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16. Abstract

This report covers the work during the first year of a project to upgrade the Highway Performance Monitoring System (HPMS) for use in Texas for estimating the current needs of the highway network in Texas and making forecasts of future needs. The objective of the project is to develop an improved energy module to make more accurate estimates of energy consumption and savings attributed to highway investment strategies.

This report documents a series of equations developed to calculate vehicle operating costs. The equations cover vehicle use consumption of fuel, oil, tires, depreciation, and maintenance. The coefficients of these equations are contained in an external data file that can be read and updated without requiring changes to the program in the future. A subroutine to read the coefficient data file is also included.

Recommendations for further work on HPMS are also included. This includes use of HPMS in making short and medium term forecasts, and incorporation of economic analysis in HPMS.

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DEVELOP AN IMPROVED ENERGY MODULE

FOR USE IN HPMS

by

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Research Report 30070-1
Work Completed During First Year of Study
Project 30070
Southwest Region University
Transportation Center

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IMPLEMENTATION STATEMENT

The changes to the user cost calculations in the Highway Performance Monitoring System (HPMS) analysis package, described in this report, can be implemented immediately. Changes would be required to several subroutines within the program, and the external coefficient data file would have to linked to the program. After the changes are made, a testing process would be required, not only to check the user cost calculations, but to determine if there are any problems with other parts of the program utilizing the results or passing parameters to the affected subroutines.

Other suggested changes to HPMS, described in this report, are not ready for implementation. These changes would require further study and work to determine their feasibility, structure, data, and implementation.

ACKNOWLEDGEMENTS

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DISCLAIMER

This study was conducted in cooperation with the Texas Department of Transportation and the Texas Governor's Energy Office. The contents of this report reflect the views of the authors and do not necessarily represent the official views or policies of TXDOT or Texas Governor's Office. This report does not constitute a standard, a specification, or a regulation, and is not intended for construction, bidding, or permit purposes.

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SUMMARY

This report covers the work during the first year of a project to upgrade the Highway Performance Monitoring System (HPMS) for use in Texas for estimating the current needs of the highway network in Texas and making forecasts of future needs. The objective of the project is to develop an improved energy module to make more accurate estimates of energy consumption and savings attributed to highway investment strategies.

This report documents a series of equations developed to calculate vehicle operating costs. The equations cover vehicle use consumption of fuel, oil, tires, depreciation, and maintenance. The coefficients of these equations are contained in an external data file that can be read and updated without requiring changes to the program in the future. A subroutine to read the coefficient data file is also included.

Incorporation into HPMS of the vehicle consumption equations described in this report would significantly improve both the estimates of energy consumption and allow for changing or modifying those estimates over time as technological and economic forces make their influence felt. It should be a high priority to finish the work started in this project in order to make the necessary changes to the HPMS analysis package and test those modifications.

There are, in addition, several other changes that can be made to HPMS to improve its ability to make shorter term forecasts and to explicitly incorporate economic analysis into the evaluation and selection of highway improvements. These changes should also receive a high priority in future modifications to the HPMS analysis package.

INTRODUCTION

A comprehensive analysis of the status and needs of the nation's highway system is presented to the U.S. Congress every two years by the Federal Highway Administration (FHWA). These reports, required by the U.S. Code, Title 23, Section 307, were first prepared in 1968 and gave the present condition of U.S. highways and future highway needs. As a result of that work, a computerized informational system was developed, called the Highway Performance Monitoring System (HPMS).

The input data for HPMS consists of inventory and condition data for a sample of highway sections selected to represent the highway system in the state. Data are collected and reported annually to FHWA by each state. All public roads are sampled except for the local functional class. The data consist of specific geometric and alignment items, physical condition data, and operational performance data [4]. Work by TTI in Study 480 [8], resulted in a substantial increase in the sample size in Texas, making it possible to make estimates at the district level.

HPMS uses the data collected by the states in a series of computer programs that can provide an analysis of the current condition of the highway system as well as the needs in the future. Different levels of investment can also be analyzed and the impacts on the future condition can be simulated [3]. There are four major models in the analysis process: the needs model, the composite index model, the investment performance model, and impact assessment model. In addition, two other models can be used within each funding period. These are the multiple deficiency model and the deferred cost model. Each of these models are briefly described below.

The needs model simulates the improvements necessary to keep the physical and operational conditions of the highway system from falling below prescribed minimum criteria during the analysis period. The model goes through several steps, including: identifying individual highway section deficiencies which

occur during the analysis period, determining the appropriate improvement to correct the deficiency, estimating the cost of improvement, and modifying the section record to reflect performance in the analysis year, with or without the improvement. Deficiencies are identified from a number of categories, including: peak hour operating speed or v/c ratio, lane width, shoulder width, pavement condition, horizontal or vertical alignment, and surface type. Improvements are made to design standards and can be constrained by widening restrictions, such as the maximum number of lanes.

The composite index model provides a measure of the current condition of the highway system in three categories: pavement condition, safety, and service. The index is similar to a sufficiency rating in that points are assigned to each item evaluated, and a total of 100 represents a highway with no defects. A lesser total represents the degree of deficiency.

The investment performance model provides a method to select improvements when there are not enough funds for all identified deficiencies to be corrected. Potential improvements are ranked using a cost-effectiveness index or one of the composite indexes. Improvements are selected from the top of the priority list downward until the funds are exhausted. The condition of the highway system at the end of the analysis period can then be compared to the condition if all deficiencies had been corrected, in order to identify the impacts of a less than fully funded highway investment program.

The impact assessment model converts existing and future highway physical and operating conditions into user costs. The vehicle performance measures which are estimated include: average overall travel speed, vehicle operating costs, fuel consumption, emissions, and accidents. Each of these measures are calculated based upon relationships and tables within the program, developed by FHWA or in conjunction with consulting contracts. The costs are calculated for seven vehicle types, with the exception of accident costs, given the physical and operational conditions for each highway segment.

The multiple deficiency model gives the number of miles and daily vehicle miles traveled (DVMT) for five different categories of deficiencies: pavement condition, geometric (rural only), roadway cross section, operational, and access control. Each category is given individually, along with various combinations of deficiencies.

The deferred cost model estimates the cost of deferred maintenance for those sections requiring resurfacing that later require reconstruction because not enough money was available to do the resurfacing when it was needed.

A recent GAO study concluded that HPMS was adequate for making needs estimates at the national level, and provides a valuable tool for making an assessment of both the current condition of the highway system and the future needs over time. [2]

Use of HPMS in Texas

The Texas Department of Transportation (TxDOT) has used HPMS in developing estimates of current and future needs in Texas. These estimates are contained in the Strategic Mobility Plan (SMP) [11]. HPMS was used to make 20 year estimates of backlog and future needs of added capacity, reconstruction and rehabilitation, and geometric improvements. Several modifications to the HPMS default data were made to more closely match conditions in Texas. These included: changes in the construction and right-of-way costs, traffic growth rates, minimum tolerable conditions, design standards, and the restriction on the maximum number of lanes. [1]

TxDOT, Division of Planning and Policy, has made a substantial positive contribution to the use of HPMS at the state level, and is certainly one of the leaders in the nation in that regard. As an example, two other states, North Carolina [5] and Kentucky [12] have been studying the use of HPMS in making needs estimates, but are far behind Texas in utilizing HPMS data and analysis potential. A recent Texas State Auditor report commended TxDOT for their efforts

in developing the SMP and encouraged further development of automated systems such as HPMS. [10]

A consulting group, Cambridge Systematics, was hired to review the use of HPMS in the SMP [9]. Their review was generally quite favorable, with most major potential problems already resolved internally by TxDOT staff, and included recommendations of several minor improvements. A TTI study has also concluded that the use of HPMS in making long-range highway needs estimates for Texas is very adequate and far superior to previous ad-hoc efforts. [6]

Calculation of Fuel Consumption and Vehicle Operating Costs

One of the main thrusts of this project is to develop an improved energy module, based upon economic criteria, for long-term needs and investment analysis, for use in HPMS. Energy consumption is part of the calculation of vehicle operating costs in HPMS and other economic evaluations of highway improvements. However, in the current program, vehicle consumption is incorporated internally into look-up tables which cannot be modified or updated without updating the program. In addition, it is very inefficient to constantly read the tabular data and interpolate between the nearest table values.

There are five cost components in operating a vehicle: fuel consumption, oil consumption, tire wear, vehicle depreciation, and maintenance and repair. Each plays a different role, some more significant than others, in the overall vehicle operating costs. There are several factors that can influence individual cost components; but, the two common ones that affect all component categories are vehicle type and traveling speed. Others factors identified include: horizontal grade level, surface type, roughness, and curvature of the road. For example, in addition to vehicle type and speed, oil, tire wear, and maintenance and repairs can also be affected by grade level, surface type and curvature of the road. Fuel consumption is independent of surface condition even though it is influenced by all other factors. Depreciation is not affected by the grade level nor by curvature.

To obtain vehicle component costs, the consumption of each component category is first estimated in terms of some roadway characteristics and multiplied by the unit price of the corresponding cost components.

There are four parts that constitute the total consumption of a vehicle cost component. They represent consumption coming from: a vehicle traveling at a uniform speed at a specific grade level of roadway, changing speeds, idling, and the different curvature of a roadway segment. Consumptions of the various components coming from a vehicle traveling at uniform speed at a specific grade level, a prevailing travel characteristic in most instances, represent the major portion of the overall consumptions. Consumptions from the remaining parts are excess consumptions. When a vehicle travels at a uniform speed, it consumes each component category differently than when it changes speed cycles in traveling or is simply idling. Similarly, additional consumptions of fuel, oil, and maintenance and repairs are required to travel on a roadway segment with some curvature. Even at a uniform speed, consumption of the cost components differs if the road segment has different grade levels. The relationship between each of the consumption of cost component categories and speed is estimated separately under uniform speeds, speed change cycles, and curvatures of roads. The estimated consumptions under uniform speeds are examined under various grade levels of roadways and further adjusted for the effect of pavement condition. Pavement adjustment factors for all the components, except fuel which is found to be insensitive to pavement conditions, are developed and applied to the respective estimated component consumptions under uniform speeds. Since idling does not involve speed, idling consumptions are handled in units of traveling hours. For each cost component, multiplying traveling hours to the unit of idling consumption yields the total excess consumption for idling which is then added to the pavement adjusted consumptions from uniform speeds, excess consumptions under speed change cycles, and curvature changes to give the total consumption.

RECOMMENDED VEHICLE OPERATING COST CALCULATIONS

For this project, consumption data were from Zaniewski's study [13]. Even though these data are over ten years old, they are the only comprehensive vehicle operating cost data currently available. Work is currently being performed at TTI to modify the fuel consumption estimates using a simulation model called ARFCOM. When those estimates become available, it would be advisable to revise the appropriate items in the coefficient data file for use in HPMS. This data file is described below.

The coefficient data file was developed using regression equations to estimate relationships from the tabular Zaniewski data. Equations were used so that they could be modified over time and put into an external file to be used with HPMS. Future updating can be performed directly by changing these coefficients, without having to make changes to the HPMS programs. Such changes could include improvements to vehicle efficiency, change in the type of vehicles operating on the highways, and other changes in consumption rates due to technological improvements. Under such circumstances, reestimation of the consumption components should be carried out and the coefficient data file modified accordingly.

Currently, the vehicle consumption tabular data is processed in the HIPTBL module. This must be revised to read and store the external coefficient data file described below. A subroutine to read the coefficient data file is included in this section (page 12). The appropriate data arrays have to be passed to the impact module, HPMSIMPT.

In addition, the HMEASR module must be modified to use the equations in order to calculate vehicle operating costs and fuel consumption rather than interpolating the tabular data in the current version. It is a relatively straightforward operation to substitute equations for the interpolated calculations currently in the program. Care must be taken to assure that the array subscripts are consistent with the vehicle operating cost output from HMEASR. These programming

changes within HPMS were not completed because the contract was terminated prematurely after the first year of work.

Described below are the format of the coefficient data file and a program to read that data from an external file. The coefficients in that file are given in the appendix.

Format for Coefficient Data File

File	Given	Variable	Dimension
Grade	for consump. comp., ICM=1-4	IG1COEF(IGR,ICM,L,ICOFGI) G1COEF(IGR,ICM,L,ICOFGR)	IG1COEF(9,4,8,3) G1COEF(9,4,8,8)
	for consump. comp., ICM=5	IG2COEF(IGR,L,ISPCAT,ICOFGI) G2COEF(IGR,L,ISPCAT,ICOFGR)	IG2COEF(9,8,3,3) G2COEF(9,8,3,8)
Curvature	for consump. comp., ICM=1-4	IC1COEF(ICR,ICM,L,ICOFCI) CR1OEF(ICR,ICM,L,ICOFCR)	IC1COEF(15,4,8,3) C1COEF(15,4,8,6)
	for consump. comp., ICM=5	IC2COEF(ICR,L,ISPCAT,ICOFCI) CR2OEF(ICR,L,ISPCAT,ICOFCR)	IC2COEF(15,8,3,3) C2COEF(15,8,3,6)
Speed Change	none	ISCCOEF(ICM,L,ISPCAT,ICOFSI) SCCOEF(ICM,L,ISPCAT,ICOFSR)	ISCCOEF(5,8,3,3) SCCOEF(5,8,3,7)
Pavement Adjustment	none	IPVCOEF(ICM,L) PVCOEF(ICM,L,ICOFPR)	IPVCOEF(5,8) PVCOEF(5,8,2)
Idling Consumption	none	CICOEF(ICM,L)	CICOEF(5,8)
Number Speed Change Cycles	none	ICYCOEF(IHWY,L,IVCRG) CYCOEF(IHWY,L,IVCRG,ICOFYR)	ICYCOEF(4,8,4) CYCOEF(4,8,4,4)
Emissions	none	IEMCOEF EMCOEF(ICOFER)	IEMCOEF EMCOEF(7)

Dependent Variable 0 linear 1 log

List of Indices:

Variable	Description	Coefficients or Category Components
IGR	grade category (1-9)	0, 1, 2, 3, 4, -1, -2, -3, -4to-8
ICR	curvature category (1-15)	1, 2, 3, 4, 5, 6, 8, 12, 16, 18, 20, 25, 30
ICM	consumption component (1-5)	fuel, oil, tire, depreciation, maintenance
L	vehicle category (1-8)	small passenger car, medium/large passenger car, pickup/van, bus, single unit 2A truck, single unit 3A truck, 2-S2 semi combination truck, 3-S2 semi combination truck
IHWY	highway type (1-4)	freeway, multilane rural, 2-lane rural, arterial
ISPCAT	Min-Max speed category (1-3)	
IVCRG	VC Range (1-4)	0-1, 1-1.2, 1.2-1.6, 1.6-2
ICOFGI	integer grade equation data	minimum speed, maximum speed, dependent variable
ICOFGR	real grade equation data	constant, speed, speed**2, log(speed), speed*grade, grade, grade**2, log(GVW)
ICOFCI	integer curvature equation data	minimum speed, maximum speed, dependent variable

ICOFCR	real curvature equation data	constant, speed, speed**2/1000, speed**3/1000, speed**4/1000, log(speed)
ICOFSI	integer speed change equation data	minimum speed, maximum speed, dependent variable
ICOFSR	real speed change equation data	constant, initial speed, initial speed**2, log(initial speed), reduced speed, reduced speed**2, log(reduced speed)
ICOFPR	pavement equation data	constant, PSI
ICOFYR	real number of speed changes equation data	constant, VC ratio, minimum VC ratio, maximum VC ratio
ICOFER	real emissions equation data	constant, log(speed), temperature, altitude (1-low, 2-high), year, percent cold starts, idling emissions)

Units of measure for coefficients:

speed	miles per hour (1.61 × kilometers per hour)
grade	degree positive or negative grade
curvature	degree horizontal curvature
GVW	gross vehicle weight in kips (.0022 × kilograms)
temperature	degrees fahrenheit [(1.8 × degrees celsius) + 32]
year	calendar year
emissions	kilograms

