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URBANA, ILLINOIS 61801

CAC Document No. 98

TRANSFERRING FROM URBAN CARS TO BUSES: THE ENERGY AND EMPLOYMENT IMPACTS

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April 1974

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ACKNOWLEDGEMENT

We wish to thank Ernest Dunwoody, Robert Herendeen and Clark Bullard for their aid in formulating the ideas in this paper, to Deborah Forman for her editing and Marcie Howell for the preparation.

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Introduction

As energy demand exceeds growth in supply, the concerned public and policymaker alike are taking a closer look at the efficiency of the energy-intensive sectors of our modern society. One of the most informative areas appears to be the use of energy for transportation.

Transportation accounts for approximately 41.8 percent of the total energy consumed in the United States (Herendeen, 1973). Automobiles consume almost one-half of the total transportation energy, and urban automobiles in turn consume more than half of the total energy used by automobiles (see table 1).

This paper describes the development and application of a method for evaluating the direct and indirect dollar, energy, and labor costs of urban passenger transportation by two modes: bus and private automobile. The change in costs when urban passengers transfer from the average car to the average bus is then evaluated.

The two travel modes, bus and private automobile, are each treated as an entire system of urban passenger transportation. The costs are evaluated in units of dollars, British Thermal Units (BTU), and man-years of labor which are required both directly and indirectly to provide each unit of travel.

Purpose of the Research

Our research was directed at answering the following questions:

1. What are the total (direct and indirect) energy and employment costs per passenger for typical United States urban cars and bus companies?
2. What are the dollar costs per passenger for these transport systems?

3. What are the dollar, energy, and employment impacts if the average urban car driver becomes an average urban bus passenger?
4. What are the dollar, energy, and employment impacts when an urban car passenger decides to become an urban bus passenger in the context of an unchanging system?
5. If the dollar cost per passenger rises or falls with the transfer from a car to a bus, what are the energy and employment impacts of this net change in dollar costs?
6. If energy conservation is a goal, how can the system be modified to allow voluntary change to the least energy-consumptive system?

This section is addressed to answering these questions. Later sections provide much useful information to the more determined reader: breakeven points are presented where dollar, energy, and employment impacts of the car and bus are equal (these allow each owner of a typical auto to determine whether he could save energy by taking the bus); energy and labor intensities of both forms of transportation are compared.

This report also includes a detailed statistical analysis of urban cars and bus companies in order to explain the variance of each variable. Using stepwise multiple regression, the top five significant variables of each entity are determined and used to develop a path model for dollar, energy, and labor costs according with linear and nonlinear characteristics. With this model the sensitivity and elasticity of the two entities are studied with respect to ridership.

We also developed a computer simulation program to deal with daily scheduling, preventive and corrective maintenance, and personnel allocations for a bus company (Puleo, 1974). In this model, buses are designated as sources of discrete events of preventive maintenance (normal or special) and performance data (repairs or breakdowns) in order to cover daily routes and schedules of the bus company. The maintenance service sector has mechanics, with day or night schedules, different skills and absence probabilities, which have to satisfy the requirements of bus transportation in a city.

The variables which describe a bus company were combined in a statistical model to produce a new set of mutually independent variables called principal components. A definition of "stress" was obtained from the combination of the principal components in a generalized n-dimensional analogy with special concepts in engineering mechanics (Hannon and Puleo, 1973).

Concept of System

A system is defined as a set of related entities, located in a specified environment.

The entities have attributes which have real or abstract meaning: they have real meaning if they are perceptible to the senses or measurable; they have abstract meaning if they are related to inherent qualities or properties of a concept.

The relationships show the logical or natural association between two or more entities, or between their attributes. The relationships can be structural or functional: they are structural if they deal with the organization, the configuration, or the properties of elements, parts, or constituents of the entities; they are functional if they deal with the natural or proper action for which the entities are assigned relative to a certain purpose or goal.

The environment is the set of all the entities. A system can be closed or open: a system is closed if the system is considered to be completely isolated from its environment; a system is open if the system maintains proper relations with the environment.

Urban Transportation Systems

Here we study a system which has as its environment urban areas and as its function the transportation of people between two points in the area. All the entities in this case are real and correspond to bus companies and individual urban cars. The relationship between the entities is structural, as we are studying the properties of their attributes related with dollar, energy, and labor costs (DEL costs). The system is closed because there is no consideration of the relationship of the system entities with their environment.

Before describing the method and results, let us examine the existing data in a preliminary effort to assess the potential for energy conservation in this area of transportation.

The approximate distribution of United States energy use by selected transportation categories is shown in table 1. In this comparison "urban automobile" is defined by Goss and McGown (1972).

This table shows that approximately 17 percent of the total U. S. transportation energy is consumed directly as fuel by urban automobiles. This is a direct consumption by the urban automobile of approximately 7.1 percent, or a total consumption of 12.3 percent of all annual U. S. energy consumption. In comparison, the urban (and suburban and school) bus consumes approximately 0.33 percent of all the direct energy used for transportation in the United States annually. This is a direct consumption by urban buses of 0.14 percent, or a total consumption of 0.24 percent, of total annual U. S. energy. Clearly the automobile dominates urban passenger transport energy consumption and is a major single consumer.

Table 2 shows that the urban automobile contributes 99.6 percent of the urban passenger vehicle miles while carrying 93.4 percent of the urban passenger trips. The urban bus on the other hand contributes about 0.3 percent of the urban passenger vehicle miles and carries 4.5 percent of the urban passenger trips.

Table 3 shows the actual and potential direct energy consumption per mile of travel for compact automobiles, standard automobiles, and urban buses as calculated by other workers. A comparison of the seat miles per gallon with the actual passenger miles per gallon for each of these three modes provides an estimate of the potential for improving the direct energy efficiency equivalent to the maximum potential energy efficiency of a compact automobile.

The data of table 3 indicate that there is a large potential for saving substantial amounts of direct energy if passengers change their mode of travel from cars to buses. Both modes have the potential for saving a lot of direct energy by increasing their occupancy level, although buses offer the greatest potential. We note that approximately 30 percent of the metropolitan families owned two or more cars in 1971 (Automobile Manufacture Association, Inc., 1971).

Attributes of the System Entities

Recall that the entities are bus companies and individual urban cars, both having the following real attributes:

1. Dollar, energy, and labor (DEL) costs for overhead, which are the fixed annual costs for each entity, for the availability of equipment
2. Dollar, energy, and labor (DEL) costs for operation, which are the annual costs for the use of the equipment and provision of services
3. Dollar, energy, and labor (DEL) costs for streets, which are the annual costs of maintenance and new constructions of bus and automobile rights-of-way
4. Dollar, energy, and labor (DEL) costs for disposal, which are the costs of final recovery and the recycle value of all equipment no longer used

Figure 1 shows the generalized scheme for the computation of DEL costs for both entities. The dollar return upon disposal may be likened to the return of a deposit and has to be subtracted from the overhead dollar cost. However, the energy and labor costs which this deposit causes in the recoverable parts and recycling industry is a cost to the system, and has to be added to the overhead energy and labor costs.

The total output for each entity, corresponding to DEL costs is the following: DELPCO is dollar, energy, and labor costs (DEL) per bus company per year; DELPCA is dollar, energy, and labor costs (DEL) per urban car per year. The general model for each entity is:

DEL = DEL(Overhead) + DEL(Operation) + DEL(Streets) + S(DEL)*DEL(Disposal) (1)

Attribute Measurements

Each attribute is measured in dollar, energy, and labor costs (DEL). Dollar cost is obtained directly from operations data.

The measurement of each variable was made after an extensive data search involving 140 urban bus companies and urban car operation in twenty-eight major U. S. cities in 1971 (see Appendix 8). There is slight dominance of larger bus companies in the data base, and the auto data came from leasing companies. This tends to slightly depress the average bus cost and elevate the average car cost. We also found that the variance in bus-data is very large compared with similar data for the urban car. See Appendix 1.

Energy and labor costs are computed using the Energy, Employment, Pollution Model developed by the Energy Research Group of the Center for Advanced Computation, University of Illinois. This method is based upon the determination of an energy and labor input-output matrix for the United States. The matrix gives energy and labor coefficients to convert dollar expenditures for final demand into the corresponding energy and labor requirements. The model has 362 specific industrial sectors, and the latest available data is for 1963. Energy and labor requirements include direct and indirect demands resulting from the demand for goods and services on each sector. Details of this method are given in Herendeen (1973).

In general, the method is used in this way: If we have a variable X (I,K) which corresponds to Sector I of the U. S. economy given in dollars at year K, the DEL costs are computed through the following equation:

$$X\ (I,K,DEL) = X(I,K) *DF\ (I,K) *I\emptyset\ (I,DEL) *IF\ (I,K,DEL) \qquad (2)$$

where:

X (I,K,DEL) : DEL costs of variable X(I,K) at year K

DF (I,K) : Dollar deflator from year K to year 1963 of sector I

IØ (I,DEL) : DEL Input-Output coefficient per dollar corresponding to sector I in year 1963

IF (I,K,DEL): DEL inflator of sector I in year 1963 to year K

Dollar Deflator: DF (I,K)

Dollar deflators of sector I from year K to year 1963 are computed using the implicit price deflators (IPD) given by the Survey of Current Business (1972). See Appendix 5.

The corresponding deflator is given by

$$DF(I,K) = \frac{IPD\ (I,1963)}{IPD\ (I,K)} \qquad (3)$$

For example, the deflator of dollars expended in the wholesaling of fuel for bus companies in 1971 corresponds to sector 69.01 (wholesale trade) which has the following implicit price deflators:

IPD (69.01, 1963) = 103.05

IPD (69.01, 1971) = 120.5

hence

DF (69.01, 1971) = 103.05/120.5 = 0.8589

DEL Input-Output coefficient: IØ (I,DEL)

These coefficients are obtained from tables determined by Herendeen (1973).

For the variable used in the last example (wholesaling of fuel for bus companies), the corresponding DEL coefficients are:

IØ (69.01, Dollar) = 1.00 Dollar/Dollar

IØ (69.01, Energy) = 0.033261×10^{6} BTU/Dollar

IØ (69.01, Labor) = 0.114199×10^{-3} Jobs/Dollar

DEL Inflator: IF (I,K,DEL)

Dollar inflator of sector I from year 1963 to year K is computed by taking the reciprocal of the corresponding dollar deflator, hence

$$\text{JF (I,K,Dollar)} = \frac{1}{\text{DF (I,K)}}$$

Energy and labor inflators of sector I from year 1963 to year K were computed by Herendeen and Sebald (1973). The corresponding values for all sectors for the year 1971 are:

IF (All sectors,1971,Energy) = 1.029 BTU 1971/BTU 1963

IF (All sectors,1971,Labor) = 0.853 Jobs 1971/Jobs 1963

If the variable used is wholesale of fuel to bus companies (WFUEL) which has a mean value of 75,230 dollars in 1971, the DEL costs are then the following:

$$\text{WFUEL (69.01,1971,Dollar)} = 75230*0.8589*1.\ \frac{*1}{0.859} = 75{,}230 \text{ Dollars}$$

$$\text{WFUEL (69.01,1971,Energy)} = 75229*0.8589 * 0.033261\text{x}10^{6}* 1.029=0.21173\text{x}10^{10} \text{ BTU}$$

$$\text{WFUEL (69.01,1971,Labor)} = 75229 * 0.8589 * 0.114199\text{x}10^{-3} * 0.853 = 6.295 \text{ Jobs}$$

Thus the wholesale of fuel to bus companies required in 1971 an average cost of 2.2 billion Btu and 6.3 jobs per bus company.

The DEL costs for each variable of the bus companies (thirty-eight company average) and urban car (twenty-eight city average) are given in tables 4 and 5, respectively, for 1971. See Appendix 1 and Appendix 8.

The data of tables 4 and 5 are totaled in table 6.

The average trip length (ATL) of the average bus passenger is computed as

$$\text{ATL} = \frac{\text{TBM x PPB}}{\text{PPCO}} \qquad (4)$$

where

PPCO = Passengers per bus company per year

TBM = Total miles per bus company per year

PPB = Passengers per bus or average loading

Estimated values of these parameters are:

TBM	= $8.3699\text{x}10^{6}$ Miles/Bus Co. - Year	See Appendix 8.
PPB	= 12 Passengers/Bux	U.S. Dept. of Transportation (1973)
PPCO	= $26.725\text{x}10^{6}$ Passengers/Bus Co. - Year	See Appendix 8.

Then the computed value of ATL is

$$ATL = 3.758 \text{ Miles}$$

The average number of passengers (ANP) per year who use a car is given by the expression:

$$ANP = \frac{MPCY^{*}PPT}{MPT} \qquad (5)$$

where

MPCY = Miles per car per year

PPT = Passengers per trip

MPT = Miles per trip

Estimated values of these parameters are

MPCY =	11200 Miles/Car-year	See Appendix 8.
PPT =	1.9 Passengers/Trip	U.S. Dept. of Transportation (1972)
MPT =	8.3 Miles/Trip	U.S. Dept. of Transportation (1972)

Then the computed value of ANP is:

$$ANP = 2563.86 \text{ Car-Passengers/year}$$

Knowing the average number of passengers and their average trip length we can construct table 7 which gives us a DEL cost comparison between the urban bus and the urban car.

The results of table 7 are familiar to the energy researcher: the car costs less per passenger mile on the average, but demands far more energy and is less labor intensive. Also note from tables 4 and 5 that increases in energy costs affect the car operation adversely relative to the bus, and that the opposite is true for employment.

Car-Bus Transfer

There are two processes of transferring from urban cars to buses, one is a nationwide change (or a shift of the average consumer) and the other is on an individual basis. The effects on the DEL costs are quite different. Typically, we have four different purposes for travel: work, family business, education, and recreation. The DEL costs of both types of transfer processes are calculated for each trip purpose and for a weighted average.

Nationwide Change

We are always assuming that the DEL costs per passenger trip by car for the remaining cars remains the same during the transfer of car passengers to buses. This is true since we assume that there are no "fixed costs" in the long run. That is, if we reduce the amount of use of the "average" car, the car will last proportionally longer (assuming no style-dependent depreciation), and the overhead costs will be distributed over a proportionally longer period of time. Also, the "fixed costs" such as insurance and licenses, etc., should be proportionally lower with each incremental transfer of passengers since auto driving will decrease. This model does not apply to the individual who changes his personal car usage if there is no accompanying change in the national amount of personal car usage. The nationwide change model transfers the "average" car passenger to the "average" bus as though the entire nation were shifting its mode of urban travel.

The following expression gives the total DEL decrease per car (TDPC) in DEL costs per year:

$$TDPC\ (DEL) = (DELPCA-DELPCO \times \frac{TPTC}{PPCO})\ MPP \quad (6)$$

where:

DELPCA: Total DEL costs per car year, given in table 6

DELPCO: Total DEL costs per bus company per year, given in table 6

PPCO : Passengers per bus company per year

MPP : Percentage of car miles, per trip purpose, per car, per year, or miles purpose percentage

TPTC : Trip purpose transfer coefficient in trip-purpose passengers per year is given by

$$TPTC = \frac{MPCY * PPTP}{MPTP} \quad (7)$$

where:

MPCY : Miles per car-year

PPTO : Passengers per trip-purpose in a car

MPTP : Miles per trip-purpose in a car

The estimated values are:

MPCY = 11200.0 miles/car-year

PPCO = 26.725×10^6 Passengers/Bus Co. - Year

The remaining estimated values are given in table 8 (U. S. Department of Transportation, 1972).

Using the computed values of DELPCA and DELPCO given in table 6 and the estimated values given previously, we can compute the total decrease per year in DEL costs for a nationwide-change. These values are given in table 9.

This table shows that the most money, energy, and labor would be saved if work and recreational trips, respectively, were made by bus rather than by car. The weighted average for this 1971 distribution of trip purposes shows that there would be a general savings of dollars, energy, and labor if passengers transferred from cars to buses.

The current urban passengers per trip-purpose per car-year (TPTC) values are given in table 10. We have also shown the sign of the total DEL decrease (+) per car, when passengers are transferred to buses for each of the trip purposes.

Table 10, in conjunction with table 9, allow the reader to estimate the DEL costs of special cases of partial national average transfer from cars to buses in the U. S. urban area.

Individual Transfer

In this case we consider the situation in which an average individual urban car owner changes his personal (and family) urban travel mode from car to bus while the system as a whole does not change. The change is envisaged as occurring incrementally by travel purpose in this order: work, recreation, family business, and education.

As the urban car owner switches his travel mode, the annual operating costs of the car decreases, while the annual fixed or overhead costs remains essentially the same. However, there will be an increase in costs associated with using the bus. The cost to the revenue passenger of using the bus system is estimated using the mean DEL values for the entities. These are the DEL cost changes to the system, not to the individual. The amount, type, and purpose distribution of urban travel has been held constant in this computation.

The total DEL decrease (TDPC) that would be experienced by an urban car owner who transferred from car to bus for his urban travel, while there was no change in the system as a whole is given by

$$ITDPC(DEL) = VCM(DEL) \sum_{K=1}^{4} MPTP(K) * TN(K) - \frac{DELPCO}{PPCO} \sum_{K=1}^{4} TN(K) * PPTP(K) \quad (8)$$

where:

ITDPC(DEL):	Individual total DEL cost decrease per car-year
VCM(DEL):	Variable DEL cost per mile
MPTD(K):	Miles per trip purpose (K) in a car
TN(K):	Number of car trips for each purpose (K) per year
DELPCO:	Total DEL costs per bus company per year
PPCO:	Total passengers per bus company per year
PPTP(K):	Passengers per trip purpose (K) in a car

Variable DEL cost per mile [VCM(DEL)] is estimated by taking the following operation and street variables: maintenance, repairs, fuel volume energy, fuel cost to produce, fuel cost to transport, fuel cost to wholesale, fuel cost to retail, and fuel volume tax. The variable DEL cost per mile is then given by:

$$VCM(DEL) = V\ COST(DEL)/MPCY \quad (9)$$

where V COST(DEL) corresponds to the sum of the given variable. DEL costs are given in table 5.

The number of car trips, TN(K), per each purpose per year is estimated assuming that for every passenger trip not made by car, an equivalent passenger trip is made by bus. Then

$$TN(K) = \frac{MPCY * MPP(K)}{MPTP(K)} \quad (10)$$

where:

MPCY: Miles per car-year

MPP(K): Percentage of car miles per trip purpose (K) per car-year, or miles purpose percentage

The estimated values of TN(K) are given in table 12; the estimated number of bus passengers PT(K) equivalent to car trips is computed by the relation

$$DT(K) = TN(K) \times PPTP(K) \tag{11}$$

The individual total DEL cost decrease per car-year ITDPC(DEL), is given in table 13 for each trip purpose.

Clearly, the average individual is not going to initiate a change from car to buses even though such a change would save energy and increase employment because all his costs are increased (negative decrease). It simply is not in his interest to give up savings to ride the bus, especially if he views urban buses as psychologically undesirable relative to his car. This situation calls for external regulation from the environment if energy conservation is to be achieved.

A significant decrease in energy consumption and increase in employment could be obtained if the nation were to use, on the average, urban buses instead of passenger cars. However, note what confronts the individual car owners when they intend to change to bus travel in the context of an unchanging system: Depreciation and fixed costs remain the same regardless of the miles driven, thus the individual who transfers a portion of his urban travel needs to buses but retains his car experiences an increase in dollar cost per mile for every trip purpose. The typical individual would at first transfer only part of his car needs and so immediately discover that this is a dollar costly process. Nevertheless, he would still decrease energy consumption and increase employment. The weighted average in table 13 assumes that the individual has switched entirely to the bus but still retains his car in operating condition. If he sells the car, the net costs would be as given in the bottom row of table 9. Note that the easiest car to eliminate would be the second car, used for work trips.

Energy and Employment Impacts in the Car to Bus Passenger Transfer

The ratios of energy and labor costs to dollar cost provide an estimate of the energy and labor impacts for both bus companies and urban cars. These intensities are given by the following equations for each transfer mode, nationwide and individual.

For bus companies:

$$EI(Bus) = \frac{DELPCO\ (Energy)}{DELPCO\ (Dollar)} \tag{12}$$

$$LI(Bus) = \frac{DELPCO\ (Labor, Jobs)}{DELPCO\ (Dollar)} \tag{13}$$

For urban cars:

$$EI(Car) = \frac{DELPCA\ (Energy)}{DELPCA\ (Dollar)} \tag{14}$$

$$LI(Car) = \frac{DELPCA\ (Labor, Jobs)}{DELPCA\ (Dollar)} \tag{15}$$

The estimated values of these impacts are given in table 14.

The urban car has a higher energy impact than the bus companies and provides less employment, per dollar.

We can also compute the saving impacts of the individual transfer from car to buses using values given in table 9 and table 13 for a nationwide change and for an individual transfer, respectively. These impacts are given in table 15.

Table 15 shows that the highest energy impact is in the individual transfer corresponding to work trips and the least is for education trips. The data in this table indicate the energy or labor savings rate (i.e., energy or labor change as a ratio to dollar change).

Table 16 reveals the impacts of other categories of transportation and some other sectors of the economy. All values have been adjusted from the base year 1963. Impacts for 1971 are estimated from national average energy and labor productivity data and are considered as estimates only.

Tables 15 and 16 can now be used in a novel and informative way. From table 15, and the supporting tables 9 and 13, we find that the switch from car to bus saves not only energy but dollars. Take, for example, the weighted average for the national transfer. Here the consumer is saving energy and dollars at the rate of 410,830 BTU per dollar. How will he spend this dollar savings so that he remains a net energy conserver? He must be careful not to choose something more energy intensive than the rate at which he saves in his transport change. Table 16 provides a partial list of personal consumption items, ranked in order of decreasing energy intensity. The labor intensity of each item is also given.

The average consumer must choose to spend his dollar savings on any of the categories shown in table 16 except electricity or gasoline if he wishes to maintain his position as a net energy saver. Note that since the individual passenger's changes require money to be extracted from other existing expenditures in every case this consumer will be an even larger energy conserver. The magnitude of the total savings can be computed only after the areas of spending reduction is chosen. The same procedure applies to the conservation of labor.

Modifying the Environment

Two economic solutions are available for the increased cost problem facing the individual who wishes to change from a car to a bus but retain his car during the process of change. They are: increasing the cost of auto fuel or decreasing the bus costs by increasing ridership. These two breakeven problems are now solved for each trip purpose.

Changing the Cost of Fuel

According to equation (9) the variable DEL cost per mile is an aggregated value of the variables given in table 17, where the corresponding estimated dollar values for 11,200 Miles/car-year in 1971 are also given.

The variable cost per mile in dollars is

$$\text{VCM (Dollar)} = 572.51/11200 = 0.0511 \text{ Dollar/Mile-year}$$

The total cost of fuel to the consumer is given by variables 4 through 8 and this is

$$\text{TFUELC} = 301.91 \text{ Dollar/Year}$$

The percentage of the total fuel cost related to total cost is

$$\text{PFUEL} = 301.91\text{x}100/572.21 = 52.73\%$$

The average cost of fuel per mile is

$$\text{CPM} = 0.027 \text{ Dollar/Mile-Year}$$

Here we assume that the change in the environment affects <u>only</u> the cost of car fuel per gallon. The average cost per gallon in 1971 was

$$CPG = 0.377 \text{ Dollar/Gallon}$$

and the average miles per gallon was

$$MPG = CPG/CPM = 0.377/0.027 = 13.96 \text{ Miles/Gallon}$$

The required change in VCM (Dollar) is given by the change in the total fuel cost per mile, hence

$$\Delta CPM = BEVCM\ (Dollar) - VCM\ (Dollar)$$

where BEVCM (Dollar) is the break-even value for variable DEL cost per mile, which determines a null DEL cost decrease in the individual transfer, given by the equation

$$BEVCM\ (DEL,K) = \frac{DELPCO}{PPCO} \times \frac{PPTP(K)}{MPTP(K)} \qquad (16)$$

where K represents each trip purpose. Values of BEVCM (DEL,K) are given in table 18.

