had put in place only 18 months earlier. The work program included the following components:

1. Reviewing the current bus fleet retirement criteria;
2. Identifying optimum economic retirement age for different vehicle types;
3. Comparing the performance of different bus types; and
4. Determining the financial penalties of operating unsuitable vehicles, retiring a vehicle type too early, delaying replacement of a vehicle type with a technically superior model, and introducing an expensive vehicle refurbishment policy.

GO Transit operates an interregional commuter bus system serving the Toronto commuter area within a radius of approximately 60 mi. At the time of the study, GO Transit was operating a heavy-duty diesel bus fleet of 200 units. The main body of vehicles conforming to GO Transit service design consisted of MCI highway buses, GM modified transit buses, and GM transit buses. These vehicles were identified as Types A, B, and C, respectively, in the analysis. In addition, the

Orion 40, an update of the GM Transit bus identified as Type D, that at the time of the study had recently been introduced into service and was being assessed as a possible replacement type, was also included in the analysis. Types A and B operated as highway or longer distance suburban-to-downtown buses, and Types C and D operated as transit vehicles on dedicated routes.

The preliminary study, which was completed in January 1988, proved satisfactory, and GO Transit is currently proceeding with the implementation of a comprehensive LCC system. An outline of the work program to date, including the current study, follows.

GO Transit LCC Study Time Scale

<i>August 1987</i>	Contract let to undertake a preliminary LCC study of the GO Transit bus fleet using a partial data base.
<i>December 1987</i>	Completion of preliminary study and delivery of study reports to GO Transit.
<i>February 1989</i>	Contract let to undertake Stage 1 of the comprehensive LCC and cost benefit projection of the GO Transit bus fleet, designed to identify and recommend the activities to be undertaken in Stage 2 to develop a full-scale LCC system.
<i>April 1989</i>	Completion of Stage 1 of the comprehensive study and delivery of the study report to GO Transit.
<i>January 1990</i>	Commencement of Stage 2; a comprehensive study to develop and deliver a full-scale bus LCC system to GO Transit.
<i>October 1990</i>	Estimated date of study completion and system delivery.

Data Base Assembly

The starting point of any LCC analysis is to identify how much of the basic LCC framework can be filled from the data available.

In an ideal situation, either a complete life history of a sufficient number of units of each bus type would be available (time series data), or the fleet would include units varying in age from 0 to (say) 20 years for each bus type with cost information available for a recent time period (cross-sectional data). In practice, it is unlikely that either of these alternatives would ever be available, leaving the more usual situation of a combination of partial information only. In this situation, the sample size and composition are dictated by the actual data available.

Previous work on vehicle operating costs identified 12 months as the most satisfactory period over which to aggregate vehicle operating costs. A 12-month period is sufficiently long to capture the real change in maintenance costs and utilization levels with increasing vehicle age, and sufficiently short to avoid problems with changes in unit costs of vehicles, parts, fuel, and tires. In the GO Transit study, the most recent 12-month period of the available 18 months of information was chosen and all costs have been converted to 1989 prices on the basis of relevant price inflation figures for vehicle and mechanical items.

The data availability for this investigation are presented in Table 2; and the basic data set is incomplete. As stated, this situation is not unusual given that few bus fleets are likely to contain vehicles purchased in every year over an extended period. To overcome this defect, a combination of time series and cross-sectional analysis is used to maximize the use that can be made of the available data. The method is to plot the available information and estimate the trend by fitting a curve to the points plotted. In this investigation, time curves for the annual miles run, the accumulated mileage, and the total materials consumed for each vehicle were constructed as shown in Figures 2-4. Using this information, the annual miles run,

TABLE 2 VEHICLE AGE AND USAGE LEVELS BY VEHICLE TYPE

Vehicle Type	Vehicle Age (Years)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	No. of Buses					25				12	5 *		14				
	Ave. 1986 Miles					87,380				76,583	49,700		56,050				
	Ave. Total Miles					449,430				637,535	489,020		805,369				
B	No. of Buses		5								20		4				
	Ave. 1986 Miles		53,920								44,870		31,200				
	Ave. Total Miles		103,641								430,660		538,200				
C	No. of Buses											12	10	10		5	15
	Ave. 1986 Miles											43,191	35,720	35,330		33,740	32,447
	Ave. Total Miles											473,958	517,151	508,682		600,680	621,867

* These Vehicles were purchased second hand and the miles run refers to the current owner only. Actual lifetime mileage is estimated to be 40% higher than these figures.

