The 1980 annual cost responsibility and user-generated revenue were determined for each vehicle class using Kentucky's highways. The incremental-cost method was selected as the procedure for assigning the responsibility for each component of the highway cost to the users. Generally, the method is based on the concept that each highway cost component can be subdivided into increments caused by vehicles of different types, sizes, and weights.

Annual costs for the highway system were based on construction, replacement or current value costs representing capital investment components of the highway. Those components were: 1) preliminary design and engineering, 2) right-of-way, 3) utilities, 4) grade and drain, 5) pavements and shoulders, and 6) bridges. Allocation factors for the first three components were based entirely on vehicle-miles traveled. However, factors for grade and drain, pavements and shoulders, and bridges were developed with cost increments based on variables such as highway type, vehicle type and weight, and pavement damage factors.

A comparison of cost responsibility and revenue generated revealed that automobiles and pickups paid 157 percent of their share, and trucks paid 54 percent of their share. In order to deal with the inequitable distribution of the cost burden to vehicle type, impacts of increasing the fuel surtax on trucks were presented.
Research Report
UKTRP-81-22

Allocation of Transportation Costs to Users

by

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Chief Research Engineer

and

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College of Engineering
University of Kentucky

in cooperation with
Department of Transportation
Commonwealth of Kentucky

and

Federal Highway Administration
US Department of Transportation

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the University of Kentucky, the Kentucky Department of Transportation, nor the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

May 1982
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Special appreciation is also expressed to members of the Study Advisory Committee who devoted their time and effort throughout the research period. Advisory Committee members were: Donald Ecton, Chairman, and William Hippe, representing the Kentucky Department of Transportation; and Leon Walden, representing the Federal Highway Administration. Another individual making a significant contribution through his review and comments was James Runke, Commissioner of the Bureau of Vehicle Regulation, KYDOT.

As referenced in the report, much of the data related to system miles, vehicle-miles traveled, and highway costs were obtained from the Kentucky Department of Transportation's Division of Project Development. Several people from that Division were responsible for collecting and compiling the data; however, contact was made and assistance was received from the following individuals: Steven Williams, Forest Harrod, and Mohamed Taqui.
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<td>Federal Motor Fuel Taxes</td>
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</table>
SUMMARY OF FINDINGS

The 1980 annual cost responsibility and user-generated revenue were determined for each vehicle class. A comparison of these indicated the share of the burden paid by each vehicle class.

The following summary of percent responsibility borne shows that automobiles and pickups paid 157 percent of their share and trucks paid 54 percent of their share, based on the 1980 tax structure. This summary also indicates the impact of increasing the fuel surtax on trucks in terms of achieving equity in revenue paid among vehicle classes and also in terms of total revenue increase. Another summary is presented which shows revenue generated by vehicle type.

To produce equity, any increase in tax rate must be directed toward vehicles that are currently underpaying. Any "across the board" tax increase would result in increasing automobiles' subsidy of other vehicle classes.

The net worth of the Kentucky maintained system is $76,931,550,000. The annuity value plus annual expenditures for maintenance and administration is 2 billion dollars.

The 1980 budget was approximately $850,000,000.

Heavily loaded two-axle trucks have a significant cost responsibility; they are exempt from the 2¢ per gallon motor fuel surtax.
**SUMMARY OF PERCENT RESPONSIBILITY BORNE**

<table>
<thead>
<tr>
<th>VEHICLE TYPE</th>
<th>1980 TAX STRUCTURE (a)</th>
<th>ADDITIONAL REVENUE (Thousands)</th>
</tr>
</thead>
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<td></td>
<td>$0.09 &amp; $0.09 &amp; $0.09 &amp; $0.09 &amp; $0.09 &amp; $0.12 $0.16 $0.21 $0.36</td>
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<tr>
<td>Standard and Compact Autos</td>
<td>164 162 158 152 138 137</td>
<td>$4,026</td>
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<tr>
<td>Subcompact Autos</td>
<td>157 156 152 146 132 131</td>
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<tr>
<td>Pickups</td>
<td>141 140 136 131 119 118</td>
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<tr>
<td>Buses</td>
<td>31 31 30 29 26 25 24</td>
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**REGISTERED WEIGHT CLASS FOR TRUCKS (Pounds)**

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<th>6,000</th>
<th>10,000</th>
<th>14,000</th>
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<th>26,000</th>
<th>32,000</th>
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<th>55,000</th>
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(a) 1980 tax structure with motor fuel tax at $0.09 per gallon on vehicles with two axles and $0.11 per gallon on vehicles with three or more axles.
(b) Alternatives are for 1980 tax structure with motor fuel tax of $0.09 per gallon on vehicles with two axles and motor fuel tax on vehicles with three or more axles varying from $0.12 to $0.36 per gallon.
### SUMMARY OF REVENUE GENERATED

<table>
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<tr>
<th>VEHICLE CLASS</th>
<th>TOTAL REGISTERED VEHICLES</th>
<th>REVENUE GENERATED (Dollars)</th>
<th>TOTAL (X 1,000)</th>
<th>PER REGISTERED VEHICLE</th>
<th>PER VEHICLE-MILE</th>
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<td>$287,466</td>
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<td>PICKUPS &amp; 6,000(b)</td>
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<td>BUSES</td>
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<td>(a)</td>
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<td>4,130.59</td>
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(a) Buses are included in truck weight classes.
(b) Registered weight classes for trucks.
INTRODUCTION

Costs of highway facilities have generally been considered as being the direct responsibility of users of those facilities. Some early roads were funded by landowners whose property the route traversed. In English tradition, this was a servitude of the landowner to the king. The king's highways were also usually available for public use -- often tolls were collected. Permits and franchises to operate toll roads ensued. Tolls were assigned on perceived benefits to the users. Freight and passenger coaches were charged more than private vehicles. The US mail carrier was sometimes exempted by statute from paying tolls. Some mail contracts were bid at extremely low rates in order for the carrier to receive free passage over the highways. So-called post roads were funded largely for the purpose of enabling delivery of the mail.

The allocation of highway costs to various classes of vehicles has been a primary concern of modern times. Trucks and automobiles are the predominant users.

PROVIDERS OF PUBLIC ROADS IN KENTUCKY

Government has been charged with the responsibility for providing services or facilities not reasonably available to the public through their own initiative. Turnpikes or toll roads were recognized very early (1797) as means of funding transportation facilities in Kentucky. In a history of Kentucky highways (1), the following quotation is found:

"By act of March 1, 1779, Joseph Crockett was appointed to erect a turnpike (i.e., tollgate) at some convenient place, and purchase as much land as may be necessary for that purpose, not exceeding two acres, on the road leading from Crab Orchard to Cumberland Gap, beyond where the road from Madison courthouse intersects said road. The turnpike (tollgate) was to be farmed out to the highest bidder, who should give bond and security payable to the Governor of the State for the faithful payment of his bid."

Similar legislation was passed between 1800 and the 1830's. Those acts authorized collection of funds for specific projects or the formation of private companies to construct and operate transportation facilities. As late as the 1950's, there were two private toll ferries and one private toll bridge operating at Burnside on the Cumberland River.

The Kentucky Department of Public Roads was organized in accordance with Section 2, Chapter 16, Acts of the 1912 Kentucky Legislature. The Legislature directed the Department to provide aid to the counties in surveying, making maps of public roads, locating new roads, and relocating existing roads. Counties were to provide chainmen, rodmen, and axemen. An annual appropriation of $25,000 was provided; however, only $10,191.20 was expended during the first fiscal year.

The 1914 General Assembly further recognized the importance of highways and directed that a system of public roads connecting county seats be constructed. That same legislature created a trust fund, the State Road Fund, for the specific purpose of funding construction of a state highway system.

In March 1973, by Executive Order 73-288, the Kentucky Department of Transportation was formed. The Department was created by combination of the existing Department of Highways, Department of Motor Vehicle Regulation, Department of Aeronautics, and other state agencies involved in the building and operation of transportation systems and services.