Subroutine to Read Coefficient Data File

```
      COMMON /LABINDF/IG1COEF(9,4,8,3),G1COEF(9,4,8,8),
     *   IG2COEF(9,8,3,3),G2COEF(9,8,3,8),
     A   IC1COEF(15,4,8,3),C1COEF(15,4,8,6),
     B   IC2COEF(15,8,3,3),C2COEF(15,8,3,6),
     1   ISCCOEF(5,8,3,3),SCCOEF(5,8,3,7),IPVCOEF(5,8),
     2  PVCOEF(5,8,2),CICOEF(5,8),ICYCOEF(4,8,4),CYCOEF(4,8,4,4),
     3   IEMCOEF,EMCOEF(7)

      INTEGER IGR,ICM,L,ICOFGI,ISPCAT,ICOFGR
      INTEGER ICR,ICOFCI,ICOFCR
      INTEGER ICOFSI,ICOFSR,ICOFPR,IHWY,IADTRG,ICOFYR,ICOFER

      OPEN(99,'c:\P30070\tams.dat',STATUS='OLD')

C  Read the first blank line..
      READ (99, '(A80)')


C  Loop for IG1COEF
      DO 5104 IGR =1,9
       DO 5103 ICM = 1,4
         DO 5102 L = 1,8
           DO 5101 ICOFGI = 1,3
              READ (99,14) IG1COEF(IGR, ICM, L, ICOFGI)
5101        CONTINUE
5102      CONTINUE
5103     CONTINUE
5104    CONTINUE


C  Loop for G1COEF
      DO 5204 IGR =1,9
       DO 5203 ICM = 1,4
         DO 5202 L = 1,8
           DO 5201 ICOFGR = 1,8
              READ (99,16) G1COEF(IGR, ICM, L, ICOFGR)
5201        CONTINUE
5202      CONTINUE
5203     CONTINUE
5204    CONTINUE


C  Loop for IG2COEF
      DO 5304 IGR =1,9
       DO 5303 L = 1,8
         DO 5302 ISPCAT = 1,3
           DO 5301 ICOFGI = 1,3
              READ (99,14) IG2COEF(IGR, L, ISPCAT, ICOFGI)
```

```
5301          CONTINUE
5302        CONTINUE
5303      CONTINUE
5304    CONTINUE


C  Loop for G2COEF
        DO 5404 IGR =1,9
         DO 5403 L = 1,8
           DO 5402 ISPCAT = 1,3
             DO 5401 ICOFGR = 1,8
                READ (99,16) G2COEF(IGR, L, ISPCAT, ICOFGR)
5401          CONTINUE
5402        CONTINUE
5403      CONTINUE
5404    CONTINUE


C  Loop for IC1COEF
        DO 5504 ICR =1,15
         DO 5503 ICM = 1,4
           DO 5502 L = 1,8
             DO 5501 ICOFCI = 1,3
                READ (99,14) IC1COEF(ICR, ICM, L, ICOFCI)
5501          CONTINUE
5502        CONTINUE
5503      CONTINUE
5504    CONTINUE


C  Loop for C1COEF
        DO 5604 ICR =1,15
         DO 5603 ICM = 1,4
           DO 5602 L = 1,8
             DO 5601 ICOFCR = 1,6
                READ (99,16) C1COEF(ICR, ICM, L, ICOFCR)
5601          CONTINUE
5602        CONTINUE
5603      CONTINUE
5604    CONTINUE


C  Loop for IC2COEF
        DO 5704 ICR =1,15
         DO 5703 L = 1,8
           DO 5702 ISPCAT = 1,3
             DO 5701 ICOFCI = 1,3
                READ (99,14) IC2COEF(ICR, L, ISPCAT, ICOFCI)
5701          CONTINUE
5702        CONTINUE
5703      CONTINUE
```

```
5704    CONTINUE


C  Loop for C2COEF
        DO 5804 ICR =1,15
         DO 5803 L = 1,8
           DO 5802 ISPCAT = 1,3
             DO 5801 ICOFCR = 1,6
                READ (99,16) C2COEF(ICR, L, ISPCAT, ICOFCR)
5801          CONTINUE
5802        CONTINUE
5803      CONTINUE
5804    CONTINUE


C  Loop for ISCCOEF
        DO 5904 ICM =1,5
         DO 5903 L = 1,8
           DO 5902 ISPCAT = 1,3
             DO 5901 ICOFSI = 1,3
                READ (99,14) ISCCOEF(ICM, L, ISPCAT, ICOFSI)
5901          CONTINUE
5902        CONTINUE
5903      CONTINUE
5904    CONTINUE


C  Loop for SCCOEF
        DO 6004 ICM =1,5
         DO 6003 L = 1,8
           DO 6002 ISPCAT = 1,3
             DO 6001 ICOFSR = 1,7
                READ (99,16) SCCOEF(ICM, L, ISPCAT, ICOFSR)
6001          CONTINUE
6002        CONTINUE
6003      CONTINUE
6004    CONTINUE


C  Loop for IPVCOEF
        DO 6102 ICM =1,5
         DO 6101 L = 1,8
           READ (99,14) IPVCOEF(ICM, L)
6101     CONTINUE
6102    CONTINUE


C  Loop for PVCOEF
        DO 6203 ICM =1,5
         DO 6202 L = 1,8
           DO 6201 ICOFPR = 1,2
```

```
                READ (99,16) PVCOEF(ICM, L, ICOFPR)
6201          CONTINUE
6202        CONTINUE
6203      CONTINUE


C  Loop for CICOEF
          DO 6302 ICM = 1,5
           DO 6301 L = 1,8
             READ (99,16) CICOEF(ICM, L)
6301       CONTINUE
6302      CONTINUE


C  Loop for ICYCOEF
          DO 6403 IHWY = 1,4
             DO 6402 L = 1,8
               DO 6401 IADTRG = 1,4
                  READ (99,14) ICYCOEF(IHWY, L, IADTRG)
6401           CONTINUE
6402         CONTINUE
6403      CONTINUE


C  Loop for CYCOEF
          DO 6504 IHWY =1,4
           DO 6503 L = 1,8
             DO 6502 IADTRG = 1,4
               DO 6501 ICOFYR = 1,4
                  READ (99,16) CYCOEF(IHWY, L, IADTRG, ICOFYR)
6501            CONTINUE
6502          CONTINUE
6503        CONTINUE
6504      CONTINUE


C  Read in IEMCOEF
         READ (99,14) IEMCOEF


C  Loop for EMCOEF
         DO 6601 ICOFER=1,7
            READ (99,16) EMCOEF(ICOFER)
 6601 CONTINUE

 14      FORMAT (I8)
 16      FORMAT (F11.5)

         CLOSE (99)
         END
```

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

Incorporation of the vehicle consumption equations described in this report would significantly improve both the estimates of energy consumption and allow for changing or modifying those estimates over time as technological and economic forces make their influence felt. It should be a high priority to finish the work started in this project in order to make the necessary changes to the HPMS analysis package and test those modifications. There are, in addition, several other changes that can be made to HPMS to improve its ability to make shorter term forecasts and to explicitly incorporate economic analysis into the evaluation and selection of highway improvements. These two potential areas of improvement are described below.

Use of HPMS in Making Short and Medium Term Forecasts

Some discussion has taken place since development of the SMP in Texas for using HPMS in making needs estimates over shorter time horizons (less than 20 years). There have been some concerns raised that HPMS is not sufficiently accurate or reliable to provide short or medium term forecasts. There is some justification for that concern. Much of the problem has to do with the internal logic the program uses to select an improvement alternative. Some of the significant aspects of the problem are outlined below.

The program first checks the current condition of each sample highway section against the minimum tolerable conditions. If no deficiency is found, the program cycles forward each year during the analysis period, simulating the impacts on the traffic and pavement condition data. When a deficiency is triggered, a complex logical structure determines what improvement to make. One key to the logical structure is that when a deficiency is detected, it cycles forward through the period to determine if any other deficiencies will occur. If other deficiencies are found, it picks the highest level improvement. This eliminates potential duplication of improvements, a valuable feature.

However, the cycling forward process is also used to determine the number of lanes to be added when a capacity deficiency is triggered. It cycles forward to a "design year", usually 20 years in the future. It checks the conditions in the design year and calculates the number of lanes to be added. The danger generally occurs when the capacity deficiency is not triggered until late in the analysis period. If a 20 year analysis period is being used, a capacity deficiency in year 20 would cycle forward to year 40 to determine the required number of lanes. With even a moderate traffic growth rate, the estimated traffic volume in 40 years can be substantial. With higher growth rates, the 40 year volumes can be very large.

One consequence of the forward cycling is that unreasonable numbers of added lanes can be simulated. TTI conducted a case study of simulated HPMS improvements in three Texas counties: Angelina, Montgomery, and Nacogdoches [6]. In more than half of the added capacity improvements, four or more lanes were added, including: 36 percent - 4 lanes, 17 percent - 6 lanes, and 2 percent - 8 lanes. It should be added that none of these counties have severely congested urban freeways or arterials. The results would be much more dramatic in an area such as Houston. This problem is compounded when the funding period analysis is used because up to four funding periods can be analyzed within the analysis period. The program can simulate an improvement for each of these funding periods.

The large number of lanes simulated for urban added-capacity improvements is the reason restrictions on the maximum number of lanes have such a substantial impact on the estimated future needs. This impact can be dramatic. For example, in the 1989 twenty year SMP [11, p. 6], the Full Needs Scenario estimate was $40.4 billion, which includes an unconstrained number of added lanes. When the maximum number of lanes was restricted to twelve, included in the Modified Full Needs Scenario, the estimate dropped to $35.4 billion, a decrease of over 12 percent. The restriction in the number of lanes is responsible for most or all of that decline.

There is another hidden effect of the maximum lane restriction. When a highway hits the maximum number of lanes, or if the facility is restricted to no additional widening, a lower level improvement is simulated for the highway, usually resurfacing. The additional congestion is ignored, while more than necessary resurfacing improvements are simulated.

A better way to handle the problem would be to restrict the number of lanes that can be added in any one funding period. Necessary multiple numbers of added lanes would occur over successive funding periods. This is a process similar to what is currently used, staging of added-capacity improvements over time as they are needed. It would also improve the accuracy of shorter term forecasts since the expensive added-capacity improvements would be spread out over more funding periods. There would be less "lumpiness" in the estimated needs. This becomes especially critical when making estimates at the district level.

Another major structural weakness within the program for making shorter term forecasts and simulating the effects of a limited budget involves the prioritization of needs. One significant advantage HPMS has over a manual procedure is that "what if" scenarios can be analyzed. Different assumed budget levels can be input and the impacts on the highway system tracked over time. This is an extremely valuable tool to demonstrate the benefits of increased funding, or conversely the negative impacts of spending cuts.

To accomplish this type of analysis, the program must go through a rather complex series of steps. The amount of available funds for each funding period, by functional class, is given in the input data when the funding period analysis is used. When the available funds are not sufficient for all simulated improvements in a given funding period, the proposed improvements are ranked, using a user selected method, either a cost effectiveness index or a composite index. Improvements are simulated, moving down the list, until the available funds are exhausted. Nothing is done for those proposed improvements that didn't rank high enough to be funded. There is no second iteration to potentially pick up a less expensive or lower level improvement for those highway sections, not even

needed resurfacing. They are merely cycled forward to the next funding period. Of course, by that time, the road may have deteriorated to the point that a much more expensive pavement reconstruction is simulated.

This "all or nothing" procedure for selecting improvements needs to be revised, both to reflect some tradeoff and to avoid unnecessary bias in simulating unnecessary pavement reconstruction expenditures. There is also a need to include a motorist benefit-cost index to prioritize the improvements when analyzing the impacts of limited funding levels. This will give much better project selection criteria and allow for explicit second level improvements through the use of an incremental benefit-cost algorithm.

A somewhat related problem involves the continued simulation of large pavement reconstruction needs in HPMS, even with no funding restrictions. For example in the SMP [6, p. 10], the modified full needs estimates shows reconstruction needs in the last five year period of about $1.9 billion. Presumably the program is simulating all pavement resurfacing needs as they occur. Why, then, are so many pavements allowed to deteriorate, requiring reconstruction? Again, the problem is the cycling forward logic. A resurfacing may be simulated at the beginning of the period, but a reconstruction by the end of the period. The higher level reconstruction is simulated, even though the resurfacing at the beginning of the period would have eliminated the need for the reconstruction.

In a related matter, the TTI case study of HPMS simulated improvements [6] found the program was allowing too much time between resurfacings. The average HPMS simulation was about 12 years, much longer than the average duration of overlays in Texas which generally have a life of 6 to 10 years.

Incorporation of Economic Analysis in HPMS

There are three areas within the current HPMS framework that would be the most likely to benefit with the addition of an economic analysis. These are the impact analysis, the rankings used in the investment analysis, and the deferred cost analysis. As described earlier, the impact analysis provides summary

information by area, functional class, and vehicle type for various performance measures. These measures include average overall travel speed in miles per hour and operating cost in dollars per thousand vehicle miles. Accident rates per 100 million vehicle miles are also given for property damage, data, and non-fatal injury accidents. Accident rates are not broken down by vehicle type; totals are given by area and functional class.

It would be very easy to convert the performance measures into a summary of total user costs, assuming a value of time for each category of vehicle and costs per accident for each of the three categories of accidents. However, those summary numbers would not give the benefits of the improvements because those user costs must be subtracted from the user costs had the improvements not been made, and the process repeated over the design life of the improvements with appropriate discounting and summing of the benefits.

Since the summary output by itself is not adequate to calculate benefits, calculations for individual sample sections must be examined. This is also necessary when considering the use of benefit-cost analysis to rank improvements in the investment analysis. The impact model is controlled by HPMSIMPT, which calls six subprograms to calculate effective speed, operating costs, fuel consumption, emissions, and accident rates. The calculations can be performed for both the base year and the target year at the end of each analysis period.

The important point here is that the impact performance measures would have to be calculated twice for each section with a simulated improvement during the analysis period, one calculation with improvement and another without the improvement. This is similar to what is already done in the needs analysis. Benefits of the improvement would simply be the difference between the two user cost calculations. Similar calculations would be required in the design year. That should not create a problem since the design v/c ratio is checked in the needs analysis for capacity deficiencies. Benefits between the target year and the design year could be interpolated; but, it may be desirable to calculate the benefits at one or more of the intermediate years,with the ideal being every year.

It should not be too difficult to modify HPMSIMPT to include the additional calculations above, including modification of the necessary data files, such as IVSTDATA. There is, however, a problem with the sequence in which the various analyses are performed. This becomes apparent when examining the section ranking analysis in HPMSIRNK which is controlled by the investment analysis model, HPMSIVST. The investment analysis, including section rankings, is completed before the impact analysis is performed. This would require a change in the order of analyses, calling the impact analysis before the investment analysis or preferably as part of the investment analysis. That way, the benefit-cost ratio could easily be added to the current techniques. In either case, the output of section rankings in HPMSLST should be modified to include the benefit-cost ratio for each improvement.

That same information could also be used in the deferred cost model, HMPSDCST. The additional user costs of deferring resurfacing could be summarized, along with the additional construction costs, to give a more complete estimate of the cost of deferring those maintenance activities.

There are some aspects of incorporating economic analysis into the HPMS analysis framework which need to be explored. One of these is the treatment of routine maintenance costs. Routine maintenance costs are generally treated as a change in the benefits that the improvement will generate. In the HPMS analysis, some types of maintenance are already considered and treated as separate improvements, such as resurfacing, either alone or in combination with other types of improvement. Other types of maintenance activities are not calculated. The potential and possibility of including some average maintenance cost by highway type and pavement condition should at least be explored. There should at least be a provision made for its possible inclusion in the future.

There is also the problem of the difference in the improvement year and the target year. An improvement may be simulated for any year during the analysis period; whereas all analyses are performed at the end of the analysis period, in the target year. It would be preferable to have the impact analysis calculate the user

benefits beginning in the improvement year rather than the target year. That way, there would be no distortion in the calculated benefits between the time the improvement is simulated and the time the analysis period ends. This calculation would require some adjustments in the data passed to the impact model, HPMSIMPT.

Another problem which will need to be resolved is what point in time should be used for discounting and present value. If construction costs are measured in terms of base year dollars, then the benefits should also be measured by the same dollars and not adjusted for inflation. However, that does not resolve the question of what year should be used as the base for discounting. One possibility would be to treat the base year analysis and each funding period analysis independently, similar to the current framework. One year in each analysis period would be designated as the base year for discounting improvements during that period. The most logical choice would be the improvement year, though the target year could also be used by using negative discounting for those years between the improvement year and target year.

The point should be made here that the benefit-cost ratio for individual sections is not affected by the year in which they are compared to each other. The same discounting factor would be applied to both the numerator benefits and the denominator costs so it would not matter for prioritizing with a limited budget. The only assumption required is that money is available from the analysis period budget in the year the improvement is simulated. By treating each analysis period separately, some care would be required in comparing user benefits. This could be accomplished by using summary benefit-cost ratios for each analysis period. These summary ratios would be an average of the benefit-cost ratios of the individual sections, weighted by the capital cost. These summary benefit-cost ratios could then be used to obtain summary ratios over multiple analysis periods, if desired. It would also be possible to provide summary net present value and internal rate of return information.

Another area that requires some attention is the incremental effects of multiple improvements on individual sections when more than one analysis period is used in the funding period analysis. As mentioned earlier, up to four analysis periods can be specified in the funding period analysis. It is, therefore, possible for an individual section to have up to four simulated improvements during the overall analysis period. Since more than one improvement can be simulated on the same highway section over time, the incremental benefits should be used for each improvement. Incremental benefits are the additional benefits of the improvement as compared to the conditions if the improvement is not made. The inventory year conditions would only be used to calculate the benefits of the first improvement. Subsequent improvements would use the conditions of the previously simulated improvement as the basis of comparison. Budget constraints would be incorporated as they are now if not enough money is available; then, any unfunded improvement would be ignored in the subsequent analysis period. That would also facilitate the deferred cost analysis since information on benefits which would have occurred had funding not been limited, could be carried to the next analysis period.

SELECTED REFERENCES

1. Elliott, A.V. Jr. "Planning for Texas' Needs Using the HPMS Analytical Process," Division of Planning and Policy, Texas Department of Transportation, Austin, Texas. Presented at the 71st annual meeting of the Transportation Research Board, Washington, D.C., January 1992.

2. "Highway Needs, An Evaluation of DOT's Process for Assessing the Nation's Highway Needs," GAO/RCED-87-136, U.S. General Accounting Office, Washington, D.C., August 1987.

3. "Highway Performance Monitoring System Analytical Process," Volume 2, Version 2.0, Technical Manual. Office of Highway Planning, Federal Highway Administration, Washington, D.C., January 1986.

4. "Highway Performance Monitoring System Field Manual," Office of Highway Planning, Federal Highway Administration, Washington, D.C., December 1987.

5. McPherson, L.W., M.R. Poole, and M.P. Strong. "Use of the Highway Performance Monitoring System (HPMS) and the Bridge Needs and Investment Process (BNIP) for Reporting Conditions, Needs, and Performance Trends," Division of Highways, North Carolina Department of Transportation. Presented at the 71st annual meeting of the Transportation Research Board, Washington, D.C., January 1992.

