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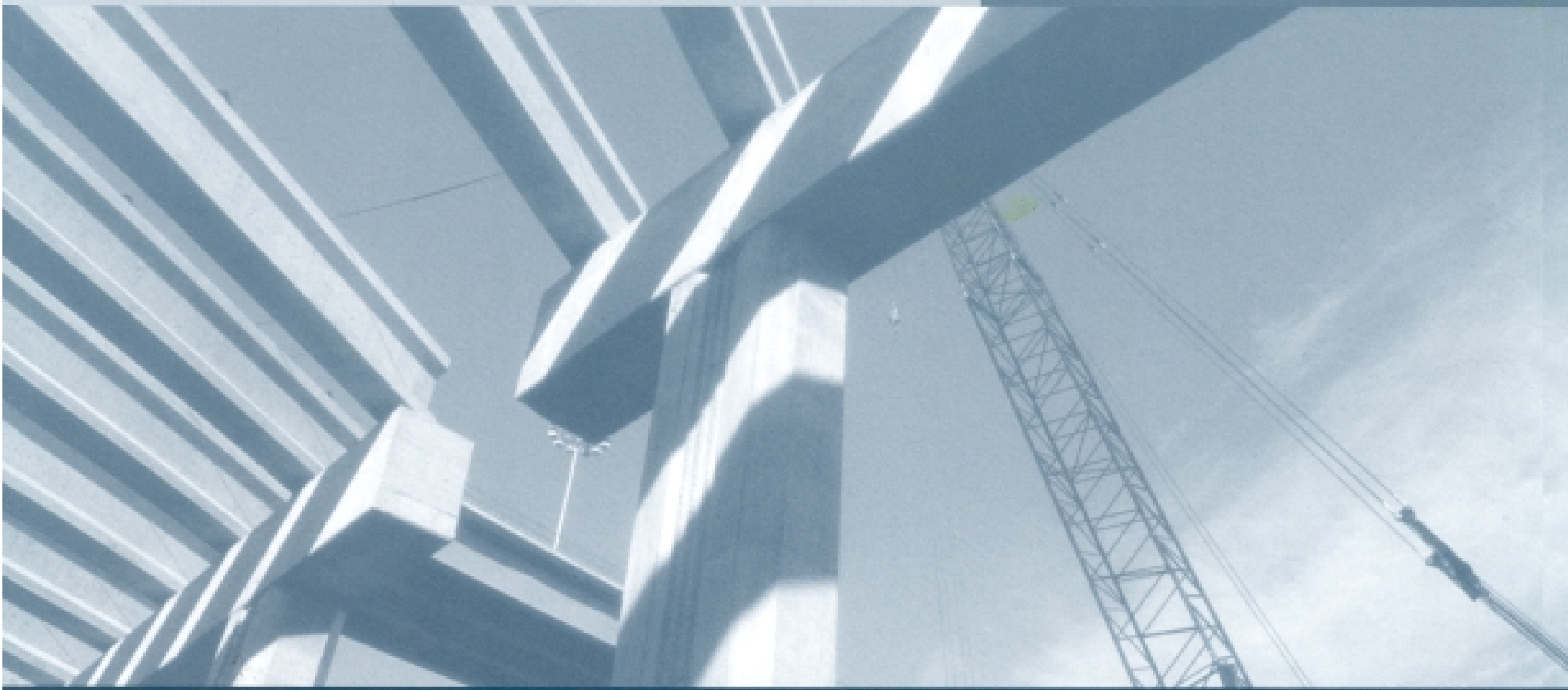

BUREAU OF TRANSPORTATION STATISTICS UNITED STATES DEPARTMENT OF TRANSPORTATION

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The Bureau of Transportation Statistics (BTS), an operating administration of the US Department of Transportation (DOT), is a national statistical agency, DOT's representative on the Federal Geographic Data Committee, and the home of the National Transportation Library. BTS compiles, analyzes, and makes accessible information about the nation's transportation systems; collects information on various aspects of transportation; and enhances the quality and effectiveness of the Department's statistical programs through research, the development of guidelines, and the promotion of improvements in data acquisition and use.