CONCEPTS

Incremental Costs -- To amortize and perpetuate a highway system fairly and directly, each vehicle must pay for those services in proportion to their share of design, construction, maintenance, and operating costs. License fees and fuel taxes are traditional means for collecting transportation monies. Tax rates are generally established on the basis of geometric and structural needs to serve automobiles only. Additional costs required to serve larger and heavier vehicles, in respect to their types and numbers, are considered solely the
Escalating costs of new construction, reconstruction (to extend service-life), and maintenance, without commensurate increases in user taxes and revenues, have the effect of depleting asset values of pavements in terms of mileages and quality of service that may be provided. In addition to inflationary effects, increased legal axleloads will cause pavements to deteriorate prematurely and will result in the expenditure of funds ahead of schedule. Increases in legal axleload limits are unpredictable; therefore, their resultant effects cannot be projected.

**Designed Service-Life vs Life in Years** -- Pavement life, in years, depends upon the accuracy of the prediction of design traffic volumes, as well as composition of the traffic stream in terms of axle configurations and axleloads. If traffic growth, especially heavy vehicles, exceeds the forecast, the life of the pavement in years will be shortened. Service-life is measured in terms of the number of weighted load repetitions actually applied or designed to be applied. The ratio of the cumulative number of equivalent loads applied by the end of the service life to the number designed to be carried is a measure of the accuracy of the prediction of the characteristics of the traffic stream. Pavements may reach design service in fewer, or more, years than expected. In terms of incremented user costs, either would be somewhat inconsequential -- that is, funds should have been generated to finance reconstruction of the facility.

**Payload vs Incremental User Costs** -- Freight and hauling costs are intricately related to payload, mechanical efficiency of the vehicle, speed, etc. In highway transportation, incremental or pro rata costs of facilities must be included in total cost analyses. Generally, transporters are aware of highway costs only in terms of license fees and fuel taxes. Pavements are very sensitive to wheel or axleloading. A pavement designed to carry a given distribution and summation of traffic loadings can be ruined by a few severe overloads (2). The severity increases in a geometric progression. For instance, a 20,000-pound single axle is 1.5 times more damaging than an 18,000-pound single axle.

**Benefit-Diffusion** -- Some roads or streets may not generate sufficient funds to be self sustaining and other facilities must compensate or make up shortfalls. In such cases, the philosophical view is that the total system benefits all.

**Effects of Increased Legal Axleloads** -- Data indicate a significant number of axles weigh more than the legal weight limits. Those excesses may be taken into account in pavement design. Future truck configurations (axles per truck) and their numbers may be predicted. Generally, those forecasts have been based on the assumption that legal axle weights would not be increased. Legal gross weights were increased four times from 1950 to the present. Following each increase, there was a gradual change in the style of truck toward the higher allowable number of axles (3). The effect on pavements was similar to that of increasing the numbers of older style trucks having fewer axles before the increase was implemented.

It may be assumed that the spectral density or frequency of 18,000-pound axles will merge upward and that a percentage of overloads will persist. That does not mean that all truck axles in a traffic stream will rise to the new legal level (20,000 pounds for single axles). However, axleloads of 20,000 pounds induce 1.5 times the damage of an 18,000-pound axle and a 22,000-pound axle (2,000-pound overload) would be 2.2 times as damaging as an 18,000-pound axleload.

Presently, Kentucky’s legal weight limits are: 20,000 pounds for single axles; 34,000 pounds for two axles in tandem; 50,000 pounds for three axle vehicles; and 82,000 pounds as the maximum gross weight. A tolerance of 5 percent per axle load is permitted, not to exceed maximum gross weight of 82,000 pounds.

**PREVIOUS STUDIES**
A 1956 in-depth study of highway funding in Kentucky, conducted by the Bureau of Business Research, University of Kentucky, College of Commerce, was the
last major review (4) of Kentucky highway cost distributions. That study was a companion to a 1955 Automotive Safety Foundation's study of highway needs in Kentucky (5). Both studies were conducted with the sponsorship and professional assistance of the Kentucky Department of Highways, the US Bureau of Public Roads, and the Kentucky Legislative Research Commission.

A basic component of the Kentucky study was an incremental analysis of highway expenditures in Kentucky (6). The incremental assignments of responsibility for highway expenditures varied with type of design element and the purpose of the expenditure. Increments were dependent upon whether the work was new construction, resurfacing, or resurfacing and widening. In each of those categories, increments were dependent upon whether expenditures were for grading and drainage, pavement, or structures. The Division of Research, Kentucky Department of Highways, provided increments of indices for weight- and size-function expenditures used in that analysis.

There have been major changes in the weights and sizes of vehicles as well as increases in traffic volumes. Those changes have made desirable a reevaluation of the assignment of costs. The oil embargo of 1973 and 1974 and attendant increases in fuel costs have been significant factors leading to the current economic status of the country. Road materials and construction costs have increased substantially since 1973.

The relationship between road and street costs and revenues produced by various vehicle classes probably has changed since the 1956 analysis. Following is a list of research by other states and by the Federal Highway Administration that has provided new and improved methods and procedures for conducting highway cost allocation studies:

2. Study by the Iowa State Highway Commission to determine automobile and truck cost responsibilities, September 1973 (8).
3. Study of transportation needs in Kentucky by the Legislative Research Commission, September 1975 (9).
4. Study of highway cost allocation by the Georgia Department of Transportation, March 1979 (10).
5. Guidelines to study highway cost allocations by the Congressional Budget Office, February 1979 (11).
7. FHWA report to the 1982 Congress (draft copy) (13).

METHODS OF ASSIGNING COSTS

Users (travelers on the road) as well as nonusers (all others receiving some benefit from the road) receive distinct and separate benefits from highways and streets. Adjacent lands are appreciated in value even though they may not have direct access. More economical freight movement may lead to reduced costs of food, building materials, and a variety of other consumer products to all citizens.

The 1956 Kentucky study was an attempt to determine a well-founded and reasonable division of responsibility of expenditures between classes of users and nonusers. Several methods were proposed and are described below.

1. Added expenditure. Highway users pay for those additional costs necessitated since the advent of the motor vehicle. Property owners and the general public pay an amount equal to the cost of roads before motor vehicles became significant.
2. Differential benefits. Various benefits enjoyed by motorists, property
owners, and the general public as a consequence of road improvements are evaluated. In the case of users, benefits may be measured in terms of time and mileage savings. The savings are then assigned a value per ton-mile and are used to allocate tax responsibilities among different groups.

3. **Standard or reasonable cost**. Highway-user charges that will amortize a representative facility are determined and translated into cost per ton-mile of travel on that road. The cost per ton-mile is then applied to total ton-mileage for all facilities and the necessary revenue figure is obtained. Deficiencies in revenue, thus determined, must be borne by all.

4. **Relative use**. Statistical data regarding traffic volume, origins and destinations, road-user characteristics, and other information are analyzed. Costs of each highway are then divided among users, property owners, and the general public on the basis of the amount of through, neighborhood, and local traffic, respectively, on the highway.

5. **Predominant use**. Highways are classified according to their predominant use or benefit, and costs are assigned accordingly. Costs of highways designed to provide optimum mobility of traffic are assigned to users. Local rural roads and urban access streets are primarily for the benefit of adjacent property owners and local communities and are thus financed through property taxes or other local contributions. Costs of intermediate roads are divided in some indefinite ratio between users and nonusers.

6. **Earnings credit**. The highway-user charge, on a vehicle-mile basis, necessary to amortize the total costs of primary highways is applied to traffic down through the various levels of the highway systems. The amount by which revenues thus computed falls short of paying the total highway costs is the nonuser cost responsibility. Local taxes necessary to pay for the total costs of local rural roads and urban access streets are applied up through the system. The amount by which such local taxes falls short of meeting the total highway costs is the motorists' responsibilities. Finally, results obtained by the two approaches are averaged to obtain an end result.

