BASIC THEORY OF CALCULATING COSTS: APPLICATIONS TO TRUCKING

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INTRODUCTION

Knowledge and control of costs is fundamental to any business enterprise. Understanding the structure of costs allows managers to achieve various goals within their organization. Costs knowledge has implications for pricing and for efficiency gains, both actions of which increase the potential profitability of the firm. Pricing of the output of the firm service, has to be based on knowledge of the costs of providing that service as well as an understanding of the market demanding the service. Additionally, improvements in internal cost structure and effective cost containment increase the potential for profit, even in a stagnant market situation.

The basic conceptual theory of costs will be presented in this report, emphasizing definitions of costs as they are applied to business situations. These costs' concepts will then be evaluated relative to differing firm characteristics that have specific impacts on those costs. Such items as measures of utilization and market situations will receive specific attention, then an approach to economic-engineering, or internal firm determination of costs, will be provided. Finally, the report will conclude with a brief section on how to determine and evaluate productivity of the resources used in producing service as a firm.

PRODUCTION AND MANAGEMENT

A basic tenet of the existence of a firm is, "it should produce something." Conceptually this is referred to as the production function, or the idea that the amount of production that results from any activity is dependent on the manner in which resources or factors, and the quality of those factors, are combined. Whether it is combining capital and labor in a trucking company, or combining hours of study with tuition and books by a student, the result is production of something that is desired, using something that has to be invested. A production function is

based on the idea that a unique and identifiable relationship exists between outputs, whether ton miles or some other output measure, and inputs such as labor or equipment or maintenance.

The relationship between output and input is quite useful in evaluating costs. If the level of output is given, such as servicing 50 customers within a given period of time, and the amount of input used to service those customers can be decreased, then a decrease in cost per unit occurs. Alternatively, if more customers can be served with the same amount of cost outlay, then the cost per unit of service decreases as well. It can be said that even if a firm's total cost of operation increased last year, its efficiency increased and its per unit cost of operation decreased. This is a common sense notion, but one that is related directly to the efficiency of the production function.

In most instances it is the management of a firm that has discretion over each decision that is being made, relative to the goals of that decision. As such, the relevant costs for a decision may change, but the definitions of the cost used remain the same. As will be seen, in some cases it makes economic sense to sell our service for less than it costs us, relative to the decision at hand. The theoretical cost concepts developed in this report are always to be used in the context of the real world situation faced by the manager.

BASIC DEFINITIONS OF COST CONCEPTS

In this section the theory of costs will be approached by defining some of the most common cost concepts. While theoretical in nature, most of these concepts have direct application to the accounting and investment decisions of managers of trucking firms.

Short-Run versus Long-Run Decision Framework

In classical cost theory there is much discussion about fixed versus variable inputs associated with a production function. But to be more specific about fixed and variable resources, and the decisions that managers make within given situations, it is necessary to associate the time period under discussion. Two general time periods are useful:

1. Short run: A period of time short enough that some resources cannot be varied.
2. Long run: A period of time long enough that all resources can be changed as desired by the manager.

In the short run, managerial decisions are affected by the inability to change all variables, such as the size of a plant, number of trucks, location of the market, or amount of land. The long run is considered to be the situation where any and all changes can be made subject to the availability of capital, information, and manager expertise. Most managerial decisions occur in the short run because seldom does a manager have perfect mobility or control of all resources necessary for his or her production process. As a famous economist once said, “In the long run, we are all dead.” That does suggest the short run is really the decision framework of relevance to a manager. What is of particular relevance is that the manager and decision maker is continually faced with opportunities to vary the length of decision time under consideration. Decisions about capital investment, equipment replacement versus maintenance, and new product development result in different degrees of mobility of resources.

Fixed Versus Variable Costs

Probably the most common category for costs used by managers and economists is the concept of fixed versus variable. The typical definition of variable costs is simply those that do change as output level changes. In the context of a trucking firm, it is those costs that will be incurred directly related to mileage or to the service output variable being examined. Fixed costs do not vary with level of production and are costs that will be incurred during the year, or appropriate decision time period, regardless of output. In operating a truck or a trucking fleet, it is those costs that do not vary directly with mileage.