6. Memmott, J.L., T. Scullion, M. Chui. "Results of Examination of the Highway Performance Monitoring System for Implementation in Texas," Research Report 1115-1F, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, November 1989 (unpublished).

7. Memmott, J.L. "Results of the Evaluation of the Highway Performance Monitoring System for Use in Texas," Research Report 480-2F, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, June 1988.

8. Memmott, J.L. "Sample Size and Accuracy of Highway Performance Monitoring System," Research Report 480-1, Texas Transportation Institute, The Texas A&M University System, College Station, Texas, May 1986.

9. "Review of the Highway Performance Monitoring System," Cambridge Systematics, Inc. with Jack Faucett Associates, March 1991.

10. "Review of the Strategic Mobility Plan of the State Department of Highways and Public Transportation," Office of the State Auditor, Austin, Texas, October 1991.

11. "Strategic Mobility Plan, Identifying Transportation Requirements 1990-2009," Texas State Department of Highways and Public Transportation, Austin, Texas, February 1989.

12. Taqui, M. "Highway Performance Monitoring System (HPMS) Analytical Process, Application of Kentucky's Adequacy Program," Division of Planning, Kentucky Transport Cabinet. Presented at the 71st annual meeting of the Transportation Research Board, Washington, D.C., January 1992.

13. Zaniewski, J.P. (et al.), "Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors," Final Report, Texas Research and Development Foundation, Austin, June 1982.

APPENDIX. Default Tables of Estimated Consumption Equations

Table A1. Estimated Equations of Fuel Consumption (gal/1,000 miles) (liter/425 km) for Passenger Vehicle, All Grades

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade	Log (GVW)
Small	0	0	5	70	Log(Fuel)	4.60257	-.06314	+.00070	0.00000	0.00000	0.00000
Med/Large	0	0	5	70	Fuel	65.46896	-1.47217	+.02127	0.00000	0.00000	0.00000
Pickup/Van	0	0	5	70	Fuel	89.01594	-2.11606	+.03107	0.00000	0.00000	0.00000
Bus[1]	0	0	5	70	Log(Fuel)	6.61674	0.00000	+.00012	-.46560	0.00000	0.00000
Small	1	3	5	70	Log(Fuel)	4.47531	-.05344	+.00059	0.00000	+.08101	0.00000
Med/Large	1	3	5	70	Fuel	69.34780	-1.5070	+.02080	0.00000	+5.8429	0.00000
Pickup/Van	1	3	5	70	Log(Fuel)	4.48628	-.02490	+.00039	0.00000	+.10702	0.00000
Bus[1]	1	1	5	70	Log(Fuel)	6.52570	0.00000	+.00006	-.32107	0.00000	0.00000
Bus[1]	2	3	5	70	Log(Fuel)	6.35517	0.00000	+.00004	-.25346	+.08302	0.00000
Small	4	8	5	70	Log(Fuel)	4.36469	-.04992	+.00060	0.00000	+.05192	0.00000
Med/Large	4	8	5	70	Log(Fuel)	4.24982	0.00000	+.00015	-.16509	+.07526	0.00000
Pickup/Van	4	8	5	70	Log(Fuel)	4.50300	-.02220	0.00037	0.00000	+.06767	0.00000
Bus[1]	4	8	5	70	Log(Fuel)	6.79373	0.00000	+.00006	-.35702	+.03851	0.00000

Table A1. Estimated Equations of Fuel Consumption (gal/1,000 miles) (liter/425 km) for Passenger Vehicle, All Grades (Continued)

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade	Log (GVW)
Small	-1	-1	5	70	Fuel	69.13242	-2.27456	+.02532	0.00000	0.00000	0.00000
Med/Large	-1	-1	5	70	Log(Fuel)	4.16310	-.03635	+.00053	0.00000	0.00000	0.00000
Pickup/Van	-1	-1	5	70	Fuel	123.95770	0.00000	+.01462	-28.45070	0.00000	0.00000
Bus[1]	-1	-1	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Small	-2	-2	5	70	Log(Fuel)	4.26029	-.06486	+.00074	0.00000	0.00000	0.00000
Med/Large	-2	-2	5	70	Fuel	62.20275	-1.83863	+.02586	0.00000	0.00000	0.00000
Pickup/Van	-2	-2	5	70	Fuel	124.33610	0.00000	+.01210	-29.52452	0.00000	0.00000
Bus[1]	-2	-2	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Small	-3	-3	5	70	Log(Fuel)	4.12032	-.06188	+.00070	0.00000	0.00000	0.00000
Med/Large	-3	-3	5	70	Fuel	63.59725	-2.05862	+.02815	0.00000	0.00000	0.00000
Pickup/Van	-3	-3	5	70	Fuel	81.61209	-2.60877	+.03224	0.00000	0.00000	0.00000
Bus[1]	-3	-3	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Small	-8	-4	5	70	Fuel	48.16088	-1.30720	+.01423	0.00000	+.90714	0.00000
Med/Large	-8	-4	5	70	Fuel	81.55231	-2.25895	+.02673	0.00000	+2.57036	0.00000
Pickup/Van	-8	-4	5	70	Fuel	91.59330	-2.84572	+.03299	0.00000	+.83643	0.00000
Bus[1]	-8	-4	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000

[1]The Buses are treated as single unit 3A trucks. Therefore, fuel consumption equations for SU-3A are used with the constants adjusted after substituting the gross vehicle weight of 35 kips into the log(GVW) terms.

Table A2. **Estimated Equations of Fuel Consumption (gal/1,000 miles) (liter/425 km) for Truck, All Grades**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade	Log (GVW)
SU-2A	0	0	5	70	Log(Fuel)	5.57605	0.00000	+.00012	-.46560	0.00000	+.29271
SU-3A	0	0	5	70	Log(Fuel)	5.57605	0.00000	+.00012	-.46560	0.00000	+.29271
2-S2	0	0	5	70	Log(Fuel)	5.57605	0.00000	+.00012	-.46560	0.00000	+.29271
3-S2	0	0	5	70	Log(Fuel)	5.57605	0.00000	+.00012	-.46560	0.00000	+.29271
SU-2A	1	1	5	70	Log(Fuel)	5.14121	0.00000	+.00006	-.32107	0.00000	+.38941
SU-3A	1	1	5	70	Log(Fuel)	5.14121	0.00000	+.00006	-.32107	0.00000	+.38941
2-S2	1	1	5	70	Log(Fuel)	5.14121	0.00000	+.00006	-.32107	0.00000	+.38941
3-S2	1	1	5	70	Log(Fuel)	5.14121	0.00000	+.00006	-.32107	0.00000	+.38941
SU-2A	2	3	5	70	Log(Fuel)	4.73411	0.00000	+.00004	-.25346	+.08302	+.45595
SU-3A	2	3	5	70	Log(Fuel)	4.73411	0.00000	+.00004	-.25346	+.08302	+.45595
2-S2	2	3	5	70	Log(Fuel)	4.73411	0.00000	+.00004	-.25346	+.08302	+.45595
3-S2	2	3	5	70	Log(Fuel)	4.73411	0.00000	+.00004	-.25346	+.08302	+.45595
SU-2A	4	8	5	70	Log(Fuel)	5.25999	0.00000	+.00006	-.35702	+.03851	+.43139
SU-3A	4	8	5	70	Log(Fuel)	5.25999	0.00000	+.00006	-.35702	+.03851	+.43139
2-S2	4	8	5	70	Log(Fuel)	5.25999	0.00000	+.00006	-.35702	+.03851	+.43139
3-S2	4	8	5	70	Log(Fuel)	5.25999	0.00000	+.00006	-.35702	+.03851	+.43139

Table A2. Estimated Equations of Fuel Consumption (gal/1,000 miles) (liter/425 km) for Truck, All Grades (Continued)

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade	Log (GVW)
SU-2A	-1	-1	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SU-3A	-1	-1	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2-S2	-1	-1	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3-S2	-1	-1	5	70	Log(Fuel)	+7.13515	0.00000	+.00025	-.72799	0.00000	-.13929
SU-2A	-2	-2	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SU-3A	-2	-2	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2-S2	-2	-2	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3-S2	-2	-2	5	70	Fuel	+403.414	0.00000	+.02398	-76.6621	0.00000	-34.4706
SU-2A	-3	-3	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SU-3A	-3	-3	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2-S2	-3	-3	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3-S2	-3	-3	5	70	Fuel	+291.820	-4.9379	+.05730	0.00000	0.00000	-47.7028
SU-2A	-8	-4	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
SU-3A	-8	-4	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2-S2	-8	-4	5	70	Fuel	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3-S2	-8	-4	5	70	Fuel	+377.779	0.00000	+.01456	-49.3651	+3.7289	-53.1810

Table A3. **Estimated Equations of Oil Consumption (qrt/1,000 miles) (liter/1,700 km) for Passenger Vehicle, All Grades**

Vehicle Type	Min. Grade Level	Max. Grade Level	Dep. Var.	Constant	Speed	$(Speed)^2$	Log (Speed)	Grade
Small	0	0	Log(Oil)	2.57939	+.01924	0.00000	-.83012	0.00000
Med/Large	0	0	Log(Oil)	2.57939	+.01924	0.00000	-.83012	0.00000
Pickup/Van	0	0	Log(Oil)	2.23085	+.00847	0.00000	-.65423	0.00000
Bus	0	0	Log(Oil)	2.38812	-.05455	+.00060	0.00000	0.00000
Small	1	8	Log(Oil)	2.26041	-.06830	+.00058	0.00000	+.14691
Med/Large	1	8	Log(Oil)	2.24299	-.06698	+.00057	0.00000	+.14936
Pickup/Van	1	8	Log(Oil)	1.96924	-.05747	+.00041	0.00000	+.14066
Bus	1	8	Log(Oil)	4.61845	+.00720	0.00000	-.87045	+.18379
Small	-3	-1	Log(Oil)	2.76915	+.02130	0.00000	-.91578	-.01851
Med/Large	-3	-1	Log(Oil)	2.77091	+.02127	0.00000	-.91649	-.01997
Pickup/Van	-3	-1	Log(Oil)	2.23085	+.00847	0.00000	-.65423	0.00000
Bus	-1	-1	Log(Oil)	3.30844	0.00000	+.00017	-.64280	0.00000
Bus	-2	-2	Log(Oil)	4.03923	0.00000	+.00023	-.87247	0.00000
Bus	-3	-3	Log(Oil)	5.24339	0.00000	+.00018	-1.13044	0.00000
Small	-8	-4	Log(Oil)	2.19462	-.09917	+.00090	0.00000	-.13498
Med/Large	-8	-4	Log(Oil)	2.14505	-.09609	+.00086	0.00000	-.14117
Pickup/Van	-8	-4	Log(Oil)	1.69875	-.08221	+.00069	0.00000	-.12817
Bus	-8	-4	Log(Oil)	4.08234	-.00763	0.00000	-.78429	-.22411

Table A4. Estimated Equations of Oil Consumption (qrt/1,000 miles) (liter/1,700 km) for Truck, All Grades

Vehicle Type	Min. Grade Level	Max. Grade Level	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade
SU-2A	0	0	Log(Oil)	1.99570	-.05372	+.00058	0.00000	0.00000
SU-3A	0	0	Log(Oil)	2.38812	-.05455	+.00060	0.00000	0.00000
2-S2	0	0	Log(Oil)	2.38812	-.05455	+.00060	0.00000	0.00000
3-S2	0	0	Log(Oil)	3.12838	-.05509	+.00054	0.00000	0.00000
SU-2A	1	8	Log(Oil)	4.11779	0.00000	0.00000	-.78006	+.17116
SU-3A	1	8	Log(Oil)	4.61845	+.00720	0.00000	-.87045	+.18379
2-S2	1	8	Log(Oil)	4.42823	0.00000	0.00000	-.73422	+.18284
3-S2	1	8	Log(Oil)	5.22750	0.00000	0.00000	-.76940	+.19248

Table A4. Estimated Equations of Oil Consumption (qrt/1,000 miles) (liter/1,700 km) for Truck, All Grades (Continued)

Vehicle Type	Min. Grade Level	Max. Grade Level	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade
SU-2A	-1	-1	Log(Oil)	1.99570	-.05372	+.00058	0.00000	0.00000
SU-3A	-1	-1	Log(Oil)	3.30844	0.00000	+.00017	-.64280	0.00000
2-S2	-1	-1	Log(Oil)	3.30844	0.00000	+.00017	-.64280	0.00000
3-S2	-1	-1	Log(Oil)	3.12838	-.05509	+.00054	0.00000	0.00000
SU-2A	-2	-2	Log(Oil)	3.55234	0.00000	+.00022	-.84156	0.00000
SU-3A	-2	-2	Log(Oil)	4.03923	0.00000	+.00023	-.87247	0.00000
2-S2	-2	-2	Log(Oil)	4.23815	0.00000	+.00023	-.92610	0.00000
3-S2	-2	-2	Log(Oil)	3.67707	-.07838	+.00077	0.00000	0.00000
SU-2A	-3	-3	Log(Oil)	4.94918	0.00000	+.00024	-1.20918	0.00000
SU-3A	-3	-3	Log(Oil)	5.24339	0.00000	+.00018	-1.13044	0.00000
2-S2	-3	-3	Log(Oil)	5.33235	0.00000	+.00016	-1.13366	0.00000
3-S2	-3	-3	Log(Oil)	4.46459	-.08908	+.00074	0.00000	0.00000
SU-2A	-8	-4	Log(Oil)	4.23252	-.00791	0.00000	-.93418	-.18195
SU-3A	-8	-4	Log(Oil)	4.08234	-.00763	0.00000	-.78429	-.22411
2-S2	-8	-4	Log(Oil)	4.08991	-.01432	0.00000	-.69386	-.21236
3-S2	-8	-4	Log(Oil)	4.46084	-.01858	0.00000	-.53919	-.22619

Table A5. Estimated Equations of Tire Consumption (% wear/1,000 miles) (% wear/1,610 km) for Passenger Vehicle, All Grades

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade	Grade^2
Small	0	0	5	70	Log(Tire)	-2.65246	+.05166	0.00000	-.24280	0.00000	0.00000	0.00000
Med/Large	0	0	5	70	Log(Tire)	-2.24359	+.05101	0.00000	-.30075	0.00000	0.00000	0.00000
Pickup/Van	0	0	5	70	Log(Tire)	-1.88830	+.04582	0.00000	-.28011	0.00000	0.00000	0.00000
Bus	0	0	5	70	Tire	.12474	0.00000	+.00013	-.01199	0.00000	0.00000	0.00000
Small	1	8	5	70	Tire	-.45900	-.00763	+.00043	0.00000	0.00000	+.29870	0.00000
Med/Large	1	8	5	70	Log(Tire)	-1.48703	+.00703	+.00017	0.00000	0.00000	+.26875	0.00000
Pickup/Van	1	8	5	70	Log(Tire)	-1.30150	+.00655	+.00016	0.00000	0.00000	+.24823	0.00000
Bus	1	8	5	70	Tire	-1.21760	0.00000	+.00037	0.00000	0.00000	+.78853	0.00000
Small	-3	-1	5	70	Tire	-.09079	0.00000	+.00018	0.00000	+.00392	-.09486	0.00000
Med/Large	-3	-1	5	70	Tire	-.00864	0.00000	+.00020	0.00000	+.00459	0.00000	+.02899
Pickup/Van	-3	-1	5	70	Tire	-.04878	0.00000	+.00021	0.00000	+.00423	-.08041	0.00000
Bus	-1	-1	5	70	Tire	+.05033	-.00398	+.00012	0.00000	0.00000	0.00000	0.00000
Bus	-2	-2	5	70	Tire	+.22044	-.00663	+.00007	0.00000	0.00000	0.00000	0.00000
Bus	-3	-3	5	70	Tire	+.44297	-.00334	-.00003	0.00000	0.00000	0.00000	0.00000
Small	-8	-4	5	70	Tire	+.04407	0.00000	+.00007	0.00000	+.00224	0.00000	+.01725
Med/Large	-8	-4	5	70	Tire	+.05195	0.00000	+.00006	0.00000	+.00249	0.00000	+.02148
Pickup/Van	-8	-4	5	70	Tire	+.03295	0.00000	+.00008	0.00000	+.00253	0.00000	+.01942
Bus	-8	-4	5	70	Tire	-1.38877	-.01409	0.00000	0.00000	0.00000	-.59043	0.00000

Table A6. **Estimated Equations of Tire Consumption (% wear/1,000 miles) (% wear/1,610 km) for Truck, All Grades**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade
SU-2A	0	0	5	70	Tire	.32219	0.00000	+.00035	-.11070	0.00000
SU-3A	0	0	5	70	Tire	.12474	0.00000	+.00013	-.01199	0.00000
2-S2	0	0	5	70	Tire	.16831	0.00000	+.00014	-.04058	0.00000
3-S2	0	0	5	70	Tire	.15559	0.00000	+.00010	-.01909	0.00000
SU-2A	1	8	5	70	Tire	-2.12563	0.00000	+.00082	0.00000	+1.13765
SU-3A	1	8	5	70	Tire	-1.21760	0.00000	+.00037	0.00000	+.78853
2-S2	1	8	5	70	Tire	-1.06507	0.00000	+.00034	0.00000	+.65886
3-S2	1	8	5	70	Tire	-1.14998	0.00000	+.00027	0.00000	+.79965