The 1956 Kentucky report concluded that "a glance at these methods should make one fact clear: scientific knowledge has not advanced to the extent that an equitable division of cost responsibility can be positively and unequivocally established."

In the 1956 Kentucky study, 10 to 15 percent of all road costs were allocated to indirect users. This proportionment in other studies ranges from 5 to 25 percent. Sources of indirect funds in Kentucky have included property taxes, coal severance taxes, federal general funds through the Appalachian Development Program, and local private fundings (industrial, commercial, and residential developers).

In view of the nature and types of road facilities normally funded by property taxes and local governmental agencies, the entire system of state maintained highways and streets (24,777 miles) was considered to be the responsibility of highway users. The County Road Aid and Municipal Aid Programs, amounting to 40 million dollars annually are allocated from the Road Fund to the local governments. The statutory limitations on those funds would severely restrict the size of construction projects such that most work performed would be considered as nominal maintenance. County Road Aid and Municipal Aid should be considered as sustaining expenditures on the 44,454 miles of roads and streets that are not state maintained.

Allocation of road user costs between automobiles and trucks is the primary thrust of this research. Several different methods have been used by various researchers in arriving at an equitable cost distribution. A brief description of seven of these methods follows.

1. **Standard Cost Method**. This method is similar in many respects to the method identified by the same name used for determining the allocation between road user and nonuser, as discussed previously. In this approach, the ton-
mileages for each type and weight group are estimated for the mid-year of an improvement program. The use of ton-miles in computing costs substantially favors commercial vehicles, particularly the heavier types.

2. **Space-Time Method.** This method suggests that highway use by various vehicle classes may be measured by the amount of space occupied by a particular vehicle and the time it takes the vehicle to traverse a given distance. This theory advances the idea that the amount of highway surface or space required largely determines the costs of the facility.

3. **Operating Cost Method.** In this method, attempts are made to allocate costs to the various classes of vehicles on the basis of the value of service received. The method measures value of service by relative amounts of motor-vehicle operating costs, less taxes, and apportions taxes in accordance with those costs. The operating cost theory proposes that value of highway service, in its most fundamental sense, is determined by the operating costs of the vehicle using the road and that taxes apportioned according to operating costs will be approximately proportional to ability or willingness to pay.

4. **Differential-Benefit Method.** The contention in the differential-benefit concept is that total user tax payments should be apportioned to the several classes of vehicles in proportion to benefits received by each user class. Therefore, the method uses a direct application of the benefits-received theory of highway taxation. It is well accepted that this method is theoretically sound, but it is usually prohibitive to administer because of the tremendous data base and manpower necessary.

5. **Cost-Function Method.** The cost-function method was developed by researchers in the motor-carrier industry and classifies all highway costs by three categories:

   (a) costs that are size- and weight-related,

   (b) costs associated with highway use, and

   (c) costs that are neither size- and weight- nor highway-use related. The allocation of cost responsibility under this method is as follows:

   (a) Road costs incurred that are size- and weight-related are assigned to all vehicles on the basis of gross ton-miles of travel,

   (b) Costs associated with highway use are assigned on the basis of vehicle-miles of travel, and

   (c) Costs not associated with highway use or size and weight are assigned on a per-vehicle basis.

6. **Gross Ton-Mile Method.** This method of allocating user costs among the several classes of users is based on the theory that each vehicle should be assessed a tax responsibility on the basis of total ton-miles of travel for each weight class. The ton-mile theory tends to allocate a larger share of cost responsibility to the heavier vehicle classes. Many authorities believe the theory sets the upper limit for the level of taxes that should be assessed against heavier vehicles.

7. **Incremental-Cost Method.** Of the theories and methods devised for determining an equitable allocation of highway costs among the various vehicle classes, the incremental method appears superior. The incremental method seeks to assign responsibility for each element of highway cost to the vehicles that occasion the cost. The foundation of this method is the concept that each element of highway design and cost can be subdivided into increments caused by vehicles of different types, sizes, and weights. The incremental method requires a sizeable number of calculations founded on a large data base; but through its application, sound engineering judgment can be exercised as opposed to many arbitrary procedures adopted for the sake of simplicity. The incremental-cost method was chosen for the basic analysis of assignments of user (automobiles and trucks) costs. Certain modifications considered proper for the Kentucky analysis have been made.
HIGHWAY SYSTEM USAGE

The first step in determining costs and revenues attributable to the highway system was that of establishing the degree of stratification necessary to adequately represent the variability of costs and revenues generated. The Federal-Aid System classification was selected as most appropriate. It should be noted that the Non-Federal-Aid category was subdivided into state maintained, county maintained, city maintained, and maintained by other agencies. Other characteristics of the highway are rural or urban locations and number of lanes. Total mileage, vehicle-miles traveled, and annual average daily traffic for each of the 22 highway classes are presented in Table 1.

At this point, a clarification should be made regarding the highway system considered appropriate for distribution of costs. Expenditures on the Non-Federal-Aid categories of county maintained, city maintained, and other agency maintained were considered as maintenance expenditures and were not included in the tabulations of total annual costs. Excluded are the Non-Federal-Aid categories of county maintained, city maintained, and other agency maintained. Because all highway classes were stratified as rural or urban, a total of six of the original 22 classes presented in Table 1 were not used in the cost responsibility calculations.

With Kentucky's varied terrain and land-use characteristics being a significant factor in determining the cost of highway construction, it was necessary to stratify the highway system into more detail. By subdividing each rural class into three terrain categories (flat, rolling, mountainous) and each urban class into two land-use categories, a total of 40 classes resulted. Total mileage and vehicle-miles traveled for the 40 classes are presented in Table 2. These 40 classes were used in the cost responsibility calculations.

Percentages of mileages assigned to the terrain categories were obtained from the Statewide Mileage File. In a separate effort by the Kentucky Department of Transportation's Division of Project Development, each county was classified as being predominately represented by either flat, rolling, or mountainous terrain. Miles of each route included on the statewide mileage file were coded so that distributions by terrain categories were available.

Highway system distributions by land-use categories were available for the sampling of mileage included on the Department of Transportation's Highway Performance Monitoring System data file. Percentages of miles in each of the highway system classes were calculated, and total mileages from the Statewide Mileage File were proportionally distributed.

Roadway costs vary considerably for many reasons. However, terrain and land-use characteristics combined with the traditional stratifications enable a practical representation of costs.

SYSTEM MILEAGE AND VEHICLE-MILES TRAVELED

Highway system mileage and vehicle-miles traveled were summarized from the Statewide Mileage File maintained by the Division of Project Development. All highway systems and their corresponding mileages and vehicle-miles traveled are presented in Table 1. Total system mileage was 69,321 and total vehicle-miles traveled was 25,163,000,000. Of the total system mileage, 25,867 miles were classified as Federal-Aid or State Maintained. These 25,867 miles represent 37.3 percent of the total mileage and 93.5 percent of the total vehicle-miles traveled. Vehicle-miles traveled in each of the 22 highway classes were used to determine revenues generated by each vehicle type. Total miles in each of the 40 highway classes presented in Table 2 were used to calculate annual costs of the system and cost responsibilities. Maximum stratifications were used for the cost components because the data were available for the refinements. The additional detail provided more accurate results for use in assigning cost responsibilities.

VEHICLE CLASSIFICATIONS

Data from the vehicle classification
file were used to determine classifications based on axle configurations for the Federal-Aid System classifications. These classifications were refined using rural or urban designations and number of lanes for a total of 22 categories. Vehicle classification data were not available for the additional stratifications of terrain and land use. The vehicle classification file contains data from classification counts conducted at approximately 1,800 sites throughout Kentucky; at 284 of those sites, counts are performed on a regular basis. At the other sites, no pattern for monitoring has been established. The most recent classification data that have been edited are for 1978 and those data are presented in Table 3.