The new cost per mile is then

$$CPM^* = CPM + \Delta CPM \qquad (17)$$

and the new cost per gallon is then

$$CPG^* = CPM^* \times MPG \qquad (18)$$

The corresponding fractional change in the cost per gallon is given by

$$PCPG = \frac{CPG^*}{CPG} \tag{19}$$

The values of ΔCPM, CPG* and PCPG per trip-purpose are given in table 19 for a null dollar decrease with transfer from car to buses.

We can see that in 1971 the new price of fuel had to be increased 2.47 times to an average cost of 0.93 dollar/gallon in order that the total dollar cost of the bus companies be equivalent to the variable dollar cost of the urban car, i.e., null dollar decrease for the transfer.

Changing the Number of Passengers Using the Bus

The number of passengers, PPCO, per bus company per year required for a break-even value necessary to reduce bus costs so that it becomes equal to the variable costs of owning a car (individual transfer case) is given by

$$BEPPCO(K) = \frac{DELPCO}{VCM(DEL)} * \frac{PPTP(K)}{MPTP(K)} \tag{20}$$

and the required fractional change is

$$PPPCO(K) = \frac{BEPPCO(K)}{PPCO} \tag{21}$$

We assume that the total bus company costs remain the same, while an increase in the number of passengers reduces the average fare.

The estimated values for dollar costs only are given in table 20.

We can see that on the average the bus companies had to increase 1.77 times their total number of passengers in order that the transfer from car to buses produces equal cost to the consumer. Work trips could be attracted to the bus by only a 6 percent increase in bus ridership.

Conclusions

Bus Companies

It costs an average urban bus company \$10,583.464 and 530.11 x 10^9 BTU and 838.63 man years of labor to operate an average of 256 buses in 1971. Each bus carried an average of 267,250 revenue passengers in 1971 at a total cost of 39.6¢, 19,835 BTU and 31.38 x 10^{-6} man years per revenue passenger trip. This total cost includes both the fixed and variable costs, and the direct and indirect costs for the urban bus company.

Other workers have expressed their results in dollars per passenger mile. Because there are no good sources of data about the characteristics of urban bus travel nationwide, such estimates are likely to vary widely. If we presume that an average urban bus traveller rides an average of 3.8 route miles per bus trip then the total costs of urban bus travel are 10.5¢, 5,279 BTU, and 8.35 x 10^{-6} man years of labor per revenue passenger mile.

Urban Cars

The cost of using one standard American automobile exclusively for an average amount of urban travel in 1971 was \$1,353.95, 189.978 x 10^6 BTU and 88.92 x 10^{-3} man years of labor. Each standard American urban automobile (or urban automobile equivalent) was used for an average of 1,349.4 vehicle trips and each trip was approximately 8.3 miles long. In travelling this amount, each average urban car provided 2,564 passenger trips at a total cost of 52.80¢, 74,099 BTU, and 34.68 x 10^{-6} man years of labor per passenger trip. This is equivalent to 6.90¢, 8,928 BTU, and 4.18 x 10^{-6} man years of labor per urban passenger mile. Again, this includes both the fixed and variable costs and the direct and indirect costs of urban car transportation. Home garage costs were not included because of a lack of data.

<u>Comparison</u>

A comparison of the total actual user costs for urban cars and buses reveals that urban bus travel costs 52 percent more money, uses 41.9 percent less energy, and is 99.8 percent more labor intensive than urban car travel on a per passenger mile basis. While many people are currently in the habit of making comparisons between different modes of transportation on a per mile basis we feel that in the instance of urban passenger transportation it is more meaningful to base comparisons on a functional unit rather than an arbitrary mileage basis. For this reason our car-bus transfer model is based on transferring trips for each of four purposes from one mode of travel to the other mode. On a passenger trip basis, urban bus travel costs 25.0 percent less money, 73.2 percent less energy and 9.5 percent less labor than travel by the urban car. These comparisons are based on total costs to the system of transportation. The numerical values may therefore be greater than the direct out-of-pocket expenses.

In making the comparison in this manner there are, no doubt, statistically significant differences in the number of miles travelled by the car and bus modes for each of the four trip purposes. The extent of the differences remains unknown because of the absence of detailed bus-use data. It is our judgment that any present differences in urban car and bus trip lengths for different purposes would be largely mitigated by compensating changes in travel patterns, route design and urban activity location, in the long run. For this reason we caution against simplistic comparisons of the two modes previously presented.

Nationwide Change

In table 9 we have shown that if urban car travel transferred to bus travel there would be a total saving by the system of $338.63, 139.12×10^{6} BTU, and 8.47×10^{-3} man years of labor per car for the year 1971. These estimates are based on the premise of a long-term national change in urban travel from cars to buses.

The amount of dollars, energy, and labor that would be saved by a transfer of passengers from urban cars to buses for each of the four major types of travel purposes and for the weighted average travel are also indicated in this table. (Negative signs indicate that there would be an increase rather than a decrease in the dollar energy or labor cost.) The largest financial savings would come from transferring work travel ($302.54) and recreational travel ($1.69.00) to the urban bus. There would be no financial saving in transferring family business and educational travel from the urban car to the urban bus; it would cost $30.18 and $53.88 per car per year more, respectively.

The transfer of all categories of urban travel from cars to buses would decrease the amount of energy used. The energy savings, for a one percent transfer, would be greatest for the transfer of work travel (64.75×10^{6} BTU), followed in order by recreation travel (49.14×10^{6} BTU), family business travel (22.92×10^{6} BTU), and educational travel (3.29×10^{6} BTU).

A one percent transfer of work and recreational travel from cars to buses would save 16.52×10^{-3} and 7.28×10^{-3} man years of labor, respectively. Family business and educational travel would require 6.07×10^{-3} and 5.17×10^{-3} more man years of labor, respectively. Overall there would be a small decrease in the amount of labor needed to provide the same amount of urban travel.

The shift to bus saves the consumer money which will be spent and consequently demand a new round of energy and employment. How much depends on the consumer choice of where he would spend his new found dollar savings. A table of the energy and employment costs of various consumer goods is provided from which the consumer could establish his alternate spending plans to maintain or even increase his energy conservation.

Individual Transfer

The individual urban car user who changes to the bus for all urban travel purposes or for some partial combination thereof, while continuing to own an average car will experience the DEL changes shown in table 13. Substitution of the bus for the car costs more for each travel purpose from a low of $14.72/year to a high of $186.46/year/car year. Substitution of the bus for the car while still owning the car causes a demand for more labor and less energy, for all urban travel purposes.

The weighted average values for DEL for the individual substitution indicate that it would cost $442.79 more, save 102.00×10^6 BTU, and require 45.58×10^{-3} more jobs per urban car per year for an individual urban car owner to retain ownership of his car but to give up using it for urban travel and use the bus in its place. The DEL costs for substituting the bus for the car for a percentage of the urban travel may again be obtained by multiplying the values in table 13 by TP where TP ranges from 0 to 1.

Here we reveal the crux of the policy problem of inducing people to change from urban auto to buses.

In the existing system, it is simply not economical in a dollar sense for an individual to replace some of the auto use by bus, while still retaining the auto for the remaining trips, even though there is an energy savings. If, for example, the individual owns a special auto used only for work trips and he decides to take a bus to work to save energy, he will lose money unless he disposes of this auto.

If, on the other hand, the auto system was regulated so that the fixed costs and depreciation of the auto become essentially functions of the mileage instead, the individual would have the dollar motivation to save a considerable amount of energy and increase employment.

Two alternative modes to remove the dollar disincentive to slowly giving up the auto and taking the bus are: taxing auto fuel and reducing the bus cost. We found that price of gasoline would have to rise from 37 to 93 cents per gallon (1971) or bus ridership would have to increase by 77 percent, before the variable cost of the car and bus cost were equal.

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Transportation Category		Percent of All Transportation Energy	Percent of All U.S. Energy
Total Transportation Used ..... (1963)	Directly	55.3[d]	23.1[c]
	Directly and Indirectly	100	41.8[c]
All U.S. Autos Used ..... (1963)	Directly	28.5[e]	11.9[c]
	Directly and Indirectly	49.5[f]	20.7[c]
All Urban Autos Used ..... (1971)	Directly	17.0[g]	7.1[h]
	Directly and Indirectly	29.4[j]	12.3[i,r]
All Urban Buses[b] Used ..... (1971)	Directly	0.33[k]	0.14[l]
	Directly and Indirectly	0.58[n]	0.24[m,s]

a. Total refers to the sum of direct and indirect energy.

b. This includes urban, rural, and school buses (not intercity).

c. Herendeen (1973).

d. Assumes that transportation and the GNP have similar indirect energy intensities (55.3% = 23.1/0.418).

e. (28.5% = 11.9/0.418)

f. (49.5% = 20.7/0.418)

g. (17.0% = 55.3 x 0.307[q])

h. (7.1% = 17.0 x 0.418)

i. (12.3% = 7.1/0.577)

j. (29.4% = 12.3/0.418)

k. (0.33% = 0.006[q] x 55.3)

l. (0.14% = 0.33 x 0.418)

m. (0.24% = 0.14/0.577)

n. (0.58% = 0.24/0.418)

p. The ratio of all auto direct energy to total transportation direct energy was 0.515 in 1963 and 0.571 in 1972[c].

q. Goss and McGowan (1972).

r. Assumes that urban autos and average autos have similar indirect energy intensities.

s. Assumes that buses have similar indirect energy intensities to average autos.

Table 1. Approximate percentage distribution of annual direct and total[a] United States energy used by selected transportation categories.

Mode	Percentage of Total U.S. Energy Consumption (1971)	Percentage of Total U.S. Urban Passenger Vehicle Miles (1970)	Percentage of Total Urban Passenger Trips (1970)
Urban Auto	12.3 [a]	99.62 [b]	93.4 [d]
Urban Bus	0.24 [a]	0.31 [c]	4.5 [e]

a. See Table 1.

b. Urban automobile mileage = $494{,}543 \times 10^6$. (U.S. Department of Transportation,1970) Transit vehicle mileage = $1{,}883 \times 10^6$. (U.S. Bureau of Census, 1973).

c. Urban bus mileage = $1{,}409 \times 10^6$ plus 8%. (U.S. Bureau of Census, 1973). See d.below.

d. Average automobile trip length in incorporated places = 8.3 miles. (U.S. Department of Transportation, 1972). Urban automobile mileage as in b. Transit passenger trips = $7{,}332 \times 10^6$ plus 8% adjustment factor. (U.S. Bureau of Census, 1973). Comparison of Federal Highway Statistics and American Transit Association (ATA) data on urban buses reveals that the ATA data does not account for approximately 8% of the U.S. urban bus fleet.

e. Urban bus passenger trips = 5.034×10^6 plus 8%. (d.) (U.S. Bureau of Census.1973).

Table 2. Energy and performance characteristics for the urban bus and automobile.

Mode	Seat[b]	Passenger[c]	Seat[b]	Passenger[c]
Compact Automobile	120[d]	42[d]	1,300[f]	--
Urban[a] Automobile	64[d]	15[d]	2,817[f]	8,100[g]
Urban Bus[a]	215[e]	110[d]	1,548[f]	3,700[g,1]
	220[d]	125[e]		

a. The three footnotes in these two categories may vary slightly in their definition of this mode.

b, Seat miles/gallon based on theoretical average seating capacity.

c. Passenger miles/gallon based on approximation of actual passenger load.

d. Goss and McGowan, (1972).

e. Rice, (1970).

f. Michaels and Maltz, (1973)

g. Hirst, (1973).

1. The figures of Michaels and Maltz (1973) are not comparable because they have expressed their values in BTU*/revenue passenger, not BTU/passenger mile.

*BTU = British Thermal Units

Table 3. Direct energy consumption per unit of transportation service by urban bus and automobile as reported by other markers.

NO.	VARIABLE	DOLLAR ($x10^3$)	ENERGY ($BTUx10^9$)	LABOR (JOBS)
	OVERHEAD			
1	Manufacture	625.217	43.252	47.192
	OPERATION			
2	General Maintenance	827.742	17.113	34.921
3	New Tires and Tubes	10.418	0.883	0.484
4	Retread Tires and Tubes	93.761	2.685	5.480
5	Repairs	891.614	66.871	83.786
6	Station	47.829	2.578	3.230
7	Transportation	945.849	21.980	74.312
8	Drivers	4136.520	0.0	0.0
9	Driver Years	0.0	0.0	407.367
10	Fuel Volume Energy	0.0	257.049	0.0
11	Fuel Cost to Produce	122.162	21.235	4.258
12	Fuel Cost to Transport	8.052	1.304	0.428
13	Fuel Cost to Wholesale	75.229	2.212	6.295
14	Fuel Cost to Retail	24.616	0.712	11.113
15	Lub. Oil Volume Energy	0.0	3.284	0.0
16	Lub. Oil Cost to Produce	6.101	1.061	0.213
17	Lub. Oil Cost to Transport	0.402	0.065	0.021
18	Lub. Oil Cost to Wholesale	3.757	0.110	0.314
19	Lub. Oil to Retail	1.229	0.036	0.145
20	Administration	1674.190	32.980	88.193
21	Traffic Services	47.587	0.937	2.507
22	Advertising	31.725	0.856	1.671
23	Insurance	351.572	7.505	23.546
24	Licenses	228.230	14.969	12.836
25	Rents	37.173	0.573	1.010
	STREETS			
26	Taxes	228.230	15.130	12.209
27	Fuel Volume Tax	186.251	12.347	9.999
	DISPOSAL			
28	Recoverable Value	23.485	1.778	6.761
29	Recyclable Value	2.609	0.606	0.340

Table 4: DEL Costs Per Bus Company Per Year (1971)

NO.	VARIABLE	DOLLAR	ENERGY (BTUx10^6)	LABOR (JOBSx10^{-3})
	OVERHEAD			
1	Manufacture	325.328	21.141	19.974
2	Rail Transport	4.077	0.242	0.272
3	Truck Transport	4.077	0.279	0.288
4	Wholesale	8.154	0.251	0.716
5	Retail	66.044	4.292	8.185
6	Financing Charge	70.648	0.922	3.703
	OPERATION			
7	Maintenance	145.600	4.169	8.509
8	Repairs	125.000	3.579	7.305
9	Fuel Volume Energy	0.0	117.738	0.0
10	Fuel Cost to Produce	93.710	16.289	3.266
11	Fuel Cost to Transport	8.935	1.773	0.466
12	Fuel Cost to Wholesale	62.335	1.833	5.216
13	Fuel Cost to Retail	42.803	1.238	5.052
14	Insurance	237.399	5.068	15.899
15	Licenses	19.740	1.295	1.110
16	Local Government	25.198	1.557	1.335
	STREETS			
17	Fuel Volume Tax	94.137	6.241	5.054
18	New Constructions	25.198	1.670	1.353
	DISPOSAL			
19	Recoverable Value	4.032	0.305	1.161
20	Recyclable Value	0.403	0.094	0.053

Table 5: DEL costs per urban car per year (1971)

ATTRIBUTE	BUS COMPANY DOLLAR ($x10^3$)	BUS COMPANY ENERGY ($BTUx10^9$)	BUS COMPANY LABOR (JOBS)	URBAN CAR DOLLAR	URBAN CAR ENERGY ($BTUx10^6$)	URBAN CAR LABOR ($JOBSx10^{-3}$)
OVERHEAD	625.217	43.252	47.192	478.327	27.129	33.139
OPERATION	9569.760	456.998	762.128	760.719	154.540	48.159
STREETS	414.481	27.477	22.209	119.335	7.911	6.407
DISPOSAL	26.094	2.382	7.101	4.435	0.399	1.213
TOTAL	10583.464	530.109	838.630	1353.950	189.978	88.919

Table 6: Dollar, energy and labor costs per year, DELPCO and DELPCA, 1971

	DOLLAR	ENERGY (BTUx10^3)	LABOR (JOBSx10^{-6})
URBAN BUS			
Cost Per Passenger	0.396	19.835	31.380
Cost Per Passenger-Mile	0.105	5.279	8.352
URBAN CAR			
Cost Per Passenger	0.528	74.099	34.682
Cost Per Passenger-Mile	0.069	8.928	4.179

Table 7: DEL Intensity comparison for urban bus and urban car , 1971

TRIP PURPOSE	PPTP	MPTP	MPP
Work	1.4	10.2	0.406
Family Business	1.9	5.6	0.200
Education	2.6	4.7	0.049
Recreation	2.5	13.1	0.333
Weighted Average	1.9	8.3	1.000

Table 8: Estimated values of passengers per trip purpose (PPTP), miles per trip purpose (MPTP), and miles purpose percentage (MPP), 1971

TRIP PURPOSE	DOLLAR	ENERGY ($BTU \times 10^6$)	LABOR ($JOBS \times 10^{-3}$)
Work	+302.542	+ 64.751	+16.516
Family Business	- 30.178	+ 22.920	- 6.065
Education	- 53.882	+ 3.287	- 5.169
Recreation	+169.002	+ 49.144	+ 7.275
Weighted Average	+338.634	+139.122	+ 8.465

Table 9: Total DEL decrease (+) per car per year, nationwide transfer 1971

TRIP PURPOSE	TPTC	DOLLAR	ENERGY	LABOR
Work	1537.25	+	+	+
Family Business	3800.00	-	+	-
Education	6195.74	-	+	-
Recreation	2137.40	+	+	+
Weighted Average	2563.85	+	+	+

Table 10: Current values of trip purpose passengers per car year (TPTC) 1971, and sign of the total DEL decrease

	DOLLAR/MILE	BTU/MILE	JOBS/MILE
VCM(DEL)	0.0511	0.0136×10^{6}	3.113×10^{-6}

Table 11: Variable DEL costs per mile per car-year, 1971

TRIP PURPOSE	MILES(*)	TRIPS	PASSENGERS
Work	4547.20	445.80	624.13
Family Business	2240.00	400.00	760.00
Education	548.80	116.77	303.60
Recreation	3729.60	284.70	711.76
Total	11200.00	1349.40	2563.86

Table 12: Car miles, car trips, and bus passenger-trips by trip purpose, 1971

(*) The four trip purpose mileages sum to slightly less than the total urban mileage because there are 1.2% of "other" or "not available" trip purposes in the data used.

TRIP PURPOSE	DOLLAR	ENERGY (BTUx10^{6})	LABOR (JOBSx10^{-3})
Work	- 14.72	+ 49.68	- 5.43
Family Business	-186.46	+ 15.50	-16.88
Education	- 92.17	+ 1.47	- 7.82
Recreation	- 91.21	+ 36.78	-10.72
Total	-442.79	+102.00	-45.58

Table 13: Individual transfer DEL cost decrease (+) per car-year, 1971

ENTITY	ENERGY (BTU/DOLLAR$\times 10^{3}$)	LABOR (JOBS/DOLLAR$\times 10^{-6}$)
Bus Co.	50.08	79.24
Urban Car	140.31	65.67

Table 14: Energy and labor impacts for 1971

TRIP PURPOSE	NATIONWIDE CHANGE ENERGY (BTU/DOLLAR)x10^3	NATIONWIDE CHANGE LABOR (JOBS/DOLLAR)x10^{-6}	INDIVIDUAL TRANSFER ENERGY (BTU/DOLLAR)x10^3	INDIVIDUAL TRANSFER LABOR (JOBS/DOLLAR)x10^{-6}
Work	+214.02	+ 54.59	-337.50	+368.89
Family Business	-759.49	+200.97	- 83.13	+ 90.53
Education	- 61.00	+ 95.93	- 15.95	+ 84.84
Recreation	+290.79	+ 43.05	-403.25	+117.53
Weighted Average	+410.83	+ 24.99	-230.36	+102.94

Table 15: Energy and labor impacts per dollar for a nationwide change and individual transfer for 1971 (decrease is +)

Personal Consumption Expenditure Sector Description	Energy Intensity BTU/$	Labor Intensity Jobs/$
Electricity	502,473	0.04363
Gasoline and oil	480,672	0.07296
Cleaning preparations	78,120	0.07332
Kitchen and household appliances	58,724	0.09551
New and used cars	55,603	0.07754
Other durable house furniture	45,593	0.08948
Food purchases	41,100	0.08528
Furniture	36,664	0.09176
Women and children's clothing	33,065	0.10008
Meals and Beverages	32,398	0.08756
Men and boys clothing	31,442	0.09845
Religious and welfare activity	27,791	0.086365
Privately controlled hospitals	26,121	0.17189
Automobile repair and maintenance	23,544	0.04839
Financial interests except insurance co.	21,520	0.07845
Tobacco products	19,818	0.05854
Telephone and Telegraph	19,043	0.05493
Tenant occupancy non-farm dwelling	18,324	0.03502
Physicians	10,271	0.03258
Owner occupancy non-farm dwelling	8,250	0.01676

Table 16. The Energy and Labor Intensity of the largest twenty activities of personal consumption expenditures, ranked in order of Decreasing Energy Intensity, 1971. (CAC Energy-Employment Model)

NO.	VARIABLE	DOLLAR
1	Maintenance	145.60
2	Repairs	125.00
3	Fuel Volume Energy	0.0
4	Fuel Cost to Produce	93.71
5	Fuel Cost to Transport	8.93
6	Fuel Cost to Wholesale	62.33
7	Fuel Cost to Retail	42.80
8	Fuel Volume Tax	94.14
	Total	572.51

Table 17: Dollar value of the variables affecting the variable DEL cost per car mile in 1971

TRIP PURPOSE	BEVCM(DEL,K) DOLLAR/MILE ($x10^{-2}$)	BTU/MILE ($x10^{3}$)	JOBS/MILE ($x10^{-6}$)
Work	5.43	2.72	4.30
Family Business	13.42	6.72	10.64
Education	21.89	10.97	17.35
Recreation	7.56	3.79	5.99
Weighted Average	9.07	4.54	7.19

Table 18: Break-even values of variable DEL cost per mile (BEVCM), 1971

TRIP PURPOSE	CPM $(x10^{-2})$	CPG^* (DOLLAR/GALLON)	PCPG
Work	+ 0.320	0.42	1.12
Family Business	+ 8.31	1.54	4.08
Education	+16.78	2.72	7.21
Recreation	+ 2.45	0.72	1.91
Weighted Average	+ 3.96	0.93	2.47

Table 19: Values of the required change in car variable cost per mile (CPM), new cost per gallon (CPG^*) and the fractional change (PCPG) in cost per gallon for 1971

TRIP PURPOSE	BEPPCO (PASS.x10^6)	PPPCO
Work	28.37	1.06
Family Business	70.21	2.63
Education	114.53	4.29
Recreation	39.56	1.48
Weighted Average	47.43	1.77

Table 20: Estimated break-even values for passengers per bus company (BEPPCO) and the fractional change (PPPCO) to produce equal variable car and bus costs

APPENDIX 1

SYSTEM ANALYSIS

Content:

The analysis for each transportation system, bus companies, and urban cars is shown in Figure 1 and also in Puleo (1974) (27). Recall that the entities are bus companies and individual cars which have the following real attributes:

a. Dollar, energy and labor (DEL) costs for overhead, which are the fixed annual costs for each entity, for the availability of equipment.

b. Dollar, energy and labor (DEL) costs for operation, which are the annual costs for the use of the equipment and provision of services.

c. Dollar, energy and labor (DEL) costs for streets, which are the annual costs of maintenance and new constructions of bus and automobile rights-of-way.