Typical fixed costs of firm management include depreciation, interest, rent, taxes and insurance, often referred to with the acronym "DIRTI." They become committed cost when the production period, for example, an annual year, is undertaken and expenses are incurred, and they become variable costs as the decision period increases; for example, should the manager get out of a market or out of a particular trucking activity.

Economists differentiate between total fixed cost and per unit or average fixed cost of production. Total fixed costs simply refer to the costs incurred during the production time period, as contrasted to per unit costs which are the total fixed costs divided by the output measure, e.g., the fixed cost per running mile for a truck.

Marginal Cost

The concept of marginal cost is probably the most relevant and most commonly used in formal economic analysis and day-to-day decision making by managers. Marginal cost is defined as the additional cost necessary to produce one more unit of output. In formal terms, that cost determines the amount of resources necessary to produce one more mile of operation, one more day of operation, or one more service stop for a customer, or whatever the relevant question being faced by the manager. On a particular trip, the additional cost of a mile may be very small because only minor amounts of additional resources are used to produce that mile of operation. The concept of marginal cost varies with the decision time period as was discussed earlier, the

long-run versus short-run period. In an extremely short period of time, marginal cost can be low; as we lengthen the decision period, marginal costs move closer and closer to variable costs, and even to total costs of operation in the extreme.

It should be noted that the marginal cost of operating a truck can be expected to vary somewhat whether that truck is loaded or unloaded. But studies do suggest that little difference occurs in the marginal cost of an additional mile or an additional trip whether that truck operates loaded or not. Finally, the laymen's term of "out-of-pocket cost" is a reasonable approximation of the economist's term of marginal cost. It is what we have to pay out of our pocket, or today, to produce an additional unit of output. Out-of-pocket or marginal--these costs become very relevant in most of the decisions faced by managers. What is of note is that these costs constitute the controllable part of the cost of production, for they can be discontinued with shutdowns or modified by changing level of service.

Overhead Cost

Another useful concept is overhead costs. These are simply defined as costs that are not attributable to specific units of output. They look in some degrees like fixed costs, but also have some facets of variable costs as part of their makeup. They are the accounting office equipment, support staff, and so on, that are necessary to operate a firm, but cannot always be specifically assigned to one output. These overhead costs can be variable in that they can be modified within a decision framework by eliminating labor, minimizing insurance, and so on. It is these costs that must be covered in the long run so that a firm can be economically profitable. As is often seen, some firms make mistakes by not covering these costs because market situations force concern about only variable costs of production. The decision to price according to variable versus overhead, versus total costs is probably the most critical of all pricing decisions made by trucking firms.

Joint or Common Cost

The concepts of joint or common cost are often mistakenly associated directly and solely to overhead costs. Costs are joint when the creation of one product unavoidably results in the output of another one. A familiar example is that of beef and hides. The raising of an animal for beef inevitably results in the production of a hide, and most of the costs incurred in rearing the animal cannot be traced to either product. The prices at which each of the two products would be sold cannot be related to its cost of production, because the joint costs are attributable to both, not to either one specifically.

Common costs are similar to joint costs in that they are incurred for the production of a number of different products, but the use of the resources to create one commodity does not unavoidably result in the production of a different one. The proportions of the different kinds of commodities turned out by a firm, such as a trucking firm, may be varied, frequently over a wide range. Changes in the proportions in which they are produced may result in variations in the common cost. Common costs may be quite closely related to the earlier discussed concept of overhead cost.

True joint costs, by definition, require that the joint products be forthcoming in fixed proportions and that there cannot be variations in the proportions resulting from variations in the cost. To the extent that the variability in proportions is impossible, there is no way the joint costs can be traced to the separate products. The most relevant example of joint costs is the fronthaul-backhaul phenomenon of trucking. In the simplest case, a movement from A to B creates automatically a movement from B to A, e.g., the fronthaul creates the backhaul possibility. These joint costs make pricing and cost allocation decisions a bit more muddled, but not impossible.