To adequately allocate cost responsibilities, it was necessary to transform vehicle classifications, by axle configuration, into vehicle gross weight categories. It should be noted that vehicle gross weights used in this study are maximum gross weights for which the vehicles are registered to operate. This was accomplished using data from the 1977 Census of Transportation (17), which presents a cross-classification of trucks by axle configuration and gross weight. In Table 4, distributions of trucks with weight categories of 6,000 to 82,000 pounds and axle configurations from pickups and other single-unit, two-axle, four-tire vehicles up to eight-axle combination trucks are presented. It was also necessary to distribute the percentages of vehicles in gross weight categories (Table 4) to the basic highway system classifications. That distribution is presented in Table 5.

DISTRIBUTION OF VEHICLE-MILES TRAVELED
An intermediate step in allocating cost responsibilities is the distribution of vehicle-miles traveled. Again, the 22 highway system categories for which vehicle classification data were available were used (although only 16 categories were used to assign cost). The distribution of vehicle-miles traveled for the vehicle classes of automobiles, pickups, buses, and 13 maximum weight categories for trucks is listed in Table 6.

HIGHWAY SYSTEM COSTS

CAPITAL INVESTMENT COMPONENTS
To determine total annual costs for the highway system in Kentucky, it was necessary to develop construction, replacement, or current value costs representing capital investment components of the highway. Data were summarized for the following components of roadway costs: 1) preliminary design and engineering, 2) right-of-way, 3) utilities, 4) grade and drain, 5) pavements and shoulders, and 6) bridges.

Methods of Determining Costs

**Bridges**

Historically, estimates of bridge construction costs were made by using deck area as the only criterion. That is a simple method, but many other variables obviously affect construction costs.

An economic model was developed using data from recently constructed bridges. All bridge projects let to contract in calendar years 1975 through 1979, except those that were pedestrian bridges, maintenance, overlay, or widening projects, were used to develop the model. The sample size was 347 bridges.

An exponential equation having four variables was derived using a sample of data and was then applied to all bridges. These four variables were number of bridges, contract year, deck area, and maximum span length. Using data from the Department of Transportation's Bridge Inventory File, an adequate representation of the average bridge cost was calculated. A detailed discussion of the development of the mathematical model for determining bridge construction costs is presented in Appendix A.

Other Components

In assigning cost responsibilities to highway users, it was necessary to determine construction, replacement, or current value costs for each of the 40
highway classes previously presented in Table 2. Unit costs for all capital investment components except bridges were developed by the Kentucky Department of Transportation's Division of Project Development. The historical file of project costs was the primary source of unit cost data.

The data file included costs for preliminary engineering and design, right-of-way, utilities, and construction. Representative sections of completed interstate segments in Kentucky were selected according to urban land use or rural terrain and number of lanes. These sections varied in length from 0.7 mile to 6.2 miles. Since Kentucky does not have any six-lane, rural interstate sections, a cost correlation was applied to the respective four-lane segments to reflect the increase in cost for the additional two lanes. A cost increase of approximately 20 percent was used for each component except preliminary engineering. Preliminary engineering costs were assumed to be five percent of the authorized construction costs. Construction costs included both grade and drain costs and pavement and shoulder costs.

In order to base unit costs on 1980 dollars, a factor representing the composite construction costs index for the year the project was authorized was applied. The composite construction costs were those used by the Federal Highway Administration to reflect the current cost structure of the highway construction industry (13).

A different methodology was used for the Federal-Aid Primary, Secondary, Urban, and Non-Federal-Aid project costs because the cost data were not readily available in the required format. Project planning study costs plus an inflation factor were used to determine unit costs. However, project planning studies have not been prepared for all categories of highway classifications. When this was the case, judgment, experience, and comparison of costs with other categories were used for unit costs.

Unit and Annual Costs of Components
All unit costs are presented in Table 7 for the 40 stratifications distributed by percentages based on terrain and land-use categories. As previously noted, detailed mileage data were available from the Statewide Mileage File.

Costs for the capital investment components were summarized so the number of highway classes was reduced from 40 to 16. It was also necessary to assign expected life to each of the components in order to determine annual costs. Previous cost allocation studies (7, 8, 10, 12) were reviewed, and it appears that factors for cost allocation to vehicle types used in this study generally represent a combination of the other sources. A life expectancy of 50 years was assigned to preliminary design and engineering, utilities, grade and drain, and bridges. Right-of-way costs were annualized over 100 years, and pavement and shoulders were expected to function over a period of 20 years. Using the appropriate life expectancy for each of the capital cost components, total annual costs for the 16 highway classes were calculated and are presented in Table 8.

Methods of Cost Allocation to Vehicle Types
Using total annual costs for each of the capital investment components in Table 8, distributions were made to the various vehicle types. Allocation factors for the preliminary design and engineering, right-of-way, and utilities components were based entirely on vehicle-miles traveled by the vehicle classes. However, allocation factors for grade and drain, pavements and shoulders, and bridges were developed with cost increments based on variables such as highway type, vehicle type and weight, and pavement damage factors. Presented in the following sections are discussions of the cost allocation factors for grade and drain, pavements and shoulders, and bridges.

Grading and Drainage
Allocations of expenditures for grading and drainage were made on a combined basis of vehicle-miles of travel for each vehicle type and factors based on gross weights. Capital expenditures for
grading vary greatly with terrain. For example, the cost per mile on rural, two-lane sections of Federal-Aid-Primary in rolling and mountainous terrains are 33 and 100 percent, respectively, greater than for flat terrain. Some of the increase is common to all vehicles. There are minimum acceptable standards for grade and sight distance and level cross section that must be provided. However, portions of those increased costs are assignable to certain classes of vehicles.

The ability of a vehicle to maintain speed is a function of highway grade and horsepower-to-weight ratio. That ratio tends to decrease with increasing gross vehicle weight. Thus, a heavy vehicle requires a flatter grade to maintain a constant speed. Additional costs of grading and drainage necessary to provide a flatter grade should be borne by heavier vehicles.

Horizontal alignment of a highway is also affected, particularly on low-speed roads, when larger vehicles are included in the traffic stream. Those vehicles have increased turning radii and thus require longer horizontal curves.

Factors used for vehicle types were adapted from a study by the Federal Highway Administration (7). That study indicated that for all highway systems, except local, all vehicles should share 91.8 percent of grade and drain costs based on vehicle-miles traveled and 8.2 percent should be borne exclusively by single-unit vehicles over 10,000 pounds and combination vehicles over 13,500 pounds. For local roads, the percentages were 93.6 and 6.4, respectively. Cost allocation increments for grading and drainage construction are presented in Table 9. Similar factors were also used by Iowa (8).

Pavement and Shoulders

The method of cost allocation for pavements and shoulders differed significantly from the traditional incremental approach. The traditional approach relies on the concept of assigning cost responsibility based on pavement cost increments for the various thicknesses of the pavement structure.

Typical pavement designs and their accompanying thicknesses are an integral part of the traditional approach.

For this study, pavement and shoulder cost allocation was based completely on the concept of proportional distribution of Equivalent Axle Loads (EAL). Percent cost responsibility was related directly to accumulated 18-kip EAL's for a 20-year design period for each highway classification. Damage factors and repetitions of vehicle types were developed from historical W-4 Tables and were used to calculate EAL's. The accumulated 18-kip EAL's for each vehicle type in Table 10 were converted to percentages and presented in Table 11. Another conversion was made such that pavement and shoulder cost responsibilities could be presented as vehicle registration weight classifications. The purpose was to summarize cost distribution and revenue data by vehicle registration weight classifications. Percent cost responsibility for the various vehicle classes and/or weight registrations for each highway classification are presented in Table 12.

Bridges

Bridge construction expenditures were allocated on the basis of vehicle-miles traveled by each vehicle class and factors based on gross vehicle weight. The number of vehicle-miles traveled by each vehicle class is also a rough measure of the number of passes on bridges by each vehicle class.