Table A6. Estimated Equations of Tire Consumption (% wear/1,000 miles) (% wear/1,610 km) for Truck, All Grades (Continued)

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Grade
SU-2A	-1	-1	5	70	Tire	.11731	-.01365	+.00037	0.00000	0.00000
SU-3A	-1	-1	5	70	Tire	.05033	-.00398	+.00012	0.00000	0.00000
2-S2	-1	-1	5	70	Tire	.06775	-.00550	+.00014	0.00000	0.00000
3-S2	-1	-1	5	70	Tire	.06956	-.00407	+.00009	0.00000	0.00000
SU-2A	-2	-2	5	70	Tire	.32440	-.01912	+.00030	0.00000	0.00000
SU-3A	-2	-2	5	70	Tire	.22044	-.00663	+.00007	0.00000	0.00000
2-S2	-2	-2	5	70	Tire	.22242	-.00785	+.00009	0.00000	0.00000
3-S2	-2	-2	5	70	Tire	.22780	-.00288	0.00000	0.00000	0.00000
SU-2A	-3	-3	5	70	Tire	.63593	-.01760	+.00014	0.00000	0.00000
SU-3A	-3	-3	5	70	Tire	.44297	-.00334	-.00003	0.00000	0.00000
2-S2	-3	-3	5	70	Tire	.40923	-.00422	-.00002	0.00000	0.00000
3-S2	-3	-3	5	70	Tire	.51077	-.00232	-.00005	0.00000	0.00000
SU-2A	-8	-4	5	70	Tire	-1.29533	-.03136	0.00000	0.00000	-.70321
SU-3A	-8	-4	5	70	Tire	-1.38877	-.01409	0.00000	0.00000	-.59043
2-S2	-8	-4	5	70	Tire	-.97556	-.01612	0.00000	0.00000	-.48257
3-S2	-8	-4	5	70	Tire	-1.51533	-.01413	0.00000	0.00000	-.65021

Table A7. **Estimated Equations of Depreciation Consumption (% dep. value/1,000 miles) (% dep. value/1,610 km) for Passenger Vehicle, All Grades**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	Log (Speed)
Small	-8	+8	5	70	DEP	2.19872	+.00160	-.38011
Med/Large	-8	+8	5	70	DEP	1.41670	0.00000	-.22743
Pickup/Van	-8	+8	5	70	DEP	.74196	+.00059	-.13068
Bus	-8	+8	5	70	DEP	1.12633	+.00279	-.24714

Table A8. **Estimated Equations of Depreciation Consumption (% dep. value/1,000 miles) (% dep. value/1,610 km) for Truck, All Grades**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	Log (Speed)
SU-2A	-8	+8	5	70	DEP	1.12634	+.00279	-.24714
SU-3A	-8	+8	5	70	DEP	1.12633	+.00279	-.24714
2-S2	-8	+8	5	70	DEP	.35453	+.00097	-.08057
3-S2	-8	+8	5	70	DEP	.39540	+.00122	-.09416

Table A9. Estimated Equations of Maintenance Consumption (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Passenger Vehicle, All Grades

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade	Grade^2
Small	0	0	5	70	MRP	55.37146	+.93672	0.00000	-7.71688	0.00000	0.00000	0.00000
Med/Large	0	0	5	70	MRP	45.27033	+.23715	+.005800	0.00000	0.00000	0.00000	0.00000
Pickup/Van	0	0	5	70	MRP	56.66170	+.95788	0.00000	-7.99505	0.00000	0.00000	0.00000
Bus	0	0	5	70	MRP	46.64396	-.04331	+.00853	0.00000	0.00000	0.00000	0.00000
Small	1	8	5	70	Log(MRP)	3.68063	+.01239	0.00000	0.00000	0.00000	+.02388	0.00000
Med/Large	1	8	5	70	Log(MRP)	3.68199	+.01259	0.00000	0.00000	0.00000	+.02644	0.00000
Pickup/Van	1	8	5	70	Log(MRP)	3.69663	+.01246	0.00000	0.00000	0.00000	+.02470	0.00000
Bus	1	8	5	70	MRP	46.14116	0.00000	+.00796	0.00000	+.14595	0.00000	0.00000

Table A9. **Estimated Equations of Maintenance Consumption (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Passenger Vehicle, All Grades (Continued)**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade	Grade^2
Small	-1	-1	5	70	MRP	39.1626	+.61719	0.00000	0.00000	0.00000	0.00000	0.00000
Med/Large	-1	-1	5	70	MRP	56.0162	+.88884	0.00000	-7.85920	0.00000	0.00000	0.00000
Pickup/Van	-1	-1	5	70	MRP	39.8846	+.62651	0.00000	0.00000	0.00000	0.00000	0.00000
Bus	-1	-1	5	15	MRP	17.3668	-.15000	0.00000	0.00000	0.00000	0.00000	0.00000
Bus	-1	-1	15	20	MRP	-80.5055	+6.37481	0.00000	0.00000	0.00000	0.00000	0.00000
Bus	-1	-1	20	70	MRP	49.3421	-.31417	+.00983	0.00000	0.00000	0.00000	0.00000
Small	-2	-2	5	70	MRP	53.0730	+1.23358	0.00000	-12.7726	0.00000	0.00000	0.00000
Med/Large	-2	-2	5	70	MRP	49.8294	+1.19805	0.00000	-11.5025	0.00000	0.00000	0.00000
Pickup/Van	-2	-2	5	70	MRP	21.7044	+.90712	0.00000	0.00000	0.00000	0.00000	0.00000
Bus	-2	-2	5	50	MRP	31.9683	-.11598	-.00205	0.00000	0.00000	0.00000	0.00000
Bus	-2	-2	50	55	MRP	-300.5124	+6.43113	0.00000	0.00000	0.00000	0.00000	0.00000
Bus	-2	-2	55	70	MRP	9.20000	+.80000	0.00000	0.00000	0.00000	0.00000	0.00000
Small	-3	-3	5	70	MRP	74.3555	-1.59324	+.02473	0.00000	0.00000	0.00000	0.00000
Med/Large	-3	-3	5	70	MRP	71.3390	-1.44313	+.02281	0.00000	0.00000	0.00000	0.00000
Pickup/Van	-3	-3	5	70	MRP	76.3409	0.00000	+.01160	-11.6211	0.00000	0.00000	0.00000
Bus	-3	-3	5	70	MRP	46.8956	-.14263	-.00153	0.00000	0.00000	0.00000	0.00000
Small	-8	-4	5	70	MRP	-33.4831	+.57559	0.00000	0.00000	+.28541	-30.0985	0.00000
Med/Large	-8	-4	5	70	MRP	61.4176	0.00000	-.00021	0.00000	+.16836	0.00000	+2.1075
Pickup/Van	-8	-4	5	70	MRP	-49.2782	+.97953	0.00000	0.00000	+.32926	-31.1880	0.00000
Bus	-8	-4	5	70	MRP	4.25714	-.25829	0.00000	0.00000	0.00000	-14.7014	0.00000

Table A10. **Estimated Equations of Maintenance and Repair Consumption (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Truck, All Grades**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade
SU-2A	0	0	5	70	MRP	63.93518	+1.38731	0.00000	-14.9073	0.00000	0.00000
SU-3A	0	0	5	70	MRP	46.64396	-.04331	+.00853	0.00000	0.00000	0.00000
2-S2	0	0	5	70	Log(MRP)	3.78787	+.00171	+.00013	0.00000	0.00000	0.00000
3-S2	0	0	5	70	Log(MRP)	3.96204	+.01817	0.00000	-.14413	0.00000	0.00000
SU-2A	1	1	5	70	MRP	18.12171	+.76545	+.01012	0.00000	0.00000	+5.44864
SU-3A	1	1	5	70	MRP	46.14116	0.00000	+.00796	0.00000	+.14595	0.00000
2-S2	1	1	5	70	MRP	43.65773	0.00000	+.00099	0.00000	+.16055	0.00000
3-S2	1	1	5	70	MRP	32.97473	+.86673	0.00000	0.00000	+.25415	0.00000
SU-2A	2	2	5	70	MRP	18.12171	+.76545	+.01012	0.00000	0.00000	+5.44864
SU-3A	2	2	5	70	MRP	46.14116	0.00000	+.00796	0.00000	+.14595	0.00000
2-S2	2	2	5	70	MRP	43.65773	0.00000	+.00099	0.00000	+.16055	0.00000
3-S2	2	2	5	70	MRP	32.97473	+.86673	0.00000	0.00000	+.25415	0.00000
SU-2A	3	3	5	70	MRP	18.12171	+.76545	+.01012	0.00000	0.00000	+5.44864
SU-3A	3	3	5	70	MRP	46.14116	0.00000	+.00796	0.00000	+.14595	0.00000
2-S2	3	3	5	70	MRP	43.65773	0.00000	+.00099	0.00000	+.16055	0.00000
3-S2	3	3	5	70	MRP	32.97473	+.86673	0.00000	0.00000	+.25415	0.00000
SU-2A	4	8	5	70	MRP	18.12171	+.76545	+.01012	0.00000	0.00000	+5.44864
SU-3A	4	8	5	70	MRP	46.14116	0.00000	+.00796	0.00000	+.14595	0.00000
2-S2	4	8	5	70	MRP	43.65773	0.00000	+.00099	0.00000	+.16055	0.00000
3-S2	4	8	5	70	MRP	32.97473	+.86673	0.00000	0.00000	+.25415	0.00000

Table A10. **Estimated Equations of Maintenance and Repair Consumption (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Truck, All Grades (Continued)**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade
SU-2A	-1	-1	5	10	MRP	+18.30000	-.34000	0.00000	0.00000	0.00000	0.00000
SU-2A	-1	-1	10	15	MRP	-26.79350	+4.16935	0.00000	0.00000	0.00000	0.00000
SU-2A	-1	-1	15	70	MRP	+37.43410	+.22229	+.00732	0.00000	0.00000	0.00000
SU-3A	-1	-1	5	15	MRP	+17.36667	-.15000	0.00000	0.00000	0.00000	0.00000
SU-3A	-1	-1	15	20	MRP	-80.50545	+6.37481	0.00000	0.00000	0.00000	0.00000
SU-3A	-1	-1	20	70	MRP	+49.34211	-.31417	+.00983	0.00000	0.00000	0.00000
2-S2	-1	-1	5	20	MRP	+15.94463	-.27050	0.00000	+1.42958	0.00000	0.00000
2-S2	-1	-1	20	25	MRP	-111.0759	+6.29466	0.00000	0.00000	0.00000	0.00000
2-S2	-1	-1	25	70	MRP	+52.81956	-.64641	+.01541	0.00000	0.00000	0.00000
3-S2	-1	-1	5	25	MRP	+18.61805	-.02683	0.00000	-.73066	0.00000	0.00000
3-S2	-1	-1	25	30	MRP	-142.8940	+6.33958	0.00000	0.00000	0.00000	0.00000
3-S2	-1	-1	30	70	MRP	+30.75908	+.41794	+.00444	0.00000	0.00000	0.00000

Table A10. **Estimated Equations of Maintenance and Repair Consumption (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Truck, All Grades (Continued)**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade
SU-2A	-2	-2	5	40	MRP	+33.62500	-.23905	-.00286	0.00000	0.00000	0.00000
SU-2A	-2	-2	40	45	MRP	-270.5989	+7.25215	0.00000	0.00000	0.00000	0.00000
SU-2A	-2	-2	45	70	MRP	+16.55904	+.87086	0.00000	0.00000	0.00000	0.00000
SU-3A	-2	-2	5	50	MRP	+31.96833	-.11598	-.00205	0.00000	0.00000	0.00000
SU-3A	-2	-2	50	55	MRP	-300.5124	+6.43113	0.00000	0.00000	0.00000	0.00000
SU-3A	-2	-2	55	70	MRP	+9.20000	+.80000	0.00000	0.00000	0.00000	0.00000
2-S2	-2	-2	5	50	MRP	+33.12500	-.04286	-.00432	0.00000	0.00000	0.00000
2-S2	-2	-2	50	55	MRP	-324.9966	+6.90357	0.00000	0.00000	0.00000	0.00000
2-S2	-2	-2	55	70	MRP	+67.89986	-1.34000	+.02000	0.00000	0.00000	0.00000
3-S2	-2	-2	5	60	MRP	+32.92954	-.03046	-.00095	0.00000	0.00000	0.00000
3-S2	-2	-2	60	65	MRP	-362.5348	+6.50361	0.00000	0.00000	0.00000	0.00000
3-S2	-2	-2	65	70	MRP	+12.10000	+.74000	0.00000	0.00000	0.00000	0.00000
SU-2A	-3	-3	5	55	MRP	+48.95636	-.16987	-.00445	0.00000	0.00000	0.00000
SU-2A	-3	-3	55	60	MRP	-348.3729	+6.80955	0.00000	0.00000	0.00000	0.00000
SU-2A	-3	-3	60	70	MRP	+15.80000	+.74000	0.00000	0.00000	0.00000	0.00000
SU-3A	-3	-3	5	70	MRP	+46.89560	-.14263	-.00153	0.00000	0.00000	0.00000

Table A10. **Estimated Equations of Maintenance and Repair Consumption (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Truck, All Grades (Continued)**

Vehicle Type	Min. Grade Level	Max. Grade Level	Min. Speed Allowed	Max. Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2	Log (Speed)	Speed* Grade	Grade
2-S2	-3	-3	5	25	MRP	49.23986	-.07822	-.00362	0.00000	0.00000	0.00000
2-S2	-3	-3	25	65	MRP	49.23986	-.07822	-.00362	0.00000	0.00000	0.00000
2-S2	-3	-3	65	70	MRP	-386.3452	+6.38779	0.00000	0.00000	0.00000	0.00000
3-S2	-3	-3	5	70	MRP	+48.39561	+.00457	-.00157	0.00000	0.00000	0.00000
SU-2A	-8	-4	5	70	MRP	4.48604	-.23424	-.00345	0.00000	0.00000	-15.46857
SU-3A	-8	-4	5	70	MRP	4.25714	-.25829	0.00000	0.00000	0.00000	-14.70143
2-S2	-8	-4	5	70	MRP	2.11791	-.10026	-.00326	0.00000	0.00000	-15.78286
3-S2	-8	-4	5	70	MRP	2.54385	-.11260	0.00000	0.00000	0.00000	-15.81357

Table A11. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for Small Auto

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	-.12004	-.01477	+.18170	0.00000	0.00000	+.11373
2	5	70	XFuel	.04782	0.00000	-.17710	0.00000	+.00004	+.03423
3	5	70	XFuel	.23458	0.00000	-.30190	0.00000	+.00008	+.01075
4	5	70	XFuel	.17393	0.00000	-.49040	0.00000	+.00014	+.07087
5	5	70	XFuel	.24939	0.00000	-.73940	0.00000	+.00024	+.09413
6	5	70	XFuel	.17900	0.00000	-1.04500	0.00000	+.00037	+.15618
8	5	70	XFuel	-.29086	0.00000	-2.03440	0.00000	+.00080	+.42323
10	5	65	XFuel	-.73334	0.00000	-3.24840	0.00000	+.00138	+.71581
12	5	55	XFuel	-1.47611	0.00000	-4.86910	0.00000	+.00222	+1.13416
14	5	50	XFuel	.28496	0.00000	-2.29520	0.00000	+.00178	+.15677
16	5	45	XFuel	-2.39275	0.00000	-23.77520	+.86380	-.00747	+2.00789
18	5	40	XFuel	.76674	0.00000	+12.83510	-.92060	+.01738	-.40581
20	5	40	XFuel	.66596	0.00000	+13.00110	-.97880	+.01919	-.34492
25	5	35	XFuel	3.04744	0.00000	+41.38690	-2.49070	+.04323	-2.14485
30	5	30	XFuel	-4.19216	0.00000	-74.78830	+4.34500	-.07096	+3.63861

Table A12. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for Medium/Large Auto

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	-.00231	-.013550	0.00000	+.00001	+.00147
2	5	70	XFuel	.14723	-.61340	+.00867	0.00000	+.07359
3	5	70	XFuel	.32919	-.63750	0.00000	+.00015	+.08602
4	5	70	XFuel	.44958	-1.06690	0.00000	+.00027	+.14245
5	5	70	XFuel	.29760	-1.59870	0.00000	+.00043	+.28454
6	5	70	XFuel	2.43712	+6.49270	-.24580	+.00258	-.98080
8	5	70	XFuel	6.03247	+22.30020	-.76500	+.00751	-3.17567
10	5	65	XFuel	.49775	-5.65390	+.12100	+.00011	+.37844
12	5	55	XFuel	.03859	-9.57100	+.24160	-.00035	+.70635
14	5	50	XFuel	.33743	-7.77310	+.13600	+.00183	+.50595
16	5	45	XFuel	.39609	-8.02610	+.11450	+.00321	+.47403
18	5	40	XFuel	1.96827	+7.64740	-.65640	+.01465	-.67102
20	5	40	XFuel	2.40092	+11.79410	-.90490	+.01963	-.98418
25	5	35	XFuel	3.07259	+19.76860	-1.39610	+.03044	-1.51748
30	5	30	XFuel	-1.12869	-45.52710	+2.31340	-.02719	+1.82773