If the backhaul is empty, that suggests that revenue from the fronthaul has to cover the joint costs of the fronthaul and backhaul combined. If the backhaul is loaded 50 percent of the time, then the fronthaul has to cover only 75 percent of the total mileage. While muddled a

bit, this ratio can be developed for any expected percentage of loaded backhauls. Not only can it be developed, appropriate pricing decisions require that it be made.

Economies of Size

A cost concept that has many definitions, some of which are very confusing, is the concept in economies of size. This concept is directly related to the possibility of getting more use out of a fixed resource. It suggests that once a truck has been purchased, increased utilization of that truck will spread the cost of the truck over more output, reflecting or rather resulting in decreasing average costs of production. The same concept holds for the purpose of a terminal for a trucking operation. The more trucks and the higher level of activity using that terminal allows spreading those costs out over more output, again achieving economies of size. These economies are the driver of many decisions to price below total costs, in a particular marketing situation, and managers must be sensitive to the relationship of increased cost efficiencies versus decreased revenue considerations.

Market Economies

A fairly new cost concept applied in the transportation arena is the concept of market economies. Market economies occur as a result of exposure to a larger trade area or sales opportunity. It is the economies that are noted when the size and age of the firm, in the trucking industry, increases the percentage of backhaul that is loaded. The ability to get loads in both directions of a movement has a strong impact on firm efficiency and competitiveness. Repeated studies in the literature of cost of trucking indicate that significant market economies are available to large firms since this size category has a larger percentage of their return mileage loaded and has a larger trade area within which to increase this return mileage. Market economies also arise because the geographical dispersion of the trade area increases the probability of higher revenue, as well as more often received revenue, e.g., higher percentage of loaded backhaul movements. Some authors have suggested that market economies includes the

knowledge of any given market by the management of a firm, usually associated with time in service in that area. In a practical sense, it may simply reflect "a good reputation."

Opportunity Cost

There has been a significant amount of discussion by economists and business people, much of it useless, about whether this concept should be called opportunity cost or opportunity return. In a straightforward fashion, opportunity cost is "what you give up to do what you are doing." What a manager gives up, is in fact, the returns that he or she could have generated as a result of business or financial activity in another option. It suggests that, even though the cost of labor that is being hired for the firm may be at a given wage, $10 an hour. If we could have used that labor within our firm in an activity that would have generated $15 an hour return, then the appropriate charge to be used in the alternative use of that labor in the firm is $15. This concept is relevant whenever choices between trips for trucks, markets to serve, or products and services to offer are being made. The cost of providing a trip should be judiciously evaluated, based on the physical costs, as well as the alternative returns that could be realized by the use of the resources. This concept holds whether we are assigning labor in the firm or whether the manager is deciding what to do on Friday night.

The basic management principle while working with opportunity costs is to try and minimize those opportunity costs. In other words, investment should always be made where the returns are highest, thereby minimizing what we "have to give up to do what we are doing." Or as former Secretary of Defense Robert McNamara used to say, "Let's get the biggest bang for our buck."

The concept of opportunity cost is also directly related to the financial decisions within a firm. In economic terms, interest rates are a measure of the opportunity cost of money. Money invested in a trucking operation, instead of being held in a money market

certificate, has an opportunity cost of six to fifteen percent. A good money manager, as well as trucking manager, will be careful to evaluate present returns on money invested versus the "costs" of passing up other earnings opportunities.

Return on Investment

Closely related to the concept of opportunity cost is the cost concept of return on investment as an expense to a firm. This is a direct expression of the alternative returns that could have been generated by the investment that took place in a trucking enterprise. It is a specific charge against the equity capital in the firm and reflects a needed return for economic justification of investment. In costing out a particular service, the corollary to return on investment (equity capital) is interest charges which are incurred on debt capital. Again as discussed earlier, the interest and return on investment reflect the alternative returns that could have been realized by the owner of that capital, whether debt or equity.

