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INDIANA HIGHWAY COST ALLOCATION STUDY: FINAL REPORT

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16. Abstract

This final report presents the findings of the highway cost-allocation study in Indiana. The cost responsibilities and revenue contributions of various vehicle classes were determined for FY 1983 and the biennial period of 1985-86. The findings indicate that passenger cars and single-unit trucks are overpaying their cost responsibility, while buses and heavy combination trucks are underpaying. The report also includes a summary of the procedures used. A thickness incremental approach was used to allocate new highway construction cost and an integrated approach was followed to allocate highway rehabilitation and routine maintenance costs. The structure-related costs were allocated by an incremental analysis. An explicit consideration was given to the effects of age, weather, salt and other chemicals on highways.

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INDIANA HIGHWAY COST-ALLOCATION STUDY:
FINAL REPORT

To: H.L. Michael, Director
Joint Highway Research Project

October 31, 1984
Revised March, 1985

From: K.C. Sinha, Research Engineer
Joint Highway Research Project

Project: C-36-54PP
File: 3-3-42

Attached is the Final Report on the HPR Part I Study titled, "Indiana Highway Cost-Allocation Study." This report presents the findings of the cost-allocation study for Indiana and it has been prepared under the direction of Professor K. C. Sinha.

The methodology conforms to the mandate of the H.E.A. 1006 of the 103rd General Assembly. The findings indicate that the passenger cars and single-unit trucks are overpaying their cost responsibility, while the buses and heavy combination trucks are underpaying their cost responsibility.

This report is forwarded for review, comment and acceptance by the IDOH and FHWA as fulfillment of the objectives of the study.

Respectfully submitted,

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and the

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Federal Highway Administration

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TABLE OF CONTENTS

Page

LIST OF TABLES v

LIST OF FIGURES xi

EXECUTIVE SUMMARY xiii

CHAPTER 1. INTRODUCTION 1

Purpose of the Study 2
Highway Classification 2
Vehicle Classification 4
Definition of Costs 5
Time Frame of Study 9
Allocated Costs 9
Attributed Revenues 14

CHAPTER 2. COST ALLOCATION METHODOLOGY 18

Guiding Principles 18
Overview of the Study Approach 19
Summary of Cost-Allocation and Revenue-Attribution Procedures 22

CHAPTER 3. RESULTS OF COST-ALLOCATION AND REVENUE-ATTRIBUTION ANALYSIS 27

Cost-Responsibility Factors for Highway and Structure Expenditure Items 27
Cost-Responsibility Factors for Major Expenditure Areas 29
Overall Statewide Vehicle Class Cost-Responsibilities 35
Proportions of Attributable and Non-Attributable Costs 38
Revenue Contribution by Vehicle Class 42
Comparison of Cost Responsibility with Revenue Contribution 42

Base Period (1983) Findings 42
Biennial Budget Period (1985-86) Findings 44

Comparison of Indiana's Findings to Findings in Other Studies 45

CHAPTER 4. CONCLUSIONS 47

APPENDIX A. DATA BASE 50

Traffic Data 50

Cost Data 50

State Highway System 51
Local Roads 52

Revenue Data 53

APPENDIX B. PROCEDURE FOR TRAFFIC DATA COLLECTION 54

Vehicle Count 54
Field Data Collection Procedures 55
Data Reduction and Analysis 55
Estimation of Vehicle-Miles of Travel 60
VMT Correspondence Matrices for Registered and Operating Weight Groups 67

APPENDIX C. HIGHWAY CONSTRUCTION COST ALLOCATION 87

General 87
Right-of-Way Costs 87
Grading and Earthwork Costs 91
Drainage and Erosion Control Costs 94
New Pavement Costs 97
Shoulder Costs 105
Reconstruction Costs 107
Miscellaneous Items 108

APPENDIX D. HIGHWAY REHABILITATION COST ALLOCATION 109

General 109
Previous Studies 109
Allocation Procedure for Pavement Rehabilitation Costs 111

APPENDIX E. STRUCTURAL CONSTRUCTION, REPLACEMENT AND REHABILITATION COST ALLOCATION 117

General 117
Adopted Incremental Method 118
Design Loadings 118
Correlation Between AASHTO and Actual Trucks 119
Selection of Bridge Samples 121
Variation of Structure Width with Live Loadings 126
Distribution Between Highway and Waterway Crossings .. 128
Allocation Factors 128

Superstructure Cost Factors 131
Substructure Cost Factors 133
Excavation and Backfill Factors 148
Drainage Pipe Factors 148
Railing Factors 148
Miscellaneous Items 150

Allocation of Cost Responsibilities 150
New Bridge Construction 152
Bridge Replacement 152
Bridge Rehabilitation 154
Culverts 154
Sign Bridges 157

APPENDIX F. MAINTENANCE COST ALLOCATION 159

General 159
Previous Studies 159
Allocation Methodology 160
Data Base for Analysis 162
Procedure for Allocating Pavement Routine Maintenance Costs 162

APPENDIX G. REVENUE ATTRIBUTION 165

State Highway Revenues 165
Federal Revenues 167
Attribution of Revenue 167

State Fuel Taxes 168
State Registration Fees 169
Other Taxes and Fees 170
Federal Taxes 170

APPENDIX H. DETERMINATION OF COST-RESPONSIBILITY FACTORS OF LOAD-RELATED AND NON-LOAD-RELATED FACTORS IN PAVEMENT REHABILITATION AND MAINTENANCE COST ALLOCATION 172

APPENDIX I. TABLES OF COST-RESPONSIBILITY FACTORS USED FOR COST-ALLOCATION COMPUTATION 183

APPENDIX J. PROBLEMS OF USING CENTS PER VEHICLE-MILES OF TRAVEL AS AN INDEX FOR EXPRESSING COST-ALLOCATION RESULTS 234

REFERENCES 239

LIST OF TABLES

Table		Page
1	Adopted Vehicle Classification	6
2	Vehicle Class Weight Group Classification	7
3	Expenditure Items by Expenditure Area	10
4	Highway User Revenues	17
5	Overall Statewide Cost-Responsibility for Year 1983	36
6	Overall Statewide Cost-Responsibility for Year 1985-86	37
7	Cost Allocation Criteria for Expenditure Items	39
8	Revenue Contribution by Vehicle Class (1983)	40
9	Revenue Contribution by Vehicle Class (1985-86)	41
10	Cost-Allocation and Revenue Attribution Summary	43
11	Comparison of Findings of the Indiana Study to Findings of Other Studies	46
B.1	Number of Traffic Count Sites	56
B.2	Volume Count Station Locations	57
B.3	Percent VMT of Vehicle Classes on Rural Interstate (1983)	61
B.4	Percent VMT of Vehicle Classes on Urban Interstate (1983)	62
B.5	Percent VMT of Vehicle Classes on State Primary (1983)	63
B.6	Percent VMT of Vehicle Classes on State Secondary (1983)	64
B.7	Percent VMT of Vehicle Classes on County Roads (1983)	65
B.8	Percent VMT of Vehicle Classes on City Streets (1983)	66
B.9	Percent VMT of Vehicle Classes on Rural Interstate	

(1985-86) 69

B.10 Percent VMT of Vehicle Classes on Urban Interstate (1985-86) 70

B.11 Percent VMT of Vehicle Classes on State Primary Routes (1985-86) 71

B.12 Percent VMT of Vehicle Classes on State Secondary Routes (1985-86) 72

B.13 Percent VMT of Vehicle Classes on County Roads (1985-86) 73

B.14 Percent VMT of Vehicle Classes on City Streets (1985-86) 74

B.15 VMT Values by Highway Functional Class 75

B.16 Indiana Bureau of Motor Vehicles Registered Vehicle Classification 76

B.17 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Single-Unit Trucks Class 3 77

B.18 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Single-Unit Trucks Class 6 78

B.19 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 7 79

B.20 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Single-Unit Trucks Class 9 80

B.21 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 10 81

B.22 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 11 82

B.23 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 12 83

B.24 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 13 85

B.25 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 14 86

C.1 Right-of-Way Width Requirements 89

C.2 Traveled-Way Width Requirements 93

E.1 Study Vehicle Classification and Equivalent AASHTO Designation 122

E.2 Vehicular Classification and Responsibility Summary for Bridge Superstructure 123

E.3 Characteristics of Typical Bridges Constructed in the Base Period 127

E.4 Bridge Width Under Different Loadings 129

E.5 Distribution Between Highway and Waterway Crossings 130

E.6 Bridge Superstructure Unit Costs 134

E.7 Bridge Deck Area 135

E.8 Superstructure Cost Factors for Interstate Rural Bridges 136

E.9 Superstructure Cost Factors for Interstate Urban Bridges 137

E.10 Superstructure Cost Factors for State Primary Highway Bridges 138

E.11 Superstructure Cost Factors for Secondary Highway Bridges 139

E.12 Superstructure Cost Factors for Local Road Bridges 140

E.13 Piling Cost Factors 147

E.14 Piers and Abutment Cost Factors 149

E.15 Railing Cost Factors 151

E.16 Percent Distribution of New Bridge Construction Cost by Cost Item and by Highway Class 153

E.17 Percent Distribution of Bridge Replacement Cost by Cost Item and by Highway Class 155

E.18 Percent Distribution of Bridge Rehabilitation Cost by Cost Item and by Highway Class 156

F.1 Pavement Routine Maintenance Activities 163

H.1 Relationship Between Present Serviceability Index (PSI) and Roughness Number (RN) 176

H.2 Proportional Responsibilities of Load-Related and Non-Load-Related Factors in Indiana Pavement Rehabilitation and Maintenance Cost Allocation 181

I.1 Pavement Construction Cost-Responsibility Factors 184

I.2 Shoulder Construction Cost-Responsibility Factors 185

I.3 Right-of-way Construction Cost-Responsibility Factors 186

I.4 Drainage & Erosion Control Cost-Responsibility Factors 187

I.5 Grading & Earthwork Cost-Responsibility Factors 188

I.6 Common Costs Cost-Responsbility Factors 189

I.7 Truck-Only Common Costs Cost-Responsibility Factors 190

I.8 Pavement Construction Cost-Responsibility of Vehicle Classes on Rural Interstate (1983) 191

I.9 Pavement Rehabilitation Cost-Responsibility Factors for Rural Interstate 192

I.10 Pavement Rehabilitation Cost-Responsibility Factors for Urban Interstate 193

I.11 Pavement Rehabilitation Cost-Responsibility Factors for State Routes Primary 194

I.12 Pavement Rehabilitation Cost-Responsibility Factors for State Routes Secondary 195

I.13 Pavement Rehabilitation Cost-Responsibility Factors for County Roads 196

I.14 Pavement Rehabilitation Cost-Responsibility Factors for City Streets 197

I.15 Pavement Maintenance Cost-Responsibility Factors for Rural Interstate 198

I.16 Pavement Maintenance Cost-Responsibility Factors for Urban Interstate 199

I.17 Pavement Maintenance Cost-Responsibility Factors for State Routes Primary 200

I.18 Pavement Maintenance Cost-Responsibility Factors for State Routes Secondary 201

I.19 Pavement Maintenance Cost-Responsibility Factors for County Roads 202

I.20 Pavement Maintenance Cost-Responsibility Factors for City Streets 203

I.21 Bridge Superstructure Cost-Responsibility Factors 204

I.22 Bridge Pier Cost-Responsibility Factors 205

I.23 Bridge Excavation Backfill Cost-Responsibility Factors 206

I.24 Bridge Drainage Cost-Responsibility Factors 207

I.25 Bridge Pile Cost-Responsibility Factors 208

I.26 Bridge Railing Cost-Responsibility Factors 209

I.27 Cost-Responsibility for State Highways (1983) 210

I.28 Cost-Responsibility for County Roads (1983) 211

I.29 Cost-Responsibility for City Streets (1983) 212

I.30 Cost-Responsibility for Bridges on State Highways (1983) 213

I.31 Cost-Responsibility for Bridges on County Roads (1983) 214

I.32 Cost-Responsibility for Bridges on City Streets (1983) 215

I.33 Cost-Responsibility for Sign Bridges (1983) 216

I.34 Cost-Responsibility for Police Enforcement (1983) 217

I.35 Weigh Station Inspection Cost-Responsibility for

Trucks (1983) 218

I.36 Cost-Responsibility for State Highways (1985-86) 219

I.37 Cost-Responsibility for County Roads (1985-86) 220

I.38 Cost-Responsibility for City Streets (1985-86) 221

I.39 Cost-Responsibility for Bridges on State Highways (1985-86) 222

I.40 Cost-Responsibility for Bridges on County Roads (1985-86) 223

I.41 Cost-Responsibility for Bridges on City Roads (1985-86) 224

I.42 Cost-Responsibility for Sign Bridges (1985-86) 225

I.43 Cost-Responsibility for Police Enforcement (1985-86) 226

I.44 Weigh Station Inspection Cost-Responsibility for Trucks (1985-86) 227

I.45 Overall Cost-Responsibility for State Highway System (1983) 228

I.46 Overall Cost-Responsibility for County Road System (1983) 229

I.47 Overall Cost-Responsibility for City Street System (1983) 230

I.48 Overall Cost-Responsibility for State Highway System (1985-86) 231

I.49 Overall Cost-Responsibility for County Road System (1985-86) 232

I.50 Overall Cost-Responsibility for City Street System (1985-86) 233

J.1 Cost-Allocaion Analysis of Example Problem 234

J.2 Cost-Allocation of Example Problem Expressed in Cents/VMT 238

LIST OF FIGURES

Figure		Page
1	Expenditure Distribution for Fiscal Year 1983	12
2	Expenditure Distribution for Budget Year 1985-86 ..	13
3	Cost-Allocation Study Flow Chart	23
4	Computation of Overall Statewide Vehicle Class Cost-Responsibilities	30
5	Computation of Statewide Vehicle Class Cost-Responsibilities for State Highways	31
6	Computation of Statewide Cost-Responsibilities for County Roads and City Streets	32
7	Derivation of Statewide Cost-Responsibilities for State Highway Bridges	33
8	Derivation of Statewide Cost-Responsibilities for Bridges on County Roads and City Streets	34
D.1	Schematic Diagram Showing Pavement Performance Considered in Highway Rehabilitation Cost Allocation	114
E.1	Modified AASHTO Live Loading Configurations for Bridge Incremental Designs	120
E.2	HS and H Trucks Correlation	124
E.3	Flow Chart Illustrating the Data Generation for the Correlation Process	123
E.4	Percent of Total Superstructure Cost vs. AASHTO HS Loading for Interstate Urban Bridges	141
E.5	Percent of Total Superstructure Cost vs. AASHTO HS Loading for Interstate Rural Bridges	142
E.6	Percent of Total Superstructure Cost vs. AASHTO HS Loading for State Primary Bridges	143
E.7	Percent of Total Superstructure Cost vs. AASHTO HS Loading for State Secondary Bridges	144
E.8	Percent of Total Superstructure Cost vs. AASHTO HS Loading for Bridges on Local Roads	145

G.1 Organization of the Motor Vehicle Highway Account (MVHA) 166

H.1 Total Pavement Damage as Defined by Zero-Maintenance Pavement Performance Curve 173

H.2 Schematic Diagram Showing Pavement Performance Curves with their Associated Routine Expenditures 174

H.3 Schematic Diagram Showing Load-Related and Non-Load-Related Effects Responsible for Pavement Damage 178

H.4 Northern and Southern Regions for Pavement Cost-Allocation 182

EXECUTIVE SUMMARY

This study was mandated by the House Enrolled Act 1006 of the 103rd Indiana General Assembly and it was conducted by the Joint Highway Research Project of Purdue University in cooperation with the Indiana Department of Highways.

The study documented the full cost of building and maintaining the state's highway system including that portion of the Federal Interstate system within Indiana. An equitable methodology based on an incremental approach was developed for allocating such costs to all the users of the system. An explicit consideration was given to the effects of age, weather, salt and other chemicals on highways.

The study findings indicated a significant imbalance between cost responsibility of and revenue payment by different vehicle classes. In FY 1983 passenger cars including panels and pickups as well as single-unit trucks overpaid their cost responsibility, while heavy combination trucks and buses underpaid their cost responsibility. The same pattern is expected in the biennial period of 1985-86. However, the underpayment by heavy trucks would be more pronounced in 1985-86. During this biennial period, passenger cars as a group would be overpaying about 25% of their cost responsibility while single-unit trucks as a group would be overpaying about 24% of their cost responsibility. At the same time buses would pay about 2% less than their cost responsibility and combination trucks as a group would pay about 46% less than their cost responsibility.

Although the passenger cars as a group would overpay, there is a significant inequity within this group. This inequity primarily involves underpayment by small cars and overpayment by large cars. In 1985-86, small cars would underpay about 24%, while large cars would overpay about 38% of their cost responsibility. Also, among single-unit trucks, 2-axle and 4-axle trucks would overpay by 45% and 3% respectively, while 3-axle trucks would underpay by 18%. At the same time, almost all vehicle classes in heavy combination group would underpay by about 50% except vehicle class 13 (other 5-axle) which would overpay by about 20%.

In the two-year period of 1985-86 the passenger cars as a group would overpay $197,960,000 and single-unit trucks as a group would overpay $31,283,000. On the other hand, combination trucks would underpay $229,130,000 and buses would underpay only $113,000. The subsidization of heavy vehicles by passenger cars and single-unit trucks would thus continue if the tax structure remains the same.

CHAPTER ONE

INTRODUCTION

The Indiana highway system consists of 11,294 miles of State Roads, 66,564 miles of County Roads and 13,818 miles of City Streets. The Federal-Aid portion of the Indiana highway system is comprised of 1144 miles of Interstates, 5064 miles of Primary, 8980 miles of Secondary and 4828 miles of Federal-Aid Urban highways. For all governmental units combined, annual expenditures for highway purposes in Indiana are about 3/4 billion dollars.

As a part of the House Enrolled Act 1006, the 103rd Indiana General Assembly required the Indiana Department of Highways (IDOH) "to undertake a highway cost-allocation study to (a) document the full cost of building and maintaining the state's highway system, including that portion of the Federal Interstate system within Indiana; and (b) develop an equitable methodology for allocating such costs to all the users of the system".

This study, entitled Indiana Highway Cost-Allocation Study, was initiated by the Advisory Board of the Joint Highway Project of Purdue University in cooperation with the IDOH on May 4, 1983. It was carried out in two phases. The major tasks undertaken in Phase I are literature review, study design, data collection and data analysis. Those included in Phase II are development of the methodological framework, preparation of an interim report, determination of travel functions and current cost responsibility, sensitivity analysis, future cost responsibility and preparation of a final report.

An interim report was issued during Phase II of this study. It examined the methodology and procedures adopted by previous studies of other states to determine cost responsibilities of various highway user groups. A procedure for use in Indiana was discussed in the report [39]. This final report presents the results, findings and conclusions of the entire study. A summary description of the cost-allocation procedures adopted is included in the Appendices to this report.

Purpose of the Study

The main objective of this study was to fulfill the requirement of the legislative directive mentioned earlier by determining the responsibility of individual vehicle classes in occasioning highway costs. The total highway costs and traffic distribution must first be determined in the highway system concerned. Subsequently, an equitable cost-allocation procedure is to be devised to derive the cost responsibilities of various vehicle classes.

Although determination of the revenue contributed by each vehicle class was not within the initial scope of the present cost-allocation study, the study would not be complete without such information. The results of the cost-allocation study would be meaningful only if it is compared to the user revenue contribution. It was therefore decided to include determination of revenue contribution of individual highway user classes as a task in the Phase II of this study. The revenue contribution of each user class could then be compared with its cost responsibility. This comparison would enable one to determine if the contribution of each user class matches its cost responsibility for the highway costs.

Highway Classification

The House Enrolled Act 1006 indicated that the highways to be considered in the cost-allocation study include the State's entire highway system, including that portion of the Federal Interstate system within Indiana. Following this directive, all public roads in Indiana are considered in this study. Toll roads, however, are not included. Exclusion of toll roads is justified because the construction and maintenance of these roads are paid directly by the toll road users and are not part of the state highway expenditures.

The main concern is to select a classification which would lead to an accurate allocation of highway cost. Two important criteria are (i) the data availability by type, and (ii) the accuracy of the cost-allocation figures. Often traffic data are available according to functional classification, while cost data are given in terms of jurisdictional classification. A classification must be sought such that matching and transferring of the two sets of data would not introduce unnecessary inaccuracy in the study results.

The most logical set of criteria for highway classification are:

a. a classification which best satisfies the needs of cost allocation;

b. a classification which covers all the road systems specified in the scope of the present study; and

c. a classification which is compatible to the available data from the IDOH and other highway agencies in Indiana.

Following these criteria, the following highway classification was adopted:

1. Interstate Urban

2. Interstate Rural

3. State Routes Primary

4. State Routes Secondary

5. County Roads

6. City Streets

The adopted highway classification conforms well to the functional classification used by the FHWA in recording HPMS data. At the same time, this classification allows identification of the highway system by jurisdiction.

Vehicle Classification

The basic idea of vehicle classification is to group vehicles having similar characteristics with respect to highway use and highway damage. Ideally, each group must be small enough so that the cost responsibility calculated would represent accurately the cost responsibility of the individual user within the group. On the other hand, the number of groups cannot be so large as to make data sets too formidable to handle. The classification used must reflect the range of highway users in Indiana. It also must be such that the existing data at the IDOH can be used and any new data collected can in turn be employed by the IDOH for other purposes.

Most classification systems used in cost-allocation study follow a two-step procedure: (i) major classes according to function type of vehicles, e.g., passenger cars, buses and trucks; (ii) subdivision of these major classes into smaller grouping based on vehicle weights and/or axle configuration.

A point to note regarding the weight classification is that different types of weights have been used for this purpose. For instance, the 1983 Maryland study [42] used gross registered weight, the 1982 Wisconsin study [48] and 1980 Oregon study [33] used gross operating weight, and the 1981 Wyoming study [45] used empty vehicle weight. Use of gross registered weight facilitates computation of revenue contribution, but transformation to operating weight is needed for assessing cost responsibilities. The reverse is true of classification using gross operating weight.

In the present study vehicles were grouped into fourteen classes as defined in Table 1. The data collected from truck weighing stations were used to subdivide nine of the fourteen classes in terms of gross operating weights. The nine classes are Class 3, 6, 7, 9, 10, 11, 12, 13 and 14. For these nine classes, all cost-allocation analyses were carried out in weight divisions of 2500 pounds. In Table 2 are listed the weight subgroups used for each of the vehicle classes. For the purpose of attributing appropriate revenues correspondence matrices were developed to relate registered vehicle weight classes to gross vehicle weight classes.

Definition of Costs

Most cost-allocation studies have chosen to use actual expenditure instead of needed expenditure as the allocated costs. The primary reason for not using needed expenditure is that there are no fixed criteria as to what level of highway needs have to be satisfied. Rather than making more assumptions in order to derive a needed expenditure, the actual expenditure was used in the present study because it represents the amount spent in a given year and can be directly related to the revenue contribution of the same year.

Table 1. Adopted Vehicle Classification.

Class	Description
1	small passenger cars
2	standard and compact passenger cars, panel and pickup
3	2-axle truck (2S and 2D)
4	bus
5	car with 1-axle trailer
6	3-axle single unit truck
7	2S1 tractor-trailer
8	car with 2-axle trailer
9	4-axle single unit truck
10	3S1 tractor-trailer
11	2S2 tractor-trailer
12	3S2 tractor-trailer
13	other 5-axle
14	6 or more axle

Table 2. Vehicle Class Weight Group Classification

Vehicle Class	Weight Group	Weight in Pounds
1	1	All
2	1	All
3	1	<7500
3	2	7500-10,000
3	3	10,000-12,500
3	4	12,500-15,000
3	5	15,000-17,500
3	6	17,500-20,000
3	7	20,000-22,500
3	8	22,500-25,000
3	9	≥25,000
4	1	All
5	1	All
6	1	<17,500
6	2	17,500-20,000
6	3	20,000-22,500
6	4	22,500-25,000
6	5	25,000-27,500
6	6	27,500-30,000
6	7	30,000-32,500
6	8	32,500-35,000
6	9	≥35,000
7	1	<20,000
7	2	20,000-22,500
7	3	22,500-25,000
7	4	25,000-27,500
7	5	27,500-30,000
7	6	30,000-32,500
7	7	32,500-35,000
7	8	35,000-37,500
7	9	≥37,500
8	1	All
9	1	<22,500
9	2	≥22,500
10	1	<27,500
10	2	27,500-30,000
10	3	30,000-32,500
10	4	≥32,500
11	1	<22,500
11	2	22,500-25,000
11	3	25,000-27,500
11	4	27,500-30,000
11	5	30,000-32,500
11	6	32,500-35,000
11	7	35,000-37,500
11	8	37,500-40,000
11	9	40,000-42,500
11	10	42,500-45,000
11	11	45,000-47,500
11	12	47,500-50,000
11	13	50,000 & Above
12	1	20,000-22,500
12	2	22,500-25,000
12	3	25,000-27,500
12	4	27,500-30,000
12	5	30,000-32,500
12	6	32,500-35,000
12	7	35,000-37,500
12	8	37,500-40,000
12	9	40,000-42,500
12	10	42,500-45,000
12	11	45,000-47,500
12	12	47,500-50,000
12	13	50,000-52,500
12	14	52,500-55,000
12	15	55,000-57,500
12	16	57,500-60,000
12	17	60,000-62,500
12	18	62,500-65,000
12	19	65,000-67,500
12	20	67,500-70,000
12	21	70,000-72,500
12	22	72,500-75,000
12	23	75,000-77,500
12	24	77,500-80,000
12	25	80,000-82,500
12	26	82,500 & Above
13	1	<42,500
13	2	42,500-45,000
13	3	45,000-47,500
13	4	47,500-50,000
13	5	50,000-52,500
13	6	52,500-55,000
13	7	55,000-57,500
13	8	57,500-60,000
13	9	60,000-62,500
13	10	62,500-65,000
13	11	65,000-67,500
13	12	67,500-70,000
13	13	70,000 & Above
14	1	<40,000
14	2	40,000-60,000
14	3	≥60,000

The HEA 1006 requires that the study consider the full cost of building and maintaining the state's highway system. Full costs are really what we have been spending and an estimate of these estimates can be made by examining actual expenditures for a period of time. Actual expenditure may change from year to year. This change may be brought about by changes in area of emphasis in expenditure program or availability of fund. However, if actual expenditures for a number of years are considered, a great part of the yearly variation can be discounted.

The definition of "full costs" used in the study is valid as confirmed by other state studies. Although "full costs" in one sense of meaning might be defined as what should have been spent to maintain the highway system at a "reasonable level," the fact remains that disagreement with users as to the "reasonable level" will result and determination of that cost will also be subject to question. On the other hand, what was spent is fact and was what the users provided.

The fact that actual expenditures are used in most cost-allocation studies explains why such a study has to be carried out from time to time to check that each user group is paying its fair share of responsibility.

In cost-allocation study, expenditure is commonly divided into distinct categories such as construction, rehabilitation and maintenance. The present study followed the general categories used in the State cost data. The exact categories are as follows:

Highway Construction

Highway Rehabilitation

Structure Construction

Structure Rehabilitation

Maintenance and Operation

Other Costs

Each expenditure category was further subdivided into a number of expenditure items. These subdivisions enabled more accurate cost-allocation to be carried out. This is mainly because each expenditure item is likely to have different responsible attributes (or cost-allocators). The detailed division of each expenditure category into smaller items depends largely upon the degree of breakdown available in the cost data. The expenditure items listed in Table 3 were adopted after careful examination of the cost data files.

Time Frame of Study

The basic input data used in the study were compiled from a period of four years, 1980 to 1983. Cost and other data were analyzed for this period to determine the appropriate allocation factors. The base period cost responsibility and revenue contribution figures were computed for the fiscal year of 1983. The allocation factors from base period were applied to the study period (1985-86) budgeted expenditure to arrive at the cost responsibility of each vehicle class for the study period. These cost responsibility figures were then compared to the appropriate revenue contribution figures.

Allocated Costs

A detailed analysis of expenditure records by cost item for the four year period, 1980-83, was conducted for the state highway system. All expenditures by contract type, by object code and by cost account were analyzed and grouped in terms of the cost categories used in the present study. No such detailed

Table 3. Expenditure Items by Expenditure Area

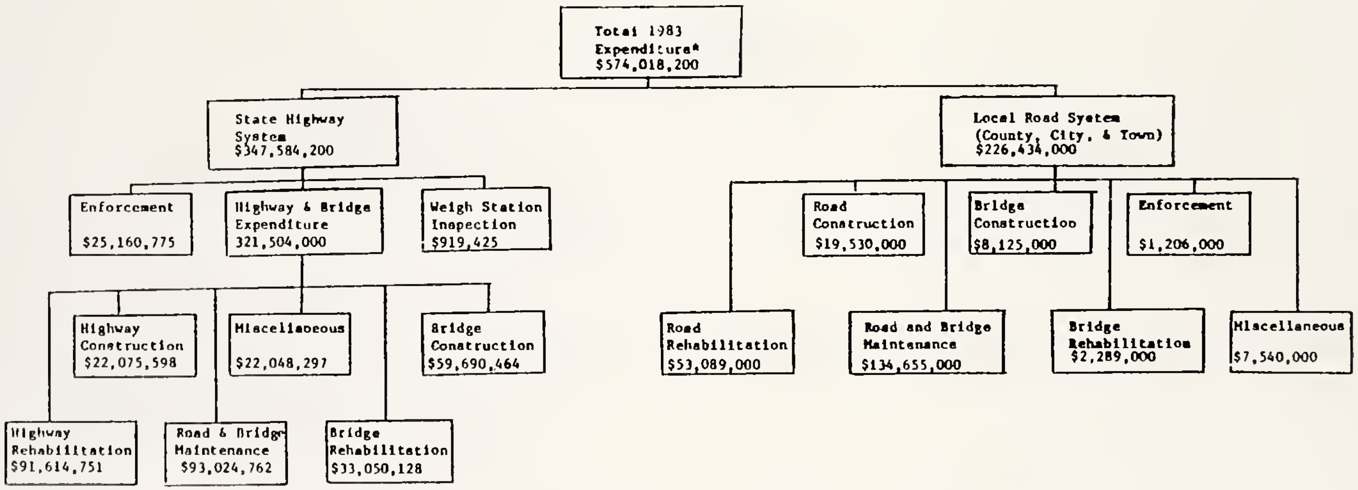
Highway Construction	Structure Construction and Replacement	Highway Rehabilitation	Structure Rehabilitation	Routine Maintenance	Other Costs
Right-of-Way	Excavation and Backfill	Grading and Earthwork	Concrete	Drainage and Erosion Control	Enforcement (policing)
Grading and Earthwork	Concrete	Drainage and Erosion Control	Steel Reinforcements	Pavement and Shoulder	Weight Inspection
Drainage and Erosion Control	Steel Reinforcements	Pavement and Shoulder	Structural Steel	Bridge	Special Railroad Crossings
Pavement	Structural Steel	Miscellaneous Items	Miscellaneous Items	Miscellaneous Items	
Shoulder	Piers and Piling				
Miscellaneous Items	Culverts and Sign Structures				
	Miscellaneous Items				

data for the local highway system were available and information from various sources was used to compile the local data. The highway expenditure data from the county annual reports, data from the Bureau of the Census and data collected directly from a number of selected counties and cities were used. In addition, information from the Office of Local Assistance of the Indiana Department of Highways was also available.

For the purpose of cost allocation, expenditures by cost category, by highway type, by pavement type and by geographic location were necessary. This detailed information for the state highway system was generated by analyzing several data files including road life record files, construction reports, itemized cost estimates, monthly expenditure files, and routine maintenance files. For the local highway system, the corresponding data were collected directly from a number of counties and cities including the counties of Tippecanoe, Monroe, Marion and cities of Lafayette, Fort Wayne, and West Lafayette. The local road inventory file maintained by the IDOH was also used. In addition, the pavement type information was supplemented by an analysis of the records of the local assistance projects supported by the IDOH. The data from the HPMS records were also used in this effort.

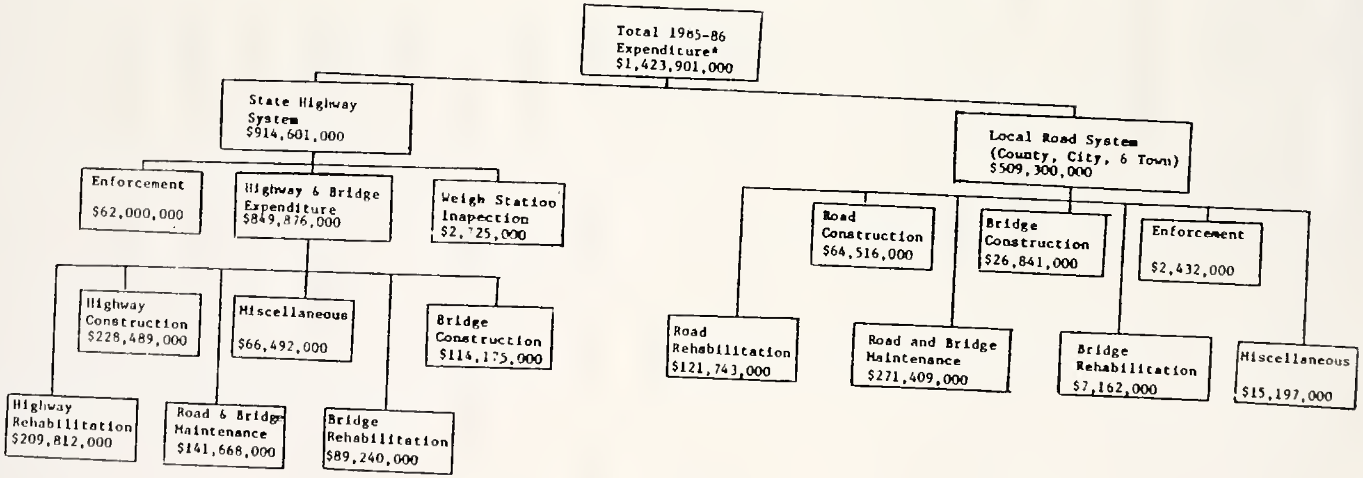
A breakdown of the total expenditure supported by user revenue in terms of major cost categories for the fiscal year 1983 is presented in Figure 1. The corresponding expenditure data for the two year period of 1985-86 are presented in Figure 2. The 1985-86 data were estimated from the available revenue information and the adopted program levels. The costs shown in Figures 1 and 2 were subsequently allocated among vehicle classes.

It should be pointed out that the total highway expenditure in Indiana is



*includes only the expenditure supported by user revenues

Figure 1. Expenditure Distribution for Fiscal Year 1983



*Includes only the expenditure supported by user revenues

Figure 2. Expenditure Distribution for Budget Period 1985/86

significantly higher than what is supported by user revenues. Although the expenditure in the state highway system is greatly dependent on user revenues with about 90 percent of the expenditure derived from user revenue in 1983, the portion of expenditure supported by user revenue at the local level was about 52 percent in 1983.

Attributed Revenues

Revenues considered in the present study were defined as those revenues contributed by Indiana highway users which were used to support highway activities. The following sources of revenue support these activities in Indiana:

1. State gasoline and special fuel taxes
2. State motor carrier fuel use tax
3. State vehicle license fees including specific periodic permit fees
4. State motor carrier fees including vehicle identification stamp fees
5. Reciprocity identification stamp fees
6. Oversize and overweight permit fees
7. Federal gasoline and special fuel taxes
8. Federal taxes on tires, tread rubber, inner tubes, lubricating oil, and truck parts (effective in 1983 but not included in 1985-86)
9. Federal tax on truck sales
10. Federal heavy vehicle use fee
11. Local option user taxes

In 1983 the State gasoline and special fuel taxes were equivalent to 11.1 cents per gallon. State motor carrier fuel use tax is collected for the fuel not purchased in Indiana but consumed on Indiana roads from all commerical vehicles with more than 2 axles including passenger vehicles that seat more than nine passengers. Information on motor fuel taxes was obtained from the Motor Fuel Tax Division of the Department of Revenue.

State vehicle registration fees include such items as license fees on passenger cars, commerical vehicles, personal license plate fees and short term permit fees. The data on registration fees were collected from the Bureau of Motor Vehicles.

Motor carrier vehicle identification stamp fees are for transporting regulated goods over Indiana highways and they include tractor fees, truck or bus fees, 30-day temporary tractor and truck or bus fees. Reciprocity identification stamp fees are collected from interstate carriers from those states with which Indiana has a reciprocity agreement. Information on these fees was obtained from the Public Service Commission.

State revenue sources excluded from revenue attribution were those fees which were charges related to specific services, such as vehicle title fee, various dealer fees, transfer fees, amateur radio fees, driver license fees, driver court fees and reinstatement fees. It should be pointed out that the costs of administering these services were also excluded so as not to affect the revenue/cost comparisons.

Federal revenue sources include motor fuel taxes and other taxes and fees. In 1983 other taxes and fees consisted of tax on tires, tread rubber, inner tubes, lubricating oil and truck parts, tax on truck sales, and heavy vehicle use fee. The STAA of 1982 and subsequent amendment made several changes in the federal tax structure. Schedules of motor fuel taxes, tax on truck sales and heavy vehicle use fee have been changed significantly and the rest of the taxes have been eliminated. Proper consideration was given to these changes for revenue attribution in 1985-86. A detailed discussion on revenue sources and related tax structures is given in Appendix G.

It should be noted that as Indiana is a donor state, only that part of the Indiana highway user payments to the Highway Trust Fund that was returned to Indiana was included in the analysis.

Table 4 shows the revenue sources and the amounts for the FY 1983 and the biennial period of FY 1985-86 included in the user revenue attribution analysis. It may be noted that the major portion of user revenues includes state and federal motor fuel taxes and state registration fees. For example, in 1985-86 out of the total attributed revenue of $1,422,910,000, these two sources comprised $1,251,170,000 or about 80 percent of the total amount.

Table 4. Highway User Revenues

Revenue Source	FY 1983	FY 1985	FY 1986	1985-86 Total
		Amount in Millions		
State Motor Fuel Taxes	305.18	308.00	306.00	614.00
State Vehicle Registration Fees	109.70	113.80	112.00	225.80
Other State and Local Fees	3.56	5.35	5.50	10.85
Subtotal (State and Local)	418.44	427.15	423.50	850.65
Federal Motor Fuel Taxes	111.03	196.44	214.93	411.37
Other Federal Taxes	44.53	76.39	85.50	161.89
Subtotal (Federal)	155.56	272.83	299.43	572.26
Total	574.00	699.98	722.93	1,423.91

COST-ALLOCATION METHODOLOGY

Guiding Principles

There are two broad approaches to highway cost-allocation studies, namely the equity approach and the efficiency approach. Ideally, highway cost-allocation study should result in an equitable and efficient highway user financing system so that each user group would be paying its fair share of cost responsibility in terms of revenue contribution.

To be fully efficient, economic theory requires that the price of a trip be equal to the extra or marginal costs caused by that trip. Under this approach, highway users during peak hours would be charged at a higher rate than other users who use highways during off-peak periods. Similarly, highway users in heavily developed area have to pay higher charges than other users in less congested areas. Understandably, much more detailed information than ordinarily available traffic and transportation data is required before such a study can be carried out. There are other difficulties in following this approach even if all the required data were available. Firstly, it cannot be applied directly in a highway cost-allocation analysis because it is extremely difficult to relate marginal costs to levels of expenditures. Most importantly, user charge instruments cannot be easily developed and implemented that vary geographically and by time of day - a requirement for efficient pricing. As a result, the efficiency has not been adopted as the main criterion in other cost-allocation studies although the approach has a sound economic concept of market pricing.

Virtually all cost-allocation studies follow the equity approach. Equity itself is a subjective concept and a clear definition is needed for application. Equity can be judged by one of the following three criteria [47]:

a. Costs should be assigned to users in proportion to the benefits they receive.

b. Costs should be assigned to users in proportion to the costs they cause (occasion).

c. Costs should be assigned to users in proportion to their ability to pay.

The definition of equity appropriate for highway cost-allocation studies is that related to cost-responsibility or the cost occasioned by various vehicle groups. The present cost-allocation study, based on the equity approach, followed a procedure which is both practical and theoretically sound.

Overview of the Study Approach

The major steps in the present cost-allocation study are identified in this section, and these are:

a. Collection of data: An extensive data collection effort was made to obtain information on highway traffic, highway expenditures and user revenues. Relevant information on highway pavement and structure characteristics was also compiled. Information on the data base is given in Appendix A.

b. Establishing Input Data: The collected data were processed to provide input information to the cost-allocation and revenue attribution analyses. The 1983 traffic data included vehicle classification by highway class, gross operating weight distribution by vehicle class, distribution of gross vehicle weights for each registered weight class, and an estimate of vehicle-miles of travel by vehicle class, by weight group, and by highway class. Appropriate adjustments were made to project traffic information to the study period of 1985-86. A more detailed discussion of the traffic data collection and analysis is presented in Appendix B.

The state highway expenditure data were compiled from the computerized records of the IDOH Accounting Division for the fiscal years of 1980 through 1983. The local highway expenditure data were compiled from various sources as mentioned earlier. The input information on expenditure included expenses by detailed cost category, by highway class, by pavement type and by geographic location. For certain cost items, such as maintenance, historical record of expenses was processed to provide appropriate input information. The 1985-86 expenditure for the State highway system was based on the expected level of revenues and proposed budgets, while the corresponding amounts for the local highway system was estimated according to the expected level of user revenues and past expenditure records.

The input for user revenue attribution analysis included information on total amounts by revenue source for state highway system, county roads and city streets. In order to attribute revenues among vehicle classes, appropriate tax structures were also provided as input.

c. Identifying Attributable and Non-attributable Costs: One of the major issues in cost-allocation study is to determine the proportions of attributable and non-attributable costs in each expenditure item. Attributable costs are costs which can be attributed to specific vehicle classes, whereas non-attributable costs are those which are not related to vehicular characteristics and vehicle use. A large part of the non-attributable costs results from the effects of age, weather, salt and other chemicals on highways. In the present study, non-attributable costs were considered as common costs to all highway users.

d. Selection of Cost-Allocators for Expenditure Items: After identifying attributable and non-attributable costs, the next step was to select suitable cost-allocators to distribute these costs among vehicle classes. Due to the differing nature and causes of various expenditure items, it is not possible to use a single cost-allocator that is satisfactory for all expenditure items. In order to distribute equitably highway costs among vehicle classes in proportion to their responsibility for occasioning these costs, an appropriate cost-allocator was selected for each expenditure item so as to reflect as closely as possible the relationships between particular expenditure items and the specific vehicle classes. A separate set of allocators also was selected for distributing the non-attributable or common costs among user groups.

e. Determination of Cost-Responsibility Factors: The direct consequence of using different expenditure items is obvious -- the proportion of cost responsibility (i.e. the cost-responsibility factor) of a specific vehicle class for different expenditure items would be different. As mentioned earlier, cost-responsibility factors were determined using the base period data. These factors were then applied to the 1985-86 biennial budgeted expenditure to arrive at the cost-responsibility for each vehicle class in the study period.

f. Determination of Revenue Attribution: Once the cost-responsibilities are determined, it is necessary to compare them with the revenues contributed by each vehicle class. This was accomplished by examining the separate sources of revenues paid by Indiana highway users and then apportioning the revenue amounts by vehicle class.

A flow chart is shown in Figure 3 to present the various steps of the cost-allocation and revenue attribution procedures. The interdependence of these steps is also indicated in the flow chart.

