ABSTRACT

This report analyzes the benefits and costs of the Kansas Comprehensive Highway Program (KCHP). The benefit-cost ratio of the program is conservatively estimated to be at least 3. In other words, the program returned at least three dollars' worth of value to Kansans for every dollar's worth of cost to Kansans.

The KCHP was a major program of highway construction and contract maintenance for the state of Kansas. It was passed by the Kansas Legislature in Spring, 1989. Major highway contracting extended from Kansas FY1990 through Kansas FY1997, but some expenditures will continue until roughly 2001. The program was directed entirely to some 10,400 miles of the Kansas State Highway System, which includes Interstate Highways, U.S. Highways, State "K"-Highways and their City Connecting Links. It did not include most city, county, and local roads.

This report has a number of distinctive technical features:

- It analyzes an entire highway program. (Previous benefit-cost analyses of transportation have generally focused on particular projects.)

- It is addressed specifically to Kansas citizens and policy-makers. Therefore, it focuses on effects of the program on Kansans only, and does not address effects of the program on citizens of the U.S. as a whole. (As such, it may be the first "open economy" benefit-cost analysis of a regional highway system [Mohring, 1993].)

- For a regional analysis of this type, multiplier effects turn out to be quite important. The report estimates multiplier effects on both the benefit and the cost side, using a "Social Accounting Matrix" model of Kansas.

- The report provides *comprehensive* benefit-cost ratios (BCRs). These ratios take all identified costs and benefits for Kansans into account. For estimating external (i.e., non-road user) costs and benefits, as well as other effects that are especially hard to measure, the report adopts a conservative or lower-bound approach that is based on extrapolations from published reports. For most of the benefits to road-users, the report develops detailed measurements using original data sources.

- The report uses a rigorous "counterfactual" analysis. In particular, it develops a fully detailed model of what would have happened on some 5,000 sections of Kansan highways over several years, if the KCHP had not been adopted.

- The report calculates benefit-cost ratios using a range of different discount rates. If a relatively low discount rate is assumed, then the comprehensive BCR could be greater than 6.

PREFACE

This research was funded by the Kansas Department of Transportation K-TRAN research program. The Kansas Transportation Research and New-Development (K-TRAN) Research Program is an ongoing, cooperative and comprehensive research program addressing transportation needs of the State of Kansas utilizing academic and research resources from the Kansas Department of Transportation, Kansas Sate University, and the University of Kansas. The projects included in the research program are jointly developed by transportation professionals in KDOT and the universities.

NOTICE

DISCLAIMER

Final Report
K-TRAN Research Project KU-97-3

BENEFITS AND COSTS OF THE KANSAS COMPREHENSIVE HIGHWAY PROGRAM

by

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and
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for

The Kansas Department of Transportation

January, 1999

(also issued as Institute for Public Policy and Business Research Report No. 250)

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ACKNOWLEDGMENTS

This research was funded by the Kansas Department of Transportation (KDOT) under its K-TRAN program and performed by the Institute for Public Policy and Business Research, University of Kansas (IPPBR). The authors of this report are David Burress and Patricia Oslund. Both authors are Research Economists at IPPBR. David Burress was the principle investigator for the study.

Charles Krider, Director of IPPBR, provided institutional management for the study and reviewed this report. His assistance and guidance are appreciated.

Many thanks are due to KDOT staff for their patience, cooperation, assistance, and feedback during this study. Dennis Slimmer, Assistant to the Director of Planning and Development, served as the main coordinator with IPPBR, was a constant source of information, and made many editorial suggestions. Reed W. Davis, Assistant to the Director of Administration, provided the KCHP Cash Flow Model and also made many editorial suggestions. Ron Balsters and Chuck Protasio of the KDOT Geometric and Accident Data Unit provided much help utilizing the CANSYS data. Ben Neaderhiser, P.E., CPMS Administrator, and Bill Roth, Manager of the CPMS Support Unit, assisted our use of the CPMS data. Helpful comments and suggestions were received from E. Dean Carlson, Secretary of Transportation, and Terry Heidner, P.E., Director of Planning and Development. Others who provided information and comments at various times included Richard McReynolds, Engineer of Research in the Bureau of Materials & Research; Rosie Ingram, Chief of the Bureau of Program Management; Dennis Gamble, Bureau of Program Management; Jim Tobaben, Chief of the Bureau of Transportation Planning; Mokhtee Ahmad, Assistant Chief of Transportation Planning; William Watts, Chief of the Office of Management and Budget; Trudy Racine, Office of Management and Budget; Susan Barker, Bureau of Construction and Maintenance; and Bernie St. Louis, Office of Engineering Support.

Special thanks also extend to the IPPBR economic modeling, data gathering and computer programming team: Alexander Barket, Programmer/Analyst; Alice Davidchuk, Graduate Research Assistant; and Irina Grigorenko, Undergraduate Research Assistant. Thelma Helyar helped with editing. Laura K. Stull and Jennifer Stewart assisted with formatting and layout.

EXECUTIVE SUMMARY

- This report provides a benefit-cost analysis for the Kansas Comprehensive Highway Program (KCHP). It shows *comprehensive* benefit-cost ratios (BCRs) from the point of view of Kansas—i.e., it ignores national benefits and costs, but takes all known Kansas costs and benefits into account. The measured BCRs were at least 3. In other words, the program returned at least three dollars' worth of value to Kansans for every dollar's worth of cost to Kansans.

- The KCHP was a major program of highway construction and contract maintenance for the state of Kansas which was administered by the Kansas Department of Transportation (KDOT). The program was directed entirely to some 10,400 miles of the Kansas State Highway System, which includes Interstate Highways, U.S. Highways, State "K"-Highways and their City Connecting Links. It did not include most city, county, and local roads.

- The KCHP was passed by the Legislature in Spring, 1989. Major highway contracting extended from FY1990 through FY1997; some expenditures will continue until roughly 2001. The major revenue sources included portions of motor fuel tax revenues, motor vehicle registration fees, and general sales and compensating use tax, as well as significant federal highway funds, and smaller amounts from other sources.

- This report focuses on effects of the program on Kansans only, and does not address effects of the program on citizens of the U.S. as a whole. It provides detailed estimates for effects of the KCHP on Kansas through calendar year 1996 (the last year for which complete data were available), and less detailed estimates for effects in subsequent years.

- This report focuses separately on two types of benefits and costs:

  - effects that can be measured with a reasonably high degree of precision (mainly retrospective road-user benefits and tax-related costs). For these items, the report provides detailed modeling and analysis.
  - effects that can be estimated within a broad range (mainly non-user costs and future benefits and costs). For these items, the report estimates conservative or lower-bound effects on the BCRs, using published information sources.

  The BCRs are broken out in further detail for each of these general types.

- From the point of view of the Kansas money economy, during the calendar years 1989-1996 (the latest years for which data were available) the most important single effect of the KCHP was to collect around $3.1 billion in state tax revenues and spend it on highway costs, and also leverage an additional $1.1 billion in federal highway funds into the state of Kansas. Additional funds were collected in subsequent years. (These totals are in current dollars, i.e., not adjusted for inflation.)

- In comparison with what would have occurred under pre-existing laws, these sums amount to about $1.6B in *additional* tax revenues and about $.2B in *additional* federal funds.

- After accounting for multiplier effects and taking present values, these *additional* financial flows from the KCHP generated about $.8M in real money income received by Kansans for each $1.0M in income lost directly and indirectly because of taxes to support the program. In other words, "Keynesian" or "pump-priming" income benefits of the KCHP by themselves contribute a benefit-cost ratio (BCR) of about .8. Note that these income benefits are in addition to other benefits of the program, especially the use-value of having good highways.

- This report provides detailed modeling for the following types of non-income benefits to users of Kansas highways:

  - time savings and operating cost savings due to improved roads and reduced congestion
  - changes in injuries due to accidents
  - changes in property damage due to accidents
  - changes in fatalities due to accidents
  - changes in riding and driving comfort on Kansas highways
  - the residual value of benefits due to improved highways after 1996 (the last year of complete data in our model).

- These benefits were estimated using computer modeling and statistical analysis over some 45,000 observations of detailed sections of Kansas state and US highways during 1990-1996. Models were constructed that showed conditions both with and without the KCHP.

- It was found that the KCHP led to a very large amount of time saving, and this was the most important type of benefit to road users. By 1996, aggregate time spent traveling on state and federal roads in Kansas had been cut by 15 percent by the KCHP (as compared with what would have happened under the pre-existing highway program). While various types of highway improvements were important, the single most important improvement was the increased quality of the pavement and roadbed (and in particular, avoiding the deterioration that would have occurred without the KCHP).

- By 1996 the value of this time saving exceeded $.5 billion per year. In present value terms, the value of time saving for 1990-1996 was between $.8 billion and $1.5 billion, depending on the discount rate. During that period of time, about $.85 million in travel-time benefits were realized per $1 million of direct and indirect costs expended on the KCHP - i.e., the contribution to the BCR was around .85. Additional travel time benefits from past KCHP construction will continue to accrue in the future.

- In present value terms, the KCHP was estimated to reduce vehicle operating costs during 1990-1996 by about $.2 billion.

- In present value terms, the net effect of the KCHP on accidents, injuries, and fatalities during 1990-1996 just about broke even.

- The KCHP was estimated to cause a reduction of about 10,000 accidents and about 2000 injuries during 1989-1996. Fatality accidents decreased at first but then increased, as speeds increased relatively to the counterfactual world.

- The KCHP did in fact create substantially safer driving conditions. However, without the KCHP, roads would have deteriorated significantly, and it is estimated that, as a consequence, traffic would have slowed down substantially. The safer conditions made possible by the KCHP did lead to a reduction in numbers of accidents. But, as a result of the increased speeds at which drivers drove, fatalities were more likely to occur for a given accident. As time wore on, highway users increasingly chose to consume their improved roads largely in the form of higher speeds and reduced non-fatal accidents, leading to reduced travel times, even at the cost of a relative increase in fatalities per accident. (In each case we are comparing actual conditions with an estimate of the conditions that would have existed in the absence of the KCHP.)

- The most important single component of the BCR was the residual value of user benefits, i.e., the value of future benefits for highway users accruing after 1996. This item by itself probably contributes a BCR of 2 or more. The value is large because it includes all of the measured user benefits lumped together and totaled over a very long time span extending after 1996. This value is rather sensitive to the assumed discount rate, and to other assumptions as well, and could be much larger than 2.

- The value of improvements in riding and driving comfort was estimated using a new survey of highway users. It was found to have a positive but rather small effect on the BCR.

- After accounting for financial or "Keynesian" costs and benefits as well as the user benefits listed above, the KCHP was found to have a BCR conservatively estimated to be at least 3.

- However, these figures account for only some of the benefits and costs of the KCHP. This report also provides a much more complete picture by looking at non-user costs and benefits (i.e., externalities or "spillovers" to persons who aren't using the highways). This is done in a less formal way, based on a review of the literature. In particular, the report examines items such as:

  - effects on air, water, and noise pollution in Kansas
  - effects on urban sprawl and adverse effects on individuals from induced land-use changes
  - effects on costs of delivering other government services
  - effects on productivity in Kansas
  - effects on economic development in Kansas.

- While these additional effects can not be measured with the same precision as user benefits, it is possible to estimate lower bounds for more comprehensive benefit-cost ratios that include all of these effects. These lower bounds for comprehensive benefit-cost ratios (of approximately 3) turn out to be not much different from the BCRs that omit these externalities.

- The comprehensive BCR is rather sensitive to the assumed discount rate. If a low discount rate is assumed (e.g., well below 5%/year), the BCR could be higher than 6.

1. INTRODUCTION

This report provides a Benefit-Cost Analysis for the Kansas Comprehensive Highway Program (KCHP). In other words, it compares the consequences of the KCHP with what would have happened had the KCHP not been adopted. The main purpose is to provide benefit-cost ratios (BCRs) for the program as a whole. BCRs measure the quality of a program. Conceptually, if and only if the BCR is greater than 1, then benefits exceed costs and the program has made Kansas as a whole better off on net.

But it is really not enough for a BCR to exceed 1; it is important that all programs adopted by government should have relatively high BCRs. Governments have limited resources and must choose between many different program alternatives; they cannot do everything they would like to do. Therefore, at least conceptually, governments should implement only those programs with the highest available BCRs. In practice, BCRs do not give a complete picture of all relevant policy issues, so they cannot be used as the sole criterion for selecting projects. However, it is generally unwise to adopt a program when its BCR is known to be less than 1; conversely, a program known to have a very high BCR does make a very strong claim on a policy-maker's attention.

What is the KCHP?

The Kansas Comprehensive Highway program, or KCHP, was a major expenditure program of the State of Kansas which was administered by the Kansas Department of Transportation (KDOT). The emphasis of the KCHP was on the Kansas State Highway System (which includes Interstate Highways, U.S. Highways, State “K”-Highways and their City Connecting Links). These roads constitute roughly 10,400 miles of roadway. Kansas has another 122,000 miles of city, county and local roads that benefitted from increased revenues provided by the legislature to the Special City Highway Fund. However, neither these roads nor the increased revenues made available for them are considered in this study.

House Bill 2014 that enacted the KCHP was passed by the legislature and signed into law in 1989. Major highway expenditures began in FY1990 (i.e., July 1989 through June 1990), and will continue until roughly 2001. However, the program came to a formal end in FY1997 when the last major projects were let to contract. The program provided for bonding, allowing expenditures to precede the receipt of tax revenues. There was a basket of taxation sources. The major revenue sources include 59.5 percent of the motor fuel tax revenues (motor fuel taxes were raised by 7 cents per gallon in steps during FY1990-93), motor vehicle registration fees, a portion of the existing sales tax, and a .25 percent general sales and compensating use tax. Revenues for the program also included significant federal highway funds.

Expenditures included both construction and major contract maintenance (but routine maintenance performed directly by KDOT was not viewed as part of the program). For a further breakdown, see Tables 2.1 and 2.2.

What types of costs and benefits?

Two types of costs and benefits are described in detail in this report, including:

- financial impacts due to taxes and expenditures, both those realized in the past and those expected in the future; and
- major user benefits that were realized in the past, as well as those user benefits expected to be realized in the future.

Note that somewhat different techniques must be used to estimate two different kinds of costs and benefits:

- those that were experienced by Kansans in the past, i.e., "retrospective" or "ex post" benefits and costs.
- those that will be experienced by Kansans in the future, i.e., "prospective" or "ex ante" benefits and costs, due to KCHP investments made in the past. (Because 1996 was the last year for which complete data were available at the time of this study, events for 1997 and subsequently are treated in this report as part of "the future.")

This report provides original estimates for the following types of benefits to users of Kansas highways:

- reductions in injuries due to accidents
- reductions in property damage due to accidents
- reductions in fatalities due to accidents
- time savings due to improved roads and reduced congestion
- the value of increases in travel comfort, and reductions in operating expenses for wear and tear on vehicles.

These benefits were estimated using computer modeling and statistical analysis over some 45,000 observations of detailed sections of Kansas state and US highways during 1989-1996. Dollar values were placed on these user benefits using conventional benefit-cost models as described in Chapter 3.

This report also provides a more complete picture by looking in more qualitative terms at non-user (i.e., "external") cost and benefits, and extrapolates to Kansas some results that have been found in other studies. In particular, it examines methods for evaluating:

- effects on air, water, and noise pollution in Kansas
- effects on urban sprawl and adverse effects on individuals from induced land-use changes
- effects on costs of delivering other government services
- effects on productivity in Kansas
- effects on economic development in Kansas

- effects at the time of construction
- effects on fairness and equity between citizens

as well as several smaller items.

While these non-user effects cannot be measured with the same precision as user benefits, it is possible to estimate lower bounds for comprehensive benefit-cost ratios that do include these effects.

Benefits to whom?

This report focuses on effects of the program on Kansans only. The purpose of the report is to assist Kansans in making highway policy decisions; in particular, it helps them understand what policies would be in the best interests of Kansans. Kansas policy-makers may wish to take effects of highways on the rest of the world into account as well; but it is not the purpose of this report to provide such information.

The benefit-cost ratios measured in this report are higher than ratios reported in some other studies of highways in the U.S. The main reason has to do with the point of view: most other studies focus on the U.S. as a whole.

Focusing on Kansas leads to a lower cost denominator because a significant portion of the costs of Kansas highways are borne by Federal highway monies.[1] In addition, some portion of Kansas fuel taxes are paid by non-Kansans who happen to be driving through Kansas. The same goes for other Kansas tax sources.

Because non-Kansans use Kansas highways, focusing on Kansas leads to a smaller benefits numerator as well. But as it turns out, focusing on Kansas reduces the costs proportionately more than the benefits. That is true mainly because of the effects of leveraging federal highway funds.

We have not found any previous empirical examples of state-oriented benefit-cost analyses of highways. However, Mohring [1993] discusses the theoretical underpinnings for a region-oriented benefit-cost analysis of transportation systems. There have been several state-oriented benefit-cost analyses in the general area of economic development policy, including Burress and Oslund [1994, 1998]; Feller and Anderson [1994]; Samaza [1970].

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[1] It is true that the source of this money does include some federal taxes paid by Kansans. Moreover, federal taxes paid in Kansas roughly approximate the federal dollars leveraged by the KCHP. However, in a technical sense, federal taxes are not viewed as a "cost" of adopting the KCHP, because adoption of the KCHP did not lead to substantial changes in the amount of federal taxes paid in Kansas. This point is explained in more detail in the discussion of the counterfactual below.

Compared to what?

The benefit-cost analysis of any government program is a comparison between the actual world which includes that program, and a hypothetical world lacking that program. The hypothetical world in which the program does not exist is referred to as the "counterfactual" world. For the benefit-cost study to be accurate and complete, the counterfactual world must be accurately modeled in all of its relevant aspects. Sometimes this modeling is done only implicitly, but studies based on merely implicit counterfactual models are prone to making theoretical errors. In this study, the counterfactual world is described and modeled explicitly.

This study is a *differential benefit-cost analysis*, comparing worlds as they would be with and without the KCHP. In the counterfactual world assumed in this study:

- The KCHP was not adopted by the legislature, and as a result there was very limited construction, and maintenance of highways in Kansas was limited mainly to maintenance performed in-house (referred to as "routine" maintenance). In particular, the contract maintenance (or, as it is sometimes called, "substantial maintenance") program was shut down after 1991.
- As a result, state taxes were not increased by the new revenues that would have been designated for the KCHP.
- As a result, in some cases federal highway matching grants were reduced due to the state's inability to provide matching funds.
- As a result, the reduced taxes had positive multiplier effects on the state economy.
- In addition, the reduced construction and contract maintenance expenditures (reflecting lost federal matching grants as well as reduced state expenditures) had negative multiplier effects on the state economy.
- Highways and bridges were allowed to deteriorate at their usual rate with limited maintenance and no reconstruction. (According to a KDOT model, funds would have been sufficient to carry out planned contract maintenance programs only through 1991.)
- As a result of deteriorated roadways (and the absence of redesigned roadways), accidents and fatalities increased and travel times lengthened.
- As a result of having worse roads, transportation was less productive, and there may have been less economic development in Kansas.
- However, it is assumed that certain variables did not change significantly within Kansas. These constant variables include:
  - miles traveled and destinations of travel (but specific routes chosen *did* change. A justification for this assumption is given in Chapter 3 below.)
  - dollars spent on police, fire, vehicle registration, and the traffic-related criminal justice system. (However, civil justice costs are included in the costs of accidents and fatalities and *did* change.)
  - the total cost and amount of parking and garaging.
  - the share borne by Kansans of national and global costs such as those related to the strategic petroleum reserve, defense of the Middle East, global warming and climate change.
  - federal highway taxes paid by Kansans. These taxes were constant because miles traveled did not change.