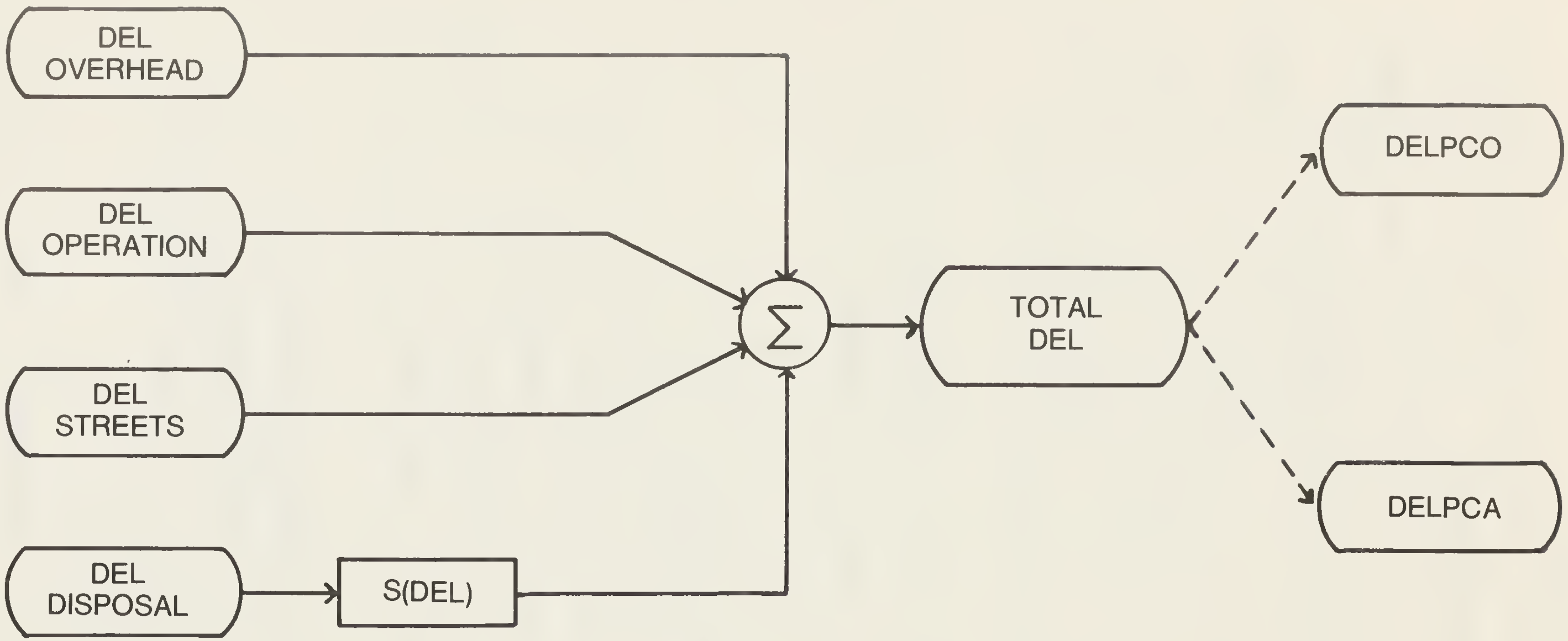
d. Dollar, energy and labor (DEL) costs for disposal, which are the costs of final recovery and recycle value of all equipment not longer in use.

Analysis of the Transportation Systems Attributes

Figure 1 shows the generalized scheme for the computation of DEL costs for both entities. The dollar return upon disposal may be likened to the return of a deposit and has to be subtracted from the overhead dollar cost. However, the energy and labor costs which this deposit causes in the recoverable parts and recycling industry is a cost to the system and has to be added to the overhead energy and labor costs.

The total output for each entity, corresponding to DEL costs is the following: DELPCO is dollar, energy, and labor costs (DEL) per bus company per year; DELPCA is dollar, energy, and labor costs (DEL) per urban car per year. The general model for each entity is then:

$$DEL = DEL(Overhead) + DEL(Operation) + DEL(Streets) + S(DEL) * DEL(Disposal)$$



$$\text{DELPCO} = \frac{\text{DOLLAR, ENERGY, LABOR}}{\text{BUS COMPANY YEAR}}$$

$$\text{DELPCA} = \frac{\text{DOLLAR, ENERGY, LABOR}}{\text{CAR YEAR}}$$

$$\text{DEL} = \text{DOLLARS, ENERGY, LABOR}$$

Fig. 1: Generalized Scheme for Bus Company and Car DEL Computation

1. DEL Overhead

The overhead models for bus companies and urban cars are shown in Figure 2 and Figure 3, respectively.

a. DEL Bus Overhead

(i) Assumptions

Buses are purchased by contract directly from the manufacturers (assembly plants) and there are in effect no transportation, wholesale or retail margins in their purchase price.

(ii) Variables

We define the following variables:

NSPCO = Number of Seats Per bus Company (1971)

CPB = Cost Per Bus (1971)

BL = Bus Life

SPB = Seats Per Bus

(iii) Parameters

We have the following parameters:

DF = Dollar Deflator, 1971 to 1963

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (28)(29) (1963)

IF(DEL) = DEL Inflator 1963 to 1971

(iv) Equations

The DEL Overhead for Bus companies is given by the following equation:

$$BUSOVH(DEL) = \frac{CPB \times NSPCO}{BL \times SPB} \times DF \times I\emptyset 5901(DEL) \times IF(DEL) \qquad (1)$$

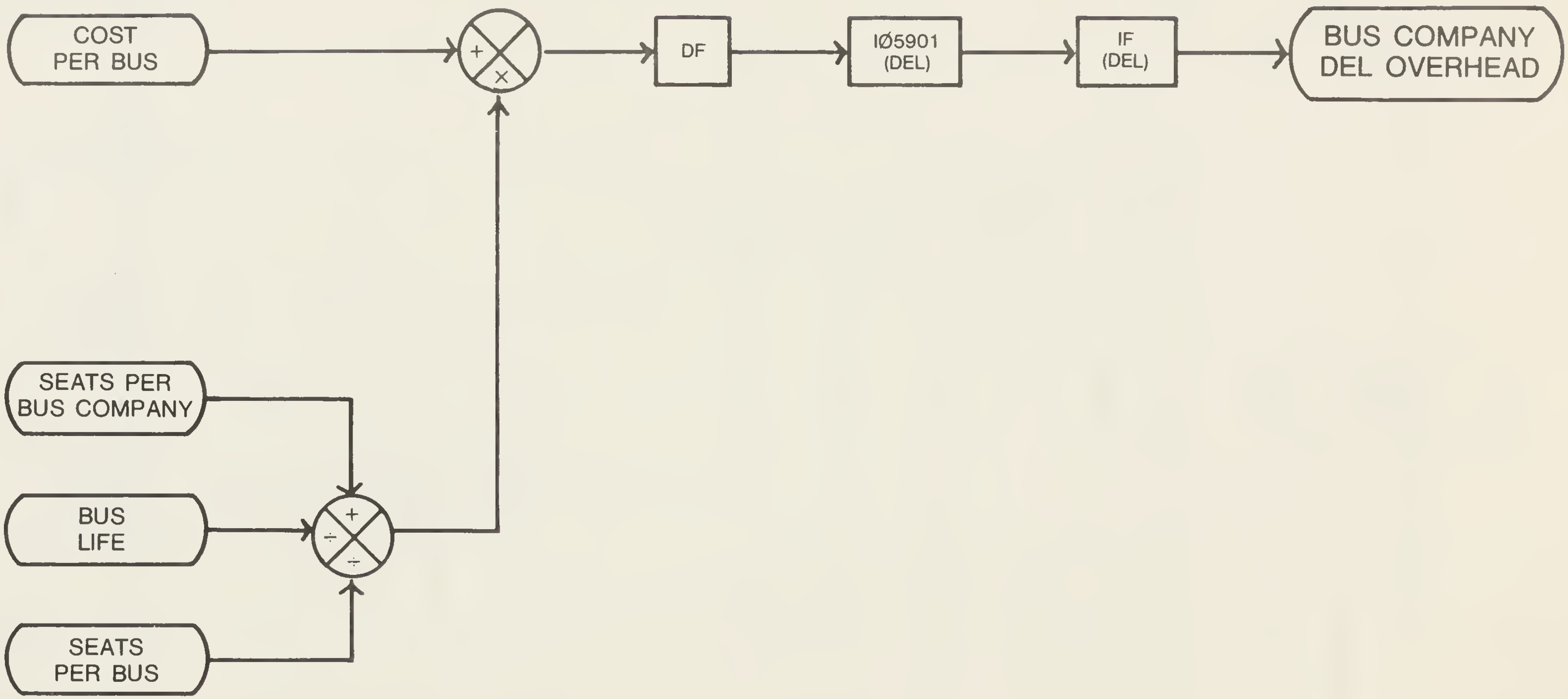


Fig. 2: Bus Company Overhead DEL Computation

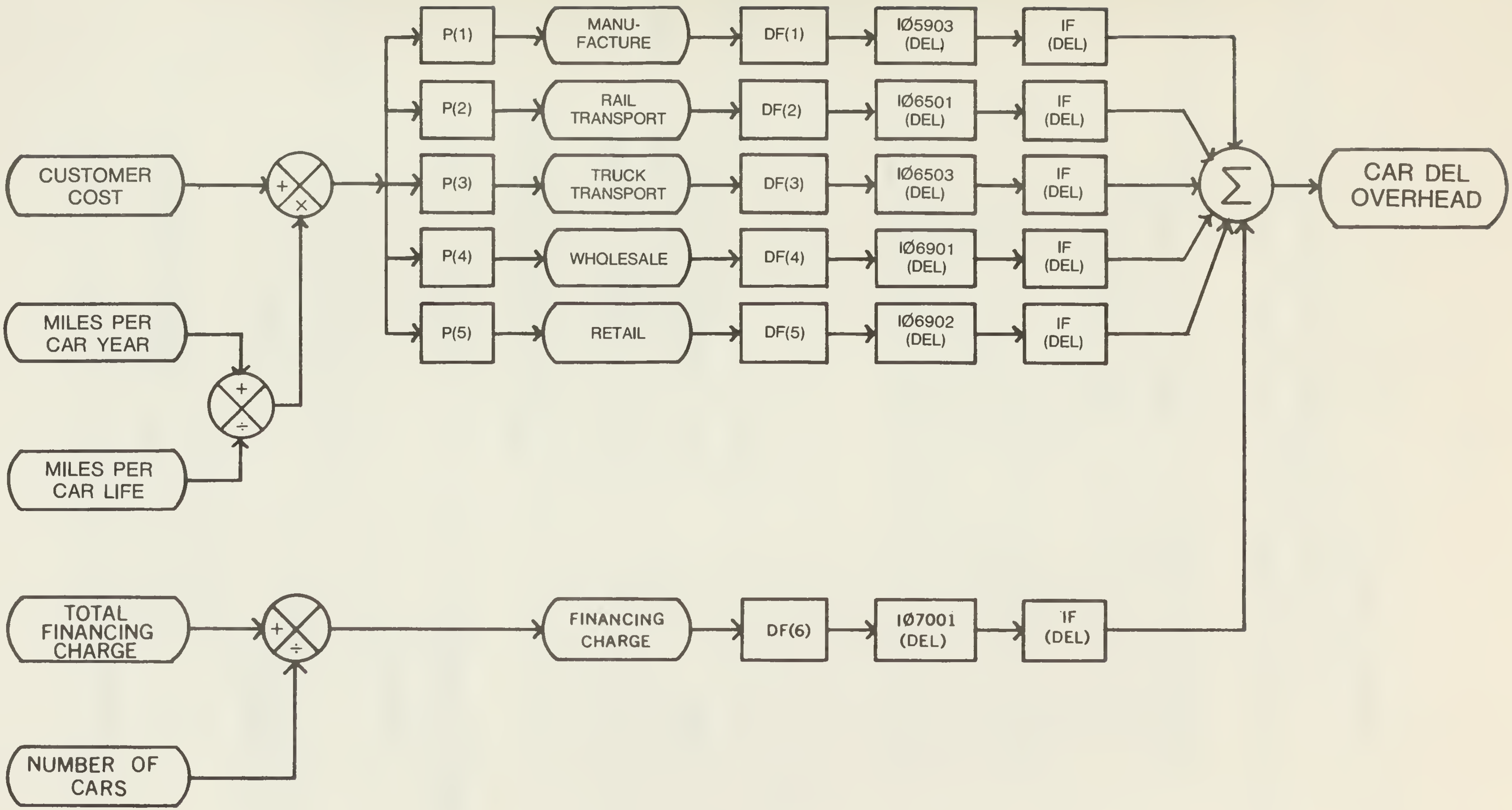


Fig. 3: Car Overhead DEL Computation

(v) Estimated Values

The estimated mean values for variables and parameters are given in the following tables.

VARIABLE	VALUE	UNIT	REFERENCE
BL	14.78	Years	6
CPB	35940	Dollar/Bus	7
NSPCO	12513.79	Seats/Bus Co.	8
SPB	48.67	Seats/Bus	8

Table 1: Estimated mean values for the bus overhead variables (1971).

Deflator	IØ(DEL)[1]				Inflator[10]		
Value[9]	Code Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)	Dollar	Energy	Labor
0.8221	5901	1.0	0.081788	0.107650	1.216	1.029	0.853

Table 2: Estimated mean values for the bus overhead parameters.

b. DEL Car Overhead

(i) Assumptions

The retail price of cars includes a margin for transportation, wholesale and retail costs.

(ii) Variables

CC = Customer Cost (1971)

MPC = Miles Per Car - Year (1971)

MPCL = Miles Per Car Life

NC = Number of Cars (1971)

TFC = Total Financing Charge per year (1971)

FC = Financing Charge per car-year (1971)

(iii) Parameters

P(K) = Percentage of total overhead used to compute variable (K), 1971.

DF(K) = Dollar Deflator, 1971 to 1963, used for variable (K).

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (1963).

IF(DEL) = DEL Inflator, 1963 to 1971.

(iv) Equations

The DEL overhead for urban cars is given by the following equations:

(a) Manufacturing Overhead

$$\text{MAN(DEL)} = \frac{\text{CC x MPC}}{\text{MPCL}} \text{ x P(1) x DF(1) x I}\emptyset\text{5903(DEL) x IF(DEL)} \quad (2)$$

(b) Rail Transportation Overhead

$$\text{RAIL(DEL)} = \frac{\text{CC x MPC}}{\text{MPCL}} \text{ x P(2) x DF(2) x I}\emptyset\text{6501(DEL) x IF(DEL)} \quad (3)$$

(c) Truck Transportation Overhead

$$\text{TRUCK(DEL)} = \frac{\text{CC x MPC}}{\text{MPCL}} \text{ x P(3) x DF(3) x I}\emptyset\text{6503(DEL) x IF(DEL)} \quad (4)$$

(d) Wholesaling Overhead

$$\text{WHOL(DEL)} = \frac{\text{CC x MPC}}{\text{MPCL}} \text{ x P(4) x DF(4) x I}\emptyset\text{6901(DEL) x IF(DEL)} \quad (5)$$

(e) Retailing Overhead

$$RET(DEL) = \frac{CC \times MPC}{MPCL} \times P(5) \times DF(5) \times I\emptyset 6902(DEL) \times IF(DEL) \quad (6)$$

(f) Financing Charge

$$FC(DEL) = \frac{TFC}{NC} * DF(6) * I\emptyset 7001(DEL) * IF(DEL) \quad (7)$$

(g) Total Urban Car Overhead

$$CAROVH(DEL) = MAN(DEL) + RAIL(DEL) + TRUCK(DEL) + WHOL(DEL) + RET(DEL) + FC(DEL) \quad (8)$$

(v) Estimated Values

The estimated mean values for variables and parameters are given in the following tables.

VARIABLE	VALUE	UNIT	REFERENCE
CC	3,640	Dollars	4
MPC	11,200	Miles/Car-Year	11
MPCL	100,000	Miles	12, 13
TFC	5.957×10^9	Dollars	25
NC	84.320×10^6	Cars	25

Table 3: Estimated mean values for the car overhead variables (1971).

PERCENTAGES (15)

P(1)	P(2)	P(3)	P(4)	P(5)
0.798	0.010	0.010	0.020	0.162

Table 4: Estimated mean percentages of the cost per type of overhead (1971).

DEFLATOR VALUE[14]		IØ(DEL)[1]				INFLATOR[10]		
		CODE NUMBER	DOLLAR	ENERGY ($x10^6$)	LABOR ($x10^{-3}$)	DOLLAR	ENERGY	LABOR
DF(1)	0.902	5903	1.0	0.070015	0.080079	1.1086	1.029	0.853
DF(2)	0.728	6501	1.0	0.079524	0.107589	1.3736	1.029	0.853
DF(3)	0.792	6503	1.0	0.084037	0.104663	1.2626	1.029	0.853
DF(4)	0.902	6901	1.0	0.033261	0.114199	1.1086	1.029	0.853
DF(5)	0.902	6902	1.0	0.032718	0.161077	1.1086	1.029	0.853
DF(6)	0.660	7001	1.0	0.019208	0.093114	1.5147	1.029	0.853

Table 5: Estimated mean values for the car overhead parameters.

2. DEL Operation

The models for the operation of bus companies and urban cars are shown in Figures 4 and 5, respectively.

a. DEL Bus Company Operation

(i) Assumptions

We assume linear relationships between the operation variables and their corresponding behavior in the system.

(ii) Variables

There are both direct and related variables. The direct variables correspond to variables that are taken directly from the data on hand. Related variables are computed from the direct variables using a specified relationship. All the variables and their corresponding codes are listed in Table 6.