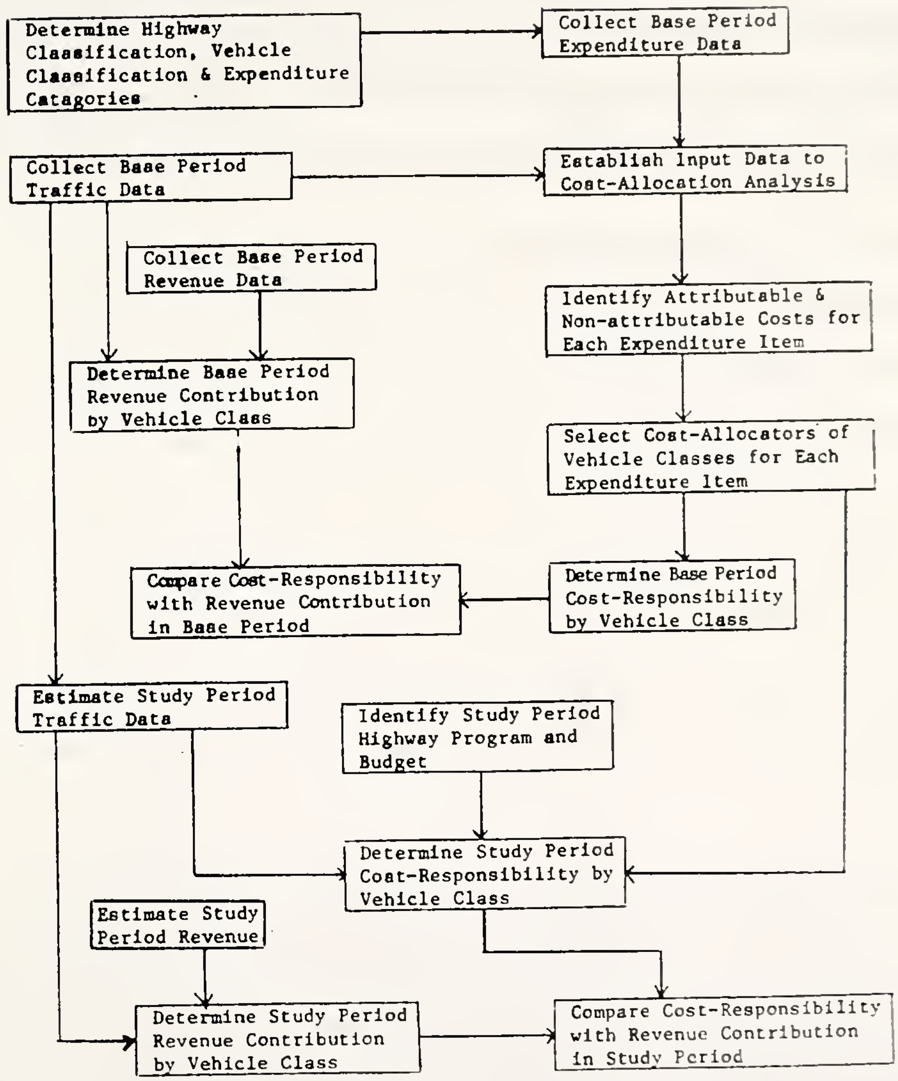
Summary of Cost-Allocation and Revenue Attribution Procedures

The various cost-allocation procedures developed in this study for individual expenditure items may be grouped into two major areas, namely the roadway related area and the structure-related area. In the first area, the main concern was to develop a rational unified allocation procedure for highway construction, routine maintenance and rehabilitation costs. In the second area, the main emphasis was to allocate equitably structure-related costs.

A new incremental approach was developed for allocation of pavement construction costs to highway users. It considers increments of pavement thickness rather than increments or decrements of traffic volume commonly employed in previous cost-allocation studies. The thickness incremental approach eliminates the need for an iterative process to compute vehicle ESAL which is required for cost-responsibility calculation. The procedure also eliminates the economy-of-scale problem present in the classical incremental cost-allocation method.

The allocation of shoulder construction costs followed a procedure similar to that used for new pavement costs. Other highway construction

Figure 3. Cost-Allocation Study Flow Chart



expenditure items, such as grading and earthwork, drainage and erosion control, and right-of-way costs, were allocated essentially on the basis of vehicle-miles of travel (VMT). A common feature of the allocation procedures for the five major highway construction items mentioned was that a minimum width was specified for each. The costs incurred within this specified width are attributable to all vehicle classes on the basis of a suitable allocator (such as ESAL, or VMT). Those costs that are associated with width beyond the specified limit were allocated using appropriate allocator weighted by PCE.

For the allocation of highway rehabilitation and routine maintenance costs, a performance-based methodology was developed for determining the cost-responsibilities of load-related and non-load-related factors. The procedure does not require an extensive amount of data collection effort. It relies entirely on recorded pavement performance data which are available in the records of IDOH, and hence eliminates the undesired element of subjective judgment commonly involved in most cost-allocation studies. For the load-related portion of the costs, the basis of allocation was ESAL. The non-load-related portion of the costs was allocated to vehicle classes in proportion to their VMT.

Police enforcement expenditures and other common costs such as traffic signal installation costs, pavement striping costs and roadside mowing costs were distributed to all vehicle classes on the basis of VMT. Such common costs do not include the costs of construction, maintenance, and rehabilitation of facilties like climbing lane and weigh station. These facilties serve only trucks and the associated costs were considered as truck-related common costs. These costs were allocated to trucks only based on their respective VMT.

Structure-related costs included expenditure for bridge construction, bridge rehabilitation, bridge replacement, culvert construction and sign structure construction. Bridge construction refers to bridges built on new alignment, while bridge replacement indicates bridges built on essentially the same alignment. Bridge rehabilitation includes such activities as partial replacement, widening and deck repair. Culvert construction involves box culverts, corrugented metal and structural plate pipes. Sign structurs are overhead sign bridges.

An incremental method that involvoes repetitive designing of a given bridge structure under different vehicle loadings was used in this study. Five types of bridge were used: reinforced concrete slab, prestressed box beam, prestressed I-beam, steel beam and steel girder. Ten AASHTO design loadings were used to approximate various observed vehicle loadings on the highway. The present study developed different cost-allocation procedures for superstructure, substructure, railing, drainage items, excavation and backfill, and miscellaneous elements. The procedures involved in the allocation of structure- related costs followed three specific steps: (1) the correlation of the adopted vehicle classes to the AASHTO design loads, (2) the incremental design of structures with specified increments of AASHTO design loads, and (3) the allocation of individual cost items among various vehicle classes.

The revenue attribution procedure used in the study included the identification of the amount of user revenues from various federal, state and local sources and appropriate attribution of these revenues among the vehicle classes. The applicable tax rates of various revenue sources were also identified. Fuel efficiency rates and other related factors were obtained from the FHWA study [9] and other available sources.

A detailed discussion of the cost-allocation and revenue attribution procedures used in this study is given in the Appendices.

CHAPTER THREE

RESULTS OF COST-ALLOCATION AND REVENUE ATTRIBUTION ANALYSIS

Detailed descriptions of cost-allocation procedures for the expenditure items listed in Table 3 are presented in Appendices C through H. These procedures were employed to determine the cost-responsibility of each vehicle class for individual expenditure item. The cost-allocators employed in the analysis were developed on the basis of information on the actual amount of each expenditure and physical features of the associated facilities obtained from records of the 4-year base period (1980-1983).

Cost-Responsibility Factors for Highway and Structure Expenditure Items

Presented in Tables I.1 through I.7 of Appendix I are the computed cost-responsibility factors (in percentages) by fourteen vehicle classes and six highway classes for the following highway construction expenditure items: pavement, shoulder, right-of-way, drainage and erosion control, grading and earthwork, common costs, and truck-related-only common costs, respectively. Although only vehicle class cost-responsibilities are shown in these tables, all cost-allocation analyses were without exception performed with the complete range of weight groups listed in Table 2. For the purpose of illustration, Table I.8 is included in Appendix I to show the breakdown of cost-responsibility factors in terms of weight groups for all the fourteen vehicle classes for pavement construction costs on Interstate Rural.

Pavement rehabilitation cost-responsibility for each vehicle class differs for different regions (northern vs southern Indiana), pavement types (rigid, overlay and flexible) and highway functional classes (Interstate Rural, Interstate Urban, State Primary, State Secondary, County Roads and City Streets). The effects of region, pavement type and highway class on vehicle class cost-responsibilities are represented by the cost-responsibility factors given in Tables I.9 through I.14 of Appendix I.

Vehicle class cost-responsibilities for pavement maintenance also vary in a similar manner with regions, pavement types and highway functional classes. The cost-responsibility factors of vehicle classes for all region-pavement type-highway class combinations are given in Tables I.15 through I.20 of Appendix I.

The cost-responsibility factors presented in Tables I.1 through I.20 form the basic expenditure item cost-responsibility values which were used to derive the resultant cost-responsibility of each vehicle class for each highway expenditure area defined in Table 3. The magnitude of this resultant cost-responsibility is a function of the basic cost-responsibility factor values of relevant items and the relative expenditure amounts of the corresponding expenditure items.

An incremental methodology for allocating structure costs was used to arrive at structure cost responsibilities. Vehicle classes were assigned costs in proportion to the effect of their size and weight characteristics. An incremental bridge design process was applied to allocate the following structure cost items:

1. superstructure;
2. substructure (Pier, Abutment, spread footing);
3. piling;
4. excavation and backfill;
5. railing;

6. drainage pipes; and
7. miscellaneous items.

The cost-responsibility factors for the first six items are shown in Table I.21 through I.26 in Appendix I. Miscellaneous items have the same cost-responsibility factors as those of common costs presented in Table I.6.

Cost-Responsibility Factors for Major Expenditure Areas

To determine the overall cost-responsibility of each vehicle class for a desired analysis year, the expenditure item cost-responsibility factors developed in the preceding sections were applied to the corresponding expenditures (budgeted or actual) for the analysis year. In the present study, cost-allocation analysis was performed for FY 1983 (July 1982 to June 1983), and then for the biennial budget period covering FY 1985 and FY 1986. For FY 1983, expenditure actually spent was used for analysis. For FY 1985 and FY 1986, the analysis was performed with budgeted expenditures.

Figures 4 through 8 present a complete flow diagram of the step-by-step cost-responsibility computation involved in the cost-allocation analysis. Expenditure item cost-responsibility factors were first applied to their corresponding expenditure amounts to obtain aggregated expenditure area cost-responsibility factors, as shown in Figures 5 through 8. These factors were then used to compute the overall cost-responsibilities of vehicle classes as explained in Figure 4.

Two sets of cost-responsibility factors for major expenditure areas are given in Appendix I. The first set, presented in Tables I.27 through I.35, pertains to vehicle class cost-responsibilities for Fiscal Year 1983. The second set, shown in Tables I.36 through I.44, is computed for the biennial period 1985 - 1986.

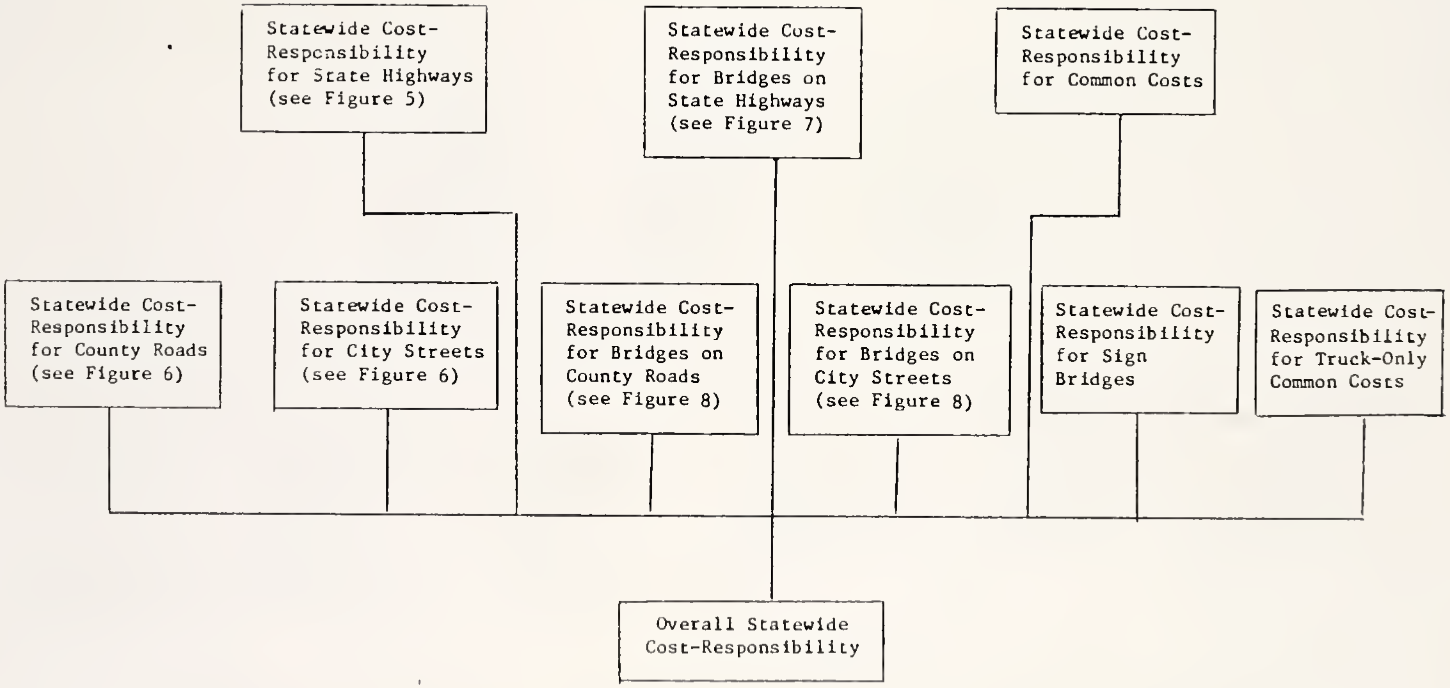


Figure 4. Computation of Overall Statewide Vehicle Class Cost-Responsibilities.

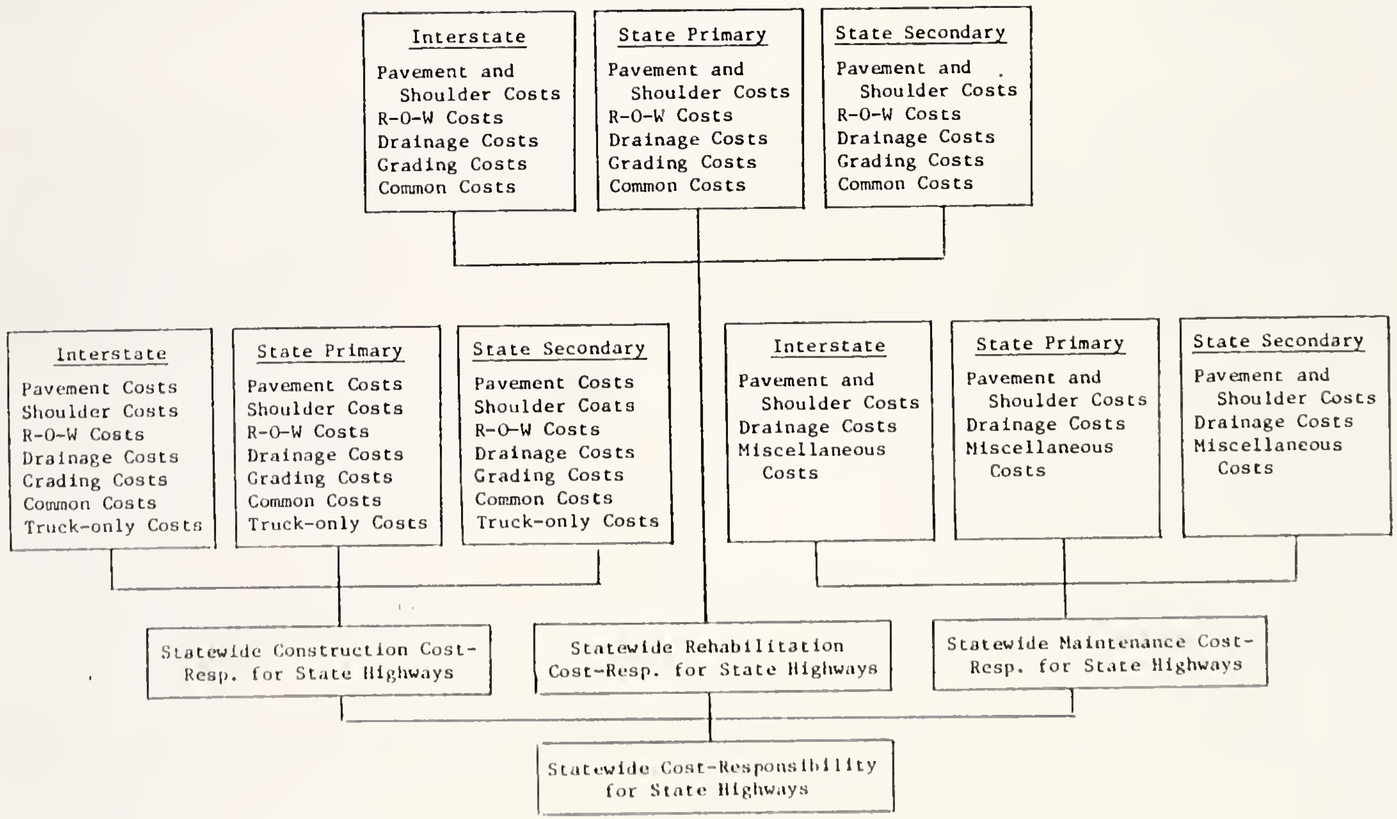
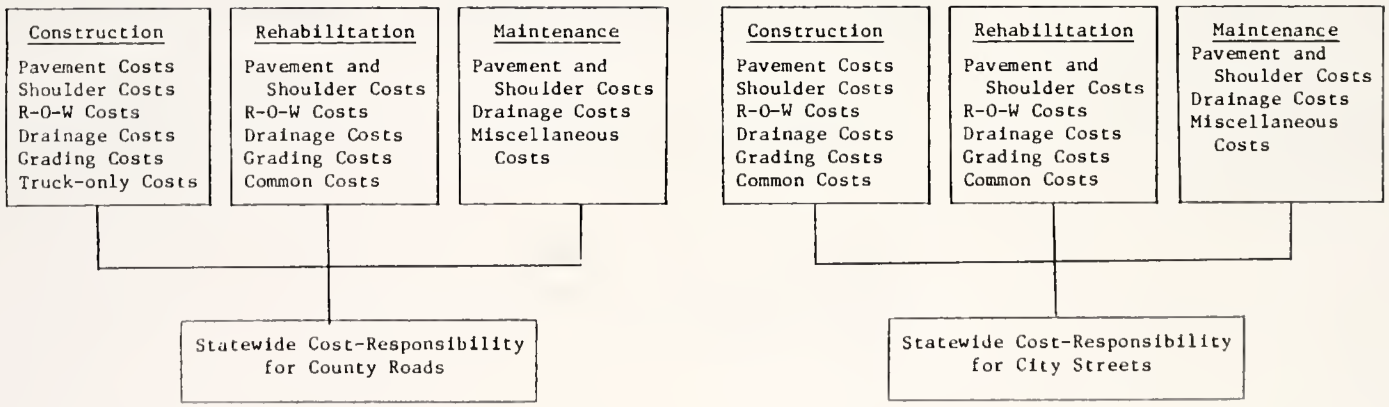


Figure 5. Computation of Statewide Vehicle Class Cost-Responsibilities for State Highways



(a) County Roads

(b) City Streets

Figure 6. Computation of Statewide Cost-Responsibilities for (a) County Roads, and (b) City Streete

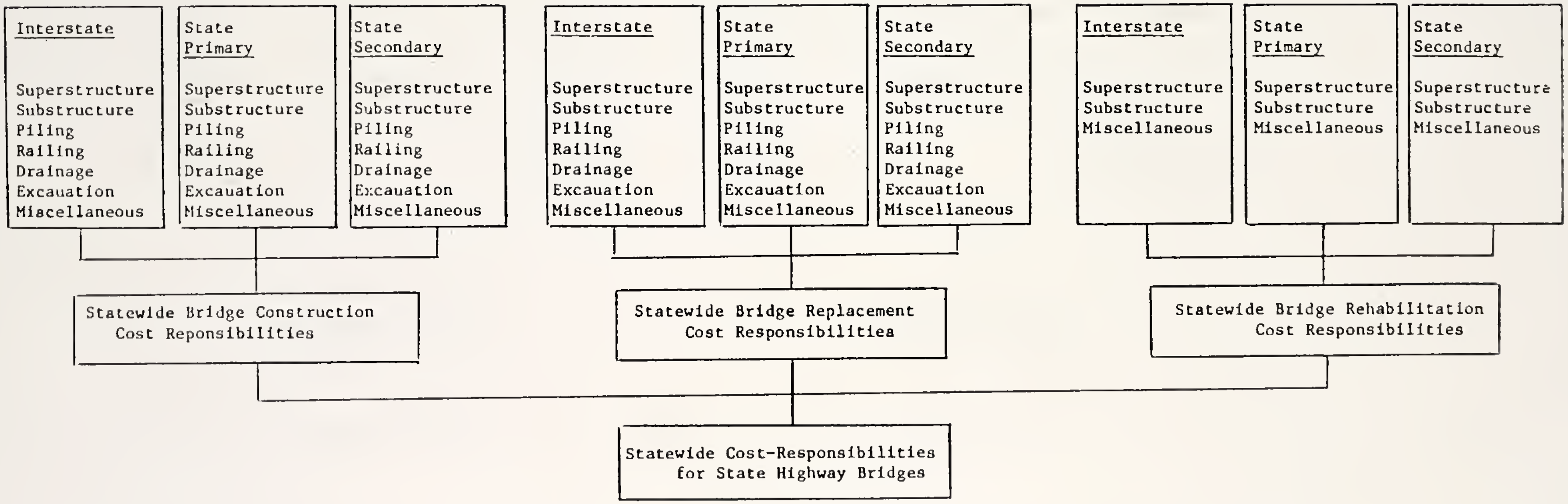


Figure 7. Derivation of Statewide Cost-Responsibilities for State Highway Bridges

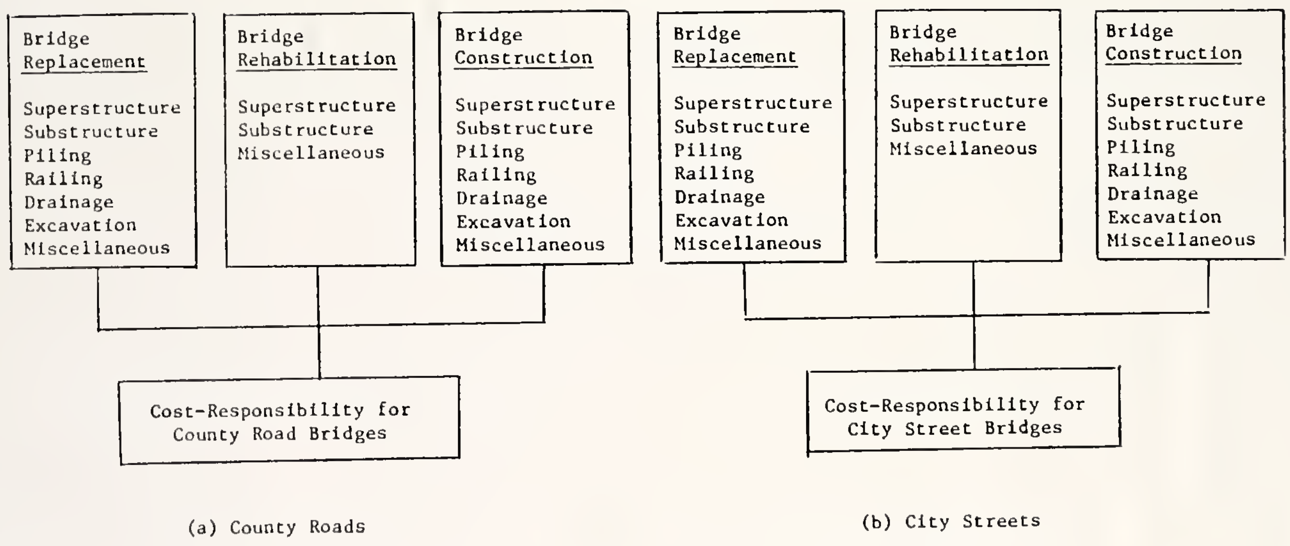


Figure 8. Derivation of Statewide Cost-Responsibilities for Bridges on County Roads and City Streets

Overall Statewide Vehicle Cost-Responsibilities

The overall statewide vehicle class cost-responsibilities for Fiscal Year 1983 and 1985-86 are presented in Tables 5 and 6, respectively. This is the most common form for expressing cost-allocation analysis results. It offers a direct and easily understood comparison with vehicle revenue contribution. This is equivalent to comparing the cost-responsibility per unit vehicle of a given vehicle class against its revenue contribution.

It is noted from the flow diagrams in Figures 4 through 8 that vehicle class cost-responsibilities for state highways, county roads and city streets are kept separate up to the final step. This is desired because these highways are constructed and maintained by different jurisdictional agencies which keep their respective cost accounts and records independently. While the ultimate goal of the present study is to determine the overall statewide cost-responsibility of each vehicle class, it is also meaningful to analyze vehicle class cost-responsibilities in terms of jurisdictional system. Vehicle class cost-responsibilities by jurisdictional system are given in Tables I.45 through I.47 for Fiscal Year 1983 and Tables I.48 through I.50 for biennial period 1985-86.

A number of previous cost-allocation studies had expressed cost-allocation results in terms of cents per vehicle-mile of travel. Unfortunately, this index does not have a clear physical meaning in cost-allocation analysis. It is also not practical to assess equity based on cents/VMT because revenues are not collected on the basis of vehicle-miles of travel.

Table 5. Overall Statewide Cost-Responsibility for Year 1983

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	10.869	10.869
2	1	41.510	41.510
3	1	6.766	0.440
3	2		0.403
3	3		0.866
3	4		0.873
3	5		0.450
3	6		1.587
3	7		1.179
3	8		0.388
3	9		0.580
4	1	0.448	0.448
5	1	0.387	0.387
6	1	2.605	0.362
6	2		0.266
6	3		0.174
6	4		0.234
6	5		0.092
6	6		0.117
6	7		0.144
6	8		0.220
6	9		0.995
7	1	0.974	0.029
7	2		0.035
7	3		0.049
7	4		0.072
7	5		0.077
7	6		0.137
7	7		0.156
7	8		0.191
7	9		0.228
8	1	0.081	0.081
9	1	1.087	0.018
9	2		1.069
10	1	0.107	0.021
10	2		0.025
10	3		0.027
10	4		0.033
11	1	2.525	0.060
11	2		0.106
11	3		0.224
11	4		0.128
11	5		0.105
11	6		0.410
11	7		0.142
11	8		0.183
11	9		0.133
11	10		0.161
11	11		0.197
11	12		0.213
11	13		0.463
12	1	30.253	0.020
12	2		0.072
12	3		0.263
12	4		0.994
12	5		0.455
12	6		0.526
12	7		0.187
12	8		0.308
12	9		0.581
12	10		0.612
12	11		0.286
12	12		0.388
12	13		0.551
12	14		0.544
12	15		0.629
12	16		0.675
12	17		0.955
12	18		3.051
12	19		1.817
12	20		3.499
12	21		5.320
12	22		3.808
12	23		3.737
12	24		0.672
12	25		0.136
12	26		0.171
13	1	1.285	0.259
13	2		0.317
13	3		0.249
13	4		0.158
13	5		0.182
13	6		0.008
13	7		0.017
13	8		0.009
13	9		0.009
13	10		0.016
13	11		0.009
13	12		0.025
13	13		0.028
14	1	1.110	0.095
14	2		0.249
14	3		0.765

Table 6. Overall Statewide Cost-Responsibility for Years 1985-86

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	11.707	11.707
2	1	43.610	43.610
3	1	5.746	0.409
3	2		0.240
3	3		0.783
3	4		0.793
3	5		0.435
3	6		1.302
3	7		0.960
3	8		0.342
3	9		0.484
4	1	0.344	0.344
5	1	0.427	0.427
6	1	2.224	0.325
6	2		0.238
6	3		0.164
6	4		0.206
6	5		0.083
6	6		0.101
6	7		0.124
6	8		0.186
6	9		0.799
7	1	0.804	0.031
7	2		0.032
7	3		0.044
7	4		0.062
7	5		0.066
7	6		0.109
7	7		0.132
7	8		0.152
7	9		0.176
8	1	0.090	0.090
9	1	1.146	0.020
9	2		1.126
10	1	0.093	0.018
10	2		0.021
10	3		0.025
10	4		0.029
11	1	2.287	0.059
11	2		0.104
11	3		0.218
11	4		0.124
11	5		0.111
11	6		0.340
11	7		0.122
11	8		0.153
11	9		0.123
11	10		0.147
11	11		0.174
11	12		0.201
11	13		0.413
12	1	29.281	0.021
12	2		0.084
12	3		0.323
12	4		1.042
12	5		0.544
12	6		0.536
12	7		0.241
12	8		0.337
12	9		0.539
12	10		0.571
12	11		0.324
12	12		0.401
12	13		0.519
12	14		0.569
12	15		0.620
12	16		0.799
12	17		0.999
12	18		2.670
12	19		1.718
12	20		3.155
12	21		4.910
12	22		3.851
12	23		3.453
12	24		0.736
12	25		0.130
12	26		0.190
13	1	1.218	0.222
13	2		0.274
13	3		0.226
13	4		0.148
13	5		0.161
13	6		0.016
13	7		0.027
13	8		0.012
13	9		0.013
13	10		0.024
13	11		0.015
13	12		0.037
13	13		0.044
14	1	1.030	0.089
14	2		0.217
14	3		0.724

Appendix J to this report offers a detailed account of the reasons why the index of cents/VMT was not used to present the final results in this study.

Proportions of Attributable and Non-Attributable Costs

Non-attributable costs refer to expenditures which are resulted by non-traffic causes such as action of environmental forces, including age, weather, salt and other chemical agents, and expend times that are incurred based upon safety or aesthetic considerations. These costs cannot be attributed to any particular user class or group of user classes. In the present study, these costs were distributed on the basis of VMT. The main reason for using this cost-allocator was simply that it has been used widely and is easily understood and accepted.

Attributable costs include (a) costs which are entirely attributable to a single vehicle class, (b) costs which are attributable to a group of vehicle classes, and (c) costs which are occasioned by the entire traffic as a whole. Table 7 classifies all expenditure items into attributable and non-attributable category as defined above. It also presents a summary of cost-allocation criteria adopted for each of these items.

Based on the classification in Table 7, it was computed that for FY 1983, attributable and non-attributable costs constituted 44.59% and 55.41% of the total expenditure, respectively. For biennial period 1985-86, the corresponding numbers are 49.15% and 50.85%.

Table 7. (cont'd)

Expenditure Items	Attributable Costs		Non-Attributable Costs	
	Proportion	Allocation Procedure	Proportion	Allocation Procedure
5. Miscellaneous				
(Traffic Service)			100%	Proportional VMT
(Administration)			100%	Proportional VMT
(Truck-Related Facilities)	100%	Proporational truck VMT		
(Others)			100%	Proportional VMT
C. <u>Highway Maintenance</u>				
1. Pavement & Shoulder	Varies 66-98%	Proportional Σ ESAL	Varies 2-34%	Proportional Σ ESAL
2. Right-of-Way			100%	Proportional VMT
3. Drainage			100%	Proportional VMT
4. Roadside Maintenance			100%	Proportional VMT
5. Miscellaneous				
(Traffic Service)			100%	Proportional VMT
(Administration)			100%	Proportional VMT
(Winter Emergency)			100%	Proportional VMT
(Truck-Related Maintenance)	100%	Proportional Truck VMT		
(Others)			100%	Proportional VMT
D. <u>Bridge Maintenance</u>				
1. Roadway Maintenance	Varies 66-98%	Proportional Σ ESAL	Varies 2-34%	Proportional VMT
2. Structural Members			100%	Proportional VMT
3. Miscellaneous			100%	Proportional VMT
E. <u>Bridge Construction, Replacement and Rehabilitation</u>				
1. Superstructures	100%	Incremental Analysis		
2. Substructures	25-35	Incremental Analysis	65-75	Proportional VMT
3. Drainage			100%	Proportional VMT
4. Excavation			100%	Proportional VMT
5. Miscellaneous			100%	Proportional VMT

Table 7. Cost Allocation Criteria for Expenditure Item

Expenditure Items	Attributable Costs		Non-Attributable Costs	
	Proportion	Allocation Procedure	Proportion	Allocation Procedure
A. Highway Construction				
1. Pavement (minimum width)	100%	Thickness Incremental method based on ESAL		
(Additional width)	100%	Thickness Incremental method based on PCE-ESAL		
2. Shoulder (minimum width)	100%	same as item A.1		
(Additional width)	100%			
3. Right-of-Way (minimum width)	100%	Proportional VMT		
(Additional width)	100%	Proportional PCE-VMT		
4. Grading & Earthwork (minimum width)	100%	Proportional VMT		
(Additional width)	100%	Proportional PCE-VMT		
5. Drainage & Erosion Control (minimum width)	100%	Proportional VMT		
(Additional width)	100%	Proportional PCE-VMT		
6. Miscellaneous (Traffic Service)			100%	Proportional VMT
(Administration)			100%	Proportional VMT
(Truck-Related Facilities)	100%	Proportional truck VMT		
(Others)			100%	Proportional VMT
B. Highway Rehabilitation				
1. Pavement & Shoulder	Varies 66-98%	Thickness Incremental method based on ESAL	Varies 2-34%	Proportional VMT
2. Right-of-Way	100%	same as item A.3		
3. Grading & Earthwork	100%	same as item A.4		
4. Drainage & Erosion control	100%	same as item A.5		

Table 8. Revenue Contribution by Vehicle Class (1983)

Veh Class	Sub-Group	% Contribution Veh Class	% Contribution Sub-Group
1	1	8.080	8.080
2	1	56.670	56.670
3	1	8.020	3.240
3	2		0.450
3	3		0.900
3	4		0.940
3	5		0.710
3	6		0.580
3	7		0.330
3	8		0.400
3	9		0.460
4	1	0.372	0.372
5	1	0.453	0.453
6	1	2.210	0.390
6	2		0.240
6	3		0.160
6	4		0.250
6	5		0.160
6	6		0.210
6	7		0.210
6	8		0.160
6	9		0.450
7	1	0.540	0.037
7	2		0.046
7	3		0.036
7	4		0.090
7	5		0.038
7	6		0.031
7	7		0.180
7	8		0.040
7	9		0.039
8	1	0.078	0.078
9	1	1.620	0.630
9	2		0.990
10	1	0.069	0.017
10	2		0.016
10	3		0.020
10	4		0.016
11	1	1.211	0.074
11	2		0.110
11	3		0.200
11	4		0.106
11	5		0.110
11	6		0.150
11	7		0.070
11	8		0.073
11	9		0.073
11	10		0.063
11	11		0.062
11	12		0.058
11	13		0.066
12	1	18.900	0.043
12	2		0.166
12	3		0.563
12	4		1.370
12	5		0.847
12	6		0.631
12	7		0.400
12	8		0.419
12	9		0.457
12	10		0.416
12	11		1.120
12	12		0.329
12	13		0.397
12	14		0.468
12	15		0.487
12	16		0.718
12	17		0.606
12	18		0.730
12	19		0.614
12	20		0.782
12	21		1.442
12	22		1.799
12	23		0.952
12	24		0.454
12	25		1.337
12	26		1.355
13	1	1.260	0.461
13	2		0.128
13	3		0.080
13	4		0.073
13	5		0.056
13	6		0.032
13	7		0.046
13	8		0.037
13	9		0.037
13	10		0.049
13	11		0.038
13	12		0.057
13	13		0.163
14	1	0.520	0.189
14	2		0.068
14	3		0.264

Table 9. Revenue Contribution by Vehicle Class (1985-86)

Veh Class	Sub-Group	% Contribution Veh Class	% Contribution Sub-Group
1	1	8.946	8.946
2	1	60.250	60.250
3	1	8.306	3.563
3	2		0.450
3	3		0.833
3	4		0.897
3	5		0.977
3	6		0.556
3	7		0.306
3	8		0.350
3	9		0.375
4	1	0.336	0.336
5	1	0.459	0.459
6	1	1.824	0.369
6	2		0.204
6	3		0.138
6	4		0.212
6	5		0.130
6	6		0.173
6	7		0.170
6	8		0.129
6	9		0.300
7	1	0.420	0.034
7	2		0.064
7	3		0.032
7	4		0.058
7	5		0.035
7	6		0.028
7	7		0.097
7	8		0.036
7	9		0.035
8	1	0.079	0.079
9	1	1.179	0.515
9	2		0.664
10	1	0.062	0.016
10	2		0.015
10	3		0.018
10	4		0.014
11	1	1.087	0.066
11	2		0.113
11	3		0.175
11	4		0.094
11	5		0.098
11	6		0.131
11	7		0.062
11	8		0.065
11	9		0.064
11	10		0.055
11	11		0.055
11	12		0.051
11	13		0.058
12	1	15.029	0.038
12	2		0.148
12	3		0.490
12	4		1.195
12	5		0.733
12	6		0.547
12	7		0.344
12	8		0.362
12	9		0.391
12	10		0.358
12	11		0.490
12	12		0.279
12	13		0.307
12	14		0.353
12	15		0.357
12	16		0.546
12	17		0.476
12	18		0.573
12	19		0.467
12	20		0.612
12	21		1.159
12	22		1.427
12	23		0.814
12	24		0.383
12	25		1.083
12	26		1.099
13	1	1.457	0.813
13	2		0.108
13	3		0.067
13	4		0.061
13	5		0.041
13	6		0.027
13	7		0.036
13	8		0.029
13	9		0.029
13	10		0.038
13	11		0.030
13	12		0.045
13	13		0.134
14	1	0.566	0.304
14	2		0.051
14	3		0.212

Revenue Contribution by Vehicle Class

The result of the revenue attribution analysis provided percentage of revenues contributed by individual vehicle classes. The revenue contribution figures for FY 1983 and the biennial period of 1985-86 are given in Tables 8 and 9, respectively. For example, in 1983 the percentage revenue contributed by vehicle class 2 (large cars) was 56.6%, while the corresponding percentage for vehicle class 12 (3S2 or 5-axle combination truck) was 18.90%. In 1985-86 these percentages were 60.25% and 15.03%, respectively.

Comparison of Cost-Responsibility with Revenue Contribution

The information on cost-responsibility and revenue contribution of vehicle classes was combined to provide a revenue/cost comparison for each vehicle class. Such a comparison would indicate the equity in revenue contribution. The revenue/cost ratios for FY 1983 and the biennial period of 1985-86 are summarized in terms of fourteen vehicle classes in Table 10.

The study findings for FY 1983 show that passenger cars, including panels and pickups, and single-unit trucks are overpaying, while heavy combination trucks are consistently underpaying their cost responsibility. The same pattern is evident in the 1985-86 results. However, the underpayment by heavy combination trucks is more pronounced in 1985-86.

Base Period (1983) Findings

While the passenger cars including panels and pick-ups as a group overpaid their cost-responsibility in 1983, there was a significant imbalance

Table 10. Cost-Allocstion and Revenue Attribution Summary

Vehicle Type	Vehicle Class	Summary for Fiscal Year 1983 Percent VMT	Percent Cost-Resp.	Percent Revenue	Revenue/Cost	Summary for Biennial Period 1985/86 Percent VMT	Percent Cost-Resp.	Percent Revenue	Revenue/Cost
Passenger Car	1	19.124	10.869	8.080	0.743	19.176	11.707	8.946	0.764
	2	68.921	41.510	56.670	1.365	68.001	43.610	60.250	1.382
	5	0.623	0.387	0.453	1.171	0.641	0.427	0.459	1.075
	8	0.107	0.081	0.078	0.963	0.127	0.090	0.079	0.878
		88.775	52.847	65.281	1.235	87.945	55.834	69.734	1.249
Bus	4	0.164	0.448	0.372	0.830	0.162	0.344	0.336	0.977
Single-Unit Truck	3	2.666	6.766	8.020	1.185	2.604	5.746	8.306	1.446
	6	0.692	2.605	2.210	0.848	0.646	2.224	1.824	0.820
	9	0.091	1.087	1.620	1.490	0.092	1.146	1.179	1.029
		3.449	10.458	11.850	1.133	3.342	9.116	11.309	1.241
Combination Truck	7	0.196	0.974	0.540	0.554	0.219	0.804	0.420	0.522
	10	0.040	0.107	0.069	0.645	0.043	0.093	0.062	0.667
	11	0.688	2.525	1.211	0.480	0.752	2.287	1.087	0.475
	12	6.385	30.253	18.900	0.625	7.211	29.281	15.029	0.513
	13	0.224	1.285	1.260	0.981	0.245	1.218	1.457	1.196
	14	0.078	1.110	0.520	0.468	0.081	1.030	0.566	0.550
		7.611	36.254	22.500	0.621	8.551	34.713	18.621	0.536

between costs and revenues within the group. In particular, small cars underpaid their cost responsibility, while large cars considerably overpaid.

Single-unit trucks as a group also overpaid their cost responsibility in 1983, although not to the same extent as the passenger cars. In addition, there was a considerable inequity within the group. While 2-axle and 4-axle single-unit trucks overpaid, 3-axle single-unit trucks underpaid their cost-responsibility.

Buses and combination trucks significantly underpaid their cost-responsibility. The underpayment was consistent among all combination trucks. However, the extent of this underpayment varied within the group.

Considering the four major vehicle groups, all passenger cars together made an overpayment of $71,288,000 in excess of their cost responsibility in 1983. Single-unit trucks as a group contributed $8,004,000 in excess of their cost responsibility. However, buses underpaid $438,000 and combination trucks as a group paid $78,854,000 less than their cost responsibility. The net result was that passenger cars and single-unit trucks subsidized the buses and combination trucks.

Biennial Budget Period (1985-86) Findings

It can be noted in Table 10 that the same general pattern of overpayments and underpayments as in 1983 is present in 1985-86. Passenger cars would be overpaying about 25% of their cost responsibility while single-unit trucks would be overpaying about 24% of their cost responsibility. At the same time buses would pay about 2% less then their cost responsibility and combination trucks would pay about 46% less than their cost-responsibility.

The within-group imbalance of costs and revenue payments in 1985-86 shows the same general pattern as in 1983 with the exception that in 1985-86 vehicle class 13 (other 5-axle) would pay about 20% more than its cost responsibility.

In the two-year period of 1985-86 the passenger cars as a group would overpay $197,960,000 and single-unit trucks as a group would overpay $31,283,000. On the other hand, combination trucks would underpay $229,130,000 and buses would underpay only $113,000. The subsidization of heavy vehicles by passenger cars and single-unit trucks would thus continue if the tax structure remains the same.

Comparison of Indiana's Findings to Findings in Other Studies

In Table 11 are shown the revenue/cost ratios for the four generalized vehicle classes determined in Indiana study along with the corresponding figures from other cost-allocation studies. This table is presented for the purpose of comparison. The studies included here covered a wide range of procedures and geographic variations. In addition, the definition of generalized vehicle classes was not the same in all studies. Furthermore, the cost-responsibility and revenue attribution figures depend on the specific expenditure patterns and revenue structures included in a study. Consequently, the results cannot be precisely compared. Nevertheless, the ratios presented in Table 11 give a broad indication of the reasonableness of the results of the Indiana study. It can be noted that the findings of the Indiana study are consistent with those of other studies.

Table 11. Comparison of Findings of the Indiana Study to Findings of Other Studies.

	User Revenue Contribution/Cost-Responsibility		
	Passenger Car	SU Truck	Combination
Florida (1979)	1.04	0.91	0.51*
Georgia (1979)	1.03	0.66	0.44*
Oregon (1980)	1.00	1.25	0.92
Colorado (1981)	1.22	1.24	0.56
Kentucky (1982)	1.57	--	0.57**
Maryland (1982)	1.17	0.83	0.56
Connecticut (1982)	1.11	1.61	0.63
Ohio (1982)	0.90	2.25	0.35
Wisconsin (1982)	0.94	1.40	0.89
Maine (1982)	1.02	1.16	0.97
North Carolina (1983)	0.96	2.14	0.78
Federal (1982)	1.10	1.50	0.60
Indiana (Base period)	1.24	1.13	0.62
(Budget period)	1.25	1.24	0.54

*5 or more axles

** for all trucks

CHAPTER FOUR

CONCLUSIONS

This report has presented the findings and the procedures used in the Indiana highway cost-allocation study. On the basis of a detailed review of the existing cost-allocation studies, an integrated set of methodologies was developed for application in Indiana. An incremental approach was followed for allocation of costs for new highway and structure construction, highway and structure rehabilitation and routine maintenance. This approach is consistent with the state-of-the-art pavement and structure design and maintenance procedures and at the same time the procedures achieved a higher degree of equity in establishing cost responsibilities among highway users than what is provided by the existing cost-allocation methodologies. In particular, the consideration of such non-attributable costs as those caused by age, weather, salt and other chemicals on highways was explicit and the allocation of these costs was achieved through an objective procedure.

The findings of the study indicated that there is a definite imbalance in cost-responsibility and revenue contribution of vehicle classes. In particular, passenger cars as a group and single-unit trucks as a group contribute more revenue than their cost responsibility, while buses and heavy combination trucks contribute less revenue than their cost responsibility. Although passenger cars as a group contribute more revenue, small cars do not pay their fair share and large cars pay more than their fair share. This general trend was determined both in 1983 as well as in the analysis for the biennial period of 1985-86.

There are several issues related to the study that need to be pointed out. First, the study did not treat out-of-state vehicles as a separate group. Heavy vehicles are statutorily required to pay fuel tax in proportion to the miles they travel in the state, so the issue would seem to be whether or not out-of-state vehicles pay their proportionate share of registration fees. Currently there are various forms of reciprocity agreements between Indiana and other states as to the travel of out-of-state commercial vehicles. These agreements allow out-of-state commercial vehicles to travel on Indiana highways practically free of any registration fees. However, Indiana based carriers also have the benefit of traveling in other reciprocity states in the same manner. A recent study examined the feasibility of Indiana's participation in the International Registration Plan (IRP) whereby registration fees of interstate vehicles can be shared among participating states in proportion to the miles traveled in a state [38]. While this arrangement would make the revenue contribution of out-of-state travel more close to their cost responsibility, Indiana's participation in the IRP under the current registration fee structure may not be financially beneficial. Furthermore, as Indiana's current registration fees are relatively low and the registration revenue from all interstate trucks of 26,000 lb. or more GVW is only about 4.5% of total user revenues, the inclusion of out-of-state heavy vehicles as a separate class would not make any significant difference in the overall results of revenue/cost comparisons. Nevertheless, it is recognized that a large portion of truck traffic on Indiana highways is due to out-of-state vehicles and an effort is needed to make these vehicles pay a more equitable share of the highway costs.