We define the *net benefits* (i.e., benefits less costs) of the KCHP as the set of all differences between this counterfactual world so defined, and our actual world in which the KCHP was carried out according to plan. We may look at one or another specific dimension of impact, such as real income or jobs or tax revenues (real income is used in traditional benefit-cost studies), but in each case we measure the net effect of the KCHP on that dimension by comparing its value in the actual world with its value in the counterfactual world. For example:

> Net income benefits = aggregate real Kansas household income in the actual world, less aggregate real Kansas household income in the counterfactual world.
>
> Net job benefits = aggregate Kansas jobs in the actual world, less aggregate Kansas jobs in the counterfactual world.

Both the actual and counterfactual world are modeled as extending across time, from the past and into the future. However, most comparisons are made in terms of discounted present values, as described below.

Note that the "net benefit" concept does not actually distinguish costs from benefits; they are all lumped together. In fact, it is possible to do an entire benefit-cost study without ever separating costs out from benefits. Indeed, when competing alternative projects are being compared in a world of perfect knowledge, the best possible plan is to select, from among all feasible projects, that set of projects which has the highest possible *net* benefit, among all combinations of projects that fit within the given budget.[2]

However, it is traditional in many situations to look at benefit-cost ratios (BCRs) rather than net benefits. That provides a convenience, because the BCR describes the quality of the project, independently of the scale or size of the project. Net benefits, on the other hand, depend on the size of the project as well its quality. Consequently, comparisons of net benefits across projects that are not in direct competition with each other for budget dollars do not make much sense. BCRs, on the other hand, allow us to establish some absolute standards of quality which allow us to compare projects in different times and places, even when they are paid for out of different budgets and have differing sizes or scales.

Unfortunately, the concepts of "cost" and "benefit" are theoretically difficult, because a range of alternative definitions is possible. Moreover, the various alternative definitions have different properties (i.e., changing the concepts can change the measured BCRs). The precise cost and benefit concepts used in this report are somewhat technical; they are described in Appendix 1.

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[2] This statement assumes that all possible benefits and costs can be measured accurately and then reconciled into a single dimension of measurement, such as "generalized income." In the real world, we have neither sufficient information nor sufficient political consensus on relative values to make such a determination with any degree of accuracy. Therefore, a real benefit-cost analysis is always an incomplete basis for decision which has to be supplemented with other kinds of information.

The "one dollar - one vote" assumption

As in many conventional benefit-cost studies, this report focuses mainly on the aggregate income dimension of costs and benefits. In other words, the net benefit to society or "social welfare" is measured based on a principle of "one dollar, one vote." This approach creates some conceptual difficulties.

First, some types of benefits and costs, such as reduction in accidents or increases in travel time, cannot be traded on conventional markets. Therefore, they do not have established market values. Various valuation models are used for these goods; the underlying assumption of all of these valuation models is that all goods should be evaluated in terms of the maximum amount of money that people would typically be willing to pay so as to obtain those goods (assuming they could be required to pay before enjoying the benefits).

Second, and more fundamentally, the "one dollar - one vote" principle ignores the distribution of effects across types of persons. For example, it assumes that a dollar has the same social value when given to a rich person as when given to a poor person. A literature review has shown that a substantial majority of benefit-cost theorists probably disagree with that assumption [Burress and Rich, 1997], but there is no consensus on how to remedy the situation. (We will address this issue briefly in Chapter 5.)

A related problem is that effects on real income by themselves are not the only economic impact issues that matter to policy-makers. Impact studies quite commonly produce information on jobs and tax revenues as well as income. Other issues that are significant but less commonly addressed include the geographical and social distributions of income. These issues are not addressed in detail in this report.

The "lower-bound" approach

In many cases, specific assumptions were needed to handle difficult measurement questions. We have attempted in general to make conservative assumptions, meaning that we are reasonably confident at each step that we are not significantly overstating the benefit-cost ratios. In other words, the BCRs in this report are intended to reflect lower-bound estimates on the true benefits, and upper-bound estimates of the true costs, of the KCHP.

This report is comprehensive, in the sense that it address *all* of the costs and benefits of the KCHP that we have been able to identify. However, not all items are addressed in equal detail or with equal accuracy. In the main body of the modeling described in Chapters 2 through 4, we attempt to provide point estimates that are the best estimates we can easily provide for the relevant costs and benefits, adopting conservative assumptions only when absolutely necessary. However, in the later parts of the report we address a number of items that are more speculative or controversial or difficult to measure; in all those cases we provide lower-bound measures rather than point estimates. The final goal of the report is to provide a lower bound on the comprehensive benefit-cost ratio of the KCHP, as well as point estimates for some of its components.

KDOT data

This report used four major computerized data sources that were made available by KDOT:

1. Cash Flow Model. A spread sheet model of cash flows of the KCHP has been constructed by Reed W. Davis, Assistant Director of Administration, KDOT. This model is reproduced for the years FY1990-1996 in Appendix 2. (This model is cited in the text as "KCHP Cash Flow Model.") In addition, Davis produced a model of what cash flows would have been in the counterfactual world, had the KCHP not been adopted.

2. CPMS, or Comprehensive Program Management System [documented in KDOT, 1997]. This dataset contains a historic record of transactions at the project level, among other elements. Ben Neaderhiser, P.E., CPMS Administrator, and Bill Roth, Manager of the CPMS Support Unit, provided data extracts and assisted with interpretation of the data. (This dataset is cited in the text as "CPMS.")

3. CANSYS, or Control Section Analysis System [documented in Vogel, 1994]. The CANSYS dataset is updated continuously, but a "snapshot" of the dataset is taken annually. Our study worked with annual records for 1989 through 1996. This data set consists of about 45,000 main records, plus a rather larger number of sub-section records. Each record provides detailed information on a section of state highway in a particular year. Ron Balsters of the KDOT Geometric and Accident Data Unit provided data extracts and assisted with interpretation of the data. (This dataset is cited in the text as "CANSYS.")

4. A model showing what contract maintenance projects would have been completed in the absence of the KCHP.

An additional important source is a KDOT-sponsored study of the pattern of expenditures made by contractors for Kansas state highway construction and contract maintenance projects [Babcock *et al.*, 1996].

Non-KDOT data

A variety of published and computerized data sources were consulted. The most important were:

1. KSSAM version 3.0 is a multisectoral model of the state of Kansas constructed by IPPBR. It is a relatively conventional multiplier model based on a Kansas "social accounting matrix" (or SAM, meaning a table showing flows of dollars between all parts of the economy). This model analyzes dollar flows in the Kansas economy into 49 business sectors, eight household sectors (depending on sources and amounts of income), and four government sectors, plus exogenous imports and final demands, for a total of 62 sectors. Capital expenditures are distinguished from operating expenditures. For each sector, the model contains parameters showing how it affects every other sector, using a total of some 6,000 parameters. These parameters were boiled down from approximately 20,000 published data items. Using these parameters, this model can analyze the total

effect in dollar terms on each sector that would result from dollars flowing into a given sector from outside Kansas. (KSSAMv3 is presently documented in internal IPPBR technical notes but not in a published report. For documentation on an earlier KSSAMv2, see Burress and Oslund [1994].)

2. An original survey of willingness to pay by Kansans for comfortable roads, conducted by the Survey Research Center at IPPBR in 1997.

3. The HERS model, or Highway Economic Requirements System, Version 2. This model was developed by Jack Faucett Associates for the Federal Highway Administration [USDOT Federal Highway Administration 1995, 1996]. A review of computerized models for benefit-cost analysis of highways convinced us this was the best available model for our purposes. It provides a set of functional modules which can be used for performing a prospective benefit-cost analysis; the analysis can be used to select between and prioritize alternative highway plans. Most importantly, the equations and dollar values used in the modules are well documented and are based on authoritative surveys of engineering and economics literature. However, the modules necessarily cover only those effects which have been studied in detail in the published literature. Equations and evaluation assumptions taken from some of these modules were adapted for use in the present study, including in particular:

- pavement deterioration model
- vehicle speed model
- vehicle operating cost model
- values of travel time
- value of accidents, injuries, and fatalities.

Modeling activities

Several new and interrelated computerized models and submodels were developed by IPPBR in the course of this study. These models include:

1. A spreadsheet model of Keynesian effects. This model is described in Chapter 2.

2. A data linking model, showing how highway sections in CANSYS are linked in time and space. This as well as several of the following models are described in Chapter 3.

3. A pavement deterioration model. This model implements a version of the HERS sub-model for pavement smoothness.

4. An accident model for Kansas highways. This regression model predicts how traffic and physical road conditions affect the number of accidents, injuries, and fatalities in Kansas.

5. A "counterfactual CANSYS" model, estimating what the CANSYS data set would have looked like if the KCHP had not been adopted.

6. A welfare change model. This model calculates the value of user benefits from the KCHP. In particular, it calculates differences in travel times, traffic, accidents and fatalities between the actual CANSYS data set and the "counterfactual" CANSYS data set, places dollar values on these differences, and calculates the present values.

7. A model of future benefits of the KCHP, which is described in Chapter 4.

8. A non-user cost and benefits model. This spreadsheet model places lower bounds on certain benefits and upper bounds on some external costs of the KCHP that are relatively hard to measure. This model is described in Chapter 5.

Discounting over time

In benefit-cost analysis, it is necessary to compare streams of benefits and costs that vary over time. Comparing benefits and costs in the future with benefits and costs experienced today is conventionally done using discounting. In other words, a real dollar's worth of value for a particular person delayed N years into the future is described as having the same value as $1/(1+R)^N$ real dollars' worth of value for that person in the present. R is referred to as the "real discount rate." Taken by itself, this is *not* an assumption—rather, it is simply one way of expressing the loss of value that the given person associates with a displacement of a valuable service in time.[3] In theory, R could depend on the person, on the number of years in the future (N), on the particular type of cost or benefit item being discounted, and even on the year in which the evaluation is being performed.

However, in the context of benefit-cost analysis, we conventionally make four important assumptions so that the discounted values can actually be calculated. In particular we assume:

1. R is constant for any number N of years in the future.
2. R is constant for all different particular types of benefits and costs.
3. R is constant for all times at which an evaluation might occur.
4. There is some empirical or political way to determine an average value of R which can be taken as a constant across all relevant persons (i.e., Kansans) who receive benefits or bear costs.

The discount rate R adopted under these assumptions is referred to as "the social discount rate."

The benefit-cost literature is filled with models and controversies about what value should be placed on R (e.g., see Lind [1982]). In this report we will not assume a particular value; instead we will mainly rely on a sensitivity analysis, using values of 1 percent, 5 percent, 10 percent, and 15 percent. These values bracket the values that generally appear in the literature.

A discount rate as low as 1 percent is not very plausible; it implies that voters view benefits that would be received 100 years into the future by entirely different and unknown persons as possessing

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[3] If there is no loss in value, then R equals zero. If there is a *gain* in value, then R is negative.

at least 1/3 the value of similar benefits received by the voters themselves today. There is overwhelming evidence that people on average value benefits of all kinds much lower when received in the distant future than when received in the present.

On the other hand, very high discount rate are equally implausible. A discount rate of 15 percent, for example, implies that benefits received 10 years in the future are worth about only one-fifth as much as the same benefits received today. The fact that a majority of people do save money even when interest rates are much less than 15 percent implies that they discount the future at less than 15 percent per year.

Hence, we do not view the extreme values of 1 percent and 15 percent as very plausible; they are reported so as to provide a complete sensitivity analysis. Most theoretical studies suggest a value in the 5 percent to 10 percent range. Some environmentalists have argued for lower rates in the range of 2-4 percent, on the grounds that we have strong ethical obligations to future generations; while this argument does have theoretical merit, in a practical sense no empirical basis has been given for selecting any particular ethically-based discount rate.

It will be clear in the subsequent results that the BCRs generally fall as the discount rate rises. That is the normal pattern for infrastructure investment; it happens because the benefits are experienced at a later time than the costs. By choosing a sufficiently high discount rate, benefits received in the future can always be discounted down to a point where they no longer justify costs borne in the present.

Accuracy

We have provided estimates of statistical or sampling errors whenever possible, but we are unable to estimate overall modeling errors. The models we used are based on many sources, most of which do not provide any means for estimating total modeling errors. Even in cases where the models originate with us, the only really convincing way to estimate modeling error would be to perform experimental physical tests, an approach far beyond our means. Our general sense of the data, however, is that modeling errors are generally small in comparison to the effects of choice of discount rate. Indeed, as we shall see, changing values of the discount rate between the two extremes of plausibility would change the measured BCR by at least a factor of two.

In our tables throughout, totals may not add due to rounding.

Time frames

The reader of this report will encounter a large and potentially confusing collection of references to years. These references are necessarily complex for a number of reasons:

- Legislation enacting the KCHP was signed into law in the Spring of 1989. This report takes the point of view of a hypothetical policy-maker at the time those decisions were being made. In particular, all present values of revenues, expenditures, and other monetary values are taken as of 1989.

- The data on dollar values were reported in nominal dollars that were subject to inflation over time. Whenever possible, we have translated all dollars into 1996 real dollars. The year 1996 was selected as the reference year for price levels because it is the most recent year for which we have full data. (Recent price levels are more meaningful to readers than older price levels.)
- Kansas fiscal data were generally reported by Kansas fiscal year. The fiscal year for a given year corresponds to July of the previous year through June of the named year. However, data from other sources were generally by calendar year. Also, data from the CANSYS system consisted of snapshots of the state highway dataset as of December of the named year, based on data collected over the course of a year.
- We have adjusted all fiscal year data into a calendar year basis. Also, we have adopted the convention that numeric years without a modifier refer to calendar years; fiscal years are given an FY prefix.
- The KCHP is formally defined as the highway program of the period FY1990 through FY1997. However, complete data were available for this study only through (calendar) 1996. Therefore, many of the tables are evaluated for 1989-1996 or 1990-1996 rather than through 1997. However, in a few cases we developed average parameters using data for 1990-1997 so as to be more representative of the entire KCHP experience.
- Fiscal impacts were analyzed in detail for calendar 1989-1996. User benefits were analyzed in detail for 1990-1996 (because no significant user benefits were created in calendar 1989).

Roadmap of the report

Chapter 2 describes financial flows in the state of Kansas resulting from the KCHP, and analyzes the effects of those flows on household income during calendar 1989-1996.

Chapter 3 describes the models of user benefits and estimates their effects on household welfare during 1990-1996.

Chapter 4 summarizes the two kinds of effects (Keynesian and User benefits), estimates the value of riding and driving comfort, and projects these several effects into the future.

Chapter 5 reviews literature on non-user benefits and external costs and discusses what effect they would be likely to have on the benefit-cost ratio.

Chapter 6 draws some policy conclusions.

Appendix 1 describes the cost and benefit concepts in more theoretical detail.

Appendix 2 provides the data utilized in the KCHP Cash Flow Model.

Appendix 3 describes in technical terms an economic model of travel demand that is used in constructing the counterfactual model.

Appendix 4 describes in technical terms the model that was used for evaluating the “residual” or “salvage” value of the KCHP after 1996.

Appendix 5 describes a telephone survey instrument that is used to help evaluate the willingness to pay that automobile drivers have for comfortable and easy driving conditions, over and above all other concerns.

2. FINANCIAL AND KEYNESIAN IMPACTS

In this chapter we take the point of view of the Kansas financial or money economy (while ignoring the innate value of having good roads), and we look at the calendar years 1989-1996. Within that frame, the most important effect of the KCHP was to raise around $3.1 billion in state tax revenues and spend it on highway costs, and also leverage an additional $1.1 billion in federal highway funds into the state of Kansas. (These totals are in current dollars, as estimated using data from the KCHP Cash Flow Model.) Some additional cash flows were generated by bonding in the early years of the program. Major contracting under the KCHP continued into FY1997, and highway-related tax revenues will continue after 1997; however, 1996 was a convenient stopping point for analyzing retrospective impacts of the program, because that was the last year for which we had complete data of all types.

At the same time, in the counterfactual world under previously existing laws, the State of Kansas would have raised about $1.5 billion in taxes, and received about $.9 billion in federal funds. The effects calculated below refer to *differences* between the two worlds, amounting to about $1.6 billion in additional taxes and about $.2 billion in additional federal funding, which resulted from the KCHP. (The difference in federal funds resulted from a failure to fully raise the matching state funds required under the federal highway program.)

These dollar flows were paid or received by businesses and governments as well as by Kansas households. Therefore, they do not directly represent effects on "welfare" or well-being, which is conventionally measured in terms of real disposable household income. Effects on household income can be calculated from these cash flows in two steps.

In the first step, "direct effects" on the economy are calculated by categorizing all government taxes, transfers, and expenditures by the type of private market agent that is directly affected. These categories include wages and salaries received and taxes paid by households, categorized into Kansas and non-Kansas households; and purchases received and taxes paid by business, categorized by the type of business and by Kansas and non-Kansas location.

In the second step, "indirect effects" are estimated. These effects include the second round of expenditures, as well as subsequent rounds, that happen after new money is injected into the Kansas economy by government expenditures; in other words, it includes the effects of purchases out of wages and salaries, as well as purchase of inputs to production by businesses. Taxes also have indirect effects on the economy, for example, because reductions in disposable income lead to reduction in purchases by households. Moreover, all of the second round indirect effects lead to third round effects, and so on.

This chapter describes the effects of these various dollar flows on Kansas households. Because this chapter focuses solely on the financial effects of spending highway dollars, without asking about the inherent usefulness of the highways purchased by those dollars, and because it employs a version of the income multiplier (which was first introduced by John Maynard Keynes), this chapter can be described as a "Keynesian" impact analysis of the KCHP.

The structure of the Keynesian impact model

Keynesian effects of the KCHP were estimated through the following steps.

1. The KCHP Cash Flow Model

The cash flow model provided a starting point which shows estimates of "past" (i.e., through 1996) and "future" (i.e., after 1996) revenues and expenditures for the KCHP, broken out into various accounts by fiscal year. The revenue accounts are distinguished by types of taxes, federal revenue sharing, and proceeds of bond sales. The expenditure accounts are distinguished by types of construction, contract maintenance, and engineering contracts, KDOT agency expenditures, transfers to local agencies, and debt service. (The entire model for FY1990-1996 is shown in Appendix 2.)

2. Converting to real and calendar year terms

All dollar flows were adjusted by deflators and converted from fiscal year into calendar year terms.

3. Reallocating into intermediate accounts

The expenditure accounts were reallocated into six categories of construction contracts defined in KDOT's previous study of highway construction impacts [Babcock *et al.*, 1996], plus other expenditures such as direct wages and salaries. These categories are listed in Table 2.1. The purpose of this step was to make use of Babcock's survey data showing detailed sectoral expenditures made by highway contractors, as described in the next step.

To help us reallocate cash flow accounts into Babcock accounts, with the help of KDOT we analyzed all expenditure records in the CPMS dataset, which contains detailed information on KDOT project transactions. Each transaction was cross-classified in terms of year and Babcock type. Some results from this analysis are shown in Table 2.2. It was found that the shares of expenditures for the various types did not undergo large changes from year to year. (The table shows that the weighted average of variations over time for a given expenditure share is about 29 percent, which is small in comparison to differences between the sizes of the different shares.) Therefore, as a simplification we assumed that those shares were constant across time.

4. Reallocating intermediate accounts into detailed sectoral demands

Using data from the Babcock study, we re-expressed the expenditures in terms of second-round payments made by the contractors to each of 51 detailed sectors (e.g., households, mineral mining, plastic materials, service stations, restaurants, etc.).

5. Reallocating detailed sectoral expenditures from Babcock sectors into KSSAMv3 sectors

The sector scheme used by Babcock differs somewhat from the sector scheme used in KSSAMv3. We used various data to re-estimate the expenditures made by contractors in terms of our own sector scheme.