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JOURNAL OF TRANSPORTATION AND STATISTICS

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Letter from the Editor

Dear Readers,

This issue of the *Journal of Transportation and Statistics* (JTS) ushers in our second year of publication, along with a few changes. First, we welcome the new Director of the Bureau of Transportation Statistics, Ashish K. Sen. As only the second director of this agency, we look to him to nurture it toward maturity and to chart a course for its future. Before coming to the BTS, Sen served as the Director of the Urban Transportation Center and the Statistics and Evaluation Laboratory at the University of Illinois in Chicago. His extensive background in transportation and statistics will bring a valuable new perspective to BTS.

This year we will be adding new editorial board members from the statistical community. We will also accept articles in LaTeX, a language widely used by statisticians, as part of an effort to better serve the statistical community. With these changes, we hope to encourage greater participation by statisticians.

JTS's fundamental objectives, however, remain unchanged. Articles will still cover the following areas:

- measurement of transportation activity and the performance of transportation systems,
- measurement and analysis of the importance of transportation and its consequences,
- measurement and analysis of transportation trends,
- advancement of the science of acquiring, validating, managing, interpreting, and disseminating transportation information.

As a publication of a federal statistical agency, the JTS will continue to focus on data, description, and analysis and will explicitly avoid policy studies.

After careful consideration, we have decided to delay quarterly publication until 2000. In the last issue of the JTS, I wrote about adding a comprehensive statistical series of transportation performance indicators starting later this year. This will not be done until BTS completes a thorough review of available measures. We will keep you updated on our publication plans.

As always, your interests, ideas, and recommendations for improving the JTS are important to us. We invite you to communicate with us via email at journal@bts.gov, by visiting our website at www.bts.gov/, or by writing to me at the address on page ii of the journal. Thank you for your continued interest and support.

DAVID L. GREENE

Editor-in-Chief

Growth in Motor Vehicle Ownership and Use: Evidence from the Nationwide Personal Transportation Survey

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ABSTRACT

The size, composition, and use of the nation's household vehicle fleet are subjects of major interest to analysts and policymakers concerned with the economic motivations and enviromental consequences of travel. The 1995 Nationwide Personal Transportation Survey (NPTS), together with similar surveys conducted in 1969, 1977, 1983, and 1990, reveals important insights into the changing patterns of household motor vehicle ownership and use, as well as the underlying behavior that produces them. This paper uses information from the NPTS to address three related subjects: 1) growth in personal motor vehicle travel and its sources; 2) changes in the number, types, and age distribution of household motor vehicles; and 3) the determinants of households' vehicle utilization patterns and demands for private motor vehicle travel. The results presented here can be useful to transportation professionals seeking to understand the patterns and determinants of motor vehicle travel, as well as to planners and policymakers in their efforts to design and implement strategies that reduce the environmental consequences of growing motor vehicle use.

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NATIONWIDE PERSONAL TRANSPORTATION SURVEY

The Nationwide Personal Transportation Survey (NPTS) is a periodic survey of demographic characteristics, motor vehicle ownership, and daily tripmaking by U.S. households. All trips by household members are surveyed for a single "travel day," with interviews conducted so that each of the seven days of the week, including holidays, is represented as a travel day for some households. Trip data collected include the time the trip began and ended, its length, the size and composition of the traveling party, the mode of transportation used, the purpose of the trip, and the specific vehicle that was used (if the trip was made in a household-owned vehicle). In addition, data on all members' trips to destinations more than 75 miles from home during the two-week period ending on the interview day is obtained from a subset of households. Responses to the 1995 survey were supplemented by summary data from the 1990 U.S. Census. This data described the characteristics of the geographic area of each sample household and where each member worked.