Another point that needs clarification is that exempt vehicles were not excluded from cost-allocation and revenue attribution analysis. Vehicles with various forms of exemptions include vehicles owned by governmental agencies, non-profit organizations, farm trucks, school buses and transit buses. In Indiana, the exempt vehicles were estimated to comprise about 2% of all vehicles. Even one assumes each exempt vehicle travels the same mileage per year as other vehicles, the impact of these vehicles would be minimal. Furthermore, the distribution of exempt vehicles is uniform among automobiles, buses and trucks, and thus the exclusion of these vehicles in both cost-allocation and revenue attribution would not introduce any bias in revenue/cost comparisons.

Highway cost allocation and subsequent analysis of revenue attribution should not be considered as a one-time exercise. Instead, it should be recognized as a part of a continuing process of pricing and financing highway services in Indiana. A periodic updating of the cost responsibility and revenue attribution factors is essential in order to keep abreast with the changing traffic distributions, changing expenditure patterns, changing program emphasis, and changing technology. In addition, the procedure and methodology of the highway cost allocation process itself change with time, as new information on such key elements as relationships between traffic load, weather, and pavement and structure damage is generated.

APPENDIX A

DATA BASE

Traffic Data

A detailed traffic count data for the state highway system are available in the IDOH. However, the available truck classification and weight data were collected not on the basis of random statistical sampling to represent the highway classes in the state. Consequently, a comprehensive vehicle classification survey was undertaken in the present study. In order to make the collected truck data usable for other purposes by the IDOH, the highway classes and vehicle classes were made to match the FHWA and IDOH truck weight study requirements.

The vehicle classification survey included a series of 24-hour manual vehicle counts and a series of 24-hour machine vehicle counts on statistically sampled sections of highways during the summer of 1983. A detailed discussion of the traffic data is presented in Appendix B of this report.

The truck weight data for several years including 1983 from weigh stations were available through the Planning Division of the IDOH. These loadometer data provide operating weight, registered weight, vehicle type, number of axles and their configurations.

Cost Data

Cost data were collected separately for the state highway system, county roads and city streets.

State Highway System

The cost and highway physical inventory was compiled for the state system on the basis of the following data sources:

1. Road Life Records - The information is based on actual contracts, and it provides a detailed description of pavement characteristics. The data from all of the 874 sections were extracted manually from the IDOH records and coded and entered in computer. Although this source provides a detailed description of the various highway activities performed on the state highway system, cost information is often not complete. When available, the cost items are given as follows: Grading and Drainage, Subgrade, Surface and Base, Bridges, Traffic Service, Landscape, and Engineering Inspection.

2. Construction Reports - These reports, prepared periodically by the Construction Division of the IDOH, provide cost information (total cost) for any contract or a group of contracts in a given time period. These data were computer coded and used when the Road Life Records did not contain enough cost information.

3. Itemized Cost Estimates - For any contract, a cost estimate proposal is prepared by the IDOH Construction Division. These itemized estimates can be used to obtain the distribution of contract costs for different expenditure items (earthwork, culverts, pavement, shoulder, etc.). These data were also computer coded.

4. Routine Maintenance Records - The IDOH Maintenance Division prepares crew day cards files to keep records of all routine maintenance activities

done in a given year. Data for the last four years were obtained and information on type of maintenance, location, production units, man-hours, material types and quantities were analyzed.

5. Highway Inventory - The highway inventory files are stored in the IDOH Computer system and are updated on an annual basis. These files include information similar to that of road life records files. Highway inventory files, however, do not include cost or structural information. On the other hand, they include information on all physical characteristics as length, width, median, etc. Also, they include roughness and traffic (ADT) information.

In addition to the above sources, expenditure data reported by the IDOH on the PR-534 and on HPMS sections were also analyzed.

Local Roads

1. Road Inventory - An inventory of physical characteristics of the local highway system in Indiana is available at the Planning Division. It should be noted, however, that the available data needed extensive updating.

2. County and Municipal Highway Expenditure Data - From the 1982 Annual Reports, data on total receipts and disbursements by fund category for each county were extracted. Similar information was gathered for municipalities from the Bureau of Census. The major categories of expenditures include administrative costs, maintenance and repair, and construction and reconstruction.

3. Personal Interviews - Personal contacts were made with a group of county and city highway agencies to receive detailed cost data that were used to distribute the aggregated data collected from the available information in various reports.

Revenue Data

Highway revenues in Indiana primarily consist of user taxes and fees, including motor fuel taxes and special fuel taxes, vehicle registration fees, motor carrier fees and vehicle operator's fees. There are some other revenues in the form of fines and charges. The highway revenues also include intergovernmental transfer of funds from federal to state and local governments and from state to local governments.

Revenue data for the base period were collected from appropriate agencies including Indiana Department of Highways, Indiana Department of Revenue, Bureau of Motor Vehicles, Public Service Commission and the State Auditor. Further information on highway revenues at local levels was collected from Annual Reports and personal interviews. Information on federal revenue was collected from the Federal Highway Administration. Supplementary data were also used from several Federal Highway Administration reports including Highway Statistics [43], Highway Taxes and Fees [44], and Road User and Property Taxes on Selected Motor Vehicles [25].

APPENDIX B

PROCEDURE FOR TRAFFIC DATA COLLECTION

One of the most critical data items necessary for a cost-allocation study is information on number of vehicle-miles traveled for each type of vehicles on each of the highway classifications. In addition, traffic data are also necessary to estimate the number of axle-miles traveled by each vehicle class on each highway type. In the present study, a detailed vehicle count survey was undertaken to estimate vehicle miles of travel. Combining these estimates with the data primarily from the IDOH Truck Weight Study, information on vehicle weight and axle-miles was compiled.

Vehicle Count

The study team conducted a vehicle classification field survey at about 60 randomly selected sites throughout Indiana during the summer of 1983. The resulting data were converted to represent an average day of the year with factors developed from the FHWA report, Vehicle Classification Case Study [26].

To obtain valid estimates of the travel by the various vehicle types on Indiana highways, it was necessary to perform classification counts at many randomly located sites. The basis for selecting a section of road was its length. This made subsequent VMT calculations easier because the VMT on a section of road with uniform flow is the product of the flow at a point and the section's length.

The counting stations were selected form the state's HPMS sample. These roads had already been picked with the probability of selection proportional to their length, and the locations were documented and marked on maps. Counting stations were determined by randomly picking mileposts from along the mileage in each highway classification.

The number of sites counted within each study class is presented in Table B.1. The variable number of sites in each study class is due to the fact that the present study classifies highway differently than the HPMS classification scheme and because 10 sites were selected from most of the HPMS classes.

The number of sites within each HPMS class is also presented in Table B.1. Only two rural interstate sites were selected because the state already has much information on these highways. Also, the percentage of vehicles within each vehicle type on rural interstates is quite stable, according to an examination of sites observed by the IDOH in 1981.

Field Data Collection Procedures

Most of the data collection was performed by a team of 4 data collectors and a team leader in 4 shifts of 6 hours each day. Partway into the data collection, a program became available for the Streeter-Amet Traficomp that accurately classifies vehicles according to axle number and spacing. Machine volume recorders were used on 11 2-lane roads late in the data collection period.

In Table B.2 is presented a list of counting sites used in the present study.

Data Reduction and Analysis

For each road section, the raw figures for the number of vehicles of each

Table B.1. Number of Traffic Count Sites

Study Class	Number of Sites
Interstate Urban	9
Interstate Rural	2
State Routes Primary	22
State Routes Secondary	7
County Roads	4
City Streets	8

HPMS Class	Number of Sites
Rural Interstate	2
Rural Other Principal Arterials	8
Rural Minor Arterials	6
Rural Major Collectors	2
Rural Minor Collectors	3
Urban Interstate	9
Urban Freeways and Expressways	8
Urban Other Principal Arterials	9
Urban Minor Arterials	4
Urban Collectors	1

Table B.2. Volume Count Station Locations

SR 18 between US 421 and Flora Corporation
Line in Carroll County
CR 167 between CR 2 (Howard County Line) and
CR 6 in Miami County
US 24 between Wabash County Line and 0.1 mile
east of SR 37 and SR 9 in Huntington County
SR 114 between Huntington County Road and
US 24 in Whitley County
Park Drive between Huntington Corporation Line
and Bartlett Street in Huntington County
SR 127 between westbound US 20 (Maumee St.)
and Angola Corporation Line in Steuben County
US 35 between CR 70 and LaPorte County Line in
Starke County
73rd Avenue between Hendricks St. and Van
Buren St. in Merrillville
US 50 between CR 261 and Martin County Line
near Loogootee in Davies County
SR 56 between Washington County Line and CR 59

SR 135 between US 50 and SR 58

US 41 at Sullivan and Knox County lines

State Street in the city of Washington between
21st and Evergreen
I-64 1.1 miles west of US 41

Tater Road between SR 56 and US 150 - east of
Paoli
CR 46 between CR 23 and CR 73 - north of Rushville

SR 3 north of US 50 - north of North Vernon

US 50 west of Aurora

US 52 at CR 800 E. in Rush County near Franklin
County line.
I-65 at milepost 108 between Raymond St. and
Keystone Ave. in Indianapolis
I-70 between Emerson Ave. and Shadeland Ave. in
Indianapolis
Shadeland Ave. (SR 100) at southwest loop ramp
of US 40 in Indianapolis.
Masschussetts Ave. between Sherman Drive and
30th in Indianapolis
I-74 between SR 25 and SR 341

SR 213 (CR 900 E.) at junction with SR 26
(CR 400 S.)
CR 1150 E. (Main Street) at corner of Division
Street in Idaville

Table B.2. (cont'd)

SR 55 at the corner of 57th Avenue in
Merrillville
CR 875 North between McCool Road and SR 149

US 31 between SR 2 and US 20 in South Bend

SR 15 (Main Street) at corner of Kercher Road
in Goshen
Raymond Street Expressway (Airport Expressway)
between Holt Road and I 70
I-70 at I 465 interchange (Mile Post 90) - east
of Indianapolis
I-70 between Holt Road and Airport Expressway
(Mile Post 76) - west of Indianapolis
SR 37 south of Edgewood - southside of Indianapolis

SR 32 east of CR 650 E. - east of Muncie

I-70 west of US 27 - north of Richmond

US 35 at junction with SR 29 in Logansport

US 31 at intersection with SR 14 - west of
Rochester
SR 3 at Ludwig Road in Fort Wayne

I-69 between US 33 and SR 1

US 30 at junction with Oak Road in Plymouth

I-80/90 east of junction with US 31 - east of
South Bend
US 30 between Horse Road and West Street - west
of SR 2 and Valparaiso
I-65 south of US 30 in Merrillville

US 41 at corner of CR 350 S - south of Princeton

Division Street at the corner of Canal Street
in Evansville
I-265 west of I-65 (mile post 6) - north of
Clarksville
SR 62 0.7 mile east of junction with SR 131 in
Clarksville
SR 37 at corner of That Road - south of
Bloomington
US 41 (Indianapolis Ave.) at the northwest
corner of 41st St. and US 41 in Highland
US 20 at the junction with CR 275 E. - northeast
of Chesterton
8th Street just west of Henry St. in Anderson

I-70 at the junction with Greenfield in Hancock
County (Truck Weight Study ID = 270)

Table B.2. (cont'd)

I-70 in Wayne County (Truck Weight Study ID = 070)

I-65 north of 2 Lake County (Truck Weight Study ID = 165)

I-65 4.0 miles south of SR 10 in Jasper County (Truck Weight Study ID = 156)

I-69 2.0 miles north of SR 5 in Huntington County (Truck Weight Study ID = 069)

I-74 2.0 miles east of SR 229 in Ripley County (Truck Weight Study ID = 074)

I-70 3.2 miles west of Putman County Line in Clay County (Truck Weight Study ID = 470)

I-64 5 miles east of junction with SR 66 in Harrison County (Truck Weight Study ID = 064)

I-74 2.0 miles west of SR 341 in Fountain County (Truck Weight Study ID = 774)

I-94 in Porter County (Truck Weight Study ID = 094)

I-65 1.4 miles west of US 50 in Jackson County (Truck Weight Study ID = 065) type that use that road on a summer weekday were available. The collected data were then adjusted to account for daily and seasonal variations. For this, we used the information from the report, Vehicle Classification Case Study [26]. In several other states, data were collected year-round and on both weekdays and weekends. From these data factors were developed that reflected the change in travel of each type of vehicle on roads within each HPMS functional class. These factors were used to adjust the observed data to estimate the yearly volume counts.

Estimation of Vehicle-Miles of Travel

Since road sections were selected with probability of selection proportional to the the section's length, the number of vehicle-miles traveled for a given vehicle type on roads of a certain highway class is simply the arithmetic average of the number of vehicles counted on the sample sites in that class times the total number of actual miles in the class times 365 days a year.

Table B.3 through B.8 show the 1983 percentage VMT computed for the fourteen vehicle classes and all the weight groups used in the present cost-allocation study. Similar traffic data were also estimated for the years 1985 and 1986 on the basis of the projected growth rates by vehicle class. The traffic growth rates were estimated on the basis of the model used by the FHWA cost allocation study [9]. The formula used is as follows:

$$VMT_1 = VMT_o e^{r * y}$$

Table B.3. Percent VMT of Vehicle Classes on Rural Interstate (1983)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	15.640	15.640
2	1	48.840	48.840
3	1	2.400	0.054
3	2		0.182
3	3		0.218
3	4		0.618
3	5		0.473
3	6		0.346
3	7		0.182
3	8		0.145
3	9		0.182
4	1	0.310	0.310
5	1	1.120	1.120
6	1	0.420	0.051
6	2		0.025
6	3		0.038
6	4		0.076
6	5		0.064
6	6		0.038
6	7		0.038
6	8		0.025
6	9		0.064
7	1	0.360	0.012
7	2		0.024
7	3		0.048
7	4		0.072
7	5		0.036
7	6		0.012
7	7		0.108
7	8		0.036
7	9		0.012
8	1	0.060	0.060
9	1	0.170	0.085
9	2		0.085
10	1	0.070	0.014
10	2		0.014
10	3		0.028
10	4		0.014
11	1	2.500	0.050
11	2		0.097
11	3		0.360
11	4		0.163
11	5		0.295
11	6		0.230
11	7		0.195
11	8		0.180
11	9		0.213
11	10		0.195
11	11		0.195
11	12		0.180
11	13		0.148
12	1	27.200	0.054
12	2		0.272
12	3		0.944
12	4		2.657
12	5		2.149
12	6		1.333
12	7		1.115
12	8		0.979
12	9		0.898
12	10		0.827
12	11		0.800
12	12		0.770
12	13		0.680
12	14		0.800
12	15		0.870
12	16		1.104
12	17		0.979
12	18		0.925
12	19		1.034
12	20		1.496
12	21		2.258
12	22		2.394
12	23		1.170
12	24		0.552
12	25		0.044
12	26		0.101
13	1	0.760	0.088
13	2		0.146
13	3		0.029
13	4		0.059
13	5		0.029
13	6		0.029
13	7		0.059
13	8		0.029
13	9		0.029
13	10		0.059
13	11		0.029
13	12		0.087
13	13		0.087
14	1	0.160	0.053
14	2		0.053
14	3		0.053

Table B.4. Percent VMT of Vehicle Classes on Urban Interstate (1983)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	20.700	20.700
2	1	63.300	63.300
3	1	2.160	0.049
3	2		0.164
3	3		0.196
3	4		0.556
3	5		0.426
3	6		0.311
3	7		0.164
3	8		0.131
3	9		0.164
4	1	0.290	0.290
5	1	0.860	0.860
6	1	0.370	0.045
6	2		0.022
6	3		0.034
6	4		0.067
6	5		0.056
6	6		0.034
6	7		0.034
6	8		0.022
6	9		0.056
7	1	0.260	0.009
7	2		0.017
7	3		0.035
7	4		0.052
7	5		0.026
7	6		0.009
7	7		0.078
7	8		0.026
7	9		0.009
8	1	0.300	0.300
9	1	0.070	0.035
9	2		0.035
10	1	0.030	0.006
10	2		0.006
10	3		0.012
10	4		0.006
11	1	0.800	0.016
11	2		0.031
11	3		0.115
11	4		0.052
11	5		0.094
11	6		0.074
11	7		0.062
11	8		0.058
11	9		0.068
11	10		0.062
11	11		0.062
11	12		0.058
11	13		0.047
12	1	10.400	0.021
12	2		0.104
12	3		0.361
12	4		1.016
12	5		0.822
12	6		0.510
12	7		0.426
12	8		0.374
12	9		0.343
12	10		0.316
12	11		0.306
12	12		0.294
12	13		0.260
12	14		0.306
12	15		0.333
12	16		0.422
12	17		0.374
12	18		0.354
12	19		0.395
12	20		0.572
12	21		0.863
12	22		0.915
12	23		0.447
12	24		0.211
12	25		0.017
12	26		0.038
13	1	0.400	0.046
13	2		0.077
13	3		0.015
13	4		0.031
13	5		0.015
13	6		0.015
13	7		0.031
13	8		0.015
13	9		0.015
13	10		0.031
13	11		0.015
13	12		0.046
13	13		0.046
14	1	0.060	0.015
14	2		0.022
14	3		0.022

Table B.5. Percent VMT of Vehicle Classes on State Primary (1983)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	20.200	20.200
2	1	68.600	68.600
3	1	2.400	0.138
3	2		0.369
3	3		0.369
3	4		0.509
3	5		0.415
3	6		0.230
3	7		0.139
3	8		0.139
3	9		0.091
4	1	0.090	0.090
5	1	0.530	0.530
6	1	0.940	0.329
6	2		0.141
6	3		0.188
6	4		0.141
6	5		0.023
6	6		0.023
6	7		0.031
6	8		0.031
6	9		0.032
7	1	0.330	0.066
7	2		0.022
7	3		0.022
7	4		0.022
7	5		0.040
7	6		0.040
7	7		0.040
7	8		0.040
7	9		0.040
8	1	0.210	0.210
9	1	0.190	0.027
9	2		0.163
10	1	0.040	0.010
10	2		0.010
10	3		0.010
10	4		0.010
11	1	0.470	0.030
11	2		0.073
11	3		0.117
11	4		0.088
11	5		0.059
11	6		0.059
11	7		0.007
11	8		0.008
11	9		0.007
11	10		0.008
11	11		0.005
11	12		0.005
11	13		0.005
12	1	5.770	0.017
12	2		0.121
12	3		0.563
12	4		0.733
12	5		0.444
12	6		0.271
12	7		0.171
12	8		0.185
12	9		0.138
12	10		0.153
12	11		0.190
12	12		0.138
12	13		0.138
12	14		0.205
12	15		0.138
12	16		0.375
12	17		0.254
12	18		0.271
12	19		0.188
12	20		0.171
12	21		0.375
12	22		0.306
12	23		0.171
12	24		0.017
12	25		0.017
12	26		0.017
13	1	0.150	0.045
13	2		0.030
13	3		0.022
13	4		0.015
13	5		0.008
13	6		0.008
13	7		0.008
13	8		0.003
13	9		0.003
13	10		0.003
13	11		0.003
13	12		0.002
13	13		0.002
14	1	0.110	0.037
14	2		0.037
14	3		0.037

Table B.6. Percent VMT of Vehicle Classes on State Secondary (1983)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	20.200	20.200
2	1	71.750	71.750
3	1	3.300	0.906
3	2		0.323
3	3		0.906
3	4		0.518
3	5		0.129
3	6		0.323
3	7		0.129
3	8		0.033
3	9		0.033
4	1	0.060	0.060
5	1	0.490	0.490
6	1	0.520	0.182
6	2		0.130
6	3		0.052
6	4		0.052
6	5		0.013
6	6		0.013
6	7		0.013
6	8		0.013
6	9		0.052
7	1	0.270	0.034
7	2		0.034
7	3		0.034
7	4		0.034
7	5		0.027
7	6		0.027
7	7		0.027
7	8		0.027
7	9		0.027
8	1	0.210	0.210
9	1	0.030	0.004
9	2		0.026
10	1	0.060	0.015
10	2		0.015
10	3		0.015
10	4		0.015
11	1	0.460	0.063
11	2		0.063
11	3		0.084
11	4		0.042
11	5		0.021
11	6		0.084
11	7		0.021
11	8		0.021
11	9		0.011
11	10		0.011
11	11		0.011
11	12		0.011
11	13		0.021
12	1	2.500	0.018
12	2		0.035
12	3		0.104
12	4		0.470
12	5		0.104
12	6		0.190
12	7		0.018
12	8		0.070
12	9		0.156
12	10		0.140
12	11		0.035
12	12		0.052
12	13		0.070
12	14		0.052
12	15		0.052
12	16		0.035
12	17		0.052
12	18		0.190
12	19		0.087
12	20		0.155
12	21		0.190
12	22		0.104
12	23		0.104
12	24		0.013
12	25		0.002
12	26		0.002
13	1	0.090	0.027
13	2		0.027
13	3		0.018
13	4		0.009
13	5		0.009
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.060	0.020
14	2		0.020
14	3		0.020

Table B.7. Percent VMT of Vehicle Classes on County Roads (1983)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	17.950	17.950
2	1	75.340	75.340
3	1	3.900	1.071
3	2		0.382
3	3		1.071
3	4		0.612
3	5		0.152
3	6		0.382
3	7		0.152
3	8		0.039
3	9		0.039
4	1	0.050	0.050
5	1	0.630	0.630
6	1	0.860	0.301
6	2		0.215
6	3		0.086
6	4		0.086
6	5		0.021
6	6		0.021
6	7		0.021
6	8		0.021
6	9		0.086
7	1	0.050	0.006
7	2		0.006
7	3		0.006
7	4		0.006
7	5		0.005
7	6		0.005
7	7		0.005
7	8		0.005
7	9		0.005
8	1	0.	0.
9	1	0.050	0.007
9	2		0.043
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	0.270	0.037
11	2		0.037
11	3		0.049
11	4		0.025
11	5		0.012
11	6		0.049
11	7		0.012
11	8		0.012
11	9		0.006
11	10		0.006
11	11		0.006
11	12		0.006
11	13		0.012
12	1	0.630	0.004
12	2		0.009
12	3		0.026
12	4		0.118
12	5		0.026
12	6		0.048
12	7		0.004
12	8		0.018
12	9		0.039
12	10		0.035
12	11		0.009
12	12		0.013
12	13		0.018
12	14		0.013
12	15		0.013
12	16		0.009
12	17		0.013
12	18		0.048
12	19		0.022
12	20		0.039
12	21		0.048
12	22		0.026
12	23		0.026
12	24		0.003
12	25		0.001
12	26		0.001
13	1	0.180	0.054
13	2		0.054
13	3		0.036
13	4		0.018
13	5		0.018
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.090	0.030
14	2		0.030
14	3		0.030

Table B.8. Percent VMT of Vehicle Classes on City Streets (1983)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	19.340	19.340
2	1	74.000	74.000
3	1	2.160	0.593
3	2		0.212
3	3		0.593
3	4		0.339
3	5		0.084
3	6		0.212
3	7		0.084
3	8		0.022
3	9		0.022
4	1	0.230	0.230
5	1	0.480	0.480
6	1	0.720	0.252
6	2		0.180
6	3		0.072
6	4		0.072
6	5		0.018
6	6		0.018
6	7		0.018
6	8		0.018
6	9		0.072
7	1	0.060	0.008
7	2		0.008
7	3		0.008
7	4		0.008
7	5		0.006
7	6		0.006
7	7		0.006
7	8		0.006
7	9		0.006
8	1	0.	0.
9	1	0.050	0.007
9	2		0.043
10	1	0.045	0.011
10	2		0.011
10	3		0.011
10	4		0.011
11	1	0.430	0.058
11	2		0.058
11	3		0.078
11	4		0.039
11	5		0.020
11	6		0.078
11	7		0.019
11	8		0.019
11	9		0.010
11	10		0.010
11	11		0.010
11	12		0.010
11	13		0.020
12	1	2.360	0.017
12	2		0.033
12	3		0.098
12	4		0.444
12	5		0.098
12	6		0.179
12	7		0.017
12	8		0.066
12	9		0.148
12	10		0.132
12	11		0.033
12	12		0.050
12	13		0.066
12	14		0.050
12	15		0.050
12	16		0.033
12	17		0.050
12	18		0.179
12	19		0.082
12	20		0.146
12	21		0.179
12	22		0.098
12	23		0.098
12	24		0.012
12	25		0.002
12	26		0.002
13	1	0.097	0.029
13	2		0.029
13	3		0.019
13	4		0.010
13	5		0.010
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.032	0.011
14	2		0.011
14	3		0.011

where,

VMT_1 = future year VMT for a vehicle class;

VMT_o = base year VMT of the given vehicle class;

r = rate of traffic growth per year for the vehicle class;

y = number of intervening years between the base and future periods.

The appropriate r-values for various classes were estimated on the basis of the 1977 and the 1985 projected national data [35] used in the Federal study [9]. The 1983 Indiana VMT figures were then projected to 1985-86 using the above formula. The 1985-86 percentage VMT values are shown in Table B.9 through B.14. The total annual VMT values for 1983 and 1985-86 by highway functional class are given in Table B.15.

<u>VMT Correspondence Matrices for Registered and Operating Weight Groups</u>

Truck registration fees in Indiana are collected in terms of vehicle registration weight classification which is different from the operating weight vehicle classification defined in Tables 1 and 2 and used in cost-responsibility computations. The vehicle registration weight classification used by the Indiana Bureau of Motor Vehicles is summarized in Table B.16.

The development of the relationship between the two types of classification is not straight forward because of the fact that vehicle weights were defined differently in each. While the cost responsibility classification was based upon the gross operating weights of vehicles, gross registered weight capacity was used in the Bureau of Motor Vehicles classification. For the purpose of distributing revenues to appropriate cost responsibility vehicle classes and weight groups, a series of correspondence matrices were developed to relate registered vehicle weight classes to operating vehicle weight classes. These matrices are presented in Tables B.17 through B.25.

The primary source of data for establishing these correspondence matrices was the IDOH Truck Weight Survey Records. Every two years, IDOH conducts a truck weight survey. Data on truck weights by truck type are collected at 28 permanent weigh stations and at several temporary locations. The data file includes records of the truck type, axle configuration, axle weights, registration weight classification and other administrative identification codes for every truck weighed. The 1981 and 1983 truck weight survey data were used in this study.

The procedure used in setting up the corresponding matrices is simple in concept. It was basically an accounting process by recording each truck weight data in the appropriate cell of one of the nine two-way classification matrices. These numbers were subsequently converted into percentages for revenue allocation purpose.

Due to the limited amount of data available from IDOH Truck Weight Survey Records, some empty cells were observed within a row of cells with finite values. These inconsistencies were corrected on the basis of information from other midwestern states [4,21,48] and the 1977 Truck Inventory and Use Survey [5].

Table B.9. Percent VMT of Vehicle Classes on Rural Interstate (1985-86)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	15.563	15.563
2	1	48.599	48.599
3	1	2.331	0.053
3	2		0.176
3	3		0.211
3	4		0.598
3	5		0.458
3	6		0.334
3	7		0.176
3	8		0.141
3	9		0.184
4	1	0.302	0.302
5	1	1.114	1.114
6	1	0.417	0.049
6	2		0.025
6	3		0.037
6	4		0.074
6	5		0.064
6	6		0.039
6	7		0.039
6	8		0.026
6	9		0.064
7	1	0.364	0.012
7	2		0.024
7	3		0.048
7	4		0.073
7	5		0.036
7	6		0.012
7	7		0.109
7	8		0.036
7	9		0.012
8	1	0.060	0.060
9	1	0.168	0.082
9	2		0.086
10	1	0.071	0.014
10	2		0.014
10	3		0.028
10	4		0.014
11	1	2.527	0.051
11	2		0.099
11	3		0.364
11	4		0.164
11	5		0.298
11	6		0.233
11	7		0.197
11	8		0.182
11	9		0.215
11	10		0.197
11	11		0.197
11	12		0.182
11	13		0.148
12	1	27.554	0.055
12	2		0.275
12	3		0.954
12	4		2.687
12	5		2.173
12	6		1.348
12	7		1.128
12	8		0.990
12	9		0.908
12	10		0.836
12	11		0.809
12	12		0.778
12	13		0.684
12	14		0.804
12	15		0.876
12	16		1.111
12	17		0.985
12	18		0.930
12	19		1.040
12	20		1.505
12	21		2.312
12	22		2.452
12	23		1.200
12	24		0.566
12	25		0.045
12	26		0.103
13	1	0.768	0.089
13	2		0.148
13	3		0.030
13	4		0.059
13	5		0.029
13	6		0.029
13	7		0.059
13	8		0.029
13	9		0.029
13	10		0.059
13	11		0.029
13	12		0.088
13	13		0.090
14	1	0.162	0.054
14	2		0.054
14	3		0.055

Table B.10. Percent VMT of Vehicle Classes on Urban Interstate (1985-86)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group	Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	20.668	20.668	11	6		0.075
				11	7		0.063
2	1	63.203	63.203	11	8		0.058
				11	9		0.069
3	1	2.105	0.048	11	10		0.063
3	2		0.159	11	11		0.063
3	3		0.191	11	12		0.058
3	4		0.540	11	13		0.048
3	5		0.413				
3	6		0.302	12	1	10.571	0.021
3	7		0.159	12	2		0.106
3	8		0.127	12	3		0.366
3	9		0.166	12	4		1.031
				12	5		0.834
4	1	0.283	0.283	12	6		0.517
				12	7		0.433
5	1	0.859	0.859	12	8		0.380
				12	9		0.348
6	1	0.368	0.043	12	10		0.321
6	2		0.022	12	11		0.310
6	3		0.033	12	12		0.299
6	4		0.065	12	13		0.262
6	5		0.057	12	14		0.309
6	6		0.034	12	15		0.336
6	7		0.034	12	16		0.426
6	8		0.023	12	17		0.378
6	9		0.057	12	18		0.357
				12	19		0.399
7	1	0.264	0.009	12	20		0.577
7	2		0.018	12	21		0.887
7	3		0.035	12	22		0.941
7	4		0.053	12	23		0.460
7	5		0.026	12	24		0.217
7	6		0.009	12	25		0.017
7	7		0.079	12	26		0.040
7	8		0.026				
7	9		0.009	13	1	0.406	0.047
				13	2		0.078
8	1	0.300	0.300	13	3		0.016
				13	4		0.031
9	1	0.070	0.034	13	5		0.016
9	2		0.036	13	6		0.016
				13	7		0.031
10	1	0.030	0.006	13	8		0.016
10	2		0.006	13	9		0.016
10	3		0.012	13	10		0.031
10	4		0.006	13	11		0.016
				13	12		0.046
11	1	0.811	0.016	13	13		0.047
11	2		0.032				
11	3		0.117	14	1	0.061	0.015
11	4		0.053	14	2		0.023
11	5		0.096	14	3		0.023

Table B.11. Percent VMT of Vehicle Classes on State Primary Routes (1985-86)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	20.187	20.187
2	1	68.556	68.556
3	1	2.338	0.135
3	2		0.359
3	3		0.359
3	4		0.495
3	5		0.404
3	6		0.224
3	7		0.135
3	8		0.135
3	9		0.093
4	1	0.088	0.088
5	1	0.530	0.530
6	1	0.920	0.320
6	2		0.137
6	3		0.183
6	4		0.137
6	5		0.024
6	6		0.024
6	7		0.032
6	8		0.032
6	9		0.033
7	1	0.335	0.067
7	2		0.022
7	3		0.022
7	4		0.022
7	5		0.040
7	6		0.040
7	7		0.040
7	8		0.040
7	9		0.040
8	1	0.210	0.210
9	1	0.192	0.026
9	2		0.166
10	1	0.041	0.010
10	2		0.010
10	3		0.010
10	4		0.010
11	1	0.477	0.030
11	2		0.074
11	3		0.119
11	4		0.090
11	5		0.060
11	6		0.060
11	7		0.007
11	8		0.008
11	9		0.007
11	10		0.008
11	11		0.005
11	12		0.005
11	13		0.005
12	1	5.863	0.018
12	2		0.123
12	3		0.572
12	4		0.744
12	5		0.451
12	6		0.275
12	7		0.173
12	8		0.188
12	9		0.141
12	10		0.156
12	11		0.193
12	12		0.141
12	13		0.140
12	14		0.207
12	15		0.140
12	16		0.379
12	17		0.257
12	18		0.274
12	19		0.189
12	20		0.173
12	21		0.386
12	22		0.315
12	23		0.176
12	24		0.018
12	25		0.018
12	26		0.018
13	1	0.152	0.046
13	2		0.030
13	3		0.023
13	4		0.015
13	5		0.008
13	6		0.008
13	7		0.008
13	8		0.003
13	9		0.003
13	10		0.003
13	11		0.003
13	12		0.002
13	13		0.002
14	1	0.112	0.037
14	2		0.037
14	3		0.038

Table B.12. Percent VMT of Vehicle Classes on State Secondary Routes (1985-86)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	20.208	20.208
2	1	71.778	71.778
3	1	3.212	0.881
3	2		0.315
3	3		0.881
3	4		0.504
3	5		0.125
3	6		0.315
3	7		0.125
3	8		0.032
3	9		0.034
4	1	0.059	0.059
5	1	0.490	0.490
6	1	0.511	0.177
6	2		0.126
6	3		0.051
6	4		0.051
6	5		0.013
6	6		0.013
6	7		0.013
6	8		0.013
6	9		0.053
7	1	0.274	0.034
7	2		0.034
7	3		0.034
7	4		0.034
7	5		0.027
7	6		0.027
7	7		0.027
7	8		0.027
7	9		0.027
8	1	0.210	0.210
9	1	0.031	0.
9	2		0.031
10	1	0.061	0.015
10	2		0.015
10	3		0.015
10	4		0.015
11	1	0.468	0.064
11	2		0.064
11	3		0.085
11	4		0.043
11	5		0.022
11	6		0.085
11	7		0.021
11	8		0.021
11	9		0.011
11	10		0.011
11	11		0.011
11	12		0.011
11	13		0.021
12	1	2.546	0.018
12	2		0.036
12	3		0.106
12	4		0.478
12	5		0.106
12	6		0.193
12	7		0.018
12	8		0.071
12	9		0.159
12	10		0.142
12	11		0.036
12	12		0.053
12	13		0.071
12	14		0.053
12	15		0.053
12	16		0.035
12	17		0.053
12	18		0.192
12	19		0.088
12	20		0.157
12	21		0.196
12	22		0.107
12	23		0.108
12	24		0.013
12	25		0.003
12	26		0.003
13	1	0.091	0.027
13	2		0.027
13	3		0.018
13	4		0.009
13	5		0.009
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.061	0.020
14	2		0.020
14	3		0.021

Table B.13. Percent VMT of Vehicle Classes on County Roads (1985-86)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	17.968	17.968
2	1	75.415	75.415
3	1	3.799	1.042
3	2		0.372
3	3		1.042
3	4		0.596
3	5		0.148
3	6		0.372
3	7		0.148
3	8		0.038
3	9		0.040
4	1	0.049	0.049
5	1	0.631	0.631
6	1	0.845	0.293
6	2		0.209
6	3		0.084
6	4		0.084
6	5		0.022
6	6		0.022
6	7		0.022
6	8		0.022
6	9		0.088
7	1	0.051	0.006
7	2		0.006
7	3		0.006
7	4		0.006
7	5		0.005
7	6		0.005
7	7		0.005
7	8		0.005
7	9		0.005
8	1	0.	0.
9	1	0.051	0.
9	2		0.051
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	0.275	0.037
11	2		0.037
11	3		0.050
11	4		0.025
11	5		0.013
11	6		0.050
11	7		0.012
11	8		0.012
11	9		0.006
11	10		0.006
11	11		0.006
11	12		0.006
11	13		0.012
12	1	0.642	0.004
12	2		0.009
12	3		0.027
12	4		0.120
12	5		0.027
12	6		0.049
12	7		0.004
12	8		0.018
12	9		0.040
12	10		0.036
12	11		0.009
12	12		0.013
12	13		0.018
12	14		0.013
12	15		0.013
12	16		0.009
12	17		0.013
12	18		0.048
12	19		0.022
12	20		0.040
12	21		0.049
12	22		0.027
12	23		0.027
12	24		0.003
12	25		0.001
12	26		0.001
13	1	0.183	0.055
13	2		0.055
13	3		0.037
13	4		0.018
13	5		0.018
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.092	0.031
14	2		0.030
14	3		0.031

Table B.14. Percent VMT of Vehicle Classes on City Streets (1985-86)

Veh Class	Sub-Group	Vehicle-Mile % Veh Class	Vehicle-Mile % Sub-Group
1	1	19.344	19.344
2	1	74.013	74.013
3	1	2.102	0.577
3	2		0.206
3	3		0.577
3	4		0.330
3	5		0.082
3	6		0.206
3	7		0.082
3	8		0.021
3	9		0.022
4	1	0.225	0.225
5	1	0.480	0.480
6	1	0.707	0.245
6	2		0.175
6	3		0.070
6	4		0.070
6	5		0.018
6	6		0.018
6	7		0.018
6	8		0.018
6	9		0.073
7	1	0.061	0.008
7	2		0.008
7	3		0.008
7	4		0.008
7	5		0.006
7	6		0.006
7	7		0.006
7	8		0.006
7	9		0.006
8	1	0.	0.
9	1	0.051	0.
9	2		0.051
10	1	0.046	0.011
10	2		0.011
10	3		0.011
10	4		0.011
11	1	0.437	0.059
11	2		0.059
11	3		0.080
11	4		0.040
11	5		0.020
11	6		0.080
11	7		0.020
11	8		0.020
11	9		0.010
11	10		0.010
11	11		0.010
11	12		0.010
11	13		0.020
12	1	2.403	0.017
12	2		0.034
12	3		0.100
12	4		0.451
12	5		0.100
12	6		0.182
12	7		0.017
12	8		0.067
12	9		0.150
12	10		0.134
12	11		0.034
12	12		0.050
12	13		0.067
12	14		0.050
12	15		0.050
12	16		0.033
12	17		0.050
12	18		0.181
12	19		0.083
12	20		0.148
12	21		0.185
12	22		0.101
12	23		0.101
12	24		0.012
12	25		0.002
12	26		0.002
13	1	0.099	0.030
13	2		0.030
13	3		0.020
13	4		0.010
13	5		0.010
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.033	0.011
14	2		0.011
14	3		0.011

Table B.15 VMT Values by Highway Functional Class

Highway Functional Class	1983 VMT	Average 1985-86 VMT
Interstate Rural	4,403,050,390	4,548,825,803
Interstate Urban	3,648,196,397	3,756,549,624
State Routes Primary	7,895,474,051	8,120,381,844
State Routes Secondary	5,406,210,594	5,556,036,215
County Roads	6,038,969,997	6,202,652,957
City Streets	11,354,525,755	11,671,149,284
Total	38,746,427,184	39,855,595,727

Table B.16 Indiana Bureau of Motor Vehicles Registered Vehicle Classification

(A) Single-Unit Trucks

Group	Registered Gross Weight (lbs)
1	0-6999
2	7000-8999
3	9000-10999
4	11000-15999
5	16000-19999
6	20000-25999
7	26000-29999
8	30000-35999
9	36000-41999
10	42000-47999
11	48000-53999
12	54000-59999
13	60000-65999
14	66000-99999

(B) Combination Trucks

Group	Registered Gross Weight (lbs)
1	0-19999
2	20000-25999
3	26000-29999
4	30000-35999
5	36000-41999
6	42000-47999
7	48000-53999
8	54000-59999
9	60000-65999
10	66000-71999
11	72000-73999
12	74000-75999
13	76000-77999
14	78000-99999

Table B.17 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Single-Unit Trucks Class 3

Registration Weight (lbs)	Operating Weight Group Percentages 1	2	3	4	5	6	7	8	9
0-6999	72	20	8						
7000-8999	67	28	4	1					
9000-10999	39	33	20	6	2				
11000-15999	20	40	20	10	9	1			
16000-19999	15	29	10	7	7	4	3		
20000-25999	6	10	16	22	18	13	7	4	4
26000-29999		6	11	23	27	18	7	5	3
30000-35999		9	9	23	23	11	7	7	11
36000-41999			13	16	20	13	13	7	18
42000-47999			6	10	16	20	10	16	22
48000-53999			5	10	15	25	10	15	20
54000-59999				2	5	20	28	15	30
60000-65999				3	5	20	27	15	30
66000-99999				3	5	20	27	15	30

Table B.18 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Single-Unit Trucks Class 6

Registration Weight (lbs)	Operating Weight Group Percentages 1	2	3	4	5	6	7	8	9
0-6999	100								
7000-8999	100								
9000-10999	90	10							
11000-15999	75	20	5						
16000-19999	60	25	13	2					
20000-25999	50	10	20	10	6	4			
26000-29999	35	5	10	11	15	15	7	2	
30000-35999	20	6	8	10	6	15	15	12	8
36000-41999	10	6	8	8	10	12	17	17	12
42000-47999		7	7	10	12	13	18	18	15
48000-53999		7	8	10	15	14	14	14	18
54000-59999			10	10	15	15	15	15	20
60000-65999			8	10	12	15	15	15	25
66000-99999				5	15	15	20	20	25

Table B.19 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 7

Registration Weight (lbs)	Operating Weight Group Percentages 1	2	3	4	5	6	7	8	9
0-19999	50	15	15	10	5	5			
20000-25999	30	10	15	10	10	10	10	5	
26000-29999	25	5	10	12	10	10	18	7	3
30000-35999	20	5	6	9	14	14	14	10	8
36000-41999	15	5	7	11	11	11	18	12	10
42000-47999	10	4	8	11	12	12	19	12	12
48000-53999	6	5	8	10	10	14	20	12	15
54000-59999	6	5	9	9	12	12	18	13	16
60000-65999	4	5	9	10	8	8	20	16	20
66000-71999		5	7	9	8	8	21	22	20
72000-73999		4	8	8	10	13	15	22	20
74000-75999		2	3	5	7	11	17	25	30
76000-77999		2	2	4	8	11	18	20	35
78000-99999			1	3	3	3	15	30	45

Table B.20 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Single-Unit Trucks Class 9

Registration Weight (lbs)	Operating Weight Group Percentages 1	2	3	4	5	6	7	8
0-6999	100							
7000-8999	100							
9000-10999	100							
11000-15999	100							
16000-19999	80	20						
20000-25999	60	40						
26000-29999	40	60						
30000-35999	30	70						
36000-41999	20	80						
42000-47999	10	90						
48000-53999	5	95						
54000-59999	5	95						
60000-65999		100						
66000-99999		100						

Table B.21 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 10

Registration Weight (lbs)	Operating Weight Group Percentages 1	2	3	4	5	6	7	8	9
0-19999	100								
20000-25999	90	10							
26000-29999	60	35	5						
30000-35999	35	25	25	15					
36000-41999	15	25	25	35					
42000-47999	10	20	25	45					
48000-53999	10	10	30	50					
54000-59999	5	15	30	50					
60000-65999	4	14	27	55					
66000-71999	2	8	30	60					
72000-73999	2	8	30	60					
74000-75999	2	3	25	70					
76000-77999	2	3	25	70					
78000-99999	2	3	25	70					

Table B.22 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 11

Registration	Operating Weight Group Percentages												
Weight (lbs)	1	2	3	4	5	6	7	8	9	10	11	12	13
0-19999	90	8	2										
20000-25999	60	20	15	5									
26000-29999	30	20	20	15	10	5							
30000-35999	10	10	15	20	17	15	10	3					
36000-41999	3	6	9	12	15	15	15	11	8	6			
42000-47999		4	5	7	8	9	12	15	10	10	10	7	3
48000-53999		1	3	4	8	8	9	10	10	12	15	13	7
54000-59999		1	2	5	6	7	9	10	13	11	11	11	14
60000-65999			3	4	7	9	10	10	10	10	10	12	15
66000-71999			2	4	8	8	8	8	9	10	11	15	17
72000-73999			2	4	7	8	8	8	8	10	12	15	18
74000-75999			2	4	7	8	8	8	8	10	12	15	18
76000-77999				5	5	7	7	7	10	11	12	16	20
78000-99999				5	5	7	7	7	10	11	12	16	20

Table B.23 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 12

Registration	Operating Weight Group Percentages												
Weight (lbs)	1	2	3	4	5	6	7	8	9	10	11	12	13
0-19999	70	18	7	5									
20000-25999	45	30	20	5									
26000-29999	25	20	20	15	10	5	5						
30000-35999	10	10	15	20	17	15	10	3					
36000-41999	3	6	9	12	15	15	15	11	8	6			
42000-47999		4	5	7	8	9	12	15	10	10	10	7	3
48000-53999		1	3	4	5	5	8	10	10	12	10	10	8
54000-59999		1	2	2	3	5	6	6	6	8	8	8	10
60000-65999			2	2	3	4	4	5	5	5	5	7	7
66000-71999				2	3	3	3	4	4	4	5	5	5
72000-73999				2	2	3	3	3	4	4	4	5	5
74000-75999				1	1	2	3	3	3	4	4	4	5
76000-77999				1	1	2	3	3	3	4	4	4	5
78000-99999				1	1	2	3	3	3	4	4	4	5

Table B.23 (Continued)

Registration	Operating Weight Group Percentages												
Weight (lbs)	14	15	16	17	18	19	20	21	22	23	24	25	26
0-19999													
20000-25999													
26000-29999													
30000-35999													
36000-41999													
42000-47999													
48000-53999	7	4	3										
54000-59999	10	8	8	6	3								
60000-65999	7	9	9	8	6	6	4	2					
66000-71999	6	6	8	8	8	8	7	5	4	2			
72000-73999	5	6	6	8	8	8	8	6	4	4	2		
74000-75999	5	5	6	6	7	8	8	8	6	4	4	2	1
76000-77999	5	5	6	6	7	8	8	8	6	4	4	2	1
78000-99999	5	5	6	6	7	8	8	8	6	4	4	2	1

Table B.24 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 13

Registration	Operating Weight Group Percentages												
Weight (lbs)	1	2	3	4	5	6	7	8	9	10	11	12	13
0-19999	100												
20000-25999	100												
26000-29999	100												
30000-35999	100												
36000-41999	85	10	5										
42000-47999	65	13	12	7	3								
48000-53999	45	12	10	10	8	7	5	3					
54000-59999	30	8	8	8	10	10	8	8	6	4			
60000-65999	25	5	5	5	7	7	7	9	9	8	6	4	3
66000-71999	20	4	4	5	5	7	8	9	10	10	8	6	4
72000-73999	20	3	4	5	5	7	8	9	10	10	8	6	5
74000-75999	20	3	4	5	5	7	8	9	10	10	8	6	5
76000-77999	20	3	4	5	5	7	8	9	10	10	8	6	5
78000-99999	20	3	4	5	5	7	8	9	10	10	8	6	5

Table B.25 Vehicle Registration Weight-Operating Weight Correspondence Matrix for Combination Trucks Class 14

Registration	Operating Weight Group Percentages												
Weight (lbs)	1	2	3	4	5	6	7	8	9	10	11	12	13
0-19999	100												
20000-25999	100												
26000-29999	100												
30000-35999	95	5											
36000-41999	90	10											
42000-47999	70	30											
48000-53999	65	35											
54000-59999	55	45											
60000-65999	45	45	10										
66000-71999	40	48	12										
72000-73999	35	50	15										
74000-75999	30	50	20										
76000-77999	25	50	25										
78000-99999	25	50	25										

APPENDIX C

HIGHWAY CONSTRUCTION COST ALLOCATION

General

Highway construction costs are divided into the following items for cost-allocation purposes:

Right-of-Way costs

Grading and earthwork costs

Drainage and erosion control costs

Pavement costs

Shoulder costs

Miscellaneous costs

There are 874 contract sections of State highway in the IDOH Road Life Records. New construction project contracts are first identified. Cost information of these contracts is then extracted from Road Life Records, Construction Reports File and Itemized Proposal File. Further classification of these extracted costs is possible by highway type (Interstate, State Route or US Route), by surface type (concrete and bituminous), and by area type (rural, urban or mixed) from Road Life Records. Breakdown of each contract cost into the five allocation items mentioned above is derived from itemized costs available in Road Life Records and Itemized Proposal File.