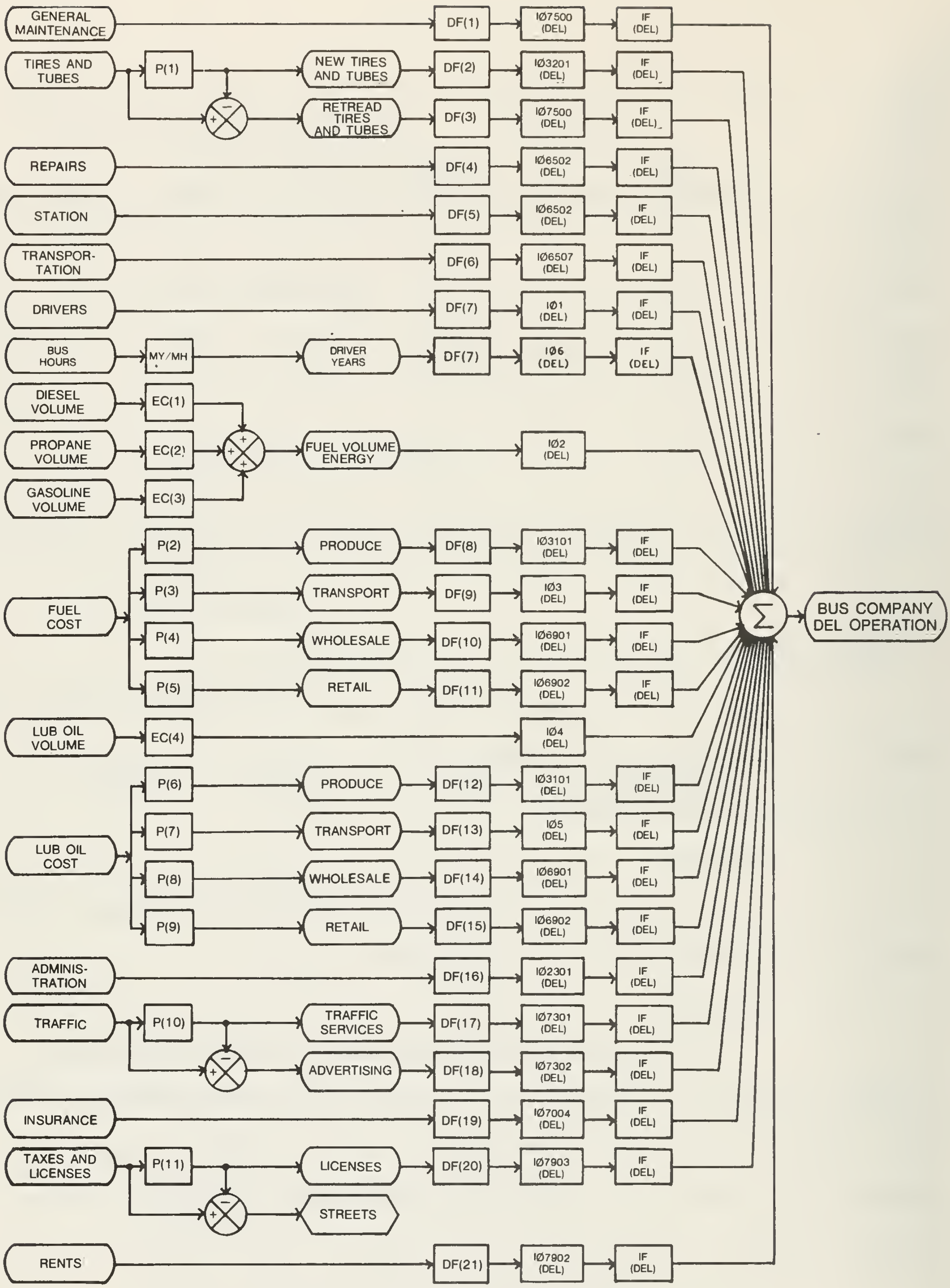


Fig. 4: Bus Company Operation DEL Computation

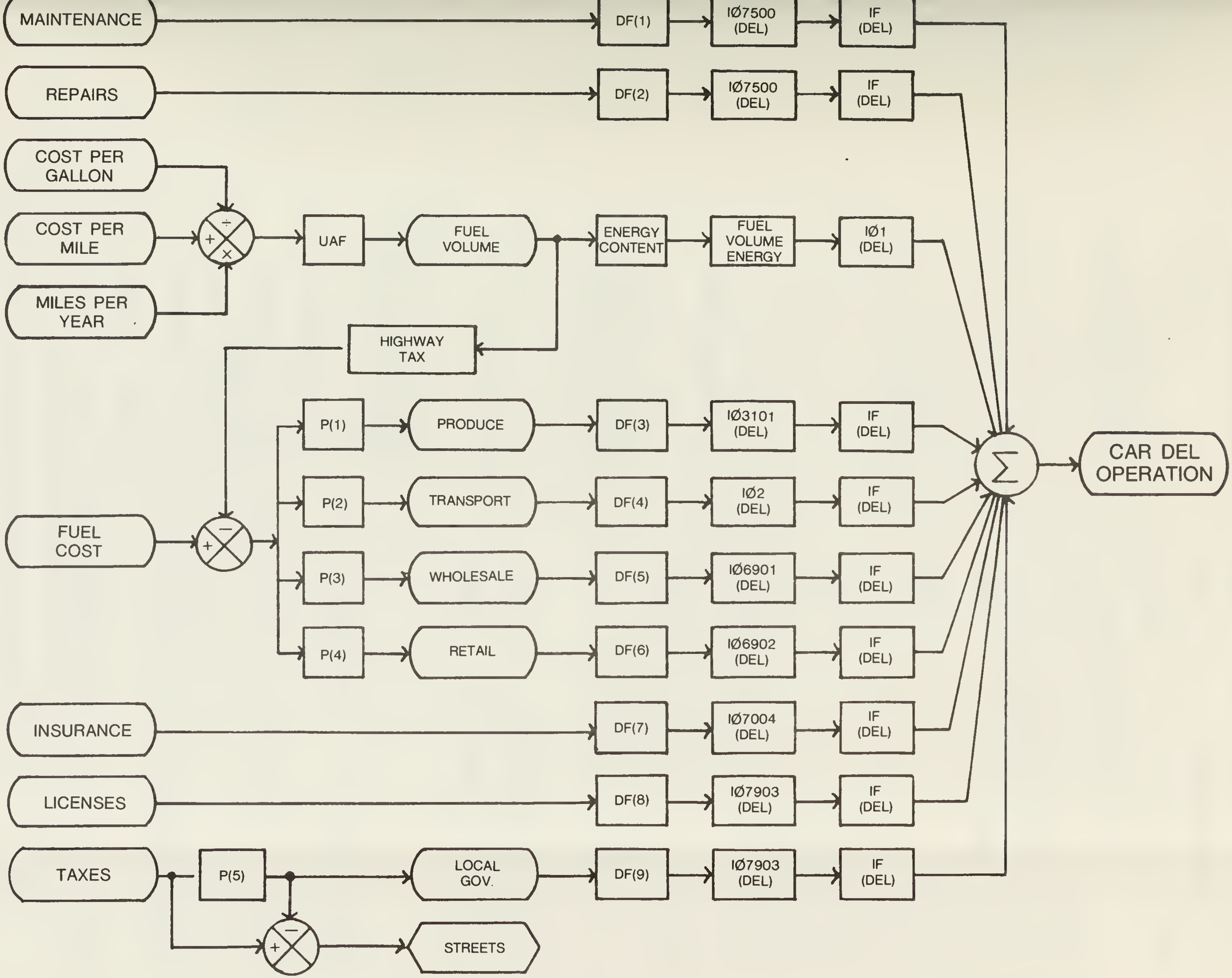


Fig. 5: Car Operation DEL Computation

Direct Variables	Code	Related Variables	Code
General Maintenance	GENM		
Tires and tubes	TT		
		New tires and tubes	NEWTT
		Retread tires and tubes	RETT
Repairs	REP		
Station Expenses	STA		
Transportation	TRAN		
Drivers	DRIV		
		Driver years	DRIVY
Bus Hours	BUSH		
Diesel volume	DIV		
Propane volume	PRV		
Gasoline volume	GAV		
		Fuel volume energy	FUELVE
Fuel cost	FUELC		
		Fuel cost to produce	FUELCP
		Fuel cost to transport	FUELCT
		Fuel cost to wholesale	FUELCW
		Fuel cost to retail	FUELCR
Lubricating oil volume	LUBOV		
		Lub oil volume energy	LUBIVE
Lubricating oil cost	LUBOC		
		Lub oil cost to produce	LUBOCP
		Lub oil cost to transport	LUBOCT
		Lub oil cost to wholesale	LUBOCW
		Lub oil cost to retail	LUBOCR
Administration	ADM		
Traffic	TRAF		
		Traffic services	TRAFS
		Advertising	ADV
Insurance	INS		
Licenses and taxes	LICT		
		Licenses	LIC
Rents	RENTS		

Table 6: Direct and related variables of the bus operation system.

(iii) Parameters

We have the following parameters:

P(K) = Percentage of a direct variable used to compute a related variable (K), 1971.

DF(K) = Dollar Deflator, 1971 to 1963, for variable (K).

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (1963).

IF(DEL) = DEL Deflator, 1963 to 1971.

MY/MH = Man Year/Man Hour

(iv) Constants

The following are constants:

EC(1) = Energy content of diesel in BTU per gallon.

EC(2) = Energy content of propane in BTU per gallon.

EC(3) = Energy content of gasoline in BTU per gallon.

EC(4) = Energy content of lubricating oil in BTU per gallon.

BTU = British Thermal Units

(v) Equations

The DEL operation for bus companies is given by the following set of equations:

(a) General Maintenance

$$\text{GENM(DEL)} = \text{GENM} \times \text{DF(1)} \times \text{IØ7500(DEL)} \times \text{IF (DEL)} \qquad (9)$$

(b) New Tires and Tubes

$$\text{NEWTT(DEL)} = \text{TT} \times \text{P(1)} \times \text{DF(2)} \times \text{IØ3201(DEL)} \times \text{JF(DEL)} \qquad (10)$$

(c) Retread Tires and Tubes

$$\text{RETT(DEL)} = \text{TT} \times [1-\text{P(1)}] \times \text{DF(3)} \times \text{IØ7500(DEL)} \times \text{IF(DEL)} \qquad (11)$$

(d) Repairs

$$\text{REP(DEL)} = \text{REP} \times \text{DF(4)} \times \text{IØ6502(DEL)} \times \text{JF(DEL)} \qquad (12)$$

(e) Station Expenses

STA(DEL) = STA x DF(5) x IØ6502(DEL) x JF(DEL) (13)

(f) Transportation

TRAN(DEL) = TRAN x DF(6) x IØ6507(DEL) x IF(DEL) (14)

(g) Drivers

DRIV(DEL) = DRIV x DF(7) x IØ1(DEL) x IF(DEL) (15)

Note that the values for IØ1(DEL) are:

IØ1(Dollar) = 1.0, IØ1(Energy) = 0.0, IØ1(Labor) = 0.0

(h) Driver years

DRIVY=BUSH x MY/MH x IØ6(DEL)

The IØ1(labor) value applies to Driver years as shown in the model. Note that the values for IØ6(DEL) are:

IØ6(Dollar) = 0.0, IØ6(Energy) = 0.0, IØ6(Labor) = 1.0

(i) Fuel Volume Energy

FUELVE(DEL) = [DIV x EC(1) + PRV x EC(2) + GAV x EC(3)] (16)
x IØ2(DEL)

Dollar and labor values do not apply to this variable and hence, for IØ2(DEL) we have:

IØ2(Dollar) = 0.0 ; IØ2(Energy) = 1.0 ; IØ2(Labor) = 0.0

(j) Fuel: Cost to Produce

FUELCP(DEL) = FUELC x P(2) x DF(8) x IØ3101(DEL) x IF(DEL) (17)

(k) Fuel: Cost to Transport

FUELCT(DEL) = FUELC x P(3) x DF(9) x IØ3(DEL) x IF(DEL) (18)

In this case, a weighted average value is used for the IØ factor in order to take into account the different kinds of transportation:[22] by rail (IØ6501), by pipeline (IØ5506), by truck (IØ6503) and by water (IØ6504). The weighted average is given by the following equation:

IØ3(DEL) = [P3(rail) x IØ6501(DEL) + P3(pipe) x IØ6506(DEL) +
P3(truck) x IØ6503(DEL) + P3(water) x IØ6504(DEL)]/
[P3(rail) + P3(pipe) + P3(truck) + P3(water)] (19)

where P3(.) is the corresponding percentage of each kind of transportation of the total fuel.

(l) Fuel Cost to Wholesale

FUELCW(DEL) = FUELC x P(4) x DF(10) x IØ6901(DEL) x IF(DEL) (20)

(m) Fuel Cost to Retail

FUELCR(DEL) = FUELC x P(5) x DF(11) x IØ6902(DEL) x IF(DEL) (21)

(n) Lubricating Oil Volume Energy

LUBOVE(DEL) = LUBOV x EC(4) x IØ4(DEL) (22)

In this case dollar and labor costs do not apply to this variable and hence the values for IØ4(DEL) are the following:

IØ4(Dollar) = 0.0 IØ4(Energy) = 1.0 IØ4(Labor) = 0.0

(o) Lubricating Oil: Cost to Produce

LUBOCP(DEL) = LUBOC x P(6) x DF(12) x IØ3101(DEL) x IF(DEL) (23)

(p) Lubricating Oil Cost to Transport

LUBOCT(DEL = LUBOC x P(7) x DF(13) x IØ5(DEL) x IF(DEL)

In this case a weighted average is used for the IØ factor in order to account for the different kinds of transportation; by rail (IØ6501), by pipeline (IØ6506), by truck (IØ6503) and by water (IØ6504). The weighted average is given by the following equation:

IØ5(DEL) = [P7(rail) x IØ6501(DEL) + P7(pipe) x IØ6506(DEL) +
P7(truck) x IØ6503(DEL) + P7(water) x IØ6504(DEL)]/
P7(rail) + P7(pipe) + P7 (truck) + P7(water) (24)

where P7(.) is the corresponding percentage of each type of transportarion of the lubricating oil.

(q) Lubricating Oil Cost to Wholesale

LUBOCW(DEL) = LUBOC x P(8) x DF(14) x IØ6901(DEL) x IF(DEL) (25)

(r) Lubricating Oil Cost to Retail

LUBOCR(DEL) = LUBOC x P(9) x DF(15) x IØ6902(DEL) x IF(DEL) (26)

(s) Administration

ADM(DEL) = ADM x DF(16) x IØ2301(DEL) x IF(DEL) (27)

(t) Traffic Services

TRAFS(DEL) = TRAF x P(10) x DF(17) x IØ7301(DEL) x IF(DEL) (28)

(u) Advertising

ADV(DEL) = TRAF[1-P(10)] x DF(18) x IØ7307(DEL) x IF(DEL) (29)

(v) Insurance

INS(DEL) = INS x DF(19) x IØ7004(DEL) x IF(DEL) (30)

(w) Licenses

LIC(DEL) = LIC x P(11) x DF(20) x IØ7903(DEL) x IF(DEL) (31)

(x) Rents

RENTS(DEL) = RENTS x DF(11) x IØ7902(DEL) x IF(DEL) (32)

(y) Total bus company operation

BUSOP(DEL) = GENM(DEL) + NEWTT(DEL)+......+RENTS(DEL) (33)

(vi) Estimated Values

The estimated mean values for variables and parameters are given in the following tables.

Variable	Value(..) ($x10^3$)	Unit
GENM	827.742	Dollar/Bus Company
TT	104.179	Dollar/Bus Company
REP	895.614	Dollar/Bus Company
STA	47.829	Dollar/Bus Company
TRAN	945.849	Dollar/Bus Company
DRIV	4136.521	Dollar/Bus Company
BUSH	782194.8	Bus Hours/Bus Company
DIV	1840.191	Gallons/Bus Company
PRV	3.938	Gallons/Bus Company
GAV	17.985	Gallons/Bus Company
FUELC	230.059	Dollar/Bus Company
LUBOV	22.759	Gallons/Bus Company
LUBOC	11.489	Dollar/Bus Company
ADM	1674.195	Dollar/Bus Company
TRAF	79.312	Dollar/Bus Company
INS	351.572	Dollar/Bus Company
LICT	456.461	Dollar/Bus Company
RENTS	37.173	Dollar/Bus Company

Table 7: 1971 Estimated mean values for the bus company operation variables, 1971. (See Appendix 8)

PERCENTAGES										
New Tires Tubes	Fuel Cost Margins[30]				Lube Oil Cost Margins[30]				Traffic Services	Licenses
P(1)	P(2)	P(3)	P(4)	P(5)	P(6)	P(7)	P(8)	P(9)	P(10)	P(11)
0.100	0.531	0.035	0.327	0.107	0.531	0.035	0.327	0.107	0.600	0.500

Table 8: Estimated mean percentages of the cost per type of direct variables operation (1971).

Constant	Value ($x10^6$)	Unit
EC(1)	0.138238	BTU/gallon
EC(2)	0.091500	BTU/gallon
EC(3)	0.125071	BTU/gallon
EC(4)	0.144286	BTU/gallon

Table 9: Energy content of the different kinds of fuel and lubricating oil.[16]

The percentages used to compute the weighted mean values of the IØ factors for the fuel cost (transport) (P3) and lubricating oil cost (transport) (P7) are given in Table 10 with their corresponding IØ (DEL) values.

Percentages[30]				IØ(DEL)			
Fuel Cost Code	Fuel Cost Value	Lub Oil Cost Code	Lub Oil Cost Value	Code Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)
P3(rail)	0.006	P7(rail)	0.006	6501	1.0	0.079524	0.107589
P3(pipe)	0.010	P7(pipe)	0.010	6506	1.0	0.488015	0.038587
P3(truck)	0.007	P7(truck)	0.007	6503	1.0	0.084037	0.104663
P3(water)	0.012	P7(water)	0.012	6504	1.0	0.138870	0.064694

Table 10: Percentages of fuel cost and lubricating oil cost need to compute IØ(DEL) of transportation.

The estimated value of the parameter, man years per man hour, (MY/MH), is:

$$MY/MH = 0.5208x10^{-3}$$

This corresponds to 48 weeks per year and 40 hours per week, giving 1920 man hours per man year.

DEFLATOR VALUE[14]		IO (DEL)[1]				INFLATOR[10]		
		Code Number	Dollar	Energy ($x10^{6}$)	Labor ($x10^{-3}$)	Dollar	Energy	Labor
DF(1)	0.5968	7500	1.0	0.033655	0.082847	1.6756	1.029	0.853
DF(2)	0.8270	3201	1.0	0.09964	0.065796	1.2092	1.029	0.853
DF(3)	0.8270	7501	1.0	0.033655	0.033655	1.2092	1.029	0.853
DF(4)	0.8270	6502	1.0	0.087740	0.132616	1.2092	1.029	0.853
DF(5)	0.5968	6502	1.0	0.087740	0.132616	1.6756	1.029	0.853
DF(6)	0.5968	6507	1.0	0.037829	0.154282	1.6756	1.029	0.853
DF(7)	0.5968	1	1.0	0.0	0.0	1.6756	1.0	1.0
DF(7)	0.5968	6	0.0	0.0	1.0	0.0	0.0	1.0
-	-	2	0.0	1.0	0.0	0.0	1.0	0.0
DF(8)	0.8589	3101	1.0	0.196658	0.047571	1.1600	1.029	0.853
DF(9)	0.8589	3	1.0	0.183171	0.072612	1.1600	1.029	0.853
DF(10)	0.8589	6901	1.0	0.033261	0.114199	1.1600	1.029	0.853
DF(11)	0.8589	6902	1.0	0.032718	0.161077	1.1600	1.029	0.853
-	-	4	0.0	1.0	0.0	0.0	1.0	0.0
DF(12)	0.8589	3101	1.0	0.196658	0.047571	1.1600	1.029	0.853
DF(13)	0.8589	5	1.0	0.183171	0.072612	1.1600	1.029	0.853
DF(14)	0.8589	6901	1.0	0.033261	0.114199	1.1600	1.029	0.853
DF(15)	0.8589	6902	1.0	0.032718	0.161077	1.1600	1.029	0.853
DF(16)	0.5968	2301	1.0	0.052344	0.133347	1.6756	1.029	0.853
DF(17)	0.5968	7301	1.0	0.032067	0.103444	1.6756	1.029	0.853
DF(18)	0.5968	7302	1.0	0.043939	0.103402	1.6756	1.029	0.853
DF(19)	0.6602	7004	1.0	0.031432	0.031432	1.5147	1.029	0.853
DF(20)	0.7064	7903	1.0	0.090283	0.118963	1.4200	1.029	0.853
DF(21)	0.6980	7902	1.0	0.072152	0.059547	1.4300	1.029	0.853

Table 11: Estimated values for bus company operating parameters.

b. DEL Urban Car Operation

(i) Assumptions

We assume a linear relationship between the variables and their corresponding behavior in the system.

(ii) Variables

There are direct and related variables. The direct variables correspond to variables that can be measured directly from the data at hand. Related variables are computed from the direct variables using a specified relationship. All the variables and their corresponding codes are listed in Table 12.

(iii) Parameters

P(K) = Percentage of a direct variable used to compute a related variable (1971).

DF(K) = Dollar deflator, 1971 to 1963.

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (1963).

IF(DEL) = DEL inflator, 1963 to 1971.

UAF = Urban adjusting factor to account for the increased fuel consumption in the urban trips relative to the national average.(19) See Appendix 3.

HTAX = Highway tax (1971)

(iv) Constants

We have only one constant in the car system:

EC = Energy Constant of gasoline in BTU per gallon.

(v) Equations

The DEL of operation for urban cars is given by the following set of equations:

(a) Maintenance

$$MAINT(DEL) = MAINT \times DF(1) \times I\emptyset7500(DEL) \times IF(DEL) \quad (34)$$

Direct Variables	Cost	Related Variables	Code
Maintenance	MAINT		
Repairs	REP		
Cost per gallon	CPG		
Cost per mile	CPM		
Miles per year	MPY		
		Fuel Volume	FUELV
		Fuel volume energy	FUELVE
Fuel cost	FUELC		
		Fuel cost to produce	FUELCP
		Fuel cost to transport	FUELCT
		Fuel cost to wholesale	FUELCW
		Fuel cost to retail	FUELCR
Insurance	INS		
Licenses	LIC		
Taxes	TAX		
		Local government	LGOV

Table 12: Direct and related variables of the urban car operation system.

(b) Repairs

$$REP(DEL) = REP \times DF(2) \times I\emptyset7500(DEL) \times IF(DEL) \qquad (35)$$

(c) Fuel Volume Energy

First we compute the fuel volume:

$$FUELV = \frac{CPM \times MPY}{PG} \times UAF \qquad (36)$$

Then the fuel volume energy is given by:

$$FUELVE(DEL) = FUELV \times EC \times I\emptyset1(DEL) \qquad (37)$$

In this case dollar and labor costs do not apply and the values for $I\emptyset1(DEL)$ are:

$I\emptyset1(Dollar) = 0.0$, $I\emptyset1(Energy) = 1.0$, $I\emptyset1(Labor) = 0.0$

(d) Fuel: Cost to Produce

$$FUELCP(DEL) = (FUELC - FUELV \times HTAX) \times P(1) \times DF(3) \times I\emptyset310(DEL) \times IF(DEL) \qquad (38)$$

where FUELV is the fuel volume as computed in part (c).

(e) Fuel: Cost to Transport

$$FUELCT(DEL) = (FUELC - FUELV \times HTAX) \times P(2) \times DF(4) \times I\emptyset2(DEL) \times IF(DEL) \qquad (39)$$

In this case a weighted average value is used for the IØ factor in order to account for the different kinds[30] of transportation by rail (IØ6501), by pipe(IØ6506) by truck (IØ6503) and by water (IØ6504). The weighted average is:

$$I\emptyset2(DEL) = [P3(rail) \times I\emptyset6501(DEL) + P3(pipe) \times I\emptyset6506(DEL) + P3(truck) \times I\emptyset6503(DEL) + P3(water) \times I\emptyset6504(DEL)]/[P3(rail) + P3(pipe) + P3(truck) + P3(water)] \qquad (40)$$

where P3(.) is the corresponding percentage of each kind of transportation of the total fuel cost.

(f) Fuel Cost to Wholesale

$$FUELCW(DEL) = (FUELC - FUELV \times HTAX) \times P(3) \times DF(5) \times I\emptyset6901(DEL) \times IF(DEL) \qquad (41)$$

(g) Fuel Cost to Retail

$$FUELCR(DEL) = (FUELC - FUELV \times HTAX) \times P(4) \times DF(6) \times I\emptyset6902(DEL) \times IF(DEL) \qquad (42)$$

(h) Insurance

$$INS(DEL) = INS \times DF(7) \times I\emptyset7004(DEL) \times IF(DEL) \qquad (43)$$

(i) Licenses

$$LIC(DEL) = LIC \times DF(8) \times I\emptyset\ 7903(DEL) \times IF(DEL) \qquad (44)$$

(j) Local Government

LGOV(DEL) = TAX x P(5) x DF(9) x IØ7903(DEL) x IF(DEL) (45)

(k) Total Urban Car Operation

CAROP(DEL) = MAINT(DEL) + REP(DEL) + ... + LIC(DEL) + LGOV(DEL) (46)

(vi) Estimated Values

The estimated mean values for variables and parameters are given in the following tables.

Variable	Value [18]	Unit
MAINT	145.6	Dollar/year
REP	125.0	Dollar/year
CPG	0.377	Dollar/gallon
CPM	0.0269	Dollar/mile
MPY	11200.0 [15]	Miles/year
FUELC	301.280	Dollar/year
INS	237.399	Dollar/year
LIC	19.741	Dollar/year
TAX	50.395	Dollar/year

Table 13: Estimated mean values for the urban car operation cost variables based on 11,200 miles per car year(1971).

PERCENTAGES [15]				
P(1)	P(2)	P(3)	P(4)	P(5) [27]
0.451	0.043	0.300	0.206	0.500

Table 14: Estimated mean percentages of the cost per type of direct operating variables,(1971).

Several additional parameters and constants are given in the following table:

Code	Value	Unit	Reference
UA F	1.175	UFV/HFV	19
HTAX	0.10	Dollar/gallon	20
EC	125071	BTU/gallon	16

Table 15: Estimated values of certain constants for the car system.

The percentages needed to compute the weighted mean value of the IØ factor for the fuel transport cost (P3) are given in Table 16 along with their corresponding IØ (DEL) values.

Code	Value	Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)
P3(rail)	0.007	6501	1.0	0.079524	0.107589
P3(pipe)	0.013	6506	1.0	0.488015	0.038587
P3(truck)	0.008	6503	1.0	0.084037	0.084037
P3(water)	0.015	6504	1.0	0.138870	0.064694

Table 16: Percentages[15] of fuel cost to compute IØ(DEL) of transportation.

Deflator	Value (14)	IØ(DEL) (1)				Inflator (10)		
		Number	Dollar	Energy (x10⁶)	Labor (x10⁻³)	Dollar	Energy	Labor
DF(1)	0.8270	7500	1.0	0.033655	0.082846	1.2092	1.029	0.853
DF(2)	0.8270	7500	1.0	0.033655	0.082846	1.2092	1.029	0.853
--	--	1	0.0	1.0	0.0	0.0	1.0	0.0
DF(3)	0.8589	3101	1.0	0.196658	0.047571	1.600	1.029	0.853
DF(4)	0.8589	2	1.0	0.224488	0.071220	1.600	1.029	0.853
DF(5)	0.8589	6901	1.0	0.033261	0.114199	1.600	1.029	0.853
DF(6)	0.8589	6902	1.0	0.032718	0.161077	1.600	1.029	0.853
DF(7)	0.6602	7004	1.0	0.031432	0.118963	1.5147	1.029	0.853
DF(8)	0.7064	7903	1.0	0.090283	0.093393	1.4156	1.029	0.853
DF(9)	0.6648	7903	1.0	0.090283	0.093393	1.5042	1.029	0.853

Table 17: Estimated values for urban car operation parameters.