6. Correcting for effects on non-Kansans

Using KSSAMv3 data, we estimated what share of purchases from each sector were likely to have been made from out-of-state firms. We also estimated what share of tax revenues were likely to have been paid by non-Kansans. In addition, we made assumptions about the effects of bonding and federal highway funding on Kansans, as follows:

- It was assumed that bond markets are national in scope, so that bonds issued in Kansas do not significantly affect interest rates enjoyed by Kansas investors.

- It was assumed that federal highway funds are fixed in amount, so that the failure of Kansas to claim its share would not lead to any reduction of federal taxes in Kansas; instead, it would merely lead to increased highway funds flowing to other states.

7. Multiplying by KSSAM multipliers

Using the KSSAMv3 model, we estimated the indirect effects and total (direct plus indirect) effects of the KCHP on each of 60 sectors in Kansas, including 8 types of households.

8. Taking present values

We discounted the various cash flows over time, using discount rates of 1%, 5%, 10%, and 15%.

9. Calculating B, C, NB, and BCRs

We calculated benefits, costs, net benefits, and benefit-cost ratios for the time period of 1989-1996 for each of the four discount rates.

Results

Table 2.3 shows BCRs by discount rate and time period.

Table 2.4 shows present values of benefits and costs, in 1996 dollars. We remind the reader that these numbers refer only to benefits received and costs paid by Kansans, so that much of the cost of the program is not accounted for in this table. Note that present values are less than the total across all years because of discounting back to 1989.

Table 2.1
Categories of Project Expenditures

I. Babcock categories of construction and contract maintenance

Category	Highway Improvement Type
1	Resurfacing
2	Restoration and Rehabilitation; Reconstruction and Minor Widening
3	New Bridges and Bridge Replacement
4	Major and Minor Bridge Rehabilitation
5	New Construction; Relocation; Major Widening
6	Safety/Traffic Operations/Traffic Systems Management; Environmentally Related; Physical Maintenance; Traffic Services

II. Categories for non-construction non-contract maintenance expenditures

Abbreviation	Highway-related activity
Agency Salaries	KDOT salaries other than PE/CE
PE/CE	Preliminary Engineering and Construction Engineering, both in KDOT and on contract
Other costs	KDOT non-salary expenses

Source: Babcock et al. [1996], p. 2. See op. cit., Appendix A, for more detailed definitions.
CPMS. Note: not all KCHP expenditures are identified with specific projects.

Table 2.2
Annual Project Expenditures by Type as a Share of Total: FY1990-1997

Expenditure type	mean	Expenditure shares standard deviation (by years)	coefficient of variation
Babcock 0	0.012	0.007	0.597
Babcock 1	0.208	0.068	0.329
Babcock 2	0.455	0.075	0.164
Babcock 3	0.050	0.015	0.311
Babcock 4	0.030	0.016	0.521
Babcock 5	0.068	0.056	0.814
Babcock 6	0.001	0.001	1.106
Agency Salaries	0.061	0.018	0.297
PE/CE	0.059	0.016	0.264
Other Costs	0.056	0.021	0.372
Sum	1.000		
Average		0.029	0.478
Weighted average			0.293

Source: IPPBR
(Calculated from the CPMS data base.)

Table 2.3
Benefit-Cost Ratios for Pure Keynesian Effects on Kansans: 1989-1996

Discount Rate	1%	5%	10%	15%
Benefit-cost Ratio	.85	.82	.79	.75

Source: IPPBR

Table 2.4
Benefits, Costs, and Net Benefits for Pure Keynesian Effects on Kansans: 1989-1996

Discount Rate	1%	5%	10%	15%
NPV Benefits	$1.5B	$1.2B	$.9B	$.7B
NPV Costs	$1.7B	$1.4B	$1.1B	$.9B
NPV Net Benefits	-$.2B	-$.2B	-$.2B	-$.2B

Source: IPPBR

Discussion

After accounting for multiplier effects and imports and exports of taxes and expenditures to non-Kansans, and after taking present values using moderate discount rates, we find that, during 1989-1996, financial flows from the KCHP probably generated about $.8 million in direct and indirect income received by Kansans for each $1.0 million in direct and indirect taxes paid by Kansans to support the program.

Calculated from the point of view of the year 1989 when the KCHP program was adopted by the legislature, discounted real costs to Kansans including multiplier effects were between $.9B and $1.7B (depending on the discount rate and measured in 1996 dollars). Again, this refers to *additional* costs of the KCHP as compared with taxes that would have been paid under the previous laws. It takes into account reductions in the cost figure due to tax exporting and the taking of present values, as well as increases in the cost figure due to inflating the earlier figures to 1996 dollars and taking Keynesian multipliers into account.

Discounted gross benefits under the same conditions were between $.7B and $1.5B. Discounted net benefits were around -$.2B. In other words, state decision makers could reasonably have expected Keynesian effects of the program to have net fiscal effects on Kansas households roughly the same in value as losing about $.2B worth of goods and services in 1989. This is a relatively small sum of money in comparison with the total dollar flows that are involved. In other words, the program comes close to being justified based on its Keynesian pump-priming effects alone.

We reiterate the fact that this calculation omits the value of benefits that result from having good roads, which is the main point of the KCHP. Those benefits are the subject of the next two chapters.

3. RETROSPECTIVE ROAD USER BENEFITS

The term "user benefits" refers to the direct effects of highway construction and contract maintenance activities on individuals who utilize roads. These benefits can be negative as well as positive. For example, under the cost concept described in Appendix 1, negative effects of construction activities on travelers would be viewed as negative benefits rather than as positive costs.

This chapter estimates "retrospective" benefits, meaning those that have already occurred, for the period 1989-1996 only. Prospective benefits for the years 1997 and subsequently are estimated in Chapter 4.

This chapter will examine the quantity and value of selected types of user benefits that could be measured with a reasonably high degree of precision. These benefits are:

- time savings due to improved roads and reduced congestion
- operating cost (fuel, vehicle maintenance, etc.) savings due to road conditions
- reductions in property damage caused by accidents
- reductions in fatalities caused by accidents
- reductions in injuries caused by accidents.

Chapter 4 will examine one additional user benefit using models that are considered to be less reliable than those used in this chapter, namely:

- changes in riding and driving comfort on Kansas highways.

Chapter 5 will discuss several additional user benefits (as well as costs) in a more qualitative fashion.

The general structure of the user benefit model

The user benefit model consists of two large datasets plus a spreadsheet model, structured as follows:

1. The augmented actual CANSYS dataset. This dataset includes all of the CANSYS data on highway sections used in this study, plus additional information about each section that is derived from various component models. For example, modeled data were constructed which show average travel speeds and travel time on each section.

2. The counterfactual CANSYS dataset. This dataset contains a detailed model of what the augmented CANSYS dataset would have looked like if the KCHP had not occurred.

3. User benefit analysis spreadsheets. These datasets contain summary information on differences in physical quantities between the actual and counterfactual CANSYS datasets. These differences are

estimates of the qualitative user benefits of the KCHP. For example, the spreadsheets contain information on differences in traffic counts, accidents, roadway miles, and travel time. The spreadsheets also contain information on the dollar values that are placed on the various physical differences, so that a welfare analysis can be performed. Finally, the spreadsheets calculate present values of the various welfare changes that resulted from the KCHP.

The main component models

These three main datasets depend on a number of component sub-models, including the following:

1. Data linking for CANSYS. This model reconstructed all connections between some 5,000 Kansas highways sections, both in time and space.

2. An economic model of the demand for travel in the counterfactual world.

3. A pavement deterioration model. This model implements a version of the HERS sub-model for pavement smoothness.

4. A model of traffic speed.

5. Accident models for Kansas highways. These regression models show how traffic and physical road conditions affected the number of accidents, injuries, and fatalities in Kansas during 1989-1996.

These component models as well as other models are described in more detail below.

Data linking for CANSYS

The data-linking model addressed two technical problems in using the CANSYS dataset:

- Some roadways could be rerouted, and new roadways could be created, so that physical locations and lengths of routes could change over time.

- Some section records could be subdivided into multiple section records from one year to the next, as a result of physical or jurisdictional changes occurring on part but not all of the section.

As a result of these changes over time, section records in the counterfactual CANSYS dataset do not always correspond to the same sections in the actual CANSYS dataset. That leads to a problem in making comparisons: which counterfactual highway section(s) should be compared to a given actual section? Moreover, what constitutes a saving in travel time?; i.e., which traffic or which route can be considered "the same" traffic or route in the two worlds?

To resolve these issues, we defined sets of records we called “supersections.” A supersection is a minimal set of records in the actual CANSYS dataset with a starting point and an ending point that stayed constant in space from 1989 through 1996 (even though interior points might change or multiply in number). The definitions of sections in the counterfactual dataset were based mostly on sections as they existed in 1989; therefore, supersections with the same starting and ending points could generally be defined in both worlds. In a few cases where completely new roads were created in the actual world, we assumed that traffic was evenly redistributed from existing highways in the same county. The supersection linking allowed us to compare values in the counterfactual world with those in the actual world, even when definitions of sections changed.

All welfare comparisons were conducted between supersections. We assumed, roughly, that all traffic on a supersection traveled straight through from the starting point to the ending point. Therefore, any reduction in travel time or accidents on that stretch of road constituted a welfare gain.

Modeling the demand for travel

Important issues in the benefit-cost analysis of transportation are raised by the changes in traffic that are induced by changes in transportation facilities. These changes are of two kinds: first, old traffic is diverted from one route or mode to another as a result of changes in relative comfort or travel time. Second, new traffic is created when reductions in discomfort cause fewer people to stay home, or when increases in travel speed mean that people are able to travel further in the same period of time. The important conceptual issues this raises are:

1. The amounts of these changes in traffic are hard to estimate. In particular, in the absence of extensive origin-destination modeling, there is nothing in the CANSYS data that can reliably show how traffic responds to changes in average aggregate road conditions.

2. The welfare values that should be assigned to these changes in traffic are also hard to estimate. However, the unit value of reduced accidents and the unit value of travel time saving for new traffic is believed to be less than that for old traffic. In particular, some of the value of the change was used up in inducing the new traffic to make a change. At most, the new traffic was on the verge of changing anyway, so that the welfare values are almost the same as for old traffic. At least, the new traffic was barely willing to change at all, so that the welfare values are almost zero. The usual rule of thumb is that induced traffic should be assigned ½ the welfare value that old traffic gains from the highway program.

Actually, estimating the induced traffic at the level of individual highways would require an entirely separate origin-destination model of Kansas, which was judged to be beyond the scope of this study. Instead, we made the following simplifying assumptions:

1. In each county in each year, each section in the counterfactual world had the same relative traffic density it had in 1989. (In other words, that section's share of total county traffic is constant over time.)

2. In each county in each year, the aggregate vehicle miles of traffic are the same in the counterfactual world as in the actual world. (In other words, the demand for aggregate distance traveled is almost perfectly inelastic with respect to unit travel times and accident rates, under the observed conditions.)

An economic model sketched in Appendix 3 shows that assumption 2 can be theoretically consistent with utility maximization under a budget constraint. It is also consistent in a very rough way with international long-run aggregate traffic data for all modes of travel [Schafer and Victor, 1997]. These data show that differences in per capita income across 12 regions of the world are vastly more important in determining aggregate travel distance per capita than all other differences, including differences between regions and differences across time. (Differences between regions and across time would include all operating-cost, time-cost, and accident-cost effects, as well as all non-cost-related cultural differences.)

However, less aggregated studies do typically find substantially negative price or travel-time elasticities of highway travel, which would contradict assumption 2. These studies generally have to do with changes in traffic on a single route when it is improved. Some of these changes involve entirely new trips that otherwise would not have been undertaken, but other changes consist in traffic diverted from one route or transport mode to another. New trips would be of limited importance in our study because state roads are predominantly rural and predominantly used for longer-than-average trips, which are less sensitive to travel time change than short trips. Diverted traffic would be of limited importance to aggregate demand, because any diverted vehicle traffic would be likely to remain on state roads, while alternative modes of transport were generally not available for the times and routes being studied. In any case, elasticities of demand on a single route (which is what are usually measured) are not directly applicable to the needed elasticity of aggregate demand for all state routes (except as outer bounds).

In addition, the relevant elasticities for our study would be short-run rather than long-run elasticities, because the main study horizon was 1990-1996, with many of the major highway changes not coming on line until the later part of that time period. Short-run elasticities are expected to be noticeably smaller than long-run elasticities for theoretical reasons (i.e., because optimal adjustment depends on making new capital investments); this has been supported by empirical findings. In particular, Moore and Thorsnes [1994, Appendix B; cited in Litman, 1998] classify short-run travel-time elasticities as "low," defined as 0.0 to -.5.

For all of these reasons, we believe that the appropriate aggregate travel-time elasticities would likely be rather small. Therefore, aggregate induced traffic very probably constituted a rather small share of total traffic under the conditions of the KCHP. We did not try to model aggregate induced traffic directly because we did not find any closely relevant studies or datasets that could be adapted (the international comparisons cited above are the closest available analogy we found). The constant aggregate traffic model was judged to be adequate for our current purposes. We reiterate, however, that it will tend somewhat to overstate the benefits received by induced traffic.

Modeling Kansas residency

To conduct a state-oriented benefit-cost analysis, it was necessary to correct user benefits for the estimated share that did not accrue to residents of the state. To accomplish that allocation, benefits to all vehicles were assumed to belong 50% to the state of origin, and 50% to the state of destination, of the vehicle trip.

In addition, benefits to trucks were assumed to be enjoyed in proportion to ton-miles driven. Using 1993 data from the USDOT Bureau of Transportation Statistics [1997a], it was found that only 51% of ton-miles on Kansas highways were due to trips of Kansas origin and destination. (Murphy and Delucchi [1998] and Chin, Hopson, and Hwang [1998] reached similar results using the same data augmented with other sources.)

Benefits to cars were assumed to be allocated in proportion to passenger-miles driven. Based on modeling using additional data from the USDOT Bureau of Transportation Statistics [1997b, c], it was estimated by IPPBR that approximately 90% of passenger-miles on Kansas state highways were due to trips originating and terminating in Kansas. (In the case of both trucks and cars, trips between Kansas and other states were weighted so that 50% of the benefit was attributed to Kansas.)

Modeling traffic speed and valuing time

The traffic speed model was adapted from the HERS version 2 model. Detailed equations are given in USDOT Federal Highway Administration [1996]. In general terms, average speed on a section is the minimum of: posted speed limit plus 5 mph; a model of speed limited by curves; a model of speed limited by stop lights and stop signs; a model of speed limited by pavement conditions; a model of speed limited by grade. (Some of the sub-models take traffic congestion into account.)

Posted speed limits in each section were modeled in the counterfactual world as equal to those in the corresponding actual world. (On supersections that changed physical location over time, we used the average speed limit on the supersection.) In cases where travel time differences became important, the counterfactual was generally limited by pavement deterioration, not by posted speed limits.

Aggregate travel times were calculated for each section for each vehicle class by multiplying numbers of vehicles in that class by the length of the section, divided by the traffic speed. Using our assumption that total miles traveled in the counterfactual world were equal to total miles traveled in the actual world, the total travel time benefit could be calculated as the difference between the state-wide total travel time in the actual and counterfactual worlds. The overall travel time savings due to the KCHP are shown in Table 3.1. Results have been corrected for Kansas residency.

The improvements in travel time due to the KCHP are estimated to have been very substantial. Overall, speed in the actual world rose from an average of 53.5 mph to 57.5 mph between 1989 and 1996, mainly because of increases in the speed limit in 1996. In the counterfactual world in the same time period, despite the higher speed limits speed fell to 48.4 mph due to roadway deterioration. Therefore, speed differences between the actual and counterfactual amounted to about nine miles per hour by 1996. Most of this difference was due to the deterioration in pavement conditions that would have occurred in the absence of the KCHP. There were also speed gains in the actual world that resulted from improvements in road design brought about by the KCHP.

Table 3.1
Estimate of Travel Time Savings Due to the KCHP
Adjusted for Share of Travel by Kansas Residents

Year	***Vehicle Type***						
	Car and 4-tire Truck Hours	6-tire Truck Hours	3-4 Axle Sing. Unit Hours	4-axle Comb. Hours	5+ axle Comb. Hours	Total Hours	Difference in Average Speed (mph)
1990	3,976,138	69,911	57,595	584	230,860	4,335,088	1.2
1991	9,215,464	177,890	159,470	1,777	631,207	10,185,809	2.7
1992	7,819,820	179,960	150,260	1,521	604,968	8,756,529	2.3
1993	10,465,862	216,898	185,540	15,425	750,232	11,633,957	3.0
1994	13,524,456	306,656	225,255	14,796	898,705	14,969,867	3.5
1995	22,975,129	490,522	599,033	19,381	1,500,632	25,584,697	5.7
1996	36,638,431	783,050	758,772	24,528	2,436,337	40,641,119	9.1
TOTAL	104,615,299	2,224,887	2,135,926	78,011	7,052,942	116,107,065	

Source: IPPBR, based on KDOT data

Using values of travel time taken from the HERS model, these time savings can be translated into dollar equivalents. The dollar values are adjusted into 1996 dollars, and do *not* include operating costs of the vehicle. Present values of the dollar savings were calculated using four different discount rates. The results are shown in Table 3.2

Using a moderate level for the discount rate (10%), the present value as of 1989 of time saving for Kansas due to the KCHP was about $950 million. That amount is approximately 85 percent of the present value of the cost to Kansans, as described in the previous chapter. In other words, pure time savings alone are high enough to justify about 85 percent of the taxpayer cost of the KCHP.

Modeling and estimating costs of vehicle operation

In addition to affecting travel time, changes in road conditions affect fuel usage and wear and tear on cars and trucks. The HERS model contains detailed equations that estimate operating costs by type of vehicle. The estimates are in 1988 dollars, which were updated to 1996 values. The main variables in the equations are speed, pavement condition, and grade. To generalize, higher speed (within the normal operating range) increases operating costs, while better pavement conditions reduce operating costs.

Table 3.2
Net Value of Travel Time Savings on Kansas State and Federal Highways
Adjusted for Share of Travel by Kansas Residents

Year	*Vehicle Type*					
	Car and 4-tire Truck	**6-tire Truck**	**3-4 Axle Sing. Unit**	**4-axle Comb.**	**5+ axle Comb.**	**TOTAL**
$ per hour (1996)	$11.89	$13.48	$25.32	$32.17	$32.35	
1990 ($M)	47.3	0.9	1.5	0.0	7.5	57.2
1991 ($M)	109.5	2.4	4.0	0.1	20.4	136.5
1992 ($M)	93.0	2.4	3.8	0.0	19.6	118.8
1993 ($M)	124.4	2.9	4.7	0.5	24.3	156.8
1994 ($M)	160.8	4.1	5.7	0.5	29.1	200.2
1995 ($M)	273.1	6.6	15.2	0.6	48.5	344.1
1996 ($M)	435.5	10.6	19.2	0.8	78.8	544.9
Present Value (15%)	617.9	14.8	26.1	1.2	113.7	773.7
Present Value (10%)	765.8	18.4	32.7	1.5	140.8	959.2
Present Value (5%)	966.3	23.2	41.7	1.9	177.5	1,210.6
Present Value (1%)	1,180.4	28.5	51.3	2.4	216.6	1,479.1

Source: IPPBR
Note: values in 1996 dollars. Per hour values from HERS model, US DOT.

Operating costs were estimated for the actual world (with KCHP improvements), and then again for the counterfactual world (in which the pavement was in much worse condition and speeds were much lower). For cars, the KCHP results in substantial operating cost savings. For trucks, the results are slightly ambiguous, depending on type of truck. This is understandable because the reduced speeds due to rougher pavement in the counterfactual world could lead to lower fuel consumption and maintenance costs per mile. In aggregate, truck operating costs also show a general improvement due to the KCHP.