The Federal Highway Administration (7) cited detailed increments (Table 13) for each highway system classification. The first increment is shared by all users based on vehicle-miles traveled. Four other increments are shared by vehicles that have operating gross vehicle weights equal to or greater than 10,000 pounds. Values of those four increments are a function of operating gross weight of each vehicle and are distributed to each
appropriate class on the basis of vehicle-miles traveled. Georgia (10) and Iowa (8) used similar increments but appeared to use registered gross vehicle weight rather than operating gross vehicle weight.

Summary of Distributed Costs
Annual cost responsibilities by highway system and vehicle classification for each of the six capital investment components were calculated. The vehicle classifications were standard and compact autos, subcompact autos, pickups, buses, and 13 registered gross vehicle weight classes. A summary of the distribution of capital investments to each vehicle classification is presented in Table 14.

ANNUAL EXPENDITURES
During 1980, annual expenditures amounted to $200,024,000. Those expenditures were separated into three broad areas for distribution to each vehicle class: maintenance, enforcement, and administration. A summary of the distribution of those expenditures is presented in Table 15.

Maintenance
Pavement and shoulder expenditures were allocated on the basis of axle-miles of travel. All vehicles shared 80 percent of the expenditures and the remaining 20 percent was shared by trucks only.

For the primary road system, Iowa (8) assigned 80 percent of the expenditures for pavement maintenance to all vehicles based on axle-miles traveled and 20 percent to trucks only. All vehicles were charged with 85 percent of the total costs for shoulder maintenance and 15 percent was assigned to trucks only. The percentage assigned to all vehicles rose to 90 percent for secondary and municipal road systems.

Similar results were noted in the Federal Highway Administration study (7), but the percentage assigned to all vehicles was nearly constant for each of the 12 highway systems listed.

All other annual maintenance expenditures were distributed to all vehicle classes on the basis of vehicle-miles traveled (8). The expenditures are for activities such as snow removal and sanding, traffic control, service facilities, unusual or disaster maintenance, and structure maintenance.

Enforcement
Traffic supervision, highway and traffic safety, and driver education were deemed to benefit all users equally. Expenditures for those activities were distributed solely on the basis of vehicle-miles traveled by all vehicle types.

Vehicle size and weight enforcement activities deal with the truck segment of the traffic stream. Distributions of those expenditures were made to trucks only based on vehicle-miles traveled by each truck class.

Administration
All expenditures for these activities were distributed to all vehicle classes on the basis of vehicle-miles traveled.

HIGHWAY SYSTEM REVENUES
MOTOR FUEL TAX REVENUES
Motor fuel tax revenues were derived from two sources: those collected by Kentucky and those collected by the Federal Government. The total from those two sources was in excess of $266 million during 1980. Following are discussions of the procedures used to calculate distributions of revenue by vehicle types.

Kentucky Motor Fuel Taxes
To determine motor fuel tax revenues by vehicle classification, data representing vehicle classifications, miles traveled, fuel consumption, and motor fuel tax rates were required. Vehicle classification data based on axle configurations and summarized by the 22 highway system categories were previously presented in Table 3. A similar summary of vehicle-miles traveled for the 22 categories was also required. Inasmuch as fuel taxes are levied on vehicle types based on the number of axles (two cents per gallon surtax for vehicles having more
than two axles), it was necessary to distribute vehicle-miles traveled according to the axle configuration categories. Those data are presented in Table 16.

Rates of fuel consumption for each vehicle type were determined by reviewing several sources that had presented data in various forms. The US Department of Transportation's cost allocation study in 1969 (7) was a comprehensive study; however, fuel consumption data for only six classes of trucks were presented. In the Iowa study (8), only three categories of fuel consumption data were used. They were for automobiles and pickups, single-unit trucks, and combination trucks. The most comprehensive fuel consumption data were presented in the US Department of Transportation's recent update of their cost allocation study (13). Those studies, along with recent fuel consumption data from the Kentucky Department of Transportation (20) and the American Trucking Association (21), were the primary sources of data. Those and other sources (17, 22) were used in compilation of fuel consumption statistics. Data used in this study and a summary of data from other sources are presented in Table 17.

The last item required for calculations of revenues generated by vehicle class was the motor fuel tax rate for each class of vehicle. In Kentucky during the 1980 study period base year, the tax was levied at a rate of $0.09 per gallon for vehicles with two axles, and $0.11 per gallon for vehicles with more than two axles.

The first calculations of motor fuel tax revenues generated by vehicles of various classes resulted in a total revenue of $192,026,388. That total compared closely with motor fuel tax receipts of $190,177,518 published by the Kentucky Department of Revenue. An adjustment factor of 0.99037 was applied to all revenues generated by vehicle type and highway classification to arrive at adjusted values for Kentucky presented in Table 18.

Federal Motor Fuel Taxes
Revenues from federal motor fuel taxes were distributed in a manner very similar to those revenues collected by Kentucky. It was assumed that distribution of revenue by vehicle class would be the same whether dealing with taxes collected by Kentucky or the Federal Government. Presented at the bottom of Table 18 is a line representing the distribution of motor fuel tax revenues collected by the Federal Government.

As noted previously, Table 18 using axle configuration categories was necessary since the fuel tax rate is a function of the number of axles. Realizing the need to summarize all cost and revenue data by vehicle maximum gross weight categories, a transformation of data in Table 18 was made. Presented in Table 19 are motor fuel tax revenues by vehicle classifications based on weight categories. Both Kentucky and federal motor fuel tax revenues are presented.

MOTOR VEHICLE REGISTRATION
Revenues generated from registrations of motor vehicles contribute to the Road Fund in Kentucky and they were included in this study. There are two methods of collection: by County Court Clerks and through apportioned registration.

County Court Clerks
The annual motor vehicle registration fee is paid to the County Court Clerk for the county in which the owner resides or in which the motor vehicle is operated. A broad outline of those fees is presented in Table 20. Many prorations, exemptions, and adjustments exist. The fees shown are the amount transferred to the Department of Transportation and do not include court clerk fees.

The total motor vehicle registration fees collected by the County Court Clerks amounted to $37,020,000 in 1980. Of that amount, $20,473,000 was for passenger car licenses and $12,405,000 was for truck licenses. Miscellaneous licenses and permits made up the difference.

Apportioned Registration
Many commercial vehicles operate a
portion of their total yearly mileage in states other than their state of registration. Kentucky is a member of the International Registration Plan through which a distribution of registration fees is made to member states. The cost of the yearly registration is determined by multiplying the percentage of miles operated in each state by that state's fee and summing. Payment is made directly to the Department of Transportation, which distributes fees to, and collects fees from, other member states. An apportioned vehicle is one that operates in two or more states that apportion fees and one that has a gross weight, including any combination trailers, in excess of 26,000 pounds or one that has three or more axles.

Revenue data were collected from a review of Department of Transportation records. Each apportioned vehicle registered in Kentucky was counted and its fee multiplied by its percentage of miles traveled in this state. The resulting dollar amount represented Kentucky's share of the registration fee for each vehicle. Those were summed for all vehicles in each vehicle class. The amount due was adjusted to account for vehicles being out of service for maintenance, repair, wreck, sale, etc., for an extended time during the registration period. An attempt was made to account for those adjustments, but not all could be adequately considered. Thus, the calculated sum of all revenue did not match the total apportioned revenue reported by the Department of Transportation. The amount assigned to each vehicle class was adjusted by prorating the calculated sum to the total reported by the Department.

No detailed breakdown was available concerning revenues sent to Kentucky by other member states. Those funds were assigned to vehicle classes in the same proportion as for those vehicles registered in Kentucky.