3. - DEL Streets

The models for bus companies and urban cars are shown in Figures 6 and 7, respectively.

a. DEL Bus Company - Streets

(i) Assumptions

We assume a linear relationship between the variables and their corresponding behavior in the system.

(ii) Variables

There are direct and related variables. The direct variables correspond to variables that can be measured directly from the available data. Related variables are computed from the direct variables using a specified relationship. All the variables and their corresponding codes are listed in Table 18.

DIRECT VARIABLES	CODE	RELATED VARIABLES	CODE
Licenses and Taxes	LICT		
		Taxes	Tax
Diesel Volume	DIV		
Propane Volume	PRV		
Gasoline Volume	GAV		
		Fuel Volume	FUELV

Table 18: Direct and related variables of the bus-streets system.

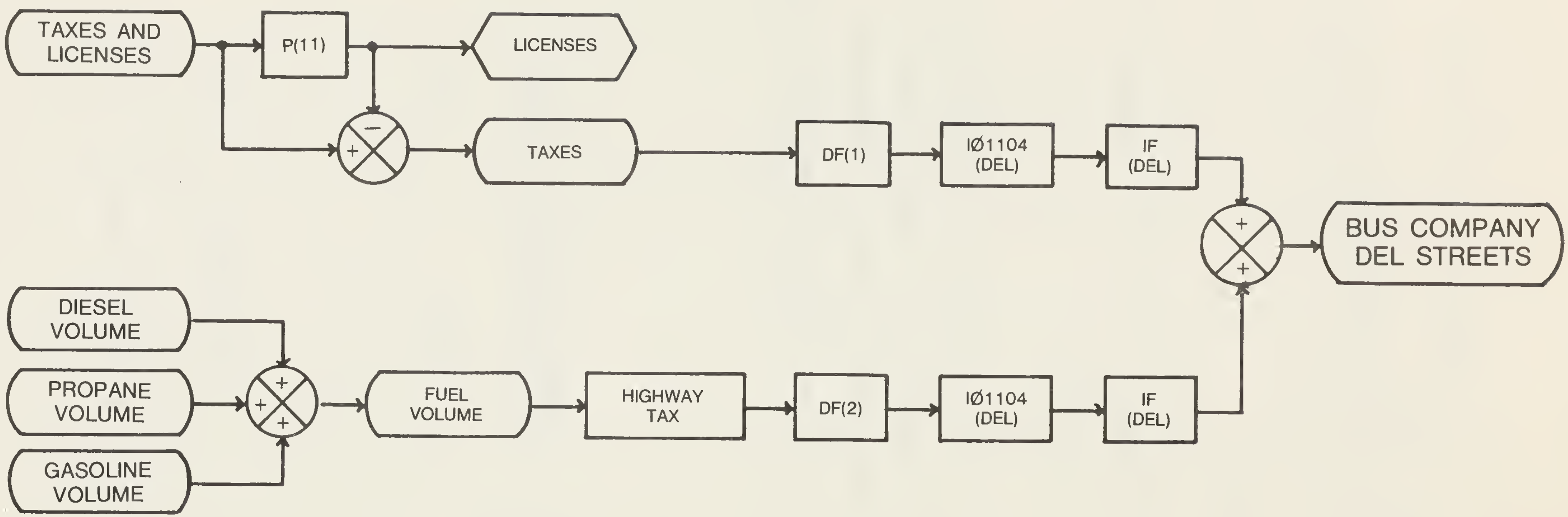


Fig. 6: Bus Company Street DEL Computation

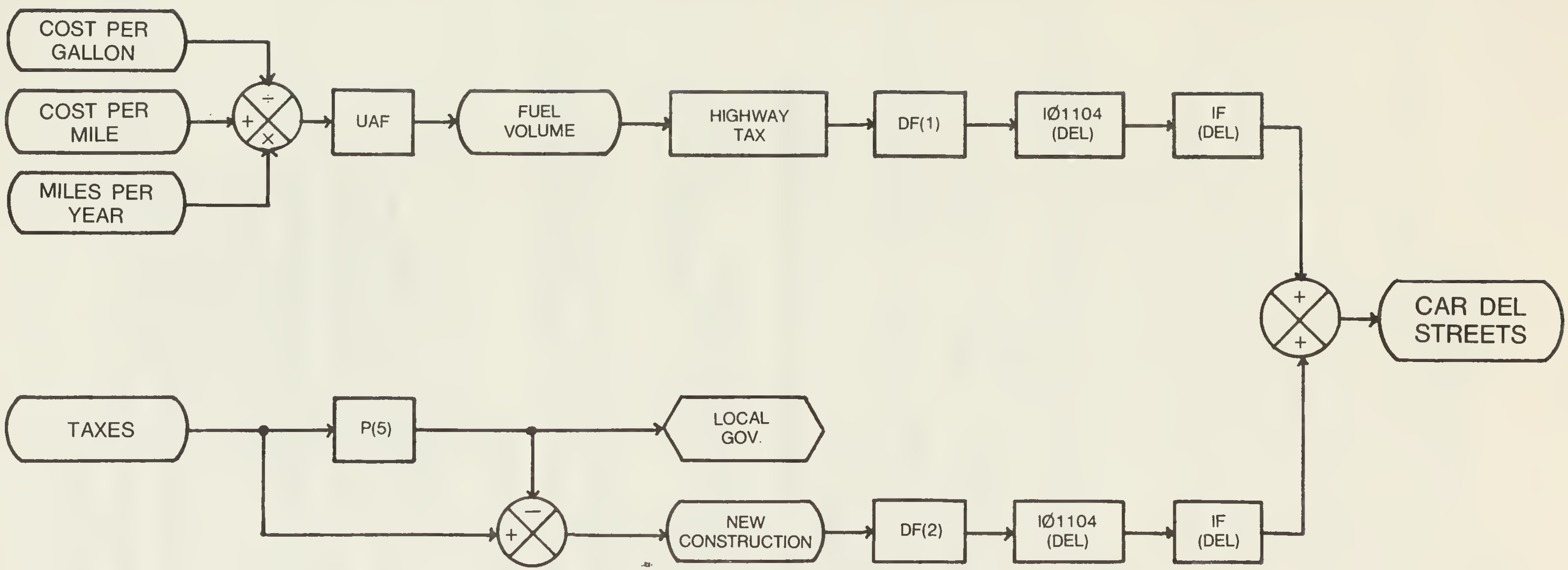


Fig. 7: Car Street DEL Computation

(iii) Parameters

We have the following parameters:

P(11) = Percentage of licenses and taxes applicable to licenses only (1971).

HTAX = Highway Tax (1971).

DF(K) = Dollar Deflator, 1971 to 1963.

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (1963).

IF(DEL) = DEL Inflator, 1963 to 1971.

(iv) Equations

The DEL of streets for bus companies is given by the following set of equations:

(a) Taxes

$$TAX(DEL) = LICT[1 - P(11)] \times DF(1) \times I\emptyset 1104(DEL) \times IF(DEL) \quad (47)$$

(b) Fuel Volume

$$FUELV(DEL) = (DIV + PRV + GAV) \times HTAX \times DF(2) \times I\emptyset 1104(DEL) \times IF(DEL) \quad (48)$$

(c) Total Bus Company DEL Streets

$$BUSST(DEL) = TAX(DEL) + FUELV(DEL) \quad (49)$$

(v) Estimated Values

The estimated mean values for the variables and parameters are given in the following tables.

VARIABLE	VALUE[17] $(x10^3)$	UNIT
LICT	456.461	Dollar/Bus Co.
DIV	1840.191	Gallons/Bus Co.
PRV	3.938	Gallons/Bus Co.
GAV	17.985	Gallons/Bus Co.

Table 19: Estimated mean values of the variables for Bus Company Streets, (1971).

The percentage of licenses and taxes corresponding to licenses only is estimated at 50% [21]:

$$P(11) = 0.500$$

The highway tax is computed at the rate of 10¢/gal. of fuel [31]:

$$HTAX = 0.10 \text{ Dollar/gallon.}$$

Deflator	Value [14]	IØ(DEL) [1]				Inflator [10]		
		Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)	Dollar	Energy	Labor
DF(1)	0.6541	1104	1.0	0.098507	0.096236	1.5288	1.029	0.853
DF(2)	0.6541	1104	1.0	0.098507	0.096236	1.5288	1.029	0.853

Table 20: Estimated values for Bus Company Streets parameters.

b. DEL Urban Car - Streets

(i) Assumptions

We assume a linear relationship between the variables and their corresponding behavior in the system.

(ii) Variables

There are direct and related variables. The direct variables can be measured directly from the collected data. Related variables are computed from the direct variables using a specified relationship. All the variables and their corresponding codes are listed in Table 21.

Direct Variables	Code	Related Variables	Code
Cost per gallon	CPG		
Cost per mile	CPM		
Miles per year	MPY		
		Fuel volume	FUELV
Taxes	TAX		
		New construction	NEWC

Table 21: Direct and related variables of the urban car-streets system.

(iii) Parameters

We have the following parameters:

P(5) = Percentage of taxes used for local government only (1971).

UAF = Urban Adjusting Factor to account for the increase in fuel consumption in the urban area relative to the average. (See Appendix 3.)

DF(K) = Dollar Deflator 1971 to 1963.

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (1963).

IF(DEL) = DEL Inflator, 1963 to 1971.

HTAX = Highway Tax (1971).

(iv) Equations

The DEL of streets for urban cars is given by the following set of equations.

(a) Fuel Volume

$$\text{FUELV(DEL)} = \frac{\text{CPM x MPY}}{\text{CPG}} \text{ x UAF x HT x DF(1) x I}\emptyset\text{1104(DEL) x IF(DEL)} \quad (50)$$

(b) New Construction

$$\text{NEWC(DEL)} = \text{TAX[1 - P(5)] x DF(2) x I}\emptyset\text{1104(DEL) x IF(DEL)} \quad (51)$$

(c) Total Urban Car DEL Streets

$$\text{CARST(DEL)} = \text{FUELV(DEL) + NEWC(DEL)} \quad (52)$$

(v) Estimated Values

The estimated mean values for variables and parameters are given in the following tables.

Variable	Value [18]	Unit
CPG	0.377	Dollar/gallon
CPM	0.0269	Dollar/mile
MPY	11200.0 [15]	Miles/year
TAX	50.395	Dollar/year

Table 22: Estimated mean values for the urban car-streets variables, 1971.

The percentage of Taxes (P(5)) assigned to local government operations is 50%.[21]

$$P(5) = 0.500$$

The urban adjusting factor as estimated in Appendix 3 is:

$$UAF = 1.175 \text{ UFV/HFV.} \quad (53)$$

The estimated highway tax is:

$$HTAX = 0.10 \text{ Dollar/Gallon.}$$ [24]

Deflator No.	Value [14]	IØ(DEL) [1] Code Number				Inflator [10] Dollar		
		Code Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)	Dollar	Energy	Labor
DF(1)	0.6541	1104	1.0	0.098507	0.096236	1.5288	1.029	0.853
DF(2)	0.6541	1104	1.0	0.098507	0.096236	1.5288	1.029	0.853

Table 23: Estimated values for urban car-streets parameters.

4. DEL Disposal

The disposal models for bus companies and urban cars are shown in Figures 8 and 9, respectively.

a. DEL Bus Disposal

(i) Assumptions

We assume a linear relationship between the variables and their corresponding behavior in the system.

(ii) Variables

There are both direct and related variables. The direct variables can be measured directly from the available data. Related variables are computed from the direct variables using a specified relationship. All the variables and their corresponding codes are listed in Table 24.

Direct Variables	Code	Related Variables	Code
Disposal value	DIVAL		
Seats per bus company	SPBCO		
Bus life	BL		
Seats per bus	SPB		
		Recoverable value	RECOV
		Recyclable value	RECYC

Table 24: Direct and related variables of the bus company-disposal system.

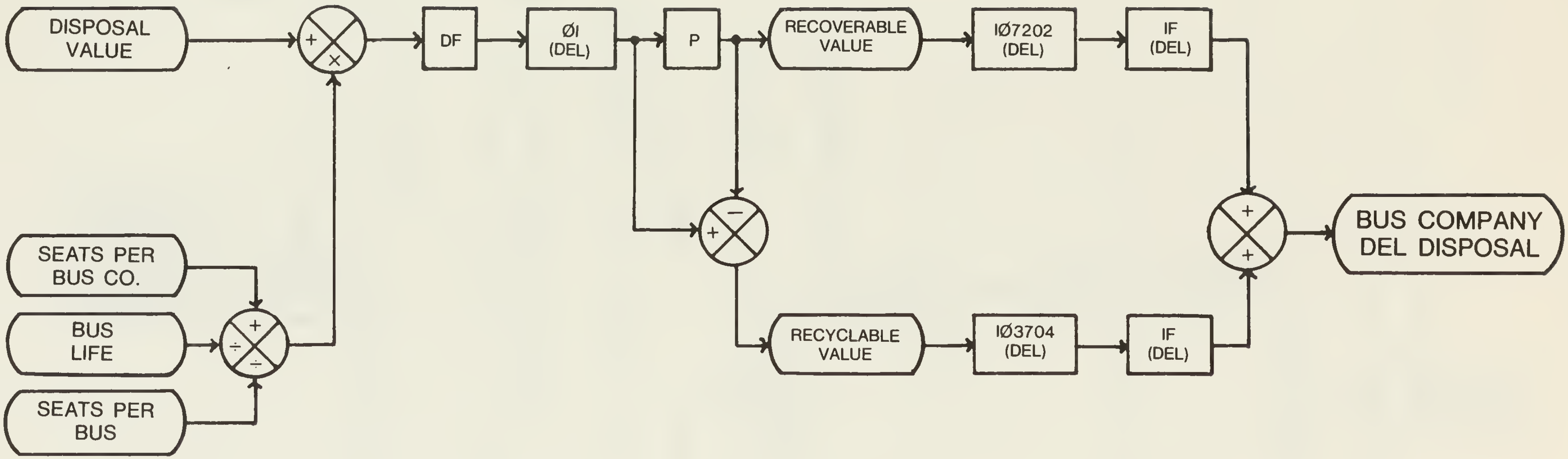


Fig. 8: Bus Company Disposal DEL Computation

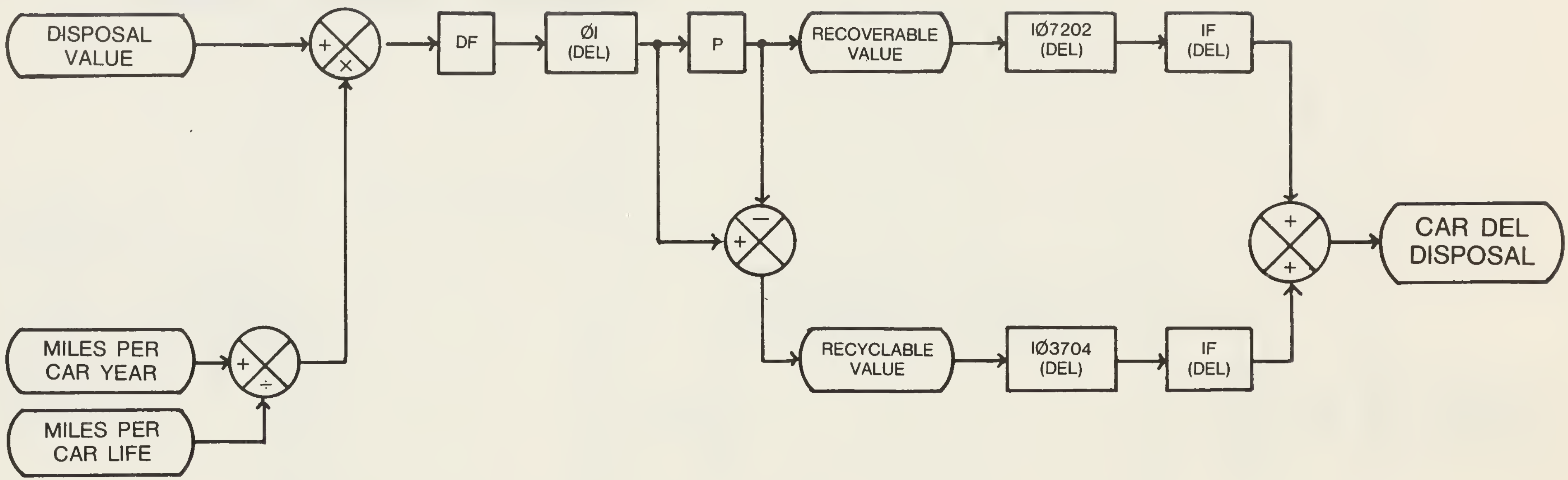


Fig. 9: Car Disposal DEL Computation

(iii) Parameters

We have the following parameters:

P = Percentage of total value used for recoverable value only (1971).

ØI(DEL) = DEL Output-Input ratio for the metal scrap industry (1963). (See Appendix 4.)

DF = Dollar Deflator, 1971 to 1963.

IØN(DEL) = Input-Output factor for DEL corresponding to code number N (1963).

IF(DEL) = DEL Inflator, 1963 to 1971.

(iv) Equations

The DEL Disposal for bus companies is given by the following set of equations.

(a) Recoverable Value

$$\text{RECOV(DEL)} = \frac{\text{DIVAL x SPBCO}}{\text{BL x SPB}} \text{ x DF x ØI(DEL) x P x IØ7202(DEL) x IF(DEL)} \quad (54)$$

(b) Recyclable Value

$$\text{RECYC(DEL)} = \frac{\text{DIVAL x SPBCO}}{\text{BL x SPB}} \text{ x DF x ØI(DEL) x (1-P) x IØ3704(DEL) x IF(DEL)} \quad (55)$$

(c) Total Bus Company DEL Disposal

$$\text{BUSDIS(DEL)} = \text{RECOV(DEL)} + \text{RECYC(DEL)} \quad (56)$$

(v) Estimated Values

The estimated mean values for the variables and parameters are given in the following tables.

Variable	Value	Unit	References
DIVAL	1500.0	Dollar/Bus	32
SPBCO	12513.79	Seats/Bus Co.	8
BL	14.78	Years	6
SPB	48.67	Seats/Bus	8

Table 25: Estimated mean values for the bus company disposal variables, 1971.

The dollar deflator 1971-1963 (DF) has the value:

DF = 0.7619 (14)

The recoverable value percentage (P) for 1971 is estimated as:

P = 0.900 (22)

The Output-Input ratio (ØI(DEL)) as shown in Appendix 4 has the following values:

ØI(Dollar) = 1.0 ØI(Energy) = 2.4 ØI(Labor) = 2.4

Then the Deflator is given by

$$DF = 0.7619 \times 2.4 = 1.82856$$

The IØ coefficients and inflators are given in the following table.

	IØ(DEL) (1)			Inflator (10)		
Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)	Dollar	Energy	Labor
7202	-1.0	0.040195	0.184524	0.546	1.029	0.853
3704	-1.0	0.123328	0.083579	0.546	1.029	0.853

Table 26: Estimated values for bus company disposal parameters.

Note that IØ(Dollar) is negative because disposal dollar value is subtracted from overhead. See Figure 1 and related text.

b. DEL Urban Car Disposal

(i) Assumptions

We assume a linear relationship between the variables and their corresponding behavior in the system.

(ii) Variables

There are both direct and related variables. The direct variables are taken directly from the available data. The related variables are computed from the direct variables using a specified relationship. All the variables and their corresponding codes are listed in Table 27.

Direct Variable	Code	Related Variables	Code
Disposal value	DIVAL		
Miles per car-year	MPCY		
Miles per car-life	MPCL		
		Recoverable value	RECOV
		Recyclable value	RECYC

Table 27: Direct and related variables of the urban car-disposal system.

(iii) Parameters

We have the following parameters:

P = Percentage of the disposal value which is due to recoverable parts (1971).

ØI(DEL) = DEL Output-Input ratio for the metal scrap industry (1963). (See Appendix 4.)

DF = Dollar Deflator, 1971 to 1963.

IØN(DEL) = Input-Output for DEL corresponding to code number, N (1963).

IF(DEL) = DEL Inflator 1963 to 1971.

(iv) Equations

The DEL for disposal of urban cars is given by the following set of equations:

(a) Recoverable Value

$$\text{RECOV(DEL)} = \frac{\text{DIVAL x MPCY}}{\text{MPCL}} \text{ x DF x ØI(DEL) x P x IØ7202(DEL) x IF(DEL)} \quad (57)$$

(b) Recyclable Value

$$\text{RECYC(DEL)} = \frac{\text{DIVAL x MPCY}}{\text{MPCL}} \text{ x DF x ØI(DEL) x (1-P) x IØ3704(DEL) x IF(DEL)} \quad (58)$$

(c) Total Urban Car DEL Disposal

$$\text{CARDIS(DEL)} = \text{RECOV(DEL)} + \text{RECYC(DEL)} \quad (59)$$

(v) Estimated Values

The estimated mean values for variables and parameters are given in the following tables.

Variable	Value	Unit	References
DIVAL	40.0	Dollars/car	23
MPCY	11,200.0	Miles/car-year	11
MPCL	100,000.0	Miles	13

Table 28: Estimated mean values for the urban car disposal variables, 1971.

The dollar deflator for 1971 to 1963 (DF) has the value

$$DF = 0.7619 \quad (14)$$

The recoverable value percentage (P) for 1971 is

$$P = 0.900 \quad (22)$$

The output-input ratio ØI(DEL) as shown in Appendix 4 has the following values:

ØI(Dollar) = 1.0 ØI(Energy) = 2.4 ØI(Labor) = 2.4

Then the Deflator is given by

$$DF = 0.7619 * 2.4 = 1.82856$$

The IØ factors and the Inflators are given in the following table.

	IØ(DEL) (1)			Inflator (10)		
Code Number	Dollar	Energy ($x10^6$)	Labor ($x10^{-3}$)	Dollar	Energy	Labor
7202	-1.0	0.040195	0.184524	0.546	1.029	0.853
3704	-1.0	0.123328	0.083579	0.546	1.029	0.853

Table 29: Estimated values for urban car disposal parameters.

Note that IØ(Dollar) is negative because disposal dollar value is subtracted from overhead. See Figure 1 and related text.

5. DEL Total

As shown in Figure 1 the DEL totals for each system are:

(a) Bus Companies

$$DELPCO = BUSOVH(DEL) + BUSOP(DEL) + BUSST(DEL) + S(DEL) \times BUSDIS(DEL) \quad (60)$$

where DELPCO is the value of DEL per bus company per year in the year 1971.

(b) Urban Cars

$$DELPCA = CAROVH(DEL) + CAROP(DEL) + CARST(DEL) + S(DEL) \times CARDIS(DEL) \quad (61)$$

where DELPCA is the value of DEL per car per year in the year 1971.

II. Results

The significant results are given in the following subsections. More detailed results and supporting evidence may be found in the relevant appendices.

1. Bus Companies (DELPCO) 1971.

The DEL values for bus companies for the year 1971 are given in Table 30. The units are DEL per bus company per year. (DELPCO)

The estimated mean values of DEL per bus company per year are the following:

Dollars = $10{,}583.46 \times 10^3$ Dollars/Bus Co. - year

Energy = 530.11×10^9 Btu/Bus Co. - year

Labor = 838.63 Jobs/Bus Co. - year

2. Urban Car DEL (DELPCA) 1971

The DEL values for urban cars for 1971 are given in Table 3. The units are DEL per car per year.