Depreciation

The concept of depreciation is not what a firm is allowed to take off on its tax forms. The concept of depreciation is used, conceptually, when in any production process some inputs are used in more than one time period. For resources used up or consumed within a given decision period, no depreciation is necessary. However, durable inputs do generate the need to spread out the utilization or consumption of a resource over the relevant time periods. In theory, the amount charged off as a cost in the current year should match the amount of the input "used up" in the current year. By matching the useful life to the annual profit-and-loss calculations, the manager can gain a measure of the economic contribution of a durable asset over time periods.

The concept of depreciation is straightforward: inputs that are used over more than one year in the production of income should have a portion of their cost deducted for each year of useful life. This concept is really recognition of three economic ideas:

1. Depreciation should be a measure of the proportion of the asset **used** in the current time period. This is the idea of measuring "wear and tear" on equipment, terminals, and so forth.

2. Depreciation is also used as a measure of economic **obsolescence** of durable inputs. This is a recognition that some inputs become obsolete before they are "worn out" simply because new, more efficient inputs are available. The new containers, new trucking configurations, or new electronic data systems are an example of items causing such depreciation in value in old assets.

3. Depreciation, in theory, should also represent the reduction of the **market value** of an input over time. Some types of equipment may "hold their value" while other inputs decline in value rapidly after only one or two years of use. A tractor-trailer rig that has developed a good reputation for durability may well be an example of its market value being higher than its depreciated use value.

In theory, the method of handling depreciation should be linked closely to the type of input in question and its unique characteristics of use, market value and obsolescence. In reality, it is not possible to actively reflect the useful life, decline in market value, and relative efficiency of every asset in the production process. Instead, the depreciation schedules so common to accountants and managers are used to represent this loss in value or consumption of a resource.

Transaction Costs

The economic system within which we operate is based on willing buyers finding willing sellers and having exchange take place. Transaction costs are considered to be those costs incurred in bringing together a buyer and seller. In the transportation area, transaction costs are often referred to as "search" costs. They are the costs of participants in the market, truckers, searching for loads or opportunities to sell their service. We might simply refer to them as the cost of deadheading from the end of one revenue-producing trip to the start of another revenue-producing trip. Telephone costs to brokers and waiting costs on the road are other examples.

These costs are real and must be factored in the overall costs of production, much in the same manner as the overhead costs discussed earlier. And, as in overhead costs, the deadhead or search cost can be allocated reasonably, but differently, in several alternatives. Should the cost be allocated against a single trip, against the given market that the truck is operating in, or as an overall expense for the entire firm? The manager must make these decisions.

Return to Management and Labor

On a conceptual level, returns to labor are reflected in wages and return to management are reflected in salaries. When the manager is labor and owner, profits become the relevant return. These returns are once again to be equated to the alternative or opportunitive returns in other activities. On a practical matter, many managers in smaller trucking firms have difficulty evaluating the difference between return to labor versus management. In an applied sense, profits are the manifestation of the return to labor and management for a single owner/operator firm, and this is an appropriate approximation.

In the trucking industry, there is a significant difference between return to labor and management. When a manager is in the truck, driving it because he or she loves to do it, there is little or no opportunity return as a manager. It is when the manager has special knowledge and skills and expertise above that of a truck driver that additional return should be incorporated as a cost of operation. As expertise in trucking management is developed, the return to management (as an opportunity cost) significantly increases. Full cost of the operation of a trucking firm should include both a return to the labor (the truck driver) and the return to management (the manager). In many trucking operations the manager can no longer “afford” to be a truck driver, again based on the opportunity returns discussed earlier.

EFFECTS OF FIRM CHARACTERISTICS ON COSTS

In the strictest theoretical sense, costs of production are dependent on only two factors: the price of factors or inputs and the amount of those inputs that is used. The price of the factors is determined, as developed in the earlier theory, by the opportunity returns of those factors. In the real world that is reflected by wage rates and/or prices paid for the factors. The amount of inputs used is based on the production function and the efficient combination of inputs in producing a given level of output. This is determined by the managerial understanding of truck operations and market conditions.

These prices of factors and the production function are then reflected in the fixed and variable costs discussed earlier. This section will look briefly at the impact of various measures of utilization of fixed and variable resources on the average costs of production.