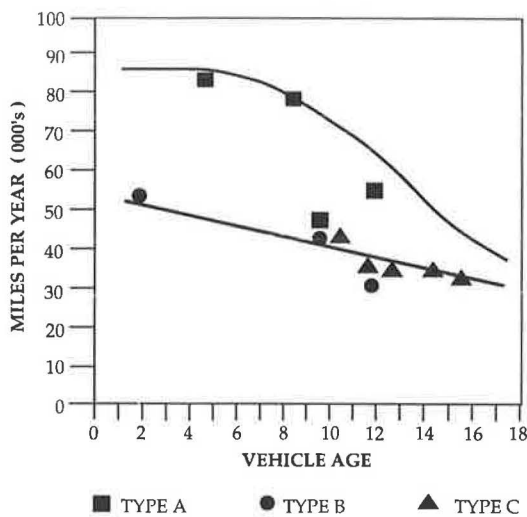


FIGURE 2 Annual miles run (1986) by bus type.

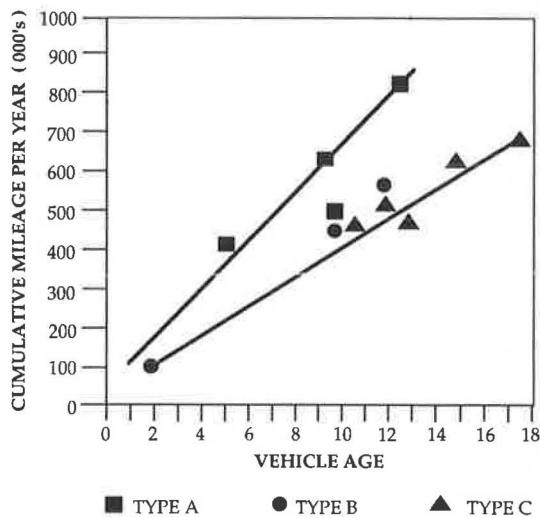


FIGURE 3 Cumulative mileage (ending in 1986) by bus type.

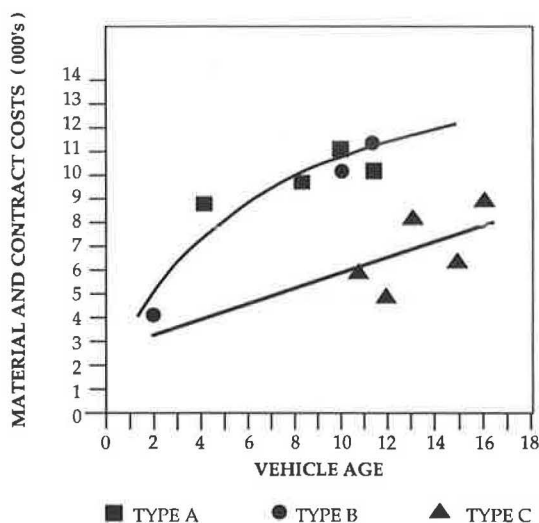


FIGURE 4 Material costs (1986) by bus type.

the accumulated annual miles, and the annual materials cost for each vehicle type were estimated. On the milcage graphs (Figures 2 and 3), Type A buses fall on one curve and the other types on a lower curve, but for the materials cost (Figure 4), Type C buses fall on one curve and the other bus types fall on a higher curve. Lines of best fit have been selected by taking into account the actual points plotted, plus extra information made available on the materials cost and miles run by the new buses brought into operation in 1987, to improve the data available at the low end of the age spectrum. The outcome of this investigation has been interpreted as follows:

- Type A buses fall on the high mileage and high materials cost curves;
- Type B buses fall on the low mileage and high materials cost curves; and
- Type C buses fall on the low mileage and low materials cost curves.