The estimated mean values of DEL per average car per year are the following:

Dollars	=	1,353.95	Dollars/car - year
Energy	=	189.98×10^6	BTU/car - year
Labor	=	0.08892	Jobs/car - year

Variable	Dollar (x 10^3)	PT* (%)	PGT** (%)	Energy (Btu x 10^9)	PT* (%)	PGT** (%)	Labor (Jobs)	PT* (%)	PGT** (%)
				OVERHEAD					
Overhead	625.21	100.00	5.91	43.25	100.00	8.16	47.19	100.00	5.63
Total	625.21	100.00	5.91	43.25	100.00	8.16	47.19	100.00	5.63
				OPERATION					
General Maintenance	827.74	8.65	7.82	17.11	3.75	3.23	34.92	4.58	4.16
New Tires and Tubes	10.42	0.11	0.10	0.88	0.19	0.17	0.48	0.06	0.06
Retread Tires and Tubes	93.76	0.98	0.89	2.69	0.59	0.51	5.48	0.72	0.65
Repairs	895.61	9.36	8.47	66.87	14.63	12.62	83.79	10.99	9.99
Station	47.83	0.49	0.45	2.58	0.56	0.49	3.23	0.42	0.39
Transportation	945.85	9.88	8.93	21.98	4.81	4.15	74.31	9.75	8.86
Drivers	4136.52	43.22	39.09	--	--	--	--	--	--
Driver Year	--	--	--	--	--	--	407.37	53.45	48.58
Fuel Volume Energy	--	--	--	257.05	56.25	48.49	--	--	--
Fuel Cost to Produce	122.16	1.28	1.15	21.24	4.65	4.01	4.25	0.56	0.51
Fuel Cost to Transport	8.05	0.08	0.08	1.30	0.29	0.25	0.43	0.06	0.05
Fuel Cost to Wholesale	75.23	0.79	0.71	2.21	0.48	0.42	6.29	0.83	0.75
Fuel Cost to Retail	24.62	0.26	0.23	0.71	0.16	0.13	11.11	1.46	1.33
Lub. Oil Volume Energy	--	--	--	3.28	0.72	0.62	--	--	--
Lub. Oil Cost to Produce	6.10	0.06	0.06	1.06	0.23	0.20	0.21	0.03	0.03
Lub. Oil Cost to Transport	0.40	0.00	0.00	0.07	0.01	0.01	0.02	0.00	0.00
Lub. Oil Cost to Wholesale	3.76	0.04	0.04	0.11	0.02	0.02	0.31	0.04	0.04
Lub. Oil Cost to Retail	1.23	0.01	0.01	0.03	0.00	0.01	0.15	0.02	0.02
Administration	1674.20	17.49	15.82	32.98	7.22	6.22	88.19	11.57	10.52
Traffic Services	47.59	0.49	0.45	0.94	0.21	0.18	2.51	0.33	0.30
Advertising	31.73	0.33	0.30	0.86	0.19	0.16	1.67	0.22	0.20
Insurance	351.57	3.67	3.32	7.50	1.64	1.42	23.55	3.09	2.81
Licenses	228.23	2.38	2.16	14.97	3.28	2.82	12.84	1.68	1.53
Rents	37.17	0.39	0.35	0.57	0.13	0.11	1.01	0.13	0.12
Total	9569.76	100.00	90.42	456.99	100.00	86.21	762.13	100.00	90.88
				STREETS					
Taxes	228.23	55.06	2.16	151.30	55.06	2.85	12.21	54.98	1.46
Fuel Volume Tax	186.25	44.94	1.76	123.47	44.94	2.32	9.99	45.02	1.19
Total	414.48	100.00	3.92	274.77	100.00	5.18	22.21	100.00	2.65
				DISPOSAL					
Recoverable Value	-23.48	90.00	-0.22	1.78	74.58	0.34	6.76	95.21	0.81
Recyclable Value	-2.61	10.00	-0.03	0.61	25.42	0.11	0.34	4.79	0.04
Total	-26.09	100.00	-0.25	2.39	100.00	0.45	7.10	100.00	0.85
GRAND TOTAL	10,583.46		100.00	530.11		100.00	838.63		100.00

Table 30. DEL per bus company per year (DELPCO)

*PT = Percent of Total
**PGT = Percent of Grand Total

Variable	Dollar	PT* (%)	PGT** (%)	Energy (x 10^6)	PT* (%)	PGT** (%)	Labor (x 10^{-3})	PT* (%)	PGT** (%)
OVERHEAD (DEPRECIATION)									
Manufacture	325.32	68.01	24.02	21.14	77.93	11.13	19.97	60.27	22.46
Rail Transport	4.08	0.85	0.30	0.24	0.90	0.13	0.27	0.82	0.31
Truck, Transport	4.08	0.85	0.30	0.28	1.03	0.15	0.29	0.87	0.32
Wholesale	8.15	1.71	0.60	0.25	0.93	0.13	0.72	2.16	0.81
Retail	66.04	13.81	4.89	4.29	15.82	2.26	8.19	24.70	9.21
Financing Charge	70.65	14.77	5.22	0.92	3.40	0.49	3.70	11.18	4.17
Total	478.83	100.00	35.33	27.13	100.00	14.28	33.14	100.00	37.27
OPERATION									
Maintenance	145.60	19.14	10.75	4.17	2.70	2.20	8.51	17.67	9.57
Repairs	125.00	16.43	9.23	3.58	2.32	1.88	7.31	15.17	8.22
Fuel Volume Energy	--	--	--	117.74	79.19	61.98	--	--	--
Fuel Cost to Produce	93.71	12.32	6.92	16.29	10.54	8.57	3.27	6.78	3.67
Fuel Cost to Transport	8.93	1.18	0.66	1.77	1.15	0.93	0.47	0.97	0.52
Fuel Cost to Wholesale	62.33	8.20	4.60	1.83	1.19	0.97	5.22	10.83	5.87
Fuel Cost to Retail	42.80	5.63	3.16	1.24	0.80	0.65	5.05	10.49	5.68
Insurance	237.40	31.21	17.53	5.07	3.28	2.67	15.90	33.01	17.88
Licenses	19.74	2.60	1.46	1.29	0.84	0.68	1.11	2.30	1.25
Local Government	25.20	3.31	1.86	1.56	1.01	0.82	1.34	2.77	1.50
Total	760.72	100.00	56.19	154.54	100.00	81.35	48.16	100.00	54.16
STREETS									
Fuel Volume Tax	94.14	78.89	6.95	6.24	78.89	3.29	5.05	78.89	5.68
New Constructions	25.20	21.12	1.86	1.67	21.11	0.88	1.35	21.11	1.52
Total	119.34	100.00	8.81	7.91	100.00	4.16	6.40	100.00	7.20
DISPOSAL									
Recoverable Value	-4.03	90.91	-0.29	0.31	76.52	0.16	0.16	95.67	1.31
Recyclable Value	-0.40	9.09	-0.03	0.09	23.48	0.05	0.05	4.33	0.06
Total	-4.43	100.00	-0.33	0.40	100.00	0.21	1.21	100.00	1.37
GRAND TOTAL	1,353.95		100.00	189.98		100.00	88.92		100.00

Table 31. DEL per car per year (DELPCA)

*PT = Percent of Total
**PGT = Percent of Grand Total

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2. U. S. Department of Transportation, Federal Highway Administration (1972). National Personal Transportation Study. Report No. 3. Seasonal Variations of Automobile Trips and Travel. Table 1, p. 8.

3. American Transit Association (1972). 1971 Transit Operating Report, Revenues, Expenses, Operating Statistics. Part II and Part V.

4. Automobile Legal Association, Auto and Travel Club (1972). What it costs to run a car. Table I and Table II.

5. American Transit Association (1971-72). 1971-1972 Transit Fact Book, p. 20.

6. Calculated from data given in reference 5 and reference 9.

7. Based on confidential communications between J. E. Dunwoody and The Cleveland Transit System, General Motors Corporation, Truck and Coach Division and Rohr Industries, Inc. (Jan., Feb., 1973).

8. Calculated from reference 5.

9. Survey of Current Business (1972). "Implicit Price Deflators," U. S. Department of Commerce, Washington, Table 8.8.

10. Herendeen, R. A. and A. Sebald (1973). The Dollar, Energy and Employment Impacts of Certain Consumer Options. Preliminary Report to the Ford Foundation. Appendix A.

11. Reference 4. Report No. 4. Annual Miles of Automobile Travel. Table 8, p. 21.

12. Liston, L. L. and C. L. Gauthier (1972). Cost of Operating an Automobile. U. S. Department of Transportation, Federal Highway Administration, p. 11.

13. Kreher, E. R. (1972). Letter from Automobile Manufacturers Association, Inc. of January 19, citing R. L. Polk and Company and reference 18.

14. Survey of Current Business (1972). Implicit Price Deflators. Tables 8.6, 8.8, 8.1 and 8.7.

15. Bureau of Economic Analysis (1971). Personal Consumption Expenditures in the 1963 Input-Output Study. Survey of Current Business. Jan. Detailed 368 level unpublished data available on request from the BEA, U. S. Department of Commerce.

16. Reardon, W. A. (1972). An Input/Output Analysis of Energy Use Changes from 1947 to 1958 and 1958 to 1963. Batelle Memorial Institute. Table B-1.

17. Calculated from reference 5. See Appendix.

18. Calculated from reference 6. See Appendix.

19. Based on a 15% decrease in urban car mileage per gallon compared with the national average urban and intercity mileage per gallon (13.57 mpg[2] or 14 mpg[6]). See Appendix 3.

20. Federal and State Highway Tax. Reference 2, Table MF-1, p. 10.

21. This is an estimate. It may be changed to reflect actual experience by any company.

22. The Association of Auto and Truck Recyclers (1972), Introducing the Auto and Truck Parts Recycling Industry, p. 8.

23. Current estimate based on: "Obituary of an Auto" by J. M. Callahan (1962) Automotive News, August 27.

24. The Highway Tax is estimated at 4¢/gallon federal, and a weighted average of 6¢/gallon state and local tax on gasoline from R. L. Polk and Company, "Handbook on Trucks in the United States," pp. 8, 9. This may be 1 to 1.2¢ per gallon underestimated.

25. See Appendix 2 and reference 26.

26. U. S. Department of Transportation. "Summary of National Transportation Statistics." Office of System Analysis and Information. November 1972, p. 20.

27. Puleo, F. "Dollar, Energy and Labor Analysis of Transportation Systems." Technical Memorandum No. 27. Center for Advanced Computation. University of Illinois, Urbana, Illinois. 1974.

28. The Technical Committee on Industrial Classification, Office of Statistical Standards (1957). Standard Industrial Classification Manual.

29. U. S. Department of Commerce (1969). Input-Output Structure of the U. S. Economy: 1963: Vol. 1-3.

30. U. S. Department of Commerce (1969). Input-Output Structure of the U. S. Economy: 1963. Combined Transactions and Margins Tape, 367 Industry Level, available from BEA.

31. As per reference 20. Although municipal bus transit companies do not pay either the federal highway tax or their state highway tax, we assume in this model that they still use a proportion of the right-of-way (streets) equal to the amount of highway tax that they would have paid, had they had to pay the tax at the current rate.

32. This is the estimated value received upon disposal of an average, 14.78 year old, urban transit bus. The estimate is based on confidential discussions with the Chicago Transit Authority and the Cleveland Transit System.

APPENDIX 2

FINANCING CHARGE

From the Summary of Transportation Statistics, November 1972, we obtain the following data:

	1960	1970
Interest on debt (dollars)	2.777×10^9	5.668×10^9
Number of vehicle registrations	61.882×10^6	82.279×10^6

Using a linear extrapolation for the year 1971, we have that the total financing charge (TFC) is given by

$$\text{TFC} = \frac{2.777\times10^9\,(1971-1970) - 5.668\times10^9\,(1971-1960)}{1960-1970} = 5.957\times10^9$$

Reference:

U. S. Department of Transportation. "Summary of National Transportation Statistics." Office of System Analysis and Information. November 1972. p. 20.

APPENDIX 3

URBAN ADJUSTING FACTOR (UAF)

From references 1, 2, and 3 we have estimates of 13.63 (1969), 13.7 (1970) and 14.00 (1971) miles per gallon respectively. These values are for a national average automobile which, from references 2 and 4, we find does between 54.9% and 63.9% of its travel in urban areas. Clearly then, the national average estimate of about 14 miles per gallon (mpg) reflects approximately 40% inter-city driving and 60% urban driving.

In our model we are concerned with a national average automobile whose annual mileage consists solely of urban travel. Such a vehicle will, on the average, obtain a smaller number of miles per gallon than an automobile which does a higher percentage of interurban travel. Apparently the high aerodynamic drag at high speeds does not add the fuel penalty of the start-stop driving of an urban area.

In our model we have chosen to estimate an annual average reduction of 15% in mpg from the national average mpg for a solely urban automobile. For example, this would mean that a car that got 20 mpg on the open highway (60%) would get about 12.5 mpg in urban travel (40%). On this basis, assuming 11,200 miles of urban travel per car per year, this represents an increase of 17.5% in the amount of fuel consumed by a strictly urban car compared to an average car. Hence, UAF = 1.175%.

REFERENCES

1. Automobile Manufacturers Association, Inc. "1971 Automobile Facts and Figures." 1971. Pg. 57.

2. U. S. Department of Transportation. "Highway Statistics." Federal Highway Administration. 1970. Table VM-1. Pg. 52.

3. Automobile Legal Association, Auto and Travel Club. "What it costs to run a car." 1972. Table I and Table II.

4. U. S. Department of Transportation. "National Personal Transportation Study." 1972. Report No. 2. Table 8. Pg. 21.

APPENDIX 4

DISPOSAL OUTPUT-INPUT RATIO

At the end of their useable life the average urban bus and car bring a dollar return when disposed of, either for scrap metal or reclaimable parts or a combination of both. Disposal of the vehicles in this way actually represents the input to the industrial sector 83.00, scrap, used and second-hand goods. The scrap portion of this sector which goes into reclaimed metals, etc. may be considered as being distributed throughout the various industrial sectors which produced the vehicle in the first place. Then the cost to produce each new vehicle has contained in it the cost of utilizing that proportion of reclaimed material attributable to it.

The energy and labor costs of the ERG, energy, employment and pollution policy model are based on the dollar value delivered to final demand. However, we only have a measure of the intermediate input value for the disposal of these urban vehicles. To estimate the energy and labor required for their disposal we need to know the value added in order to obtain the total inputs.

Sector 83.00 has no value added according to the input-output structure of the U. S. economy. However, 90% or greater of the value of a disposed car or bus is realized, from the recovery of salvageable parts. As far as this applies to cars and buses we believe that there is a genuine value added in the recovery of these parts. For this reason we have applied the output-input ratio of sector 72.02, Personal and Repair Services, to evaluating the final demand worth of the disposed vehicles.

From Sector 72.02 we have:

$$\text{Total Intermediate Inputs} = 3.7 \times 10^9$$

$$\text{Value Added} = 5.1 \times 10^9$$

$$\text{Total Inputs} = 8.8 \times 10^9$$

Then the output/input (Ø/I) ratio is:

$$\emptyset/I = \frac{8.8 \times 10^9}{3.7 \times 10} = 2.4$$

REFERENCES

1. U. S. Department of Commerce. "Input-Output Structure of the U. S. Economy, 1963. Transactions Data for Detailed Industries." 1969. Vol. 1. Pg. 195.

2. The Association of Auto and Truck Recyclers. "Introducing the Auto and Truck Parts Recycling Industry." 1972. Pg. 8.

APPENDIX 5

ECONOMIC DEFLATORS

The ERG energy, employment and pollution policy model is presently structured for the year 1963. Our data for the urban car and bus systems was collected for the year 1971. The following deflators were used to convert from 1971 to 1963 dollars.

Model, Input Account Name	National Income Product Account Table	National Income Product Account Name	1963 Index	1971 Index	Ratio (1963/1971)
Manufacture	8.6	New Cars and Net Purchases of Used Cars	101.6	112.7	0.9015
Rail Transport	8.6	Purchased Inter-city Railway Transportation	102.3	140.4	0.7286
Truck Transportation	8.6	Purchased Inter-city Transportation	110.2	139.2	0.7917
Wholesale	8.8	Passenger Cars	101.6	111.4	0.9015
Retail	8.6	New Cars and Net Purchases of Used Cars	101.6	112.7	0.9015
Financing Charge	8.6	Services	118.7	179.8	0.6602
Maintenance	8.6	Tires,Tubes,Accessories and Spares	93.7	113.3	0.8270
Repairs	8.6	" " " "	93.7	113.3	0.8270
Fuel Production	8.6	Gasoline and Oil	103.5	120.5	0.8589
Fuel Transport	8.6	" " "	103.5	120.5	0.8589
Fuel Wholesale	8.6	" " "	103.5	120.5	0.8589
Fuel Retail	8.6	" " "	103.5	120.5	0.8589
Insurance	8.6	Services Furnished----	118.7	179.8	0.6602
Licenses	8.3	Services	112.6	159.4	0.7064
Taxes,Local Gov't.	8.1	State and Local	116.4	175.1	0.6648
Streets	8.7	Highways and Streets	100.6	153.8	0.6541
Disposal	8.8	Sale of Equipment Scrap	83.2	109.2	0.7619

Table 1. Car System Deflators.

Model, Input Account Name	National Income Product Account Table	National Income Product Account Name	1963 Index	1971 Index	Ratio (1963/1971)
Cost Per Bus	8.8	Trucks, Buses and Truck Trailers	98.4	119.7	0.8221
General Maintenance	8.6	Street and Electric Railway and Local Bus	118.9	199.2	0.5968
New Tires and Tubes	8.6	Tires, Tubes, Accessories and Parts	93.7	113.3	0.8270
Retread Tires and Tubes	8.6	" " " " "	93.7	113.3	0.8270
Repairs	8.6	" " " " "	93.7	113.3	0.8270
Station	8.6	Street and Electric Railway and Local Bus	118.9	199.2	0.5968
Transportation	8.6	" " " "	118.9	199.2	0.5968
Drivers	8.6	" " " "	118.9	199.2	0.5968
Fuel Production	8.6	Gasoline and Oil	103.5	120.5	0.8589
Fuel Transport	8.6	" " "	103.5	120.5	0.8589
Fuel Wholesale	8.6	" " "	103.5	120.5	0.8589
Fuel Retail	8.6	" " "	103.5	120.5	0.8589
Lube Oil Production	8.6	" " "	103.5	120.5	0.8589
Lube Oil Transport	8.6	" " "	103.5	120.5	0.8589
Lube Oil Wholesale	8.6	" " "	103.5	120.5	0.8589
Lube Oil Retail	8.6	" " "	103.5	120.5	0.8589
Administration	8.6	Street and Electric Railway and Local Bus	118.9	199.2	0.5968
Traffic Services	8.6	" " " "	118.9	199.2	0.5968
Advertising	8.6	" " " "	118.9	199.2	0.5968
Insurance	8.6	Services Furnished---	118.7	179.8	0.6602
Licenses	8.3	Services	112.6	159.4	0.7064
Rents	8.7	Private Structures	108.9	156.0	0.6980
Streets	8.7	Highways and Streets	100.6	153.8	0.6541
Disposal	8.8	Sale of Equipment Scrap	83.2	109.2	0.7619

Table 2 . Bus System Deflators.

APPENDIX 6

CAR DEL VARIABLE COST PER MILE (VCM)

To compute the DEL variable cost per mile (VCM) corresponding to the use of the car we take the values given in Table 5 of the main report corresponding to the following operation and streets variables:

Operation:

- Maintenance
- Repairs
- Fuel volume energy
- Fuel cost to produce
- Fuel cost to transport
- Fuel cost to wholesale
- Fuel cost to retail

Streets:

- Fuel volume tax

The DEL variable cost per mile (VCM) is then given by:

$$VCM(DEL) = VCOST(DEL)/MPCY$$

where VCOST(DEL) corresponds to the sum of the given variables in dollar, energy, and labor costs respectively. According with Table 5 results:

VCOST(Dollar)	=	572.32	Dollar/car-year
VCOST(Energy)	=	152.32×10^6	BTU/car-year
VCOST(Labor)	=	0.03487	Jobs/car-year

The variable cost per mile for 11,200 miles per car-year of use (MPCY) are:

VCM(Dollar)	=	0.0511	Dollar/Mile
VCM(Energy)	=	0.0136×10^{6}	BTU/Mile
VCM(Labor)	=	3.1133×10^{6}	Jobs/Mile

APPENDIX 7

BUS AVERAGE TRIP LENGTH (BATL)

The average trip length for a bus (BATL) is computed through the total passenger-mile (TPM) and the passengers per bus company (PPCO) in the following form:

$$BATL = \frac{TPM}{PPCO}$$

but

$$TPM = TBM * PPB$$

where

TBM = Total miles per bus company per year

PPB = Passengers per bus

hence

$$BATL = \frac{TBM * PPB}{PPCO}$$

Values of TBM and PPCO for bus companies used in this report are:

$TBM = 8.3699 \times 10^6$ Miles/Bus Co.-Year (1)

$PPCO = 0.26725 \times 10^8$ Passengers/Bus Co.-Year (1)

The value of PPB given by reference (2) is:

PPB = 12 Passenger/Bus

Then the computed value of ATL is:

$$ATL = \frac{8.3699 \times 10^6 \times 12}{0.267250 \times 10^8} = 3.758$$

REFERENCES

1. See Appendix 8.

2. French, A. Federal Highway Administration. Highway Statistics Division. November 1973.

APPENDIX 8

STATISTICAL ANALYSIS

Contents:

1. Introduction

A statistical analysis of the direct and indirect dollar, energy, and labor (DEL) costs of shifting passengers from urban cars to buses has been completed. Previous workers have neglected to include the indirect DEL costs in their evaluation of urban transportation systems. Grover[3] developed a comprehensive cost model for urban automobile, bus and rail network flow calculations. This model includes the dollar cost of all the components of each transportation system, but it does not include their indirect costs to the rest of the economy or the energy and labor costs of each system.

The method developed in this report enables computation of both the direct and indirect dollar, energy, and labor costs of operating a transit bus company and an urban car. It is important to realize the limiting assumptions of the model: a) Input/Output modeling assumes a linear relationship between the variables, and b) both passenger transfer models are linear. The car-bus transfer model both for nationwide and individual changes provides a conservative or lower bound estimate of the dollar, energy and labor changes. This is because the DEL cost per passenger of using the bus system is held constant while more passengers are transferred to the system. No cost savings due to economy of scale of operation have been allowed for, although they might reasonably be expected to occur. Welbs and Thomas[4] have shown that the urban bus transit industry was economically more prosperous when it carried an average of 3.24 revenue passengers per vehicle mile in 1960 than it was in 1969 when it carried an average of 2.81 revenue passengers per vehicle mile.

The bus-car model was developed from data supplied by the American Transit Association and the Automobile Legal Association.

From the American Transit Association[1] data, we selected 38 companies (all those possessing complete input account records) from their 143 reporting members. These companies operated 9,731 buses in 1971, the year of our study, or 48% of the total number of buses for which some data was reported. Thus, our study is slightly biased toward the larger companies. Each of these companies reported on 39 common variables which formed the basis of the bus model investigation.

The Automobile Legal Association[2] data was based on average standard size U. S. cars from 28 different major cities, costing $3,640 retail in 1971. The data on 8 separate expense variables was available and formed the data set for this model.