The first three surveys (1969, 1977, and 1983) were conducted by the Census Bureau using face-to-face home interviews of a sample of households selected randomly from address files, while the 1990 and 1995 surveys were conducted by the Research Triangle Institute using random digit telephone dialing. The sample sizes of the five surveys varied widely: approximately 15,000 households were interviewed for the 1969 NPTS; 18,000 for 1977; 6,500 during 1983; 22,000 during 1990; and nearly 40,000 in the most recent survey.[1] The 1995 survey was conducted from May 1995 to July 1996.

HOUSEHOLD MOTOR VEHICLE TRAVEL

The 1995 NPTS contains three different types of information that can be used to produce estimates of total vehicle-miles traveled (VMT) in personal motor vehicles: 1) estimates of the number and usage of household motor vehicles, 2) data on the number of drivers and their estimates of how much they drive, and 3) estimates of the number and length of trips by household members using personal motor vehicles. This section explains how each of these types of information can be used to estimate total VMT and compares the results; table 1 reports the various estimates and the data sources used to construct them.

Vehicle-Based Estimates

One estimate of total VMT can be derived from survey respondents' estimates of the total number of miles each household vehicle was driven by all drivers during the previous 12 months.[2] Multiplying their average estimate of vehicle use (12,226 miles per year) by the 1995 NPTS estimate of the total number of household motor vehicles (176.1 million) produces a figure of 2.153 trillion annual VMT (table 1, line 1). The 1995 survey also obtained odometer readings for about 44% of all household vehicles at the beginning and end of a period of several weeks, and these can be extrapolated to their annual equivalents.[3] The estimate of annual vehicle use constructed from these odometer data is 11,801 miles per year, or about 4% less than the self-reported estimate; the total household VMT estimate based on this figure is 2.078 trillion annually (table 1, line 2). Both of these estimates presumably include commercial driving in *household* vehicles but not in vehicles garaged outside the home.

[1] Approximately 24,000 households were included in the national sample drawn for the survey, while the remaining 16,000 were included in order to enrich the sample in a few specific states and urban areas.

[2] The survey asked respondents to estimate use of each vehicle "available to" the household, so presumably some company-provided cars were included in addition to those owned or leased by household members. The specific question it asked was, "About how many miles was this vehicle driven [in the last 12 months] since the date (month/year) it was bought or received? Include mileage driven by all drivers." Mileage estimates for vehicles owned less than 12 months were annualized during post-processing of the data.

[3] Any seasonal variation in vehicle use that might make the annualized estimates of *individual* vehicles' usage unreliable should not significantly affect the estimate of *average* annual vehicle mileage because the survey was administered over approximately a year-long period and thus included roughly equal numbers of mileage measurements recorded during each season of the year.

TABLE 1 Estimates of Total Vehicle-Miles Traveled (VMT) During 1995

Line	Source	Basis of estimate	Type of data	Estimate (trillion VMT)
1	NPTS	Household vehicle use	Owner estimates	2.153
2	NPTS	Household vehicle use	Odometer readings	2.078
3	NPTS	Driving for all purposes	Driver estimates	2.383
4	NPTS	Driving for personal travel	Trip diaries	2.181
5	NPTS	Driving for all purposes	Trip diaries	2.279
6	FHWA	Light-duty vehicle travel	State traffic counts	2.228
7	FHWA	All motor vehicle travel	State traffic counts	2.423

Sources: 1995 NPTS; and the U.S. Department of Transportation, Federal Highway Administration (FHWA), *Highway Statistics 1995* (Washington, DC: 1995), table VM-1.

Driver-Based Estimates

A second source of VMT estimates from the NPTS can be derived from surveyed drivers' estimates of the total number of miles they each drove during the previous 12-month period.[4] Because respondents were specifically instructed to include commercial driving ("miles driven as a part of work") in their responses, the total VMT estimate from this source should be *higher* than the vehicle-based estimates, which included only driving in vehicles owned by household by members. The resulting average of 13,478 annual miles per driver multiplied by the NPTS estimate of 176.8 million drivers produces an estimate of 2.383 trillion annual VMT (table 1, line 3), which is indeed considerably larger than the two estimates that include only household vehicle use.