Table A13. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for Pickup/Van

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	+.12857	+.64730	-.022130	+.00023	-.08236
2	5	70	XFuel	+.31411	+1.05130	-.046570	+.00051	-.08097
3	5	70	XFuel	.38643	+1.63170	-.086690	+.00103	-.01532
4	5	70	XFuel	1.13073	+4.35900	-.19290	+.00218	-.36570
5	5	70	XFuel	1.88308	+8.37680	-.35060	+.00391	-.79444
6	5	70	XFuel	3.78933	+17.48410	-.67180	+.00716	-1.94754
8	5	65	XFuel	6.58963	+34.38590	-1.32310	+.01440	-3.76237
10	5	55	XFuel	3.52723	+16.02640	-.73270	+.00974	-1.69684
12	5	50	XFuel	-1.61337	-23.64780	+.81260	-.00626	+1.87158
14	5	50	XFuel	-2.15578	-29.55200	+1.02920	-.00745	+2.26783
16	5	45	XFuel	-2.61448	-35.32800	+1.25490	-.00870	+2.63010
18	5	40	XFuel	.90377	+2.56920	-.60560	+.01842	-.00548
20	5	35	XFuel	1.29721	+6.30870	-.87090	+.02503	-.29160
25	5	35	XFuel	.87860	+1.94720	-.89690	+.03393	+.02907
30	5	30	XFuel	4.06724	+51.38940	-4.06350	+.09760	-2.48754

Table A14. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for Bus

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	-.16472	0.00000	-.31890	0.00000	+.00027	+.093981
2	5	70	XFuel	-1.26330	0.00000	-3.77670	0.00000	+.00088	+1.38230
3	5	70	XFuel	-2.58741	0.00000	-8.19290	0.00000	+.00200	+2.86620
4	5	65	XFuel	-4.27543	0.00000	-13.55840	0.00000	+.00363	+4.43987
5	5	65	XFuel	-6.52723	0.00000	-19.94200	0.00000	+.00597	+6.09281
6	5	55	XFuel	-4.98749	0.00000	-21.07290	0.00000	+.00724	+5.57733
8	5	55	XFuel	6.80158	+1.03062	0.00000	-1.83250	+.03377	-4.51476
10	5	55	XFuel	7.63917	+.99803	0.00000	-2.07340	+.04284	-4.68605
12	5	45	XFuel	1.44154	+.06654	0.00000	-1.65330	+.04402	+1.86502
14	5	40	XFuel	-4.54485	0.00000	-44.87820	0.00000	+.03266	+6.17435
16	5	40	XFuel	-5.27732	0.00000	-53.79370	0.00000	+.04437	+6.73465
18	5	35	XFuel	-4.42510	0.00000	-56.75430	0.00000	+.05344	+6.26160
20	5	30	XFuel	-3.14184	0.00000	-58.06280	0.00000	+.06219	+5.51961
25	5	30	XFuel	-3.60491	0.00000	-73.37330	0.00000	+.09813	+5.92667
30	5	30	XFuel	-4.09677	0.00000	-92.17830	0.00000	+.14890	+6.45109

Table A15. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for Single Unit 2A Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	Log(Speed)
1	5	70	XFuel	.01368	-.00383	+.16010	+.00116
2	5	70	XFuel	.17868	-.14728	+1.43800	+.92475
3	5	70	XFuel	.21873	-.31160	+3.09050	+1.98035
4	5	65	XFuel	.56296	-.45947	+4.81120	+2.75639
5	5	65	XFuel	.02935	-.65694	+7.33960	+3.94820
6	5	55	XFuel	.47806	-.75887	+9.12510	+4.23327
8	5	55	XFuel	-.19574	-1.13630	+15.44390	+6.04943
10	5	55	XFuel	-.62918	-1.48570	+22.54070	+7.44643
12	5	45	XFuel	-9.57213	-3.03657	+47.01340	+17.24307
14	5	40	XFuel	-9.90162	-3.35137	+55.01830	+18.27787
16	5	40	XFuel	-15.52142	-4.59393	+77.78160	+25.20402
18	5	35	XFuel	-8.72121	-3.67306	+66.85580	+18.37593
20	5	30	XFuel	-3.21116	-2.85474	+55.94680	+12.64704
25	5	30	XFuel	-7.67792	-4.28063	+89.65080	+19.19073
30	5	30	XFuel	-13.08751	-6.18484	+136.2422	+27.66604

Table A16. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for Single Unit 3A Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	-.16472	0.00000	-.31890	0.00000	+.00027	+.093981
2	5	70	XFuel	-1.26330	0.00000	-3.77670	0.00000	+.00088	+1.38230
3	5	70	XFuel	-2.58741	0.00000	-8.19290	0.00000	+.00200	+2.86620
4	5	65	XFuel	-4.27543	0.00000	-13.55840	0.00000	+.00363	+4.43987
5	5	65	XFuel	-6.52723	0.00000	-19.94200	0.00000	+.00597	+6.09281
6	5	55	XFuel	-4.98749	0.00000	-21.07290	0.00000	+.00724	+5.57733
8	5	55	XFuel	6.80158	+1.03062	0.00000	-1.83250	+.03377	-4.51476
10	5	55	XFuel	7.63917	+.99803	0.00000	-2.07340	+.04284	-4.68605
12	5	45	XFuel	1.44154	+.06654	0.00000	-1.65330	+.04402	+1.86502
14	5	40	XFuel	-4.54485	0.00000	-44.87820	0.00000	+.03266	+6.17435
16	5	40	XFuel	-5.27732	0.00000	-53.79370	0.00000	+.04437	+6.73465
18	5	35	XFuel	-4.42510	0.00000	-56.75430	0.00000	+.05344	+6.26160
20	5	30	XFuel	-3.14184	0.00000	-58.06280	0.00000	+.06219	+5.51961
25	5	30	XFuel	-3.60491	0.00000	-73.37330	0.00000	+.09813	+5.92667
30	5	30	XFuel	-4.09677	0.00000	-92.17830	0.00000	+.14890	+6.45109

Table A17. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for 2-S2 Semi Combination Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	1.69360	0.00000	+9.28540	-.30600	+.00286	-1.10768
2	5	70	XFuel	-4.87610	-1.46989	+48.76540	-.92840	+.00682	+7.56539
3	5	70	XFuel	-12.87511	-3.90900	+129.89090	-2.42100	+.01742	+19.60726
4	5	65	XFuel	-15.70361	-4.75771	+159.07590	-3.07960	+.02333	+24.16031
5	5	65	XFuel	-32.28002	-10.76117	+369.70300	-6.92420	+.05022	+50.42532
6	5	55	XFuel	-9.67473	-1.81262	+37.48220	-.78150	+.00858	+13.58436
8	5	55	XFuel	-30.57533	-10.05327	+332.58530	-6.27250	+.04856	+48.36413
10	5	55	XFuel	-75.12823	-28.40855	+1021.15250	-19.50300	+.14590	+123.36268
12	5	45	XFuel	8.11932	+10.22560	-566.23270	+14.21870	-.12210	-26.09094
14	5	40	XFuel	27.69520	+23.48727	-1223.69900	+31.21710	-.28390	-70.48930
16	5	40	XFuel	42.14697	+34.26170	-1778.55570	+46.10310	-.42840	-105.48322
18	5	35	XFuel	39.78753	+34.04993	-1806.33750	+47.59110	-.44000	-103.04241
20	5	30	XFuel	-17.21870	-12.52746	+688.14140	-25.63970	+.41920	+43.61487
25	5	30	XFuel	-47.88570	-39.30053	+2158.56680	-71.29390	+1.02190	+126.25355
30	5	30	XFuel	-23.14850	-22.65304	+1368.40340	-54.28480	+.97120	+70.01340

Table A18. Excess Fuel Consumption on Curvature (gal/1,000 miles) (liter/425 km) for 3-S2 Semi Combination Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000	Log(Speed)
1	5	70	XFuel	-.32497	-.20312	+8.48750	-.16400	+.00122	+.71584
2	5	70	XFuel	-.03554	+.44390	-18.39890	+.23710	-.00067	-.40349
3	5	70	XFuel	-.84223	+.58153	-26.65050	+.29560	-.00010	+.53836
4	5	65	XFuel	+.53330	+1.5724	-67.64470	+.96450	-.00341	-2.17007
5	5	65	XFuel	-2.60766	+.83377	-49.30340	+.64030	-.00031	+2.17306
6	5	55	XFuel	-5.73180	+.18442	-36.83530	+.48700	+.00139	+6.19152
8	5	55	XFuel	-22.30810	-5.76726	+164.48000	-3.14510	+.02881	+32.43790
10	5	55	XFuel	-63.79710	-22.56290	+789.26900	-15.15360	+.11930	+101.58900
12	5	45	XFuel	11.09148	+12.35540	-651.64900	+15.46100	-.12110	-33.13460
14	5	40	XFuel	30.11332	+25.36880	-1295.68600	+31.92250	-.27290	-76.65080
16	5	40	XFuel	45.60968	+36.73810	-1879.11200	+47.36000	-.41710	-113.67945
18	5	35	XFuel	46.87631	+39.30220	-2042.04200	+52.06920	-.45310	-120.32120
20	5	30	XFuel	-26.66325	-20.24210	+1135.97400	-40.87220	+.63330	+67.71784
25	5	30	XFuel	-37.72635	-33.16347	+1926.49600	-69.60740	+1.09230	+104.44610
30	5	30	XFuel	-47.19685	-46.25769	+2775.97000	-102.50290	+1.65560	+140.02660

Table A19. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for Small Auto

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	+.05754	-.01587	+1.40680	-.03588	+.00059
2	5	70	XTire	2.43591	+.00531	-.58700	-.09109	+.00173
3	5	70	XTire	4.90160	+.00491	-2.14920	-.14440	+.00314
4	5	70	XTire	7.35499	-.08762	+1.66640	-.33640	+.00603
5	5	70	XTire	9.52113	-.30062	+13.87640	-.74400	+.01111
6	5	70	XTire	12.59656	-.78871	+43.81680	-1.58780	+.02012
8	5	70	XTire	33.68804	-5.54555	+354.44190	-9.35890	+.08775
10	5	65	XTire	32.24756	-5.33603	+362.35000	-10.54380	+.11120
12	5	55	XTire	18.05152	-1.93084	+134.95450	-5.44690	+.08266
14	5	50	XTire	17.36667	-1.79157	+123.21440	-5.54090	+.09613
16	5	45	XTire	14.87778	-1.17552	+79.55550	-4.81350	+.10420
18	5	40	XTire	13.40179	-.73363	+37.16290	-3.73890	+.10620
20	5	40	XTire	14.90000	-1.23657	+84.54550	-5.94340	+.15030
25	5	35	XTire	14.22858	-1.10743	+74.16680	-6.84650	+.21030
30	5	30	XTire	13.08333	-.71720	+22.80560	-5.72960	+.25000

Table A20. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for Medium/Large Auto

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	-.39046	+.07390	-3.47340	+.06306	0.00000
2	5	70	XTire	1.75070	+.27921	-16.04850	+.20280	0.00000
3	5	70	XTire	6.23339	+.00434	-2.81980	-.17550	+.00387
4	5	70	XTire	9.25639	-.08639	+.55130	-.39140	+.00736
5	5	70	XTire	12.32422	-.42126	+19.41880	-.97280	+.01421
6	5	70	XTire	15.94018	-.99386	+55.18840	-2.00340	+.02540
8	5	70	XTire	33.57891	-4.87766	+310.30630	-8.59320	+.08605
10	5	65	XTire	22.60228	-2.24926	+149.12790	-5.55590	+.07650
12	5	55	XTire	22.69393	-2.40719	+168.57450	-6.84580	+.10430
14	5	50	XTire	20.60000	-1.90255	+132.81640	-6.46920	+.11740
16	5	45	XTire	18.97222	-1.50990	+102.03170	-6.13490	+.13250
18	5	40	XTire	17.04196	-.94562	+48.60030	-4.79720	+.13540
20	5	40	XTire	18.30179	-1.48863	+114.23130	-8.36010	+.20590
25	5	35	XTire	18.33572	-1.49076	+100.0000	-8.83030	+.26790
30	5	30	XTire	16.54167	-.90467	+27.65270	-7.16480	+.31500

Table A21. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for Pickup/Van

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	-.05529	+.00680	+.28820	-.01142	+.00046
2	5	70	XTire	2.77153	+.04670	-3.11070	-.05330	+.00164
3	5	70	XTire	5.73117	+.02628	-3.71280	-.14360	+.00349
4	5	70	XTire	8.61264	-.07418	+.15140	-.35350	+.00675
5	5	70	XTire	11.26074	-.35448	+16.04730	-.85780	+.01284
6	5	70	XTire	14.60430	-.87616	+48.38630	-1.78830	+.02297
8	5	65	XTire	19.01469	-1.67770	+103.88370	-3.62560	+.04619
10	5	55	XTire	16.20910	-.84856	+47.17140	-2.66000	+.04844
12	5	50	XTire	14.89167	-.53345	+20.74770	-2.29130	+.05639
14	5	50	XTire	18.87500	-1.70884	+118.80820	-5.83630	+.10660
16	5	45	XTire	17.25556	-1.31478	+88.07260	-5.46140	+.11990
18	5	40	XTire	15.55893	-.80107	+38.11730	-4.16510	+.12140
20	5	35	XTire	13.92857	-.29863	-14.83340	-2.59600	+.11940
25	5	35	XTire	16.72858	-1.29469	+84.66680	-7.83840	+.24240
30	5	30	XTire	15.25000	-.82952	+26.25010	-6.63330	+.29000

Table A22. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for Bus

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	-.23197	+.04326	-2.06510	+.03928	0.00000
2	5	70	XTire	2.70724	+.03479	-3.59580	-.01381	+.00107
3	5	70	XTire	6.00694	-.02592	-2.71320	-.12170	+.00292
4	5	65	XTire	8.50909	-.03105	-4.75620	-.19370	+.00506
5	5	65	XTire	10.53217	-.14485	-.23610	-.41870	+.00886
6	5	55	XTire	11.26061	-.02973	-11.15380	-.26450	+.00998
8	5	55	XTire	13.60909	-.24815	-.16090	-.85810	+.02172
10	5	55	XTire	15.85455	-.67254	+28.49770	-2.00670	+.04089
12	5	45	XTire	14.16111	-.22857	-10.13670	-1.20010	+.04354
14	5	40	XTire	14.02679	-.17658	-21.40530	-1.06920	+.05258
16	5	40	XTire	14.40179	-.32479	-10.73110	-1.82580	+.07530
18	5	35	XTire	14.35714	-.30035	-18.66670	-1.84240	+.08970
20	5	30	XTire	13.03333	+.13566	-70.44450	-.02963	+.08000
25	5	30	XTire	14.51667	-.37637	-28.13900	-2.67040	+.16330
30	5	30	XTire	15.23334	-.67632	-3.61100	-4.94070	+.26000

Table A23. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for Single Unit 2A Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	-.34855	+.06572	-3.24040	+.05987	0.00000
2	5	70	XTire	2.77802	+.24657	-16.11470	+.20660	0.00000
3	5	70	XTire	5.60260	+.51958	-34.37670	+.44620	0.00000
4	5	65	XTire	8.44056	+.70731	-51.72580	+.71490	0.00000
5	5	65	XTire	14.69511	-.20624	+.01373	-.59560	+.01248
6	5	55	XTire	15.95152	-.09896	-11.71210	-.46790	+.01478
8	5	55	XTire	19.02121	-.36443	+.83450	-1.22420	+.03058
10	5	55	XTire	22.11515	-.92102	+38.24240	-2.76580	+.05688
12	5	45	XTire	20.34445	-.45288	-4.59360	-1.95220	+.06359
14	5	40	XTire	19.46429	-.23053	-30.27270	-1.51110	+.07394
16	5	40	XTire	20.31608	-.51704	-8.38250	-2.81360	+.10860
18	5	35	XTire	19.71429	-.33148	-32.99990	-2.37980	+.12360
20	5	30	XTire	19.05000	-.08928	-68.75010	-1.30000	+.13000
25	5	30	XTire	19.63333	-.32291	-58.94450	-3.02960	+.22000
30	5	30	XTire	21.15000	-.89444	-9.91660	-6.78890	+.36330

Table A24. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for Single Unit 3A Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	-.23197	+.04326	-2.06510	+.03928	0.00000
2	5	70	XTire	2.70724	+.03479	-3.59580	-.01381	+.00107
3	5	70	XTire	6.00694	-.02592	-2.71320	-.12170	+.00292
4	5	65	XTire	8.50909	-.03105	-4.75620	-.19370	+.00506
5	5	65	XTire	10.53217	-.14485	-.23610	-.41870	+.00886
6	5	55	XTire	11.26061	-.02973	-11.15380	-.26450	+.00998
8	5	55	XTire	13.60909	-.24815	-.16090	-.85810	+.02172
10	5	55	XTire	15.85455	-.67254	+28.49770	-2.00670	+.04089
12	5	45	XTire	14.16111	-.22857	-10.13670	-1.20010	+.04354
14	5	40	XTire	14.02679	-.17658	-21.40530	-1.06920	+.05258
16	5	40	XTire	14.40179	-.32479	-10.73110	-1.82580	+.07530
18	5	35	XTire	14.35714	-.30035	-18.66670	-1.84240	+.08970
20	5	30	XTire	13.03333	+.13566	-70.44450	-.02963	+.08000
25	5	30	XTire	14.51667	-.37637	-28.13900	-2.67040	+.16330
30	5	30	XTire	15.23334	-.67632	-3.61100	-4.94070	+.26000