The relationship between measures of utilization and firm characteristics are very simply portrayed in Figure 1. The following discussion is based on both theory and actual studies commonly available to and from the industry. They are based on average experiences of thousands of trucking firms; individual firms will vary significantly around these cost relationships and of expenditures based on managerial expertise and differing market situations. However, the same general relationships will usually be found.

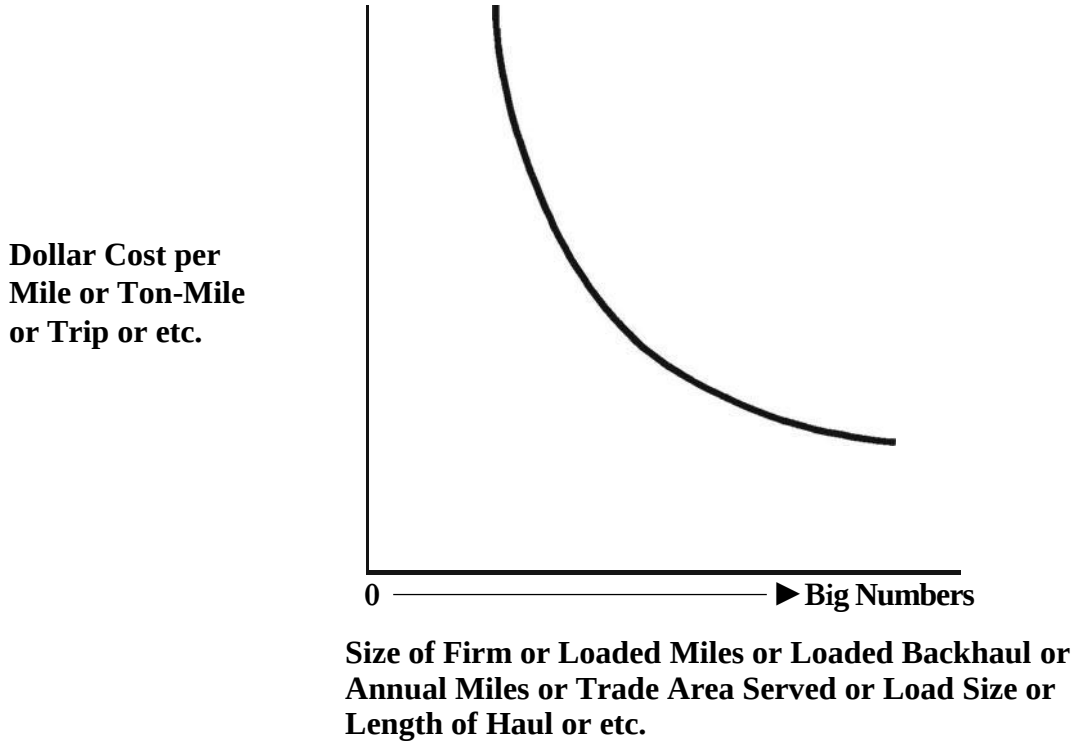

Figure 1. Economies of Size or Utilization (a Common Occurrence).

Size of firm: Average costs of production have been shown to decrease as size of firm increases in the industry. While this varies significantly from market to manager, the overall relationship is solid. These economies of size result from discontinuous inputs, a term simply meaning that if a firm can buy a larger insurance policy or operate with a fleet purchase discount it can lower the cost of inputs to the process. Additionally, some of the output measures associated with size of firm, such as loaded backhaul or annual miles per vehicle, improve significantly.

Loaded miles: A majority of the expenses of a trucking firm are related to miles traveled. As the amount of loaded miles increases during the year, a decrease in costs occur and, because the miles are loaded, an increase in revenue occurs. This results in a delightful combination of lower permit costs and higher revenue per operating mile.

Annual miles: "When a truck isn't running, I'm not making any money" is a common statement. This reflects the impact if the fixed costs of a truck can be spread over more miles within a time period. This not only allows the direct costs associated with a vehicle, but the overhead and fixed costs of the firm as well, to be spread over more output units.