The maintenance labor costs were compared with the materials costs and found to be similar but approximately 7.5 percent greater. They were therefore treated as having age-related curves similar to those of the materials consumed but 7.5 percent higher over the whole range.

In the absence of any detailed information, allowance was made for the cost of the vehicle maintenance facilities exceeding the hourly mechanics cost by doubling the rate. This adjustment, which was decided on after discussions with GO Transit, took into account current commercial and municipal transit garage markups on basic mechanic rates.

A structural integrity body repair program was introduced after 8 years for Type A and B buses and after 12 years for Type C. The program was repeated approximately every 3 years depending on vehicle design and use, and was included in the analysis. GO Transit also undertakes an engine and power train rebuild program. These costs were also included in the analysis.

Fuel costs were provided by GO Transit as a fleet-wide average and were applied to the LCC tables on a mileage run basis.

Contract tire costs also provided by GO Transit for radial and bias tires were also applied on a mileage run basis.

Purchase prices for the buses were obtained from recent quotes received by GO Transit. An estimate of residual values for Type A buses of different ages was obtained by GO Transit. However, little information was available for Types B and C, because of the limited demand for these buses, but values were estimated and agreed on when they were required in the analysis.

Sufficient data were therefore obtained to carry out an LCC analysis for the three bus types. All the LCC calculations were carried for an 18-year period using a discount rate of 8 percent per year. A sensitivity analysis was also undertaken.

Results of the Analysis

In addition to computing the cost per mile at the end of each year, the cost per mile was recalculated for those years when structural integrity and engine rebuild programs were scheduled, omitting these costs. This procedure enabled the option

of foregoing the program and retiring the vehicle at the end of the year to be examined.

The results showed that for Types A, B, and C, for which lifetime data were available, the lowest cost bus is Type A, followed by Type B, with Type C the most expensive to operate.

Bus Type	Optimum Vehicle Age (years)
A	12
B	18
C	18

Of the three bus types (Types A and B are operated on the same route type and are compared directly), the economic superiority of A was well demonstrated in the analysis. Although the optimum age for the Type A bus is 12 years, the minimum cost after 8 years is less than 1 percent greater than the 12-year cost. Within the limits of accuracy of the data, these two values are not significantly different.

Types C and D are variants of the same type of vehicle, which is designed to carry out a type of operation different from that of Type A. An additional interest in the LCC analysis was to determine the optimum age for replacing Type C by Type D, which is a derivative of Type C with improved fuel consumption and brake component life.

A sensitivity analysis was also undertaken. Each of the cost components was varied by ± 10 and ± 20 percent in turn and the effect on the LCC of each vehicle type was monitored. The results showed that the LCC computations were robust. There was no change in the optimum age for Types B and C, and although Type A varied between 8 and 12 years, the difference in cost per mile for any particular combination of component costs is a maximum of 1.5 percent only.

The financial implications of the results, presented in Table 3 and shown in Figures 5 through 8, are that

- Operating an unsuitable vehicle type was costing an additional \$7,000 per vehicle for each year of operation;
- Retiring a particular vehicle type too early imposed a penalty of \$4,000 per vehicle for each year the vehicle was operated;
- An inadequate vehicle refurbishment program was costing an additional \$1,000 per vehicle per year, ignoring the effects of reduced vehicle availability and consequent loss of revenue;

- Failure to make an early replacement of a particular vehicle type with an improved model would cost an additional \$4,000 per vehicle per year if the older vehicles were operated the full length of their economic life.

The total cost savings of these operating policies amounted to the equivalent of replacing 1.5 percent of the vehicle fleet each year.

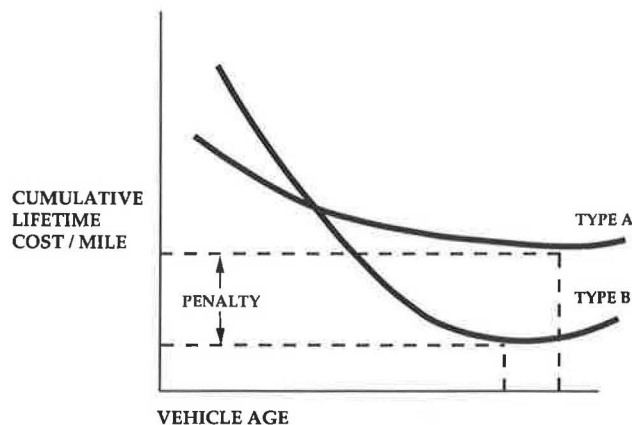


FIGURE 5 Economic effect of purchasing an unsuitable vehicle.