Trip-Based Estimates

A third source of VMT estimates can be constructed using the trip-level data recorded in NPTS household travel diaries, which asked respondents to itemize their trips ending on the previous day, the "travel day," and also all trips of 75 miles or more ending during the previous two weeks, the "travel period." By counting only those trips where the respondent was a driver of a personal motor vehicle, we estimated their average daily miles of travel.[5] The resulting annual VMT estimates from combining the travel day and travel period data are 2.181 trillion miles for personal travel only (table 1, line 4), slightly above the higher of the two vehicle-based estimates, and 2.279 trillion VMT including commercial driving (table 1, line 5), somewhat lower than the driver-based estimate.

Comparing the Estimates

Although they are derived from completely separate sections of the survey, the three VMT estimates that include only driving in household-owned vehicles are reasonably consistent with one another; the range from lowest to highest is only about 5%. Similarly, the difference between the two NPTS estimates that include commercial driving in non-household vehicles is about 5%. For comparison, the Federal Highway Administration (FHWA) reports in its annual *Highway Statistics* publication that 2.228 trillion miles were driven in passenger cars and light trucks during 1995 (USDOT 1995) (table 1, line 6), including both their personal and commercial use; adding heavy-duty vehicle use

[4] The question asked was, "About how many miles did you personally drive during the past 12 months in all licensed motorized vehicles? Include miles driven as a part of work."

[5] The survey asked respondents who made *more than 10 daily trips* as a part of work (e.g., as a truck or taxi driver) to give a separate estimate of their total daily commercial driving. The trips made by commercial drivers who made *10 or fewer trips* on the travel day were included as part of the travel day diary. A comprehensive estimate of total annual VMT includes the sum of all three of these components: travel day VMT, travel period VMT, and daily commercial VMT. (The 2,900 travel day trips in the sample, which were recorded in both the travel day and travel period data, were eliminated from the travel day VMT estimate to avoid double counting.)

brings the FHWA estimate of total VMT to 2.423 trillion (table 1, line 7)[6] (USDOT 1995). As would be expected, both of the NPTS-derived VMT estimates that include driving in nonhousehold vehicles (table 1, lines 3 and 5) fall between the two FHWA figures.

Recent Growth in VMT

While several changes between the 1990 and 1995 NPTSs complicate the task of comparing VMT estimates for these two years, the basic survey method (household telephone survey) and the self-reported annual driving and vehicle-use questions remained unchanged between the two surveys, making VMT estimates using these two sources directly comparable for 1990 and 1995. The total VMT estimates derived from responses to these questions show very different changes over the five-year period between the two surveys: the total, based on survey respondents' estimates of household vehicle use, rose 4.4% (about 0.9% annually), while that based on their estimates of annual driving increased 11.4% (2.2% annually). Unfortunately, it is not possible to derive an estimate of VMT growth from the odometer-based VMT estimate, because this method was introduced into the NPTS for the first time in 1995.

Comparing the *trip-based* VMT estimates from the 1990 and 1995 surveys is complicated by a major change in methodology: while the 1990 survey asked respondents to recall their trips from the previous day, the 1995 survey asked respondents to record all of their trips on a designated travel day in travel diaries, which were subsequently read to interviewers. Not surprisingly, the 1995 method recorded many more trips than the 1990 procedure and earlier surveys; specifically, many short trips that had apparently been overlooked using the recall method were recorded by the diary method. Although the change in survey method is likely to have greatly improved the accuracy and completeness of trip recording, the 1990 NPTS trip-based estimate of total VMT in retrospect seems likely to have been an underestimate. Comparing the estimate of total household motor vehicle travel reported in the 1990 NPTS almost certainly leads to a substantial overestimate of the 1990 to 1995 growth in VMT.