Trade area: The size of the trade area has been documented to be positively reflected with increases in backhaul being loaded and average miles per vehicle. The concept developed earlier of market economies is a direct driver of decreases in cost as the trade area increases.

Length of haul: For those vehicles engaged in longer lengths of haul, less down time is identified and less overhead associated with down time is experienced. A short length of haul calls for a managerial decision to incorporate specific charges for down haul into their pricing process. In any case, short movements are more expensive on almost any output measure a manager or economist can conceive.

Load size: This is probably the most obvious of the cost relationships. Few additional costs are incurred as the size of a truck's load is increased. Yet, the increase in payload allows a decrease in costs of production to be incurred.

Older equipment: Studies are quite consistent in indicating that the costs of operating older equipment are often less than utilizing newer equipment. The tradeoff is due to the significant depreciation and return on investment or interest charges of a new piece of equipment versus the increased maintenance of a piece of used equipment. While realizing decreased average costs of production in many cases, the manager must balance that off against reliability, reputation, and overall firm efficiency in the market.

ECONOMIC-ENGINEERING OF COSTS: THE CONCEPTUAL MECHANICS

It is not the purpose of this report to determine the operating costs of an individual firm. However, it is useful to show how the cost concepts developed earlier are applied in determining costs of a typical trucking firm. The approach chose is what is referred to as an economic-engineering approach, which essentially estimates the production function (based on knowledge of the trucking firms under consideration) and the factor prices, usually based on surveys on firms in the industry. The economic-engineering approach begins by synthesizing a "typical trucking firm."

Fixed Costs

Fixed costs are often considered "sunk" costs and are those that do not change as mileage changes. They generally include: depreciation on capital investment; interest charges or return on investment; license fees and taxes, insurance, housing costs, and management or overhead expenses.

Depreciation

Depreciation can be considered either arising from use or time, as earlier discussed. In most economic engineering it is based on a charge related to time, or the estimated useful life in years. Firm equipment costs, mostly tractors and trailers, are developed by subtracting the salvage value from the purchase price and dividing this figure by the estimated useful life in years. This results in the amount of depreciation costs that are incurred within a given year.

Return on Investment

These charges can be considered either interest on debt capital or return on equity investment. Return is calculated at the prevailing loan rate or opportunity return on long term investments during the relevant time period. They are calculated by dividing the purchase price minus salvage value by two to get average investment over the period. This value is then added to the salvage value and multiplied by the interest rate to generate the return on investment costs per year for the firm.

An associated cost needing return on investment is the need for on and off-season working capital to operate a firm. That capital is charged at the required interest rate and becomes an annual cost to the firm.

License Fees and Taxes

License, permit costs and taxes depend on the states where the motor carrier drives and how many miles or trips are driven in each state. It does have some element of variable cost associated with it, but is generally treated as a fixed cost. The estimated miles driven in each state are multiplied by the estimated tractor and trailer license fee and taxes associated with each of those states. This generates a total truck or fleet cost for the year.

Insurance

Most truckers carry full coverage insurance on new tractor and trailer equipment. Such coverage includes: liability, physical damage and cargo insurance. Estimates of coverage are available from insurance agencies and truckers in the industry. This becomes an annual figure as well.

Housing Costs

Housing costs include investment costs and depreciation in any garage facility, tools, utilities and miscellaneous expenses associated with operating a firm. It is usually developed on a square footage basis, multiplied by the cost estimate, per square foot. It becomes an annual expense for shop or housing costs.

Management and Overhead Expenses

Management cost includes the annual cost of management and administrative help. Overhead cost could include reported annual expenditures for advertising and communications. Other relevant costs are dispatch, sales, front line managers, bookkeeping/accounting/payroll, and year around management. Most of these costs are the result of expenditures on wages or salaries. They do become an annual cost as well to the firm.

Variable Costs

Variable costs are directly related to mileage. These costs include: tires, fuel, maintenance and repairs, and driving labor.