Right-of-Way Costs

The total right-of-way width is the sum of the widths of the following elements: pavements, shoulders, medians and borders. Pavement, shoulder and median costs will be treated separately under headings of pavement costs and shoulder costs.

Costs considered under right-of-way include acquisition costs of right-of-way, preparation costs of right-of-way, relocation cost, utility adjustment cost and roadside development costs. Since right-of-way requirements are not the same for different highway classes, it is necessary to separate right-of-way costs according to the types of highways. A more complex procedure is to classify right-of-way costs by highway class, terrain type, and location (urban or rural). An analysis of the cost data is needed to determine if a detailed classification of right-of-way costs is justifiable.

Depending upon the design practice used in each state, right-of-way cost may or may not be a function of vehicle characteristics. For instance, Maryland [42] considered all right-of-way costs to be basic cost, whereas in Wisconsin study [48], only 47.4% are basic costs, the remaining 52.6% are allocated by incremental method with vehicle-miles used as the inter-group cost-allocator. Oregon study [33] allocated right-of-way cost incrementally by observed vehicle gross weight which was used as a proxy for vehicle size.

Of the various components of right-of-way costs, the land acquisition cost appears relatively easy to be allocated in the sense that it can be assumed to be proportional to overall right-of-way width. For other costs, there is no obvious logical procedure to be followed for allocation.

There is no specific right-of-way width requirements in Indiana. Generally the AASHTO standard [1] is adopted in practice. A summary of AASHTO right-of-way width design guidelines is shown in Table C.1. These design widths are applicable for rural highways where land acquisition is not a major

Table C.1. Right-of-Way Width Requirements

Highway Type		Right-of-way Width (ft.)
2-lane	low type surface	66-80
	intermediate type surface	80-100
	high type surface	100-120
4-lane divided highway	restricted	90-110
	intermediate	140-180
	desirable	210-310
6-lane and 8-lane highways		add width of 12-ft lanes to 4-lane right-of-way width

problem. Such widths are usually not attainable in urban highway construction.

An incremental approach may be developed for right-of-way costs on the basis that right-of-way width bears some relationship to design-hour volume expressed in passenger-car equivalents. This approach is not used in the present study for the following reasons:

1. As traffic volume increases, wider pavement, shoulder and median are needed to provide certain desired level of service. Wider right-of-way is required as a result. However, an increase in traffic volume generally represents a proportionate increase in all classes of vehicles rather than in a particular class of vehicle.

2. Greater width requirement represents a relatively small percentage of total right-of-way width. For a rural 4-lane highway with a right-of-way width of say 200 feet, an additional width of 8 ft accounts for only 4% of total width. Any additional responsibility of truck is likely to be offset by the automobile responsibility mentioned in item 3.

3. Wider highway is designed to accommodate peak traffic volume. For both rural and urban highways, studies [16] have indicated that the percentage of passenger cars and light trucks in design-hour volume is higher than their percentage in average daily traffic. On this aspect, passenger cars and light trucks tend to have higher responsibility than their percentage in ADT suggests.

The present study defines two components of right-of-way costs. The first portion of cost corresponds to a minimum right-of-way width as defined by the AASHTO standard [1] - 66 feet for 2-lane highway, 90 feet for 4-lane, 108 and 120 feet for 6 and 8 lane highway, respectively. These form non-attributable portions of the right-of-way cost which is to be shared by all vehicles using the highway. The vehicle-miles of travel, which measures the relative use of highway by different vehicle classes, was used to allocate this common cost. The right-of-way costs of any highway with a right-of-way width below the stipulated minimum was allocated entirely on the basis of VMT.

Any additional width above the stipulated minimum, which leads to the second portion of right-of-way costs, can be considered to be capacity-related requirement. As such, they should be allocated in proportion to PCE-VMT (passenger car equivalent (PCE) - miles of travel).

In summary, the common cost portion of right-of-way costs is computed as the ratio of minimum right-of-way width to the actual width of the right-of-way. This cost portion is allocated on the basis of VMT. The remaining right-of-way costs are allocated according to VMT weighted by PCE.

Grading and Earthwork Costs

Most studies consider the amount of grading and earthwork to be related to vehicle width and thus is a function of pavement width. Maryland study [42] divided these costs into two increments, namely the base facility costs for automobiles and the second increment for trucks and buses. The cost-allocator used within the two increments is PCE-miles of travel. Based upon the design criteria for different terrain characteristics, Wisconsin study [48] utilized computations for three standard terrain types (flat, rolling and hilly) to estimate the effect of different vehicle sizes. An incremental analysis based on vehicle width was then used to allocate grading and earthwork costs. Oregon study [33] also allocated these costs incrementally by observed gross weight of vehicles.

In the present study, grading and earthwork costs represent the sum of roadbed excavation, filling, leveling and compaction costs. These cost items were extracted from data base compiled from IDOH cost files.

Following the same approach as in allocation of right-of-way costs, the grading and earthwork costs associated with a minimum road width was specified as common costs to be shared by all vehicles. Cost associated with additional road width in excess of the minimum was considered to be facility needed to satisfy capacity and level of service requirements. For the first portion of costs which correspond to work performed within the minimum road width, the cost-allocator was vehicle-miles of travel. The remainder of the costs was allocated on the basis of PCE-miles of travel.

AASHTO design guides [1] for traveled way widths were adopted for defining the minimum widths which were computed as the sum of minimum widths of pavement, median and shoulder, as shown in Table C.2.

A refinement in the allocation of grading and earthwork costs would have been possible if compaction costs could be extracted from the cost data. This compacted subgrade layer is frequently included in pavement design as a structural component of flexible pavement [49]. It serves to reduce the structural requirements of the pavement resting on it. It would therefore be more logical to distribute the compaction costs with a weight-related cost-allocator.

The costs of excavation in rolling or hilly terrain require a more

Table C.2. Traveled-Way Width Requirements

Highway Type	Min. Traveled - Way Width (ft.)
2-lane highway	26
4-lane highway	44
6-lane highway	56
8-lane highway	68

detailed allocation procedure. Studies [17,40,46] have shown that the rate and length of a given grade have more effects in reducing the speeds of heavy vehicle. It has been found that the travel speed of vehicles on grades is a function of their weight-power ratio. AASHTO [1] provides recommended critical length of grade for design based on the requirement of heavy trucks with a weight-power ratio of 600 pounds per horsepower. Similar critical length and rate of grade relationships can be derived for other weight-power ratios. An incremental approach for allocation of grading costs in rolling or hilly terrain may be developed based on the different critical length and grade requirements of vehicles with different weight-power ratios.

This refined analysis was found unnecessary for the present study for the following reasons. Construction records for the base period (1980-83) show that most of the construction projects were reconstruction which were mainly improvements involving very little or no excavation of slopes. Of the few new construction projects completed within the base period, the length constructed in each project was relatively short. None of these construction projects were found to involve critical length consideration. The pattern of future construction in the study period (1985-86) is expected to remain the same, that is, predominantly reconstruction to improve geometric features and safety. Exclusion of critical length analysis for excavation costs therefore does not have any significant effect on the overall grading and earthwork cost-allocation.

Drainage and Erosion Control Costs

Highway drainage facilities are constructed to remove storm water from paved roadway as well as across the entire width of the right-of-way.

Properly designed highway drainage facilities are essential to erosion prevention and control. The extent of drainage facilities and erosion control measures required is directly related to the amount of runoff expected. A logical allocation parameter for drainage and erosion control costs is therefore the runoff quantity which, for a given rainfall intensity, is a function of the area and surface type of the runoff watershed concerned.

Virtually all previous cost-allocation studies chose to combine drainage costs with grading costs and these costs were allocated largely on the basis of VMT or PCE-VMT. However, recognizing the distinct feature of design consideration concerning drainage and erosion control facilities as discussed in the preceding paragraph, it was decided in the present study to treat the costs associated with providing these facilities separately from grading and earthwork costs.

The allocation procedure for drainage and erosion control costs adopted in this study has its basis on the long-used rational method for runoff estimation. This method is still the most practical approach for calculating the peak rate of runoff for roadway. The basic equation is:

$$Q = ciA$$

where,

Q = peak rate of runoff, in cfs;

c = runoff coefficient;

i = rainfall intensity in/hr;

A = watershed area in acres.

For heavily vegetated area, the runoff coefficient was taken as 0.2 and for paved surfaces, it was 0.9. This means that, for a given rainfall intensity, a unit area of paved surface would produce 4.5 times as much runoff as that from a unit area of vegetated ground. Using this value of 4.5 as weighting factor for paved surfaces, the cost-allocating procedure proceeded as follows:

i. The total drainage and erosion control cost was first split into two components, namely paved-surface responsibility cost, and non-paved-surface responsibility cost. These two cost components were computed in proportion to their respective weighted widths. Paved surface is basically the roadway itself and the weighting factor is 4.5. For non-paved surface, the weighting factor is 1.0.

ii. The paved-surface responsibility cost was allocated by first defining a minimum roadway width. This minimum roadway width is the sum of minimum traveled way width and minimum shoulder width, specified respectively in Table C.2 and in section on allocation of shoulder costs. Cost associated with the minimum roadway width was allocated as common cost on the basis of VMT. Cost corresponding to additional roadway width in excess of the minimum was allocated on the basis of PCE-miles of travel.

iii. The non-paved-surface responsibility cost was allocated by considering minimum non-paved-surface width which is given by the difference between minimum right-of-way defined in Table C.2 and the minimum roadway width computed in Step ii above. Again, costs associated with the minimum width was allocated on the basis of VMT, and that associated with excess width on the basis of PCE-VMT.

iv. For each vehicle class, its total cost responsibility was determined by the sum of its respective cost responsibility computed in Steps ii and iii.

New Pavement Costs

This section covers allocation of costs for constructing new pavement only. Cost of repair for pavement deterioration with age or pavement damage through vehicle use are dealt with in the section on rehabilitation cost allocation. Because of this distinction, it was decided that allocation of new pavement cost would not be based on wear-related criteria. Instead, occasioned costs were determined by analyzing engineering details involved in the design of pavement. The appropriate costs were assigned to the responsible vehicle class or classes accordingly.

The procedure of rigid and flexible pavement design adopted by IDOH [50] formed the basis of engineering analysis for pavement cost in this study. This procedure followed essentially the method outlined in 1980 AASHTO Interim Guide for Design of Pavement Structures [2]. Traffic loadings were expressed in terms of equivalent 18-kip single axle load applications (ESAL) for design of both flexible and rigid pavements. Thickness of flexible pavement was obtained by converting the structural number of the pavement concerned using Indiana material factors recommended by IDOH [50]. The structural number, determined with charts in AASHTO Interim Guide [2], is a function of serviceability index, soil support value, regional location, ADT factor and total 18 kip single axle load applications. Thickness of rigid pavement is derived directly from charts in AASHTO Interim Guide [2] with the following input data: serviceability index, modulus of subgrade reaction, load transfer factor for reinforced concrete (RC) pavement, working stress and modulus of elasticity of concrete, ADT factor and total 18 kip single axle load applications.

Traditionally, pavement thickness costs have been allocated using the standard incremental method [24] developed almost two decades ago. However, recent research on pavement performance suggests several drawbacks of the traditional incremental method of new pavement cost-allocation. The most important drawback is that this method arbitrarily assigns the benefits of economy of scale to heavier vehicles [7].

A revised incremental procedure was developed in the present study aiming to (i) overcome the problem of economies of scale in pavement cost-allocation, and (ii) be in consistence with the design procedure used in Indiana.

The cost-allocation procedure, known as the Thickness Incremental Method, was developed by Fwa and Sinha [12] for the present study. It begins by defining pavement thickness increments, in contrast to the common practice of starting with traffic increments or decrements. There are two advantages with the proposed approach: (a) by beginning with a given thickness, no iterative procedure is necessary in calculating ESALs; (b) because pavement cost is more directly related to pavement thickness than traffic loading, a better control over the accuracy of the result can be achieved by using pavement thickness as the starting parameter.

In defining the number and magnitude of pavement thickness increments, the minimum practical pavement thickness must first be determined. In accordance with IDOH design practice, the following minimum thicknesses were considered to be the basic cost components which are required for flexible pavement regardless of the traffic level:

Surface Course	1 inch
Base Course	3 inches
Subbase Course	4 inches (if subbase is used)

For rigid pavements, the minimum thickness was taken as 4-1/2 inches. Only those costs corresponding to the thickness in excess of the specified minimum were allocated by the incremental approach described in this section. The pavement costs associated with the minimum thickness were allocated on the basis of VMT.

The total thickness in excess of a specified minimum is divided into increments, the number and thickness of which depend on the desired accuracy of the final results. Beginning with the specified minimum thickness, a thickness increment is first added. With this total thickness, the ESAL of each vehicle type or a representative vehicle type of a vehicle class can be computed directly from the following equation which was developed from the AASHO Road Test [2,15]:

$$\text{Log } ESAL_x = G_t \left[\frac{1}{b_{18}} - \frac{1}{b_x} \right] + \text{Log} \left\{ \left[\frac{L_x + L_2}{19} \right]^A / L_2^B \right\}$$

where, $ESAL_x$ = equivalent single axle load of axle type x;

G_t = a function of the ratio of loss in serviceability to the potential loss taken to a point where terminal serviceability index (p_t) is 1.5;

b_x = a function related to axle weight of vehicle type x, pavement strength and pavement thickness;

b_{18} = a function related to a single axle weight of 18 kips, pavement strength and pavement thickness;

L_x = axle load in kips;

L_2 = 1 for single axles, 2 for tandem axles;

A = 4.79 for flexible pavement, 4.62 for rigid pavement;

B = 4.33 for flexible pavement, 3.28 for rigid pavement.

In calculating ESAL with the above formula, Indiana practice [50] was followed. A terminal serviceability index p_t value of 2.5 or 2.0 was used for flexible pavement, and 2.5 for rigid pavement. The following material constants were used for computing pavement strength:

Bituminous Surface = 0.4/inch

Bituminous Binder = 0.34/inch

Bituminous Base = 0.3/inch

Bituminous Stabilized Subbase = 0.24/inch

Compacted Aggregate Type "p" = 0.14/inch

Granular Subbase = 0.08/inch

The same procedure was repeated for each additional increment until the total thickness was reached. The incremental pavement thickness cost corresponding to each thickness increment was assigned to all vehicle classes based on their need for that thickness according to pavement design procedure. Accordingly, the proportional amount of pavement thickness cost attributable to a given vehicle is in direct proportion to its ESAL value. With the same reasoning, the proportional cost responsibility of a given vehicle class is equal to its proportional contribution to the total ESAL of the entire traffic stream.

At any given pavement thickness, it is possible to calculate the corresponding total ESAL. However, this information is not essential because only the proportional contribution of ESAL from individual vehicle classes are needed. It can be logically assumed that the traffic responsible for any intermediate pavement thickness has the same vehicle class composition as that of the actual traffic stream for which the total pavement thickness is designed. Since the proportions of individual vehicle classes in the entire traffic stream are known, their proportional ESAL at any given pavement thickness can be obtained by multiplying each vehicle class traffic proportion by a single vehicle ESAL representative of the vehicle class. However, as the procedure can be made more accurate with information on axle weight distribution within each vehicle class, the analysis in this study was performed in terms of axle weight groups. Extending the idea further, the same cost-allocation procedure can be even followed using individual vehicle type, instead of vehicle class or axle weight group, as the basic unit. This means that a separate within-class cost-allocation step is not necessary with the proposed procedure.

By having each vehicle class proportionally represented each time an incremental cost is allocated, the cost-allocation procedure described above effectively eliminates the economies of scale problem associated with the traditional incremental method. It also allocates all pavement thickness in excess of a specified minimum in consistence with thickness design concept and avoids the problem of having an unaccounted for residual thickness as is found when using Wisconsin's BAR method [48]. Iterative procedure which is a routine in all existing methods is bypassed by taking thickness increment as the starting parameter. Furthermore, the procedure is easy to understand because it follows the usual thinking of increasing pavement thickness to account for increasing traffic. A description of the computational algorithm of the thickness incremental method is presented below.

Inputs to the algorithm include (a) cost information, (b) pavement data, (c) traffic composition, vehicle axle configuration and axle-weight data. For rigid pavement, cost can be assumed to be directly proportional to the slab thickness. For flexible pavement, separate costs for surface, base and subbase construction are needed.

The computation algorithm for cost-allocation involves the following steps:

1. Divide the pavement thickness in excess of a practical minimum into N equal increments. In the case of flexible pavement, each increment is composed of thickness of surface, base and subbase materials in the same proportions as are in the total `excess' thickness to be allocated.

2. Calculate the cost for the minimum thickness and distribute to all vehicle classes on the basis of VMT.

3. Calculate the incremental thickness cost.

4. Add an increment to the minimum thickness, and compute ESAL for all vehicle classes (or vehicle types if desired) using AASHTO ESAL equations.

5. Compute the cost responsibility factor of each vehicle class (or vehicle types) as the following ratio:

$$F(i,j) = P(i) \times ESAL(i,j) \Big/ \sum_{r=1}^{M} \left[P(r) \times ESAL(r,j) \right]$$

where,

$F(i,j)$ = cost responsibility factor of vehicle class i for thickness increment j

$P(i)$ = proportion of vehicle class i in traffic stream

$ESAL(i,j)$ = ESAL of vehicle class i for thickness increment j

M = total number of vehicle classes

6. Allocate incremental thickness cost to each vehicle class as follows:

$$c(i,j) = F(i,j) \times Cd(j)$$

where,

$c(i,j)$ = cost allocated to vehicle class i for thickness increment j

$Cd(j)$ = incremental cost for thickness increment j

7. Repeat steps 5 and 6 for each new thickness increment until the full pavement thickness is reached.

8. Calculate the total allocated cost for vehicle class j by summing up its cost responsibility for all increments:

$$C(i) = Cm(i) + \sum_{j=1}^{N} c(i,j)$$

where,

$C(i)$ = total cost responsibility of vehicle class i

$Cm(i)$ = cost responsibility of vehicle class i for the miniumum thickness

N = total number of thickness increments

For new pavement width in excess of a specified minimum pavement width, a slightly modified allocation procedure is required. A pavement width of 9 feet per lane was taken as the minimum width in the present study. The portion of pavement width in excess of 9 feet was allocated by the same incremental allocation procedure described earlier, except that the pavement costs associated with each extra thickness increment for the additional width were allocated differently. Instead of allocating according to each vehicle class' share of total ESAL, a combination of PCE and ESAL is used as the allocator. This is in recognition of the effects larger vehicles have on roadway width and roadway capacity.

Shoulder Costs

In previous highway cost-allocation studies, shoulder costs have been handled in several different ways. Some studies [7] suggest that shoulder and pavement costs be grouped together on the assumption that both costs are occasioned by the same vehicles in the same proportions. Other studies [32, 48] treated shoulder costs separately using a minimum width approach by assuming certain shoulder width is required by all vehicles. Any width in excess of this minimum is taken to be occasioned by larger vehicles.

In the process of selecting a procedure for allocating shoulder costs in the present study, the major functions of a shoulder were first examined. The AASHTO Manual on Geometric Design [1] lists the following shoulder functions:

1. Space is provided for stopping free of the traffic lane due to motor trouble, flat tire or other emergency.

2. Space is provided for the occasional motorist who desires to stop to consult road maps, to rest, or for any other purpose.

3. Space is provided to escape potential accidents or reduce their severity.

4. The sense of openness created by shoulders of adequate width contributes much to driving ease and freedom and strain.

5. Sight distance is improved in cut sections and, thus, hazard is reduced.

6. The capacity of the highway is improved. Uniform speed is encouraged.

7. Space is provided for maintenance operations.

8. Lateral clearance is provided for signs and guard rails.

9. Storm water can be discharged farther from the pavement and seepage adjacent to the pavement minimized.

10. Structural support is given to the pavement.

Strictly speaking, only items 1, 2 and 3 are affected by the presence of trucks. It is therefore not entirely correct to claim that shoulder width in excess of a certain minimum is due completely to larger or heavier vehicles. Consequently, it appears that an equitable approach is to allocate excess width costs on the basis of PCE-VMT, which is a parameter more closely related to capacity and level of service considerations.

In allocating shoulder thickness costs, it is realized that shoulder thickness is not designed for the same traffic loading as that for pavement. It may be argued, however, that the same percentage of cars and trucks in traffic stream will make use of the shoulder provided. If this assumption is true, then it would be acceptable to follow pavement cost-allocation procedure.

A procedure was developed to satisfy both the shoulder width and thickness criteria described above. Shoulders of 2-foot and 6-foot were considered to be the minimum widths in this study for 2-lane and 4-or more lane highway, respectively. This implies that the costs of all shoulders with width less than the minimum were allocated using the thickness incremental approach developed for pavement cost-allocation. For shoulder width in excess of the minimum, the corresponding cost in proportion to width was allocated by the same procedure, but with the allocation parameter weighted by PCE.

Reconstruction Costs

Reconstruction involves construction on approximate alignment of an existing route where old pavement may be removed and replaced. It includes widening projects which provide additional width to existing pavements; improvements of highway geometry such as realignment of roadway on existing right-of-way, and upgrading of unsafe features.

In many cases, reconstruction projects recorded in the IDOH construction records included other incidental improvements such as resurfacing of adjoining existing pavement in a roadway realignment project or resurfacing of existing lanes in a widening contract. These resurfacing costs were separated from new pavement construction cost, and allocated by means of rehabilitation cost-allocation procedure discussed in a later section of this report.

Other expenditures such as right-of-way, shoulder, drainage improvements and earthwork costs in reconstruction projects were allocated using the same procedure developed for allocating the corresponding items in new construction.

Miscellaneous Items

Construction costs of items not allocated under the four cost categories discussed in previous sections were considered individually to determine the cause for incurring these costs and the appropriate cost-allocator was used.

Engineering services, installation of traffic control devices, pavement marking are examples of cost items which cannot be allocated specifically to any vehicle groups. These costs can be treated as common costs and allocated on the basis of VMT, which is a measure of the relative use of highway by various vehicle groups.

For items which are provided exclusively for a specific group of vehicles, the corresponding costs should be allocated accordingly to this vehicle group only. Some examples are construction of climbing lanes and weigh stations. These facilities are constructed exclusively to serve heavy vehicles. Cost of these items should therefore be allocated entirely to these vehicles. Further within-group distribution of these costs was based on VMT. Miscellaneous costs also included administration and supervision costs. These costs were distributed as common costs among all vehicle classes according to VMT.

APPENDIX D

HIGHWAY REHABILITATION COST ALLOCATION

General

Rehabilitation can be considered as a large scale maintenance operation in the sense that both rehabilitation and maintenance aim at maintaining ride quality and structural condition. They are different, however, since maintenance refers to minor activities which are carried out routinely, whereas rehabilitation activities are required only when routine maintenance operation can no longer maintain the quality of highway desired. It is therefore important to realize in allocating expenditures of a highway item, particularly pavement related expenditures, that although the causes for maintenance and rehabilitation operations are usually the same, there is a significant difference in the scale of deterioration associated with the operations.

Rehabilitation costs in this study are defined as being the expenditures spent to restore the level-of-service of highways in Indiana. Rehabilitation consists of major reconstruction or resurfacing activities that are not classified and coded as routine maintenance activities of IDOH.

Previous Studies

Only a few previous cost-allocation studies treated rehabilitation as a separate expenditure category. A majority of these studies grouped rehabilitation costs with construction costs and allocated them based on the same methods used for allocating construction costs [28,33,42]. The

1982 Virginia study [22] separated rehabilitation projects into construction and maintenance categories. Rehabilitation costs were included in construction costs and allocated accordingly if rebuilding occurred along with improvement in capacity, alignment, grade or other features of roadway geometry. Otherwise, they were allocated as maintenance costs.

Wisconsin study [48] allocated rehabilitation costs separately from construction and maintenance costs. Rehabilitation costs were divided into basic, service, and fixed portions. The basic portion included costs required to provide the level-of-service to accommodate the passenger cars. The service portion of costs were required to provide a level-of-service beyond the basic level-of-service. Fixed costs were the costs resulted from natural phenomena. Different methods and cost-allocators were employed to allocate these three types of costs.

In most cases, previous studies allocated common costs based on VMT and traffic attributable costs based on weight-related cost-allocators, such as ESAL, axle-miles, and ton-miles although the methods may vary among the studies. The decision to estimate rehabilitation costs caused by weather only was primarily based on engineering judgments.

The recent FHWA Cost-Allocation Study [9,34] recommended an approach to allocate rehabilitation costs using a series of distress functions. The distress functions were developed for the most important distress types for both flexible and rigid pavements and four different climatic zones were considered. Appropriate load equivalency factors were generated to represent the interaction of traffic and weather in causing a particular distress. These equivalency functions can then be used to allocate rehabilitation costs, once the proportion of these costs occasioned by individual distress types are identified.

FHWA model [34] developed for application in nationwide study is not directly applicable to any state level analysis without considerable amount of modification. In addition, FHWA study did not consider routine maintenance costs since routine maintenance is the charge of individual state highway agencies. Consequently, the FHWA procedure does not provide any criterion for differentiating rehabilitation responsibilities from routine maintenance responsibilities of vehicle classes. If FHWA procedure were to be used for allocating rehabilitation costs at state level, one would be confronted with the problem of what type of damage or distress functions should be used for allocating routine maintenance costs. Double counting appears to be unavoidable if a damage function approach is also used for allocating routine maintenance costs.

Allocation Procedure for Pavement Rehabilitation Costs

Rehabilitation and routine maintenance, though involve different forms of activities and end results, are interdependent and closely related. It is important that a consistent unified approach be used for allocating rehabilitation and routine maintenance costs so that rehabilitation responsibilities could be separated from routine maintenance responsibilities, and that no double counting would occur. Described in this section is a procedure for allocating pavement rehabilitation costs, which presents an attempt to satisfy the above requirements. The corresponding procedure for allocating routine maintenance costs is presented in a subsequent section.

Pavement design procedures adopted by Indiana DOH has been described in the section on allocation of new pavement costs. Following this design concept, it implicitly implies that, in an ideal situation where the design conditions are correctly predicted, a pavement constructed accordingly would be able to serve the design traffic until the end of its design life when the pavement PSI reaches a predetermined terminal PSI level at which a rehabilitation is deemed necessary to restore the pavement PSI to its original as-constructed level.

It is logical to say that the cost incurred in designing and constructing the original pavement has accounted for the pavement wear caused by traffic over the period of its design life. The purpose of rehabilitating the pavement is to give it another service life span to serve the traffic. The vehicle classes that use the rehabilitated pavement must therefore pay for the rehabilitation cost. With this reasoning, a cost allocation concept similar to that used for allocating new pavement cost was followed.

Consider again the ideal design conditions and assume that a decision to rehabilitate a pavement is made at the end of the design life of the pavement. If there is no other factors additional to those for which the pavement was designed, the rehabilitation costs incurred would be due to design factors only and therefore have to be shared by all the vehicles that would be using the rehabilitated pavement.

There is no standard or generally accepted overlay design procedure available. AASHTO Interim Guide [2] classifies overlay design practice into several categories. For the purpose of the present study, the

AASHTO Interim Guide procedure was considered to be most suitable in that it provides consistency in approaches in allocating different components of pavement costs.

The basic idea of the AASHTO Interim Guide [2] approach for overlay design is to subtract the existing pavement structure thickness from the total thickness required by a new design analysis. In using this procedure, in addition to a soil support value, each of the existing layers is assigned a layer coefficient.

In a cost-allocation analysis, the thickness of overlay constructed is known from the base year data. It is not necessary to go through the design computation again. The procedure developed in the present study for allocating new pavement costs, namely the Thickness Incremental Method, was applied to allocate the part of the rehabilitation cost related entirely to traffic based upon the thickness of overlay constructed.

Factors other than traffic loading which is the primary factor in Indiana pavement design procedure, are also responsible for the loss of PSI of a pavement. These non-traffic factors include severe weather and de-icing chemicals, faults in engineering design, defects in material used, and poor construction quality. If no routine maintenance were carried out, a pavement performance in terms of PSI would fall below the PSI curve predicted by pavement design equations as shown in Figure D.1.

In Figure D.1, area A represents a measure of the pavement wear or damage due to traffic and other design factors, and area B represents the further pavement wear due to non-traffic factors and interaction of

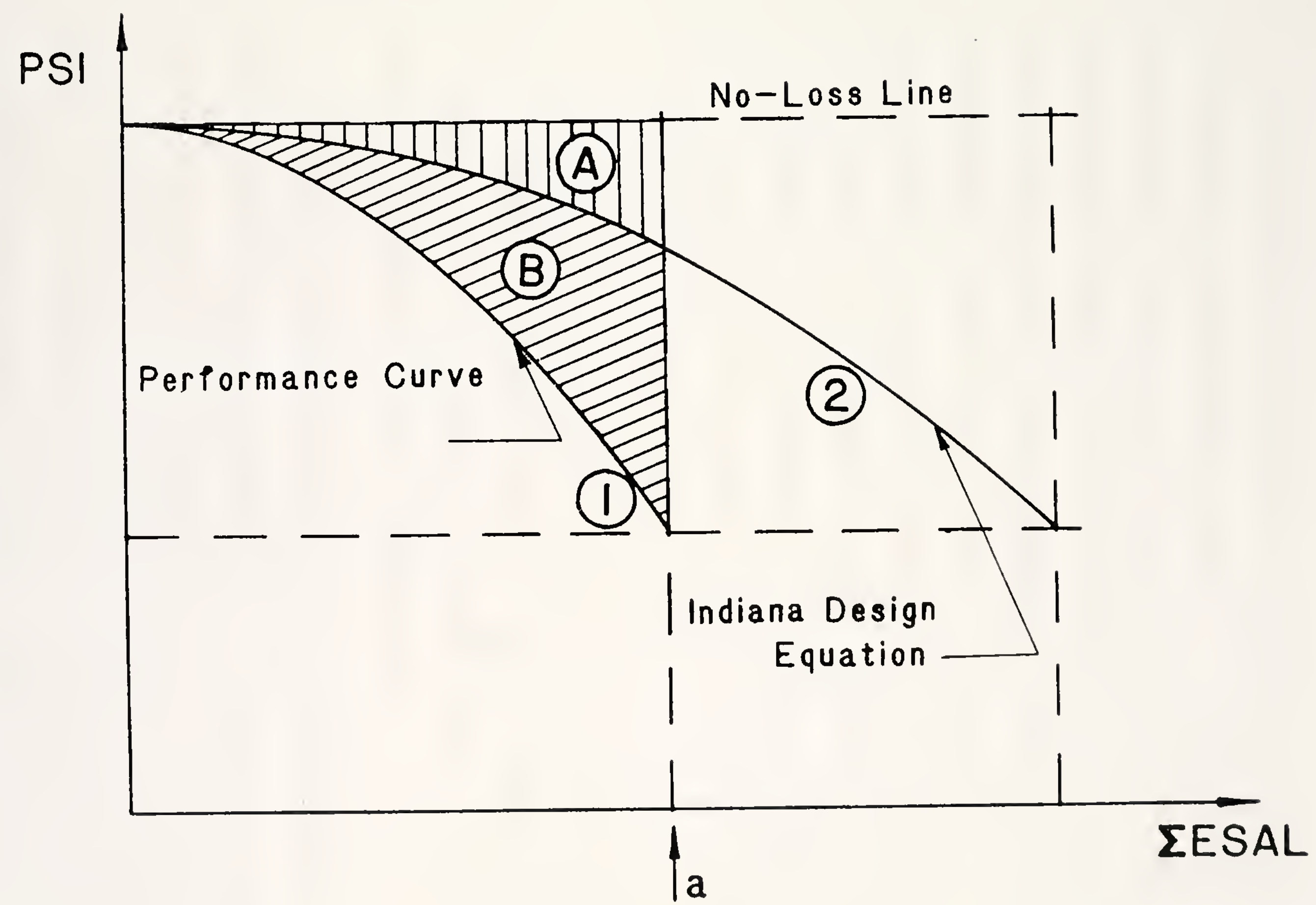


Figure D.1. Schematic Diagram Showing Pavement Performance Considered in Highway Rehabilitation Cost Allocation traffic and non-traffic factors. We may conclude that the proportion of design-factor related rehabilitation costs is given by $(\frac{A}{A+B})$.

The non-traffic plus interaction effects are responsible for $(\frac{B}{A+B})$ of the costs for rehabilitation at stage 'a'. This portion of the rehabilitation costs would have to be further divided into traffic-related and non-traffic related costs. Direct allocation on the basis of a cost allocator such as VMT or ESAL is undesirable because such approach does not differentiate between traffic and non-traffic effects. Delphi technique has been used in some studies to obtain the proportional responsibility of traffic and non-traffic effects. However, on a topic such as this where there is a wide disparity of views among highway pavement experts, it is doubtful that efforts to find averages from pooling opinions would produce any meaningful results.

A methodology was developed for use in the present study to determine the responsibilities of load-related and non-load-related factors for pavement routine maintenance and rehabilitation costs. The procedure involved is described in detail in Appendix H.

As design criteria are different for different climatic regions, highway classes and types of pavement, it is necessary to group pavements by region, highway class and pavement type. In the present study, two regions, five highway classes and four pavement types are being considered. The two regions refer to northern and southern Indiana. The five highway classes include Interstate, state routes primary, state routes secondary, city streets and county roads. The four pavement types are flexible pavements, rigid pavements with bituminous overlay, JRC and

CRC pavements. Appropriate pavement wear responsibility factors were developed by region, highway class and pavement type.

These factors were then used to compute load-related and non-load-related portions of the pavement rehabilitation cost of a given rehabilitation project. For the load-related portion of the cost, the Thickness Incremental Method was applied for cost-allocation computation. In this instance, the original existing pavement thickness was taken as the basic minimum thickness with zero cost, and the incremental analysis was carried out for the added overlay thickness. The non-load-related portion of the cost was considered to be common cost and it was allocated on the basis of VMT.

APPENDIX E

STRUCTURAL CONSTRUCTION, REPLACEMENT AND REHABILITATION COST ALLOCATIONS

General

In the present study, structural expenditures included the following:

(a) bridge construction

(b) bridge rehabilitation

(c) bridge replacement

(d) culvert construction

(e) sign structure construction

Definitions of these expenditure items are as follows:

1. Bridge Construction: New bridges constructed on new alignment.

2. Bridge Replacement: Bridges built to replace existing bridges basically on the same alignment.

3. Bridge Rehabilitation: Widening, deck repair and partial replacement.

4. Culvert Construction: Drainage structures such as box culverts and metal pipes.

5. Sign Sructure Construction: Overhead traffic signs.

An incremental method involving repetitive designing of a given structure for different vehicle loadings was selected for allocating the structure costs.

Adopted Incremental Method

In this procedure, a bridge was designed and cost estimated for the full design loading anticipated. The first group of heavy vehicles was then removed and a second design was prepared and cost estimated. The difference in costs between the initial design and the second design was assigned to the heavy vehicles removed. Next, a second group of heavy vehicles was removed along with the first, and a third design was made with associated cost estimate. The difference in costs between the second and third designs was assigned to all vehicles removed up to this point. This process was repeated until no significant difference could be observed in the cost of the needed facility due to the removal of a vehicle group. Costs below this point were assigned to all vehicles expected to use the bridge.

Design Loadings

In this study, bridges were designed according to guidelines prepared by the American Association of State Highway and Transportation Officials (AASHTO). The AASHTO Bridge Specifications [3] provided traffic related loadings designated with a H prefix followed by a number indicating the total weight of trucks in tons for a two-axle trucks or with a HS prefix followed by a number indicating the weight in tons for tractor-trailer combinations. The smallest loading used in the study was

6000 pounds corresponding to AASHTO loading H3. The effect of vehicle weight below this level is almost totally obscured by the effect of snow, wind and the dead weight of the bridge itself. The vehicle loading of H3 corresponded to the 'basic' vehicle in this study.

The AASHTO live load configurations used in the study are shown in Figure E.1. For heavier vehicles, weights were distributed to front and rear axles in accordance with AASHTO specifications [3]. For lighter vehicles, the share of the total weight on each axle was gradually shifted towards the front wheel so that the axle weights become close to the axle weights that result from passenger cars. Since these AASHTO design vehicle are not the trucks seen operating on the highways but rather trucks with configurations that would simulate the most severe live loads on the structure, a quantitative correlation between the real trucks operating on highways and the design index loading was established in order to assign the cost increment to a vehicle group used in the study.

<u>Correlation Between AASHTO and Actual Trucks</u>

Many methods of establishing correlation had been established by other cost allocation studies. The FHWA study [9] and the Wisconsin study [48] used the gross vehicle weight (GVW) to correlate the AASHTO vehicle types with the observed vehicle groups. This approach assumes a simple relationship between design vehicle loading and gross vehicle weight of observed vehicles. From the design point of view, this assumption is not justifiable because factors such as axle-load distribution and axle spacing are neglected. The Maryland study [42] used a more

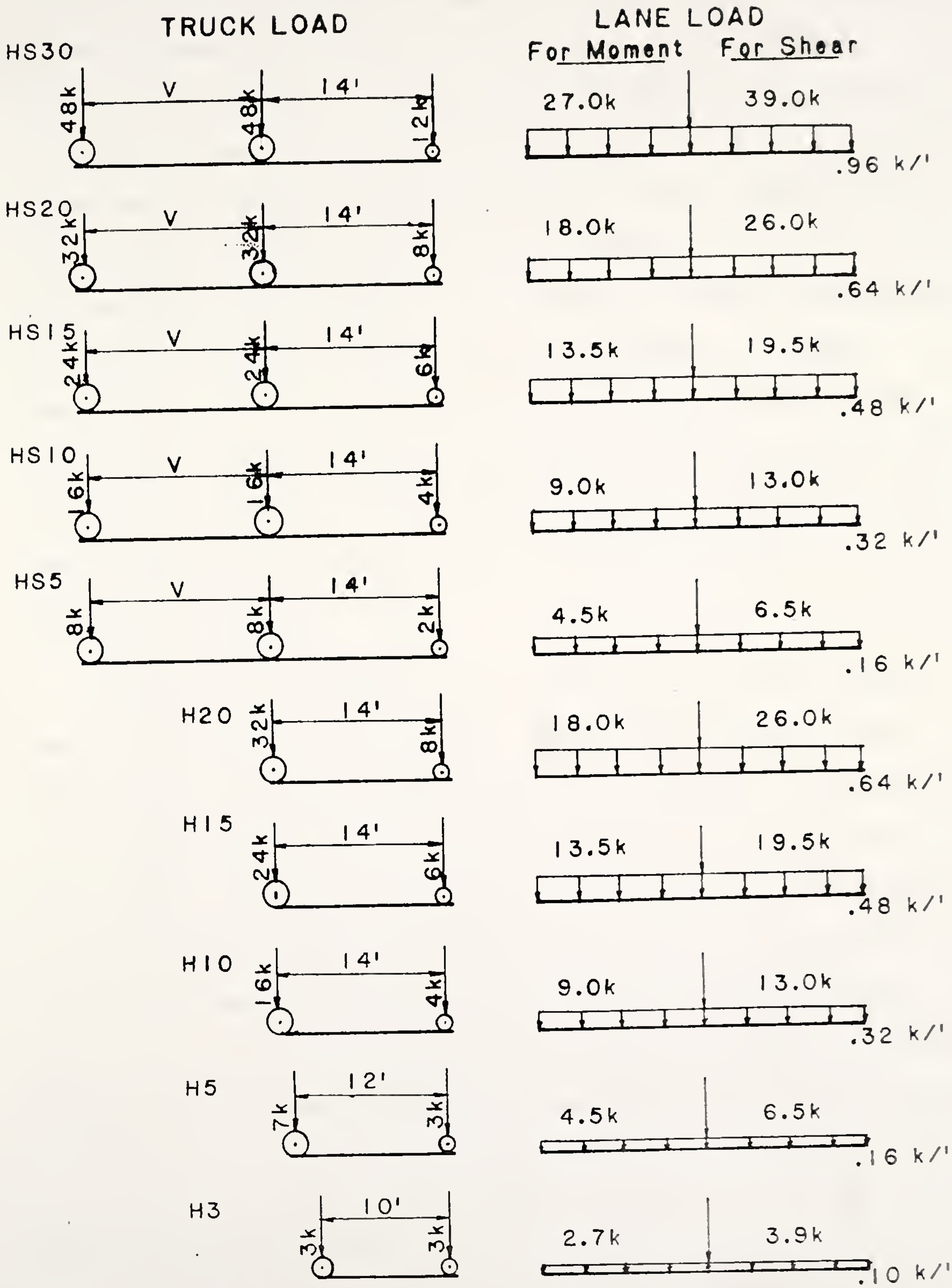


Figure E.1. Modified AASHTO Live Loading Configurations for Bridge Incremental Designs rational method in establishing the correlation as it incorporated both axle loading and axle spacing. However, each truck type was placed on a series of simple spans instead of a continuous span. The results obtained by using a series of simple spans would involve some approximations when extended to bridges with continuous spans. In this study, design vehicles and the observed vehicles were related according to the bending moment they created on a continuous bridge of typical spans. The observed vehicles were divided into 14 classes and some of these classes consisted of vehicles operating at a wide distribution of weights. Therefore, the axle-load distribution and axle spacing of each of the vehicle classes were determined by analyzing the 1983 IDOH truck weight survey data. A summary of this analysis is presented in Table E.1. The resulting correlation between design vehicle types and observed vehicle classes is given in Table E.2.

In order to make the correlation between H and HS trucks and the observed vehicles, it was necessary to develop a relationship between AASHTO H and HS trucks as shown in Figure E.2. A computer program was used to obtain this correlation. The program moved a vehicle across a bridge (with variable span lengths) such that each axle in turn falls at the critical point of equal continuous spans. As each axle was positioned, the moment at the critical point was calculated for the whole vehicle on the bridge. The results were expressed in terms of equivalent AASHTO vehicle. A flow diagram of the computer program is shown in Figure E.3.