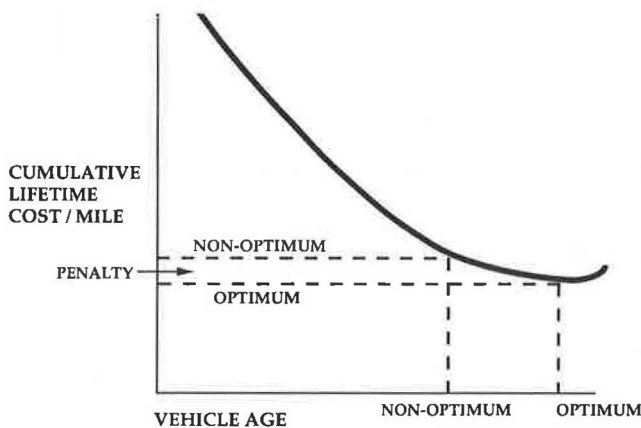


FIGURE 6 Economic effect of retiring a vehicle prematurely.

TABLE 3 COST PENALTIES OF NONOPTIMUM MANAGEMENT AND OPERATIONAL DECISIONS

	COST PER VEHICLE PER YEAR
UNSUITABLE VEHICLE TYPE :	\$ 7,000
PREMATURE RETIREMENT:	\$ 4,000
INADEQUATE REFURBISHING PROGRAM:	\$ 1,000
FAILURE TO REPLACE OLD MODEL:	\$ 4,000

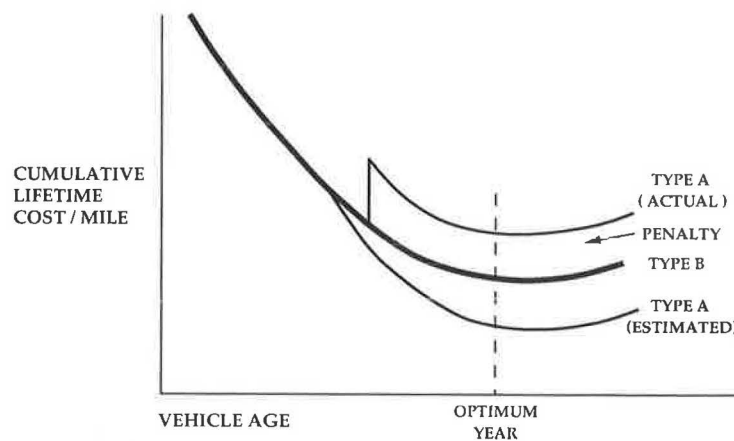


FIGURE 7 Economic effect of underestimating midlife refurbishment requirements.

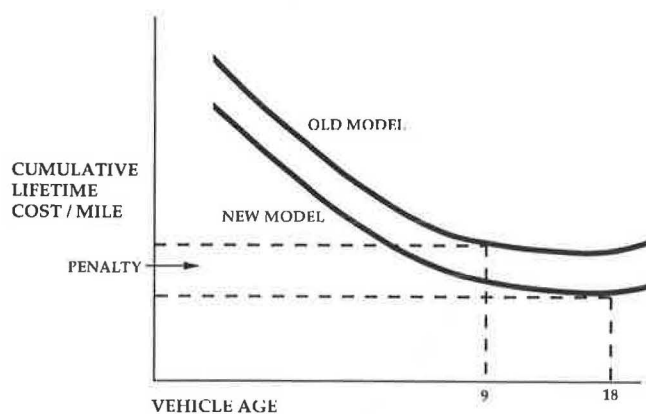


FIGURE 8 Economic effect of not replacing old model.