Table A25. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for 2-S2 Semi Combination Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	+.02802	-.00825	+.64270	-.01519	+.00035
2	5	70	XTire	2.35899	+.01748	-2.28570	-.03116	+.00109
3	5	70	XTire	5.00769	-.00544	-3.07470	-.09190	+.00246
4	5	65	XTire	7.11259	-.01734	-4.44290	-.15760	+.00429
5	5	65	XTire	8.85525	-.11449	-.55090	-.34910	+.00751
6	5	55	XTire	9.42728	-.00842	-10.32630	-.20760	+.00839
8	5	55	XTire	11.22121	-.16432	-3.00470	-.65420	+.01781
10	5	55	XTire	13.44546	-.58772	+25.52920	-1.73210	+.03487
12	5	45	XTire	12.13333	-.26119	-3.05010	-1.17090	+.03828
14	5	40	XTire	11.51786	-.07461	-23.34090	-.74650	+.04273
16	5	40	XTire	12.09643	-.25396	-10.40160	-1.51010	+.06333
18	5	35	XTire	11.80000	-.18601	-21.66670	-1.32930	+.07273
20	5	30	XTire	11.11667	+.06370	-54.13890	-.22590	+.07000
25	5	30	XTire	11.93333	-.23775	-31.44460	-1.94070	+.13330
30	5	30	XTire	12.76667	-.56074	-2.72220	-4.21480	+.22000

Table A26. Excess Tire Wear on Curvature (% wear/1,000 miles) (% wear/1,610 km) for 3-S2 Semi Combination Truck

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000	(Speed)^4/1000
1	5	70	XTire	.01523	-.00828	+.85570	-.02217	+.00045
2	5	70	XTire	3.01059	+.02699	-3.28650	-.02759	+.00125
3	5	70	XTire	6.35524	-.01114	-3.64810	-.11910	+.00308
4	5	65	XTire	9.13916	-.04167	-4.56690	-.21960	+.00552
5	5	65	XTire	11.08601	-.12913	-1.45210	-.42450	+.00932
6	5	55	XTire	12.03030	-.04932	-10.13520	-.33750	+.01119
8	5	55	XTire	14.27273	-.23540	-1.71100	-.87300	+.02275
10	5	55	XTire	16.83031	-.70838	+29.90450	-2.12150	+.04336
12	5	45	XTire	15.17778	-.28330	-7.36170	-1.37120	+.04713
14	5	40	XTire	14.58929	-.08632	-31.05310	-.87370	+.05303
16	5	40	XTire	15.39465	-.36922	-8.51890	-2.05200	+.08136
18	5	35	XTire	14.98572	-.21384	-30.66660	-1.53130	+.08970
20	5	30	XTire	22.25714	-2.46769	+154.16660	-6.36160	+.11090
25	5	30	XTire	14.70000	-.16333	-54.00000	-1.86670	+.16000
30	5	30	XTire	16.26667	-.75915	+2.11110	-5.52590	+.28000

Table A27. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Small Auto

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
1	50	55	XMRP	-.94638	+.01893	0.00000	0.00000
1	55	70	XMRP	-28.50000	1.43667	-24.00000	+.13330
2	5	55	XMRP	0.00000	0.00000	0.00000	0.00000
2	55	60	XMRP	-1.10000	+.02000	0.00000	0.00000
2	60	70	XMRP	-93.50001	4.56000	-74.00000	+.40000
3	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
3	50	55	XMRP	-.94941	+.01899	0.00000	0.00000
3	55	70	XMRP	-10.74857	+.57691	-10.57140	+.06667
4	5	45	XMRP	0.00000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.82467	+.01833	0.00000	0.00000
4	50	70	XMRP	-11.63492	+.69220	-13.96830	+.09630
5	5	45	XMRP	0.00000	0.00000	0.00000	0.00000
5	45	50	XMRP	-1.14246	+.02539	0.00000	0.00000
5	50	70	XMRP	-11.31111	+.71902	-15.73020	+.11850
6	5	40	XMRP	0.00000	0.00000	0.00000	0.00000
6	40	45	XMRP	-1.09022	+.02726	0.00000	0.00000
6	45	70	XMRP	-20.91191	+1.35921	-29.80950	+.22220
8	5	35	XMRP	0.00000	0.00000	0.00000	0.00000
8	35	40	XMRP	-1.80684	+.05162	0.00000	0.00000
8	40	70	XMRP	-42.08788	+2.91503	-67.17750	+.51920

Table A27. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Small Auto (Continued)

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	35	XMRP	0.00000	0.00000	0.00000	0.00000
10	35	40	XMRP	-2.60295	+.07437	0.00000	0.00000
10	40	65	XMRP	-60.68335	+4.31754	-102.66700	+.82220
12	5	30	XMRP	0.00000	0.00000	0.00000	0.00000
12	30	35	XMRP	-1.02944	+.03431	0.00000	0.00000
12	35	55	XMRP	-21.42222	+1.83569	-52.96820	+.51850
14	5	30	XMRP	0.00000	0.00000	0.00000	0.00000
14	30	35	XMRP	-1.76499	+.05883	0.00000	0.00000
14	35	50	XMRP	-22.30572	+1.96071	-58.57140	+.60000
16	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
16	25	30	XMRP	-.55335	+.02213	0.00000	0.00000
16	30	45	XMRP	-12.21714	+1.27667	-44.85710	+.53330
18	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
18	25	30	XMRP	-1.00000	+.04000	0.00000	0.00000
18	30	40	XMRP	-7.00000	+.78000	-30.00000	+.40000
20	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
20	25	30	XMRP	-1.49600	+.05984	0.00000	0.00000
20	30	40	XMRP	-21.50000	+2.22667	-78.00000	+.93330
25	5	20	XMRP	0.00000	0.00000	0.00000	0.00000
25	20	25	XMRP	-.40000	+.02000	0.00000	0.00000
25	25	35	XMRP	-2.40000	+.40000	-22.00000	+.40000
30	5	20	XMRP	0.00000	0.00000	0.00000	0.00000
30	20	25	XMRP	-1.20000	+.06000	0.00000	0.00000
30	25	30	XMRP	+3.80000	-.39000	+10.00000	0.00000

Table A28. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Medium/Large Auto**

Curvature	Mininum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
1	50	55	XMRP	-.94638	+.01893	0.00000	0.00000
1	55	70	XMRP	-28.50000	+1.43667	-24.00000	+.13330
2	5	55	XMRP	0.00000	0.00000	0.00000	0.00000
2	55	60	XMRP	-1.10008	+.02000	0.00000	0.00000
2	60	70	XMRP	-1.10000	+.02000	.00000	0.00000
3	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
3	50	55	XMRP	-.94638	+.01893	0.00000	0.00000
3	55	70	XMRP	-23.00000	+1.22667	-22.00000	+.13330
4	5	45	XMRP	0.00000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.75978	+.01688	0.00000	0.00000
4	50	70	XMRP	-13.99683	+.84331	-17.15870	+.11850
5	5	45	XMRP	0.00000	0.00000	0.00000	0.00000
5	45	50	XMRP	-1.62927	+.03621	0.00000	0.00000
5	50	70	XMRP	-21.15397	+1.27878	-26.30160	+.18520
6	5	40	XMRP	0.00000	0.00000	0.00000	0.00000
6	40	45	XMRP	-.94762	+.02369	0.00000	0.00000
6	45	70	XMRP	-21.65239	+1.43853	-32.21430	+.24440
8	5	35	XMRP	0.00000	0.00000	0.00000	0.00000
8	35	40	XMRP	-1.96917	+.05626	0.00000	0.00000
8	40	70	XMRP	-47.05229	+3.25982	-75.18400	+.58180

Table A28. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Medium/Large Auto (Continued)**

Curvature	Mininum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	30	XMRP	0.00000	0.00000	0.00000	0.00000
10	30	35	XMRP	-.85373	+.02846	0.00000	0.00000
10	35	60	XMRP	-20.75595	+1.72187	-47.69050	+.44440
12	5	30	XMRP	0.00000	0.00000	0.00000	0.00000
12	30	35	XMRP	-1.13480	+.03783	0.00000	0.00000
12	35	55	XMRP	-22.64842	+1.95755	-56.99210	+.56300
14	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
14	25	30	XMRP	-.59615	+.02385	0.00000	0.00000
14	30	50	XMRP	-13.19921	+1.32419	-44.45240	+.50370
16	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
16	25	30	XMRP	-.60000	+.02400	0.00000	0.00000
16	30	45	XMRP	-10.38000	+1.11500	-40.50000	+.50000
18	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
18	25	30	XMRP	-.99600	+.03984	0.00000	0.00000
18	30	40	XMRP	-15.75000	+1.67167	-60.00000	+.73330
20	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
20	25	30	XMRP	-1.50000	+.06000	0.00000	0.00000
20	30	40	XMRP	-15.75000	+1.70500	-63.00000	+.80000
25	5	20	XMRP	0.00000	0.00000	0.00000	0.00000
25	20	25	XMRP	-.39825	+.01991	0.00000	0.00000
25	25	35	XMRP	-3.90000	+.60167	-31.00000	+.53330
30	5	20	XMRP	0.00000	0.00000	0.00000	0.00000
30	20	25	XMRP	-1.20000	+.06000	0.00000	0.00000
30	25	30	XMRP	+4.80000	-.48000	+12.00000	0.00000

Table A29. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Pickup/Van

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
1	50	55	XMRP	-.94638	+.01893	0.00000	0.00000
1	55	70	XMRP	-28.50000	+1.43667	-24.00000	+.13330
2	5	55	XMRP	0.00000	0.00000	0.00000	0.00000
2	55	60	XMRP	-1.10008	+.02000	0.00000	0.00000
2	60	70	XMRP	-1.10000	+.02000	0.00000	0.00000
3	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
3	50	55	XMRP	-.94941	+.01899	0.00000	0.00000
3	55	70	XMRP	-10.74857	+.57691	-10.57140	+.06667
4	5	45	XMRP	0.00000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.86400	+.01920	0.00000	0.00000
4	50	70	XMRP	-17.40000	+1.01667	-20.00000	+.13330
5	5	45	XMRP	0.00000	0.00000	0.00000	0.00000
5	45	50	XMRP	-1.07541	+.02390	0.00000	0.00000
5	50	70	XMRP	-13.67301	+.87013	-18.92060	+.14070
6	5	40	XMRP	0.00000	0.00000	0.00000	0.00000
6	40	45	XMRP	-1.09136	+.02728	0.00000	0.00000
6	45	70	XMRP	-23.12381	+1.50270	-32.90480	+.24440
8	5	35	XMRP	0.00000	0.00000	0.00000	0.00000
8	35	40	XMRP	-1.08619	+.03103	0.00000	0.00000
8	40	65	XMRP	-24.07619	+1.75492	-42.95240	+.35560

Table A29. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Pickup/Van (Continued)**

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	35	XMRP	0.00000	0.00000	0.00000	0.00000
10	35	40	XMRP	-1.50500	+.04300	0.00000	0.00000
10	40	55	XMRP	-15.95428	+1.28238	-35.28570	+.33330
12	5	30	XMRP	0.00000	0.00000	0.00000	0.00000
12	30	35	XMRP	-.69357	+.02312	0.00000	0.00000
12	35	50	XMRP	-9.78286	+.93452	-30.28570	+.33330
14	5	30	XMRP	0.00000	0.00000	0.00000	0.00000
14	30	35	XMRP	-1.69640	+.05655	0.00000	0.00000
14	35	50	XMRP	-21.31715	+1.90214	-57.71430	+.60000
16	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
16	25	30	XMRP	-.66755	+.02670	0.00000	0.00000
16	30	45	XMRP	-12.15143	+1.26667	-44.57140	+.53330
18	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
18	25	30	XMRP	-.99600	+.03984	0.00000	0.00000
18	30	40	XMRP	-10.50000	+1.13667	-42.00000	+.53330
20	5	25	XMRP	0.00000	0.00000	0.00000	0.00000
20	25	30	XMRP	-1.50000	+.06000	0.00000	0.00000
20	30	35	XMRP	+4.50000	-.38000	+8.00000	0.00000
25	5	20	XMRP	0.00000	0.00000	0.00000	0.00000
25	20	25	XMRP	-.39825	+.01991	0.00000	0.00000
25	25	35	XMRP	-4.40000	+.64667	-32.00000	+.53330
30	5	20	XMRP	0.00000	0.00000	0.00000	0.00000
30	20	25	XMRP	-1.20000	+.06000	0.00000	0.00000
30	25	30	XMRP	+3.80000	-.39000	+10.00000	0.00000

Table A30. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Bus

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	40	XMRP	0.00000	0.00000	0.00000	0.00000
1	40	45	XMRP	-.66414	+.01660	0.00000	0.00000
1	45	70	XMRP	-5.90952	+.34532	-6.71430	+.04444
2	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
2	50	55	XMRP	-.94638	+.01893	0.00000	0.00000
2	55	70	XMRP	-23.00000	+1.22667	-22.00000	+.13330
3	5	50	XMRP	+.10000	0.00000	0.00000	0.00000
3	50	55	XMRP	-.93885	+.02078	0.00000	0.00000
3	55	70	XMRP	-6.13492	+.48220	-11.96830	+.09630
4	5	45	XMRP	+.10000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.94175	+.02315	0.00000	0.00000
4	50	65	XMRP	-26.86000	+1.71762	-36.85710	+.26670
5	5	45	XMRP	+.10000	0.00000	0.00000	0.00000
5	45	50	XMRP	-2.53439	+.05854	0.00000	0.00000
5	50	65	XMRP	-9.67779	+.83053	-22.95240	+.20740
6	5	40	XMRP	+.10000	0.00000	0.00000	0.00000
6	40	45	XMRP	-1.50000	+.04000	0.00000	0.00000
6	45	55	XMRP	-26.70000	+1.95000	-48.00000	+.40000
8	5	35	XMRP	+.10000	0.00000	0.00000	0.00000
8	35	40	XMRP	-.84080	+.02688	0.00000	0.00000
8	40	55	XMRP	-12.90856	+1.23143	-38.57140	+.40000

Table A30. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Bus (Continued)

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	35	XMRP	+.10000	0.00000	0.00000	0.00000
10	35	40	XMRP	-3.18552	+.09387	0.00000	0.00000
10	40	55	XMRP	-26.10952	+2.39706	-73.47620	+.75560
12	5	30	XMRP	+.10000	0.00000	0.00000	0.00000
12	30	35	XMRP	-1.70788	+.06026	0.00000	0.00000
12	35	45	XMRP	-15.00000	+1.58333	-56.00000	+.66670
14	5	30	XMRP	+.10000	0.00000	0.00000	0.00000
14	30	35	XMRP	-3.49213	+.11974	0.00000	0.00000
14	35	40	XMRP	-4.90000	+.76667	-36.00000	+.53330
16	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
16	25	30	XMRP	-.90400	+.04016	0.00000	0.00000
16	30	40	XMRP	-6.40000	+.94333	-44.00000	+.66670
18	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
18	25	30	XMRP	-1.90000	+.08000	0.00000	0.00000
18	30	35	XMRP	+13.10000	-1.02000	+20.00000	0.00000
20	5	15	XMRP	+.10000	0.00000	0.00000	0.00000
20	15	25	XMRP	+.10000	0.00000	0.00000	0.00000
20	25	30	XMRP	-3.40000	+.14000	0.00000	0.00000
25	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
25	20	25	XMRP	-.70000	+.04000	0.00000	0.00000
25	25	30	XMRP	+11.30000	-1.04000	+24.00000	0.00000
30	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
30	20	25	XMRP	-2.30000	+.12000	0.00000	0.00000
30	25	30	XMRP	-8.30000	+1.46000	-84.00000	+1.60000

Table A31. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Single Unit 2A Truck**

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000
1	5	40	XMRP	0.00000	0.00000	0.00000
1	40	45	XMRP	-.39852	+.00996	0.00000
1	45	70	XMRP	+1.05714	-.05024	+.61900
2	5	50	XMRP	0.00000	0.00000	0.00000
2	50	55	XMRP	-.60000	+.01200	0.00000
2	55	70	XMRP	+5.12000	-.20200	+2.00000
3	5	50	XMRP	+.10000	0.00000	0.00000
3	50	55	XMRP	-.64295	+.01486	0.00000
3	55	70	XMRP	+14.41143	-.55743	+5.42860
4	5	45	XMRP	+.10000	0.00000	0.00000
4	45	50	XMRP	-.18575	+.00635	0.00000
4	50	65	XMRP	+16.26000	-.67971	+7.14290
5	5	45	XMRP	+.10000	0.00000	0.00000
5	45	50	XMRP	-1.52000	+.03600	0.00000
5	50	65	XMRP	+26.08000	-1.11600	+12.00000
6	5	40	XMRP	+.10000	0.00000	0.00000
6	40	45	XMRP	-.70000	+.02000	0.00000
6	45	55	XMRP	+17.30000	-.83000	+10.00000
8	5	35	XMRP	+.10000	0.00000	0.00000
8	35	40	XMRP	+.24000	-.00400	0.00000
8	40	55	XMRP	+23.12000	-1.21600	+16.00000

Table A31. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Single Unit 2A Truck (Continued)