**OPERATOR'S LICENSES**

The motor-vehicle operator's license fee is $4.00 and is collected in advance for a 2-year period. The license is for the operation of automobiles and trucks. The fee is distributed as follows: $1.25 to the Transportation Fund; $1.75 to the General Fund; $0.50 to the photographic program; $0.25 for driver education; and $0.25 is returned to the issuing county's road fund. A 2-year motorcycle operator's license is also issued for a $4.00 fee and distributed the same as the motor-vehicle operator's license. For the operator of both motor vehicles and motorcycles, a 2-year "combination" license is issued for a $7.00 fee. That fee is distributed as follows: $2.50 to the Transportation Fund; $3.00 to the General Fund; $0.50 to the photographic program; $0.50 for driver education; and $0.50 to the issuing county's road fund. Beginning January 1, 1981, some licenses were issued for a 4-year period, and all licenses issued after December 31, 1981, are to be valid for 4 years.

The portion of the operator's license fee that was dedicated to the General Fund was not considered in this study. Remaining portions were distributed among vehicle classes on the basis of vehicle-miles traveled. Revenue from motor-vehicle operator licenses was $2,639,922 in 1980.

**OTHER REVENUES**

Other revenues attributable to highway users were road tolls, motor-carrier taxes, motor-vehicle usage taxes, and other federal taxes or funds. Road tolls, which are collected by vehicle type and number of axles, were transformed from toll classes to weight classes to make them compatible with the other data. Total receipts were $18,775,829 in 1980. Motor-carrier taxes were collected in three general categories. Registered automobiles, which were primarily taxicabs, made up a small portion of the revenue source. Buses were another minor source. Trucks were obviously the major component of this tax category and their receipts of $336,784 were distributed by vehicle-miles of travel.

Motor-vehicle usage tax was a significant portion of total revenues. The five percent usage tax was levied on 90 percent of the factory advertised price
of automobiles and trucks weighing 10,000 pounds and less, 81 percent of the retail price of trucks weighing over 10,000 pounds, 100 percent of the average retail value of used automobiles and trucks, and 90 percent of the average retail price on used trucks over 10,000 pounds. In calendar year 1980, this tax generated $86,764,505. Vehicle-miles of travel were used for the distribution of those revenues.

Federal taxes, other than those for motor fuel, amounted to $31,622,000 in 1980. Of that total, $11,342,000 were distributed to all vehicles based on vehicle-miles of travel, and $20,280,000 were distributed to trucks based on vehicle-miles.

Another significant source of revenue was the excess received from the Federal Highway Administration over that amount paid by Kentucky in federal motor fuel and other miscellaneous taxes. Federal funds received by Kentucky that were attributable to the highway user amounted to $194,437,000. However, only $107,617,000 in federal fuel and use taxes were collected from Kentucky. The difference was $86,820,000, and it was distributed to all vehicles based on vehicle-miles.

SUMMARY OF DISTRIBUTED REVENUES
Total income to the Kentucky Department of Transportation during calendar year 1980 amounted to $851,105,000. Obviously, a significant portion of that income was not generated by the highway user and should not be considered as revenue in this study. Specifically, a major revenue item, not user generated, was reimbursement from the Turnpike Authority for $170,166,165. Of this total, over $161 million was for bond issues related to Resource Recovery Projects. Also, $33,195,000 was transferred to the Department of Transportation as the portion of the coal severance tax designated for highways. Another $32,916,000 was an appropriation from the General Fund. Federal funds from the Federal Highway Administration amounted to $233,781,000 in 1980; however, only about $194,437,000 was attributable to highway users. Overall, $312,242,000 was nonuser generated revenue in 1980.

Table 21 is a summary of all highway user-generated revenues distributed to the various vehicle classifications. The total for 1980 was $538,863,000. Motor fuel tax revenues collected by Kentucky amounted to approximately $190,177,000 of that total. Another $75,995,000 in motor fuel taxes was collected by the Federal Government. Of the $190,177,000 collected by Kentucky, approximately $59,927,000 was generated by trucks. Registration fees, operator licenses, and usage taxes amounted to $134,441,000.

RESULTS AND CONCLUSIONS
In this effort to allocate costs to highway users, the cost responsibility and revenue generated by each vehicle type or maximum registered weight category have been determined. Cost responsibility was subdivided into annual capital investments and annual expenditures. Capital expenditures amounted to $2,007,305,000. This is a cost that results from annualizing capital investments over the life expectancy of each component. Obviously, the calculated annual capital investment cost is far in excess of the average capital construction outlay for Kentucky's state maintained highways. It is an apparent indication that Kentucky is failing to provide sufficient construction funds to maintain its present system of highways. Annual expenditures other than capital construction amounted to $200,024,000. The total annual cost responsibility was $2,207,329,000.

Realizing that it may be more appropriate to present the cost responsibility in terms of annual expenditures by the Department of Transportation, a distribution of the 1980 expenditures was made. Only the proportion of expenditures that could be attributed to user-generated revenues was used. That proportion of expenditures for 1980 amounted to $538,863,000. Table 22 is a summary of the 1980 expenditure and the percent expenditure responsibility associated with each vehicle type or weight category.
Also presented in Table 22 is a summary of the 1980 user-generated revenue and percent revenue generated by each vehicle type or weight category. To provide a representation of the relationship between expenditure responsibility and revenue generated, the ratio of the revenue generated to expenditure responsibility was calculated. This ratio clearly shows the magnitude of the problem of underpayment and overpayment for specific vehicle types. The range of this ratio is from 1.64 for standard and compact automobiles to 0.31 for buses. Trucks bearing the least responsibility were those registered in the maximum gross weight classes of 18,000 and 38,000 pounds. The ratio for these two classes was 0.47. Overall, autos and pickups account for 157 percent of their expenditure responsibility and trucks account for 54 percent of their responsibility.

To deal with the problems of inequitable distribution of the cost burden to vehicle types and insufficient funds to maintain the present system of highways, impacts of alternative schemes were also presented in Table 22. The four alternative tax schemes use the 1980 tax structure as the base. The portion of the overall tax structure impacted by the alternatives would be the fuel surtax on trucks with three or more axles. Each alternative presumes a motor fuel tax of $0.09 per gallon on vehicles with two axles and variations (from $0.12 to $0.36 per gallon) in the motor fuel tax on vehicles with three or more axles. With the total motor fuel tax rates of $0.12, $0.16, $0.21, and $0.36; revenue generated would be approximately $4,000,000 for each additional $0.01 beyond the rate of $0.11 per gallon. Therefore, to generate an additional $100 million, it would require a motor fuel tax rate of $0.36 ($0.09 plus $0.27 surtax) per gallon on vehicles with three or more axles. Even with the tax rate of $0.36 per gallon, the ratio of revenue generated to expenditure responsibility still shows underpayment by trucks (132 percent responsibility covered by autos and pickups and 77 percent responsibility covered by trucks).

If an additional fuel surtax were charged trucks with three or more axles, there would still be some trucks with a significant cost responsibility that is not being impacted. There are heavily loaded two-axle trucks that are presently exempt from the fuel surtax.