THE ADVANTAGES OF DEVELOPING A FULL LCC SYSTEM AND DATA BASE

With the availability of the information provided by the data base and LCC analytical system, the bus operator will be in a position to

1. Improve the ongoing monitoring, planning, and budgeting of the bus fleet;
2. Strengthen the management capability through improved information availability;
3. Assess the short- and long-term financial implications both of technical and strategic planning decisions;
4. Reduce the current unit cost of operating the bus fleet; and
5. Provide an improved service to the public at a more economic price.

IMPLICATIONS FOR USE AS A MANAGEMENT TOOL

Because virtually all management decisions have immediate cost implications in a transportation company, management must be able to assess these implications quickly and efficiently.

The implementation of a comprehensive LCC system will give management the ability to monitor current cost trends, predict future costs, and assess the implication of different policy decisions concerning vehicle replacement, route patterns, garaging locations, ridership changes, and financial constraints.

Current Cost Trends

The availability of detailed operating cost information on a continuous basis will enable management to compare actual vehicle expenditures with current forecasts and take appropriate action should any divergence begin. It will also permit the financial implication of any major forced or requested change in the scheduled operating pattern to be assessed.

Future Cost Trends

The LCC system will provide information on the effect of increasing vehicle age on unit operating costs, indivisible expenditures such as engine rebuilds, vehicle refurbishment needs, and vehicle replacement requirements. Future financial demands can thus be programmed to avoid uneven expenditure and ensure either that funds are available as and when they are needed or that expenditures are timed to coincide with the availability of funds.

Vehicle Replacement

A comprehensive LCC system will provide information on the performance and costs of all vehicle types being operated by the organization. This information can be used to assess the most efficient vehicle types for different operating patterns and provide a base case against which potential new vehicle purchases can be compared. It also means that manufacturers can be asked to provide performance guarantees on the basis of the real costs of the current vehicle fleet.

Route Patterns

As the LCC system provides information on the operating costs of individual vehicles, the potential will exist to examine the effect of different route characteristics on revenues and expenditures. It will therefore be possible to assess the fleet requirements for accommodating a potential change in, or addition to, the current route system.

Garage Locations

Any potential change in garaging locations can be assessed both for changes in dead running miles and unit costs of vehicle maintenance resulting from a more efficient maintenance facility.

Ridership Changes

Potential changes in ridership levels, whether local or general, due to rezoning, private travel restrictions, or general changes in demand for public transport, can be costed, and allowance can be made for accelerated or delayed new vehicle purchases and associated changes in maintenance, fuel, and tire requirements.

Financial Constraints

In addition to providing optimum cost solutions, the LCC system will equally well assess the effect of short- or long-term financial constraints and provide a best solution within any particular financial constraint. This solution may take the form of deferred vehicle purchase, increased usage of the current fleet, or hiring in extra capacity on a short-term basis.

SUMMARY

The application of an LCC system to the operation of a transportation company leads to improvements in the efficiency both of fleet purchasing and operating strategies. It enables the performance both of individual vehicles and vehicle types to be monitored and direct operating cost comparisons to be made. In addition to comparing the cost per unit distance traveled, the effect of variations in vehicle availability and use can be assessed, and hence the fleet size required for a particular operation pattern and the revenue earning capacity can be calculated. The combination of information on unit operating costs and vehicle performance characteristics enables the optimum economic life to be computed both for individual vehicles and vehicle types. To purchase the most cost-effective type of vehicle for any particular operation and to monitor individual vehicles within the fleet, both to control particular cost components, such as fuel or brakes, and to identify rogue vehicles at an early stage, are therefore possible.

The information needed for the operation of an LCC system is no more than is normally available within a commercial vehicle operating company. The component costs of operating the vehicle fleet are frequently aggregated by accounts depart-

ments for overall company financial control. The only additional resource input required is in setting up a data flow system that ensures that the current information is fed into the basic LCC framework table. This system can be either a parallel activity to the company accounting system, or more efficiently, a stage prior to final aggregated accounting, that will enable a far higher level of financial information to be made available to management for use in strategic decision making.

The benefits to one particular transportation company of introducing an LCC system have been demonstrated to be the equivalent of renewing 1.5 percent of the vehicle fleet per year at no extra cost, in addition to associated improvements in vehicle availability and, therefore, in revenue generation.

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