The overall operating cost benefits for the seven-year period analyzed depends on the discount rate. For a discount rate of 10 percent, savings due to KCHP amount to over $170M.

Table 3.3
Operating Cost Savings Due to KCHP

Year	Vehicle Type: Car and 4-tire Truck	6-tire Truck	3-4 Axle Sing. Unit	4-axle Comb.	5+ axle Comb.	TOTAL
1990 ($M)	12.9	0.5	1.3	0.0	6.6	21.2
1991 ($M)	38.1	1.6	3.7	0.1	16.6	60.1
1992 ($M)	47.2	2.4	4.2	0.0	22.1	75.8
1993 ($M)	45.5	1.4	3.6	0.9	20.6	72.0
1994 ($M)	4.3	-0.9	-0.7	0.6	3.1	6.3
1995 ($M)	5.8	-1.3	9.0	0.6	-2.2	12.0
1996 ($M)	32.0	-0.4	8.1	0.7	17.6	58.0
Present Value (15%)	89.9	2.2	12.1	1.1	40.9	146.2
Present Value (10%)	104.4	2.4	14.7	1.4	47.5	170.3
Present Value (5%)	122.8	2.5	18.2	1.7	55.9	201.1
Present Value (1%)	141.5	2.5	22.0	2.1	64.3	232.4

Source: IPPBR. Based on HERS model.

Modeling and valuing accidents, injuries, and fatalities

The CANSYS database provides actual counts of accidents, injuries, and fatalities. However, we needed estimates of what accidents, injuries, and deaths would have been like in a counterfactual world, in which many of the KCHP improvements did not take place. This required us to construct a predictive statistical model of accidents, injuries, and fatalities based on information about road and traffic conditions. Technically, we implemented a Poisson regression model. The Poisson model is appropriate for estimating the number of events (such as accidents) that take place randomly on an interval (such as a vehicle mile). We estimated predictive parameters for "accidents per 100,000 vehicle miles," "injuries per accident," and "fatalities per accident."

We started with a list of factors that potentially affect accidents, injuries, and fatalities. We mapped these factors to variables from the CANSYS data set. Included were:

1. Type of road. We divided highways into four categories: two-lane undivided, four-lane undivided, four-lane divided, and six or more lane.
2. Daily truck traffic.
3. Total daily traffic (cars plus trucks).
4. Daily cross-traffic per mile of highway.
5. Pavement condition (pavement structural index, or PSI).
6. Average effective speed. We calculated speed using equations from the Highway Economic Requirements System (HERS) model of the U.S. Department of Transportation. The model

of speed takes into account pavement condition, curves, speed limits, signal lights, and other factors.

7. Speed limited by curves. We used this as a proxy for the number and degree of curves on a road segment.
8. Number of passing restrictions per mile. This is applicable only for the two-lane highways.
9. Access control. This variable indicates whether access is totally restricted, partially restricted, or not restricted. It is especially relevant for the four-lane divided highways, where there is a mixture of access types.
10. Volume to capacity ratio. This is a measure of average congestion.
11. Outside shoulder width.
12. Year. For example, accidents may show a trend over time. In addition, "year" captures the effect of variables such as weather that are not explicit to the model.

With the exception of car traffic, *all* of the above factors proved to be statistically significant in explaining accidents for at least some of the road types examined (with p=.05 or better). (Car traffic is redundant with total traffic and truck traffic.) However, given that an accident had taken place, only pavement condition, speed, amount of truck traffic, and passing restrictions proved significant in explaining injuries and fatalities.

Regression Results

Tables 3.4 through 3.7 show the results of the accident, injury, and fatality regressions. The regressions are broken into four sets: two-lane undivided highways, four-lane undivided highways, four-lane divided highways, and highways with six or more lanes.

In all of the regressions, dummy variables for the years 1990 through 1996 capture time trends, weather conditions, and any other explanatory factors not explicitly included in the equations. The dummy variables are usually statistically significant in the total accidents regressions but may or may not be significant in the regressions for fatalities and non-fatal injuries. (The data are for 1989-1996; the intercept terms correspond to the year 1989 effects.)

For two-lane undivided highways, higher cross-traffic, more passing restrictions, higher speed, and higher congestion tend to increase the accident rate per 100,000 vehicle miles. Higher "speed limited by curves" (a variable inversely related to extent of curves), higher pavement structural indexes, larger outside shoulder widths, and higher truck traffic all tend to decrease the accident rate per 100,000 vehicle miles. The result for truck traffic has the "wrong" sign and is puzzling. It may be the case that the higher truck traffic is acting as an additional indicator of a better quality road rather than as a direct causal variable for accidents, in which case this particular equation may be somewhat biased.

Given that an accident has taken place, higher speed and more truck traffic contribute to the chance that the accident will be fatal on two-lane highways. A higher pavement structural index reduces the probability of a fatality. Passing restrictions along with speed and truck traffic help explain non-fatal injuries.

Four-lane undivided highways comprise a fairly small portion of the state highway system. On these roads, cross-traffic, curves, ratio of traffic volume to capacity, pavement index, and shoulder width help predict total accidents. Speed is the only significant variable that helps prediction of the rate of fatalities once an accident has occurred. Speed and pavement index help predict non-fatal injuries.

Four-lane divided highways have slightly different explanatory factors. Access control is important for four lane divided highways. Totally restricted access reduces accident rates. Passing restrictions are not relevant on divided highways. Cross traffic, total traffic, curves, pavement index, and shoulder width are significant explanatory variables in the regression for total accidents. Speed and pavement index help predict fatalities and non-fatal injuries once an accident has happened.

Cross-traffic, trucks, curves, the ratio of volume to capacity, pavement index, and outside shoulder width affect the rate of accidents on six lane highways. However, once an accident has occurred, none of the potential explanatory variables adds additional explanation for the rate of fatalities or non-fatal injuries on these roads.

Table 3.4
Regressions for 2 Lane Undivided Highways

Table 3.4A
Total Accidents: 2 Lane
Estimates of log(accidents per 100,000 vehicle miles)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-0.0094128	0.0297358
Year 1990	-0.0156609	0.0159001
Year 1991	-0.0246368	0.0160292
Year 1992	-0.0327103	0.0163835
Year 1993	0.0891041	0.0156094
Year 1994	0.0495192	0.0155002
Year 1995	0.0586305	0.0154654
Year 1996	0.1262271	0.0157342
Cross Traffic	0.0000057	0.0000003
Passing Restrictions	0.0054042	0.0009021
Trucks/day	-0.0005749	0.0000173
Speed limited by curves	-0.0238074	0.0007051
Average speed	0.0056277	0.0010881
Volume to capacity	0.0048534	0.0002001
Pavement index	-0.0093174	0.0008838
Outside shoulder	-0.0455451	0.0012716

Table 3.4B
Fatalities: 2 Lane
Estimates of log(fatalities per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-7.7362254	0.3391843
Year 1990	-0.0956779	0.1161669
Year 1991	-0.0733877	0.1165206
Year 1992	-0.0833535	0.1200042
Year 1993	-0.0297183	0.1125902
Year 1994	-0.2641086	0.1169822
Year 1995	-0.2831962	0.1168629
Year 1996	-0.6214912	0.1190679
Trucks/day	0.0007037	0.0000856
Average speed	0.0700274	0.0060191
Pavement index	-0.0124719	0.0073853

Table 3.4C
Non-fatal Injuries: 2 Lane
Estimates of log(non-fatal injuries per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-1.9577953	0.0481659
Year 1990	-0.0213604	0.0282216
Year 1991	-0.1308726	0.0291938
Year 1992	-0.0986456	0.0289418
Year 1993	-0.1890182	0.0286460
Year 1994	-0.2265192	0.0288147
Year 1995	-0.3075979	0.0292352
Year 1996	-0.3031180	0.0285333
Trucks/day	0.0003763	0.0000234
Average speed	0.0122735	0.0007859
Passing Restrictions	0.0045385	0.0017873

Table 3.5
Regressions for 4 Lane Undivided Highways

Table 3.5A
Total Accidents: 4 Lane Undivided
Estimates of log(accidents per 100,000 vehicle miles)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	0.6897543	0.0374646
Year 1990	-0.0421203	0.0218967
Year 1991	-0.0773351	0.0218647
Year 1992	-0.1259010	0.0220129
Year 1993	0.0188156	0.0212450
Year 1994	-0.0349912	0.0216433
Year 1995	-0.0228455	0.0213427
Year 1996	-0.0648249	0.0215473
Cross Traffic	0.0000010	0.0000002
Pavement index	-0.0050344	0.0007673
Speed limited by curves	-0.0372758	0.0007963
Volume to capacity	0.0060510	0.0003464
Outside shoulder	-0.0304849	0.0032193

Table 3.5B
Fatalities: 4 Lane Undivided
Estimates of log(fatalities per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-8.3570171	0.6399233
Year 1990	-0.1264501	0.4743495
Year 1991	-0.1451849	0.4743540
Year 1992	-0.2438023	0.4929052
Year 1993	-0.1620796	0.4751706
Year 1994	0.6265408	0.3989832
Year 1995	-0.6667220	0.5479621
Year 1996	0.0254101	0.4472927
Average Speed	0.0598894	0.0138576

Table 3.5C
Non-fatal Injuries: 4 Lane Undivided
Estimates of log(non-fatal injuries per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-1.6470369	0.0715734
Year 1990	-0.1418366	0.0432753
Year 1991	-0.1900078	0.0437055
Year 1992	-0.2583078	0.0449855
Year 1993	-0.3693294	0.0448204
Year 1994	-0.2638383	0.0442777
Year 1995	-0.3371904	0.0444327
Year 1996	-0.2890485	0.0442946
Average Speed	0.0127096	0.0015466
Pavement Index	-0.0033676	0.0016832

Table 3.6
Regressions for 4 Lane Divided Highways

Table 3.6A
Total Accidents: 4 Lane Divided
Estimates of log(accidents per 100,000 vehicle miles)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	0.2546715	0.0350732
Year 1990	-0.0457879	0.0172520
Year 1991	-0.0448506	0.0173474
Year 1992	-0.1721293	0.0179042
Year 1993	0.0705399	0.0167972
Year 1994	-0.1005108	0.0171465
Year 1995	-0.0769589	0.0168395
Year 1996	-0.0044980	0.0166368
Access Control	-0.5346302	0.0134588
Cross Traffic	0.0000035	0.0000002
Daily Traffic	0.0000157	0.0000007
Speed Limited by Curves	-0.0261068	0.0006118
Pavement Index	-0.0028300	0.0007027
Shoulder Width	-0.0425319	0.0015074

Table 3.6B
Fatalities: 4 Lane Divided
Estimates of log(fatalities per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-6.7789463	0.3290814
Year 1990	0.0173211	0.1749492
Year 1991	-0.6203822	0.2096381
Year 1992	-0.3285905	0.2000339
Year 1993	-0.5292158	0.1948688
Year 1994	-0.3410815	0.1889350
Year 1995	-0.3506399	0.1831286
Year 1996	-0.2708248	0.1733768
Speed	0.0514509	0.0062224
Pavement Index	-0.0213934	0.0113837

Table 3.6C
Non-fatal Injuries: 4 Lane Undivided
Estimates of log(non-fatal injuries per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-1.2908708	0.0461368
Year 1990	-0.0839731	0.0317232
Year 1991	-0.1700676	0.0326205
Year 1992	-0.1819430	0.0339612
Year 1993	-0.1989112	0.0318036
Year 1994	-0.1444933	0.0319802
Year 1995	-0.2066029	0.0318448
Year 1996	-0.1494814	0.0309445
Speed	0.0076694	0.0008759
Pavement Index	-0.0068274	0.0016050
Trucks/day	-0.0000831	0.0000156

Table 3.7
Regressions for 6 or More Lane Divided Highways

Table 3.7A
Total Accidents: 6 Lane Divided
Estimates of log(accidents per 100,000 vehicle miles)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	0.6250237	0.0697278
Year 1990	-0.2095607	0.0337146
Year 1991	-0.0783488	0.0331680
Year 1992	-0.1276009	0.0340543
Year 1993	0.0738351	0.0320456
Year 1994	-0.2164831	0.0324289
Year 1995	-0.2098312	0.0319992
Year 1996	-0.1250420	0.0320065
Cross Traffic	0.0000052	0.0000002
Trucks/day	-0.0000778	0.0000126
Speed limited by curves	-0.0182589	0.0008729
Volume to capacity	0.0018503	0.0002700
Pavement Index	-0.0321328	0.0018118
Shoulder Width	-0.0424091	0.0026974

Table 3.7B
Fatalities: 6 Lane Divided
Estimates of log(fatalities per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-4.9751410	0.2773501
Year 1990	-0.2955768	0.4336291
Year 1991	-0.6301354	0.4688072
Year 1992	-1.1385035	0.5717636
Year 1993	-0.8174345	0.4688069
Year 1994	-0.5557749	0.4493585
Year 1995	-0.4015253	0.4206222
Year 1996	-0.8981781	0.4688064

Table 3.7C
Non-fatal Injuries: 6 Lane Undivided
Estimates of log(non-fatal injuries per accident)

Variable	Parameter Estimate	Asymptotic Std. Error
Intercept	-1.4397714	0.0473514
Year 1990	0.0608739	0.0671545
Year 1991	0.0284691	0.0663123
Year 1992	0.0578920	0.0666693
Year 1993	-0.1291060	0.0658347
Year 1994	0.0031999	0.0657684
Year 1995	0.0066267	0.0646540
Year 1996	0.0646682	0.0619030

Estimated Accidents, Fatalities, and Injuries

The results from the regression equations provided us with a mechanism for modeling how many accidents, fatalities, and injuries would have taken place in the **absence** of the Kansas Comprehensive Highway Program. For each road segment, we modeled what the road condition and characteristics would have been had KCHP not taken place. We applied the regression equations to the counterfactual data. We estimated accidents on each road segment and then aggregated the results. A comparison of actual accidents with an estimate of what would have taken place is found in Table 3.8.[4]

[4]After we estimated a model of the causes of accidents using actual world data, we turned it around and used actual data on road conditions to predict the number of accidents on each road segment. The *modeled* number of actual world accidents tracks the actual CANSYS data quite closely in aggregate, but it does not match exactly because an exact match is not generated by the non-linear procedure used to fit the Poisson accident model. Consequently, we made adjustments to our counterfactual world estimates to eliminate any biases. Instead of making an unbalanced comparison between the model of the counterfactual and what actually occurred, we were able to isolate only those particular changes in accidents that would be predicted by the model from the changes in pavement structure, highway type, congestion, travel speed, and other relevant variables.

Table 3.8
Accidents, Fatalities, and Non-Fatal Injuries
Actual versus Counterfactual

Year		***Actual***			***Counterfactual***			***Difference***	
	Accidents	Fatalities	Non-Fatal Injuries	Accidents	Fatalities	Non-Fatal Injuries	Accidents	Fatalities	Non-Fatal Injuries
1989	21,042	244	6,372	21,042	244	6,372	0	0	0
1990	20,250	225	5,846	20,799	223	5,971	-549	2	-125
1991	20,160	192	5,301	21,030	188	5,485	-870	4	-184
1992	19,298	193	5,107	20,487	192	5,382	-1,189	1	-275
1993	23,175	231	5,668	24,970	229	6,039	-1,795	2	-371
1994	21,910	214	5,567	23,489	206	5,902	-1,579	8	-335
1995	23,067	213	5,475	24,798	202	5,808	-1,731	11	-333
1996	24,483	255	6,211	27,036	232	6,702	-2,553	23	-491
TOTAL	173,385	1,767	45,547	183,650	1,716	47,661	-10,265	51	-2,114

Source: IPPBR.

These results may be surprising and require some explanation. We estimated that a large reduction in accidents and injuries resulted from the KCHP. However, there was actually a small estimated *increase* in fatalities. In other words, there are fewer accidents due to KCHP, but those accidents that did occur became more deadly.

The reasons for this are quite interesting. The KCHP did in fact create substantially safer driving conditions. The safer conditions did lead to a reduction in numbers of accidents. But, as a result of the increased speed chosen by drivers given the KCHP, fatalities were more likely to occur for a given accident. Without the KCHP, roads would have deteriorated significantly, and as a consequence, traffic would have slowed down noticeably. We estimate that the average speed on Kansas highways actually rose from 53.5 mph in 1989 to 57.5 mph in 1996 (mainly because of changes in speed limits). However, our counterfactual simulation shows average speed falling to 48.4 mph by 1996 due to deteriorating roads. The difference is about 9 mph by 1996, and it accounts for the difference in fatalities. It appears that highway users have chosen to consume their improved roads in the form of higher speeds, leading to increased travel distances and reduced travel times, even at the cost of a small increase in fatalities.

Value of Accidents, Injuries, and Fatalities

The accidents, injuries, and fatalities shown above must be translated into dollar terms in order to include them in the benefit-cost analysis. They must also be adjusted by the share of accidents that involved Kansas residents. Dollar values for property damage, injuries, and fatalities were provided by the HERS model. The most controversial of these estimates is that for the "value of life." The HERS model uses a figure of $2.5 million in 1993. We updated these figures to reflect 1996 values. We attributed 80 percent of accidents, injuries, and fatalities to Kansas residents [Table 3.9].

Table 3.9
Estimated Net Benefit of Accident Changes Due to Kansas Comprehensive Highway Program (Adjusted for Kansas Residence)

Year	Accidents	Fatalities	Non-Fatal Injuries	Total
Value per occurrence	$6,400	$2,670,000	$27,900	
1990 ($M)	$2.8	-$4.9	$2.8	$0.7
1991 ($M)	$4.5	-$9.0	$4.1	-$0.5
1992 ($M)	$6.1	-$1.3	$6.1	$10.9
1993 ($M)	$9.2	-$4.1	$8.3	$13.3
1994 ($M)	$8.1	-$17.4	$7.5	-$1.9
1995 ($M)	$8.9	-$23.3	$7.4	-$7.0
1996 ($M)	$13.1	-$49.5	$11.0	-$25.5
Present Value (15%)	$27.8	-$51.6	$25.3	$1.6
Present Value (10%)	$33.8	-$65.0	$30.7	-$0.5
Present Value (5%)	$41.8	-$83.5	$37.7	-$4.0
Present Value (1%)	$50.1	-$103.5	$45.0	-$8.3

Source: IPPBR

The negative effect of increased fatalities almost balances out the positive effect of reduced accidents and injuries. The cumulative value of accident, injury, and fatality costs depends on the discount rate. For a 10 percent rate, the negative effect is about $0.5 million over the seven years of the KCHP that were analyzed. As discussed earlier, the fatality results are due solely to the faster speeds allowed on improved and well-maintained highways.

Discussion and Summary

These results are summarized in Table 3.10. They show substantial retrospective user benefits from the KCHP. The travel time gains in particular have a very high dollar value. The future gains in travel time could be expected to be even more formidable, because the road surface in the counterfactual worlds will continue to deteriorate at a rapid rate; this issue is addressed in the next chapter. According to the HERS data, road surfaces deteriorate very slowly when they are new, and then more rapidly once the Pavement Structural Index (or PSI, a measure of pavement quality) drops below a certain level.

Of course these results are being driven by the basic assumption that no contract maintenance took place in the counterfactual world after 1991. That is the logical consequence of having passed no new highway program at all in 1989, so that funds from existing sources were exhausted by 1992.

Our analysis shows that the measured user benefits through 1996 fully justified the taxpayer costs of the highway program. This does not include any Keynesian effects, residual value, or other effects discussed in Chapters 4 and 5. Once these additional effects are added in, having the KCHP was much better than having passed no new highway program at all.