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000
10	5	35	XMRP	+.10000	0.00000	0.00000
10	35	40	XMRP	-1.68073	+.05088	0.00000
10	40	55	XMRP	+37.77143	-2.03257	+27.42860
12	5	30	XMRP	+.10000	0.00000	0.00000
12	30	35	XMRP	-1.25000	+.04500	0.00000
12	35	45	XMRP	+18.87500	-1.19500	+19.00000
14	5	30	XMRP	+.10000	0.00000	0.00000
14	30	35	XMRP	-3.50000	+.12000	0.00000
14	35	40	XMRP	+17.50000	-1.18000	+20.00000
16	5	25	XMRP	+.10000	0.00000	0.00000
16	25	30	XMRP	-.52500	+.02500	0.00000
16	30	40	XMRP	+15.37500	-1.13500	+21.00000
18	5	25	XMRP	+.10000	0.00000	0.00000
18	25	30	XMRP	-1.90000	+.08000	0.00000
18	30	35	XMRP	+13.10000	-1.02000	+20.00000
20	5	15	XMRP	+.10000	0.00000	0.00000
20	15	25	XMRP	+.10000	0.00000	0.00000
20	25	30	XMRP	-3.40000	+.14000	0.00000
25	5	20	XMRP	+.10000	0.00000	0.00000
25	20	25	XMRP	-.70000	+.04000	0.00000
25	25	30	XMRP	+11.30000	-1.04000	+24.00000
30	5	20	XMRP	+.10000	0.00000	0.00000
30	20	25	XMRP	-2.30000	+.12000	0.00000
30	25	30	XMRP	+15.70000	-1.50000	+36.00000

Table A32. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Single Unit 3A Truck**

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	40	XMRP	0.00000	0.00000	0.00000	0.00000
1	40	45	XMRP	-.66414	+.01660	0.00000	0.00000
1	45	70	XMRP	-5.90952	+.34532	-6.71430	+.04444
2	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
2	50	55	XMRP	-.94638	+.01893	0.00000	0.00000
2	55	70	XMRP	-23.00000	+1.22667	-22.00000	+.13330
3	5	50	XMRP	+.10000	0.00000	0.00000	0.00000
3	50	55	XMRP	-.93885	+.02078	0.00000	0.00000
3	55	70	XMRP	-6.13492	+.48220	-11.96830	+.09630
4	5	45	XMRP	+.10000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.94175	+.02315	0.00000	0.00000
4	50	65	XMRP	-26.86000	+1.71762	-36.85710	+.26670
5	5	45	XMRP	+.10000	0.00000	0.00000	0.00000
5	45	50	XMRP	-2.53439	+.05854	0.00000	0.00000
5	50	65	XMRP	-9.67779	+.83053	-22.95240	+.20740
6	5	40	XMRP	+.10000	0.00000	0.00000	0.00000
6	40	45	XMRP	-1.50000	+.04000	0.00000	0.00000
6	45	55	XMRP	-26.70000	+1.95000	-48.00000	+.40000
8	5	35	XMRP	+.10000	0.00000	0.00000	0.00000
8	35	40	XMRP	-.84080	+.02688	0.00000	0.00000
8	40	55	XMRP	-12.90856	+1.23143	-38.57140	+.40000

Table A32. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for Single Unit 3A Truck (Continued)

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	35	XMRP	+.10000	0.00000	0.00000	0.00000
10	35	40	XMRP	-3.18552	+.09387	0.00000	0.00000
10	40	55	XMRP	-26.10952	+2.39706	-73.47620	+.75560
12	5	30	XMRP	+.10000	0.00000	0.00000	0.00000
12	30	35	XMRP	-1.70788	+.06026	0.00000	0.00000
12	35	45	XMRP	-15.00000	+1.58333	-56.00000	+.66670
14	5	30	XMRP	+.10000	0.00000	0.00000	0.00000
14	30	35	XMRP	-3.49213	+.11974	0.00000	0.00000
14	35	40	XMRP	-4.90000	+.76667	-36.00000	+.53330
16	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
16	25	30	XMRP	-.90400	+.04016	0.00000	0.00000
16	30	40	XMRP	-6.40000	+.94333	-44.00000	+.66670
18	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
18	25	30	XMRP	-1.90000	+.08000	0.00000	0.00000
18	30	35	XMRP	+13.10000	-1.02000	+20.00000	0.00000
20	5	15	XMRP	+.10000	0.00000	0.00000	0.00000
20	15	25	XMRP	+.10000	0.00000	0.00000	0.00000
20	25	30	XMRP	-3.40000	+.14000	0.00000	0.00000
25	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
25	20	25	XMRP	-.70000	+.04000	0.00000	0.00000
25	25	30	XMRP	+11.30000	-1.04000	+24.00000	0.00000
30	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
30	20	25	XMRP	-2.30000	+.12000	0.00000	0.00000
30	25	30	XMRP	-8.30000	+1.46000	-84.00000	+1.60000

Table A33. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for 2-S2 Semi Combination Truck**

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	40	XMRP	0.00000	0.00000	0.00000	0.00000
1	40	45	XMRP	-.58908	+.01473	0.00000	0.00000
1	45	70	XMRP	-2.86905	+.16397	-3.19050	+.02222
2	5	50	XMRP	0.00000	0.00000	0.00000	0.00000
2	50	55	XMRP	-.83504	+.01670	0.00000	0.00000
2	55	70	XMRP	-8.24571	+.48405	-9.71430	+.06667
3	5	50	XMRP	+.10000	0.00000	0.00000	0.00000
3	50	55	XMRP	-1.14241	+.02485	0.00000	0.00000
3	55	70	XMRP	-4.01905	+.37659	-10.33330	+.08889
4	5	45	XMRP	+.10000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.55916	+.01465	0.00000	0.00000
4	50	65	XMRP	-4.18001	+.46810	-14.28570	+.13330
5	5	45	XMRP	+.10000	0.00000	0.00000	0.00000
5	45	50	XMRP	-3.49775	+.07995	0.00000	0.00000
5	50	65	XMRP	+19.12500	-.89036	+10.35710	0.00000
6	5	40	XMRP	+.10000	0.00000	0.00000	0.00000
6	40	45	XMRP	-1.26000	+.03400	0.00000	0.00000
6	45	55	XMRP	+16.83000	-.81800	+10.00000	0.00000
8	5	35	XMRP	+.10000	0.00000	0.00000	0.00000
8	35	40	XMRP	-.00151	+.00290	0.00000	0.00000
8	40	55	XMRP	+25.13143	-1.32257	+17.42867	0.00000

Table A33. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for 2-S2 Semi Combination Truck (Continued)

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	35	XMRP	+.10000	0.00000	0.00000	0.00000
10	35	40	XMRP	-2.01876	+.06054	0.00000	0.00000
10	40	55	XMRP	+30.10572	-1.73686	+24.85710	0.00000
12	5	30	XMRP	+.10000	0.00000	0.00000	0.00000
12	30	35	XMRP	-1.82000	+.06400	0.00000	0.00000
12	35	45	XMRP	+19.60000	-1.24800	+20.00000	0.00000
14	5	30	XMRP	+.10000	0.00000	0.00000	0.00000
14	30	35	XMRP	-4.46000	+.15200	0.00000	0.00000
14	35	40	XMRP	+14.02000	-1.00600	+18.00000	0.00000
16	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
16	25	30	XMRP	-.45000	+.02200	0.00000	0.00000
16	30	40	XMRP	+17.73000	-1.30400	+24.00000	0.00000
18	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
18	25	30	XMRP	-1.90400	+.08016	0.00000	0.00000
18	30	35	XMRP	-11.90000	+1.61333	-72.00000	+1.06670
20	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
20	25	30	XMRP	-3.90000	+.16000	0.00000	0.00000
20	30	30	XMRP	+8.10000	-.72000	+16.00000	0.00000
25	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
25	20	25	XMRP	-1.10000	+.06000	0.00000	0.00000
25	25	30	XMRP	+10.90000	-1.02000	+24.00000	0.00000
30	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
30	20	25	XMRP	-3.42000	+.17600	0.00000	0.00000
30	25	30	XMRP	+8.68000	-.95800	+26.00000	0.00000

Table A34. **Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for 3-S2 Semi Combination Truck**

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
1	5	35	XMRP	0.00000	0.00000	0.00000	0.00000
1	35	40	XMRP	-.52829	+.01509	0.00000	0.00000
1	40	70	XMRP	-2.93485	+.19099	-4.18610	+.03232
2	5	55	XMRP	+.10000	0.00000	0.00000	0.00000
2	55	60	XMRP	-2.01123	+.03839	0.00000	0.00000
2	60	70	XMRP	-1.15143	+.22976	-7.42860	+.06667
3	5	50	XMRP	+.10000	0.00000	0.00000	0.00000
3	50	55	XMRP	-2.13755	+.04475	0.00000	0.00000
3	55	70	XMRP	-11.04920	+.83553	-20.39680	+.16300
4	5	45	XMRP	+.20000	0.00000	0.00000	0.00000
4	45	50	XMRP	-.54466	+.01655	0.00000	0.00000
4	50	65	XMRP	-4.36001	+.62857	-20.71430	+.20000
5	5	45	XMRP	+.20000	0.00000	0.00000	0.00000
5	45	50	XMRP	-4.01452	+.09366	0.00000	0.00000
5	50	65	XMRP	-28.87222	+2.18780	-54.90480	+.45930
6	5	40	XMRP	+.20000	0.00000	0.00000	0.00000
6	40	45	XMRP	-1.76920	+.04923	0.00000	0.00000
6	45	55	XMRP	-20.34286	+1.76048	-49.85710	+.46670
8	5	35	XMRP	+.20000	0.00000	0.00000	0.00000
8	35	40	XMRP	-1.38613	+.04532	0.00000	0.00000
8	40	55	XMRP	-25.45717	+2.35953	-72.14290	+.73330

Table A34. Excess Maintenance and Repairs on Curvature (% avg. cost/1,000 miles) (% avg. cost/1,610 km) for 3-S2 Semi Combination Truck (Continued)

Curvature	Minimum Speed Allowed	Maximum Speed Allowed	Dep. Var.	Constant	Speed	(Speed)^2/1000	(Speed)^3/1000
10	5	35	XMRP	+.20000	0.00000	0.00000	0.00000
10	35	40	XMRP	-5.57157	+.16490	0.00000	0.00000
10	40	55	XMRP	-44.59525	+4.09159	-125.33340	+1.28890
12	5	30	XMRP	+.20000	0.00000	0.00000	0.00000
12	30	35	XMRP	-2.70541	+.09685	0.00000	0.00000
12	35	45	XMRP	-21.01713	+2.35333	-86.85710	+1.06670
14	5	30	XMRP	+.20000	0.00000	0.00000	0.00000
14	30	35	XMRP	-6.40782	+.22026	0.00000	0.00000
14	35	40	XMRP	-.80001	+.57333	-38.00000	+.66670
16	5	25	XMRP	+.20000	0.00000	0.00000	0.00000
16	25	30	XMRP	-1.29600	+.05984	0.00000	0.00000
16	30	40	XMRP	-15.30000	+2.08667	-92.00000	+1.33330
18	5	25	XMRP	+.10000	0.00000	0.00000	0.00000
18	25	30	XMRP	-3.90400	+.16016	0.00000	0.00000
18	30	35	XMRP	-7.90000	+1.25333	-64.00000	+1.06670
20	5	15	XMRP	+.10000	0.00000	0.00000	0.00000
20	15	25	XMRP	+.10000	0.00000	0.00000	0.00000
20	25	30	XMRP	-1.90000	+.10000	0.00000	0.00000
25	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
25	20	25	XMRP	-1.90000	+.10000	0.00000	0.00000
25	25	30	XMRP	+16.10000	-1.52000	+36.00000	0.00000
30	5	20	XMRP	+.10000	0.00000	0.00000	0.00000
30	20	25	XMRP	-4.69825	+.23991	0.00000	0.00000
30	25	30	XMRP	-8.70000	+1.66667	-104.00000	+2.13330

Table A35. **Vehicle Operating Component Consumption During Idling**

Component Type	Vehicle Type	Consumption	Unit
Fuel	Small	271.0	gal/1000 hrs
Fuel	Med/Large	563.0	gal/1000 hrs
Fuel	Pickup/Van	756.0	gal/1000 hrs
Fuel	Bus	398.0	gal/1000 hrs
Fuel	SU-2A	198.0	gal/1000 hrs
Fuel	SU-3A	398.0	gal/1000 hrs
Fuel	2-S2	470.0	gal/1000 hrs
Fuel	3-S2	470.0	gal/1000 hrs
Oil	Small	5.80	qt/1000 hrs
Oil	Med/Large	5.80	qt/1000 hrs
Oil	Pickup/Van	3.50	qt/1000 hrs
Oil	Bus	3.46	qt/1000 hrs
Oil	SU-2A	3.20	qt/1000 hrs
Oil	SU-3A	3.46	qt/1000 hrs
Oil	2-S2	3.46	qt/1000 hrs
Oil	3-S2	3.46	qt/1000 hrs
Tire	Small	0.00	% of wear/1000 hrs
Tire	Med/Large	0.00	% of wear/1000 hrs
Tire	Pickup/Van	0.00	% of wear/1000 hrs
Tire	Bus	0.00	% of wear/1000 hrs
Tire	SU-2A	0.00	% of wear/1000 hrs
Tire	SU-3A	0.00	% of wear/1000 hrs
Tire	2-S2	0.00	% of wear/1000 hrs
Tire	3-S2	0.00	% of wear/1000 hrs
Depreciation	Small	0.81	% of new veh. price/1000 hrs
Depreciation	Med/Large	0.81	% of new veh. price/1000 hrs
Depreciation	Pickup/Van	0.50	% of new veh. price/1000 hrs
Depreciation	Bus	1.10	% of new veh. price/1000 hrs
Depreciation	SU-2A	1.10	% of new veh. price/1000 hrs
Depreciation	SU-3A	1.10	% of new veh. price/1000 hrs
Depreciation	2-S2	0.38	% of new veh. price/1000 hrs
Depreciation	3-S2	0.38	% of new veh. price/1000 hrs

Table A35. **Vehicle Operating Component Consumption During Idling (Continued)**

Component Type	Vehicle Type	Consumption	Unit
Maint. & Repairs	Small	57	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	Med/Large	58	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	Pickup/Van	60	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	Bus	26	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	SU-2A	23	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	SU-3A	26	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	2-S2	24	% of avg. cost per 1000 miles/1000 hrs
Maint. & Repairs	3-S2	24	% of avg. cost per 1000 miles/1000 hrs

Note: The buses are treated as single unit 3A trucks.

Source: Zaniewski, J.P. et al., *Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors*, Final Report, Texas Research and Development Foundation, Asutin, Texas, June 1982.

Table A36. **Excess Consumption of Fuel for Speed Changes [1] (gal/1,000 miles) (liter/425 km)**

Vehicle Type	Minimum Initial Speed	Maximum Initial Speed	Dep. Var.	Constant	Initial Speed	(Initial Speed)^2	Log(Initial Speed)	Reduced Speed	(Reduced Speed)^2
Small	5	35	XFuel	2.41303	+.246398	0.00000	-1.75499	-.114124	0.00000
Small	45	70	XFuel	-14.1573	+.453737	0.00000	0.00000	0.00000	-.003457
Med/Large	5	35	XFuel	3.22137	+.442216	0.00000	-2.43436	-.253405	0.00000
Med/Large	45	70	XFuel	-17.6035	+.657460	0.00000	0.00000	0.00000	-.006176
Pickup/Van	5	35	XFuel	3.33915	+.454516	0.00000	-2.51352	-.260038	0.00000
Pickup/Van	45	70	XFuel	425.1284	+3.48997	0.00000	-148.311	-.382702	0.00000
Bus	5	35	XFuel	25.7473	+2.79844	0.00000	-19.8595	-1.23219	0.00000
Bus	45	70	XFuel	-113.740	+4.27935	0.00000	0.00000	0.00000	-.039555
SU-2A	5	35	XFuel	20.5583	+2.18757	0.00000	-16.1274	-.900924	0.00000
SU-2A	45	70	XFuel	-83.4913	+3.14834	0.00000	0.00000	0.00000	-.029133
SU-3A	5	35	XFuel	25.7473	+2.79844	0.00000	-19.8595	-1.23219	0.00000
SU-3A	45	70	XFuel	-113.740	+4.27935	0.00000	0.00000	0.00000	-.039555
2-S2	5	35	XFuel	15.2892	+2.71045	0.00000	-11.9878	-1.75167	0.00000
2-S2	45	70	XFuel	-117.816	+4.41970	0.00000	0.00000	0.00000	-.041802
3-S2	5	35	XFuel	21.1992	+3.59400	0.00000	-17.4550	-2.15175	0.00000
3-S2	45	70	XFuel	-119.023	+4.98740	0.00000	0.00000	0.00000	-.052354

[1]For Beginning Speeds between 35-45 mph (56.35-72.45 kph), the program internally interpolates XFUEL from the two equations.