Using the ERG[a] energy, employment, pollution policy model, a 362 sector linear input-output model developed at the Center for Advanced Computation, we converted these expense variables to the total (direct and indirect) energy and labor which they required. Since the I/O model technology is for 1963, the latest available complete data, we had to deflate the 1971 expenses to 1963 and then convert 1963 energy and labor costs back to 1971 using suitable energy and labor productivity ratios. The I/O model attempts to account for all activities except the costs of new capital formation. This omission is believed to produce less than a 5% error in the energy and employment estimates.

2. <u>Methodology</u>

To study the bus and car transportation systems all the endogeneous variables, which are potential sources of variation on which the output of the system depends, were taken and classified into four groups according to their

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a. Energy Research Group - CAC

characteristics in:

a. overhead variables

b. operation variables

c. streets variables

d. disposal variables

2.1 Variables and Sources of Data

Variables corresponding to the bus companies are given in table 1, where exogeneous variables not related with the system are also given. These variables were obtained from data supplied by the American Transit Association (ATA). In table 1 the method of computation is indicated based upon this source of data. For example, general maintenance, variable number 1 (GENM) is given by the relation

$$\text{GENM} = K(4) - K(5) - K(6)$$

meaning that the values given in the rows corresponding to key numbers 4, 5, and 6 are used according to this expression in order to compute GENM.

Sometimes values already computed are used to compute another variable. For example, lubricating oil cost to produce, variable number 23 (LUBOCP) is computed using values of variable 22, lubricating oil cost.

Table 2 corresponds to variables and sources of data of the urban car transportation system. In this case data was supplied by the Automobile Legal Association (ALA) and was taken on basis of 11,200 miles per car-year.

2.2 Dollar, Energy, and Labor (DEL) Model

In order to compute the dollar, energy, and labor values for each system we use the following expression:

Variable	Code	Description	Relationship
Endogeneous			
1	GENM	General maintenance	K(4) - K(5) - K(6)
2	TT	Tires and tubes	K(6)
3	NEWTT	New tires and tubes	K(6) x 0.1
4	RETT	Retread tires and tubes	K(6) x 0.9
5	REP	Repairs	K(5)
6	STA	Station	K(13)
7	TRAN	Transportation	K(7) - K(8) - K(9) - K(10) - K(11) - K(12)
8	DRIV	Drivers	K(8)
9	BUSH	Bus hours	K(32)
10	DRIVY	Driver years	K(32) x 0.5208 x 10^{-3}
11	DIEVOL	Diesel volume	K(35)
12	PROVOL	Propane volume	K(34)
13	GAVOL	Gasoline volume	K(33)
14	FUELVE	Fuel volume energy	K(35) x 138238.0 + K(34) x 91500.0 + K(33)x125071.0
15	FUELC	Fuel cost	K(9) + K(10) + K(11)
16	FUELCP	Fuel cost to produce	V(16) x 0.531
17	FUELCT	Fuel cost to transport	V(16) x 0.035
18	FUELCW	Fuel cost to wholesale	V(16) x 0.327
19	FUELCR	Fuel cost to retail	V(16) x 0.107
20	LUBOV	Lubricating oil volume	K(36)
21	LUBOVE	Lubricating oil volume energy	V(21) x 144286.0
22	LUBOC	Lubricating oil cost	K(12)
23	LUBOCP	Lubricating oil cost to produce	V(22) x 0.531
24	LUBOCT	Lubricating oil cost to transport	V(22) x 0.035
25	LUBOCW	Lub. oil cost to whole-sale	V(22) x 0.327
26	LUBOCR	Lub. oil cost to retail	V(22) x 0.107
27	ADM	Administration	K(17)
28	TRF	Traffic	K(14)
29	TRFS	Traffic services	V(28) x 0.60
30	ADV	Advertising	V(28) x 0.40
31	INS	Insurance	K(15)
32	TAXL	Taxes and licenses	K(20)
33	LIC	Licenses	V(32) x 0.50
34	STRT	Streets	V(32) x 0.50
35	RENT	Rents	K(21)
Exogeneous			
36	POP	Population	--
37	ROUTM	Round trip route miles	K(24)
38	NBUS	Number of active buses	K(25)
39	TBM	Total bus miles	K(28)
40	REVP	Revenue passengers	K(38)
41	NSTS	Number of seats	--
42	PREV	Passenger revenue	K(3)
43	EMP	Employees	K(27)
44	PRFT	Profit	K(23)

Table 2. Variables and Sources of Data for Bus Company Variables

K(I) → Refers to key number of Section A of ATA 1971.
V(I) → Refers to variable number (I).

$$Y(I) = \sum_{K=1}^{M} CDEL(I,K) \times W(I,K) \qquad I=1:3 \qquad (1)$$

where

Y(I) = Dependent variable number (I) corresponding to:

Dollar = Y(1)

Energy = Y(2)

Labor = Y(3)

M = Number of endogeneous variables

CDEL(I,K) = DEL coefficient for independent variable (K) and dependent variable (I)

W(I,K) = Endogeneous variable (K) corresponding to dependent variable (I)

The coefficient CDEL(I,K) used in equation 1 is given by the following expression:

$$CDEL(I,K) = DF(I,K) * I\emptyset(I,K) * IF(I) \qquad (2)$$

where

DF(I,K) = Deflator coefficient for independent variable (K) and dependent variable (I)

IØ(I,K) = Input-Output coefficient for independent variable (K) and dependent variable (I)

IF(I) = Inflator coefficient for dependent variable (I)

All these coefficients were given in Appendix 1.

The mean values of all variables classified into four groups are given in table 3 for bus companies and in table 4 for urban cars for the year 1971.

Table 5 and table 6 gives the statistical characteristic values of each variable related with dollar costs only. Table 7 gives the total dollar, energy, and labor costs statistical characteristics for both systems.

Variable	Code	Description	Relationship
1	MAINT	Maintenance	C(3) x 0.01 x V(5) ≐ 145.6
2	REPRS	Repairs	K(4,1) ≐ 125.0
3	CPG	Cost per gallon	C(1) x 0.01
4	CPM	Cost per mile	C(2) x 0.01
5	MPY	Miles per car-year	Estimated at 11,200.0
6	FUELV	Fuel volume	V(4) x V(5) ÷ V(3) x 1.175
7	FUELVE	Fuel volume energy	V(6) x 125071.0
8	FUELT	Fuel tax	V(6) x 0.10
9	TFUELC	Total fuel cost	V(4) x V(5)
10	NFUELC	Net fuel cost	V(9) - V(8)
11	NFUELCP	Net fuel cost to produce	V(10) x 0.451
12	NFUELCT	Net fuel cost to transport	V(10) x 0.043
13	NFUELCW	Net fuel cost to wholesale	V(10) x 0.300
14	NFUELCR	Net fuel cost to retail	V(10) x 0.206
15	INS	Insurance	[K(1.1) + K(1.2) + K(1.3) + K(1.4)] x 2/3 + K(1.5)
16	LIC	Licenses	K(2.3) + K(2.4)
17	TAX	Taxes	K(2.1)
18	LGOV	Local government	V(17) x 0.50
19	STRT	Streets	V(17) x 0.50

Table 3. Variables and Sources of Data for Urban Car Variables (*)
K(I,J) ⇛ Refers to item number (I) and line (J) of Table II - ALA/1971.
C(I) ⇛ Refers to column number (I) of Table I - ALA/1971.
V(I) ⇛ Refers to variable number (I).

NO.	VARIABLE	DOLLAR (x10³)	ENERGY (BTUx10⁹)	LABOR (JOBS)
	OVERHEAD			
1	Manufacture	625.217	43.252	47.192
	OPERATION			
2	General Maintenance	827.742	17.113	34.921
3	New Tires and Tubes	10.418	0.883	0.484
4	Retread Tires and Tubes	93.761	2.685	5.480
5	Repairs	891.614	66.871	83.786
6	Station	47.829	2.578	3.230
7	Transportation	945.849	21.980	74.312
8	Drivers	4136.520	0.0	0.0
9	Driver Years	0.0	0.0	407.367
10	Fuel Volume Energy	0.0	257.049	0.0
11	Fuel Cost to Produce	122.162	21.235	4.258
12	Fuel Cost to Transport	8.052	1.304	0.428
13	Fuel Cost to Wholesale	75.229	2.212	6.295
14	Fuel Cost to Retail	24.616	0.712	11.113
15	Lub. Oil Volume Energy	0.0	3.284	0.0
16	Lub. Oil Cost to Produce	6.101	1.061	0.213
17	Lub. Oil Cost to Transport	0.402	0.065	0.021
18	Lub. Oil Cost to Wholesale	3.757	0.110	0.314
19	Lub. Oil to Retail	1.229	0.036	0.145
20	Administration	1674.190	32.980	88.193
21	Traffic Services	47.587	0.937	2.507
22	Advertising	31.725	0.856	1.671
23	Insurance	351.572	7.505	23.546
24	Licenses	228.230	14.969	12.836
25	Rents	37.173	0.573	1.010
	STREETS			
26	Taxes	228.230	15.130	12.209
27	Fuel Volume Tax	186.251	12.347	9.999
	DISPOSAL			
28	Recoverable Value	23.485	1.778	6.761
29	Recyclable Value	2.609	0.606	0.340

Table 4: DEL Costs Per Bus Company Per Year (1971)

VARIABLE	COUNT	MEAN	STANDARD DEVIATION	VARIANCE	SKEWNESS	KURTOSIS
1	38.	0.6252174D 06	0.1204345D 07	0.1450448D 13	0.3005377D 01	0.8732405D 01
2	38.	0.8277422D 06	0.2422985D 07	0.5870855D 13	0.4450465D 01	0.2047986D 02
3	38.	0.1041788D 05	0.2586150D 05	0.6688174D 09	0.3528284D 01	0.1147552D 02
4	38.	0.9376099D 05	0.2327536D 06	0.5417425D 11	0.3528284D 01	0.1147551D 02
5	38.	0.8956142D 06	0.2524688D 07	0.6374051D 13	0.4408537D 01	0.1996555D 02
6	38.	0.4782863D 05	0.2360628D 06	0.5572563D 11	0.5501255D 01	0.2967281D 02
7	38.	0.9458492D 06	0.3601779D 07	0.1297281D 14	0.5034860D 01	0.2551639D 02
8	38.	0.4136521D 07	0.1000764D 08	0.1001529D 15	0.3660789D 01	0.1363506D 02
9	38.	0.4073668D 03	0.8880920D 03	0.7887074D 06	0.3556155D 01	0.1277937D 02
10	38.	0.2570486D 12	0.5264798D 12	0.2771810D 24	0.3189440D 01	0.9834011D 01
11	38.	0.1221617D 06	0.2517255D 06	0.6336571D 11	0.3230941D 01	0.1027401D 02
12	38.	0.8052091D 04	0.1659207D 05	0.2752968D 09	0.3230940D 01	0.1027401D 02
13	38.	0.7522954D 05	0.1550174D 06	0.2403038D 11	0.3230941D 01	0.1027401D 02
14	38.	0.2461640D 05	0.5072434D 05	0.2572959D 10	0.3230941D 01	0.1027401D 02
15	38.	0.3283736D 10	0.7627066D 10	0.5817214D 20	0.3503929D 01	0.1139575D 02
16	38.	0.6100868D 04	0.1194107D 05	0.1425890D 09	0.3248088D 01	0.1003346D 02
17	38.	0.4021287D 03	0.7870759D 03	0.6194884D 06	0.3248088D 01	0.1003346D 02
18	38.	0.3757031D 04	0.7353537D 04	0.5407450D 08	0.3248088D 01	0.1003346D 02
19	38.	0.1229365D 04	0.2406203D 04	0.5789813D 07	0.3248088D 01	0.1003346D 02
20	38.	0.1674195D 07	0.5929253D 07	0.3515604D 14	0.5029739D 01	0.2553833D 02
21	38.	0.4758727D 05	0.1098293D 06	0.1206248D 11	0.2951029D 01	0.8782481D 01
22	38.	0.3172484D 05	0.7321956D 05	0.5361104D 10	0.2951029D 01	0.8782482D 01
23	38.	0.3515716D 06	0.8721276D 06	0.7606066D 12	0.3549867D 01	0.1172852D 02
24	38.	0.2282302D 06	0.5480189D 06	0.3003248D 12	0.3786820D 01	0.1459258D 02
25	38.	0.3717271D 05	0.1516120D 06	0.2298619D 11	0.5417059D 01	0.2909818D 02
26	38.	0.2282302D 06	0.5480189D 06	0.3003248D 12	0.3786820D 01	0.1459258D 02
27	38.	0.1862509D 06	0.3807414D 06	0.1449640D 12	0.3190139D 01	0.9838325D 01
28	38.	0.2348479D 05	0.4523833D 05	0.2046507D 10	0.3005377D 01	0.8732403D 01
29	36.	0.2609421D 04	0.5026481D 04	0.2526551D 08	0.3005377D 01	0.8732405D 01

Table 6 : Statistical characteristics of each variable of the bus companies

NO.	VARIABLE	DOLLAR	ENERGY ($BTUx10^6$)	LABOR ($JOBSx10^{-3}$)
	OVERHEAD			
1	Manufacture	325.328	21.141	19.974
2	Rail Transport	4.077	0.242	0.272
3	Truck Transport	4.077	0.279	0.288
4	Wholesale	8.154	0.251	0.716
5	Retail	66.044	4.292	8.185
6	Financing Charge	70.648	0.922	3.703
	OPERATION			
7	Maintenance	145.600	4.169	8.509
8	Repairs	125.000	3.579	7.305
9	Fuel Volume Energy	0.0	117.738	0.0
10	Fuel Cost to Produce	93.710	16.289	3.266
11	Fuel Cost to Transport	8.935	1.773	0.466
12	Fuel Cost to Wholesale	62.335	1.833	5.216
13	Fuel Cost to Retail	42.803	1.238	5.052
14	Insurance	237.399	5.068	15.899
15	Licenses	19.740	1.295	1.110
16	Local Government	25.198	1.557	1.335
	STREETS			
17	Fuel Volume Tax	94.137	6.241	5.054
18	New Constructions	25.198	1.670	1.353
	DISPOSAL			
19	Recoverable Value	4.032	0.305	1.161
20	Recyclable Value	0.403	0.094	0.053

Table 5: DEL costs per urban car per year (1971)

VARIABLE	COUNT	MEAN	STANDARD DEVIATION	VARIANCE	SKEWNESS	KURTOSIS
1	28.	0.32532840 03	0.0	0.0	0.0	0.0
2	28.	0.4076798D 01	0.0	0.0	0.0	0.0
3	28.	0.4076798D 01	0.0	0.0	0.0	0.0
4	28.	0.8153598D 01	0.0	0.0	0.0	0.0
5	28.	0.6604411D 02	0.0	0.0	0.0	0.0
6	28.	0.7064781D 02	0.0	0.0	0.0	0.0
7	28.	0.1456000D 03	0.0	0.0	0.0	0.0
8	28.	0.1250000D 03	0.0	0.0	0.0	0.0
9	28.	0.1177330D 09	0.6277214D 06	0.3940342D 12	0.4448898D 01	0.1943584D 02
10	28.	0.9371004D 02	0.6808134D 01	0.4635068D 02	0.1253435D 00	-0.2566415D 00
11	28.	0.8934660D 01	0.6491126D 00	0.4213472D 00	0.1253435D 00	-0.2566423D 00
12	28.	0.6233483D 02	0.4528693D 01	0.2050906D 02	0.1253413D 00	-0.2566438D 00
13	28.	0.4280325D 02	0.3109703D 01	0.9670251D 01	0.1253429D 00	-0.2566417D 00
14	28.	0.2373993D 03	0.7927170D 02	0.6284003D 04	0.1675888D 01	0.2434793D 01
15	28.	0.1974035D 02	0.1090613D 02	0.1189437D 03	0.9276745D 00	0.2602328D 00
16	28.	0.2519767D 02	0.1098010D 02	0.1205625D 03	-0.2496406D 00	-0.2437784D 00
17	28.	0.9413692D 02	0.5018894D 00	0.2518930D 00	0.4448881D 01	0.1943574D 02
18	28.	0.2519767D 02	0.1098010D 02	0.1205625D 03	-0.2496406D 00	-0.2437784D 00
19	28.	0.4031999D 01	0.0	0.0	0.0	0.0
20	28.	0.4031997D 00	0.0	0.0	0.0	0.0

Table 7 : Statistical characteristics of each variable of the urban car

ENTITY	COUNT	MEAN	STANDARD DEVIATION	VARIANCE	SKEWNESS	KURTOSIS
<u>Bus Companies</u>						
Dollar	38	0.1058337D 08	0.2831010D 08	0.8014616D 15	0.4063035D 01	0.1681146D 02
Energy	38	0.5301101D 12	0.1217215D 13	0.1481613D 25	0.3574356D 01	0.1261673D 02
Labor	38	0.8386324D 03	0.2093154D 04	0.4381295D 07	0.3959030D 01	0.1595654D 02
<u>Urban Car</u>						
Dollar	28	0.1353947D 04	0.9129908D 02	0.8335522D 04	0.1642493D 01	0.2692981D 01
Energy	28	0.1899781D 09	0.3231956D 07	0.1044554D 14	0.5388319D 00	0.5334302D 00
Labor	28	0.8891919D 01	0.5951514D 02	0.3542052D 04	0.1677837D 01	0.2760635D 01

Table 8: Statistical characteristics of dollar, energy and labor costs

From table 7 three observations are drawn:

a. The potential variation of the estimated mean DEL costs of the bus companies are ± 87 percent, ± 47 percent, and 79 percent respectively, and for the urban car are ± 2 percent, ± 0.3 percent, and ± 2 percent respectively. This means that the estimated means for bus companies must be used with caution.

b. The bus companies data have a leptokurtic distribution, that is, the variance is high and the distribution has a high positive skewness with a high kurtosis.

c. The urban car data has a platykurtic distribution, that is, it has a small variance and small positive skewness with small kurtosis.

The skewness is a measure of the lack of symmetry in a distribution, whose value is zero for a symmetrical distribution. Kurtosis is the relative peakedness or flatness of a distribution, whose value is equal to three for the normal distribution.

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APPENDIX 9

FRACTIONAL DISTRIBUTION OF THE DOLLAR, ENERGY, AND LABOR COSTS FOR BUS COMPANIES AND URBAN CARS

Contents:

1. Introduction

The transportation systems under study in this report and bus companies and urban cars which have attributes measured over twenty-nine variables for the bus companies and over twenty variables for the urban car. All these variables were given in Appendix 1 and in Appendix 8.

In this appendix energy costs have been divided into four additional categories: coal energy, refined petroleum energy, electricity and gas energy.

2. Fractional Distribution

Tables 1 and 2 give values of dollar, energy, and labor costs in per unit of each total as was given in Appendix 1.

For bus companies, Table 1, we can see that variable 8 (drivers) and 20 (administration) have 55 percent of the total expenses. Variables 5 (repairs) and 10 (fuel volume energy) have 61 percent of the energy requirements and variables 9 (driver years) and 20 (administration) have 59 percent of the labor utilized.

In the urban car, variables 1 (manufacture), 7 (maintenance), and 14 (insurance) have 52 percent of the total expenses. Variables 1 (manufacture) and 9 (fuel volume energy) have 73 percent of the energy requirements, and variables 1 (manufacture) and 14 (insurance) have 40 percent of the labor utilized.

VARIABLE NUMBER*	DOLLAR	COAL	REFINED PETROL	ELECTRICITY	NATURAL GAS	TOTAL ENERGY	TOTAL LABOR
1	0.05938	0.25727	0.02473	0.17304	0.16632	0.08159	0.05627
2	0.07821	0.06156	0.01739	0.09441	0.06867	0.03228	0.04164
3	0.00098	0.00426	0.00062	0.00353	0.00360	0.00167	0.00058
4	0.00886	0.00966	0.00273	0.01481	0.01078	0.00507	0.00653
5	0.08462	0.09879	0.12885	0.18001	0.13150	0.12615	0.09991
6	0.00452	0.00331	0.00497	0.00694	0.00507	0.00486	0.00385
7	0.08937	0.03937	0.03841	0.07589	0.05852	0.04146	0.08861
8	0.39085	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.48575
10	0.0	0.0	0.64922	0.0	0.0	0.48490	0.0
11	0.01154	0.01909	0.02347	0.02822	0.09678	0.04006	0.00508
12	0.00076	0.00077	0.00154	0.00096	0.01375	0.00246	0.00051
13	0.00711	0.00553	0.00302	0.00781	0.00771	0.00417	0.00751
14	0.00233	0.00198	0.00076	0.00378	0.00320	0.00134	0.01325
15	0.0	0.0	0.00829	0.0	0.0	0.00619	0.0
16	0.00058	0.00095	0.00117	0.00141	0.00483	0.00200	0.00025
17	0.00004	0.00004	0.00008	0.00005	0.00069	0.00012	0.00003
18	0.00035	0.00028	0.00015	0.00039	0.00038	0.00021	0.00037
19	0.00012	0.00010	0.00004	0.00019	0.00016	0.00007	0.00017
20	0.15819	0.31525	0.03781	0.21699	0.17232	0.06221	0.10516
21	0.00450	0.00323	0.00083	0.00497	0.00440	0.00177	0.00299
22	0.00300	0.00380	0.00066	0.00358	0.00366	0.00162	0.00199
23	0.03322	0.02524	0.00604	0.04545	0.03823	0.01416	0.02808
24	0.02157	0.03583	0.00800	0.06586	0.11517	0.02824	0.01531
25	0.00351	0.00452	0.00326	0.00742	0.00408	0.00108	0.00120
26	0.02157	0.05559	0.01965	0.02987	0.04349	0.02854	0.01456
27	0.01760	0.04536	0.01604	0.02438	0.03549	0.02329	0.01192
28	-0.00222	0.00563	0.00206	0.00699	0.00672	0.00335	0.00806
29	-0.00025	0.00211	0.00022	0.00305	0.00446	0.00114	0.00041

Table 1: Fractional distribution of the dollar, energy, and labor costs for bus companies in 1971

*See Table 4 of Appendix 8 for the variable description.

VARIABLE NUMBER*	DOLLAR	COAL	REFINED PETROL	ELECTRICITY	NATURAL GAS	TOTAL ENERGY	TOTAL LABOR
1	0.24028	0.52997	0.03204	0.33861	0.19624	0.11128	0.22463
2	0.00301	0.01243	0.00023	0.04463	0.00019	0.00128	0.00306
3	0.00301	0.00077	0.00179	0.00123	0.00093	0.00147	0.00324
4	0.00602	0.00250	0.00095	0.00374	0.00224	0.00132	0.00806
5	0.04878	0.02218	0.00597	0.04489	0.02307	0.02259	0.09205
6	0.05218	0.01250	0.00200	0.02449	0.01216	0.00485	0.04165
7	0.10754	0.05959	0.01176	0.09689	0.04276	0.02195	0.09570
8	0.09232	0.05116	0.01009	0.08318	0.03671	0.01884	0.08216
9	0.0	0.0	0.82534	0.0	0.0	0.61975	0.0
10	0.06921	0.05819	0.04997	0.04786	0.42937	0.08574	0.03673
11	0.00660	0.00340	0.00410	0.00456	0.04094	0.00933	0.00524
12	0.04604	0.01921	0.00694	0.02725	0.01632	0.00965	0.05866
13	0.03161	0.01369	0.00369	0.02771	0.01424	0.00652	0.05681
14	0.17534	0.06770	0.01131	0.12926	0.06596	0.02668	0.17881
15	0.01458	0.01231	0.00192	0.02399	0.02546	0.00682	0.01249
16	0.01861	0.01480	0.00231	0.02885	0.03061	0.00819	0.01501
17	0.06953	0.09108	0.02250	0.05190	0.04584	0.03285	0.05684
18	0.01861	0.02438	0.00602	0.01389	0.01227	0.00879	0.01521
19	-0.00298	0.00384	0.00098	0.00505	0.00295	0.00161	0.01305
20	-0.00030	0.00130	0.00010	0.00199	0.00176	0.00049	0.00059

Table 2: Fractional distribution of the dollar, energy, and labor costs for urban cars in 1971

*See Table 5 of Appendix 8 for variable description.