Table 3.10
Summary of Kansas User Benefits

Type of Benefit	***Discount Rate***			
	1%	5%	10%	15%
Travel Time	1,479	1,211	959	774
Operating Costs	232	201	170	146
Accidents, Fatalities, Injuries	-8	-4	-1	2
User Benefit Total	1,703	1,408	1,129	922
Costs to Kansas Taxpayers	1,701	1,403	1,123	916

These results suggest the question of whether a smaller or perhaps a larger highway program might have been even better than what we actually had. It would be possible (though time-consuming) to repeat our analysis assuming a counterfactual with a reduced level of contract maintenance after 1991, rather than no contract maintenance at all. In other words, we could analyze the marginal net benefits that would result when choosing various levels of expenditure on a highway program. However, that is a very different question from the question of the absolute value of the KCHP as a whole, and one which we have not addressed in this report.[5]

[5] However, in work we will not document here in detail, we did partially analyze a counterfactual world in which all expenditures on Kansas state highways were terminated as of FY1990. In contrast, the main counterfactual of this report assumes that substantial expenditures did occur in FY1990-FY1991. By comparing the two situations, we found that the marginal benefit-cost ratio of those 1990-1991 expenditures was substantially higher than the marginal benefit-cost ratio of the KCHP. In other words, the highway program shows declining marginal benefit-cost ratios when expenditures increase. This is exactly what would ordinarily be expected to occur—i.e., it shows that highway expenditures were prioritized, so that the most valuable projects were done first.

4. PROSPECTIVE AND TOTAL USER BENEFITS

This chapter addresses two additional types of benefits not considered in Chapters 2 and 3:

- the "salvage," "scrap," or "residual" value of the KCHP after 1996, and
- the value of the comfortable and easy driving and riding conditions that are provided by good highways, over and above the value of safety and travel time.

These two items are considered more difficult to measure than costs and benefits discussed previously. The reasons for this will become apparent. Therefore, in both cases we will adopt a "lower-bound" approach. On the other hand, the measurements we will provide are based on original data and modeling and in that sense are less speculative than the items that will be considered in the next chapter. This chapter concludes by summarizing all of those benefits and costs that have been fully modeled in this report.

Modeling the value of prospective benefits after 1996

The KCHP has a substantial value that extends well beyond the years 1989-1996. Exactly how these future or prospective values should be estimated is somewhat controversial in the highway literature. The controversy is a significant one, first, because details of the model of residual value can have substantial effects on the benefit-cost ratio, and second, because the theoretical issues that are involved are complicated. We have taken an approach which leads to a moderate residual value for the KCHP, neither as large as some approaches nor as small as others, but one which we believe is reasonably justifiable. And within that approach, we have used lower-bound assumptions to handle the detailed modeling issues.

The issues involved are rather technical. The full details of our model are given in Appendix 4. Here we will explain the logic in a moderately technical way. Readers who find the following discussion tedious may want to jump ahead to the section entitled "a constant maintenance model."

Theoretic definition of the "residual value" of a highway system

The correct definition of the residual value depends on exactly how it is to be incorporated into the BCR calculation, and it is closely related to the definition of "costs" and "benefits," which were considered in Chapter 1 and Appendix 1. Perhaps the simplest way to proceed is to define residual benefits separately from residual costs, and then write:

$$(4.1)\quad BCR = [B_{resid} + B_{1989\text{-}1996}]/[C_{resid} + C_{1989\text{-}1996}].$$

In this equation, $B_{1989\text{-}1996}$ and $C_{1989\text{-}1996}$ refer to the present-values (in 1989) of benefits and costs already measured; B_{resid} refers to the present value (in 1989) of gross benefits for the years 1997 until the end of time; and C_{resid} refers to the present value (in 1989) of costs for the years 1997 until the end of time.

Defining B_{resid} and C_{resid} any further than this depends, at least conceptually, on extending the definition of the "counterfactual world" (i.e., the modeled world in the absence of the KCHP) until the end of time. It also depends on a series of modeling assumptions as to how the future counterfactual world, as well as the future actual world, can be predicted and measured. Net benefits are then defined as differences in value between conditions in the actual and counterfactual worlds; net benefits are partitioned into gross benefits and costs using the methods described in Appendix 1.

Or to put this all in less technical terms: in order to settle the residual value, we first need to settle the "compared to what?" Residual value is the difference between what "'will' happen" and what "would have happened" in the absence of the KCHP. We have to decide on both the "what 'will' happen" and the "what would have happened." There are many equally valid yet different pairs of answers to these questions, each leading to a different residual value. Or to turn this around, there are many different highway policies that Kansas might pursue in the future, each of which implies a different residual value. (We will illustrate this with two examples below.) Our problem is to choose for consideration the future highway policies that are *most relevant to the real decisions facing Kansas policy-makers*.

Two approaches we did not follow

Scrap value. We might have assumed that Kansas will never adopt a new highway program after 1996; i.e., the highway system will be used as is and allowed to deteriorate without limit. In the actual world, the system would deteriorate starting from its measured condition in 1996. In the counterfactual world, it would continue deteriorating from the point of disrepair it had reached in 1996 (recall that contract maintenance was abandoned in that world after FY1991). The highway costs would be zero in both worlds. The gross benefits would be just the difference in use values between the actual and counterfactual world.

According to the pavement deterioration and traffic models we used, pavement deteriorates slowly at first but then goes very rapidly if truck traffic continues after a critical level of damage has been done to the roadway. Consequently, the counterfactual world would relatively quickly reach a point at which the traffic could barely move. As a result, the time cost of travel would be extremely high; therefore, use values in the future actual world (where traffic was still moving) would be extremely high, relative to the counterfactual world. Eventually, however, the actual world pavement would also deteriorate to the point at which traffic barely moved, so that relative use values would drop off again. However, the "bulge" of use values in the middle out-years would have an extremely large present value in 1989.

We did not adopt this model because:

- the residual values would be so large as to completely dominate the BCR;
- it is not really plausible that the highway system would be abandoned in this fashion; and
- we are not confident of the accuracy of our models when extrapolated to such extreme conditions.

Replacement cost. We might have assumed that Kansas will promptly adopt a new highway program after 1996. In the actual world, contract maintenance and new construction would be decided in some nearly optimal fashion. In the counterfactual world, a crash program in 1997 would bring the highway system up to its actual world functional level within one year. Thereafter, the highway programs and costs and benefits would be identical in the two worlds. The net benefits would be just the difference in use values between the actual and counterfactual world in 1997, plus the cost of the crash program (plus its multiplier effects) in the counterfactual world, plus the Keynesian effects of the crash program in the counterfactual world. All of these effects would be measured in the single year 1997 and then discounted back to 1989.

We did not adopt this model because:

- The result is very sensitive to the cost of the crash program.
- We cannot easily estimate the cost of the crash program.

We note however that the cost of the crash program would be much larger than the actual cost of the KCHP, for two reasons: first, doing construction quickly is much more expensive that doing it at the most efficient rate; and second, severe (non-linear) deterioration due to neglect of highways in the counterfactual world during 1991-1996 would lead to damages that would be very expensive to fix.

A constant maintenance model

In the model of residual values actually selected for this report, we assumed that a level of maintenance would be adopted after 1996 in both the actual and counterfactual worlds that had the effect of holding average pavement quality constant at its 1996 level until the end of time. This constant level of quality would be higher in the actual world than in the counterfactual world, so there would be a stream of positive benefits in all future years. We also made a number of simplifying, lower-bound assumptions:

- Maintenance costs would be identical in the two worlds. (This is a conservative or lower-bound model of net benefits because future maintenance costs would actually be expected to be higher in the counterfactual world, which had suffered substantial pavement damage prior to 1997, than in the actual world.)
- Traffic would stay constant at its 1996 levels. (This is conservative, because growing traffic would lead to higher net benefits.)

- The probability that outputs of the KCHP investments will continue to be in use would decay in proportion to $\epsilon^{-S(t-1997)}$ for each year t after 1997. (This type of assumption is necessary because otherwise the residual value gets larger and larger without limit when the discount rate approaches zero.) We will assume the decay rate S = 5 percent per year, based on an assumption that the probability that the KCHP has important residual effects would drop to less than 1 percent in 100 years.

It is shown in Appendix 4 that the residual costs are zero, and the residual benefits are:

$$(4.2) \quad B_{resid} = B_0\epsilon^{-(1997-1989)R}/(R+S),$$

where B_0 is the steady state value of user benefits (assumed equal to 1996 user benefits). It turns out that (despite inclusion of the S factor) this formula is extremely sensitive to the chosen discount rate R—which is a common result when evaluating long-lasting streams of future benefits. Using 1996 user benefits reported in the previous chapter to evaluate B_0, and assuming a discount rate between 5% and 10%, we have calculated that this residual value contributes an amount between 1.6 and 2.8 to the benefit-cost ratio. (See Table 4.1 for a break-out by discount rate.)

Consequently, unless the discount rate is very high the residual value represents the most important single contribution to the BCR. In other words, the stream of future benefits from the KCHP after 1996 is as important to the BCR as, or more important than, the benefits actually realized during the evaluation period of 1989-1996. The costs of the KCHP were front-loaded, and (as modeled in this report) ended in 1997. But the benefits are backloaded and continue long after 1996. Also, during the period 1989-1996, the benefits started out very small and only gradually climbed to a high level. Just when they reached a high level, the study period came to an end.

We reiterate, however, that the calculated residual value is sensitive to the particular framework question that is chosen. If we compare a differing future actual world with differing alternative worlds, then we will find differing valuations for the relative outcomes.

Table 4.1
Modeled Residual Values and BCRs of the KCHP after 1996

Discount Rate	1%	5%	10%	15%
Value of Residual Benefits	$9.0B	$3.9B	$1.7B	$.9B
Contribution to BCR	5.3	2.8	1.6	1.0

Source: IPPBR. See text for assumptions.

Willingness to pay for comfortable and easy driving in Kansas

In the fall of 1997 IPPBR surveyed 400 Kansans who possessed valid drivers licenses and asked what value they placed on having good roads, over and above the contribution that road quality makes to improved travel time and safety. In particular, we asked about the value of changes in road quality when travel time is held constant. We used the results to infer the value of comfortable and easy driving that resulted from the KCHP, using procedures described below. The survey was conducted in conjunction with IPPBR's Kansas Consumer Sentiment Survey of November, 1997. The survey instrument is described in Appendix 5.

The approach we used is called "contingent valuation," meaning that survey respondents were asked to give dollar amounts they would be willing to pay under various hypothetical conditions. Contingent valuation (or CV) methods are increasingly widely used in benefit-cost analysis because they provide types of information that otherwise would be unavailable. However, these methods are still somewhat controversial [Portney, 1994; Hanemann, 1994; Diamond and Hausman, 1994].

The most important criticism of CV methods is that respondents may give biased answers in cases where they do not have any direct experience of actually paying money for the good in question. Empirical comparisons of CV with other approaches have tended to find that CV does in fact have an upward bias, which could range from as much as 300% down to zero [Kealy, Montgomery, and Dovidio, 1990; Loomis *et al.* 1996; Choe, Whittington, and Lauria, 1996]. Because we were seeking a conservative measure of benefits, in the measures adopted here we assumed there is an upward bias of 200% and corrected the results accordingly. However, we doubt that the bias is that large in the present case, because respondents were asked about a situation that was not far removed from choices they actually were accustomed to making; namely, choices about whether to pay to take a turnpike, or instead take a less highly-controlled road with no toll charges.

In particular, our survey respondents were asked to consider a two hour trip which could be taken either on a typical county road paved with asphalt, or on an Interstate highway. Respondents were told that travel time would not be affected by choice of road. Respondents were then asked what they would pay, if anything, in order to travel on the Interstate rather than the county road.

Our questions did not directly ask what maximum amount respondents would be willing to pay to take the better road. Instead, the sample was split 5 ways; within each group, respondents were asked if they would be willing to pay a given predetermined amount. The predetermined amounts were $.50, $1, $2, $4, and $8. This procedure measured *minimum* amounts the respondents would pay. However, "willingness to pay" refers to the *maximum* amount an individual would pay; hence we did not actually measure the true willingness to pay *for any one individual*. Nevertheless, from the fall-off in numbers of individuals willing to pay a given amount with the size of that amount, we were able to infer the approximate statistical distribution of maximum willingness to pay. (We used this somewhat convoluted approach because individuals are more accustomed to making purchasing decisions when faced with a fixed price, than to deciding on the maximum price they would be willing to pay. Previous research has shown that the approach we adopted leads to less biased results.) The survey results are summarized in Table 4.2.

Table 4.2
Survey Results: Willingness to Pay for Comfortable Driving

Sample group	N	N refusing I-road	% of those with opinion	% taking I-road	Marginal population share	Average value for group	Value contribution
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Formula			col.(3)/ 360	.761*[1-col.(3)/ col.(2)]	difference of column col.(5)	midvalue of column col.(1)	col.(6)* col.(7)
Sample	400						
No license	24	0					
No opinion on which road	15	0					
No opinion on paying $8.00	1						
Prefer county road	86	86	23.9%		23.9%	$.00	$0.00
(Total preferring I-road)	274	146	76.1%				
[$0.00]				76.1%			
$0.50	59	13	16.4%	59.3%	16.8%	$.25	$0.04
$1.00	62	30	17.2%	51.6%	7.7%	$.75	$0.06
$2.00	57	29	15.8%	49.1%	2.5%	$1.50	$0.04
$4.00	52	38	14.4%	26.9%	22.2%	$3.00	$0.67
$8.00	44	36	12.2%	18.2%	8.7%	$6.00	$0.52
				0.0%	18.2%	$10.00	$1.82
Totals	400	232	100.0%		100.0%		$3.15

Source: IPPBR. See text for explanation of columns (5) through (8).

The results of this question were then extrapolated to Kansas highways. In particular, we estimated the demand curve for driving on an interstate as opposed to a county (i.e., cumulative population shares of drivers by maximum willingness to pay for using the Interstate). This was accomplished by differencing the population shares by level of their minimum willingness to pay to drive on the Interstate. For example, the sample showed that 26.9% of drivers were willing to pay at least $4, and 18.2% were willing to pay at least $8. Therefore, we assumed that 26.9%-18.2% = 8.7% had a *maximum* willingness to pay falling between $4 and $8, and we assumed that the average maximum willingness to pay for this group was the average of $4 and $8, or $6. (This analysis is also shown in Table 4.2.)

We made three additional assumptions:

- We assumed that persons willing to pay at least $8 (the highest group) had an average maximum willingness to pay of $10. (We believe this assumption is conservative, because it tends to imply an absolute and fairly low ceiling on willingness to pay. In most empirical cases, aggregate willingness to pay tends to be dominated by a small share of individuals who are willing to pay relatively high amounts; but the very highest paying individuals were truncated out of the estimated demand curve by this procedure.)
- We assumed that all sampled persons with drivers licenses were equally likely to drive on state highways (a minimum-information assumption).
- We assumed that survey respondents were providing the total willingness to pay of the driver plus all passengers in the vehicle (a conservative assumption).

This model showed that the average Kansan was willing to pay $3.15 to drive a 2-hour trip on an Interstate road rather than on a typical asphalt county road (even in the absence of any time saving).

Survey respondents were also asked to allocate the amount they would be willing to pay into fractional amounts corresponding to various motives, namely:

- improved safety;
- more comfortable ride and improved ease of driving;
- more interesting scenery;
- savings in cost of gasoline; and
- savings in wear and tear on the car.

The importance of each item to willingness to pay was ranked on a scale of 1 to 10. Assuming this scale of importance reflects a linear measure, the average share of importance allocated to comfortable ride was 23.3%. This share had a relatively small standard deviation of 7.6%, and was almost perfectly uncorrelated with the dollar amount of willingness to pay.

This led to an estimate of willingness to pay specifically for comfortable roads, based on several additional assumptions:

- Willingness to pay for driving comfort on an Interstate was estimated by multiplying the fractional share of importance allocated to comfortable ride and ease of driving, times the total willingness to pay for driving on an Interstate highway.
- We assumed that the value of driving comfort on a well maintained state highway is midway between the value for a county road and the value for an Interstate. (This assumption is not necessarily conservative, but it is a minimum information assumption.)
- We assumed that driving comfort falls linearly with the Pavement Structural Index (PSI, a measure of pavement quality collected by KDOT for the actual world and modeled in our counterfactual world). We assumed driving comfort on an Interstate reaches the level of a well-maintained county highway when the Interstate's PSI falls to 50% of its maximum value. (We believe this assumption is conservative, because a road with a PSI that low is bad enough to slow

down the traffic on an Interstate by perhaps 20 mph. Hence it probably overstates the comfort value of deteriorated roads and understates the gains due to the KCHP.)

- We assumed that willingness to pay for comfort depends on distance traveled rather than on the time it takes. (This is a conservative assumption, because it ignores the extra value that would ordinarily be placed on comfort on a given trip when traffic slows down in the counterfactual world.)
- We assumed the willingness to pay of truck drivers was the same as for auto drivers. (This is probably conservative, because rough roads have a harsher effect on truck drivers than on automobile drivers.)
- Finally, the result was divided by a factor of 3 to account conservatively for any remaining bias in the overall CV approach.

The results for 1989-1996 show an aggregate value in Kansas rising over time toward $5M/year, with a present value in 1989 around $15M. This has an effect of raising the BCR by about .02. (See Table 4.3 for a break-out by discount rate.)

As noted this is a lower-bound measure. We believe that an upper-bound measure could be as much as five times as large. But even at that rate, it is apparent that driving comfort alone would not be expected to make any very important contribution to the BCR.

Table 4.3
Lower-Bound NPV Benefits and BCRs for Driving Comfort: 1989-1996

Discount Rate	1%	5%	10%	15%
NPV benefits	$22M	$19M	$16M	$13M
Contribution to BCR	.02	.02	.01	.01

Source: IPPBR. See text for assumptions.

Summary of all modeled effects on the BCR

After putting together all costs and benefits that were estimated using detailed modeling, we found an overall BCR of between 3 and 7, depending on the discount rate. However, the most likely value is around 4. See Table 4.4 for details.

Using a less formal approach, the next Chapter will estimate one additional user benefit:

- the value of increases in business productivity, over and above the reductions in transportation costs (meaning time cost as well as money cost).

Chapter 5 will also provide estimates of certain additional costs, and lists several additional benefits without estimating them. The purpose of the chapter is to provide a more comprehensive lower bound on the BCR of the KCHP than we are able to provide from direct modeling. It does not provide any original modeling of the additional issues; instead it interprets the implications for Kansas of previous research by others. As we shall see, under conservative assumptions the full BCR is not dramatically different from the BCR shown in table 4.4

Table 4.4
Summary: Contributions to Benefit-Cost Ratios from All Modeled Components

Discount Rate	1%	5%	10%	15%
Component				
Keynesian benefits	0.85	0.82	0.79	0.75
Travel time saving	0.87	0.86	0.85	0.84
Operation cost saving	0.14	0.14	0.15	0.16
Accidents	0.00	0.00	0.00	0.00
Residual value	5.27	2.78	1.55	0.96
Driving comfort	0.02	0.02	0.01	0.01
Total	7.14	4.62	3.36	2.73

Source: IPPBR

5. EXTERNAL COSTS AND BENEFITS

This Chapter discusses external costs and benefits, as well as a few other items not analyzed in Chapters 2, 3, and 4. Most of these costs and benefits are associated with non-user benefits and non-market externalities (i.e., side-effects) of highways. This Chapter uses reviews of the literature and informal analysis, rather than original modeling, to estimate some of these benefits and costs.

While these valuations cannot be measured with the same precision as those considered in Chapters 2 and 3, it will be possible to estimate an outer range on the size of these effects for the KCHP, and in most cases we can specify the general direction. Using these data, we will form a somewhat speculative idea of more inclusive benefit-cost ratios for the KCHP, at least in lower-bound terms. These more inclusive BCRs turn out to be surprisingly similar to those reported in the last chapter. This is not a trivial finding: some of the individual adjustments are significant, but taken as whole they tend to cancel out.