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<table>
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<tr>
<th>HIGHWAY CLASSIFICATION</th>
<th>RURAL OR URBAN</th>
<th>NUMBER OF LANES</th>
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| NON-FEDERAL AID STATE MAINTAINED | RURAL | 2            | 12,074.67 | 2,192,806 | 498
|                        | URBAN          | 4               | 3.14    | 1,801                             | 1,571                       |
|                        | URBAN          | 2               | 79.59   | 75,657                            | 2,604                       |
|                        | URBAN          | 4               | 2.16    | 4,697                             | 5,958                       |
| NON-FEDERAL AID COUNTY MAINTAINED | RURAL | 2            | 37,224.21 | 559,502  | 43
|                        | URBAN          | 2               | 1,097.01| 190,011                           | 475                         |
| NON-FEDERAL AID CITY MAINTAINED | RURAL | 2            | 1,536.75 | 73,111    | 130
|                        | URBAN          | 2               | 2,939.66| 713,367                           | 665                         |
| NON-FEDERAL AID OTHER AGENCIES | RURAL | 2            | 474.67   | 45,680    | 264
|                        | URBAN          | 2               | 182.22  | 34,393                            | 517                         |
| TOTAL ALL SYSTEMS      |                | 69,321.27       | 25,163,000 | 994
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* TRUCK AXLE CONFIGURATION ABBREVIATIONS
  SU = SINGLE-UNIT
  T = TIRES
  A = AXLE
  C = COMBINATION TRACTOR AND TRAILER
TABLE 4. PERCENTAGE OF TRUCKS IN VEHICLE GROSS WEIGHT CATEGORIES (17)

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(A) VALUE EQUALS ZERO OR LESS THAN 0.005
(17) FROM US DEPARTMENT OF COMMERCE, REFERENCE NO. 17
## TABLE 5. PERCENTAGE OF TRAFFIC STREAM BY AUTOMOBILES, PICKUPS, BUSES, AND TRUCK WEIGHT CLASSES

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### MAXIMUM GROSS WEIGHT CLASS FOR TRUCKS (POUNDS)

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<th>MEDIUM GROSS WEIGHT CLASS FOR TRUCKS (POUNDS)</th>
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TABLE 8. ANNUAL COSTS OF THE HIGHWAY SYSTEM (THOUSAND DOLLARS)

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<th>HIGHWAY CLASSIFICATION</th>
<th>RURAL OR URBAN</th>
<th>NUMBER OF LANES</th>
<th>SYSTEM MILES</th>
<th>TOTAL ANNUAL PRELIMINARY DESIGN AND ENGINEERING COST</th>
<th>TOTAL ANNUAL RIGHT-OF-WAY COST</th>
<th>TOTAL ANNUAL UTILITIES COST</th>
<th>TOTAL ANNUAL GRADE AND DRAIN COST</th>
<th>TOTAL ANNUAL PAVEMENT AND SHOULDER COST</th>
<th>TOTAL ANNUAL BRIDGE COST</th>
<th>TOTAL ANNUAL COST</th>
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<tr>
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**TABLE 9. COST ALLOCATION INCREMENTS FOR GRADING AND DRAINAGE CONSTRUCTION (a)**

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<th>S--under 10,000 lbs</th>
<th>S--over 10,000 lbs</th>
<th>C--over 13,500 lbs</th>
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<td>except local</td>
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<tr>
<td>Local</td>
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S = single unit vehicle
C = combination vehicle

(a) Summarized from FHWA, Reference No. 7
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<th>SUB-4A Autos</th>
<th>PICKUPS</th>
<th>BUSES</th>
<th>SU-2A-4T</th>
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*Damage Factors Used to Calculate Equivalent Axleloads*
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## Table 12. Percent Cost Responsibility - Pavements and Shoulders by Automobiles, Pickups, Buses, and Trucks

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<th>SUBCOMPACT</th>
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<th>BUSES</th>
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### Total All Systems

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<th>SUBCOMPACT</th>
<th>PICKUPS</th>
<th>BUSES</th>
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### Maximum Gross Weight Class for Trucks (Pounds)

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<th>SUBCOMPACT</th>
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<th>BUSES</th>
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### Total All Systems

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TABLE 13  INCREMENTS FOR BRIDGE CONSTRUCTION COSTS (7)

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GROSS VEHICLE WEIGHT

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<th>S--30,000 TO 40,000 LBS</th>
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<tr>
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<td>75.9%</td>
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<td>4.0%</td>
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<tr>
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<td>3.0%</td>
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S = SINGLE UNIT VEHICLE
C = COMBINATION VEHICLE

(7) REFERENCE NUMBER 7.
### Table 14. Distribution of Capital Expenditures - Annual (thousand dollars)

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<th>26,000</th>
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<th>44,000</th>
<th>55,000</th>
<th>67,000</th>
<th>73,000</th>
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<td>1,683</td>
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### Table 15. Distribution of Annual Expenditures - Maintenance and Administration (thousand dollars)

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<th>SUBCOMPACT Autos</th>
<th>PICKUPS</th>
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<th>14,000</th>
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<th>22,000</th>
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<th>44,000</th>
<th>55,000</th>
<th>67,000</th>
<th>73,000</th>
<th>82,000</th>
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<td>451,045</td>
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<th>SU-4A-6T</th>
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**TABLE 18. MOTOR FUEL TAX REVENUES BY VEHICLE CLASSIFICATION (CALENDAR YEAR 1980)**
TABLE 19.  MOTOR FUEL TAX REVENUE BY GROSS WEIGHT CATEGORIES (THOUSANDS OF DOLLARS)

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<tr>
<th>VEHICLE TYPE</th>
<th>MAXIMUM GROSS WEIGHT CLASS FOR TRUCKS (POUNDS)</th>
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<td>FEDERAL</td>
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<td>952.6</td>
<td>1,691.1</td>
<td>1,040.2</td>
<td>5,712.3</td>
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TABLE 20. MOTOR VEHICLE REGISTRATION FEES

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<td>FARM TRUCKS</td>
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<td>6,001 - 10,000</td>
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<tr>
<td>SCHOOL AND CHURCH BUSES</td>
<td>11.50</td>
<td>10,001 - 14,000</td>
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<tr>
<td>MOTORCYCLES</td>
<td>5.00</td>
<td>14,001 - 18,000</td>
</tr>
<tr>
<td>MOTOR VEHICLE DEALERS</td>
<td>25.00</td>
<td>18,001 - 22,000</td>
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<tr>
<td>HOUSE CARS</td>
<td>20.00</td>
<td>22,001 - 26,000</td>
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<tr>
<td>TRAILERS DRAWN BY PASSENGER CARS</td>
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<td>26,001 - 32,000</td>
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<tr>
<td>TRAILERS DRAWN BY TRUCKS</td>
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<td>32,001 - 38,000</td>
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<tr>
<td>HOUSE TRAILERS</td>
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MAXIMUM GROSS WEIGHT (POUNDS)