Selection of Bridge Samples

After reviewing the data for the base period it was observed that

Table E.1. Study Vehicle Classification and Equivalent AASHTO Designation

Vehicle Type[1]	Gross Wt Kips	Design Axle Load (Kips)[2] A	B	C	D	E	F	Axle Spacing (Ft.)[3] AB	BC	CD	DE	EF	Equivalent AASHTO Vehicle[4]
1	4.0	2.0	2.0					7.2					H2.9
2	6.0	3.0	3.0					10.05					H4.0
3	30.0	12.0	18.0					31.65					H17.0
4	5-10.0	4.5	5.5					11.0					H6.5
4	10-15.0	6.5	8.5					13.0					H9.41
4	15-20.0	7.7	12.3					14.0					H12.95
4	20-25.0	10.2	14.8					15.0					H15.29
4	25-30.0	12.0	18.0					17.0					H17.67
5	9.0	4.0	4.0	1.0				11.5	8.6				HS3.0
6	10-15.0	5.0	6.0	4.0				14.0	4.0				HS6.0
6	15-20.0	8.0	6.0	6.0				14.0	4.0				HS7.0
6	20-25.0	10.0	7.0	8.0				14.0	4.0				HS8.0
6	25-30.0	12.0	8.0	10.0				14.0	4.0				HS10.0
6	30-35.0	13.0	10.0	12.0				14.0	4.0				HS11.0
6	35-40.0	15.0	12.0	13.0				14.0	4.0				HS13.0
7	0-20.0	7.0	8.0	5.0				10.0	16.0				HS6.0
7	20-25.0	9.0	10.0	6.0				10.0	17.0				HS7.0
7	25-30.0	9.0	11.0	10.0				10.0	18.0				HS8.0
7	30-35.0	10.0	13.0	12.0				10.0	21.0				HS9.0
8	10.00	4.0	4.0	1.0	1.0			11.5	8.60	5.80			HS3.50
9	0-30.0	6.0	6.0	18.0				4.0	40.0				HS13.0
9	30-60	16.0	16.0	28.0				4.0	40.0				HS23.0
10	0-40.0	13.0	9.0	9.0	9.0			17.30	4.0	21.00			HS10.0
11	20-25.0	7.0	8.0	5.0	5.0			10.0	22.0	4.0			HS7.0
11	25-30.0	8.0	10.0	6.0	6.0			10.0	22.0	4.0			HS8.0
11	30-35.0	9.0	11.0	7.0	8.0			10.0	22.0	4.0			HS9.0
11	35-40.0	10.0	14.0	8.0	8.0			10.0	22.0	4.0			HS10.0
11	40-45.0	10.0	15.0	10.0	10.0			10.0	22.0	4.0			HS11.0
11	45-50.0	10.0	16.0	12.0	12.0			10.0	22.0	4.0			HS12.0
11	50-55.0	11.0	18.0	13.0	13.0			10.0	22.0	4.0			HS14.0
12	20-25.0	7.0	6.0	6.0	3.0	3.0		10.0	4.0	25.0	4.0		HS7.0
12	25-30.0	8.0	7.0	7.0	4.0	4.0		10.0	4.0	25.0	4.0		HS8.0
12	30-35.0	9.0	8.0	8.0	5.0	5.0		10.0	4.0	25.0	4.0		HS9.0
12	35-40.0	10.0	9.0	9.0	6.0	6.0		10.0	4.0	25.0	4.0		HS10.0
12	40-45.0	11.0	10.0	10.0	7.0	7.0		10.0	4.0	25.0	4.0		HS11.0
12	45-50.0	12.0	11.0	11.0	8.0	8.0		10.0	4.0	25.0	4.0		HS12.0
12	50-55.0	11.0	12.0	12.0	10.0	10.0		10.0	4.0	25.0	4.0		HS13.0
12	55-60.0	10.0	13.0	13.0	12.0	12.0		10.0	4.0	25.0	4.0		HS14.0
12	60-65.0	10.0	14.0	14.0	13.0	13.0		10.0	4.0	25.0	4.0		HS15.0
12	65-70.0	10.0	16.0	16.0	14.0	14.0		10.0	4.0	25.0	4.0		HS17.0
12	70-75.0	11.0	17.0	17.0	15.0	15.0		10.0	4.0	25.0	4.0		HS18.0
12	75-80.0	12.0	18.0	18.0	16.0	16.0		10.0	4.0	25.0	4.0		HS19.0
13	0-40.0	5.0	7.0	12.0	8.0	8.0		9.0	18.0	5.0	11.0		HS11.0
13	40-70.0	10.0	18.0	16.0	13.0	13.0		9.0	18.0	5.0	11.0		HS17.0
14	0-40.0	8.0	7.0	7.0	8.0	5.0	5.0	10.0	4.0	21.0	5.0	11.0	HS11.0
14	40-60.0	9.0	12.0	12.0	13.0	7.0	7.0	10.0	4.0	21.0	5.0	11.0	HS19.0
14	60-80.0	9.0	16.0	16.0	17.0	11.0	11.0	10.0	4.0	21.0	5.0	11.0	HS24.0

1. Refer to Table 1 for vehicle type description.

2. A = first axle B = second axle C = third axle D = fouth axle
E = fifth axle F = sixth axle

3. AB, BC, CD, DE, and EF = distance in feet between adjacent sxles

4. Refer to Figure E.1 for AASHTO vehicle type description.

Table E.2. Vehicular Classification and Responsibility Summary for Bridge Superstructure

AASHTO Classification		Gross Vehicle Weight (Kips) of Vehicle Type[1]													
HS[2]	H[3]	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.5														
2	2.9	*[4]	*												
3	4.4					*									
4	5.9				5-10				*						
5	7.4														
6	8.8				10-15		10-15	0-20							
7	10.3						15-20	20-25				20-25	20-25		
8	11.8				15-20		20-25	25-30				25-30	25-30		
9	13.2							30-35				30-35	30-35		
10	14.7				20-25		25-30				*	35-40	35-40		
11	16.2			*			30-35					40-45	40-45	0-40	0-40
12	17.7				25-30							45-50	45-50		
13	19.1						35-40			0-30			50-55		
14	20.6											50-55	55-60		
15	22.1												60-65		
16	23.5														
17	25.0												65-70	40-70	
18	26.5												70-75		
19	27.9												75-80		40-60
20	29.4														
21	30.9														
22	32.3									30-60					
23	33.8														
24	35.3														60-80
25	36.8														
26	38.2														
27	39.7														
28	41.2														
29	42.6														
30	44.1														

1. Refer to Figure E.1 for AASHTO vehicle type description
2. HS = single unit trucks
3. H = combination trucks
4. * = vehicle class without weight subdivision

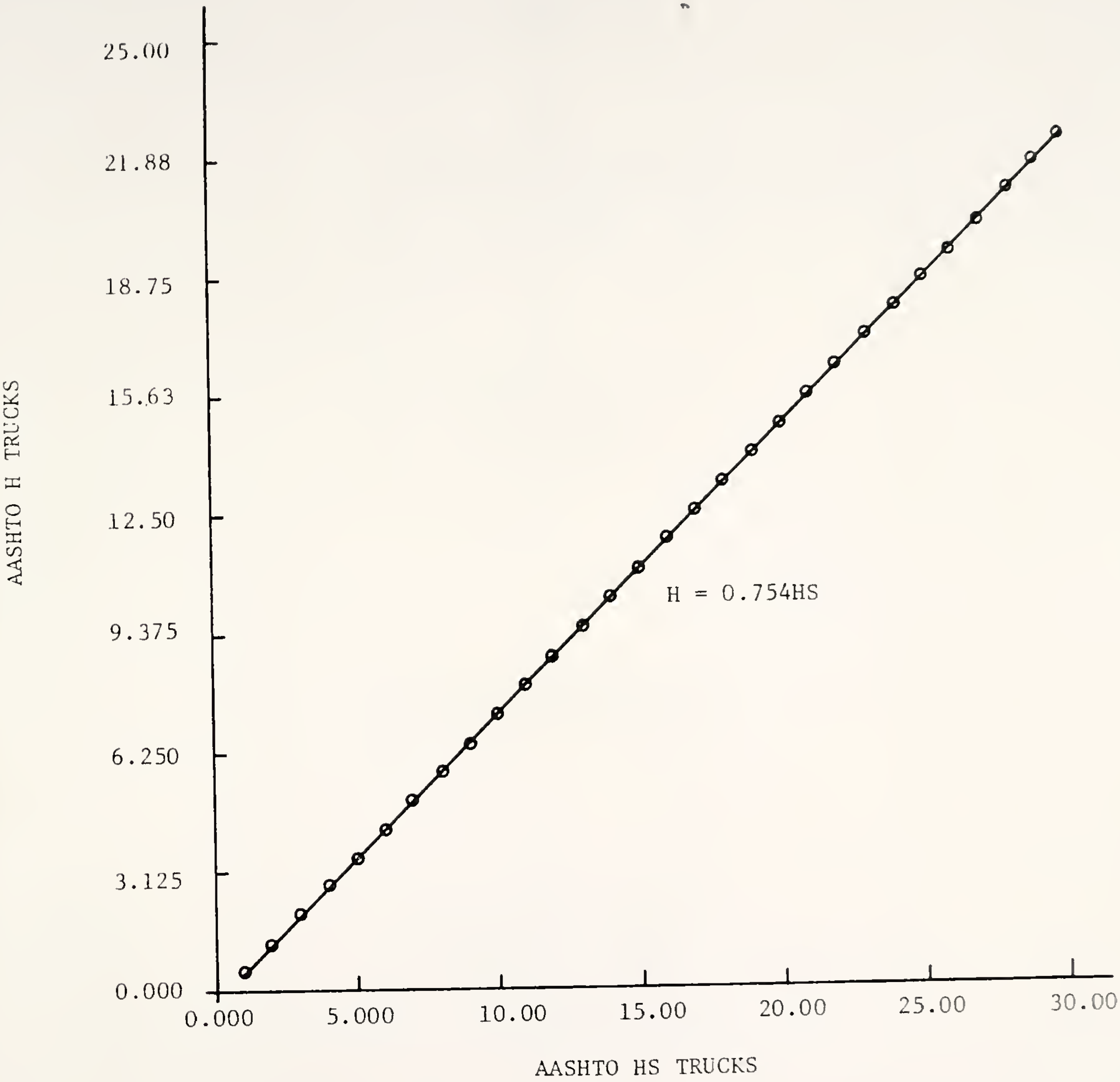


Figure E.2. HS and H Trucks Correlation

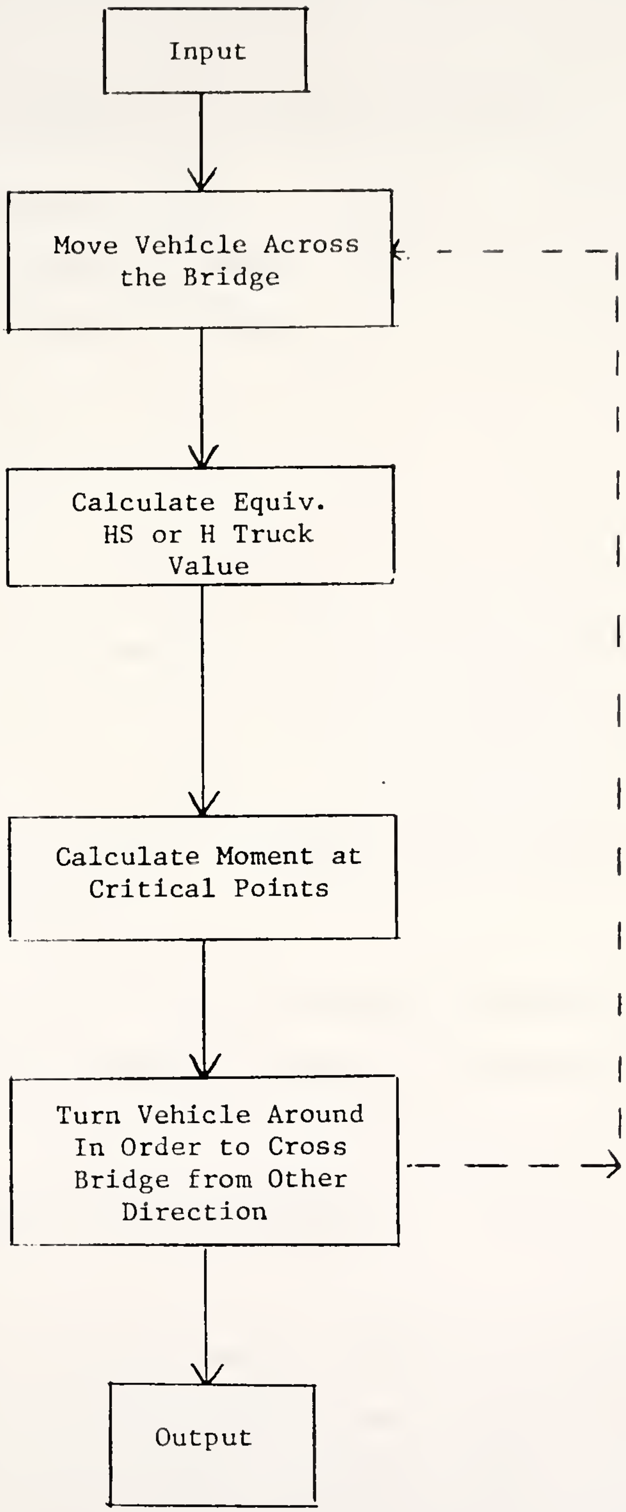


Figure E.3. Flow Chart Illustrating the Data Generation for the Correlation process.

all bridges built in Indiana can be grouped as follows:

(a) Reinforced Concrete Slab

(b) Prestressed Concrete I-Beam

(c) Prestressed Concrete Box-Beam

(d) Steel Beam

(e) Steel Girder

For the purpose of incremental cost estimation for each of the bridge types, a combination of the representative method and semi-statistical method was used to develop appropriate cost distribution functions [39]. This approach required selection of representative bridge structures and a detailed incremental analysis was performed. The sample bridges were selected from Indiana Bridge Inventory files.

Table E.3 shows the selected bridges and their characteristics that were considered representative of respective bridge types constructed in the base period.

<u>Variation of Structure Width with Live Loading</u>

Structure width for different highway categories was selected to be compatible with the width of the approaching highway as specified in AASHTO Manual [1]. The FHWA study [9] assumed a constant width for all classes of vehicle. The Wisconsin study [48] assumed a distinct cut-off point between the basic vehicle and the rest of the design vehicles. In this study, the width of a bridge from curb to curb was proportionally reduced according to

Table E.3 Characteristics of Typical Bridges Constructed in the Base Period

Bridge Type	Deck Area (Sq.ft.)	No. of Spans	Unit Cost (1983 $)	Design Load
Reinforced Concrete Slab	3997.43	3	33.40	HS20
Prestressed Box Beam	8435.42	3	36.42	HS20
Prestressed I-Beam	9420.38	4	36.88	HS20
Steel Beam	9193.75	2	45.28	HS20
Steel Girder	9441.50	2	47.66	HS20

size of design vehicles.

Table E.4 presents the variation of bridge width for different design loadings and for different highway categories. The relationship between design vehicles and observed vehicles as shown in Table E.2 was used to establish the variation of bridge width for different design loadings.

Distribution Between Highway and Waterway Crossings

Since the cost of substructure of bridges constructed over waterways tend to be more than bridges constructed over highways, a weighing was performed to adjust for this distribution based on data on all bridges built in Indiana within the base period, as shown in Table E.5. Within the base period only a few new or replacement bridges were constructed on local roads. An estimate was therefore made for bridges on local roads on the basis of information from neighboring states.

For highway crossings, the vertical clearance of bridge piers was reduced proportionately of the required vertical clearance of the design vehicle. This proportionality assumption was found to be reasonable on the basis of actual computations. Vertical clearencs associated with design vehicles are 10 ft for H3; 12 ft. for H5 and HS5; and 16 ft. for H10 through HS 20 [48].

Allocation Factors

Allocation factors were developed for the major structure cost items listed below:

(a) Superstructure

Table E.4. Bridge Width Under Different Loadings.

Highway System	Bridge Width (ft.) by AASHTO Loading Type[1]									
	H3	H5	H10	H15	H20	HS5	HS10	HS15	HS20	HS30
Interstate Rural	36	36	40	40	44	36	40	40	44	44
Interstate Urban	38	38	42	42	44	38	42	42	44	44
State Primary	34	34	40	40	40	34	40	40	40	40
State Secondary	30	30	34	34	40	30	34	34	40	40
County Road	28	28	30	30	34	28	30	30	34	34
City Street	40	40	44	44	48	40	44	44	48	48

1. Refer to Figure E.1 for description.

Table E.5. Distribution Between Highway and Waterway Crossings

	Highway (%) Crossings	Waterway(%) Crossings
Interstate-Rural	80	20
Interstate-Urban	85	15
State-Primary	50	50
State-Secondary	30	70
Local	40	60

(b) Piers, Abutments and Spread Footings

(c) Piling

(d) Excavation and Backfill

(e) Railing

(f) Drainage Pipes

(g) Miscellaneous Items

The development of each cost allocation factor was based primarily on the effects of load and width requirements of the design vehicles.

Superstructure Cost Factors

The allocation factors for superstructure construction costs were developed through the incremental design method discussed earlier. A series of hypothetical superstructures was designed and cost estimated with various design load increments and design standards specified in the AASHTO Manual [1]. In the design procedure the same materials were included as used in the original design of a sample bridge considered in the base period. The steps taken to obtain the superstructure cost factors were as follows:

1. The actual design drawing, plans and bid information for the five representative bridge types shown in Table E.3 were obtained from the Indiana Department of Highways.

2. Computer programs were used to determine the following information for each design loading.

    Slab Bridge: Negative and positive moments at critical points.

Prestressed I-Beam: Strand pattern at midspan area of steel for main reinforcement.

Prestressed Box-Beam: Strand pattern at midspan area of steel for main reinforcement.

Steel Beam: Beam weight

Steel Girder: Beam weight

There were 10 different design loadings and a total of 50 computer runs were made for 5 bridge types. The original characteristics of these bridges that were independent of the size and weight of design vehicles were retained as much as possible.

3. Bids for each sample bridge were analyzed and the unit costs of the three lowest bids were averaged out. Any items that were considered unreasonable were discarded and the engineer's estimate used. It was found that the total cost of superstructure for the sample bridges under full design loading (HS 20) was close to the cost estimated from the computer program used in the study. This was due to the fact that bridge characteristics were kept almost the same as originally built and that there was only a small variation in bid prices. The total cost of superstructure under full design loading calculated was set equal to the total cost of existing superstructure. The ratio of the actual cost and calculated cost was then applied to all subsequent cost estimates associated with different design loadings.

4. The unit cost per square foot of deck surface was obtained for each type

of bridge under each design loading. These unit costs were then updated to 1983 dollars using appropriate cost indices. Table E.6 shows the unit cost per square foot for superstructure by design loading and by bridge type.

5. The total deck areas constructed for different bridge types and for different highway classes during the base period were obtained from the bridge inventory files of the Indiana Department of Highways and a summary of this information is presented in Table E.7.

6. Total deck areas were multiplied by the unit cost to give the superstructure cost factors for each highway class. The resulting factors are presented in Tables E.8 through E.12.

7. As mentioned earlier, a semi-statistical approach was used in combination with the representative bridge method to arrive at the allocation functions. A least square analysis was performed on the results of the incremental design analysis. It was found that a parabolic equation of the form, $a + b\sqrt{X}$, where a and b are constants, provided the best fit with a $r^2 = 0.96 \pm 0.02$, for all highway classes. Figures E.4 through E.8 present the plots of percent of total superstructure cost versus AASHTO loadings obtained from the regression equations.

Substructure Cost Factors

Substructures are structural elements of a bridge that support the superstructure. Typical substructure elements are piers, abutments, piles, and spread footing. An accurate design of piers, piles and other substructure elements in a true incremental context is complicated due to

Table E.6. Bridge Superstructure Unit Costs.

	Unit Cost in Dollars per Sq.Ft of Deck Area by AASHTO Loading Type[1]									
Bridge Type	H3	H5	H10	H15	H20	HS5	HS10	HS15	HS20	HS30
Slab	12.19	14.27	17.44	18.73	19.92	16.41	18.61	19.90	21.17	23.03
Box Beam	16.03	17.07	18.25	19.45	20.48	17.87	19.30	20.63	22.31	25.02
I-Beam	14.78	15.53	16.63	17.71	18.62	16.19	17.59	18.75	19.94	22.10
Steel Beam	15.71	17.36	20.19	22.91	26.31	19.37	23.16	26.48	29.81	32.73
Steel Girder	18.07	19.97	23.22	26.34	30.26	22.85	26.64	30.45	34.29	37.64

1. Refer to Figure E.1 for description.

Table E.7. Bridge Deck Area

Total Deck Area [Sq.Ft] Constructed in 1980-1983

Bridge Type	Highway Classification				
	Interstate Urban	Interstate Rural	State Primary	State Secondary	Local Roads
SLAB	*	*	97723.60	97795.40	10967.50
BOX BEAM	*	*	18566.50	4146.90	*
I-BEAM	14464.80	*	188871.30	126291.80	2412.00
STEEL BEAM	17606.30	29702.4	133766.20	72970.90	*
STEEL GIRDER	*	*	171835.50	91637.50	*

* No bridge of this type constructed within the base period.

Table E.8. Superstructure Cost Factors fur Interstate Rural Bridges

Bridge Type	Cost in Dollars by AASHTO Vehicle Type[1]									
	H3	H5	HS5	H10	HS10	H15	H20	HS15	HS20	HS30
Continuous Steel Beam	466624	515633	590186	599691	680482	687907	781470	786519	885429	972160
Percent of Total Cost	52	58	66	67	76	77	88	88	100	110

1. Refer to Figure E.1 for description.

Table E.9. Superstructure Coat Factors for Interatate Urban Bridges

	Cost in dollars by AASHTO Loading Type[1]									
Bridge Type	H3	H5	HS5	H10	HS10	H15	H20	HS15	HS20	HS30
Prestressed I Beam	213789	224638	234185	240549	256171	254435	269334	271215	286981	319672
Continuous Steel Beam	276595	305645	349837	355471	403360	407761	463221	466214	524843	576254
Total	490384	530283	584022	596020	659531	662196	732555	737429	811824	895926
Percent of Total Cost	60	65	72	73	81	81	90	90	100	110

1. Reference to Figure E.1 for description.

Table E.10. Superstructure Cost Factors for State Primary Highway Bridges

Bridge Type	Cost in Dollars by AASHTO Loading Type[1]									
	H3	H5	HS5	H10	HS10	H15	H20	HS15	HS20	HS30
Prestressed I-Beam	1191250	1394515	1603644	1704299	1818636	1830363	1876293	1944699	2068808	2250574
Reinforced Concrete Slab	297620	316930	331783	338839	358333	361118	380241	383027	414218	464534
Prestressed Box-Beam	2791517	2933171	3057826	3140929	3322246	3344911	3516784	3542128	3987570	4378167
Continuous Steel Beam	2101467	2322181	2657934	2700739	3064584	3098025	3519388	3542128	3987570	4378167
Continuous Steel Girder	3105067	3431554	3926441	3990050	4526147	4577697	5199742	5232390	5892239	6467888
Total	9486921	10398351	11577628	11874826	13089946	13212114	14492448	14643581	16110042	17939330
Percent of total Cost	58	64	71	74	81	82	90	90	100	110

1. Refer to Figure E.1 for description.

Table E.11. Superstructure Cost Factors for State Secondary Bridges

	Cost in dollars by AASHTO Loading Type[1]									
Bridge Type	H3	H5	HS5	H10	HS10	H15	H20	HS15	HS20	HS30
Prestressed I-Beam	1192125	1395540	1604822	1705551	1819972	1831708	1946128	1948084	2070328	2252228
Reinforced Concrete Slab	66474	70788	74105	75680	80035	80657	84928	85550	92517	103755
Prestressed Box-Beam	1866592	1961311	2044664	2100232	2221473	2236628	2351553	2367971	2505629	2791049
Continuous Steel Beam	1146372	1266774	1449932	1473282	1671763	1690006	1919864	1932269	2175263	2388337
Continuous Steel Grider	1655889	1830000	2093916	2127822	2413731	2441223	2772950	2790361	3142249	3449236
Total	5927452	6524413	7267439	7482567	8206974	8280222	9075423	9124231	9985982	10984605
Percent of Total Cost	59	65	73	74	82	83	91	91	100	110

1. Refer to Figure E.1 for description.

Table E.12. Superstructure Cost Factors for Local Road Bridges

	Cost in dollars by AASHTO Loading Type[1]									
Bridge Type	H3	H5	HS5	H10	HS10	H15	H20	HS15	HS20	HS30
Prestressed I-Beam	133693	156506	179976	191273	204105	205421	218253	218473	232182	252582
Reinforced Concrete Slab	35649	37458	39050	40111	42427	42716	44911	45225	47854	53305
Total	169342	193964	219026	231384	246532	248137	263164	263698	280036	305887
Percent of Total Cost	60	69	78	83	88	88	94	94	100	110

1. Refer to Figure E.1 for description.

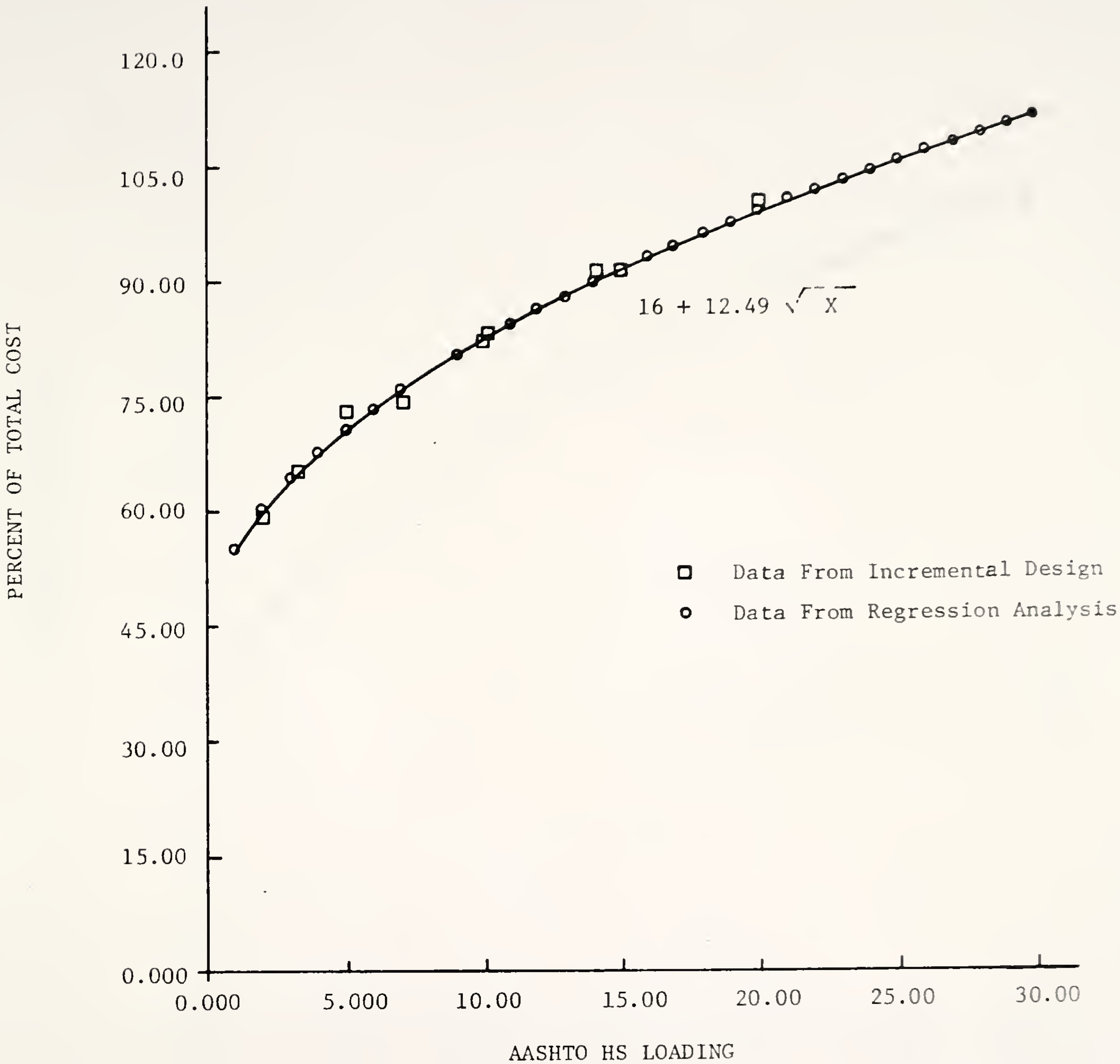


Figure E.4. Percent of Total Superstructure Cost vs. AASHTO HS Loading for Interstate Urban Bridges

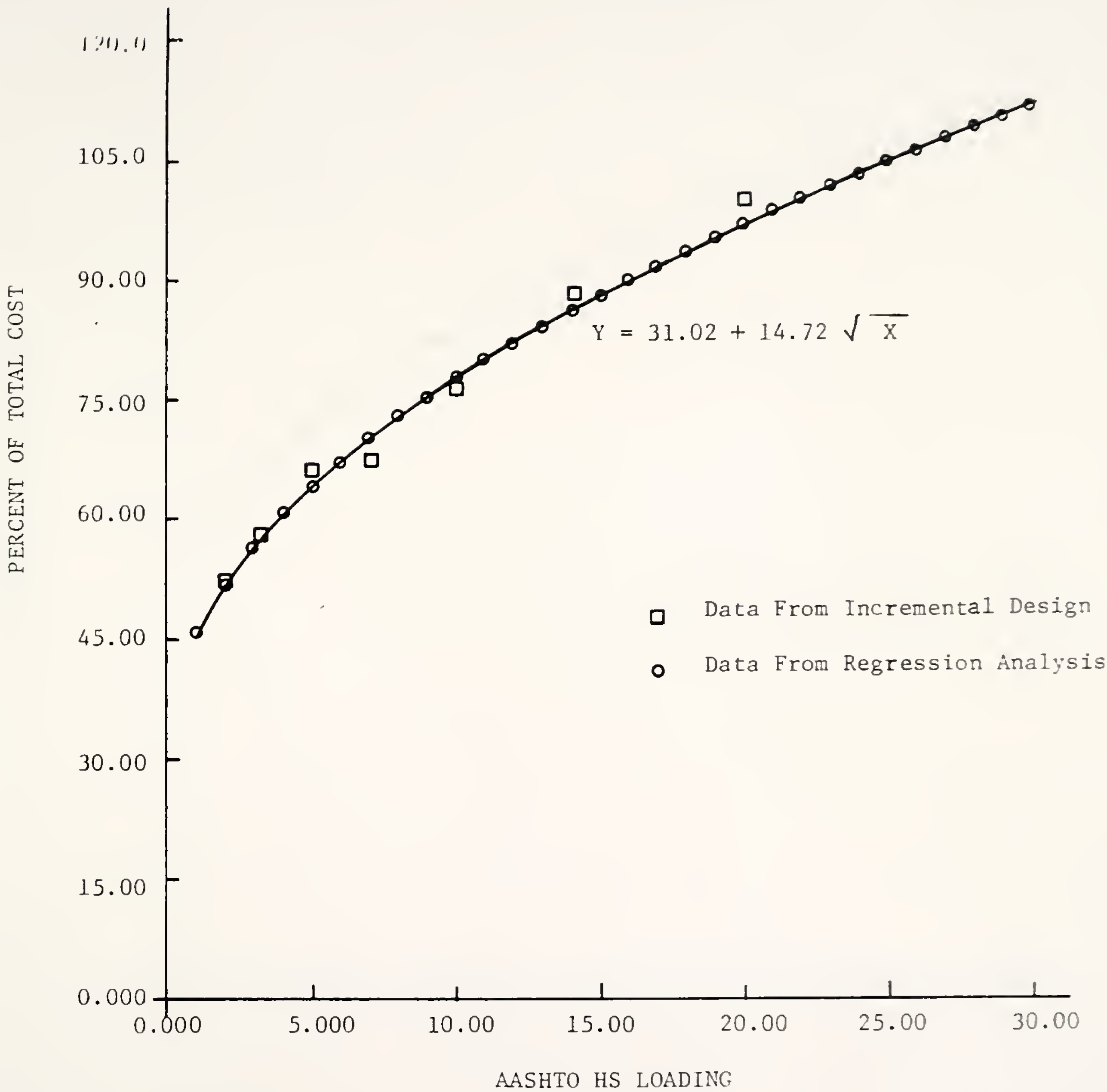


Figure E.5. Percent of Total Superstructure Cost vs. AASHTO HS Loading for Interstate Rural Bridges

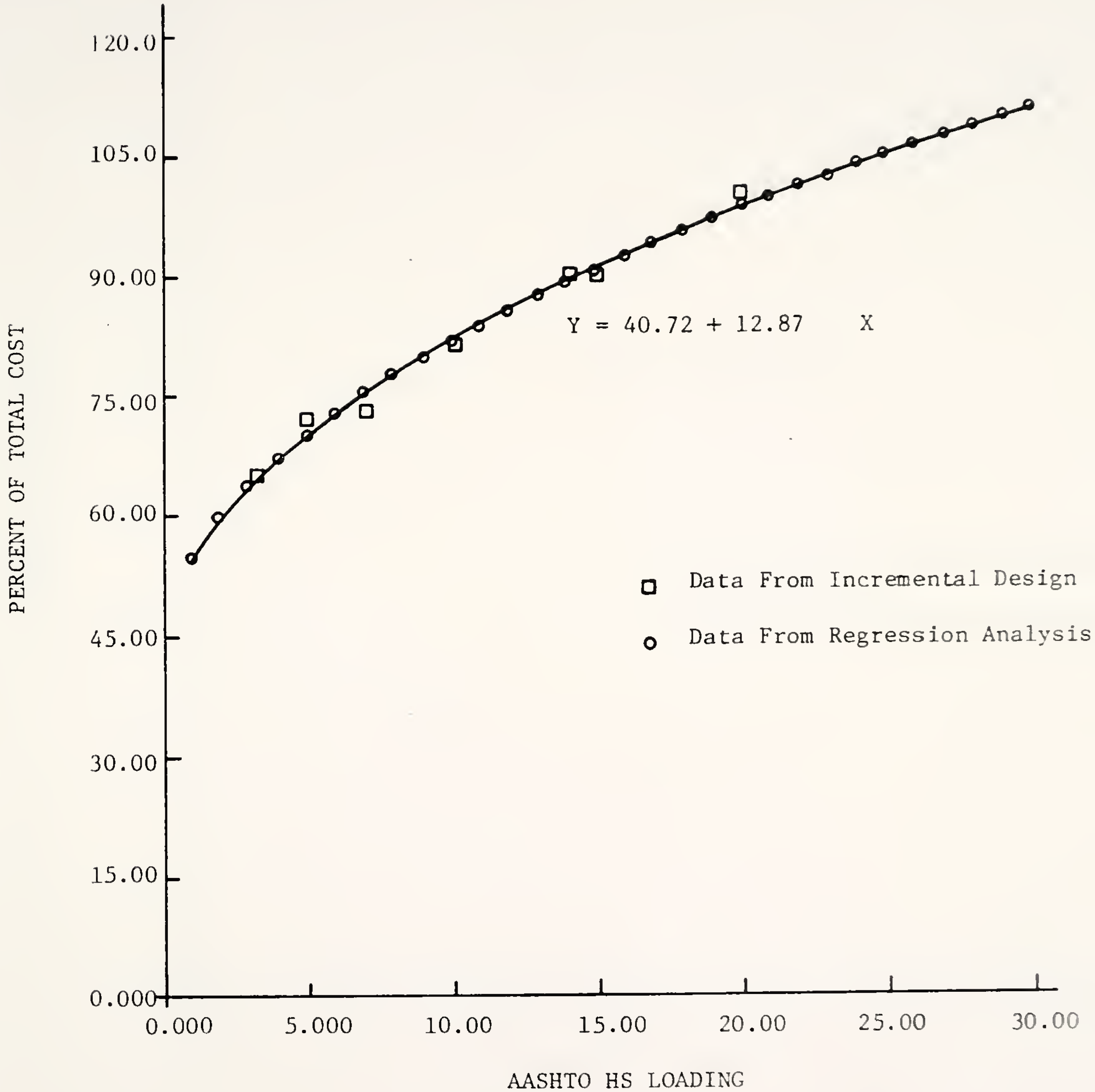


Figure E.6. Percent of Total Superstructure Cost vs. AASHTO HS Loading for State Primary Bridges

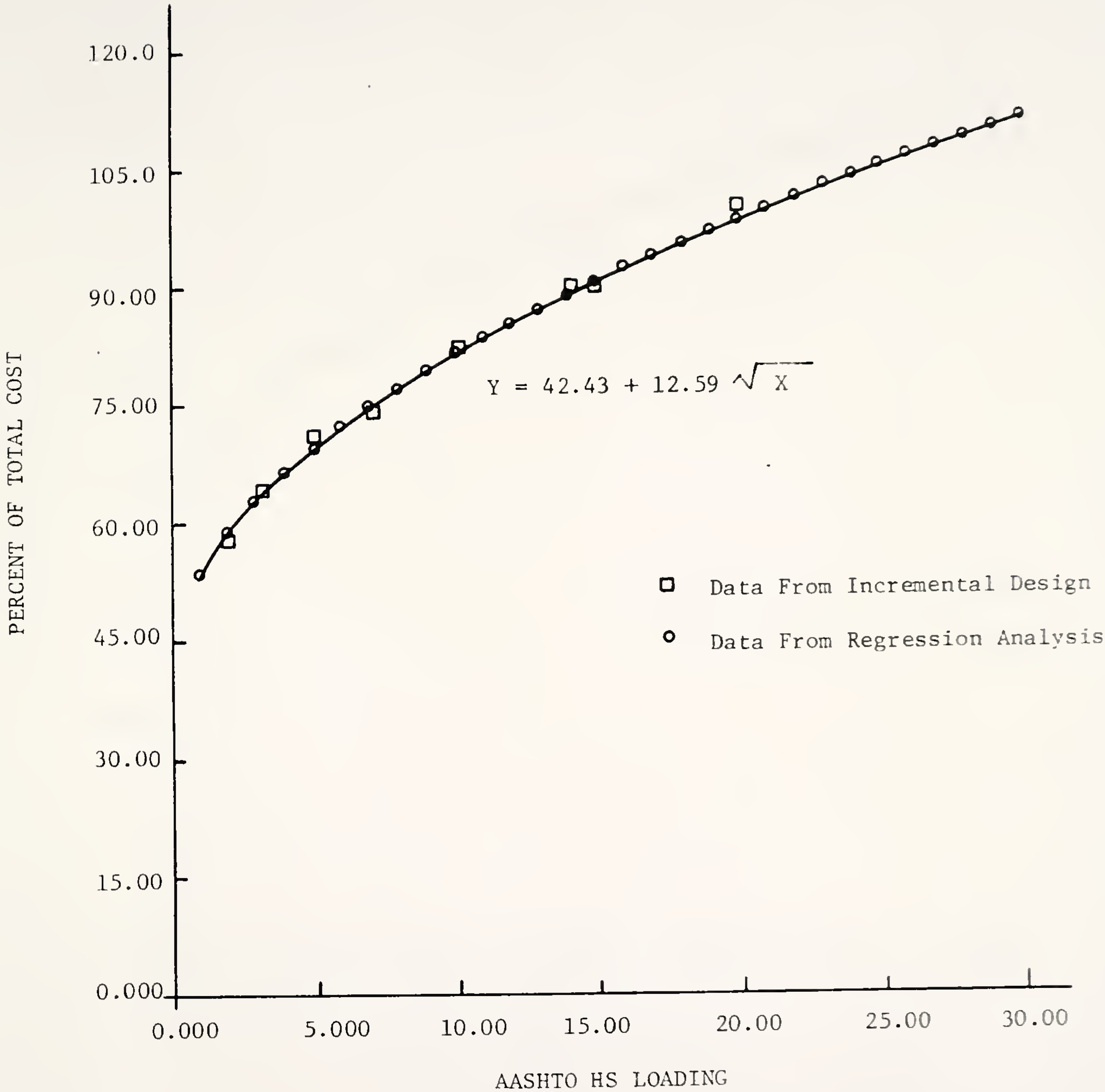


Figure E.7. Percent of Total Superstructure Cost vs. AASHTO HS Loading for State Secondary Bridges

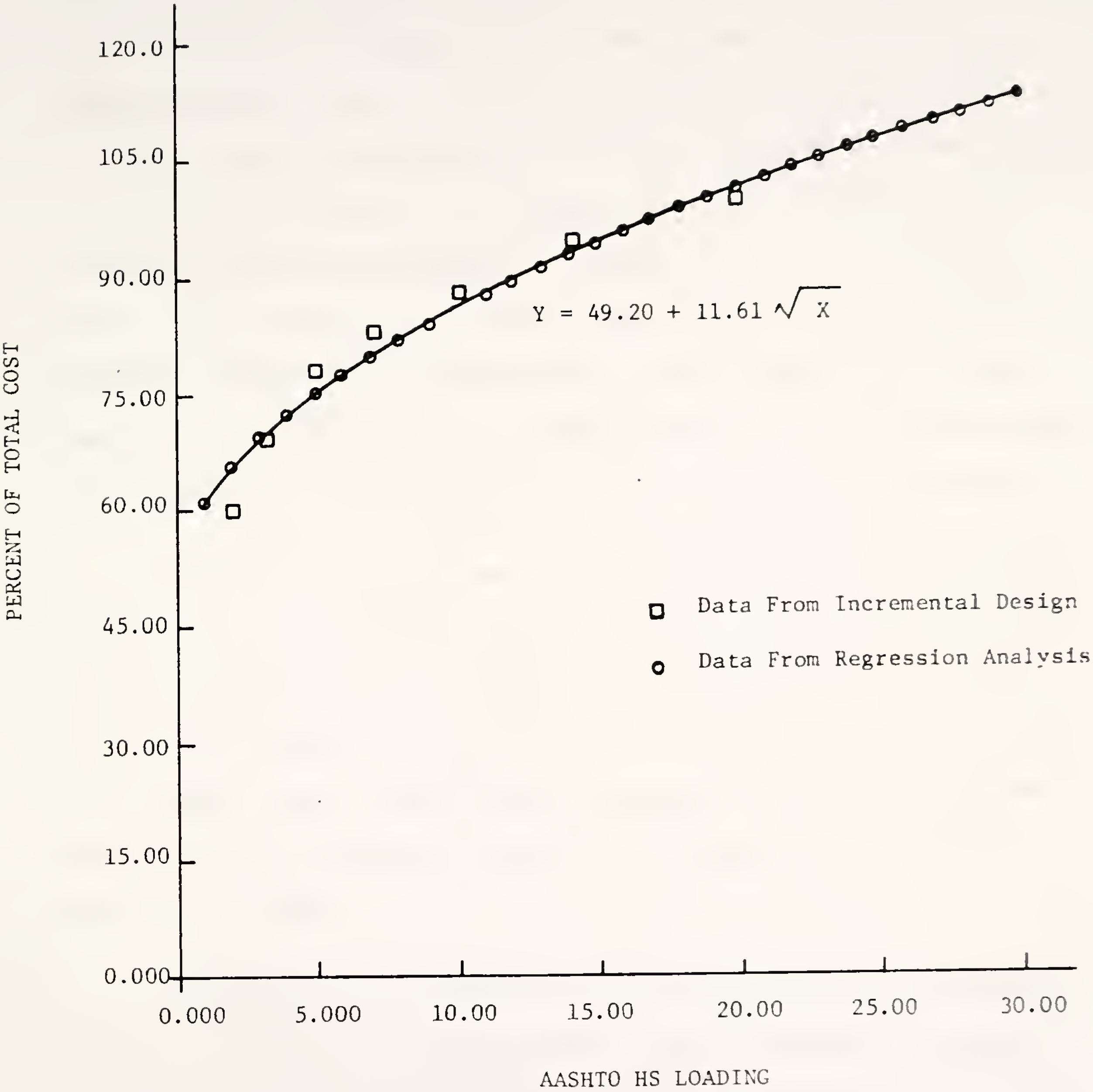


Figure E.8. Percent of Total Superstructure Cost vs. AASHTO HS Loading for Bridges on Local Roads the effect of other loadings such as ice, thermal stream flow, wind and so on [42]. These loadings affect the design almost independently of vehicle characteristics. Furthermore, the effect of these non-traffic loadings on bridge substructure is difficult to identify. It should also be noted that soil condition and loading capacity of the soil greatly influence the substructure design. Consequently, as in the 1982 FHWA cost allocation study [9], the soil mechanical properties of the sample bridge and hypothetical bridges designed on an incremental basis were assumed to be identical and the loading capacity of the soil was assumed to vary linearly and therefore, proportional to the load placed upon it.