Sources and concepts

Our empirical analysis will draw most heavily on Litman (1998), which is an ongoing effort to provide a comprehensive review of information related to aggregate roadway transportation costs and negative benefits as a share of GNP. Litman provides an upper bound, a lower bound, and a most likely point estimate for each cost item he reviews. Litman's review generally estimates significantly higher aggregate costs than other reviews of the literature; he estimates that the total cost of highway transportation amounts to some 50 percent of monetary GNP. (This percentage is rather misleading because the majority of these costs are non-market costs; total costs would constitute a much smaller share if they were compared to market GNP plus non-market GNP.) These costs are high partly because Litman includes a much more comprehensive list of cost items than other reviewers, and partly because he sometimes endorses results from studies that had higher-than-average values for cost measurements. Therefore, following Litman's suggestions is probably a conservative approach. However, in certain cases we will deviate from Litman's recommendations because we believe other sources are either more credible or else more relevant.

Some authors, including Litman, have argued that there are no non-user benefits of highways [e.g., Rothengatter 1994]. Gamble and Davinroy [1978] attempt to provide an exhaustive catalog of possible benefits (but most of the items they list could also occur as costs). This question depends partly on the analytic framework; for example, the same item may be either a positive cost or a negative benefit, depending on the exact cost concepts that are adopted. In the present study, most “cost” items have been classified as negative benefits (see Chapter 1 and Appendix 1). Also, an item which was a negative benefit in the context of a benefit-cost analysis, could be considered a positive external cost in the context of determining optimal taxes or user charges. Moreover, some government programs can cause decreases in negative benefits—which is to say, can cause positive benefits—even when the item in question would ordinarily be classified as a negative benefit or a cost.

Therefore, in our framework highway programs can have positive as well as negative external benefits (and also negative as well as positive costs). We believe this especially important in the case of a state-level analysis, as will be apparent in some of the specific cases we discuss below.

Costs and benefits that may be negligible

Several cost items that could be important in some situations fade into insignificance under the conditions being analyzed by our study. In particular, even though these cost and benefit items could be large *per se*, either they do not vary between the actual world and counterfactual world examined in this study, or else the changes in costs and benefits are borne mainly by citizens outside the state of Kansas. Other items are simply small in any case.

Costs and benefits outside the state of Kansas

The following items are not especially relevant for a Kansas-based study:

- effects of highways on global warming, climate change, and the ozone layer
- effects on the US strategic petroleum reserve and on the price of energy
- US costs to defend the oil producers in the middle east
- effects on acid rain
- effects on pollution of the oceans
- effects on extinction of non-Kansas species
- effects on loss of wilderness
- effects on exhaustion of non-renewable resources
- effects on over-utilization of common-property renewable resources
- costs of energy-related and transportation-related R&D (other than R&D that is specific to Kansas conditions).

The effects of highway travel on these factors is significant over the US as a whole, but Kansas highways contribute only a tiny share (roughly 1%) of the total influence of highways on the relevant outcomes. Also, any effects of Kansas activities on these outcomes tend to be spread across the US or world as a whole, so that only a tiny share of any US-wide benefit or damage that results is then experienced in Kansas. Moreover, for some of these items Kansans are less at risk than citizens in other states.

Benefits at the local level but (arguably) not at the state level

One type of benefit has been fairly well documented at the local level, but its existence at the state level is in question, namely:

- effects of highways on economic development.

We will define "economic development" in a somewhat narrow way so as to distinguish it from a closely-related benefit having to do with the productivity of industry. In particular, *economic* *development* refers to new business start-ups or relocations or substantial new investments made at a given place and caused by a highway program. *Productivity improvements* refers to real cost reductions experienced by existing businesses at a given place and caused by a highway program, when these reductions have to do with changes in the manner of production rather than merely reductions in input prices.[6] Productivity improvements are discussed further below.

In general, local economic development has limited effects on the total GNP of the US as a whole; instead, it mainly has to do with changing the *location* of business.[7] Even in cases where start-ups or expansions of existing businesses are caused by a highway program, in the absence of those new investments the demand would eventually have been met by business expansions elsewhere in the country.[8]

Research generally shows that highways do encourage economic development at specific locations, provided that other conditions are also favorable [Rephann, 1993]. The key question for our study is whether or not economic development gains caused by highways at one location in the state lead to offsetting economic development losses at other places in the same state. Much of the research suggests that substantial offsets do occur, so that highways are not highly associated with net state-wide economic development gains. Eagle and Stephanedes [1989] give a well-constructed negative example using Minnesota data. Aschauer [1990] argues that economic development gains *do* exist at the state level; however, his measure included productivity effects as well as relocation effects.

We will assume, conservatively, that no economic relocation benefits exist for Kansas as a whole.

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[6] In most cases, productivity improvements are in fact associated with new investments by existing firms. The analytic distinction we have in mind is this: economic development has to do with changes in output and employment location resulting from reductions in input prices, including reductions in the time cost as well as money price of transportation, and also the cascading short-run effects of those costs on other costs. Productivity improvement has to do with long-run changes in the method of production, such as adoption of just-in-time inventory control.

[7] To the extent that the chosen location is either more or less socially efficient than its alternative location, then real GNP will either increase or decrease. However, locational decisions are generally based on private efficiency, not on social efficiency. To the extent that private efficiency is correlated with social efficiency, some small share of economic development gains may translate into increased real GNP.

A more important exception is the case of a start-up that plans to export some goods from the US rather than merely sell them domestically. To the extent that highways changed the decision to export itself, rather than merely the location of production, and to the extent that there is some degree of unemployment, then economic development could lead to Keynesian gains in real US GNP.

[8] Or the slack could have been taken up by lost sales experienced by firms in other parts of the country. We are speaking, however, only of *marginal* effects on GNP. In average terms, the US has a high GNP that is caused in part by intensely entrepreneurial economic development efforts that continually take place all across the country, which affects GNP through channels such as those described in the previous footnote.

Costs and benefits that do not vary substantially between actual and counterfactual worlds

The following items are assumed not to be affected by the KCHP:

- dollars spent on related government services: police, fire, license registration, emergency response, planning, street lighting, parking enforcement, and the traffic-related criminal justice system. (However, civil justice costs *do* vary and are included in the costs of accidents and fatalities.)
- the total cost and amount of parking and garaging
- fixed costs of vehicle ownership
- rental value of land dedicated to pre-existing roads
- damage to structures due to vibration generated by traffic
- cost of crimes against, or facilitated by, motor vehicles
- infra-marginal user benefits, i.e., "consumers surplus."

All the items listed above tend to increase when traffic increases, and are negative benefits. However, these items do not change much because of our basic assumption that total vehicle-miles traveled are constant (i.e., net induced traffic is zero; see Chapter 3).

Costs and benefits of road construction activities

Highway construction activities have temporary physical effects on their immediate surroundings, which may lead to:

- changes in vehicle accidents
- changes in vehicle travel time
- changes in the level of business activity in nearby businesses
- changes in the cost of doing business in nearby businesses
- changes in soil run-off and other short-term environmental impacts

Previous research on this subject is rather limited. Wildenthal and Buffington [1996] looked at various impacts of one construction project, but their findings most relevant to our purposes were qualitative rather than quantitative.

In general, these effects are one-time and occur at the time of construction rather than ongoing. (It is true that maintenance construction is necessarily recurring at each location; but in most years at a given location maintenance is not occurring and these effects are not present. Also, the side-effects of maintenance are typically much smaller than the side-effects of major construction.) Moreover, in our assumed counterfactual world, contract maintenance construction continued through 1991, so that construction cost differences would show up mainly for the years 1992-1996 (and then be discounted back to 1989). Consequently, these effects can be ignored in the BCR unless they are especially large in the year of construction.

Highway construction zones on existing roads with vehicle traffic present are especially hazardous places for construction workers. However, *vehicle* accidents can actually be *reduced* by construction zones, because the traffic is moving slower and in a more disciplined manner. Preliminary data collected from the Kansas Accident Records System for FY 1996 do show *lower* rates of accidents per vehicle mile traveled in construction zones than elsewhere, both for fatal accidents (.82 versus 1.59 per vmt) and for injury accidents (.32 versus .50 per Mvmt) [Slimmer, 1997]. Our analysis of the underlying data showed that these differences are statistically significant (with p better than .001).

Increases in travel time due to construction are a negative benefit. However, total delay times at construction sites is a relatively small share of over-all travel-time on state highways (great though it may seem to the individuals actually being delayed); while overall travel-time benefits due to the KCHP were found in Chapter 3 to be a rather significant share of overall travel time. For example, in 1996 vehicles traveled about 1.4B vmt in construction zones, or about 10% of the 13.6B vmt on state highways as a whole. Data are not available on the amount of increased travel time that resulted. Assuming however that traffic was slowed by no more than 15% on average, the annual net effect would amount to about 10% of the travel time savings estimated in Chapter 3. Moreover, as noted above this effect would not kick in until 1992.

Our rough estimates indicate that the value of reductions in accidents and especially in fatalities more than offset the value of losses in travel time; and, moreover, that both effects are relatively small. Therefore, we believe that ignoring net effects of construction on road users will not seriously understate (and could overstate) the BCR.

Changes in the level of business transactions near a construction site are a temporary cost to the affected business owners, but there are offsetting gains to other business owners who capture the displaced transactions. The net effects on aggregate welfare can be expected to be negligible.

Changes in the cost of business near construction zones (e.g., delivery delays and the cost of taking circuitous routes, the cost of posting compensating advertising) are real social costs, but they are judged likely to be negligibly small in comparison to overall costs and benefits.

We have not located usable information on the short-term environmental impacts of highway construction, but it is believed to be much smaller than the long-term environmental effects of highways that are examined below.

Costs and benefits largely handled under other rubrics

The following items are sometimes listed as separate social cost or benefit items but are omitted from our study so as to avoid double counting:

- congestion costs
- benefits from increasing returns to scale in highway construction, maintenance, and use
- increased value of land due to improved access

- value of infrastructure deterioration
- value of personal mobility.[9]

Congestion costs are handled implicitly in the value of time as calculated in Chapter 3. (The traffic speed model does contain a factor that estimates congestion.)

The Kansas-specific benefits (or costs) from increasing (or decreasing) returns to scale in highway construction and maintenance, are implicit in the amounts actually expended by the KCHP and in the various other benefits actually received. Any spillovers to other states are not relevant to our study.

Increases in land values due to improved access are simply an indirect market effect of users' benefits (such as reduced travel time) that were estimated previously.

The cost of infrastructure deterioration has two aspects:

- lost use value during 1990-1996. This depreciation has been incorporated through its effects on travel time, accidents, and the cost of wear and tear on vehicles; see Chapter 3.
- lost residual value or salvage value of the infrastructure after 1996. We used a lower-bound proxy based on user benefits that would be experienced if pavement quality were maintained at a constant level forever after; see Chapter 4.

The value of personal mobility has four aspects:

- the direct user benefit to second parties. This value is estimated in Chapters 3 and 4 and is very large.
- the indirect user benefit to third parties who have contractual or obligatory relationships with second parties to provide transport-related services. This benefit is reflected in the derived demand function of second parties, so it must be omitted to avoid double counting.
- the indirect benefit that the personal mobility of highway users may have for third parties, above and beyond any derived demand functions. (An arguable example would be a case where a driver ran an impromptu errand for an immobile person for purely altruistic reasons having nothing to do with any ongoing relationship.) We have located no research that attempts to measure this kind of indirect mobility benefit. However, it is believed to be relatively small; and in any case, omitting it is consistent with calculating a lower-bound estimate.
- the option value of having highways available when needed. This value is discussed separately below.

[9] Some authors, though generally not economists, have claimed that mobility is a value over and above traditional user benefits; see e.g., Green [1995]. Green provides no clear model for this claim, which remains unoperationalized in the existing literature.

Some omitted user benefits that are presumably positive

Because of limitations in existing research, some effects that cause increases in user benefits (or reductions in user costs) were omitted from the estimates in Chapters 3 and 4, and also will not be quantitatively addressed here. These effects would be expected to have a positive influence on the benefit-cost ratio; therefore omitting them leads to a conservative estimate.

Reductions in transport variability

Some effects mainly have to do with the effects of variability of speed and travel time (as opposed to the average speed and travel time). In general, it is likely that better roads and better maintenance lead to reduced variability in speed and travel time. Variability is generally a deleterious influence in economic affairs; hence omitting effects of variability tends to lead to a lower-bound estimate of the benefit-cost ratios. Some of these effects are:

- costs of uncertainty about arrival time
- costs of uncertainty about actual cost in transit
- increases in accidents due to variations in speed
- increases in emitted pollution due to variations in speed.[10]

For example, Ross *et al.* [1995, as cited in Greene and Jones, 1997] show that emissions of carbon monoxide and hydrocarbons may increase by two orders of magnitude under heavy acceleration. However, we have omitted these effects from our analysis because we located no directly usable research on them. The KCHP probably did lead to positive benefits in the form of reductions in these user costs; therefore omitting these effects will lead to a conservative estimate of the benefit-cost ratio. (Effects of speed variation on accidents probably would have been partly, but not completely, proxied by variables such as curves included in our accident regressions in Chapter 3.)

One additional effect of speed variation that *is* included in the HERS model of operating costs used in Chapter 3 is:

- increases in operating costs due to variations in speed.

Pro-poor redistribution of net benefits (an equity effect)

Studies of highway use by income class show that total expenditures and total miles driven increase with income. However, when viewed as a share of income, personal expenditures related to highway travel *fall* with income. This fact has two generally opposing implications (which have been borne out by more detailed studies):

[10] Pollution is actually a non-user effect, but it is included here for expositional convenience.

- Highway-related taxes are generally *regressive*, meaning that the share of income that goes for taxes related to highways falls as income increases. That is, the poor are hurt proportionately more by highway taxes than the rich.

- The value of highway services used directly by the household is generally *progressive*, because its value as a share of income falls with income. That is, the poor are helped proportionately more by highway services than the rich (even though they use highways less).[11]

Consequently, the total benefits of highways programs, net of taxes paid, could be either regressive or progressive, depending on the balance of these two factors. In fact, however, the amounts spent on highway services for Kansans under the KCHP exceeded the amount raised from Kansans to support them.[12] Therefore, the marginal benefits of KCHP probably tend to outweigh the marginal taxes due to KCHP, and net outcome is probably progressive; i.e., it is probably relatively pro-poor.

The existence of welfare programs and progressive income taxes demonstrates the fact that Kansas government (and presumably Kansas citizens) really do place some positive value on redistributing net benefits from the rich to the poor. However, there is no accepted way in the benefit-cost literature to place a social dollar value on these benefit redistributions.

Geographical redistribution of benefits (an equity effect)

To the extent that highways cause local economic development, they tend to move industry from place to place within the state. These effects are uneven and complicated. (See Eagle and Stephanedes [1989] for an empirical example.) No measures of these effects are available for Kansas.

Democratic political processes do commonly accept fairness between regions as a policy criterion. But again, there is no accepted way to place a social dollar value on any geographical redistribution of benefits that may result from state interventions in the economy.

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[11] Statement (2) requires some qualification: it assumes that highway services are given the same unit value when delivered to poor and to rich. Because highway services are non-marketed goods, users are not faced with well-defined or constant unit prices; hence that assumption may not be valid. However, since the tax rates of the transportation taxes that are directly related to road usage (mainly the fuel tax rate) are constant across income classes, statement (2) is clearly true provided that highway services are evaluated at the price of the fuel tax and other unit usage taxes paid. But, as noted below, full highway service delivery costs exceed the fuel tax paid. Also, willingness to pay for highway services probably differs from the amount of the fuel tax, due to the fact that the fuel tax is bundled with fuel purchases. A full analysis of this situation would probably reach the same conclusions reached above, but the argument would have to be substantially more detailed.

[12] This is true for two reasons explained in Chapters 1 and 2. First, a portion of the motor fuel tax as well as other taxes are paid by non-Kansans; second, federal highway funds increased as a result of the KCHP but federal taxes paid in Kansas did not. An offsetting influence is that some benefits of the KCHP were received by non-Kansans.

The individual projects included in the KCHP were determined by an objective decision-making process that was created under the legitimate democratic legal procedures of the State of Kansas. And in particular, Kansas law provided for a floor amount of construction, such that at least that amount would be performed in each county under the KCHP. Therefore, there should be at least a weak presumption that regional equity has been taken into account in the resulting allocation decisions. Consequently, there is at least a weak presumption that the dollar value of geographical benefits is positive, and hence ignoring them would lead to a conservative measure of the BCR.

The option value of additional roads

Some things have value merely by existing, even if they are never used. This value is referred to as "existence value" and is measured by people's willingness to pay in order to ensure continued existence of the item, even in the absence of use. An example is the value that some people would place on maintaining the existence of an endangered species, even in the absence of ever seeing or using that species.

A closely-related concept is "option value." This value refers to the amount that people are willing to pay in order to assure that a particular good or service will be available, should the need for that good ever arise. As such, it is a form of insurance value. It is separate from the amount that people would be willing to pay in order to actually use the good, once the need did arise. For example, voluntary donations to help build a community hospital are given, in part, because the donors want to ensure that a hospital is present if they should later happen to need it.

Highways probably have no existence value as such, but building new miles of roads may create an option value. This refers to the value that highways have for persons who may never actually use them, provided there is some chance that need for them might arise in the future. We have not located any research that actually attempted to measure the pure option value of having additional roads. We believe however that omitting this item would not have a very large effect on the benefit-cost ratio because only a small share of the KCHP was devoted to creating new routes. In any case, option values are likely to be relatively small in comparison to direct user benefits of roads (just as aggregate donations to help build a hospital are typically small in comparison with the hospital's aggregate user charges).

External and non-user benefits from improved travel time: productivity

The KCHP produced one benefit that may be important but is quite hard to measure:

- positive effects on productivity in Kansas.

This benefit has to do with improved travel time, but it goes beyond the value of time that was estimated in Chapter 3. The earlier benefit had to do with improvements in the cost of transportation; this benefit has to do with improvements in the location or production method of business activities. We will make a rather speculative yet reasonably conservative estimate of their values based on some recent literature.

A substantial literature over the last decade has led to general agreement that highways do affect the productivity of private capital [Lewis, 1991]. Moreover, for most regions in the US and Canada these effects probably have not been exhausted at the margin; in other words, additional investments in highways are likely to lead to additional improvements in productivity.[13] There is widespread disagreement, however, on the exact size of those marginal effects; estimates vary from very small to very large. There is growing agreement that the effects differ from state to state and year to year, and that a number of careful econometric techniques need to be used in order to obtain accurate measurements.[14]

Moreover, no study has yet included all of the econometric features that appear to be needed. The most authoritative study we have seen is Bell and McGuire [1997], and we will rely on some of their estimates, interpreted conservatively. In particular, we will assume the smallest effects that resulted among several models they estimated. In the most conservative models, highways were found to have statistically insignificant effects on production of manufactured goods, but positive effects in three other sectors. These sectors, and their corresponding output elasticities of highway capital, were:

- transportation and utilities: $.076 \pm .045$
- retail trade: $.064 \pm .031$
- services: $.063 \pm .027$.[15]

Moreover, we will conservatively assume that the actual effects are one standard deviation lower than the point estimates, which implies an elasticity of around .03 for each sector. To use these results, we first need an estimate of the percent change in highway capital in Kansas caused by the KCHP. Bell and McGuire estimate Kansas highway capital per capita as $3220 for 1986 (in 1982 dollars). (They also cite estimates from two other sources that agree to within 8%.) Correcting the dollar basis and multiplying by 1986 Kansas population leads to an aggregate highway capital of about $10.9B in 1986 (in 1996 dollars). During 1989-1996, the KCHP included increased highway expenditures with a present value of between $.9B and $1.7B (in 1996 dollars, depending on the discount rate). That implies that the KCHP increased highway capital in Kansas by between 10% and 20% (depending on detailed assumptions). Multiplying by an elasticity of .03 implies that the KCHP increased output by between .3% and .6% in the three affected sectors. In 1989-1996, Kansas personal income in those sectors amounted to around $14B per year (in 1996 dollars). Therefore, assuming that personal

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[13] This does *not* imply that additional highways investments are justified without limit. It implies that additional investments generally have additional productivity benefits, not that these benefits always outweigh the additional costs.