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<th>14,001 - 18,000</th>
<th>18,001 - 22,000</th>
<th>22,001 - 26,000</th>
<th>26,001 - 32,000</th>
<th>32,001 - 38,000</th>
<th>38,001 - 44,000</th>
<th>44,001 - 50,000</th>
<th>50,001 - 62,000</th>
<th>62,001 - 73,280</th>
<th>73,281 - 82,000</th>
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<td>120.00</td>
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</tr>
<tr>
<td>TABLE 21. TOTAL REVENUE GENERATED (THOUSANDS OF DOLLARS)</td>
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<td><strong>SUBCOMPACT AUTOS</strong></td>
<td><strong>PICKUPS</strong></td>
<td><strong>BUSES</strong></td>
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(A) FUNDS RECEIVED FROM THE FEDERAL HIGHWAY ADMINISTRATION IN EXCESS OF THOSE PAID BY KENTUCKY IN FEDERAL MOTOR FUEL TAXES, USE TAXES, AND TAXES ON AUTOMOTIVE PRODUCTS.
<table>
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<tr>
<th>Standard</th>
<th>Compact</th>
<th>Subcompact</th>
<th>Pickup</th>
<th>SUV</th>
<th>5,000</th>
<th>10,000</th>
<th>14,000</th>
<th>20,000</th>
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<td>IMPACT OF ALTERNATIVE TAX SCHEDULES (A)</td>
<td>186,625</td>
<td>22,042</td>
<td>95,501</td>
<td>4,633</td>
<td>1,119</td>
<td>22,470</td>
<td>8,233</td>
<td>3,056</td>
<td>3,056</td>
</tr>
<tr>
<td>REVENUE GENERATED WITH $0.36 PER GALLON FUEL TAX ON TRUCKS</td>
<td>186,625</td>
<td>22,042</td>
<td>95,501</td>
<td>4,633</td>
<td>1,119</td>
<td>22,470</td>
<td>8,233</td>
<td>3,056</td>
<td>3,056</td>
</tr>
<tr>
<td>PERCENT REVENUE GENERATED</td>
<td>46.05</td>
<td>6.08</td>
<td>17.61</td>
<td>0.65</td>
<td>0.21</td>
<td>4.14</td>
<td>0.99</td>
<td>1.02</td>
<td>0.99</td>
</tr>
<tr>
<td>RATIO OF REVENUE GENERATED TO EXPENDITURES</td>
<td>1.55</td>
<td>1.52</td>
<td>1.34</td>
<td>1.29</td>
<td>0.78</td>
<td>0.68</td>
<td>0.55</td>
<td>0.47</td>
<td>0.57</td>
</tr>
<tr>
<td>TAX ON VEHICLES</td>
<td>216,625</td>
<td>22,042</td>
<td>95,501</td>
<td>4,633</td>
<td>1,119</td>
<td>22,470</td>
<td>8,233</td>
<td>3,056</td>
<td>3,056</td>
</tr>
<tr>
<td>PERCENT REVENUE GENERATED</td>
<td>46.05</td>
<td>6.08</td>
<td>17.61</td>
<td>0.65</td>
<td>0.21</td>
<td>4.14</td>
<td>0.99</td>
<td>1.02</td>
<td>0.99</td>
</tr>
<tr>
<td>RATIO OF REVENUE GENERATED TO EXPENDITURES</td>
<td>1.48</td>
<td>1.46</td>
<td>1.33</td>
<td>1.29</td>
<td>0.82</td>
<td>0.69</td>
<td>0.56</td>
<td>0.48</td>
<td>0.50</td>
</tr>
<tr>
<td>MAXIMUM GROSS WEIGHT CLASS FOR TRUCKS (POUNDS)</td>
<td>26,000</td>
<td>32,000</td>
<td>38,000</td>
<td>44,000</td>
<td>50,000</td>
<td>60,000</td>
<td>75,000</td>
<td>90,000</td>
<td></td>
</tr>
<tr>
<td>EXPENDITURE RESPONSIBILITY</td>
<td>9,525</td>
<td>13,500</td>
<td>17,702</td>
<td>11,499</td>
<td>12,795</td>
<td>22,489</td>
<td>69,337</td>
<td>53,925</td>
<td>58,565</td>
</tr>
<tr>
<td>PERCENT EXPENDITURE RESPONSIBILITY</td>
<td>1.77</td>
<td>2.51</td>
<td>3.96</td>
<td>7.13</td>
<td>13.06</td>
<td>22.07</td>
<td>10.21</td>
<td>18.00</td>
<td></td>
</tr>
<tr>
<td>USER REVENUE GENERATED</td>
<td>6,127</td>
<td>6,900</td>
<td>6,479</td>
<td>4,597</td>
<td>10,175</td>
<td>11,156</td>
<td>14,650</td>
<td>18,107</td>
<td>22,063</td>
</tr>
<tr>
<td>PERCENT REVENUE GENERATED</td>
<td>1.34</td>
<td>1.31</td>
<td>1.30</td>
<td>1.22</td>
<td>1.78</td>
<td>2.07</td>
<td>3.29</td>
<td>5.61</td>
<td>100.00</td>
</tr>
<tr>
<td>RATIO OF PERCENT REVENUE GENERATED TO PERCENT EXPENDITURE RESPONSIBILITY</td>
<td>0.44</td>
<td>0.45</td>
<td>0.47</td>
<td>0.45</td>
<td>0.49</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
</tbody>
</table>

(A) The four alternative tax schedules are for the 1980 tax structure with motor fuel tax of $0.36 per gallon on vehicles with two axles and variations (from $0.12 to $0.36 per gallon in the motor fuel tax on vehicles with three or more axles.)
APPENDIX A
METHODS OF DETERMINING COSTS OF BRIDGES

The following list of variables were considered for inclusion in the mathematical model:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract year</td>
<td>Length</td>
</tr>
<tr>
<td>Out-to-out width</td>
<td>Driving width</td>
</tr>
<tr>
<td>Deck area</td>
<td>Minimum beam depth</td>
</tr>
<tr>
<td>Maximum beam depth</td>
<td>Single or twin bridges</td>
</tr>
<tr>
<td>Number of supports</td>
<td>Number of spans</td>
</tr>
<tr>
<td>Skew angle</td>
<td>River crossing or not</td>
</tr>
<tr>
<td>Railroad crossing or not</td>
<td>Maximum span length</td>
</tr>
</tbody>
</table>

The contract year was included to account for changing construction costs with time.

Some independent variables were interactive or represented similar data. The bridge out-to-out-width was tested against driving width; only one was to be included in the model. Interactive variables such as deck area, length, and width competed independently for inclusion in the model.

Notably missing from the list of independent variables is the highway system classification. That information was not available in the sample data set. Using deck area as the only indicator of cost, the Division of Bridges provided the information, based on a small sample, summarized in Table A1. In 1980, the unit costs were almost identical for federal-aid and non-federal-aid systems. There was an obvious difference in 1979, but the unit cost for federal-aid bridges that year appeared high in comparison with 1978 and 1980. It was assumed that a satisfactory mathematical model could be obtained to estimate construction cost without including the highway system classification.

Several equation forms were investigated:

- Contract price: \( k + (k' \times A) + (k'' \times A^2) + \ldots + (k'''' \times B) \)
- Contract price: \( k + (k' \times A) + (k'' \times B) + \ldots \)
- \( \ln(\text{Contract price}) = k + (k' \times \ln(A)) + (k'' \times \ln(B)) + \ldots \)

where \( A \) and \( B \) represent independent variables and the \( k's \) represent coefficients.

The \( \ln \)-equation form proved superior, as was anticipated, since inflation historically affects costs somewhat exponentially.

Using deck area and contract year as the only independent variables, the following equation resulted:

- Contract price: \(-127,630 + 46,952 \times (\text{contract year} - 1975) + 48.98 \times (\text{deck area}, \text{sq ft})\)
- \( r^2 = 0.709 \)
- Mallow's Cp = 146.6

Using the exponential form,

- \( \ln(\text{contract price}) = 4.136 + 0.07922 \times \ln(\text{contract year} - 1975) \)
+ 0.9404 \times \ln(\text{deck area, sq ft}) \\
r-square = 0.852 \\
\text{Mallow's Cp} = 38.7

Allowing many independent variables to compete for a position in the equation, the lowest Mallow's Cp was obtained for

\[ \ln(\text{Contract price}) = 3.6645 \]

\[ + 0.0888 \times \ln(\text{contract year - 1975}) \]
\[ - 0.1741 \times (\text{number of bridges}) \]
\[ + 0.8274 \times \ln(\text{deck area, sq ft}) \]
\[ + 0.3435 \times \ln(\text{max span length, ft}) \]

r-square = 0.867 \\
\text{Mallow's Cp} = 4.36

Note that the 'number of bridges' in the above equation equals 1 for a single bridge or 2 for twin bridges. Comparing these models using \(r\)-square, or preferrably Mallow's Cp, it is noted that

1) the exponential form is vastly superior, as demonstrated in the two deck area-contract year models, and
2) the four-variable exponential equation is superior to the deck area-contract year models.

The four-variable exponential equation was derived using 347 bridges let to contract from 1975 through 1979. This equation was then applied to all bridges. Data for bridges were contained in a bridge inventory file maintained by the Department of Transportation. However, data were missing for some bridges, and thus a contract price could not be found. For those bridges with complete data entries, the current construction costs were calculated. The average cost of those bridges was found and used to estimate the cost of the other bridges.

### TABLE A1. BRIDGE CONSTRUCTION COSTS

<table>
<thead>
<tr>
<th>Contract Year</th>
<th>Federal Aid</th>
<th>Sample Size</th>
<th>Non-Federal Aid</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>$45.64</td>
<td>15</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>1979</td>
<td>$70.43</td>
<td>31</td>
<td>$50.73</td>
<td>21</td>
</tr>
<tr>
<td>1980</td>
<td>$54.52</td>
<td>32</td>
<td>$55.23</td>
<td>15</td>
</tr>
</tbody>
</table>