Tire Cost

The motor carrier has a wide range of alternatives when selecting tires. Estimates of tire cost and associated mileage must be developed for recap, fabric and radial tires. This information will

yield an estimated per mile cost for the trucker. Attention should be paid to front tires, driver tires, trailer tires, and the degree of retreading of those tires.

Fuel Cost

Fuel consumption by trucks varies only slightly between loaded and unloaded movements. Any differences should be manifested in a weighted miles per gallon experienced by the vehicles in the firm. The fuel price per gallon is then multiplied times this miles per gallon to yield an estimated per mile cost. This results in a direct per mile variable cost element.

Maintenance and Repair

It is quite difficult to obtain reliable and consistent maintenance and repair estimates from motor carriers. Estimates of engine life time, overall cost, and other repairs must be combined to generate a maintenance and repair cost. Generally the maintenance and repair costs include lubricants, tune-ups, engine overhauls, and general repairs. In some firms the cost of a maintenance contract can serve as the indicator of repair and maintenance expenses. Alternatively, precise attention should be paid to the role and expense of mechanic supervisor, full- and part-time mechanics, tire people and shop supplies.

Driving Labor

Truck drivers may be paid in many different ways. The two most common methods of payment are according to a percentage of the freight bill or on a per mile basis. Other existing methods include per trip, per time period, per mile or simply “dividing up what is left over after expenses.” Full attention to drivers' labor should include rate per mile plus FICA, federal unemployment, health insurance, paid vacation, bonuses and any other fringe benefits.

Total Cost per Mile

The preceding information allows cost to be collected on a per mile, per truck or per fleet basis. As indicated in Figure 2, these costs can be then collected and divided by annual mileage to determine an average cost per mile on both variable and fixed basis. As discussed earlier, the average total cost will vary with mileage. As the fixed costs per fleet or firm are spread out over more total mileage, the average cost per mile decreases.

Figure 2. Economic-Engineering Cost Elements

	Per Mile	Per Truck	Per Fleet
FIXED COSTS			
Depreciation		X	X
ROI		X	X
License		X	X
Housing		X	X
Management		X	X
Total Fixed		X	X
VARIABLE COSTS			
Tires	X		
Fuel	X		
Maintenance	X		
Labor	X		
Total Variable	X		
TOTAL COSTS		X	X
Annual Mileage		X	X
Average Cost per Mile	X		

FIRM PRODUCTIVITY

Economists and traffic or transportation managers studying motor carrier transportation have developed many measures of utilization or estimates of transportation productivity. Many authors in various literature offer alternative ways of evaluating the realized efficiencies in costs of production. The most common elements are those discussed earlier: annual mileage per truck, loaded miles and average weight per load.

In an attempt to evaluate the costs of production that have been discussed in the preceding sections, and to determine the positive impact on the bottom line of any balance sheet, it is useful to look at what does affect costs of production, as indicated in Figure 3. Some selected indicators of productivity are presented. Also identified are some constraints on utilization that allow an intra-firm evaluation of productivity. For example, a reasonable measure of productivity is miles per vehicle, whether annually or in any time period. That measure will be affected directly by the number of stops required of the movement and the length of trip associated with that movement. Miles per gallon of fuel are also affected by the load size, at least to a minimal degree, but also by the number of stops and the length of trip. The productivity of the driver can be evaluated by looking at miles per driver hour. This measure is directly affected by load size, number of stops, and length of trip. Ignoring these constraints gives a biased view of driver productivity.

This process of measuring utilization—what is the capacity for accomplishing work relative to the work to be done—should be developed looking at personnel separately from vehicles. A solid knowledge of costs of operation is the precursor and prerequisite to doing a good job in determining productivity.

Figure 3. Firm Utilization and Efficiency Measures

Measure	Utilization Constraints			
	Shipment Size	Load Size	No. of Stops	Length of Trip
Fleet Miles per Maintenance Employee	X			
Weight Handled per Platform Employee Hour	X			
Miles per Vehicle			x	x
Miles per Trailer/Tractor Day			x	x
Miles per Gallon Fuel		x	x	x
Miles per Driver Hour		x	x	x