The 1982 FHWA study [9] designed piles based on the assumption that pile length is proportional to the applied load. Thus, pile length was reduced proportionally as the loading was reduced. The piers for the hypothetical bridges were assumed to have the same general configuration as the sample bridge. The stem of the pier and of abutment was varied according to the road width variation. The wing wall and width were maintained constant.

In the present study, individual cost responsibility factors were obtained for piles, piers and abutments. Other components of substructure, such as pile cap, were assumed to be non-attributable cost. The pile length was assumed directly proportional to the applied load. It was found that 75% of the total applied load was dead load and 25% was due to the live load. Hence, 75% of the cost was assumed to be non-attributable cost and the remaining 25% was distributed according to the live load. The cost responsibility factors for piles are shown in Table E.13. The stem of pier and abutment was varied according to the road

Table E.13. Piling Cost Factors.

	AASHTO Loading Types									
	H3	H5	HS5	H10	H15	HS10	H20	HS15	HS20	HS30
GVW (KIPS)	6	10	18	20	30	36	40	54	72	108
75% Common Factor	.750	.750	.750	.750	.750	.750	.750	.750	.750	.750
25 % of GVW Factor	.0207	.0345	.0623	.0629	.104	.125	.139	.187	.25	.375
Piling Cost Factor	.7707	.7845	.8123	.8129	.854	.875	.888	.937	1.00	1.125

width variation. The cost responsibility factors for pier and abutment are shown in Table E.14.

Excavation and Backfill Factors

The FHWA study [9] proportioned the cost of backfill and excavation according to the deck width. The smaller the width of the bridge, the lesser the amount of backfill and excavation. The same procedure was used in the present study and therefore the factors are the same as in the case of pier and abutment.

Drainage Pipe Factors

Although most of the previous cost allocation studies assumed the cost of drainage pipes to be non-attributable cost, it can be argued that the size of drainage pipes is related to the quantity of runoff which in turn is related to the width of the deck surface. As the deck width can be related to vehicle width, drainage pipe can be considered to be an attributable cost. The same approach as that taken for pier and abutment can be applied here and therefore the drainage pipe cost factors are the same as in the case of pier and abutment.

Railing Factors

According to AASHTO specification [3], the minimum railing height is 2′-3". Railing members are designed for a moment due to concentrated loads at the center of the panel and at the posts of the railing for PL/6 where P is the concentrated load and L is the post spacing. The common

Table E.14. Piers and Abutment Cost Factors

	Cost Factors by AASHTO Loading Type									
Highway System	H3	H5	H10	H15	H20	HS5	HS10	HS15	HS20	HS30
Interstate Rural	.82	.82	.90	.90	1.0	.82	.90	.90	1.0	1.0
Interstate Urban	.86	.86	.95	.95	1.0	.86	.95	.95	1.0	1.0
State Primary	.85	.85	1.0	1.0	1.0	.85	.85	1.0	1.0	1.0
State Secondary	.75	.75	.85	.85	1.0	.75	.85	.85	1.0	1.0
County Road	.82	.82	.88	.88	1.0	.82	.88	.88	1.0	1.0
City Street	.83	.83	.92	.92	1.0	.92	.92	.92	1.0	1.0

cost portion was determined by using the cost related to the smallest vehicle loading in the formula. This portion was found to be 25% of the total railing cost. The remaining 75% was distributed according to the gross vehicle weight. The cost responsibility factors for railing are shown in Table E.15.

Miscellaneous Items

Miscellaneous items consist of those costs that are independent of vehicle size or weight and they include such items as engineering services, installation of traffic control devices, landscaping, and so on. These costs were thus considered to be non-attributable and distributed among all vehicles as common costs in proportion of their respective vehicle-miles of travel.

Allocation of Cost-Responsibilities

Appropriate cost factors were developed for each of the structural cost components, and these cost factors were expressed in terms of AASHTO vehicle types. The next step was to combine these cost items and relate them to the appropriate respective vehicle classes considered in the present study. The steps involved in this procedure are listed below:

1. The VMT of each of the AASHTO vehicle types was obtained by using the correspondence matrix for matching AASHTO vehicle types with study vehicle classes shown in Table E.2.

2. The common portion of the total cost was distributed among all AASHTO vehicles according to VMT.

Table E.15. Railing Cost Factors.

	AASHTO Loading Types									
	H3	H5	HS5	H10	H15	HS10	H20	HS15	HS20	HS30
GVW (KIPS)	6	10	18	20	30	36	40	54	72	108
25% Common Factor	.250	.250	.250	.250	.250	.250	.250	.250	.250	.250
75 % OF GVW Factor	.0623	.103	.186	.207	.312	.372	.415	.561	.75	1.125
Railing Cost Factor	.312	.353	.463	.457	.562	.622	.665	.811	1.00	1.375

3. Subsequent incremental costs were then allocated to appropriate AASHTO vehicle types.

4. The total allocated costs for each of the AASHTO vehicle types were assigned to the study vehicle classes using the correspondance matrix established in Table E.2.

New Bridge Construction

If a bridge was constructed during the base period specifically on a new alignment, it was taken to be a new construction. All new construction costs within the base period were analyzed in terms of cost items and grouped into different highway classes. Table E.16 shows the percent distribution of new structure construction costs by cost item and by highway class.

Bridge Replacement

Bridges are replaced due to the deficiencies of the original structures. Consequently, the FHWA study [9] treated bridge replacement costs differently from new bridge costs. A structural sufficiency rating was used to determine the relative contribution of each factors which were responsible. Costs were assigned to vehicles based on the sufficiency rating components. Deficiencies in original structures may include low load carrying capacity, inadequate lane width, fatigue worn components, and inadequate overhead clearances. However, the federal study simplified the allocation procedure by considering only load-deficiency related replacements. It further assumed that losses or inadequacies in load-bearing capacity are entirely attributable to heavy vehicle use. Because of the difficulty of determining age and environmental factors on load bearing capacity, it was decided in the present study to use the

Table E. 16. Percent Distribution of New Bridge Construction Cost by Cost Item and by Highway Class

	Interstate (Rural & Urban)	State Primary	State Secondary	Local Roads
Superstructure	14%	17%	26%	25.06
Substructure				
Piers and Abutments	1.9%	8%	6.4%	6.29
Piling	0.3%	1.8%	2.9%	2.87
Excavation and Backfill	0.7%	6.6%	6.6%	9.43
Drainage	0.02%	0.01%	0.02%	0.05
Railing	0.41%	0.46%	5.8%	5.59
Miscellaneous	79%	64%	48%	50.71
Total	100%	100%	100%	100%

same approach as used in the new construction but with different distribution of cost components. A replacement project would not involve much excavation work, but it will require removal of the existing structure.

The percent distribution of component costs for replacement project was determined by analyzing the itemized cost files from the IDOH. The resulting cost distribution by cost item and by highway class is presented in Table E.17.

Bridge Rehabilitation Cost

Bridge rehabilitation costs included cost of widening, deck repair and partial replacement of structural components. Bridge rehabilitation costs are different from bridge maintenance costs, because rehabitation work is not done routinely and it is normally more expensive than routine maintenance.

Many studies combined the rehabilitation costs with replacement costs. Other studies assumed rehabilitation costs to be common costs. In this study, the cost responsibility factors for bridge rehabilitation project were developed using the same approach as the new construction, but with different distribution of cost components. The cost distribution by cost item and by highway class is shown in Table E.18. It may be noted that a large percent of the rehabilitation cost is non-attributable cost.

Culverts

In the base period, not too many box culverts were built. Most of the box culverts were replaced by metal pipes and structural plates. The size of the pipes is dependent mainly on the drainage requirement of the surrounding

Table E.17. Percent Distribution of Bridge Replacement Cost by Cost Item and by Highway Class

	Interstate (Rural & Urban)	State Primary	State Secondary	Local Roads
Superstructure	28.5%	29.5%	26.2%	27.00%
Substructure				
Piers & Abutments	7%	2.6%	6.0%	5.74%
Piling	0.01%	0.6%	0.13%	1.37%
Excavation & Backfill	9.88%	19.6%	18.6%	18.51%
Drainage	0.01%	0.10%	0.007%	0.12%
Railing	5.7%	3.2%	6.50%	6.08%
Miscellaneous	48.9%	44.4%	42.50%	41.18%
Total	100%	100%	100%	100%

Table E.18. Percent Distribution of Bridge Rehabilitation Cost by Cost Item and by Highway Class

	Interstate (Rural & Urban)	State Primary	State Secondary	Local Roads
Superstructure	7.60%	5.72%	19.3%	14.82%
Substructure				
Piers & Abutments	0.60%	0.50%	1.9%	0.79%
Piling	0.03%	0.01%	0.9%	0.20%
Excavation & Backfill	0.10%	2.79%	5.5%	0.55%
Drainage	2.70%	0.008%	0.004%	0.23%
Railing	6.70%	7.70%	5.70%	6.42%
Miscellaneous	82.40%	83.20%	66.70%	76.99%
Total	100%	100%	100%	100%

areas. Consequently, it was considered a common cost. Box culvert is largely related to the weight of overfill and the weight of overhead roadway slabs. Therefore, all future culvert costs were assigned to all vehicle classes as common cost.

Sign Bridges

Sign bridges were singled out because their cost responsibility is vehicle-size related. For lighter and thus smaller vehicles, the horizontal and vertical clearances can be reduced appropriately. A typical sign bridge has a vehicle clearance of 18 feet and a span length of 80 feet. The procedure used by the Wisconsin study [48] was followed to allocate sign bridge costs.

For autos (H3) and light trucks (H5), the sign bridge geometry can be reduced as follows:

	H3	H5	HS5	H10-H20
Column	11′	13′	15′	18′
Span	48′	68′	72′	80′

Responsibility factors for sign bridges are then:

$$\text{H3} \qquad \frac{48 + 11}{80 + 18} = 0.60$$

$$\text{H5} \qquad \frac{13 + 68}{80 + 18} = 0.82$$

$$\text{HS5} \qquad \frac{72 + 15}{80 + 18} = 0.88$$

H10 - HS20 $\frac{80 + 18}{80 + 18} = 1.00$

APPENDIX F

MAINTENANCE COST ALLOCATION

General

A particular item of maintenance cost can be classified as a "common" or an "attributable" cost. A common cost is a cost that cannot be specifically allocated to a class or classes of vehicles, and is therefore distributed among all highway users. For example, mowing of grass or the pick up of litter within right-of-way can be considered as common cost. Common costs are to be borne by all users in direct proportion to the number of miles driven by each. Therefore, the common-cost allocator for each vehicle class is the VMT by that class as a percentage of the total VMT by all vehicle classes.

An attributable maintenance cost is a cost that can be directly allocated to a particular class or classes of vehicles. Attributable costs can be allocated on the basis of weight related allocators for those items that can be associated with vehicle weights. Some items can be allocated according to capacity related allocators when vehicle size affects the cost.

Previous Studies

Methodologies to allocate maintenance costs used by cost allocation studies by nine states were reviewed for comparison. These nine states are Connecticut, Florida, Maine, Maryland, North Carolina, Oregon, Washington, Wisconsin, and Virginia.

It was found from this comparison that there exists no universal method for the allocation of maintenance costs. This is especially true for the costs (pavement, shoulders and bridges) that are related to the weight of vehicles. The selection of cost allocators is based on various assumptions and reasonings. A majority of these states used ESAL as the cost allocator of pavement related maintenance costs. It seems however that the use of vehicle-miles of travel (VMT) has been accepted in most of the allocation studies for allocation of the common costs.

Allocation Methodology

Routine maintenance activities are classified into the following major groups:

1. Roadway and shoulder maintenance
2. Roadside
3. Drainage
4. Bridge
5. Traffic Control
6. Winter and Emergency
7. Public Service
8. Others

Roadway maintenance consists of activities such as patching, leveling, and sealing of cracks and joints. The associated pavement damages are considered to be caused either by climatic conditions or by the interaction of climate and the weight of vehicles.

For the purpose of allocating roadway maintenance costs due to traffic and its interaction with weather, a procedure was developed in the present study to separate the load-related and non-load-related effects, as discussed later in this section.

In the case of shoulder construction, use of capacity related cost allocators is justified; however, they may not be appropriate for the allocation of shoulder maintenance costs, because shoulder damages are more of a function of weather and traffic. The weather affects shoulder conditions more severely than pavements. Once constructed, functions of highway shoulders are to hold roadway pavement in place and strengthen it. Obviously the heavier trucks would cause more distress than the lighter vehicles. It was decided, therefore, to allocate the traffic-related component of shoulder maintenance costs in proportion to the costs assigned to vehicles for pavement maintenance. In this approach, assumption is made that the probability of using shoulders for emergency stops is equal for all vehicle classes.

All other maintenance costs, except bridge maintenance costs, were allocated as common costs to all vehicle classes because these costs cannot be directly related to the variation in highway use by different vehicle classes.

There are seven items under bridge maintenance of which bridge maintenance contract work can be judged partly to be the result of the interaction of traffic and weather. Consequently, this part of the maintenance cost was allocated using the approach used for pavement related maintenance costs. All other bridge maintenance costs were considered to be common costs.

Some of the activities in the "Other" category include operational overhead such as supervision and equipment repair and maintenance and therefore these operational overhead costs were grouped with administrative overhead. Administrative and operational overhead costs were allocated to all vehicle classes in proportion to the sum of direct maintenance costs. These costs were first assigned percentwise to the three maintenance costs groups, then, allocated to vehicle classes by the cost allocator(s) of each cost group.

Data Base for Analysis

Routine maintenance costs for the state highway system were estimated using the Routine Maintenance Records and Construction Reports. As for cost items, Routine Maintenance Records contain only labor, production units, types and quantities of materials used. Maintenance costs for labor and material were computed by multiplying the labor and material units required for each activity by separately provided unit costs. Fuel consumption data are not found in Routine Maintenance Records, but are reported in lump sum for all maintenance works for each fiscal year. To distribute fuel costs to each activity, results of a previous study [36] concerning the fuel consumption rates of routine maintenance activities was used. Routine maintenance activities that have been done by contract are found in Construction Reports file.

Procedure for Allocating Pavement Routine Maintenance Costs

The procedure for allocating pavement routine maintenance costs pursues the same concept adopted for allocating pavement rehabilitation costs. The maintenance expenditure items included in the computation of pavement routine maintenance costs are shown in Table F.1.

As explained earlier in the section on allocation of pavement rehabilitation costs, an actual field performance curve of a given pavement would lie between the no-loss line and the zero-maintenance curve. The higher the level of routine maintenance performed, the closer is the field performance curve to the no-loss line.

Table F.1. Pavement Routine Maintenance Activities

IDOH Code No.	Activity Name
201	Shallow patching
202	Deep patching
203	Premix leveling
204	Full width shoulder seal
205	Seal coating
206	Seal longitudinal cracks and joints
207	Sealing cracks
209	Cutting relief joints
219	Others

In Appendix H, a technique is described which enables the zero-maintenance curve to be derived by considering pavement performance curves and their associated routine maintenance expenditure expressed in terms of average annual routine maintenance expenditure per lane-mile. Also presented in Appendix H is a proportionality rule by means of which the respective responsibility proportions of load-related and non-load-related effects of pavement damage can be computed.

Since the effects of non-load-related factors may be different for different regions (northern and southern Indiana), and pavement types (overlay, rigid and flexible pavements), maintenance expenditure data were divided into six region-pavement type groups. In addition, six highway classes were used in the present study and each with a different vehicle composition. This means that 36 routine maintenance expenditure subgroups in total needed to be analysed in the cost-responsibility factor computation.

APPENDIX G

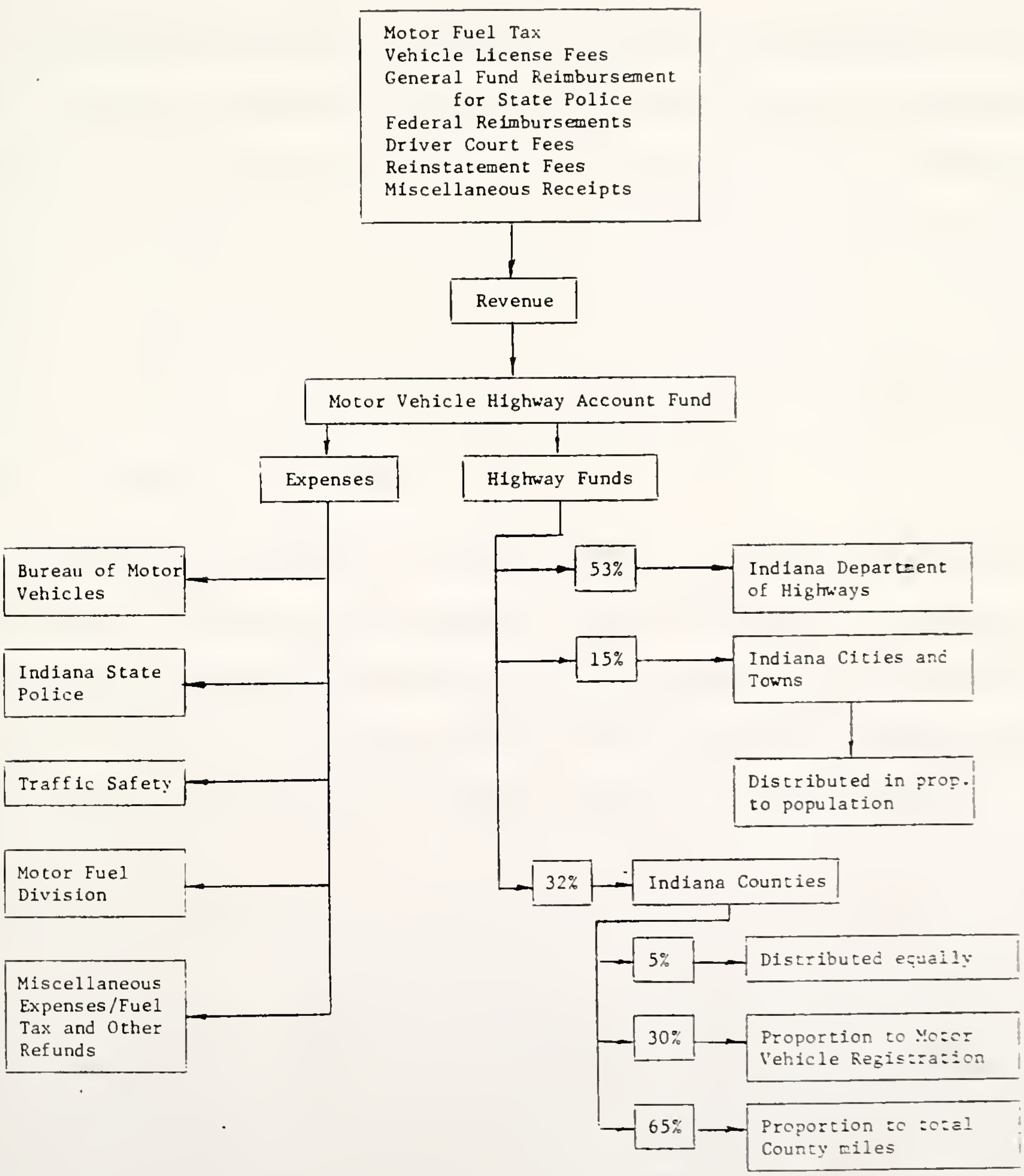
REVENUE ATTRIBUTION

After cost responsibilities are identified it is necessary to examine revenue payment by vehicle class to provide a base for comparison. The apportionment was done of appropriate revenues paid by Indiana highway users to state, federal and local governments. In particular, the user revenues considered are those which went to support highway construction, operation and maintenance activities in Indiana.

State Highway Revenues

The Indiana system of funding of highway activities includes two major accounts, Motor Vehicle Highway Account (MVHA) and Highway Road and Street Fund (HRSF). The sources of revenue consist primarily of the motor fuel taxes, registration fees, and motor carrier fees. In addition, miscellaneous revenues in the nature of fines and charges are collected and deposited in the Motor Vehicle Highway Account (MVHA). Furthermore, in recent years some user fees and taxes have been imposed by some local governments in the form of local option taxes. In Figure G.1 is presented the current organization of the MVHA. The majority of highway revenues in Indiana is gathered in MVHA where fuel taxes and registration fees are the main sources of revenue. The other highway related fund is the Highway Road and Street Fund (HRSF). A part of the motor fuel tax and truck registration fee is gathered in the HRSF for use in two separate accounts, the Primary Highway Fund and the Local Road and Street Fund.

Figure G.1. Organization of the Motor Vehicle Highway Account (MVHA)



The motor fuel taxes are the major sources of highway revenues in Indiana and they consist of three items, motor fuel tax on gasoline, special fuel tax involving primarily diesel fuel, and motor carrier fuel tax imposed on interstate carriers.

Federal Revenues

Federal funds available to Indiana are generated through Federal Trust Fund. In 1983 the revenues included motor fuel tax, tax on new trucks and trailers, parts and accessories tax, tires and tubes tax, tax on lubricating oil and heavy vehicle use fee. The Surface Transportation Assistance Act of 1982 and its subsequent amendment resulted in several changes in federal tax structure. For example, taxes on tread rubber, inner tubes, lubricating oil, and truck parts were eliminated and new tax schedules were introduced for fuel taxes and taxes on truck sales and heavy vehicle use.

It should be noted that only that portion of the federal revenues that was received by Indiana was considered in revenue analysis. For example, in 1983 the amount received by Indiana was $155.56 million or about 75% of the revenues contributed by Indiana highway users to the Highway Trust Fund. The STAA of 1982 stipulated the percentage of return to be at least 85%.

Attribution of Revenue

Each of the state highway user charges were examined separately to attribute the shares of revenues to vehicle classes. In each case the revenues attributed were equal to the amount available for highway purposes. For example, the disbursements to the Bureau of Motor Vehicles from the Motor Vehicle

Highway Account were considered to be associated with the collection of state registration fees and were thus deducted from the gross amount. Similarly, the disbursements to the Motor Fuels Tax Division of the Department of Revenue were deducted from the total fuel taxes collected. However, these expenses of collecting and administering these taxes were not included in cost computation.

State Fuel Taxes

In FY83 total state fuel taxes collected in Indiana consisted of gasoline tax, special fuel tax (diesel) and motor carrier fuel use tax; and the total amount available for MVHA, HRSF and regular distribution was $314.248 million with 81% from gasoline tax, 17% from special fuel tax and 2% from motor carrier fuel use tax. Considering the gasoline tax refunds and disbursements for the Motor Fuel Tax Division and other associated expenses, the net amount available for highway activities was $305.175 million. This amount was shared by the IDOH, counties, cities, and the State Police. The corresponding amount for the biennial period of 1985-86 would be $614 million.

Fuel taxes are dependent upon fuel consumption which in turn is related to vehicle-miles of travel and vehicle fuel efficiency. The VMT values by vehicle class for 1983 were available from the traffic count data. Fuel efficiency estimates by vehicle class for both 1983 and 1985-86 were generated by combining the figures from the FHWA Cost Allocation Study [9] with the findings of an earlier study performed for the IDOH [29]. To compute fuel consumption, annual VMT for a specific vehicle class was divided by its fuel efficiency value. Gallons of fuel consumed was then multiplied by the appropriate tax rate. It should be pointed out that percentage of vehicles powered by gasoline and diesel were estimated from the information available in the National Truck Characteristics Report [23]. For example, 11.94% of 2-axle single-unit trucks was estimated to contain diesel engines, while 99.35% of combination trucks with 5 or more axles would have diesel engines. These estimates were made by vehicle type and by number of axles. Furthermore, while gasoline and special fuel taxes were attributed among all vehicle classes, motor carrier fuel use tax was distributed only among trucks with more than 2-axles.

The same procedure was used to attribute the state fuel tax revenues for the 1985-86 period on the basis of the estimated VMT and fuel efficiency rates for these years. The 1985-86 VMT projections were developed using the factors developed in connection with the Federal Cost-Allocation Study and factors used in the studies conducted by several midwestern states.

State Registration Fees

A flat vehicle registration fee is charged to private automobiles in Indiana, while the fees schedules for commercial vehicles are graduated by registered weight. The total motor vehicle registration fees available for highway related activities in Indiana in FY83 were $109.7 million, after deducting disbursements for the Bureau of Motor Vehicles, miscellaneous expenses and the amounts associated with dealer's fees, transfer fees and other fees, such as fees for amateur radio. The registration fees for 1985-86 were estimated on the basis of the information provided by the IDOH and the Bureau of Motor Vehicles. The net amount estimated to be available for highway purposes in the two-year period of 1985-86 is $225.8 million.

Registration fees were attributed directly in proportion of the number of units of each vehicle class and associated registration fee rate. As mentioned earlier, a correspondence matrix was used to relate vehicles classified by gross operating weight with registered vehicle weight groups.

Other Taxes and Fees

Other taxes and fees at the state level were $2.502 million in 1983 or about 0.4% of the total available revenues. The majority of these fees came from oversize and overweight permits. The rest of these fees came from vehicle identification stamp fees, reciprocity fees and others. These fees were distributed among commerical vehicles in proportion to number of units. In 1985-86 miscellaneous state fees are estimated to be $5.35 million and the attribution would follow the same procedure as in 1983.

Local option taxes in 1983 amounted to $1.058 million or about 0.2% of the total. In 1985-86, the estimated amount is $5.5 million. Local option taxes are levied by counties and consist of an excise tax imposed on all motor vehicles and a wheel tax imposed on motor vehicles that are not subject to an excise tax. The attribution of these taxes was done by distributing the amount in proportion of registered units of all motor vehicles.

Federal Taxes

All federal taxes were attributed according to the appropriate user charge schedules. The applicability of each type of tax or fee along with the effective date of implementation of each tax or fee type was considered for appropriate vehicle classes. The factor for distributing 1983 taxes on oil, tire, tubes, tread rubber and truck parts were obtained from the report [35] prepared for the Federal Highway Cost-Allocation Study. The 1983 factors were developed by interpolating the 1977 and 1985 factors given in the report. The rate of new truck sales and associated prices were also generated using the information given in the report [35]. Heavy vehicle use fee was attributed in proportion of number of units in each commerical vehicle class of concern. The rates and effective dates were carfully considered in estimating the amount of this fee.

APPENDIX H

Determination of Cost-Responsibility Factors of Load-Related and Non-Load-Related Costs in Pavement Rehabilitation and Maintenance Cost Allocation

The procedure discussed herein follows a performance-based approach developed by Fwa and Sinha [13]. A summary of this approach is presented in this Appendix.

As discussed in the section on allocation procedure of pavement rehabilitation costs, pavement wear or damage may be represented by appropriate areas in a pavement performance (PSI vs. ΣESAL) plot. In Figure H.1, the shaded area $(A + B)_o$ between curves 3 and 4 represent the total pavement damage of a given stretch of pavement. Curve 3 is a hypothetical no-loss line and curve 4 is a hypothetical performance curve for the pavement concerned in a situation where no maintenance at all has been carried out.

Consider a stretch of pavement which is maintained by a particular highway agency with known technology, facilities, and manpower, and assume that the efficiency of the working crew remain the same for the period of analysis. Under these conditions it is reasonable to say that the expenditure spent on maintaining the pavement would be positively related to the level of routine maintenance performed. That is, in terms of constant dollars higher expenditure is likely to be associated with higher levels of maintenance. In Figure H.2, one would expect the expenditure level S_3 to be greater than S_2, S_2 greater than S_1, and so on.

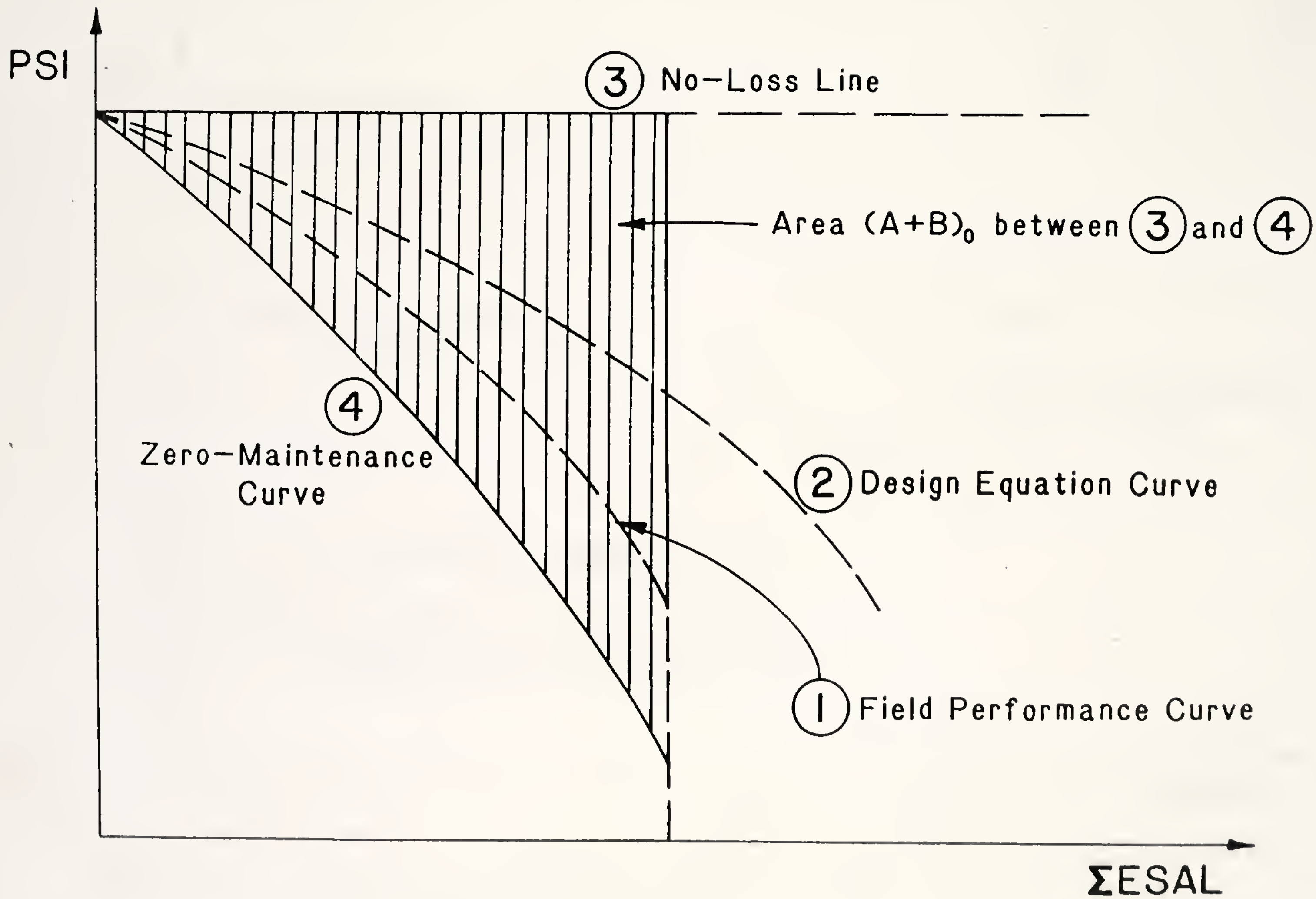


Figure H.1. Total Pavement Damage as Defined by Zero-Maintenance Pavement Performance Curve

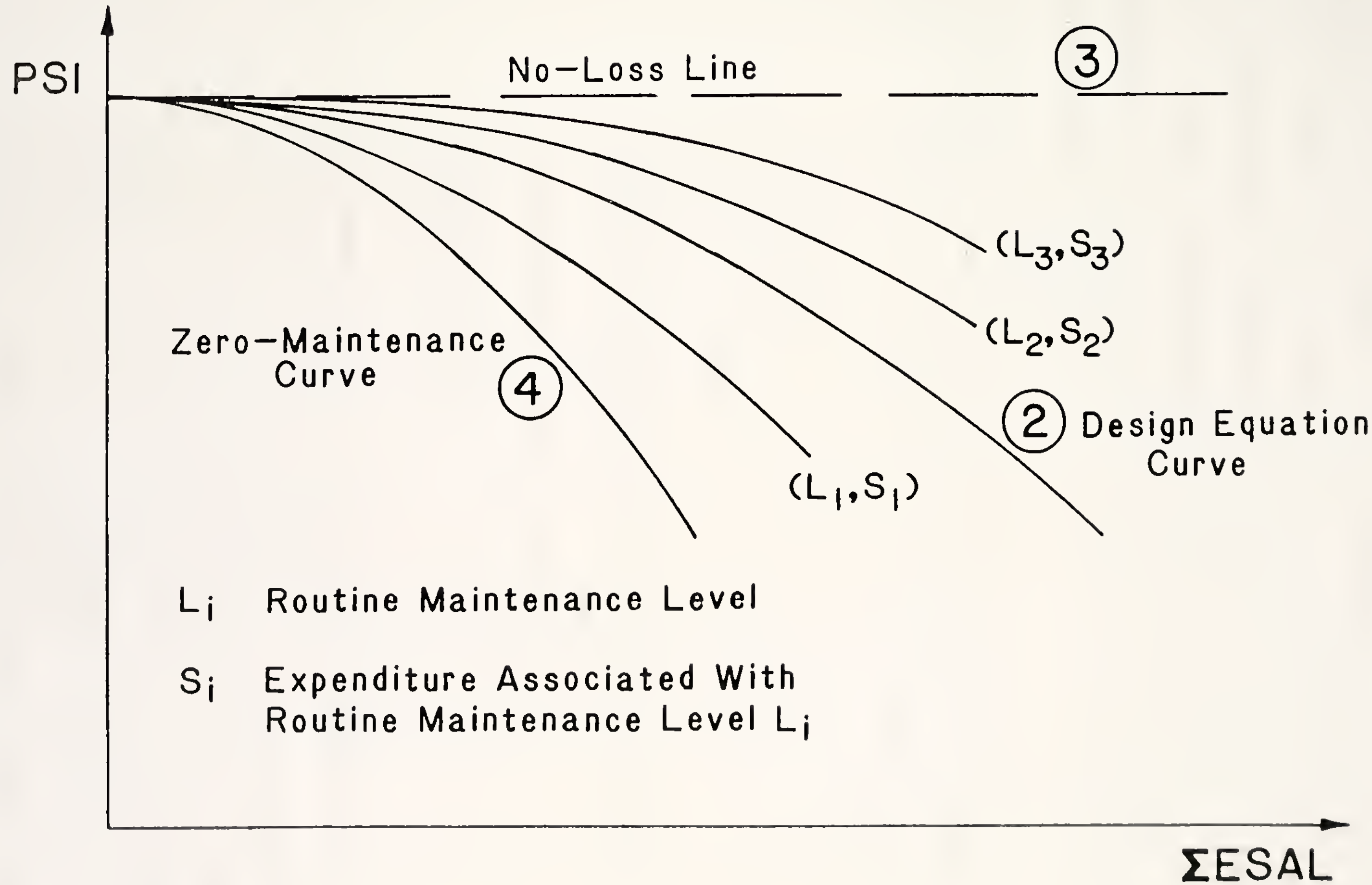


Figure B.2. Schematic Diagram Showing Pavement Performance Curves with their Associated Routine Expenditures.

Performance curves based on Indiana design equations vary with the following factors: type of pavement, region, terminal PSI, materials and traffic. Indiana material and regional factors estimated in an earlier work done at Purdue University [6] were used for this purpose. Cost-allocation analyses would be performed by highway class and type of pavement. For each pavement section on which a rehabilitation had been performed during the base period, performance curves corresponding to Indiana design equations and actual field performance were developed.

The Road-Life Records of the Indiana Department of Highways contain the following information for each route of the State Highway system:

1. Pavement type

2. Pavement thickness

3. Pavement age since the time of major improvement

4. Layer material characteristics, and

5. Construction costs

Pavement roughness measurements on Indiana State Highways since 1979 are available from JHRP tapes at Purdue University. These roughness measurements can be related to PSI by using relationships established for Indiana in previous studies performed at Purdue University [30,31]. The relationships derived for different types of pavements are summarized in Table H.1.

For a given pavement, knowing a PSI value and the corresponding cumulative ESAL, a point on the actual performance curve of the pavement is obtained. This procedure may be repeated for other points of time at which

Table H.1. Relationship Between Present Serviceability Index (PSI) and Roughness Number (RN)

Pavement	Relationship
Asphalt	PSI = 3.94 - 0.00072(RN)
Overlay	PSI = 4.37 - 0.00174(RN)
Jointed Reinforced Concrete (JRC)	PSI = 4.69 - 0.00141(RN)
Continuously Reinforced Concrete (CRC)	PSI = 4.40 - 0.00070(RN)
JRC & CRC (combined)	PSI = 4.58 - 0.00114(RN)

data are available. Field performance curve of the pavement may then be plotted, and the area between this curve and the no-loss line, ie. area (A+B), may be computed.

The annual routine maintenance cost per lane-mile of a pavement section was obtained by dividing its annual routine maintenance expenditures by its total lane-miles. The annual routine maintenance expenditures over the base period were considered to compute the average maintenance cost for the highway section under consideration.

Routine maintenance information is documented by highway section which is defined as the portion of a highway that lies within the boundaries of a county. Highway section was therefore chosen as the basic unit of analysis in the present study. When a pavement section contains more than one roughness measurement, a weighted average of area (A+B) was calculated using the lane-mile of each roughness measurement as the weighting factor.

For a stretch of pavement with more than one highway section, the zero-maintenance curve of the pavement was derived by plotting the areas (A+B) of these highway sections against their respective average annual routine maintenance expenditure per lane-mile. A least square line was then fitted to the data points. The intercept of this line with the (A+B) axis gives area $(A+B)_o$ of the zero-maintenance curve of the pavement under consideration.

The next step involves the computation of load-related and non-load-related responsibility factors using proportionality assumption. Figure H.3 assumes that the interaction effects is composed of two components, namely the load-related and non-load-related parts. Proportion a is equal to $\frac{A}{(A+B)_o}$ which could be computed for a given stretch of pavement with the procedure

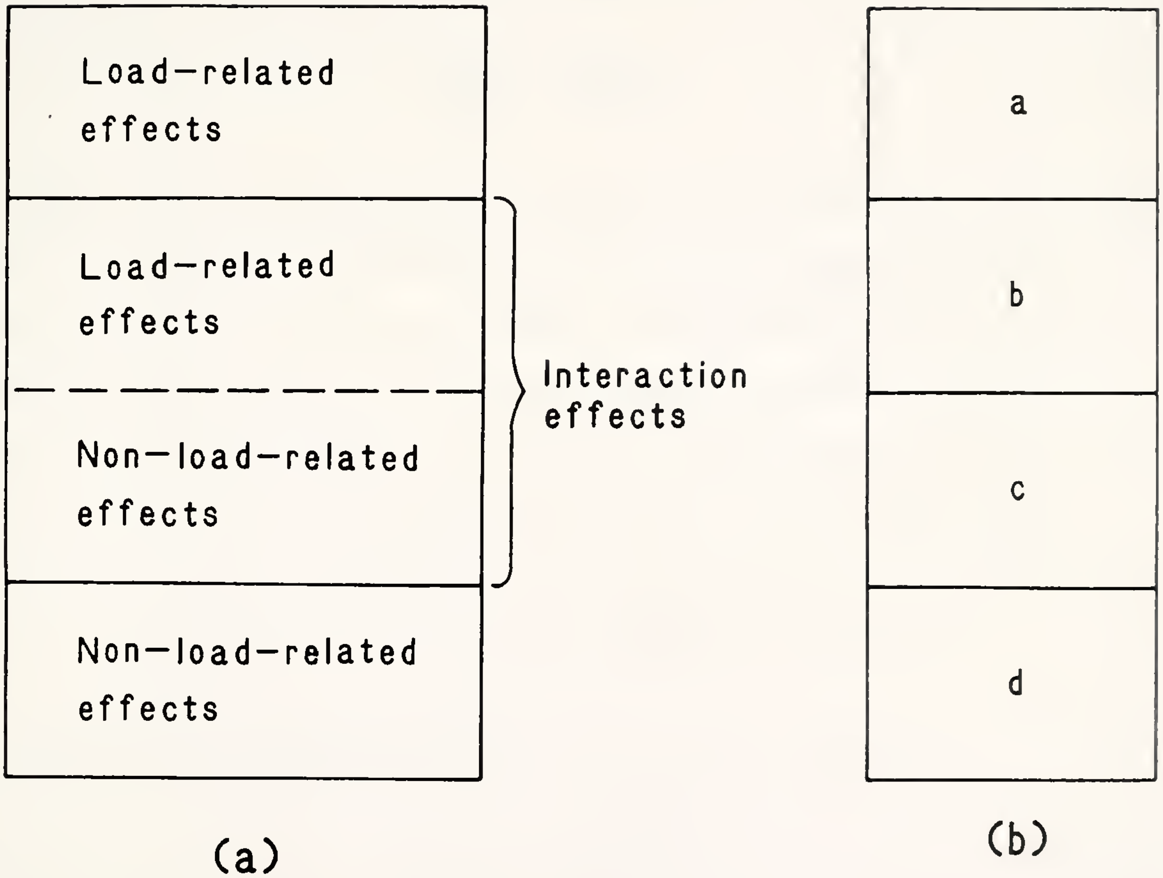


Figure H.3. Schematic Diagram Showing Load-related and Non-load-related Effects Responsible for Pavement Damage described in preceding paragraphs.

Knowing proportion a, it is possible to calculate proportions b, c and d by making the following proportionality assumption:

$$\frac{b}{b+c+d} = \frac{a}{a+b+c+d} \tag{H.1}$$

$$\frac{c}{a+b+c} = \frac{d}{a+b+c+d} \tag{H.2}$$

Equation (H.1) assumes that for a given 'pure' load-related effects (proportion a), the share of load-related effects in the remaining non-load-related and interaction effects is directly proportional to the share of 'pure' load-related effects in the overall effects (a+b+c+d). Similarly, equation (H.2) assumes that for a given 'pure' non-load-related effects (proportion d), the share of non-load-related effects in the remaining load-related and interaction effects is directly proportional to the share of the 'pure' non-load-related effects in the overall effects (a+b+c+d).

Solving for d using equations (H.1) and (H.2), it gives:

$$d = 1 - \sqrt{1-(1-a)^2} \tag{H.3}$$

Proportions b and c may then be determined from solving equations (H.1) and (H.2). The total responsibility proportion of load-related effects is given by (a+b) and the total responsibility proportion of non-load-related effects by (c+d).

Applying the procedure described in this Appendix to Indiana highways, the resulted proportional responsibilities of load-related and non-load related factors for different regions and pavement types are summarized in Table H.2.

The regional effect changes gradually from northern to southern Indiana and there exists no distinct boundary between them. For the present cost-allocation study, the two regions were defined as shown in Figure H.4.