[14] E.g., using time-series/cross section data sets with controls for both time and location; differencing to remove non-stationarily; flexible functional forms to avoid assuming that marginal productivity is constant across states; controlling for simultaneity, because increases in income causes political decisions to build highways; controlling for regional price changes that may affect quantity measurements. The results are also rather sensitive to assumptions used in the construction of estimates for private capital by state and sector.

[15] Standard errors were calculated from t-statistics included in the original source.

income rose proportionately to output, the KCHP added between $40M and $80M per year to Kansas personal income, as a result of improved productivity in Kansas.

More detailed calculations in a spreadsheet model led to the conclusion that productivity gains would have increased the KCHP BCR for 1989-1996 by between .2 and .3, depending on the discount rate. (See Table 5.2 for more detailed BCRs.)

External costs related mainly to fuel consumption and traffic volume

The KCHP may have effects on two types of pollution caused directly by traffic:

- effects on waste disposal in Kansas related to fuel refining and distribution, vehicle maintenance, and road run-off
- effects of air pollution in Kansas.

Highways cause added waste disposal through two main channels:

- Road runoff, vehicle maintenance waste, and junking of vehicles, which is mainly related to the volume of traffic; and
- Waste from the refining and distribution of petroleum products, which is mainly related to the amount of fuel consumed.

Waste disposal costs related to volume of traffic will be neglected in this study because traffic is assumed equal in the actual and counterfactual worlds. Waste disposal related to refining of petroleum occurs in national markets; reduced fuel use in Kansas would mainly lead to increased sales to other states from Kansas refineries rather than reductions in refinery production.[16] Moreover, data in Litman [1998] show that traffic-related waste disposal costs of all types together are probably less than 10 percent of air pollution costs. Since only a small share of this cost consists in waste that is relevant to this study (i.e., waste from wholesalers, fuel truckers, and gas stations), we will ignore all waste disposal costs.

Air pollution effects of highways are mainly determined by the amount of fuel consumption. (A secondary effect has to do with the rate at which fuel and air are burned into CO_2 and H_2O as opposed to more noxious chemicals and particulates. This rate can be affected by both average travel speed and by speed variation, but we uncovered no usable research that measured these effects in detail. However, much of the research does distinguish between rural travel and urban travel.) We have assumed that miles traveled were not affected by the KCHP. Therefore, the main effect of the KCHP on fuel consumption had to do with changes in the gallons of fuel burned per mile traveled. And the main factor affecting fuel consumption per mile is vehicle speed.

[16] In any case, oil refining has been of declining importance in Kansas because Kansas supplies of petroleum are moving towards exhaustion.

It turns out that fuel consumption per mile is minimized by driving at speeds in the neighborhood of 55 miles per hour (or thereabouts, depending on the particular vehicle), and tends to increase when the speed is either higher or lower than that optimal point [Davis and McFarlin, 1996, pp. 3.47-3.48]. According to our highway section model, average operating speeds on highways were about 55 mph in the actual world, and about 38 mph in the counterfactual world. Consequently, the KCHP tended to speed up those vehicles that were driving at the average speed and as a result reduced their fuel consumption. However, there are some important distributional effects that work in the opposite direction. In particular, about half of the vehicles in the actual world were operating at speeds higher than 55 mph, which means they were above the minimum fuel point; most of them moved farther into that region of operation as a result of the KCHP. Of course there were offsetting effects in the original direction, as slower-moving vehicles gained fuel efficiency by speeding up. However, the fuel efficiency curve is not symmetric; the changes in fuel consumption with speed are larger on the high side of 55 mph than on the low side.

To sort all of this out, we built a small spread-sheet model. According to the model, changes in fuel consumption caused by the KCHP are fairly sensitive to speed variation on a given highway, and especially sensitive to *differences* in speed variation between the actual and counterfactual worlds. The model suggests that the KCHP was more likely to *reduce* fuel consumption than increase it. However, to form a conservative estimate, we will use a worst-case analysis. In particular, assuming relatively extreme parameters[17] the KCHP could have increased fuel consumption in Kansas by up to 3%.

Data in Litman [1998] imply local pollution costs for autos of .5 to 2 cents a mile on rural roads (state highways are predominately rural), and up to 10 times as much for heavy trucks. KDOT Division of Planning and Development [1996] estimated state highway travel at 23M vehicle miles per day. About 10% of this traffic is heavy trucks. These figures suggest that local state-highway-related pollution costs in Kansas do not exceed $300M per year. Therefore, if the KCHP led to a 3% increase in fuel consumption, the increased pollution costs would probably not exceed $10M per year. (We reiterate that this is an upper bound; it appears more likely that the KCHP actually led to reductions in pollution costs.)

The net present value in 1989 of these upper bound pollution costs for 1989-1996 would be between $50M and $80M. It would lead to an (additive) reduction in the BCR for those years by about .05, almost independently of the discount rate.

[17] In particular, vehicle speeds were assumed to vary evenly between 31 mph and 79 mph in the actual world, and between 26 and 50 mph in the counterfactual world.

External and non-user costs related mainly to new road additions

The following effects mainly occur when there are large traffic changes (i.e., when new roads are constructed, or to a lesser extent when existing roads are radically reconfigured), rather than when there are small changes in traffic speed or load on existing roads:

- effects on noise pollution
- barrier effects on human beings (i.e., the costs traffic imposes on bicyclists and pedestrians)
- land use externalities (aesthetics; the costs of sprawl; effects on historic buildings; severance effects on ecological units -i.e., the robustness that is lost when habitats are broken up into units that are too small to keep a population or its gene pool reasonably stable; road-kill; effects on extinction of native Kansas species)
- effects of water pollution in Kansas
- lost option value of having alternative motor transport modes

Using data from Litman [1998], an extreme upper bound cost per vehicle mile for rural auto traffic for all of these items is $.28 (see Table 5.1). Based on 23 million vehicle miles per day, and assuming heavy trucks are 10 percent of traffic and impose 10 times as large an environmental cost, the total traffic-related local environmental costs of the entire Kansas highway system would not exceed $4.5 billion per year (with $1 billion being a more plausible estimate).

Since new and reconfigured highways in Kansas resulting from the KCHP were a small share of all Kansas highways, it follows that the KCHP costs were a small share of the total costs imposed for these items by all Kansas highways. Only about 10% of the KCHP was devoted to construction of new roadways,[18] while KCHP highway capital constituted less than 20 percent of all state highway capital; hence, traffic-related external costs of the KCHP would not exceed $100 million per year (but were probably much lower).

Based on a more detailed calculation, the (additive) effect of these costs would be to reduce the BCR for 1989-1996 by .2 to .4 at most, depending on the discount rate. (See Table 5.2 for more detailed BCRs.)

[18] Defined here as Babcock type 5, as defined in Chapter 3.

Table 5.1
External Costs Related to Road Location

Item	rural auto, cost/mile upper bound	rural auto, cost/mile point estimate
Noise pollution	$0.060	$0.005
Barrier effects on human beings (i.e., the costs traffic imposes on bicyclists and pedestrians)	$0.020	$0.005
Other land use externalities (aesthetics; the costs of sprawl; effects on historic buildings; loss of greenbelts and wetlands)	$0.125	$0.035
Water pollution	$0.030	$0.010
Lost option value of having alternative motor transport modes	$0.050	$0.005
Total	$0.285	$0.060

Source: Litman [1998]

Keynesian effects on external costs

We argued in Chapter 2 that the KCHP had a positive "Keynesian" pump-priming effect on the Kansas economy. We argued in this chapter that the KCHP had additional positive effects on the Kansas economy in the form of increased productivity and production. All of these additions to the Kansas economy quite naturally generate additions to the external costs due to environmental damage imposed on Kansans by industry. These costs actually should appear as deductions at several different points in the BCR calculation, but the main ones are as follows:

- Keynesian benefits in the numerator should be reduced by the value of the externalized pollution damage they cause; and
- The cost denominator should be reduced by the value of external pollution that is avoided, due to the fact that multiplier effects of taxes tend to reduce industrial activity.

Symbolically, we will assume the following model:

$$(5.1) \quad BCR = B/C = [B_{nmark} + B_{mark}(1-\delta)]/[C_{nmark} + C_{mark}(1-\delta)],$$

where B represents benefits, C represents costs, the subscript "nmark" represent non-market (i.e., non-monetized) items such as value of time, the subscript "mark" represents market or monetized items, and δ is the average ratio of induced pollution damage to induced state money income.

Now as it happens, the cost denominator as defined in Chapter 1 and Appendix 1 is entirely monetized or market-related,[19] and hence $C_{nmark} = 0$. Therefore we have

$$(5.2) \quad BCR = [B_{nmark}/(1-\delta) + B_{mark}]/C_{mark}.$$

Thus, perhaps surprisingly, accounting for pollution damage due to Keynesian multiplier effects tends to *increase* the BCR for the KCHP. We will estimate

δ = E_{US}/G_{US}, where
G_{US} = Gross US Domestic Product, and
E_{US} = US-wide external costs of all economic activity.

In other words, Kansas local externalities are assumed to have about the same relationship to Kansas state product as US local externalities have to US product.

As before, we exclude costs for items that would mainly be experienced externally to Kansas. Therefore, we will include only the following items:

- effects of air pollution other than on acid rain, the ozone layer, and global climate change
- effects of water pollution (fresh-water only)
- effects on waste disposal.

An estimate of these US external costs as a share of the GNP for 1993 is about 10 percent.[20]

Summary and conclusion

Table 5.2 summarizes the various effects described in this chapter. It shows that, in a conservative or worst-case analysis, the benefit-cost ratios are either not substantially modified, or else may be slightly increased, by the additional external effects that were accounted for in this chapter. At very worst, the benefit-cost ratio of the KCHP is likely to exceed 3. The main result however, is that all of these corrections together leave the BCRs barely different from what they were measured at in the previous chapter. Since we have omitted a number of influences on the BCR that are likely to be positive, and probably overstated some of the negative influences, the true value of the BCR is almost certainly significantly higher than 3.

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[19] Because the only differences between the "counterfactual" world and the "non-benefitted" world are those which result from withdrawing tax monies from the Kansas economy.

[20] Source: calculated by the authors using data and estimates from USDOC [1997, Tables 379, 380, 383, 389], Litman [1998], Peat Marwick Stevenson & Kellogg. 1993 [1993], CEC/US [1993] as cited in Hamilton and Atkinson [1996].

Table 5.2
Summary: Contributions to BCRs from Modeled Components Plus Externalities

Discount Rate	1%	5%	10%	15%
Component				
Keynesian benefits	0.85	0.82	0.79	0.75
Raw non-Keynesian BCR (calculated from Table 4.4)	6.29	3.80	2.57	1.98
Productivity BCR	0.28	0.24	0.20	0.18
Kansas pollution—fuel and traffic	-0.04	-0.05	-0.05	-0.05
Kansas pollution—roadway	-0.32	-0.28	-0.25	-0.22
Uncorrected net effects except Keynesian	6.21	3.71	2.48	1.89
US pollution correction factor	0.10	0.10	0.10	0.10
Corrected net effects using equation (5.2), except Keynesian	6.88	4.12	2.75	2.09
Net BCR	7.73	4.94	3.54	2.84

Source: IPPBR

6. CONCLUSIONS

Findings and policy implications

As a lower bound and using social discount rates of 10% or lower, the benefit-cost ratio of the Kansas Comprehensive Highway Program was at least 3. Does a BCR in that range indicate a "high enough" return on public investment?

This report has compared the KCHP with only one alternative: namely, returning all additional tax burdens due to the KCHP to the taxpayers, in the form of reduced taxes. Our finding means that, in aggregate terms, the KCHP has been at least 3 times as valuable to the taxpayers as returning their tax dollars would be. We believe the same would be true of a new highway program (assuming it were at least as well designed and managed as the KCHP).

However, that in itself may not be sufficient reason to adopt a new highway program. From a traditional and narrow benefit-cost perspective, the most that can be said is that a new highway program should be adopted *unless some other alternative use of the funds would have a higher benefit-cost ratio*. In other words, no benefit-cost study can stand alone; it has to be compared with analyses of other possible programs available to the given unit of government.

Unfortunately, very few benefit-costs analyses have been performed as yet from a state-level perspective; of those few, none were concerned with highways. However, a review of state-level economic development programs has found that a BCR of 3 constitutes, at least in relative terms, a good return on public investment [Burress and Oslund, 1998, Chapter 8].

From a broader perspective, a benefit-cost analysis is not a substitute for political judgment. It is however a potentially useful input to that judgment. Our analysis does provide a technical and economic justification for a new program. Because of many imponderables that are necessarily omitted from this or any such analysis, it cannot provide a complete weighing of all the values that are at stake. And it certainly does not show that a new highway program is what the people of Kansas actually want done; that will have to be determined by their elected representatives.

The current KCHP highway program is moving towards a close, and Kansas policymakers now face a decision on whether to renew or replace it. The relative economic benefits produced by the KCHP take on a heightened significance in that context. There is of course no guarantee that the next highway program will have equally high benefit-cost ratios or net benefits as the last one. However, the authors of this report believe that those benefits would be likely to be comparable to the benefits of the KCHP. Or in particular, the present value of benefits to Kansans from the next highway program is likely to exceed three times its cost.

Implementation

Reports in this series (i.e., K-TRAN reports) are expected to include recommendations on implementation. The present report provides general information intended to assist the process of policy formation and does not make specific proposals or provide concrete designs. As such, the only possible implementation would consist in the broad dissemination of these findings to policy-makers. We suggest that the following steps would be appropriate:

- identify policy-makers who may have a special interest in designing or affecting the next Kansas highway program. That would include not only KDOT officials and members of the relevant legislative committees, but also key opinion leaders in the state.
- make copies of the report available to these designated policy-makers.
- prepare an abstracted summary and a press release, and distribute them to the press.
- provide oral briefings, first to KDOT officials, and then to the interested legislative committees.

APPENDIX 1: THE CONCEPTS OF "BENEFIT" AND "COST"

The "net benefit" concept is described in Chapter 1. As noted, calculating benefit-cost ratios (BCRs) requires partitioning net benefits into separate gross benefits B and costs C. This Appendix sketches an approach based on Burress [1996].

Either benefits or costs need to be given an independent definition. Once one concept has been defined, the other can be inferred from the accounting identity

(A1.1) $NB = B - C$,

where NB is net benefits. NB will be defined as in Chapter 1 (i.e., differences between the actual world and the counterfactual world).

Unfortunately, the concept of cost is theoretically difficult, because many alternative definitions are possible. Moreover, alternative definitions have different properties. Consequently, arguments about whether a certain item is a "negative benefit" or a "positive cost" can be hard to settle; yet those decisions can have large effects on the BCR. Indeed, much of the benefit-cost literature seems to us rather incoherent on this point. We suggest that the problem mainly has to do with failure to be completely explicit about the counterfactual and other aspects of the underlying policy question, and also the properties of the "cost" concept.

In general terms, "cost" refers to opportunity cost, i.e., the value of the alternative that policy-makers have given up in order to received the benefits that were received. But the question of what was given up is settled as soon as the counterfactual world has been described. As we saw in the introduction, defining the counterfactual world gives us net benefits but not costs or benefits separately. It turns out that there is a second "compared to what" question implied when we partition net benefits into gross benefits and gross costs. How should we decide what to compare with?

We argue that the concepts of "cost" and "benefits" should be defined in such a way as to have four additional important or axiomatic properties:

(A1.2) The BCR is greater than 1 if and only if it is better to do the project than not to do the project, given a somewhat elastic budget constraint (i.e., if and only if NB is positive).

(A1.3) The project with the highest BCR among its alternatives is the one it would be best to undertake, given a somewhat elastic budget constraint.[21]

[21] With a fixed budget constraint, it is sometime the case that a small project with a relatively low BCR should be selected because it uses up budgetary dollars that otherwise would be wasted. BCRs, unlike net benefits, are not intended to handle that case.

(A1.4) Benefits should be defined so as to include indirect and multiplier effects, because these are part of the true regional consequences of the project. (These effects are often omitted for a national benefit-cost study, because they are believed to be not very important. But they can be extremely important for a regional benefit-cost study such as this one, and should not be omitted.)

(A1.5) BCR = eval(B)/eval(C), where eval(.) is a given function which evaluates vectors of benefit and cost into a common scalar metric of value, such as dollars.

Finding such a concept of cost is a bit tricky, for the following reason.

First, starting from axiom (A1.3) the most straightforward definition of "cost" in the context of maximization under a budget constraint is quite simply the budgetary expenditure. That is, the change in benefits per change in budgetary expenditure is a correct figure of merit for choosing projects that maximize net benefits subject to a fixed total expenditure. Second, assuming axioms (A1.4) and (A1.5), it can be shown that defining cost as budgetary expenditure violates axiom (A1.2)! The reason has to do with the fact that the benefits numerator contains multiplier effects, while the cost denominator does not. Consequently, with this definition a project could have a BCR greater than 1 and still have negative net benefits. (Another problem is that budgetary expenditure is a scalar monetary notion of cost, while equations (A1.1) and (A1.5) can be more usefully interpreted in terms of general vector-valued collections of cost and benefit items.)

The following concepts of costs and benefits do have the five axiomatic properties, and are used in this study.

We define a "cost" as what ever changes in Kansas as a result of withdrawing dollars from the Kansas economy to support the KCHP. Note that this definition includes indirect and multiplier effects of taxes in the cost, as well as the direct effects (which are just the tax revenues raised from Kansas). Also, this definition focuses purely on Kansas and ignores costs (such as federal taxes for highway programs) paid by the rest of the US or the world.

Similarly, we define "benefit" in general terms as anything that happens as a result of putting KCHP dollars back into the economy to pay for construction and other services. Once again, we include multiplier effects as well as direct effects and ignore effects on the rest of the world.

The eval(.) function used in the main part of this report is based on conventional models taken from the benefit-cost literature. For example, property damage in accidents is evaluated in terms of ordinary monetary cost; injuries are evaluated in terms of medical costs plus foregone earnings.

Once we have conceptually separated withdrawing dollars from the economy from putting the dollars back, then we will need to revisit the question of "compared to what?" That is, how do we determine what changes have occurred "after" you withdraw the dollars and "before" you spend them (so to speak)? To do this, it turns out that we need to introduce a second hypothetical world. In this world, tax dollars for KCHP have been pulled out of the Kansas economy and simply given away to people who are so far away from Kansas that their economic activities have no appreciable effect on Kansas. We could call it the "non-benefitted" world, since, from the narrow point of view of Kansas, the budget has been spent without any benefits resulting.

Costs are defined as all differences between the non-benefitted world and the counterfactual world. Benefits are defined as all differences between the actual world and the non-benefitted world. Net benefits are defined as all differences between the actual world and the counterfactual world. (Note that NB = B - C is then satisfied automatically.)

These definitions are important for two main reasons:

- they clarify the point that C must include multiplier effects; and
- they clarify the distinction between costs and negative benefits.

For example, if the KCHP leads to more travel, which then leads to an increase in damages from pollution, then that is a negative benefit, because it happens after the KCHP expenditures have been made. However, if pulling dollars out of the economy leads to reductions in Kansas output, which then leads to reductions in pollution, then that is a negative cost.

In general, most of the negative externalities that have been considered in the highway literature appear in our model as negative benefits rather than as positive costs.