APPENDIX 10

PATH ANALYSIS

Content:

1. Introduction

To study the bus and car transportation systems we have classified their variables in the following way:

a. State Variables

These variables are the sources of variation that account for the greatest reduction in variance of the output. When linear multiple regression is used to estimate these variables, they make the greatest improvement in "goodness of fit" or, stated in another way, they are variables which are significant in the regression equation. These variables may be determined using the stepwise linear multiple regression method with an F statistical criterion.

b. Relational Variables

They are all the remaining non-significant variables which can be related to the state variables through some linear or non-linear function.

2. Statistical Models

In order to describe the inherent structure of selected aspects (Dollar, Energy, Labor) of both systems, we can use two kinds of models through which to express the relationship of the state variables with the output in which we are interested.

a. Linear Model

In this model the equation relating the state variables with the outputs is linear and has the following form:

$$Y(I) = \hat{Y}(I) + E(I) \qquad I = 1:3 \qquad (1)$$

where

$Y(I)$ = Dependent variable number (I) corresponding to

Dollar = Y(1)
Energy = Y(2)
Labor = Y(3)

$\hat{Y}(I)$ = Estimated linear value of Y(I)

$E(I)$ = Error value of Y(I)

Using stepwise linear multiple regression we can determine the "significant" variables which explain the maximum amount of variance. By definition, these are the state variables of the systems. The estimated dependent variable $\hat{Y}(I)$ is given by

$$\hat{Y}(I) = A(I,0) + \sum_{j=1}^{P} A(I,J) \times Z(I,J) \qquad (2)$$

where

P = Number of state variables for a certain value of the coefficient of determination R^2.

R^2 = Coefficient of Determination. This gives a measure of the proportion of the total variation of the depnedent variable which the linear relationship with the state variables accounts for.

A(I,0) = Independent coefficient of dependent variable (I).

A(I,J) = Linear coefficient of state variable (J) corresponding to dependent variable (I).

Z(I,J) = State variable (J) corresponding to dependent variable (I).

b. Power Model

In this model the equation relating the state variables with outputs is a power function of the following form:

$$Y(I) = \hat{Y}(I) \times E(I) \qquad J = 1{:}3 \tag{3}$$

where

$Y(I)$ = Dependent variable

$\hat{Y}(I)$ = Estimated power value of $Y(I)$

$E(I)$ = Error value of $Y(I)$

Using stepwise linear multiple regression applied to the logarithm of each variable which explains the maximum amount of the variance, we obtained the following expression for the estimated dependent variable

$$\hat{Y}(I) = B(I,0) \times \prod_{i=1}^{P} Z(I,J) \text{ xx } B(I,J) \tag{4}$$

where

$B(I,0)$ = Independent coefficient

$B(I,J)$ = Power coefficient of state variable $Z(I,J)$

P = Number of state variables for a certain value of the coefficient of determination, R^2.

3. <u>Sensitivity and Elasticity for Bus and Car Transportation Systems</u>

Both models can be used to study the possible changes in the car and bus systems. This is done by calculating the sensitivity and elasticity for each system from its state variables.

a. <u>Sensitivity</u>

From the linear model we obtain

$$\frac{\partial Y(I)}{\partial Z(J)} = A(I,J) \doteq \frac{\Delta Y(I)}{\Delta X(J)} \tag{5}$$

This relationship represents the change in the dependent variable $Y(I)$ per unit of change in the state variable $Z(J)$.

b. Elasticity

From the power model we obtain:

$$\frac{\partial Y(I)/Y(I)}{\partial Z(J)/Z(J)} = B(I,J) \doteq \frac{\Delta Y(I)/Y(I)}{\Delta Z(J)/Z(J)} \qquad (6)$$

This relationship represents the percentage of change in the dependent variable Y(I) per percentage unit of change in Z(J).

4. Path Analysis

If we express all of the variables in standard form then the technique of path analysis can be used to represent the bus and car transportation systems. This technique deals with observed interrelated variables for which it can be assumed that there are several "ultimate" variables that completely determine the behavior of the system.

Using the state variables and the relational variables we can represent the system as in Fig. 1, where the coefficients correspond to the standard regression coefficients and the error is calculated by

$$e(I) = \sqrt{1 - R(I)^2} \qquad (7)$$

5. Results

Using data from thirty-eight bus companies and urban car operations in twenty-eight major U.S. cities, all in 1971, and following the model given in the main text of this report the results are as follows.

a. Linear Model

Stepwise multiple regression was used to compute the linear models for the bus and car transportation systems. The corresponding coefficients and variables are given in Tables 1 and 2 respectively, where:

P = Number of state variables

R^2 = Coefficient of Determination

M = Mean Value

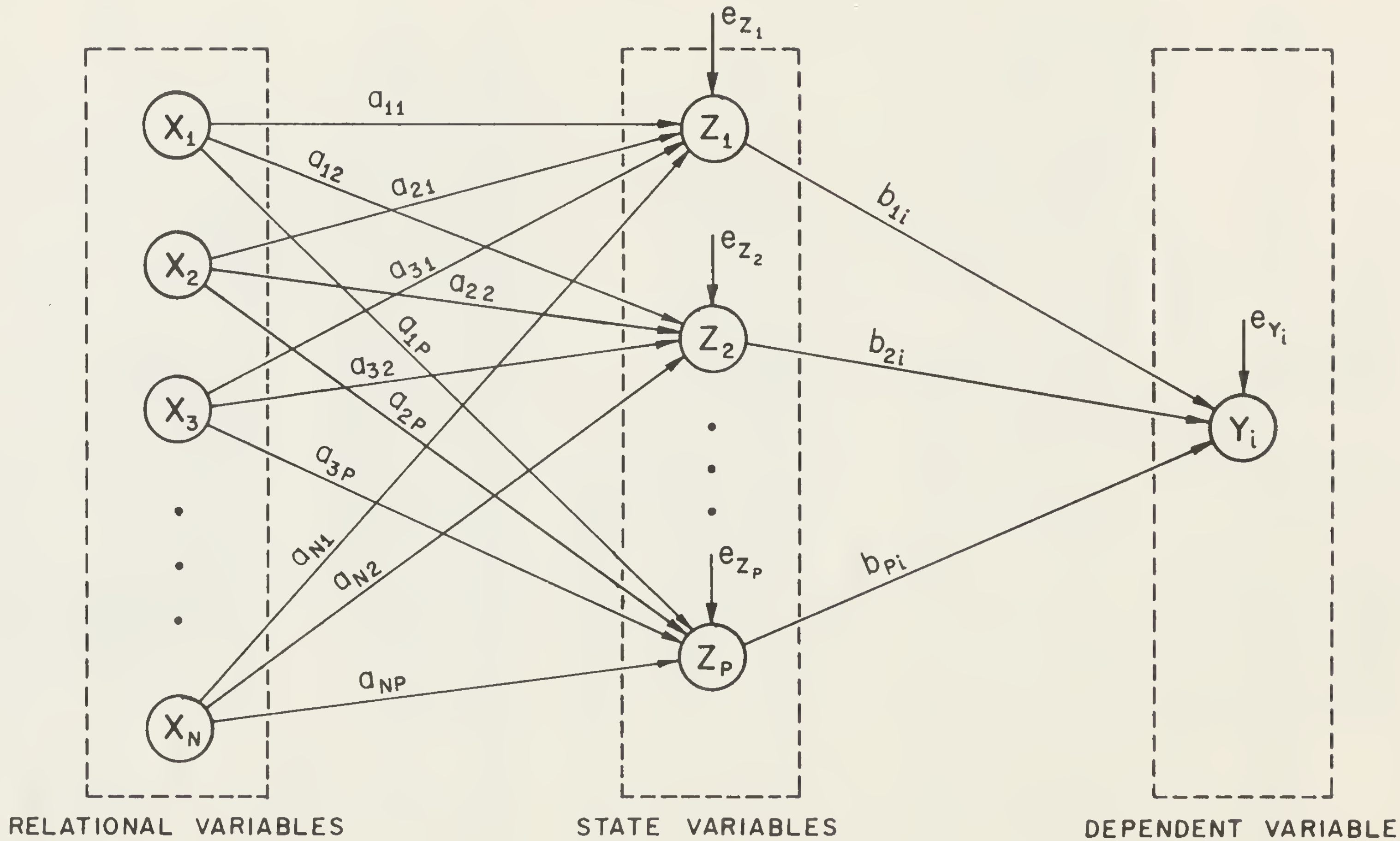

FIG. 1 GENERAL PATH DIAGRAM.

Sy = Standard error of estimated dependent variable.

Se = Standard error of estimate.

Se/M = Ratio of Se with the mean value of the dependent variable.

( ) = Number in parenthesis correspond to the variable number.

b. Power Model

Stepwise multiple regression was used to compute the power models for the bus and car transportation systems. The corresponding coefficients and variables are given in Tables 3 and 4 respectively.

c. Sensitivity and Elasticity

The sensitivities of each system to the state variables are given by the coefficient A(I,J) which are given in Table 1 for bus companies and in Table 2 for urban cars.

The elasticities of each system to the state variables are given by the coefficient B(I,J) and these are given in Table 3 for bus companies and in Table 4 for urban cars.

d. Path Analysis

The corresponding path diagrams for dollars, energy and labor for the bus and car transportation systems are shown in Figs. 2 and 3. For the sake of simplicity, the relational variables have been omitted in these figures.

These figures show the values for the standard regression coefficients (b_{ij}). The standard regression coefficients are a measure of the relative importance of each variable in explaining the variance of the dependent variable.

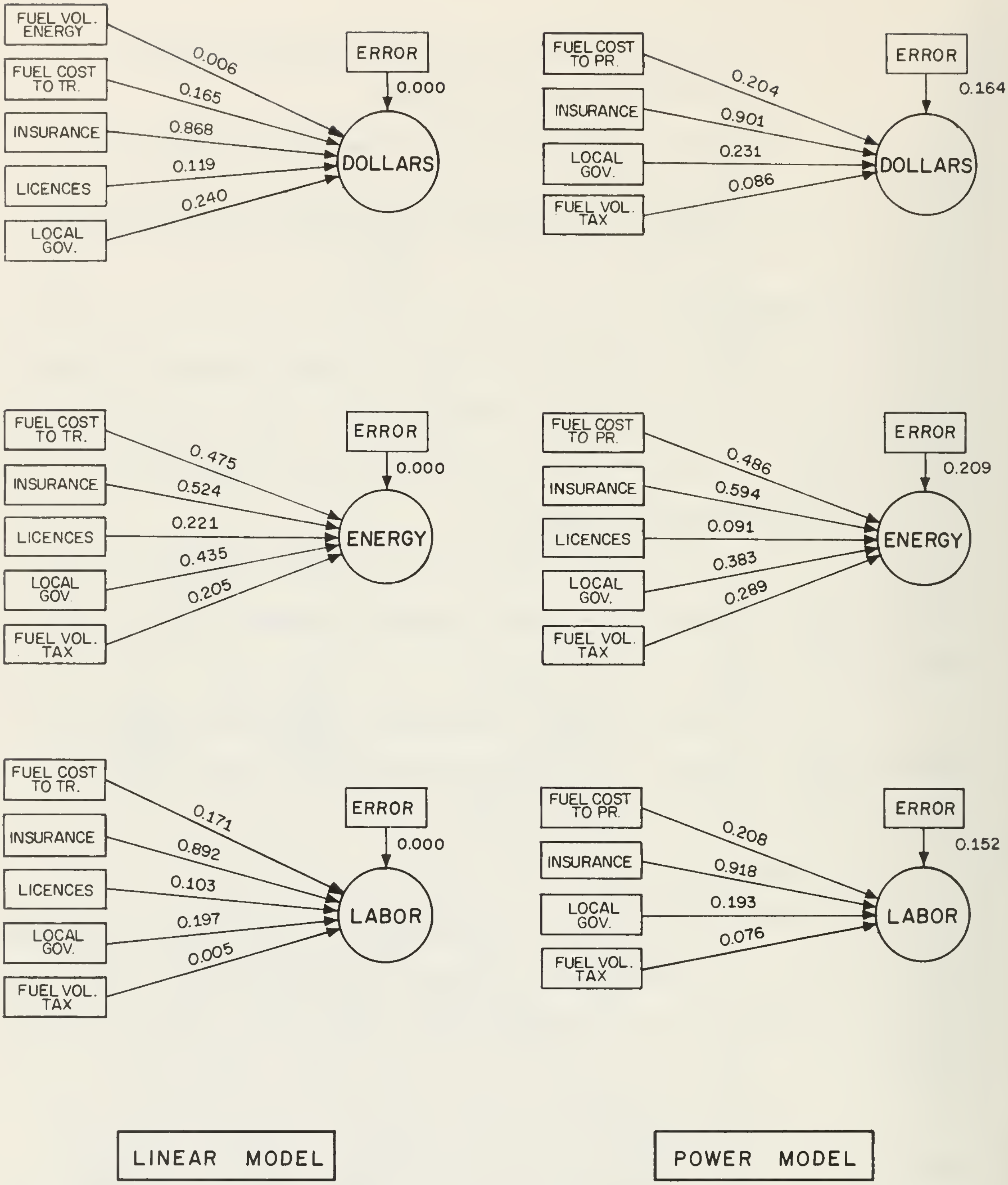

FIG. 3 PATH DIAGRAMS OF THE CAR TRANSPORTATION SYSTEM.

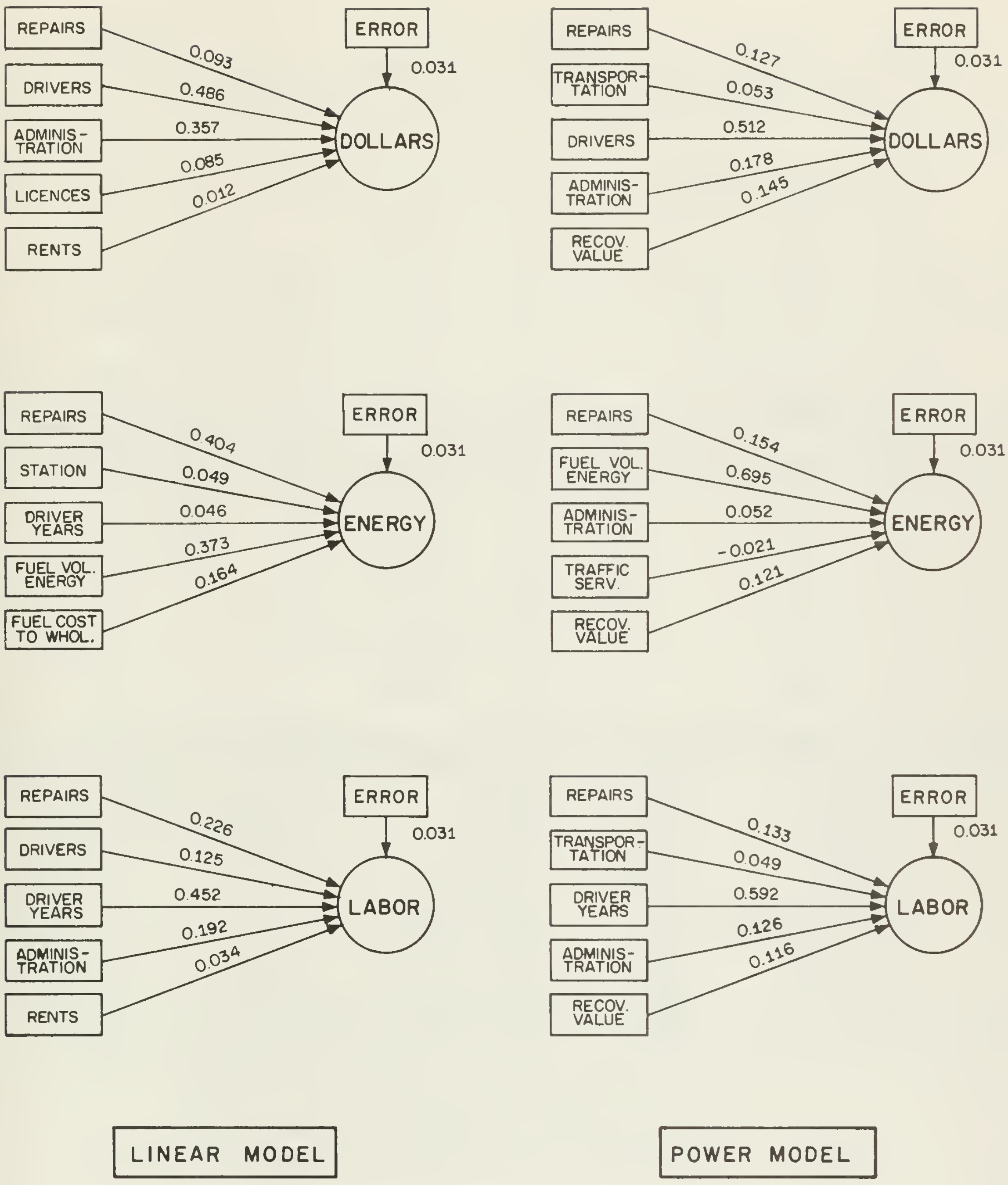

FIG. 2 PATH DIAGRAMS OF THE BUS TRANSPORTATION SYSTEM.

	DOLLAR		ENERGY		LABOR	
P	5		5		5	
M	10.583×10^6		530.109×10^9		838.630	
R^2	0.999		0.999		0.999	
Sy	0.183×10^5		0.151×10^{10}		2.520	
Se	0.112×10^6		0.916×10^{10}		15.330	
Se/M	0.011		0.017		0.018	
A(I,0)	0.269×10^5		-0.545×10^9		-3.075	
A(I,1)	1.039		0.195×10^6		0.188×10^{-3}	
A(I,2)	1.374		0.253×10^6		0.262×10^{-4}	
A(I,3)	1.705		62.367×10^6		1.066	
A(I,4)	4.413		0.863		0.679×10^{-4}	
A(I,5)	2.176		1.284×10^6		0.464×10^{-3}	
Z(I,1)	Repairs	(5)	Repairs	(5)	Repairs	(5)
Z(I,2)	Drivers	(8)	Station	(6)	Drivers	(8)
Z(I,3)	Administration	(20)	Driver Years	(9)	Driver Years	(9)
Z(I,4)	Licenses	(24)	Fuel Vol. En.	(10)	Administration	(20)
Z(I,5)	Rents	(25)	Fuel Cost to Whol.	(13)	Rents	(25)

Table 1. Linear Model of the Bus Transportation System.

	DOLLAR		ENERGY		LABOR	
P	5		5		5	
M	1353.950		189.978×10^{6}		88.919×10^{-3}	
R^2	1.000		1.000		1.000	
Sy	0.131×10^{-4}		6.696		0.198×10^{-8}	
Se	0.680×10^{-4}		34.795		0.103×10^{-7}	
Se/M	0.0000		0.0000		0.0000	
A(I,0)	744.923		0.352×10^{8}		0.050	
A(I,1)	0.799×10^{-6}		0.237×10^{7}		0.157×10^{-2}	
A(I,2)	0.232×10^{2}		0.213×10^{5}		0.669×10^{-4}	
A(I,3)	1.000		0.656×10^{5}		0.562×10^{-4}	
A(I,4)	0.999		0.128×10^{6}		0.107×10^{-3}	
A(I,5)	1.999		0.132×10^{7}		0.536×10^{-4}	
Z(I,1)	Fuel Vol. Energy	(9)	Fuel Cost to Tr.	(11)	Fuel Cost to Tr.	(11)
Z(I,2)	Fuel Cost to Transport	(11)	Insurance	(14)	Insurance	(14)
Z(I,3)	Insurance	(14)	Licenses	(15)	Licenses	(15)
Z(I,4)	Licenses	(15)	Local Gov.	(16)	Local Gov.	(16)
Z(I,5)	Local Gov.	(16)	Fuel Vol. Tax	(17)	Fuel Vol. Tax	(17)

Table 2. Linear Model of the Urban Car Transportation System.

	DOLLAR		ENERGY		LABOR	
P	5		5		5	
M	7.025		11.724		2.924	
R^2	0.999		0.999		0.999	
Sy	0.344×10^{-2}		0.264×10^{-2}		0.246×10^{-2}	
Se	0.209×10^{-1}		0.016		0.015	
Se/M	0.003		0.001		0.005	
B(I,0)	8.954		139.959		0.146	
B(I,1)	0.127		0.146		0.125	
B(I,2)	0.046		0.693		0.040	
B(I,3)	0.505		0.044		0.609	
B(I,4)	0.162		-0.009		0.107	
B(I,5)	0.159		0.126		0.119	
Z(I,1)	Repairs	(5)	Repairs	(5)	Repairs	(5)
Z(I,2)	Transportation	(7)	Fuel Vol. En	(10)	Transportation	(7)
Z(I,3)	Drivers	(8)	Administration	(20)	Driver Years	(9)
Z(I,4)	Administration	(20)	Traffic Serv.	(21)	Administration	(20)
Z(I,5)	Recov. Value	(28)	Recov. Value	(28)	Recov. Value	(28)

Table 3. Power Model of the Bus Transportation System.

	DOLLAR		ENERGY		LABOR	
P	4		5		4	
M	3.132		8.279		-1.051	
R^2	0.973		0.956		0.977	
Sy	0.948×10^{-3}		0.329×10^{-3}		0.882×10^{-3}	
Se	0.493×10^{-2}		0.171×10^{-2}		0.418×10^{-2}	
Se/M	0.0015		0.0002		0.0043	
B(I,0)	1.649		1.335×10^{6}		0.183×10^{-3}	
B(I,1)	0.179		0.113		0.182	
B(I,2)	0.202		0.035		0.205	
B(I,3)	0.019		0.271×10^{-2}		0.016	
B(I,4)	1.041		0.848×10^{-2}		0.924	
B(I,5)	--		0.928		--	
Z(I,1)	Fuel Cost to Pr.	(10)	Fuel Cost to Pr.	(10)	Fuel Cost to Pr.	(10)
Z(I,2)	Insurance	(14)	Insurance	(14)	Insurance	(14)
Z(I,3)	Local Gov.	(16)	Licenses	(15)	Local Gov.	(16)
Z(I,4)	Fuel Vol. Tax	(17)	Local Gov.	(16)	Fuel Vol. Tax	(17)
Z(I,5)	--		Fuel Vol. Tax	(17)	--	

Table 4. Power Model of the Urban Transportation System.