Table H.2. Proportional Responsibilities of Load-Related and Non-load-related Factors in Indiana Pavement Rehabilitation and Maintenance Cost Allocation

	Northern Indiana			Southern Indiana		
Factor	Flexible Pavement	Rigid Pavement	Overlay	Flexible Pavement	Rigid Pavement	Overlay
Load-Related	0.87	0.66	0.80	0.98	0.70	0.98
Non-Load-Related	0.13	0.34	0.20	0.02	0.30	0.02

Figure H.4. Northern and Southern Regions for Pavement Cost-Allocation

APPENDIX I

TABLES OF COST-RESPONSIBILITY FACTORS

Table I.1. Pavement Construction Cost-Responsibility Factors

(a) Pavement Construction Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	8.667	11.869	11.564	5.560	5.069	5.376
2	27.239	36.848	40.652	22.174	27.215	23.289
3	2.057	2.806	3.919	4.919	14.699	4.124
4	0.269	0.376	0.189	0.211	1.683	3.430
5	0.657	0.537	0.340	0.176	0.273	0.167
6	0.411	0.607	1.640	1.876	7.622	2.740
7	0.459	0.577	1.392	2.120	0.646	0.379
8	0.036	0.192	0.142	0.088	0.	0.
9	0.226	0.179	1.484	0.603	0.019	0.015
10	0.066	0.042	0.091	0.234	0.	0.120
11	3.619	2.117	1.122	2.840	3.845	2.785
12	54.202	41.641	36.157	57.711	34.465	56.600
13	1.857	2.048	0.772	0.660	2.945	0.721
14	0.233	0.160	0.537	0.829	1.520	0.252

(b) Pavement Construction Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	8.620	11.869	11.556	5.560	5.053	5.366
2	27.089	36.848	40.609	22.144	26.368	22.884
3	1.989	2.806	3.790	4.736	11.646	3.220
4	0.261	0.376	0.184	0.205	0.381	0.804
5	0.653	0.537	0.340	0.175	0.263	0.163
6	0.406	0.607	1.594	1.821	6.812	2.449
7	0.462	0.577	1.399	2.123	0.934	0.540
8	0.036	0.192	0.142	0.088	0.	0.
9	0.222	0.179	1.484	0.615	2.473	1.025
10	0.067	0.042	0.092	0.235	0.	0.182
11	3.634	2.117	1.129	2.852	3.913	2.824
12	54.465	41.641	36.364	57.957	36.099	59.317
13	1.861	2.048	0.775	0.659	3.028	0.744
14	0.234	0.160	0.541	0.832	3.030	0.481

Table I.2. Shoulder Construction Cost-Responsibility Factors

(a) Shoulder Construction Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	7.202	10.217	10.432	5.467	3.162	3.647
2	22.647	31.726	36.701	22.494	16.977	15.799
3	1.790	2.379	4.491	6.011	12.393	3.306
4	0.462	0.834	0.523	0.851	1.788	3.172
5	0.590	0.502	0.330	0.181	0.230	0.134
6	0.415	0.627	1.795	2.123	9.770	2.535
7	0.522	0.666	1.020	1.597	0.828	0.537
8	0.032	0.179	0.138	0.094	0.	0.
9	0.229	0.174	1.637	0.011	0.024	0.014
10	0.070	0.044	0.077	0.172	0.	0.141
11	4.099	2.434	1.346	2.901	4.928	3.263
12	59.353	47.430	38.908	56.953	44.177	66.311
13	2.324	2.602	2.019	0.680	3.775	0.845
14	0.263	0.187	0.583	0.466	1.949	0.296

(b) Shoulder Construction Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	5.368	8.035	8.055	3.258	3.258	3.722
2	16.868	24.946	28.306	12.974	12.974	14.822
3	1.542	2.459	3.412	3.724	3.724	3.744
4	0.242	0.405	0.202	0.202	0.202	0.186
5	0.506	0.471	0.306	0.138	0.138	0.139
6	0.402	0.814	2.190	2.161	2.161	1.659
7	0.569	0.774	1.921	2.520	2.520	2.963
8	0.028	0.168	0.128	0.069	0.069	0.069
9	0.220	0.241	2.038	0.729	0.729	0.560
10	0.082	0.056	0.127	0.279	0.279	0.271
11	4.478	2.838	1.551	3.385	3.385	3.289
12	67.114	55.834	49.957	68.794	68.794	66.856
13	2.293	2.745	1.064	0.782	0.782	0.760
14	0.289	0.215	0.743	0.987	0.987	0.959

Table I.3. Right-of-Way Construction Cost-Responsibility Factors

(a) Right-of-Way Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	13.294	19.187	19.528	20.177	17.936	19.328
2	41.513	58.674	66.319	71.670	75.281	73.952
3	2.317	2.352	2.584	3.319	3.925	2.166
4	0.335	0.363	0.107	0.061	0.051	0.231
5	1.081	0.936	0.571	0.493	0.634	0.481
6	0.473	0.542	1.253	0.530	0.878	0.725
7	0.472	0.381	0.440	0.275	0.051	0.061
8	0.058	0.327	0.226	0.211	0.	0.
9	0.192	0.103	0.253	0.031	0.051	0.050
10	0.092	0.044	0.053	0.061	0.	0.046
11	3.280	1.173	0.627	0.469	0.276	0.436
12	35.686	15.245	7.692	2.549	0.643	2.393
13	0.997	0.586	0.200	0.092	0.184	0.098
14	0.210	0.088	0.147	0.061	0.092	0.032

(b) Right-of-Way Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	13.211	19.142	19.516	20.185	17.954	19.331
2	41.253	58.537	66.278	71.697	75.355	73.968
3	2.247	2.289	2.517	3.231	3.823	2.108
4	0.326	0.353	0.104	0.060	0.050	0.226
5	1.074	0.934	0.571	0.493	0.635	0.481
6	0.469	0.539	1.226	0.521	0.862	0.712
7	0.477	0.387	0.447	0.279	0.052	0.062
8	0.058	0.326	0.226	0.211	0.	0.
9	0.189	0.102	0.256	0.032	0.052	0.051
10	0.093	0.044	0.055	0.062	0.	0.047
11	3.309	1.187	0.636	0.477	0.281	0.443
12	36.077	15.475	7.816	2.596	0.655	2.436
13	1.006	0.594	0.203	0.093	0.187	0.100
14	0.212	0.089	0.149	0.062	0.094	0.033

Table I.4. Drainage & Erosion Control Cost-Responsibility Factors

(a) Drainage & Erosion Control Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	13.985	19.633	19.778	20.183	17.939	19.330
2	43.672	60.038	67.168	71.689	75.295	73.963
3	2.342	2.295	2.515	3.315	3.919	2.165
4	0.328	0.341	0.100	0.061	0.051	0.231
5	1.093	0.914	0.555	0.492	0.633	0.481
6	0.458	0.492	1.135	0.528	0.873	0.724
7	0.439	0.345	0.399	0.274	0.051	0.061
8	0.058	0.319	0.220	0.211	0.	0.
9	0.185	0.093	0.229	0.030	0.051	0.050
10	0.085	0.040	0.048	0.061	0.	0.045
11	3.050	1.063	0.568	0.467	0.274	0.434
12	33.183	13.816	6.969	2.537	0.640	2.385
13	0.927	0.531	0.181	0.091	0.183	0.098
14	0.195	0.080	0.133	0.061	0.091	0.032

(b) Drainage & Erosion Control Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	13.904	19.592	19.768	20.191	17.957	19.334
2	43.420	59.913	67.134	71.717	75.370	73.979
3	2.272	2.235	2.450	3.226	3.817	2.107
4	0.319	0.333	0.098	0.060	0.049	0.226
5	1.086	0.912	0.555	0.492	0.634	0.481
6	0.454	0.488	1.111	0.519	0.858	0.711
7	0.443	0.350	0.405	0.278	0.052	0.062
8	0.058	0.319	0.220	0.211	0.	0.
9	0.183	0.093	0.232	0.031	0.052	0.051
10	0.086	0.040	0.050	0.062	0.	0.046
11	3.078	1.076	0.576	0.475	0.279	0.442
12	33.563	14.029	7.082	2.584	0.652	2.428
13	0.936	0.539	0.184	0.092	0.186	0.100
14	0.197	0.081	0.135	0.062	0.093	0.033

Table I.5. Grading & Earthwork Cost-Responsibility Factors

(a) Grading & Earthwork Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	14.807	20.164	20.011	20.032	17.845	19.252
2	46.240	61.660	67.958	71.154	74.901	73.663
3	2.371	2.228	2.450	3.443	4.083	2.208
4	0.319	0.316	0.095	0.066	0.055	0.241
5	1.106	0.887	0.541	0.511	0.660	0.491
6	0.439	0.431	1.026	0.596	0.991	0.755
7	0.400	0.303	0.360	0.310	0.058	0.069
8	0.059	0.309	0.214	0.219	0.	0.
9	0.178	0.082	0.207	0.034	0.058	0.052
10	0.078	0.035	0.044	0.069	0.	0.050
11	2.776	0.932	0.513	0.527	0.311	0.474
12	30.206	12.118	6.297	2.867	0.726	2.602
13	0.844	0.466	0.164	0.103	0.207	0.107
14	0.178	0.070	0.120	0.069	0.104	0.035

(b) Grading & Earthwork Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	14.729	20.127	20.011	20.039	17.864	19.255
2	45.995	61.549	67.958	71.179	74.978	73.677
3	2.301	2.170	2.450	3.351	3.978	2.149
4	0.310	0.308	0.095	0.065	0.054	0.236
5	1.100	0.886	0.541	0.511	0.661	0.491
6	0.436	0.429	1.026	0.586	0.974	0.742
7	0.404	0.307	0.360	0.314	0.059	0.071
8	0.059	0.309	0.214	0.219	0.	0.
9	0.175	0.082	0.207	0.036	0.059	0.053
10	0.079	0.035	0.044	0.070	0.	0.051
11	2.804	0.944	0.513	0.537	0.317	0.482
12	30.575	12.309	6.297	2.919	0.740	2.649
13	0.852	0.473	0.164	0.104	0.211	0.109
14	0.180	0.071	0.120	0.070	0.106	0.036

Table I.6. Common Costs Cost-Responsibility Factors

(a) Common Costs Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	15.640	20.700	20.200	20.200	17.950	19.340
2	48.840	63.300	68.600	71.750	75.340	74.000
3	2.400	2.160	2.400	3.300	3.900	2.160
4	0.310	0.290	0.090	0.060	0.050	0.230
5	1.120	0.860	0.530	0.490	0.630	0.480
6	0.420	0.370	0.940	0.520	0.860	0.720
7	0.360	0.260	0.330	0.270	0.050	0.060
8	0.060	0.300	0.210	0.210	0.	0.
9	0.170	0.070	0.190	0.030	0.050	0.050
10	0.070	0.030	0.040	0.060	0.	0.045
11	2.500	0.800	0.470	0.460	0.270	0.430
12	27.200	10.400	5.770	2.500	0.630	2.360
13	0.760	0.400	0.150	0.090	0.180	0.097
14	0.160	0.060	0.110	0.060	0.090	0.032

(b) Common Costs Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	15.563	20.668	20.187	20.208	17.968	19.344
2	48.599	63.203	68.556	71.778	75.415	74.013
3	2.331	2.105	2.338	3.212	3.799	2.102
4	0.302	0.283	0.088	0.059	0.049	0.225
5	1.114	0.859	0.530	0.490	0.631	0.480
6	0.417	0.368	0.920	0.511	0.845	0.707
7	0.364	0.264	0.335	0.274	0.051	0.061
8	0.060	0.300	0.210	0.210	0.	0.
9	0.168	0.070	0.192	0.031	0.051	0.051
10	0.071	0.030	0.041	0.061	0.	0.046
11	2.527	0.811	0.477	0.468	0.275	0.437
12	27.554	10.571	5.863	2.546	0.642	2.403
13	0.768	0.406	0.152	0.091	0.183	0.099
14	0.162	0.061	0.112	0.061	0.092	0.033

Table I.7. Truck-Only Common Costs Cost-Responsibility Factors

(a) Truck-Only Common Costs Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.
3	7.051	14.845	23.077	45.268	64.677	36.278
4	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.
6	1.234	2.543	9.038	7.133	14.262	12.093
7	1.058	1.787	3.173	3.704	0.829	1.008
8	0.	0.	0.	0.	0.	0.
9	0.499	0.481	1.827	0.412	0.829	0.840
10	0.206	0.206	0.385	0.823	0.	0.756
11	7.344	5.498	4.519	6.310	4.478	7.222
12	79.906	71.478	55.481	34.294	10.448	39.637
13	2.233	2.749	1.442	1.235	2.985	1.629
14	0.470	0.412	1.058	0.823	1.493	0.537

Truck-Only Common Costs Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.
3	6.785	14.335	22.414	44.276	63.984	35.403
4	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	0.
6	1.213	2.509	8.822	7.038	14.233	11.905
7	1.059	1.796	3.210	3.783	0.857	1.027
8	0.	0.	0.	0.	0.	0.
9	0.490	0.474	1.841	0.421	0.858	0.857
10	0.206	0.207	0.389	0.841	0.	0.770
11	7.354	5.525	4.576	6.447	4.627	7.362
12	80.186	71.978	56.215	35.092	10.813	40.468
13	2.234	2.761	1.459	1.260	3.082	1.659
14	0.472	0.416	1.074	0.843	1.546	0.549

Table I.8. Pavement Construction Cost-Responsibility of Vehicle Classes on Rural Interstate (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	8.667	8.667
2	1	27.239	27.239
3	1	2.057	0.032
3	2		0.109
3	3		0.137
3	4		0.415
3	5		0.354
3	6		0.301
3	7		0.199
3	8		0.172
3	9		0.338
4	1	0.269	0.269
5	1	0.657	0.657
6	1	0.411	0.035
6	2		0.018
6	3		0.029
6	4		0.062
6	5		0.059
6	6		0.039
6	7		0.042
6	8		0.034
6	9		0.092
7	1	0.459	0.009
7	2		0.020
7	3		0.043
7	4		0.072
7	5		0.040
7	6		0.018
7	7		0.166
7	8		0.066
7	9		0.025
8	1	0.036	0.036
9	1	0.226	0.058
9	2		0.169
10	1	0.066	0.013
10	2		0.013
10	3		0.026
10	4		0.015
11	1	3.619	0.036
11	2		0.078
11	3		0.308
11	4		0.145
11	5		0.281
11	6		0.250
11	7		0.229
11	8		0.243
11	9		0.331
11	10		0.392
11	11		0.433
11	12		0.422
11	13		0.472
12	1	54.202	0.040
12	2		0.206
12	3		0.735
12	4		2.160
12	5		1.834
12	6		1.182
12	7		1.033
12	8		0.960
12	9		0.925
12	10		0.922
12	11		0.951
12	12		0.996
12	13		0.961
12	14		1.242
12	15		1.479
12	16		2.062
12	17		2.040
12	18		2.156
12	19		2.712
12	20		4.440
12	21		7.672
12	22		9.102
12	23		4.976
12	24		2.627
12	25		0.224
12	26		0.570
13	1	1.857	0.108
13	2		0.182
13	3		0.043
13	4		0.090
13	5		0.053
13	6		0.063
13	7		0.152
13	8		0.071
13	9		0.085
13	10		0.177
13	11		0.094
13	12		0.329
13	13		0.410
14	1	0.233	0.049
14	2		0.066
14	3		0.119

Table I.9. Pavement Rehabilitation Cost-Responsibility Factors for Rural Interstate

(a) Pavement Rehabilitation Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.323	3.136	4.697	5.322	--	--
2	1.270	10.007	14.793	16.738	--	--
3	1.784	1.897	1.461	1.515	--	--
4	0.193	0.215	0.172	0.180	--	--
5	0.031	0.231	0.340	0.385	--	--
6	0.361	0.372	0.320	0.326	--	--
7	0.529	0.498	0.327	0.329	--	--
8	0.002	0.013	0.018	0.021	--	--
9	0.313	0.286	0.219	0.217	--	--
10	0.042	0.047	0.040	0.041	--	--
11	4.785	4.365	3.020	2.990	--	--
12	86.643	75.723	72.667	70.068	--	--
13	3.439	2.947	1.691	1.638	--	--
14	0.286	0.263	0.235	0.230	--	--

(b) Pavement Rehabilitation Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.321	3.121	4.674	5.296	--	--
2	1.260	9.955	14.718	16.655	--	--
3	1.713	1.827	1.410	1.463	--	--
4	0.186	0.207	0.166	0.174	--	--
5	0.031	0.230	0.338	0.383	--	--
6	0.354	0.366	0.316	0.321	--	--
7	0.528	0.498	0.328	0.330	--	--
8	0.002	0.013	0.018	0.021	--	--
9	0.305	0.280	0.215	0.212	--	--
10	0.042	0.047	0.040	0.042	--	--
11	4.781	4.367	3.025	2.997	--	--
12	86.754	75.881	72.824	70.237	--	--
13	3.435	2.945	1.691	1.638	--	--
14	0.286	0.263	0.235	0.231	--	--

Table I.10. Pavement Rehabilitation Cost-Responsibility Factors for Urban Interstate

(a) Pavement Rehabilitation Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.446	4.166	6.227	7.054	--	--
2	2.194	13.418	19.453	21.961	--	--
3	3.858	3.546	2.333	2.330	--	--
4	1.720	1.458	0.841	0.813	--	--
5	0.034	0.186	0.266	0.300	--	--
6	0.766	0.693	0.541	0.532	--	--
7	0.925	0.803	0.479	0.469	--	--
8	0.019	0.071	0.096	0.108	--	--
9	0.312	0.268	0.088	0.041	--	--
10	0.034	0.033	0.023	0.023	--	--
11	3.721	3.185	2.050	1.971	--	--
12	80.796	67.866	65.066	61.968	--	--
13	4.907	4.079	2.336	2.237	--	--
14	0.267	0.229	0.200	0.193	--	--

(b) Pavement Rehabilitation Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.446	4.160	6.217	7.043	--	--
2	2.197	13.402	19.418	21.920	--	--
3	3.785	3.476	2.257	2.249	--	--
4	0.426	0.399	0.265	0.266	--	--
5	0.034	0.186	0.266	0.300	--	--
6	0.767	0.693	0.536	0.527	--	--
7	0.945	0.820	0.481	0.469	--	--
8	0.019	0.071	0.096	0.108	--	--
9	0.314	0.269	0.194	0.187	--	--
10	0.043	0.041	0.029	0.029	--	--
11	3.792	3.244	2.085	2.013	--	--
12	82.463	69.258	65.882	62.721	--	--
13	4.504	3.751	2.077	1.981	--	--
14	0.266	0.229	0.196	0.189	--	--

Table I.11. Pavement Rehabilitation Cost-Responsibility Factors for State Routes Primary

(a) Pavement Rehabilitation Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.479	4.101	6.096	6.901	0.502	2.703
2	3.781	15.705	21.655	24.337	4.464	11.370
3	6.039	5.391	3.251	3.203	6.114	5.675
4	0.302	0.265	0.151	0.148	0.308	0.282
5	0.035	0.126	0.170	0.191	0.042	0.094
6	2.046	1.854	1.341	1.318	2.127	1.961
7	2.728	2.294	1.264	1.211	2.706	2.454
8	0.026	0.060	0.072	0.080	0.031	0.049
9	3.315	2.744	1.735	1.646	3.239	2.936
10	0.128	0.112	0.071	0.069	0.134	0.121
11	1.666	1.453	0.911	0.886	1.725	1.560
12	76.940	63.786	61.898	58.690	76.066	68.518
13	1.472	1.235	0.657	0.628	1.493	1.336
14	1.042	0.873	0.728	0.693	1.049	0.941

(b) Pavement Rehabilitation Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.480	4.101	6.094	6.899	0.504	2.704
2	3.837	15.743	21.694	24.372	4.535	11.422
3	6.531	5.772	3.554	3.484	6.592	6.092
4	1.133	0.940	0.540	0.514	1.110	1.005
5	0.036	0.127	0.171	0.191	0.043	0.095
6	1.902	1.731	1.345	1.321	1.980	1.829
7	1.505	1.297	0.735	0.712	1.530	1.388
8	0.026	0.060	0.073	0.081	0.032	0.050
9	3.249	2.684	2.535	2.401	3.194	2.880
10	0.077	0.071	0.048	0.048	0.084	0.076
11	1.882	1.630	1.040	1.008	1.937	1.750
12	74.198	61.609	59.611	56.540	73.356	66.141
13	4.134	3.389	1.974	1.870	4.084	3.655
14	1.009	0.847	0.586	0.55[illegible]	1.018	0.914

Table I.12. Pavement Rehabilitation Cost-Responsibility Factors for State Routes Secondary

(a) Pavement Rehabilitation Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.550	4.159	6.134	6.938	0.560	2.772
2	6.337	18.368	23.824	26.578	6.666	14.228
3	8.389	7.469	4.641	4.585	8.564	8.097
4	0.392	0.332	0.187	0.180	0.402	0.370
5	0.054	0.134	0.168	0.186	0.057	0.108
6	2.697	2.302	1.672	1.614	2.754	2.543
7	3.907	3.243	1.815	1.736	3.935	3.540
8	0.046	0.077	0.082	0.090	0.049	0.069
9	1.025	0.842	0.548	0.521	1.021	0.906
10	0.373	0.316	0.198	0.191	0.385	0.358
11	4.713	3.936	2.474	2.370	4.762	4.314
12	69.197	56.895	56.928	53.744	68.474	60.539
13	1.209	1.007	0.543	0.521	1.250	1.148
14	1.111	0.919	0.787	0.746	1.120	1.007

(b) Pavement Rehabilitation Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.548	4.160	6.135	6.940	0.558	2.771
2	6.280	18.326	23.801	26.557	6.606	14.176
3	8.066	7.189	4.466	4.415	8.236	7.792
4	0.381	0.323	0.181	0.175	0.391	0.360
5	0.054	0.134	0.167	0.186	0.057	0.108
6	2.618	2.236	1.622	1.566	2.674	2.470
7	3.916	3.251	1.817	1.738	3.945	3.551
8	0.046	0.076	0.082	0.089	0.049	0.069
9	1.046	0.860	0.559	0.531	1.042	0.925
10	0.374	0.318	0.198	0.192	0.387	0.360
11	4.736	3.956	2.483	2.379	4.787	4.337
12	69.611	57.242	57.158	53.965	68.895	60.923
13	1.208	1.006	0.542	0.520	1.249	1.148
14	1.116	0.923	0.789	0.748	1.125	1.011

Table I.13. Pavement Rehabilitation Cost-Responsibility Factors for County Roads

(a) Pavement Rehabilitation Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.609	3.795	5.545	6.255	0.615	2.566
2	11.474	23.217	28.510	31.198	11.711	19.037
3	20.327	17.318	11.741	11.310	20.407	18.608
4	0.665	0.553	0.359	0.342	0.669	0.602
5	0.123	0.216	0.254	0.276	0.126	0.184
6	9.145	7.627	6.404	6.096	9.183	8.274
7	1.522	1.251	0.802	0.760	1.519	1.351
8	0.	0.	0.	0.	0.	0.
9	3.660	2.996	2.221	2.099	3.636	3.215
10	0.	0.	0.	0.	0.	0.
11	5.824	4.804	3.444	3.267	5.819	5.192
12	38.269	31.326	35.267	33.236	37.891	33.436
13	4.864	4.007	2.583	2.450	4.911	4.413
14	3.519	2.889	2.870	2.711	3.512	3.122

(b) Pavement Rehabilitation Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.609	3.798	5.550	6.260	0.615	2.568
2	11.443	23.206	28.495	31.188	11.681	19.019
3	19.718	16.802	11.362	10.947	19.798	18.055
4	0.649	0.539	0.350	0.333	0.653	0.588
5	0.123	0.216	0.254	0.276	0.126	0.184
6	8.947	7.464	6.248	5.948	8.986	8.097
7	1.546	1.271	0.812	0.770	1.543	1.373
8	0.	0.	0.	0.	0.	0.
9	3.717	3.043	2.249	2.126	3.694	3.266
10	0.	0.	0.	0.	0.	0.
11	5.907	4.873	3.483	3.304	5.902	5.267
12	38.834	31.790	35.678	33.625	38.455	33.937
13	4.924	4.057	2.607	2.473	4.973	4.469
14	3.582	2.941	2.913	2.751	3.575	3.179

Table I.14. Pavement Rehabilitation Cost-Responsibility Factors for City Streets

(a) Pavement Rehabilitation Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.523	3.979	5.877	6.647	0.527	2.642
2	6.412	18.834	24.719	27.542	6.558	14.241
3	5.693	5.049	3.190	3.138	5.747	5.383
4	1.544	1.304	0.756	0.728	1.562	1.425
5	0.052	0.131	0.166	0.184	0.053	0.102
6	3.864	3.290	2.450	2.357	3.902	3.571
7	0.920	0.763	0.428	0.408	0.924	0.829
8	0.	0.	0.	0.	0.	0.
9	1.844	1.515	0.973	0.922	1.842	1.639
10	0.284	0.240	0.157	0.151	0.288	0.264
11	4.677	3.899	2.454	2.344	4.699	4.235
12	72.236	59.378	57.761	54.563	71.923	63.887
13	1.321	1.098	0.621	0.593	1.342	1.217
14	0.631	0.521	0.449	0.425	0.633	0.567

(b) Pavement Rehabilitation Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.521	3.978	5.877	6.647	0.525	2.640
2	6.351	18.787	24.688	27.514	6.496	14.186
3	5.471	4.857	3.069	3.020	5.524	5.176
4	1.492	1.261	0.730	0.703	1.509	1.377
5	0.052	0.130	0.165	0.183	0.053	0.102
6	3.747	3.192	2.375	2.285	3.784	3.464
7	0.924	0.766	0.429	0.409	0.928	0.832
8	0.	0.	0.	0.	0.	0.
9	1.857	1.526	0.978	0.927	1.856	1.651
10	0.286	0.243	0.158	0.152	0.291	0.266
11	4.694	3.914	2.461	2.350	4.716	4.251
12	72.632	59.710	57.988	54.780	72.322	64.249
13	1.332	1.107	0.625	0.597	1.352	1.226
14	0.642	0.530	0.456	0.432	0.645	0.577

Table I.15. Pavement Maintenance Cost-Responsibility Factors for Rural Interstate

(a) Pavement Maintenance Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.480	3.136	4.697	5.322	--	--
2	1.792	10.017	14.794	16.739	--	--
3	1.825	1.906	1.464	1.518	--	--
4	0.207	0.218	0.172	0.180	--	--
5	0.044	0.232	0.340	0.385	--	--
6	0.380	0.377	0.321	0.327	--	--
7	0.548	0.504	0.328	0.330	--	--
8	0.003	0.013	0.018	0.021	--	--
9	0.320	0.289	0.220	0.217	--	--
10	0.045	0.048	0.040	0.041	--	--
11	4.780	4.367	3.029	2.999	--	--
12	85.864	75.681	72.644	70.047	--	--
13	3.417	2.948	1.697	1.643	--	--
14	0.294	0.266	0.235	0.231	--	--

(b) Pavement Maintenance Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.478	3.121	4.674	5.296	--	--
2	1.780	9.964	14.719	16.655	--	--
3	1.752	1.835	1.414	1.466	--	--
4	0.200	0.211	0.167	0.174	--	--
5	0.043	0.230	0.338	0.383	--	--
6	0.374	0.371	0.317	0.322	--	--
7	0.548	0.504	0.329	0.331	--	--
8	0.003	0.013	0.018	0.021	--	--
9	0.312	0.283	0.215	0.213	--	--
10	0.045	0.048	0.040	0.042	--	--
11	4.777	4.369	3.034	3.005	--	--
12	85.981	75.839	72.802	70.216	--	--
13	3.413	2.946	1.697	1.644	--	--
14	0.294	0.266	0.236	0.231	--	--

Table I.16. Pavement Maintenance Cost-Responsibility Factors for Urban Interstate

(a) Pavement Maintenance Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.657	4.168	6.227	7.054	--	--
2	2.954	13.463	19.457	21.962	--	--
3	3.988	3.629	2.348	2.338	--	--
4	0.469	0.422	0.275	0.276	--	--
5	0.045	0.186	0.266	0.300	--	--
6	0.817	0.717	0.548	0.537	--	--
7	0.973	0.829	0.482	0.469	--	--
8	0.024	0.071	0.096	0.108	--	--
9	0.324	0.276	0.198	0.190	--	--
10	0.047	0.042	0.029	0.029	--	--
11	3.769	3.242	2.091	2.017	--	--
12	81.204	68.979	65.703	62.543	--	--
13	4.456	3.745	2.082	1.986	--	--
14	0.272	0.230	0.196	0.188	--	--

(b) Pavement Maintenance Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.656	4.161	6.218	7.043	--	--
2	2.935	13.431	19.421	21.923	--	--
3	3.834	3.494	2.264	2.255	--	--
4	0.452	0.407	0.266	0.267	--	--
5	0.044	0.186	0.266	0.300	--	--
6	0.802	0.705	0.538	0.529	--	--
7	0.975	0.831	0.484	0.471	--	--
8	0.023	0.071	0.096	0.108	--	--
9	0.320	0.272	0.195	0.188	--	--
10	0.046	0.042	0.029	0.029	--	--
11	3.769	3.244	2.092	2.019	--	--
12	81.410	69.176	65.851	62.692	--	--
13	4.461	3.750	2.084	1.988	--	--
14	0.272	0.231	0.197	0.189	--	--

Table I.17. Pavement Maintenance Cost-Responsibility Factors for State Routes Primary

(a) Pavement Maintenance Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.681	4.100	6.096	6.901	0.477	2.692
2	4.483	15.664	21.673	24.339	3.711	11.056
3	6.032	5.361	3.288	3.207	5.991	5.628
4	0.302	0.262	0.153	0.148	0.298	0.278
5	0.041	0.126	0.170	0.191	0.035	0.091
6	2.052	1.836	1.357	1.320	2.018	1.921
7	2.711	2.287	1.280	1.212	2.718	2.458
8	0.028	0.059	0.073	0.080	0.025	0.047
9	3.284	2.743	1.755	1.649	3.315	2.964
10	0.128	0.111	0.072	0.069	0.126	0.118
11	1.665	1.441	0.922	0.887	1.646	1.531
12	76.088	63.912	61.762	58.674	77.147	68.956
13	1.468	1.226	0.667	0.629	1.456	1.323
14	1.036	0.870	0.731	0.693	1.037	0.937

(b) Pavement Maintenance Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.680	4.097	6.092	6.897	0.475	2.690
2	4.452	15.632	21.647	24.312	3.681	11.024
3	5.808	5.167	3.170	3.093	5.767	5.422
4	0.292	0.254	0.148	0.143	0.288	0.269
5	0.040	0.126	0.170	0.190	0.034	0.091
6	1.985	1.778	1.314	1.279	1.952	1.860
7	2.719	2.295	1.284	1.216	2.726	2.467
8	0.028	0.059	0.072	0.080	0.025	0.046
9	3.280	2.740	1.751	1.645	3.310	2.960
10	0.130	0.113	0.073	0.070	0.127	0.119
11	1.670	1.447	0.925	0.890	1.651	1.536
12	76.404	64.190	61.951	58.856	77.460	69.249
13	1.470	1.228	0.667	0.630	1.458	1.325
14	1.042	0.876	0.735	0.697	1.044	0.943

Table I.18. Pavement Maintenance Cost-Responsibility Factors for State Routes Secondary

(a) Pavement Maintenance Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.758	4.168	6.134	6.937	0.542	2.745
2	7.272	18.653	23.846	26.546	6.086	13.324
3	8.502	7.620	4.671	4.542	8.230	7.579
4	0.398	0.341	0.188	0.178	0.383	0.341
5	0.061	0.137	0.168	0.186	0.052	0.100
6	2.729	2.351	1.683	1.597	2.644	2.372
7	3.902	3.267	1.828	1.717	3.875	3.447
8	0.050	0.079	0.082	0.089	0.044	0.062
9	1.013	0.839	0.552	0.516	1.025	0.913
10	0.381	0.327	0.199	0.189	0.362	0.322
11	4.716	3.978	2.490	2.346	4.668	4.169
12	67.872	56.272	56.821	53.899	69.813	62.616
13	1.235	1.042	0.548	0.514	1.174	1.031
14	1.109	0.926	0.788	0.744	1.103	0.980

(b) Pavement Maintenance Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.757	4.168	6.136	6.939	0.541	2.744
2	7.213	18.609	23.822	26.526	6.031	13.280
3	8.177	7.335	4.495	4.373	7.912	7.290
4	0.387	0.331	0.183	0.173	0.372	0.332
5	0.061	0.136	0.168	0.186	0.051	0.099
6	2.650	2.284	1.633	1.550	2.566	2.303
7	3.912	3.276	1.830	1.718	3.884	3.455
8	0.050	0.078	0.082	0.089	0.044	0.061
9	1.034	0.857	0.562	0.526	1.046	0.931
10	0.383	0.329	0.200	0.189	0.363	0.323
11	4.740	4.000	2.500	2.355	4.690	4.189
12	68.288	56.625	57.053	54.118	70.220	62.978
13	1.234	1.041	0.547	0.513	1.172	1.029
14	1.114	0.931	0.790	0.746	1.107	0.984

Table I.19. Pavement Maintenance Cost-Responsibility Factors for County Roads

(a) Pavement Maintenance Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.791	3.800	5.546	6.254	0.605	2.549
2	12.321	23.422	28.527	31.173	11.289	18.380
3	20.240	17.387	11.766	11.273	20.248	18.361
4	0.663	0.556	0.360	0.341	0.661	0.590
5	0.130	0.219	0.254	0.276	0.121	0.177
6	9.100	7.660	6.417	6.077	9.106	8.154
7	1.505	1.249	0.804	0.758	1.523	1.358
8	0.	0.	0.	0.	0.	0.
9	3.605	2.975	2.224	2.094	3.677	3.278
10	0.	0.	0.	0.	0.	0.
11	5.764	4.799	3.450	3.258	5.828	5.206
12	37.541	31.002	35.192	33.345	38.598	34.532
13	4.861	4.048	2.590	2.440	4.821	4.274
14	3.479	2.883	2.869	2.712	3.523	3.140

(b) Pavement Maintenance Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.757	4.168	6.136	6.939	0.541	2.551
2	7.213	18.609	23.822	26.526	6.031	18.361
3	8.177	7.335	4.495	4.373	7.912	17.810
4	0.387	0.331	0.183	0.173	0.372	0.576
5	0.061	0.136	0.168	0.186	0.051	0.177
6	2.650	2.284	1.633	1.550	2.566	7.978
7	3.912	3.276	1.830	1.718	3.884	1.379
8	0.050	0.078	0.082	0.089	0.044	0.
9	1.034	0.857	0.562	0.526	1.046	3.329
10	0.383	0.329	0.200	0.189	0.363	0.
11	4.740	4.000	2.500	2.355	4.690	5.279
12	68.288	56.625	57.053	54.118	70.220	35.038
13	1.234	1.041	0.547	0.513	1.172	4.326
14	1.114	0.931	0.790	0.746	1.107	3.196

Table I.20. Pavement Maintenance Cost-Responsibility Factors for City Streets

(a) Pavement Maintenance Cost-Resp.(%) for 1983

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.718	3.983	5.877	6.646	0.519	2.630
2	7.224	18.961	24.730	27.527	6.297	13.834
3	5.708	5.095	3.199	3.124	5.643	5.222
4	1.548	1.320	0.759	0.724	1.528	1.372
5	0.057	0.132	0.166	0.183	0.051	0.099
6	3.868	3.322	2.458	2.345	3.829	3.458
7	0.915	0.766	0.430	0.406	0.917	0.818
8	0.	0.	0.	0.	0.	0.
9	1.826	1.513	0.976	0.918	1.844	1.641
10	0.285	0.244	0.157	0.150	0.280	0.251
11	4.654	3.917	2.462	2.333	4.657	4.171
12	71.242	59.109	57.714	54.630	72.505	64.789
13	1.328	1.116	0.623	0.589	1.303	1.157
14	0.627	0.523	0.449	0.424	0.628	0.560

(b) Pavement Maintenance Cost-Resp.(%) for 1985/86

Vehicle Class	South Overlay	North Overlay	South Rigid	North Rigid	South Flexible	North Flexible
1	0.757	4.168	6.136	6.939	0.541	2.629
2	7.213	18.609	23.822	26.526	6.031	13.783
3	8.177	7.335	4.495	4.373	7.912	5.021
4	0.387	0.331	0.183	0.173	0.372	1.325
5	0.061	0.136	0.168	0.186	0.051	0.098
6	2.650	2.284	1.633	1.550	2.566	3.354
7	3.912	3.276	1.830	1.718	3.884	0.821
8	0.050	0.078	0.082	0.089	0.044	0.
9	1.034	0.857	0.562	0.526	1.046	1.653
10	0.383	0.329	0.200	0.189	0.363	0.254
11	4.740	4.000	2.500	2.355	4.690	4.186
12	68.288	56.625	57.053	54.118	70.220	65.140
13	1.234	1.041	0.547	0.513	1.172	1.166
14	1.114	0.931	0.790	0.746	1.107	0.570

Table I.21. Bridge Superstructure Cost-Responsibility Factors

(a)Bridge Superstructure Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	7.615	10.080	11.137	11.337	10.701	11.520
2	23.779	30.823	37.821	40.269	44.914	44.079
3	2.565	3.973	5.136	8.073	11.421	5.490
4	0.445	0.794	0.349	0.396	0.483	1.447
5	0.693	0.670	0.485	0.519	0.727	0.553
6	0.504	0.799	2.075	1.842	4.152	2.612
7	0.377	0.463	0.749	0.862	0.209	0.205
8	0.044	0.312	0.260	0.316	0.	0.
9	3.723	3.820	6.692	3.928	5.506	5.394
10	0.084	0.065	0.114	0.266	0.	0.208
11	3.301	1.967	1.233	2.063	1.771	1.995
12	49.177	38.579	28.243	23.210	10.399	21.743
13	1.539	1.700	0.718	0.594	1.806	0.634
14	6.153	5.954	4.986	6.326	7.915	4.125

(b)Bridge Superstructure Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	7.578	10.064	11.133	11.342	10.701	11.520
2	23.665	30.777	37.809	40.286	44.914	44.079
3	2.482	3.854	4.991	7.870	11.421	5.490
4	0.430	0.768	0.339	0.385	0.483	1.447
5	0.688	0.667	0.485	0.520	0.727	0.553
6	0.499	0.794	2.033	1.822	4.152	2.612
7	0.379	0.467	0.758	0.876	0.209	0.205
8	0.044	0.310	0.259	0.317	0.	0.
9	3.856	3.797	6.674	3.913	5.506	5.394
10	0.084	0.065	0.116	0.269	0.	0.208
11	3.316	1.977	1.246	2.086	1.771	1.995
12	49.484	38.794	28.441	23.377	10.399	21.743
13	1.539	1.700	0.720	0.599	1.806	0.634
14	5.957	5.962	4.996	6.339	7.915	4.125

Table I.22. Bridge Pier Cost-Responsibility Factors

(a)Bridge Pier Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.823	16.974	17.165	15.150	15.273	16.442
2	40.043	51.905	58.292	53.811	64.103	62.911
3	2.773	3.492	3.992	7.527	8.200	3.434
4	0.421	0.611	0.251	0.448	0.369	1.075
5	0.921	0.711	0.455	0.374	0.546	0.415
6	0.486	0.600	1.098	1.358	1.958	1.216
7	0.402	0.396	0.583	0.775	0.177	0.147
8	0.055	0.309	0.182	0.302	0.	0.
9	0.323	0.244	0.753	0.358	0.602	0.450
10	0.094	0.062	0.109	0.300	0.	0.214
11	3.322	1.629	1.095	2.119	1.555	1.609
12	36.880	21.889	15.113	16.120	4.819	11.288
13	1.050	0.867	0.424	0.672	1.381	0.471
14	0.404	0.310	0.488	0.687	1.018	0.327

(b)Bridge Pier Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.761	16.948	17.159	15.156	15.273	16.442
2	39.851	51.826	58.273	53.833	64.103	62.911
3	2.687	3.389	3.874	7.319	8.200	3.434
4	0.408	0.593	0.243	0.435	0.369	1.075
5	0.917	0.709	0.455	0.374	0.546	0.415
6	0.483	0.598	1.082	1.350	1.958	1.216
7	0.406	0.400	0.589	0.785	0.177	0.147
8	0.054	0.308	0.182	0.303	0.	0.
9	0.323	0.242	0.754	0.360	0.602	0.450
10	0.095	0.063	0.110	0.303	0.	0.214
11	3.345	1.642	1.105	2.140	1.555	1.609
12	37.212	22.097	15.254	16.274	4.819	11.288
13	1.056	0.873	0.427	0.677	1.381	0.471
14	0.400	0.311	0.491	0.691	1.018	0.327

Table I.23. Bridge Excavation & Backfill Cost-Responsibility Factors

(a)Bridge Excavation & Backfill Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.823	16.974	17.165	15.150	15.273	16.442
2	40.043	51.905	58.292	53.811	64.103	62.911
3	2.773	3.492	3.992	7.527	8.200	3.434
4	0.421	0.611	0.251	0.448	0.369	1.075
5	0.921	0.711	0.455	0.374	0.546	0.415
6	0.486	0.600	1.098	1.358	1.958	1.216
7	0.402	0.396	0.583	0.775	0.177	0.147
8	0.055	0.309	0.182	0.302	0.	0.
9	0.323	0.244	0.753	0.358	0.602	0.450
10	0.094	0.062	0.109	0.300	0.	0.214
11	3.322	1.629	1.095	2.119	1.555	1.609
12	36.880	21.889	15.113	16.120	4.819	11.288
13	1.050	0.867	0.424	0.672	1.381	0.471
14	0.404	0.310	0.488	0.687	1.018	0.327

(b)Bridge Excavation & Backfill Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.761	16.948	17.159	15.156	15.273	16.442
2	39.851	51.826	58.273	53.833	64.103	62.911
3	2.687	3.389	3.874	7.319	8.200	3.434
4	0.408	0.593	0.243	0.435	0.369	1.075
5	0.917	0.709	0.455	0.374	0.546	0.415
6	0.483	0.598	1.082	1.350	1.958	1.216
7	0.406	0.400	0.589	0.785	0.177	0.147
8	0.054	0.308	0.182	0.303	0.	0.
9	0.323	0.242	0.754	0.360	0.602	0.450
10	0.095	0.063	0.110	0.303	0.	0.214
11	3.345	1.642	1.105	2.140	1.555	1.609
12	37.212	22.097	15.254	16.274	4.819	11.288
13	1.056	0.873	0.427	0.677	1.381	0.471
14	0.400	0.311	0.491	0.691	1.018	0.327

Table I.24. Bridge Drainage Cost-Responsibility Factors

(a)Bridge Drainage Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.823	16.974	17.165	15.150	15.273	16.442
2	40.043	51.905	58.292	53.811	64.103	62.911
3	2.773	3.492	3.992	7.527	8.200	3.434
4	0.421	0.611	0.251	0.448	0.369	1.075
5	0.921	0.711	0.455	0.374	0.546	0.415
6	0.486	0.600	1.098	1.358	1.958	1.216
7	0.402	0.396	0.583	0.775	0.177	0.147
8	0.055	0.309	0.182	0.302	0.	0.
9	0.323	0.244	0.753	0.358	0.602	0.450
10	0.094	0.062	0.109	0.300	0.	0.214
11	3.322	1.629	1.095	2.119	1.555	1.609
12	36.880	21.889	15.113	16.120	4.819	11.288
13	1.050	0.867	0.424	0.672	1.381	0.471
14	0.404	0.310	0.488	0.687	1.018	0.327

(b)Bridge Drainage Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.761	16.948	17.159	15.156	15.273	16.442
2	39.851	51.826	58.273	53.833	64.103	62.911
3	2.687	3.389	3.874	7.319	8.200	3.434
4	0.408	0.593	0.243	0.435	0.369	1.075
5	0.917	0.709	0.455	0.374	0.546	0.415
6	0.483	0.598	1.082	1.350	1.958	1.216
7	0.406	0.400	0.589	0.785	0.177	0.147
8	0.054	0.308	0.182	0.303	0.	0.
9	0.323	0.242	0.754	0.360	0.602	0.450
10	0.095	0.063	0.110	0.303	0.	0.214
11	3.345	1.642	1.105	2.140	1.555	1.609
12	37.212	22.097	15.254	16.274	4.819	11.288
13	1.056	0.873	0.427	0.677	1.381	0.471
14	0.400	0.311	0.491	0.691	1.018	0.327

Table I.25. Bridge Pile Cost-Responsibility Factors

(a)Bridge Pile Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	12.041	15.939	15.549	15.554	13.835	14.894
2	37.602	48.740	52.806	55.246	58.070	56.990
3	2.387	2.828	3.572	4.855	7.245	3.206
4	0.394	0.574	0.270	0.308	0.407	1.163
5	0.862	0.662	0.408	0.377	0.486	0.370
6	0.449	0.551	1.277	1.140	2.781	1.624
7	0.330	0.291	0.440	0.453	0.111	0.108
8	0.046	0.231	0.162	0.162	0.	0.
9	0.398	0.333	2.145	0.816	2.306	1.397
10	0.069	0.038	0.065	0.138	0.	0.111
11	2.914	1.383	0.778	1.321	1.219	1.299
12	39.917	26.035	19.988	16.980	7.992	16.674
13	1.155	1.048	0.516	0.461	1.522	0.509
14	1.437	1.347	2.025	2.190	4.027	1.653

(b)Bridge Pile Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	11.983	15.915	15.544	15.560	13.835	14.894
2	37.421	48.666	52.788	55.269	58.070	56.990
3	2.316	2.751	3.473	4.721	7.245	3.206
4	0.381	0.556	0.262	0.298	0.407	1.163
5	0.858	0.661	0.408	0.377	0.486	0.370
6	0.446	0.550	1.256	1.130	2.781	1.624
7	0.333	0.294	0.445	0.459	0.111	0.108
8	0.046	0.231	0.162	0.162	0.	0.
9	0.393	0.328	2.137	0.812	2.306	1.397
10	0.070	0.039	0.065	0.140	0.	0.111
11	2.935	1.393	0.787	1.333	1.219	1.299
12	40.245	26.218	20.129	17.084	7.992	16.674
13	1.160	1.052	0.519	0.465	1.522	0.509
14	1.413	1.346	2.026	2.189	4.027	1.653

Table I.26. Bridge Railing Cost-Responsibility Factors

(a)Bridge Railing Cost-Resp.(%) for 1983

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	5.473	7.245	7.068	7.070	6.289	6.770
2	17.092	22.155	24.003	25.112	26.395	25.905
3	2.333	3.924	5.552	8.603	13.723	6.121
4	0.441	0.844	0.433	0.519	0.689	2.016
5	0.392	0.301	0.185	0.171	0.221	0.168
6	0.466	0.797	2.129	2.138	5.339	3.210
7	0.310	0.401	0.708	0.855	0.220	0.218
8	0.030	0.204	0.172	0.212	0.	0.
9	6.640	6.866	13.744	8.242	12.373	12.074
10	0.066	0.052	0.100	0.237	0.	0.202
11	3.255	2.104	1.255	2.518	2.496	2.577
12	56.891	48.551	39.350	36.383	18.077	36.339
13	1.525	1.767	0.867	0.779	2.575	0.883
14	5.085	4.791	4.434	7.162	11.603	3.518

(b)Bridge Railing Cost-Resp.(%) for 1985/86

Vehicle Class	Int. Rural	Int. Urban	State Primary	State Second.	County Roads	City Streets
1	5.447	7.234	7.065	7.073	6.289	6.770
2	17.010	22.121	23.995	25.122	26.395	25.905
3	2.258	3.805	5.393	8.382	13.723	6.121
4	0.425	0.815	0.419	0.504	0.689	2.016
5	0.390	0.301	0.185	0.172	0.221	0.168
6	0.462	0.792	2.090	2.119	5.339	3.210
7	0.312	0.404	0.716	0.869	0.220	0.218
8	0.029	0.203	0.171	0.213	0.	0.
9	6.889	6.827	13.701	8.204	12.373	12.074
10	0.067	0.053	0.101	0.240	0.	0.202
11	3.264	2.112	1.267	2.542	2.496	2.577
12	57.173	48.751	39.575	36.596	18.077	36.339
13	1.526	1.768	0.871	0.785	2.575	0.883
14	4.750	4.813	4.450	7.183	11.603	3.518

Table I.27. Cost-Responsibility for State Highways (1983)*

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	11.303	11.303
2	1	40.460	40.460
3	1	4.591	0.377
3	2		0.214
3	3		0.641
3	4		0.651
3	5		0.352
3	6		0.982
3	7		0.709
3	8		0.280
3	9		0.385
4	1	0.223	0.223
5	1	0.384	0.384
6	1	1.267	0.207
6	2		0.144
6	3		0.105
6	4		0.129
6	5		0.051
6	6		0.058
6	7		0.071
6	8		0.103
6	9		0.401
7	1	1.486	0.041
7	2		0.049
7	3		0.072
7	4		0.106
7	5		0.116
7	6		0.211
7	7		0.239
7	8		0.297
7	9		0.356
8	1	0.119	0.119
9	1	0.527	0.017
9	2		0.510
10	1	0.153	0.027
10	2		0.033
10	3		0.040
10	4		0.052
11	1	2.256	0.053
11	2		0.099
11	3		0.205
11	4		0.118
11	5		0.108
11	6		0.336
11	7		0.121
11	8		0.153
11	9		0.126
11	10		0.153
11	11		0.180
11	12		0.203
11	13		0.403
12	1	36.035	0.022
12	2		0.086
12	3		0.327
12	4		1.093
12	5		0.560
12	6		0.586
12	7		0.248
12	8		0.373
12	9		0.616
12	10		0.667
12	11		0.363
12	12		0.469
12	13		0.622
12	14		0.680
12	15		0.756
12	16		0.968
12	17		1.240
12	18		3.402
12	19		2.177
12	20		4.024
12	21		6.224
12	22		4.882
12	23		4.310
12	24		0.917
12	25		0.174
12	26		0.249
13	1	0.741	0.115
13	2		0.142
13	3		0.110
13	4		0.078
13	5		0.078
13	6		0.016
13	7		0.028
13	8		0.015
13	9		0.015
13	10		0.027
13	11		0.017
13	12		0.044
13	13		0.054
14	1	0.458	0.056
14	2		0.109
14	3		0.294

*Costs do not include structure and enforcement costs

Table I.28. Cost-Responsibility for County Roads (1983)*

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	5.806	5.806
2	1	30.494	30.494
3	1	15.174	0.457
3	2		0.884
3	3		1.535
3	4		1.772
3	5		0.868
3	6		4.098
3	7		3.139
3	8		0.946
3	9		1.476
4	1	0.589	0.589
5	1	0.277	0.277
6	1	6.703	0.791
6	2		0.609
6	3		0.391
6	4		0.572
6	5		0.227
6	6		0.299
6	7		0.378
6	8		0.614
6	9		2.823
7	1	1.027	0.016
7	2		0.027
7	3		0.042
7	4		0.064
7	5		0.078
7	6		0.155
7	7		0.160
7	8		0.217
7	9		0.268
8	1	0.	0.
9	1	2.315	0.011
9	2		2.304
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	4.092	0.060
11	2		0.136
11	3		0.284
11	4		0.173
11	5		0.115
11	6		0.733
11	7		0.226
11	8		0.317
11	9		0.205
11	10		0.262
11	11		0.331
11	12		0.363
11	13		0.888
12	1	27.767	0.008
12	2		0.025
12	3		0.089
12	4		0.526
12	5		0.150
12	6		0.322
12	7		0.034
12	8		0.170
12	9		0.446
12	10		0.500
12	11		0.151
12	12		0.275
12	13		0.449
12	14		0.390
12	15		0.500
12	16		0.388
12	17		0.775
12	18		3.352
12	19		1.817
12	20		3.785
12	21		5.396
12	22		3.449
12	23		3.974
12	24		0.547
12	25		0.125
12	26		0.124
13	1	3.363	0.721
13	2		0.896
13	3		0.739
13	4		0.454
13	5		0.554
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	2.392	0.227
14	2		0.545
14	3		1.620

*Costs do not include structure and enforcement costs

Table 1.29. Cost-Responsibility for City Streets (1983)*

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	10.366	10.366
2	1	41.629	41.629
3	1	3.619	0.338
3	2		0.287
3	3		0.527
3	4		0.458
3	5		0.188
3	6		0.804
3	7		0.578
3	8		0.174
3	9		0.266
4	1	0.999	0.999
5	1	0.276	0.276
6	1	2.136	0.322
6	2		0.244
6	3		0.137
6	4		0.188
6	5		0.069
6	6		0.089
6	7		0.111
6	8		0.173
6	9		0.802
7	1	0.414	0.009
7	2		0.014
7	3		0.019
7	4		0.028
7	5		0.033
7	6		0.061
7	7		0.063
7	8		0.084
7	9		0.103
8	1	0.	0.
9	1	0.747	0.007
9	2		0.740
10	1	0.144	0.026
10	2		0.032
10	3		0.036
10	4		0.050
11	1	2.271	0.056
11	2		0.094
11	3		0.180
11	4		0.107
11	5		0.069
11	6		0.414
11	7		0.126
11	8		0.172
11	9		0.109
11	10		0.139
11	11		0.174
11	12		0.184
11	13		0.447
12	1	36.485	0.017
12	2		0.045
12	3		0.151
12	4		0.838
12	5		0.227
12	6		0.478
12	7		0.050
12	8		0.242
12	9		0.625
12	10		0.688
12	11		0.206
12	12		0.371
12	13		0.603
12	14		0.519
12	15		0.663
12	16		0.509
12	17		1.016
12	18		4.376
12	19		2.363
12	20		4.913
12	21		6.985
12	22		4.456
12	23		5.125
12	24		0.705
12	25		0.161
12	26		0.156
13	1	0.618	0.137
13	2		0.167
13	3		0.135
13	4		0.081
13	5		0.098
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.297	0.031
14	2		0.069
14	3		0.197

*Costs do not include structure and enforcement costs.