APPENDIX 2: THE KCHP CASH FLOW MODEL

KDOT		**^HB 2014 AS PASSED**	
STATE HIGHWAY FUND including		^With Revisions	
Highway Bond Proceeds & Highway Bond Debt Service Funds			
Assumptions:	Growth in Substantial Maintenance & Construction:		5.20%

($000)	FY1990	FY1991	FY1992	FY1993	FY1994	FY1995	FY1996
BEGINNING BALANCE	48,500	124,561	168,141	344,502	817,954	956,476	1,069,276
REVENUES:							
Motor Fuel Taxes	113,792	120,467	129,278	157,998	167,158	167,988	174,300
SGF (Sales Tax) Transfer	63,489	74,371	78,025	75,501	79,079	81,451	83,198
Sales & Compensating Tax	46,545	53,986	56,348	60,817	66,449	70,320	71,436
Registration Fees	91,859	101,234	104,081	107,777	104,981	114,188	115,282
Drivers Licences Fees	4,380	4,808	6,291	4,786	4,941	6,093	6,099
Special Vehicle Permits	277	294	290	361	403	416	444
Interest on State Highway Fund	7,859	11,519	14,780	17,660	20,781	32,171	58,478
Oil, Gas, Mineral & Sand	602	483	515	643	576	450	502
Sales of Land & Buildings	838	258	587	227	835	490	382
Useable Condemned Equipment	460	425	600	847	1,089	627	1,730
Insurance Reimbursement	433	1,152	352	401	409	786	520
Publications	118	122	143	155	157	203	213
Misc. Revenues	953	540	572	1,049	2,789	3,656	1,045
Transfers:							
State Vehicle Registration	393	415	435	448	438	452	493
Motor Carrier Fund Excess	3,176	3,144	3,414	3,448	368	3,806	3,302
Maintenance Transfer SFF	7,150	8,006	7,098	35,963	0	0	0
Construction Transfer	1,992	1,389	293	0	0	0	0
Other Transfers	0	1,606	20	0	25	0	0
Subtotal	344,318	384,218	403,123	468,080	450,476	483,097	517,425
Federal Construction Reimbursement							
FY92 and prior	99,400	101,948	91,696	114,473	145,144	114,860	138,675
FY93 to FY97	0	0	0	0	0	0	0
FY98 and subsequent	0	0	0	0	0	0	0
Total Federal	99,400	101,948	91,696	114,473	145,144	114,860	138,675
Local Construction - Federal	0	0	0	0	46,700	45,183	71,215

Local Construction Reimbursement		0	5,871	1,689	5,998	3,996	17,691	26,220
System Enhancements: Local Share								
CE / PE: Direct to third parties		0	12,606	9,964	6,343	5,238	3,709	2,584
To KDOT		0	219	139	186	362	1,721	1,324
Received from KDOT		0	0	(136)	(268)	(14)	(2)	(393)
Construction: Direct to third parties		0	40,612	27,884	7,245	6,341	6,236	23,539
To KDOT		0	233	337	617	1,860	8,076	10,650
Received from KDOT		0	(21,714)	(11,383)	(2,736)	(1,077)	(304)	(2,894)
Total System Enhancements		0	31,956	26,805	11,387	12,710	19,436	34,810
TOTAL to KDOT		0	452	476	803	2,222	9,797	11,974
Miscellaneous Federal Aid		7,917	8,525	7,493	12,573	16,176	12,091	12,021
Subtotal Federal & Local		107,317	116,796	101,354	133,847	214,238	199,622	260,104
Total before Bonding		451,635	501,014	504,477	601,928	664,713	682,718	777,529
Bond Sales (net)	98.5%	0	0	250,297	370,733	125,173	139,465	0
Interest on bond proceeds	0.00%	0	0	1,325	4,782	8,092	10,731	2,259
Net from Bond Sales:		0	0	251,622	375,516	133,265	150,196	2,259
TOTAL REVENUES		451,635	501,014	756,100	977,443	797,978	832,915	779,788

EXPENDITURES:							
Maintenance							
Routine Maintenance:							
Agency Operations	(77,435)	(81,299)	(82,330)	(86,074)	(84,085)	(85,280)	(87,616)
City Connecting Links	(1,750)	(2,160)	(2,165)	(2,143)	(2,169)	(2,168)	(2,137)
Total Routine Maintenance	(79,185)	(83,459)	(84,494)	(88,217)	(86,254)	(87,447)	(89,753)
Contract (Substantial) Maintenance:							
Program Years FY 1992 and prior	(51,347)	(70,604)	(69,480)	(73,576)	(81,128)	(89,389)	(100,932)
FY 1993 - FY 1997 Program	0	0	0	0	0	0	0
FY 1998 and subsequent	0	0	0	0	0	0	0
Total Contract Maintenance	(51,347)	(70,604)	(69,480)	(73,576)	(81,128)	(89,389)	(100,932)
Total Maintenance	(130,532)	(154,063)	(153,975)	(161,793)	(167,383)	(176,836)	(190,685)

Construction								
Major Modifications & Priority Bridges								
Program Years FY 1992 and prior		(131,042)	(142,315)	(175,111)	(151,699)	(254,311)	(197,722)	(303,212)
FY 1993 - FY 1997 Program		0	0	0	0	0	0	(6,036)
FY 1998 and subsequent		0	0	0	0	0	0	0
Agency CE & PE		(40,073)	(40,213)	(38,131)	(39,078)	(42,790)	(36,098)	(35,896)
Contract CE & PE		(4,908)	(20,279)	(17,701)	(23,244)	(20,333)	(21,490)	(27,487)
Local Federal Aid Projects		0	0	0	0	(46,700)	(56,479)	(89,018)
Buildings		(3,641)	(3,375)	(1,411)	(2,428)	(2,209)	(4,779)	(2,250)
Total Major Modifications		(179,664)	(206,181)	(232,355)	(216,449)	(366,343)	(316,568)	(463,899)
System Enhancements								
Construction : Local		0	(40,612)	(27,884)	(7,245)	(6,341)	(6,236)	(23,539)
KDOT		0	(2,778)	(13,419)	(21,755)	(7,084)	(85,822)	(110,009)
Total Construction		0	(43,390)	(41,303)	(29,000)	(13,425)	(92,058)	(133,548)
KDOT to Locals		0	(21,714)	(11,383)	(2,736)	(1,077)	(304)	(2,894)
TOTAL KDOT		0	(24,492)	(24,802)	(24,491)	(8,161)	(86,126)	(112,903)
CE / PE : Local		0	(12,606)	(9,964)	(6,343)	(5,238)	(3,709)	(2,584)
KDOT		0	(4,115)	(4,957)	(5,489)	(4,205)	(10,883)	(13,854)
Total CE / PE		0	(16,721)	(14,921)	(11,832)	(9,443)	(14,592)	(16,438)
KDOT to Locals		0	0	(136)	(268)	(14)	(2)	(393)
TOTAL KDOT		0	(4,115)	(5,093)	(5,757)	(4,219)	(10,885)	(14,247)
TOTAL System Enhancements		0	(60,111)	(56,224)	(40,832)	(22,868)	(106,650)	(149,986)
TOTAL payments by KDOT		0	(28,607)	(29,895)	(30,248)	(12,380)	(97,011)	(127,150)
Total Construction		(179,664)	(234,788)	(262,250)	(246,697)	(378,723)	(413,579)	(591,049)
Local Support								
Agency Operations		(1,993)	(2,594)	(2,815)	(2,756)	(2,962)	(3,042)	(3,012)
Categorical Grants		(5,180)	(5,249)	(4,748)	(6,195)	(9,061)	(7,076)	(5,438)
Total Local Support		(7,173)	(7,844)	(7,563)	(8,951)	(12,023)	(10,118)	(8,449)
Management		(30,621)	(33,532)	(29,451)	(30,272)	(33,090)	(37,594)	(37,963)
Transfers Out		(27,584)	(27,208)	(126,500)	(37,735)	(33,409)	(36,177)	(35,256)
TOTAL before Debt Service		(375,574)	(457,434)	(579,739)	(485,448)	(624,627)	(674,304)	(863,402)
		0	0	0	0	0	0	0
New Debt Service @	0.00%	0	0	0	(18,544)	(34,828)	(45,812)	(56,991)
Term =	151,754							
TOTAL EXPENDITURES		(375,574)	(457,434)	(579,739)	(503,991)	(659,456)	(720,115)	(920,393)
ANNUAL SURPLUS (DEFICIT)		76,061	43,580	176,361	473,452	138,523	112,799	(140,605)
ENDING FUND BALANCE:		124,561	168,141	344,502	817,954	956,476	1,069,276	928,670

Source: KDOT Division of Administration.
Note: the Cash Flow Model (like the KCHP itself) continued into FY1997, but 1997 data are not shown here because they were not used in the analysis.

APPENDIX 3: AN ECONOMIC MODEL OF TRAVEL DEMAND

This appendix sketches an economic model in which distance traveled is approximately constant, even when travel speeds rise and unit travel times fall.

A model of utility maximization is:

$$\text{MAX } U = \log(D) + .5DT - \alpha T - \log(T) - .5\beta(t-t_0)^2 - .5\gamma(C-C_0)^2 \qquad \text{w.r.t} \quad D, T, t,$$

SUBJECT TO the travel technology:

(A3.1) $D = \lambda T$, and the budget constraint:

(A3.2) $C = \omega(H-T-t)$, where

U = household utility,
T = travel time, $T \geq 0$,
D = distance traveled, $D \geq 0$,
λ is average speed, $\lambda > 0$,
t is leisure time, $t_0 \geq t \geq 0$,
C is consumption, $C_0 \geq C \geq 0$,
H is total time available, $H > 0$,
ω is the real wage rate, $\omega > 0$, and
$\alpha, \beta, \gamma > 0$.

Note that U is increasing in inputs, or

$$\partial U/\partial D = 1/D + T > 0, \text{ and}$$

$$\partial U/\delta T = .5D - \alpha - 1/T < 0$$

in the region where

(A3.3) $\alpha > .5D$

(and therefore the utility representation U used here may not be valid outside that region). More general linear terms in t and C are omitted from U because they do not importantly affect the result. Assuming interior solutions, we maximize

(A3.4) $\log(\lambda T) + .5\lambda T^2 - \alpha T - \log(T) - .5\beta(t-t_0)^2 - .5\gamma(\omega(H-T-t)-C_0)^2$

with respect to T and t. The FOCs are:

(A3.5) $0 = \lambda T^* - \alpha + \gamma\omega(\omega(H-T^*-t^*)-C_0)$, and

(A3.6) $0 = \beta(t^*-t_0) + \gamma\omega(\omega(H-T^*-t^*)-C_0)$.

Hence:

$$\lambda T^* - \alpha = \beta(t^*-t_0)$$

$$t^* = [(\lambda T^* - \alpha)/\beta + t_0]$$

$$0 = \lambda T^* - \alpha + \gamma\omega(\omega(H-T^*- [(\lambda T^* - \alpha)/\beta + t_0])-C_0)$$

$$(\lambda - \gamma\omega^2 - \gamma\omega^2\lambda/\beta)\ T^* = \alpha - \gamma\omega(\omega(H- [(- \alpha)/\beta + t_0])-C_0)$$

$$T^* = \{\alpha - \gamma\omega^2(H + \alpha/\beta - t_0) - \gamma\omega C_0)\}/(\lambda - \gamma\omega^2 - \gamma\omega^2\lambda/\beta).$$

And hence the optimal travel distance D* is given by:

(A3.7) $D^* = \lambda T^* = \{\alpha - \gamma\omega^2(H + \alpha/\beta - t_0 - C_0/\omega)\}/(1 - \gamma\omega^2\ (1/\lambda+1/\beta)$.

When preferences and wages are such that

(A3.8a) $\alpha \gg \gamma\omega^2(H + \alpha/\beta - t_0)$,

(A3.8b) $\alpha \gg \gamma\omega C_0$, and

(A3.8c) $\beta \gg \gamma\omega^2$,

then we have

(A3.9) $D^* \approx \alpha$,

a constant, for all travel speeds $\lambda \gg \gamma\omega^2$. Note that under conditions (A3.8),

(i) (A3.3) is satisfied; and

(ii) miles traveled are approximately constant, independently of average speed λ.

APPENDIX 4: MODELING THE RESIDUAL VALUE OF THE KCHP

Our goal is to construct a conservative yet reasonable estimate of the residual value of the KCHP in 1997.

Definition: residual value or scrap value is purely a shortcut device to avoid running the modeled actual and counterfactual worlds on out to infinity. In particular, the true definition of residual value for our situation is given implicitly by:

$$(1)\ BCR_{1989-\infty} = B_{1989-\infty} / C_{1989-\infty}$$

$$= [B_{1989-1996} + RV]/C_{1989-1996} = BCR_{1989-1996} + RV/C_{1989-1996},$$

where RV is the residual value, C is present value costs evaluated at 1989, B is present value benefits evaluated at 1989, BCR is the benefit cost ratio evaluated at 1989, and subscripts indicate the time period for which actual and counterfactual data are assumed available and used.

When that is kept clearly in mind, some of the models of residual value that have been proposed can be shown to be pretty far off. We believe it is generally simpler and more transparent to keep referring directly to counterfactuals, not to residual values; to explicitly define the future actual and counterfactual worlds for all future time; and then to use only the first line of equation (1).

MODEL: constant maintenance costs forever.

Assumption 1: Assume there is a steady state starting in 1997 such that

B_0* = gross benefits in 1997 = gross benefits in each successive year = annual B-C each year.

Let R = discount rate.

Then the present value of B_0* forever as of 1997 would be $PV_{1997} (B_t) = B_0{}^*/R$.
Its present value as of 1989 would be $B_0{}^* \epsilon^{-R(1997-1989)} /R$.

However, the last formula is unreasonable for small R because it increases without limit as R—>0. The infinity comes in because we assumed the project has a roughly constant value at the beginning of each and every project period in the future, and this value goes on forever. If one doubts that this assumption corresponds to likely future reality (and we do doubt it), one should add an additional discount factor. This discount rate is separate from the social discount rate; it represents the extra risk for, or the decay of information about the future of, or the declining share of causality for future transport systems from, *this specific project*. In particular, we assume that the chances are zero that the Kansas highway system as such will last forever, and we try to estimate how fast its survival chances will dribble away.

Assumption 2: a better formula is to replace B_0*/R —>

(2) $PV_{1997}(B_t) = B_0^*/(R+S)$

where S represents an estimate of the average rate of decay in probability of the future survival of the Kansas highway system as such.

Then we have

$$(3)\ BCR_{1989-\infty} = B_{1989-\infty} / C_{1989-\infty} = [B_{1989-1996} + B_{1997-\infty}]/[C_{1989-1996} + C_{1997-\infty}]$$

$$= [B_{1989-1996} + B_0^*\epsilon^{-8R}/(R+S)]/[C_{1989-1996} + C_{1997-\infty}],$$

(where $B_{1997-\infty}$ and $C_{1997-\infty}$ are evaluated as of 1989).

But how do we evaluate S?

Assumption 3: A plausible guess is that in 200 years the Kansas transport system will not have much to do with what it is now. In fact, not even the right-of-way will have much value, because surface transport will be abolished. However, to be conservative, let us assume it is only 100 years. Consequently we will need $\epsilon^{-100S} \approx 0$. Let us assume in particular, on the analogy of assuming a 1% significance level, that

(4) $\epsilon^{-100S} = .01$.

Solving leads to S = 5%/year = .05/year.

We still need to measure B and C.

Assumption 4: Actual traffic each year in the future equals actual 1996 level, and counterfactual traffic equals counterfactual 1996 level. (This assumption tends to understate residual value, so it's conservative.) Therefore, gross annual benefits except for Keynesian benefits (call it user benefits for simplicity), equals its 1996 level; say B_0. Keynesian benefits are then determined by maintenance costs.

Assumption 5. The highways can be and are held in constant condition using constant maintenance expenditures. In the actual world, that level of maintenance might be estimated as average annual maintenance during KCHP; say C_0. In the counterfactual world, it would be more, but how much more is not known. Assuming costs are the same in the two worlds understates the residual value, which is conservative and hence acceptable. So we will that assume both costs and Keynesian benefits are identical in the two worlds. (Then given another assumption, as seen below, C_0 will drop out of the BCR expression.)

Now let us proceed carefully here. Let taxes C_0, expenditures C_0*, and benefits B_i, be vectors of changes, and let M be a multiplier matrix. Expenditures C_0 and taxes C_0* refer to the same total amount of dollars, but they differ in a vector sense because different economic sectors are affected, and a different share is exported to the rest of the world. We have:

Counterfactual world: tax cost = C_0*, Keynesian tax effects = - MC_0*, expenditures = C_0, Keynesian benefits = MC_0, user benefits = B_1.

Assumption 6: assume the non-benefitted world is identical to the counterfactual world after 1996. So there is no cost of the KCHP after 1996. (That is mainly a definition of what we mean by "cost of the KCHP.")

(Modeled, future) actual world: tax cost = C_0*, Keynesian tax effects = - MC_0*, expenditures = C_0, Keynesian benefits = MC_0, user benefits = $B_2 > B_1$.

We define $B_2 - B_1 = B_0$, which is constant for each period after 1997.

Hence:
$B_{1997-\infty}$ = residual benefit = PV {Actual world less Non-benefitted world} = PV{$B_2 - B_1$} = $B_0/R\epsilon^{-8R}$.
$C_{1997-\infty}$ = residual cost = PV {Counterfactual world less Non-benefitted world} = 0.
Hence:

$$(4)\ BCR_{1989-\infty} = [B_{1989-1996} + B_0\epsilon^{-8R}/(R+S)]/C_{1989-1996}$$

Note: From (1) we could now calculate the residual value as:

$$RV = B_0\epsilon^{-8R}/(R+S),$$

which is reasonably intuitive. (It states that the residual value is the present value of gross benefits, with an extra discount rate to allow for future risk that the Kansas highway system will become obsolete.) However, the necessary assumptions, and also the demonstration that this is a conservative estimate, do not seem intuitive to us at all.

APPENDIX 5: TELEPHONE SURVEY INSTRUMENT— WILLINGNESS TO PAY FOR GOOD HIGHWAYS

[This sequence of questions was included in the Kansas Consumer Sentiment Survey conducted by IPPBR in the Fall 1997.]

1. *Do have a valid driver's licence*?
yes
no
no opinion
[branch out if no or no opinion]

The next question has to do with the quality of Kansas highways. In particular, we would like to know something about the importance you place on good roads.

Suppose that you will be driving a car for a trip of about 2 hours and have a choice of two routes. One route mainly follows an interstate highway. The other route mainly follows typical asphalt county roads like those in your county.
Suppose that the two routes take about the same time.
[If they ask, state that the county highways follow a shorter route.]

2. *Would you take the interstate highway or the county highway?*
Interstate
County
no opinion

[reverse the order of highways in half the sample]
[branch out if they prefer the county route or have no opinion]

3. *Now suppose that toll gates are put on the same interstate highway and you would be charged* [split the sample 5 ways: $.50, $1, $2, $4, $8] *for the 2 hour trip. Keeping in mind that the travels times are about the same, now would you take the interstate highway or the county highway?*
Interstate
County
no opinion

[keep the order of highways parallel to question 2]
[branch out if they prefer the county route or have no opinion]

4. *Now we would like you to allocate the extra value you received from using the interstate between various categories using a scale of 1 to 10, where 10 is the most value, and 1 is the least. The categories are:* [read the categories, then repeat, for each category:] *on a scale of 1 to 10, how much value would you assign to* [name of category]*?*

______ improved safety
______ more comfortable ride and improved ease of driving
______ more interesting scenery
______ savings in cost of gasoline
______ savings in wear and tear on the car
______ no opinion

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