Table A37. **Excess Consumption of Oil for Speed Changes (qrt/1,000 miles) (liter/1,700 km)**

Vehicle Type	Minimum Initial Speed	Maximum Initial Speed	Dep. Var.	Constant	Initial Speed	(Initial Speed)^2	Log(Initial Speed)	Reduced Speed
Small	5	70	XOil	.026555	+.001092	0.00000	-.012638	-.000615
Med/Large	5	70	XOil	.006148	+.000117	+.000006	0.00000	-.000548
Pickup/Van	5	70	XOil	.022922	+.000960	0.00000	-.011111	-.000529
Bus	5	70	XOil	.046307	0.00000	+.000076	0.00000	-.004580
SU-2A	5	70	XOil	.018370	0.00000	+.000041	0.00000	-.002281
SU-3A	5	70	XOil	.046307	0.00000	+.000076	0.00000	-.004580
2-S2	5	70	XOil	.046072	0.00000	+.000076	0.00000	-.004569
3-S2	5	70	XOil	.115244	0.00000	+.000131	0.00000	-.008814

Table A38. **Excess Consumption of Tire for Speed Changes (% wear/1,000 miles) (% wear/1,610 km)**

Vehicle Type	Minimum Initial Speed	Maximum Initial Speed	Dep. Var.	Constant	Initial Speed	(Initial Speed)^2	Log(Initial Speed)	Reduced Speed	(Reduced Speed)^2
Small	5	70	XTire	-.468066	+.047113	0.00000	0.00000	-.033755	0.00000
Med/Large	5	70	XTire	1.12143	+.085211	0.00000	-.791724	-.016861	-.000552
Pickup/Van	5	70	XTire	-.521852	+.056328	0.00000	0.00000	-.041340	0.00000
Bus	5	70	XTire	.209682	0.00000	+.000669	0.00000	0.00000	-.000785
SU-2A	5	70	XTire	.365613	0.00000	+.000940	0.00000	0.00000	-.001144
SU-3A	5	70	XTire	.209682	0.00000	+.000669	0.00000	0.00000	-.000785
2-S2	5	70	XTire	.178225	0.00000	+.000552	0.00000	0.00000	-.000651
3-S2	5	70	XTire	.211596	0.00000	+.000712	0.00000	0.00000	-.000829

Table A39. **Excess Consumption of Depreciation for Speed Changes (% dep. value/1,000 miles) (% dep. value/1,610 km)**

Vehicle Type	Minimum Initial Speed	Maximum Initial Speed	Dep. Var.	Constant	Initial Speed	(Initial Speed)^2	Log(Initial Speed)	Reduced Speed
Small	5	70	XDEP	-.000900	+.000427	0.00000	0.00000	-.000401
Med/Large	5	70	XDEP	.005626	+.000329	0.00000	-.002791	-.000217
Pickup/Van	5	70	XDEP	-.000364	+.000210	0.00000	0.00000	-.000199
Bus	5	70	XDEP	.006159	0.00000	+.000006	0.00000	-.000422
SU-2A	5	70	XDEP	.006299	0.00000	+.000005	-.001209	-.000292
SU-3A	5	70	XDEP	.006159	0.00000	+.000006	0.00000	-.000422
2-S2	5	70	XDEP	.001578	+.000231	0.00000	-.000781	-.000200
3-S2	5	70	XDEP	.001578	+.000231	0.00000	-.000781	-.000200

Table A40. Excess Consumption of Maintenance and Repair for Speed Changes (% avg. cost/1,000 miles) (% avg. cost/1,610 km)

Vehicle Type	Minimum Initial Speed	Maximum Initial Speed	Dep. Var.	Constant	Initial Speed	(Initial Speed)^2	Reduced Speed	(Reduced Speed)^2
Small	5	70	XMRP	-1.69275	+.110691	0.00000	-.025311	-.000885
Med/Large	5	70	XMRP	-1.71697	+.110012	0.00000	-.024113	-.000879
Pickup/Van	5	70	XMRP	-1.70058	+.110982	0.00000	-.025441	-.000883
Bus	5	70	XMRP	-.162242	0.00000	+.001274	0.00000	-.001181
SU-2A	5	70	XMRP	-.115194	0.00000	+.001283	0.0000	-.001218
SU-3A	5	70	XMRP	-.162242	0.00000	+.001274	0.00000	-.001181
2-S2	5	70	XMRP	-.159433	0.00000	+.001378	0.00000	-.001287
3-S2	5	70	XMRP	-.320010	0.00000	+.001697	0.00000	-.001515

Table A41. Number of Speed Change Cycles Related to v/c Ratios, by Highway Type and Vehicle Type

Highway Type	Vehicle Type	Equations for No. of Speed Change Cycles			Min. Range of v/c Ratio	Max. Range of v/c Ratio
		Dependent Variable	Constant	v/c		
Freeway	Small	SPCYL	0	+1.19	0	1.00
Freeway	Small	SPCYL	-.24	+4.14	1.00	1.20
Freeway	Small	SPCYL	+10.73	-5.52	1.20	1.60
Freeway	Small	SPCYL	+ 2.52	0	1.60	2.00
Freeway	Med/Large	SPCYL	0	+1.19	0	1.00
Freeway	Med/Large	SPCYL	-.24	+4.14	1.00	1.20
Freeway	Med/Large	SPCYL	+10.73	-5.52	1.20	1.60
Freeway	Med/Large	SPCYL	+ 2.52	0	1.60	2.00
Freeway	Pickup/Van	SPCYL	0	+1.19	0	1.00
Freeway	Pickup/Van	SPCYL	-.24	+4.14	1.00	1.20
Freeway	Pickup/Van	SPCYL	+10.73	-5.52	1.20	1.60
Freeway	Pickup/Van	SPCYL	+2.52	0	1.60	2.00
Freeway	Bus	SPCYL	0	+.90	0	1.00
Freeway	Bus	SPCYL	+.73	+3.92	1.00	1.25
Freeway	Bus	SPCYL	+13.32	-6.15	1.25	1.72
Freeway	Bus	SPCYL	+2.74	0	1.72	2.00
Freeway	SU-2A	SPCYL	0	+.90	0	1.00
Freeway	SU-2A	SPCYL	+.73	+3.92	1.00	1.25
Freeway	SU-2A	SPCYL	+13.32	-6.15	1.25	1.72
Freeway	SU-2A	SPCYL	+2.74	0	1.72	2.00
Freeway	SU-3A	SPCYL	0	+.90	0	1.00
Freeway	SU-3A	SPCYL	+.73	+3.92	1.00	1.25
Freeway	SU-3A	SPCYL	+13.32	-6.15	1.25	1.72
Freeway	SU-3A	SPCYL	+2.74	0	1.72	2.00
Freeway	2-S2	SPCYL	0	+.83	0	1.00
Freeway	2-S2	SPCYL	-1.87	+7.48	1.00	1.30
Freeway	2-S2	SPCYL	+17.86	-7.70	1.30	1.80
Freeway	2-S2	SPCYL	+4.00	0	1.80	2.00
Freeway	3-S2	SPCYL	0	+.83	0	1.00
Freeway	3-S2	SPCYL	-1.87	+7.48	1.00	1.30

Table A41. Number of Speed Change Cycles Related to v/c Ratios, by Highway Type and Vehicle Type (Continued)

Highway Type	Vehicle Type	Equations for No. of Speed Change Cycles			Min. Range of v/c Ratio	Max. Range of v/c Ratio
		Dependent Variable	Constant	v/c		
Freeway	3-S2	SPCYL	+17.86	-7.70	1.30	1.80
Freeway	3-S2	SPCYL	+4.00	0	1.80	2.00
Multiln, Rural	Small	SPCYL	0	+1.67	0	1.00
Multiln, Rural	Small	SPCYL	+.01	+3.83	1.00	1.20
Multiln, Rural	Small	SPCYL	+10.95	-5.29	1.20	1.60
Multiln, Rural	Small	SPCYL	+2.48	0	1.60	2.00
Multiln, Rural	Med/Large	SPCYL	0	+1.67	0	1.00
Multiln, Rural	Med/Large	SPCYL	+.01	+3.83	1.00	1.20
Multiln, Rural	Med/Large	SPCYL	+10.95	-5.29	1.20	1.60
Multiln, Rural	Med/Large	SPCYL	+2.48	0	1.60	2.00
Multiln, Rural	Pickup/Van	SPCYL	0	+1.67	0	1.00
Multiln, Rural	Pickup/Van	SPCYL	+.01	+3.83	1.00	1.20
Multiln, Rural	Pickup/Van	SPCYL	+10.95	-5.29	1.20	1.60
Multiln, Rural	Pickup/Van	SPCYL	+2.48	0	1.60	2.00
Multiln, Rural	Bus	SPCYL	0	+1.33	0	1.00
Multiln, Rural	Bus	SPCYL	+.68	+3.92	1.00	1.25
Multiln, Rural	Bus	SPCYL	+12.84	-5.80	1.25	1.74
Multiln, Rural	Bus	SPCYL	+2.74	0	1.74	2.00
Multiln, Rural	SU-2A	SPCYL	0	+1.33	0	1.00
Multiln, Rural	SU-2A	SPCYL	+.68	+3.92	1.00	1.25
Multiln, Rural	SU-2A	SPCYL	+12.84	-5.80	1.25	1.74
Multiln, Rural	SU-2A	SPCYL	+2.74	0	1.74	2.00
Multiln, Rural	SU-3A	SPCYL	0	+1.33	0	1.00
Multiln, Rural	SU-3A	SPCYL	+.68	+3.92	1.00	1.25
Multiln, Rural	SU-3A	SPCYL	+12.84	-5.80	1.25	1.74
Multiln, Rural	SU-3A	SPCYL	+2.74	0	1.74	2.00
Multiln, Rural	2-S2	SPCYL	0	+.89	0	1.00
Multiln, Rural	2-S2	SPCYL	-.49	+6.36	1.00	1.30
Multiln, Rural	2-S2	SPCYL	+17.50	-7.48	1.30	1.80
Multiln, Rural	2-S2	SPCYL	+4.04	0	1.80	2.00

Table A41. Number of Speed Change Cycles Related to v/c Ratios, by Highway Type and Vehicle Type (Continued)

Highway Type	Vehicle Type	Equations for No. of Speed Change Cycles			Min. Range of v/c Ratio	Max. Range of v/c Ratio
		Dependent Variable	Constant	v/c		
Multiln, Rural	3-S2	SPCYL	0	+.89	0	1.00
Multiln, Rural	3-S2	SPCYL	-.49	+6.36	1.00	1.30
Multiln, Rural	3-S2	SPCYL	+17.50	-7.48	1.30	1.80
Multiln, Rural	3-S2	SPCYL	+4.04	0	1.80	2.00
2-Ln, Rural	Small	SPCYL	0	+1.50	0	1.00
2-Ln, Rural	Small	SPCYL	-.10	+3.99	1.00	1.20
2-Ln, Rural	Small	SPCYL	+11.14	-5.37	1.20	1.60
2-Ln, Rural	Small	SPCYL	+2.55	0	1.60	2.00
2-Ln, Rural	Med/Large	SPCYL	0	+1.50	0	1.00
2-Ln, Rural	Med/Large	SPCYL	-.10	+3.99	1.00	1.20
2-Ln, Rural	Med/Large	SPCYL	+11.14	-5.37	1.20	1.60
2-Ln, Rural	Med/Large	SPCYL	+2.55	0	1.60	2.00
2-Ln, Rural	Pickup/Van	SPCYL	0	+1.50	0	1.00
2-Ln, Rural	Pickup/Van	SPCYL	-.10	+3.99	1.00	1.20
2-Ln, Rural	Pickup/Van	SPCYL	+11.14	-5.37	1.20	1.60
2-Ln, Rural	Pickup/Van	SPCYL	+2.55	0	1.60	2.00
2-Ln, Rural	Bus	SPCYL	0	+1.22	0	1.00
2-Ln, Rural	Bus	SPCYL	+.73	+3.92	1.00	1.25
2-Ln, Rural	Bus	SPCYL	+13.03	-5.92	1.25	1.74
2-Ln, Rural	Bus	SPCYL	+2.79	0	1.74	2.00
2-Ln, Rural	SU-2A	SPCYL	0	+1.22	0	1.00
2-Ln, Rural	SU-2A	SPCYL	+.73	+3.92	1.00	1.25
2-Ln, Rural	SU-2A	SPCYL	+13.03	-5.92	1.25	1.74
2-Ln, Rural	SU-2A	SPCYL	+2.79	0	1.74	2.00
2-Ln, Rural	SU-3A	SPCYL	0	+1.22	0	1.00
2-Ln, Rural	SU-3A	SPCYL	+.73	+3.92	1.00	1.25
2-Ln, Rural	SU-3A	SPCYL	+13.03	-5.92	1.25	1.74
2-Ln, Rural	SU-3A	SPCYL	+2.79	0	1.74	2.00
2-Ln, Rural	2-S2	SPCYL	0	+1.08	0	1.00
2-Ln, Rural	2-S2	SPCYL	-.49	+6.36	1.00	1.30

Table A41. Number of Speed Change Cycles Related to v/c Ratios, by Highway Type and Vehicle Type (Continued)

Highway Type	Vehicle Type	Equations for No. of Speed Change Cycles			Min. Range of v/c Ratio	Max. Range of v/c Ratio
		Dependent Variable	Constant	v/c		
2-Ln, Rural	2-S2	SPCYL	+17.50	-7.48	1.30	1.80
2-Ln, Rural	2-S2	SPCYL	+4.04	0	1.80	2.00
2-Ln, Rural	3-S2	SPCYL	0	+1.08	0	1.00
2-Ln, Rural	3-S2	SPCYL	-.49	+6.36	1.00	1.30
2-Ln, Rural	3-S2	SPCYL	+17.50	-7.48	1.30	1.80
2-Ln, Rural	3-S2	SPCYL	+4.04	0	1.80	2.00
Urban Art	Small	SPCYL	0	+1.52	0	1.00
Urban Art	Small	SPCYL	-.50	+4.71	1.00	1.20
Urban Art	Small	SPCYL	+12.42	-6.06	1.20	1.60
Urban Art	Small	SPCYL	+2.73	0	1.60	2.00
Urban Art	Med/Large	SPCYL	0	+1.52	0	1.00
Urban Art	Med/Large	SPCYL	-.50	+4.71	1.00	1.20
Urban Art	Med/Large	SPCYL	+12.42	-6.06	1.20	1.60
Urban Art	Med/Large	SPCYL	+2.73	0	1.60	2.00
Urban Art	Pickup/Van	SPCYL	0	+1.52	0	1.00
Urban Art	Pickup/Van	SPCYL	-.50	+4.71	1.00	1.20
Urban Art	Pickup/Van	SPCYL	+12.42	-6.06	1.20	1.60
Urban Art	Pickup/Van	SPCYL	+2.73	0	1.60	2.00
Urban Art	Bus	SPCYL	0	+1.27	0	1.00
Urban Art	Bus	SPCYL	+1.02	+5.41	1.00	1.25
Urban Art	Bus	SPCYL	+17.57	-7.83	1.25	1.76
Urban Art	Bus	SPCYL	+3.79	0	1.76	2.00
Urban Art	SU-2A	SPCYL	0	+1.27	0	1.00
Urban Art	SU-2A	SPCYL	+1.02	+5.41	1.00	1.25
Urban Art	SU-2A	SPCYL	+17.57	-7.83	1.25	1.76
Urban Art	SU-2A	SPCYL	+3.79	0	1.76	2.00
Urban Art	SU-3A	SPCYL	0	+1.27	0	1.00
Urban Art	SU-3A	SPCYL	+1.02	+5.41	1.00	1.25
Urban Art	SU-3A	SPCYL	+17.57	-7.83	1.25	1.76
Urban Art	SU-3A	SPCYL	+3.79	0	1.76	2.00

Table A41. Number of Speed Change Cycles Related to v/c Ratios, by Highway Type and Vehicle Type (Continued)

Highway Type	Vehicle Type	Equations for No. of Speed Change Cycles			Min. Range of v/c Ratio	Max. Range of v/c Ratio
		Dependent Variable	Constant	v/c		
Urban Art	2-S2	SPCYL	0	+1.13	0	1.00
Urban Art	2-S2	SPCYL	-1.30	+9.05	1.00	1.30
Urban Art	2-S2	SPCYL	+23.80	-10.26	1.30	1.80
Urban Art	2-S2	SPCYL	+5.33	0	1.80	2.00
Urban Art	3-S2	SPCYL	0	+1.13	0	1.00
Urban Art	3-S2	SPCYL	-1.30	+9.05	1.00	1.30
Urban Art	3-S2	SPCYL	+23.80	-10.26	1.30	1.80
Urban Art	3-S2	SPCYL	+5.33	0	1.80	2.00

Note: SPCYL is defined as the number of speed change cycles per vehicle-mile.

Table A42. Pavement Adjustment Factors of Vehicle Operating Cost Components By Vehicle Type

Vehicle Type	Log (Oil)	Log(Tires)	Log (Maintenance & Repair)	Log (Depreciation)
Passenger Cars				
Small Auto	0.88716-0.23837 PSI[1]	1.16723-0.32962 PSI[1]	1.11904-0.30623 PSI[1]	0.15157-0.04129 PSI[1]
Med/Large Auto	0.88716-0.23837 PSI[1]	1.16723-0.32962 PSI[1]	1.11904-0.30623 PSI[1]	0.15157-0.04129 PSI[1]
Pickup/Van	0.88716-0.23837 PSI[1]	1.16723-0.32962 PSI[1]	1.11904-0.30623 PSI[1]	0.15157-0.04129 PSI[1]
Bus[2]	0.21903-0.06069 PSI[1]	0.61140-0.16788 PSI[1]	0.66300-0.18382 PSI[1]	0.35047-0.09721 PSI[1]
Trucks				
SU-2A	0.21903-0.06069 PSI[1]	0.61140-0.16788 PSI[1]	0.66300-0.18382 PSI[1]	0.35047-0.09721 PSI[1]
SU-3A	0.21903-0.06069 PSI[1]	0.61140-0.16788 PSI[1]	0.66300-0.18382 PSI[1]	0.35047-0.09721 PSI[1]
2-S2	0.21903-0.06069 PSI[1]	0.61140-0.16788 PSI[1]	1.01853-0.28092 PSI[1]	0.33956-0.09436 PSI[1]
3-S2	0.21903-0.06069 PSI[1]	0.61140-0.16788 PSI[1]	1.01853-0.28092 PSI[1]	0.33956-0.09436 PSI[1]

[1]The maximum PSI allowed is 4.5 and the minimum is 1.0.
[2]The buses are treated as single unit 3A trucks.

Source: Zaniewski, J. P., et al., *Vehicle Operating Costs, Fuel Consumption, and Pavement Type and Condition Factors*, Final Report, Texas Research and Development Foundation, Austin, Texas, June 1982.