Table I.30. Cost-Responsibility for Bridges on State Highways (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	Sub-Group
1	1	15.468	15.468
2	1	53.114	53.114
3	1	4.165	0.629
3	2		0.295
3	3		0.840
3	4		0.631
3	5		0.374
3	6		0.619
3	7		0.415
3	8		0.150
3	9		0.213
4	1	0.277	0.277
5	1	0.598	0.598
6	1	0.950	0.197
6	2		0.128
6	3		0.085
6	4		0.090
6	5		0.039
6	6		0.049
6	7		0.050
6	8		0.050
6	9		0.261
7	1	0.453	0.038
7	2		0.036
7	3		0.042
7	4		0.056
7	5		0.042
7	6		0.050
7	7		0.075
7	8		0.061
7	9		0.054
8	1	0.175	0.175
9	1	1.154	0.033
9	2		1.121
10	1	0.126	0.036
10	2		0.036
10	3		0.029
10	4		0.025
11	1	1.627	0.082
11	2		0.099
11	3		0.237
11	4		0.118
11	5		0.121
11	6		0.210
11	7		0.112
11	8		0.107
11	9		0.093
11	10		0.088
11	11		0.107
11	12		0.102
11	13		0.151
12	1	19.624	0.034
12	2		0.118
12	3		0.408
12	4		1.504
12	5		0.770
12	6		0.707
12	7		0.343
12	8		0.399
12	9		0.692
12	10		0.631
12	11		0.363
12	12		0.396
12	13		0.535
12	14		0.512
12	15		0.544
12	16		0.587
12	17		0.628
12	18		1.278
12	19		0.847
12	20		1.358
12	21		2.743
12	22		1.998
12	23		1.674
12	24		0.378
12	25		0.071
12	26		0.106
13	1	0.549	0.111
13	2		0.125
13	3		0.064
13	4		0.045
13	5		0.036
13	6		0.010
13	7		0.026
13	8		0.013
13	9		0.013
13	10		0.024
13	11		0.013
13	12		0.036
13	13		0.036
14	1	1.739	0.075
14	2		0.343
14	3		1.321

Table L.31. Cost-Responsibility for Bridges on County Roads (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	14.537	14.537
2	1	61.016	61.016
3	1	7.126	1.174
3	2		0.419
3	3		1.491
3	4		0.853
3	5		0.486
3	6		1.222
3	7		0.864
3	8		0.222
3	9		0.396
4	1	0.314	0.314
5	1	0.603	0.603
6	1	2.460	0.419
6	2		0.299
6	3		0.165
6	4		0.165
6	5		0.069
6	6		0.122
6	7		0.122
6	8		0.135
6	9		0.963
7	1	0.116	0.009
7	2		0.009
7	3		0.009
7	4		0.012
7	5		0.010
7	6		0.016
7	7		0.016
7	8		0.018
7	9		0.018
8	1	0.	0.
9	1	2.076	0.078
9	2		1.998
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	1.096	0.070
11	2		0.070
11	3		0.157
11	4		0.079
11	5		0.045
11	6		0.178
11	7		0.069
11	8		0.069
11	9		0.039
11	10		0.039
11	11		0.063
11	12		0.063
11	13		0.154
12	1	6.303	0.008
12	2		0.017
12	3		0.050
12	4		0.379
12	5		0.084
12	6		0.174
12	7		0.016
12	8		0.064
12	9		0.224
12	10		0.200
12	11		0.055
12	12		0.083
12	13		0.179
12	14		0.134
12	15		0.148
12	16		0.099
12	17		0.166
12	18		0.602
12	19		0.312
12	20		0.557
12	21		1.211
12	22		0.664
12	23		0.747
12	24		0.090
12	25		0.020
12	26		0.020
13	1	1.132	0.340
13	2		0.340
13	3		0.226
13	4		0.113
13	5		0.113
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	3.229	0.189
14	2		0.971
14	3		2.069

Table I.32. Cost-Responsibility for Bridges on City Streets (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	Sub-Group
1	1	15.405	15.405
2	1	58.942	58.942
3	1	3.428	0.641
3	2		0.229
3	3		0.791
3	4		0.452
3	5		0.213
3	6		0.535
3	7		0.343
3	8		0.088
3	9		0.136
4	1	1.006	1.006
5	1	0.453	0.453
6	1	1.576	0.336
6	2		0.240
6	3		0.121
6	4		0.121
6	5		0.045
6	6		0.073
6	7		0.073
6	8		0.079
6	9		0.486
7	1	0.116	0.010
7	2		0.010
7	3		0.010
7	4		0.013
7	5		0.010
7	6		0.015
7	7		0.015
7	8		0.016
7	9		0.016
8	1	0.	0.
9	1	1.903	0.
9	2		1.903
10	1	0.124	0.037
10	2		0.037
10	3		0.025
10	4		0.025
11	1	1.274	0.099
11	2		0.099
11	3		0.198
11	4		0.099
11	5		0.054
11	6		0.215
11	7		0.079
11	8		0.079
11	9		0.043
11	10		0.043
11	11		0.062
11	12		0.062
11	13		0.142
12	1	14.198	0.028
12	2		0.056
12	3		0.166
12	4		1.121
12	5		0.249
12	6		0.493
12	7		0.045
12	8		0.181
12	9		0.600
12	10		0.538
12	11		0.144
12	12		0.217
12	13		0.417
12	14		0.313
12	15		0.335
12	16		0.223
12	17		0.359
12	18		1.300
12	19		0.647
12	20		1.156
12	21		2.433
12	22		1.335
12	23		1.555
12	24		0.186
12	25		0.050
12	26		0.050
13	1	0.424	0.127
13	2		0.127
13	3		0.085
13	4		0.042
13	5		0.042
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	1.351	0.047
14	2		0.226
14	3		1.078

Table I.33. Cost-Responsibility for Sign Bridges (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	11.475	11.475
2	1	41.353	41.353
3	1	5.732	0.795
3	2		0.437
3	3		0.920
3	4		0.775
3	5		0.686
3	6		0.791
3	7		0.517
3	8		0.293
3	9		0.519
4	1	0.650	0.650
5	1	0.374	0.374
6	1	1.842	0.351
6	2		0.217
6	3		0.245
6	4		0.240
6	5		0.078
6	6		0.090
6	7		0.096
6	8		0.086
6	9		0.440
7	1	0.472	0.037
7	2		0.026
7	3		0.033
7	4		0.071
7	5		0.059
7	6		0.046
7	7		0.095
7	8		0.059
7	9		0.046
8	1	0.168	0.168
9	1	0.661	0.133
9	2		0.528
10	1	0.113	0.027
10	2		0.027
10	3		0.033
10	4		0.027
11	1	2.540	0.126
11	2		0.170
11	3		0.330
11	4		0.175
11	5		0.182
11	6		0.245
11	7		0.158
11	8		0.150
11	9		0.148
11	10		0.138
11	11		0.249
11	12		0.233
11	13		0.238
12	1	33.029	0.055
12	2		0.228
12	3		0.850
12	4		2.132
12	5		1.287
12	6		0.956
12	7		0.587
12	8		0.605
12	9		0.924
12	10		0.865
12	11		0.689
12	12		0.661
12	13		1.173
12	14		1.343
12	15		1.322
12	16		1.867
12	17		1.610
12	18		2.030
12	19		1.684
12	20		2.386
12	21		3.629
12	22		3.391
12	23		1.865
12	24		0.666
12	25		0.081
12	26		0.143
13	1	1.103	0.175
13	2		0.200
13	3		0.092
13	4		0.077
13	5		0.052
13	6		0.025
13	7		0.080
13	8		0.039
13	9		0.039
13	10		0.074
13	11		0.039
13	12		0.106
13	13		0.106
14	1	0.486	0.095
14	2		0.196
14	3		0.196

Table I.34. Cost-Responsibility for Police Enforcement (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	19.124	19.124
2	1	68.921	68.921
3	1	2.666	0.506
3	2		0.278
3	3		0.585
3	4		0.493
3	5		0.245
3	6		0.282
3	7		0.131
3	8		0.074
3	9		0.072
4	1	0.164	0.164
5	1	0.623	0.623
6	1	0.692	0.223
6	2		0.138
6	3		0.088
6	4		0.086
6	5		0.028
6	6		0.023
6	7		0.024
6	8		0.022
6	9		0.061
7	1	0.196	0.024
7	2		0.017
7	3		0.021
7	4		0.025
7	5		0.021
7	6		0.017
7	7		0.034
7	8		0.021
7	9		0.017
8	1	0.107	0.107
9	1	0.091	0.018
9	2		0.073
10	1	0.040	0.010
10	2		0.010
10	3		0.012
10	4		0.010
11	1	0.688	0.045
11	2		0.061
11	3		0.118
11	4		0.062
11	5		0.065
11	6		0.087
11	7		0.040
11	8		0.038
11	9		0.037
11	10		0.035
11	11		0.034
11	12		0.032
11	13		0.033
12	1	6.385	0.020
12	2		0.081
12	3		0.303
12	4		0.761
12	5		0.459
12	6		0.341
12	7		0.210
12	8		0.216
12	9		0.234
12	10		0.219
12	11		0.174
12	12		0.167
12	13		0.162
12	14		0.185
12	15		0.182
12	16		0.258
12	17		0.222
12	18		0.280
12	19		0.232
12	20		0.329
12	21		0.501
12	22		0.468
12	23		0.257
12	24		0.092
12	25		0.011
12	26		0.020
13	1	0.224	0.044
13	2		0.051
13	3		0.023
13	4		0.020
13	5		0.013
13	6		0.006
13	7		0.011
13	8		0.005
13	9		0.005
13	10		0.010
13	11		0.005
13	12		0.015
13	13		0.015
14	1	0.075	0.024
14	2		0.027
14	3		0.027

Table I.35. Weigh Station Inspection Cost-Responsibility for Trucks (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	Sub-Group
1	1	0.	0.
2	1	0.	0.
3	1	27.156	4.912
3	2		3.040
3	3		5.901
3	4		5.025
3	5		2.638
3	6		2.791
3	7		1.329
3	8		0.818
3	9		0.705
4	1	0.	0.
5	1	0.	0.
6	1	6.212	2.049
6	2		1.134
6	3		0.932
6	4		0.824
6	5		0.224
6	6		0.191
6	7		0.217
6	8		0.200
6	9		0.441
7	1	2.826	0.398
7	2		0.265
7	3		0.291
7	4		0.319
7	5		0.305
7	6		0.277
7	7		0.388
7	8		0.305
7	9		0.277
8	1	0.	0.
9	1	0.929	0.163
9	2		0.767
10	1	0.486	0.118
10	2		0.118
10	3		0.131
10	4		0.118
11	1	5.744	0.440
11	2		0.624
11	3		1.079
11	4		0.625
11	5		0.529
11	6		0.780
11	7		0.275
11	8		0.265
11	9		0.240
11	10		0.228
11	11		0.219
11	12		0.207
11	13		0.233
12	1	54.179	0.188
12	2		0.803
12	3		3.182
12	4		6.951
12	5		3.791
12	6		2.942
12	7		1.590
12	8		1.776
12	9		1.970
12	10		1.883
12	11		1.477
12	12		1.362
12	13		1.371
12	14		1.610
12	15		1.446
12	16		2.351
12	17		1.924
12	18		2.601
12	19		1.912
12	20		2.573
12	21		4.064
12	22		3.531
12	23		2.055
12	24		0.580
12	25		0.107
12	26		0.154
13	1	1.675	0.367
13	2		0.373
13	3		0.191
13	4		0.151
13	5		0.097
13	6		0.054
13	7		0.082
13	8		0.038
13	9		0.038
13	10		0.067
13	11		0.038
13	12		0.090
13	13		0.090
14	1	0.792	0.253
14	2		0.269
14	3		0.269

Table I.36. Cost-Responsibility for State Highways (1985-86)*

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	12.439	12.439
2	1	43.225	43.225
3	1	3.564	0.317
3	2		0.212
3	3		0.505
3	4		0.553
3	5		0.346
3	6		0.635
3	7		0.453
3	8		0.237
3	9		0.308
4	1	0.214	0.214
5	1	0.475	0.475
6	1	0.986	0.181
6	2		0.117
6	3		0.101
6	4		0.118
6	5		0.046
6	6		0.047
6	7		0.057
6	8		0.074
6	9		0.245
7	1	0.991	0.038
7	2		0.038
7	3		0.055
7	4		0.078
7	5		0.086
7	6		0.131
7	7		0.171
7	8		0.185
7	9		0.209
8	1	0.118	0.118
9	1	0.489	0.025
9	2		0.464
10	1	0.110	0.021
10	2		0.024
10	3		0.031
10	4		0.035
11	1	1.993	0.049
11	2		0.090
11	3		0.207
11	4		0.117
11	5		0.133
11	6		0.249
11	7		0.110
11	8		0.128
11	9		0.126
11	10		0.149
11	11		0.168
11	12		0.180
11	13		0.288
12	1	34.205	0.025
12	2		0.113
12	3		0.442
12	4		1.228
12	5		0.779
12	6		0.635
12	7		0.381
12	8		0.448
12	9		0.576
12	10		0.612
12	11		0.454
12	12		0.512
12	13		0.599
12	14		0.735
12	15		0.787
12	16		1.209
12	17		1.297
12	18		2.563
12	19		1.938
12	20		3.285
12	21		5.478
12	22		4.995
12	23		3.652
12	24		1.050
12	25		0.151
12	26		0.261
13	1	0.837	0.098
13	2		0.120
13	3		0.105
13	4		0.082
13	5		0.063
13	6		0.032
13	7		0.051
13	8		0.023
13	9		0.026
13	10		0.046
13	11		0.029
13	12		0.073
13	13		0.090
14	1	0.355	0.050
14	2		0.088
14	3		0.217

*Costs do not include structure and enforcement costs

Table I.37. Cost-Responsibility for County Roads (1985-86)*

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	5.812	5.812
2	1	28.778	28.778
3	1	10.882	0.415
3	2		0.240
3	3		1.228
3	4		1.354
3	5		0.650
3	6		3.000
3	7		2.284
3	8		0.680
3	9		1.031
4	1	0.371	0.371
5	1	0.255	0.255
6	1	4.626	0.543
6	2		0.441
6	3		0.277
6	4		0.387
6	5		0.158
6	6		0.207
6	7		0.261
6	8		0.421
6	9		1.932
7	1	1.751	0.029
7	2		0.046
7	3		0.073
7	4		0.115
7	5		0.125
7	6		0.261
7	7		0.271
7	8		0.371
7	9		0.460
8	1	0.015	0.015
9	1	1.784	0.009
9	2		1.775
10	1	0.109	0.017
10	2		0.023
10	3		0.028
10	4		0.041
11	1	3.779	0.064
11	2		0.141
11	3		0.265
11	4		0.157
11	5		0.101
11	6		0.641
11	7		0.195
11	8		0.273
11	9		0.181
11	10		0.231
11	11		0.291
11	12		0.361
11	13		0.879
12	1	37.686	0.012
12	2		0.034
12	3		0.125
12	4		0.732
12	5		0.211
12	6		0.448
12	7		0.049
12	8		0.239
12	9		0.627
12	10		0.706
12	11		0.209
12	12		0.386
12	13		0.629
12	14		0.573
12	15		0.678
12	16		0.534
12	17		1.077
12	18		4.598
12	19		2.480
12	20		5.115
12	21		7.257
12	22		4.616
12	23		5.287
12	24		0.717
12	25		0.163
12	26		0.184
13	1	2.294	0.478
13	2		0.606
13	3		0.507
13	4		0.315
13	5		0.388
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	1.857	0.174
14	2		0.404
14	3		1.280

*Costs do not include structure and enforcement costs.

Table I.38. Cost-Responsibility for City Streets (1985-86)*

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	9.934	9.934
2	1	39.843	39.843
3	1	3.746	0.327
3	2		0.142
3	3		0.553
3	4		0.496
3	5		0.209
3	6		0.895
3	7		0.647
3	8		0.192
3	9		0.286
4	1	0.641	0.641
5	1	0.265	0.265
6	1	1.976	0.289
6	2		0.228
6	3		0.129
6	4		0.170
6	5		0.065
6	6		0.083
6	7		0.104
6	8		0.161
6	9		0.746
7	1	0.769	0.016
7	2		0.023
7	3		0.035
7	4		0.053
7	5		0.056
7	6		0.113
7	7		0.117
7	8		0.159
7	9		0.196
8	1	0.010	0.010
9	1	0.774	0.005
9	2		0.769
10	1	0.164	0.027
10	2		0.035
10	3		0.042
10	4		0.059
11	1	2.353	0.061
11	2		0.105
11	3		0.184
11	4		0.107
11	5		0.067
11	6		0.401
11	7		0.120
11	8		0.165
11	9		0.108
11	10		0.137
11	11		0.171
11	12		0.212
11	13		0.514
12	1	38.507	0.018
12	2		0.045
12	3		0.157
12	4		0.866
12	5		0.237
12	6		0.495
12	7		0.053
12	8		0.255
12	9		0.659
12	10		0.732
12	11		0.215
12	12		0.394
12	13		0.641
12	14		0.582
12	15		0.685
12	16		0.537
12	17		1.091
12	18		4.653
12	19		2.509
12	20		5.178
12	21		7.355
12	22		4.686
12	23		5.378
12	24		0.731
12	25		0.166
12	26		0.189
13	1	0.627	0.134
13	2		0.167
13	3		0.138
13	4		0.085
13	5		0.103
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.391	0.039
14	2		0.087
14	3		0.265

*Costs do not include structure and enforcement acts.

Table I.39. Cost-Responsibility for Bridges on State Highways (1985-86)

Veh Class	Sub-Group	% Responsibility Veh Class	Sub-Group
1	1	16.137	16.137
2	1	55.606	55.606
3	1	4.344	0.626
3	2		0.345
3	3		0.901
3	4		0.690
3	5		0.450
3	6		0.607
3	7		0.370
3	8		0.171
3	9		0.184
4	1	0.236	0.236
5	1	0.545	0.545
6	1	1.051	0.275
6	2		0.161
6	3		0.124
6	4		0.111
6	5		0.040
6	6		0.048
6	7		0.053
6	8		0.054
6	9		0.185
7	1	0.507	0.056
7	2		0.040
7	3		0.044
7	4		0.050
7	5		0.046
7	6		0.061
7	7		0.075
7	8		0.069
7	9		0.066
8	1	0.213	0.213
9	1	1.739	0.033
9	2		1.706
10	1	0.126	0.031
10	2		0.031
10	3		0.033
10	4		0.031
11	1	1.350	0.077
11	2		0.102
11	3		0.234
11	4		0.130
11	5		0.109
11	6		0.197
11	7		0.078
11	8		0.076
11	9		0.062
11	10		0.060
11	11		0.063
11	12		0.060
11	13		0.103
12	1	15.895	0.031
12	2		0.120
12	3		0.457
12	4		1.444
12	5		0.695
12	6		0.642
12	7		0.286
12	8		0.355
12	9		0.555
12	10		0.519
12	11		0.331
12	12		0.332
12	13		0.394
12	14		0.416
12	15		0.400
12	16		0.572
12	17		0.584
12	18		1.066
12	19		0.701
12	20		1.027
12	21		1.787
12	22		1.318
12	23		1.416
12	24		0.267
12	25		0.081
12	26		0.100
13	1	0.447	0.105
13	2		0.105
13	3		0.061
13	4		0.040
13	5		0.030
13	6		0.009
13	7		0.020
13	8		0.009
13	9		0.009
13	10		0.014
13	11		0.009
13	12		0.018
13	13		0.018
14	1	1.828	0.078
14	2		0.312
14	3		1.438

Table I.40. Cost-Responsibility for Bridges on County Roads (1985-86)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	15.039	15.039
2	1	63.124	63.124
3	1	6.958	1.206
3	2		0.430
3	3		1.618
3	4		0.925
3	5		0.478
3	6		1.200
3	7		0.671
3	8		0.172
3	9		0.258
4	1	0.251	0.251
5	1	0.622	0.622
6	1	2.124	0.455
6	2		0.325
6	3		0.152
6	4		0.152
6	5		0.071
6	6		0.099
6	7		0.099
6	8		0.112
6	9		0.659
7	1	0.120	0.010
7	2		0.010
7	3		0.010
7	4		0.012
7	5		0.009
7	6		0.016
7	7		0.016
7	8		0.019
7	9		0.019
8	1	0.	0.
9	1	2.129	0.
9	2		2.129
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	0.987	0.068
11	2		0.068
11	3		0.161
11	4		0.081
11	5		0.046
11	6		0.182
11	7		0.056
11	8		0.056
11	9		0.032
11	10		0.032
11	11		0.041
11	12		0.041
11	13		0.122
12	1	4.814	0.008
12	2		0.016
12	3		0.049
12	4		0.389
12	5		0.086
12	6		0.177
12	7		0.016
12	8		0.065
12	9		0.181
12	10		0.163
12	11		0.046
12	12		0.069
12	13		0.116
12	14		0.087
12	15		0.101
12	16		0.067
12	17		0.132
12	18		0.477
12	19		0.259
12	20		0.463
12	21		0.755
12	22		0.414
12	23		0.577
12	24		0.069
12	25		0.016
12	26		0.016
13	1	0.937	0.281
13	2		0.281
13	3		0.187
13	4		0.094
13	5		0.093
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	2.897	0.156
14	2		0.754
14	3		1.988

Table L41. Cost-Responsibility for Bridges on City Streets (1985-86)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	15.935	15.935
2	1	60.972	60.972
3	1	3.486	0.666
3	2		0.238
3	3		0.881
3	4		0.504
3	5		0.214
3	6		0.539
3	7		0.278
3	8		0.071
3	9		0.096
4	1	0.829	0.829
5	1	0.466	0.466
6	1	1.467	0.374
6	2		0.267
6	3		0.118
6	4		0.118
6	5		0.048
6	6		0.062
6	7		0.062
6	8		0.068
6	9		0.350
7	1	0.124	0.012
7	2		0.012
7	3		0.012
7	4		0.013
7	5		0.010
7	6		0.016
7	7		0.016
7	8		0.017
7	9		0.017
8	1	0.	0.
9	1	2.286	0.
9	2		2.286
10	1	0.129	0.032
10	2		0.032
10	3		0.032
10	4		0.032
11	1	1.205	0.100
11	2		0.100
11	3		0.208
11	4		0.104
11	5		0.057
11	6		0.225
11	7		0.067
11	8		0.067
11	9		0.037
11	10		0.037
11	11		0.044
11	12		0.044
11	13		0.116
12	1	11.507	0.028
12	2		0.057
12	3		0.168
12	4		1.180
12	5		0.262
12	6		0.516
12	7		0.048
12	8		0.190
12	9		0.509
12	10		0.456
12	11		0.124
12	12		0.186
12	13		0.290
12	14		0.218
12	15		0.239
12	16		0.159
12	17		0.294
12	18		1.064
12	19		0.544
12	20		0.972
12	21		1.517
12	22		0.832
12	23		1.395
12	24		0.167
12	25		0.046
12	26		0.046
13	1	0.363	0.109
13	2		0.109
13	3		0.073
13	4		0.036
13	5		0.036
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	1.420	0.040
14	2		0.204
14	3		1.176

Table 1.46. Overall Cost-Responsibility for County Road System (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	5.901	5.901
2	1	30.713	30.713
3	1	15.075	0.481
3	2		0.948
3	3		1.542
3	4		1.745
3	5		0.866
3	6		4.027
3	7		3.082
3	8		0.928
3	9		1.456
4	1	0.607	0.607
5	1	0.285	0.285
6	1	6.662	0.790
6	2		0.603
6	3		0.388
6	4		0.567
6	5		0.224
6	6		0.298
6	7		0.376
6	8		0.604
6	9		2.811
7	1	0.999	0.016
7	2		0.027
7	3		0.041
7	4		0.063
7	5		0.077
7	6		0.151
7	7		0.156
7	8		0.210
7	9		0.259
8	1	0.	0.
9	1	2.364	0.016
9	2		2.348
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	4.038	0.061
11	2		0.134
11	3		0.285
11	4		0.174
11	5		0.116
11	6		0.728
11	7		0.226
11	8		0.314
11	9		0.202
11	10		0.258
11	11		0.327
11	12		0.352
11	13		0.861
12	1	27.483	0.008
12	2		0.025
12	3		0.089
12	4		0.533
12	5		0.150
12	6		0.324
12	7		0.034
12	8		0.170
12	9		0.449
12	10		0.499
12	11		0.151
12	12		0.274
12	13		0.450
12	14		0.386
12	15		0.499
12	16		0.385
12	17		0.766
12	18		3.308
12	19		1.792
12	20		3.729
12	21		5.345
12	22		3.409
12	23		3.926
12	24		0.540
12	25		0.123
12	26		0.120
13	1	3.334	0.724
13	2		0.892
13	3		0.730
13	4		0.446
13	5		0.541
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	2.539	0.231
14	2		0.599
14	3		1.709

Table I.47. Overall Cost-Responsibility for City Street System (1983)

Veh Class	Sub-Group	% Responsibility Veh Class	Sub-Group
1	1	10.434	10.434
2	1	41.798	41.798
3	1	3.649	0.352
3	2		0.318
3	3		0.541
3	4		0.456
3	5		0.191
3	6		0.792
3	7		0.567
3	8		0.170
3	9		0.263
4	1	1.074	1.074
5	1	0.282	0.282
6	1	2.139	0.328
6	2		0.246
6	3		0.138
6	4		0.188
6	5		0.068
6	6		0.090
6	7		0.111
6	8		0.170
6	9		0.801
7	1	0.398	0.009
7	2		0.014
7	3		0.019
7	4		0.027
7	5		0.033
7	6		0.059
7	7		0.061
7	8		0.080
7	9		0.097
8	1	0.	0.
9	1	0.838	0.006
9	2		0.832
10	1	0.144	0.027
10	2		0.033
10	3		0.036
10	4		0.048
11	1	2.248	0.059
11	2		0.093
11	3		0.185
11	4		0.110
11	5		0.070
11	6		0.415
11	7		0.128
11	8		0.173
11	9		0.108
11	10		0.137
11	11		0.172
11	12		0.174
11	13		0.423
12	1	36.011	0.017
12	2		0.046
12	3		0.154
12	4		0.875
12	5		0.233
12	6		0.491
12	7		0.051
12	8		0.244
12	9		0.641
12	10		0.695
12	11		0.209
12	12		0.371
12	13		0.608
12	14		0.514
12	15		0.665
12	16		0.506
12	17		0.998
12	18		4.290
12	19		2.313
12	20		4.799
12	21		6.886
12	22		4.375
12	23		5.034
12	24		0.691
12	25		0.158
12	26		0.148
13	1	0.617	0.141
13	2		0.168
13	3		0.134
13	4		0.080
13	5		0.095
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.386	0.032
14	2		0.084
14	3		0.270

Table I.48. Overall Cost-Responsibility for State Highway System (1985-86)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	13.321	13.321
2	1	46.179	46.179
3	1	3.750	0.391
3	2		0.244
3	3		0.599
3	4		0.585
3	5		0.370
3	6		0.628
3	7		0.433
3	8		0.221
3	9		0.278
4	1	0.220	0.220
5	1	0.491	0.491
6	1	1.001	0.204
6	2		0.127
6	3		0.106
6	4		0.116
6	5		0.045
6	6		0.047
6	7		0.056
6	8		0.069
6	9		0.230
7	1	0.876	0.042
7	2		0.039
7	3		0.052
7	4		0.071
7	5		0.076
7	6		0.115
7	7		0.148
7	8		0.157
7	9		0.175
8	1	0.141	0.141
9	1	0.787	0.027
9	2		0.760
10	1	0.114	0.023
10	2		0.026
10	3		0.031
10	4		0.034
11	1	1.840	0.056
11	2		0.093
11	3		0.213
11	4		0.120
11	5		0.127
11	6		0.236
11	7		0.102
11	8		0.115
11	9		0.111
11	10		0.128
11	11		0.143
11	12		0.151
11	13		0.244
12	1	29.836	0.026
12	2		0.115
12	3		0.445
12	4		1.280
12	5		0.759
12	6		0.637
12	7		0.359
12	8		0.426
12	9		0.571
12	10		0.590
12	11		0.425
12	12		0.469
12	13		0.550
12	14		0.658
12	15		0.694
12	16		1.057
12	17		1.127
12	18		2.206
12	19		1.643
12	20		2.746
12	21		4.597
12	22		4.118
12	23		3.119
12	24		0.863
12	25		0.134
12	26		0.223
13	1	0.744	0.100
13	2		0.116
13	3		0.095
13	4		0.072
13	5		0.055
13	6		0.026
13	7		0.044
13	8		0.020
13	9		0.022
13	10		0.038
13	11		0.024
13	12		0.060
13	13		0.073
14	1	0.707	0.057
14	2		0.142
14	3		0.509

Table I.49. Overall Cost-Responsibility for County Road System (1985-86)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	6.412	6.412
2	1	32.501	32.501
3	1	13.836	0.495
3	2		0.291
3	3		1.538
3	4		1.698
3	5		0.834
3	6		3.835
3	7		2.941
3	8		0.872
3	9		1.331
4	1	0.438	0.438
5	1	0.299	0.299
6	1	6.211	0.717
6	2		0.580
6	3		0.368
6	4		0.513
6	5		0.213
6	6		0.281
6	7		0.352
6	8		0.570
6	9		2.617
7	1	0.999	0.017
7	2		0.026
7	3		0.041
7	4		0.064
7	5		0.070
7	6		0.149
7	7		0.154
7	8		0.213
7	9		0.265
8	1	0.	0.
9	1	2.543	0.011
9	2		2.531
10	1	0.	0.
10	2		0.
10	3		0.
10	4		0.
11	1	3.924	0.067
11	2		0.145
11	3		0.275
11	4		0.162
11	5		0.105
11	6		0.659
11	7		0.201
11	8		0.282
11	9		0.187
11	10		0.239
11	11		0.303
11	12		0.377
11	13		0.925
12	1	27.004	0.009
12	2		0.024
12	3		0.088
12	4		0.520
12	5		0.148
12	6		0.314
12	7		0.034
12	8		0.166
12	9		0.435
12	10		0.489
12	11		0.145
12	12		0.267
12	13		0.438
12	14		0.399
12	15		0.473
12	16		0.373
12	17		0.762
12	18		3.264
12	19		1.770
12	20		3.665
12	21		5.235
12	22		3.345
12	23		3.859
12	24		0.526
12	25		0.120
12	26		0.136
13	1	3.224	0.673
13	2		0.852
13	3		0.712
13	4		0.442
13	5		0.544
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	2.610	0.234
14	2		0.572
14	3		1.804

Table I.50. Overall Cost-Responsibility for City Street System (1985-86)

Veh Class	Sub-Group	% Responsibility Veh Class	% Responsibility Sub-Group
1	1	10.327	10.327
2	1	41.349	41.349
3	1	3.440	0.340
3	2		0.142
3	3		0.540
3	4		0.456
3	5		0.190
3	6		0.789
3	7		0.567
3	8		0.167
3	9		0.249
4	1	0.769	0.769
5	1	0.279	0.279
6	1	2.060	0.307
6	2		0.241
6	3		0.134
6	4		0.175
6	5		0.068
6	6		0.087
6	7		0.108
6	8		0.167
6	9		0.772
7	1	0.420	0.010
7	2		0.014
7	3		0.020
7	4		0.029
7	5		0.030
7	6		0.061
7	7		0.063
7	8		0.086
7	9		0.106
8	1	0.	0.
9	1	0.960	0.005
9	2		0.956
10	1	0.152	0.026
10	2		0.033
10	3		0.039
10	4		0.054
11	1	2.267	0.063
11	2		0.103
11	3		0.183
11	4		0.105
11	5		0.065
11	6		0.385
11	7		0.116
11	8		0.158
11	9		0.103
11	10		0.130
11	11		0.163
11	12		0.202
11	13		0.492
12	1	36.958	0.019
12	2		0.045
12	3		0.156
12	4		0.877
12	5		0.236
12	6		0.490
12	7		0.052
12	8		0.247
12	9		0.641
12	10		0.706
12	11		0.206
12	12		0.377
12	13		0.613
12	14		0.554
12	15		0.652
12	16		0.510
12	17		1.040
12	18		4.431
12	19		2.393
12	20		4.939
12	21		7.042
12	22		4.488
12	23		5.192
12	24		0.706
12	25		0.162
12	26		0.183
13	1	0.621	0.135
13	2		0.166
13	3		0.136
13	4		0.083
13	5		0.101
13	6		0.
13	7		0.
13	8		0.
13	9		0.
13	10		0.
13	11		0.
13	12		0.
13	13		0.
14	1	0.411	0.034
14	2		0.083
14	3		0.295

APPENDIX J

PROBLEMS OF USING CENTS PER VEHICLE-MILES OF TRAVEL AS AN INDEX FOR EXPRESSING COST-ALLOCATION RESULTS

The index cents/VMT was used in a number of cost-allocation studies to asses whether individual vehicle types were paying their fair share of cost responsibilities. This index is not adopted in this study to compare cost-responsibilities of vehicle classes and their revenue contribution because of a number of problems involved in its use.

Firstly, it is recognized that the index cents/VMT does not have a sound meaning in cost-allocation analysis. This is because not all expenditure items are functions of vehicle-miles of travel. For instance, a large portion of bridge related costs cannot be meaningfully related to vehicle-miles of travel. Consider two vehicle classes with identical percentage cost-responsibility of bridge construction cost based on individual vehicular loading consideration. When expressed in terms of cents/VMT, the vehicle class with a higher VMT would have a lower cents/VMT value. This appears to suggest that one vehicle class has a lower 'unit cost' than the other, which is actually not true. This clearly indicates that cents/VMT is a poor unit cost-responsibility measure in cost-allocation study where many expenditure items could not be allocated in direct proportion to vehicle class VMT. One must therefore be refrained from making comparison on the relative cost-responsibility of vehicle classes based on their cents/VMT values.

Secondly, since all user revenues can not be related to vehicle-miles of travel, the use of cents/VMT to measure vehicle class revenue contribution is a misrepresentation.

Lastly, the term cents/VMT, as it is being used in cost-allocation, is not uniquely defined. There are a few possible ways of computing cents/VMT cost-responsibility for vehicle classes in cost-allocation study, and each produces a different set of cents/VMT values. A simple hypothetical example is presented below to illustrate this point.

Consider a cost-allocation problem involving two highway classes and two vehicle classes. The total expenditures on highway classes 1 and 2 are $90,000 and $ 10,000 respectively, and the results of cost-allocation analysis are summarized in Table J.1.

The results in Table J.1 indicate that vehicle class A underpays by $8,000 or 13.33%, and vehicle class B overpays by $8,000 or 20.00%. A fair revenue collection scheme would require vehicle class A to increase its contribution by 13.33%, and vehicle class B to decrease by 20.00%.

Table J.2 shows four differents ways by which the same cost-allocation results may be expressed in terms of cents/VMT. Method (a) produces the same conclusion as that in Table J.1 regarding cost-responsibility. However, the resultant cents/VMT values are illogical and misleading in the sense that vehicle class A is lower in cents/VMT value than vehicle class B for both highway classes 1 and 2, yet the computed resultant cents/VMT values indicate the opposite.

Methods (b), (c) and (d) compute weighted average values of cents/VMT using different parameters as weighting factors. Method (b) concludes that both vehicle classes A and B are overpaying, whereas method (c) indicates that both are underpaying. The last method, method (d), leads to yet another conclusion: vehicle class A overpays and vehicle class B underpays.

Table J.1 Cost-Allocation analysis of Example Problem

(a) Problem data

Highway Class 1 -	Total Expenditure	\$90,000
	Total Mileage	10,000 miles
	Total VMT	10×10^6
	Vehicle Class A VMT	8×10^6
	Vehicle Class B VMT	2×10^6
Highway Class 2 -	Total Expenditure	\$10,000
	Total Mileage	20,000
	Total VMT	10×10^6
	Vehicle Class A VMT	5×10^6
	Vehicle Class B VMT	5×10^6
Revenue Contribution -	Vehicle Class A	\$60,000
	Vehicle Class B	\$40,000

(b) Cost-Allocation Results

	Highway Class 1 Cost-Responsibility	Highway Class 2 Cost-Responsibility	Total Cost-Responsibility	Total Revenue Contribution
Vehicle Class A	\$64,000	\$4,000	\$68,000	\$60,000
Vehicle Class B	\$26,000	\$6,000	\$32,000	\$40,000

The example above shows that, depending on the computational procedure adopted, the final cost-responsibility values expressed in cents/VMT can vary over a relatively wide range. Conclusions drawn from different versions of cents/VMT values also can be very different. The problem of these conflicting results is further complicated by the fact that none of the four procedures presented in Table J.2 can be claimed to be perfect, and none can be said to be completely wrong.

Based on the discussion above, it is clear that a fair and sound comparison between vehicle classes' cost-responsibilities and their revenue contribution cannot be made by expressing cost-responsibilities or revenue contribution or both in cents/VMT. It was therefore decided that the results of the present study would not be expressed in terms of cents/VMT.

Table J.2 Cost Allocation of Example Problem Expressed in Cents/VMT

(a) Total Sum Method

	Highway Class 1			Highway Class 2			Overall			
	VMT	Cost-Responsibility	Cost in Cents/VMT	VMT	Cost-Responsibility	Cost in Cents/VMT	VMT	Cost-Responsibility	Cost in Cents/VMT	Revenue in cents/VMT
Vehicle Class A	8×10^6	$64,000	0.80	5×10^6	$4,000	0.08	13×10^6	$68,000	0.52	0.46
Vehicle Class B	2×10^6	$26,000	1.30	5×10^6	$6,000	0.12	7×10^6	$32,000	0.46	0.57

(b) Weighted Average Method Based on Highway Class Mileages

	Costs in cents/VMT			
	Highway Class 1	Highway Class 2	Overall	Revenue in cents/VMT
Vehicle Class A	0.80	0.08	0.32	0.46
Vehicle Class B	1.30	0.12	0.51	0.57
Weighting Factor	0.3333	0.6667		

(c) Weighted Average Method based on Expenditures

	Costs in cents/VMT			
	Highway Class 1	Highway Class 2	Overall	Revenue in cents/VMT
Vehicle Class A	0.80	0.08	0.73	0.46
Vehicle Class B	1.30	0.12	1.18	0.57
Weighting Factor	0.90	0.10		

(d) Weighted Average Method based on Highway Class VMT

	Costs in cents/VMT			
	Highway Class 1	Highway Class 2	Overall	Revenue in cents/VMT
Vehicle Class A	0.80	0.08	0.44	0.46
Vehicle Class B	1.30	0.12	0.71	0.57
Weighting Factor	0.50	0.50		

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