For the 1994 pretest of the 1995 NPTS, some surveys were completed with the new method (diary) and some with the old (respondent recall), so that the effects of the change in methodology can be compared directly. (A full discussion of this issue is presented in the appendix). Adjustment factors for trips and miles traveled were calculated based on the pretest data (shown in appendix table A-1) and applied to the 1990 trip-based data to produce a VMT estimate more closely comparable to the 1995 figure. The change between the resulting adjusted 1990 trip-based VMT estimate and the 1995 figure, 18.1% over the five-year period or 3.4% per year, is much greater than the corresponding changes in the driver- and vehicle-based VMT estimates reported previously. It is important to emphasize, however, that even the adjusted 1990 trip-based VMT estimate is not completely comparable to the 1995 figure, because these adjustments do not account for other changes in the survey, such as the inclusion of commercial driving during 1995. In contrast, the questions and methods used in the driver and vehicle estimates of VMT did not change between the 1990 and 1995 administrations of the survey, so the estimates of VMT growth they produce should be more reliable.

For comparison, the annual growth rates implied by the FHWA *Highway Statistics* data for 1990 to 1995 are 2.3% annually for light-duty vehicles only and 2.5% per year including heavy-duty vehicles. These fall approximately midway between the estimates based on NPTS respondents' reports of household vehicle use (0.9% annually) and the number and lengths of their trips (3.4% per year), but they conform quite closely with the growth rate (2.2% annually) derived from respondents' estimates of their driving activity. On the basis of its close agreement with the growth rates implied by the FHWA data, it appears that the NPTS driving-based estimate of total VMT may provide the most reliable indicator of the pace of recent growth in household travel.

[6] The FHWA definition of light trucks includes all two-axle, four-tire trucks.

Longer Term Growth in VMT

Fortunately, there is somewhat closer agreement about the longer term pattern and average rate of growth in motor vehicle travel, both between the two NPTS methods and between their results and other sources. Figure 1 reports annualized growth rates for the NPTS driver- and vehicle owner-based estimates of total travel in household-owned motor vehicles from 1977 to 1995, as well as for all light-duty vehicles as reported in FHWA's *Highway Statistics*. As the figure indicates, the three sources yield estimates of annual VMT growth over this extended period ranging from 2.8% to 3.6%, not an unreasonably wide interval considering the differences in methods and data used to produce them.

All three sources also show the rate of VMT growth accelerating sharply between 1983 and 1990, from its moderate 1977 to 1983 pace, and then slowing from 1990 to 1995. The most significant disagreement seems to be over *how much* the rate of growth slowed during this latter period. But as figure 1 shows, the FHWA *Highway Statistics* data indicate both a lower average growth rate over the entire 1977 to 1995 period and more stability among the three separate intervals comprising it. The consistency of the procedures used to develop the FHWA estimates throughout most of this period and the continuous annual basis of that data series probably mean that it provides a more reliable picture of both longer term average growth in travel and shorter term variations in the pattern of its growth than can be obtained from an occasionally administered survey such as the NPTS. The primary advantage of the NPTS is the insight it provides into the changing patterns of household vehicle ownership and use and their underlying causes.

SOURCES OF GROWTH IN HOUSEHOLD TRAVEL

As an illustration, total VMT can be divided into several individually meaningful components in order to gain more insight into the forces producing growth in motor vehicle travel. Figure 2 employs the calculation previously used to derive the NPTS driver-based estimate of total annual VMT—average annual miles driven per licensed driver multiplied by the estimated number of licensed drivers—to show how the 1990 to 1995 *change* in total VMT can be broken down into changes in annual miles per driver and in the number of licensed drivers.[7] The NPTS shows that

[7] One potential problem in interpreting the vehicle- and driver-based VMT estimates in this way is that the number of household vehicles and the number of licensed drivers vary throughout the year, and some arbitrary date must be chosen to count them. In effect, the NPTS sets this date individually for each surveyed household, but this is likely to be a very minor problem.

FIGURE 1 Comparison of Total VMT Estimates

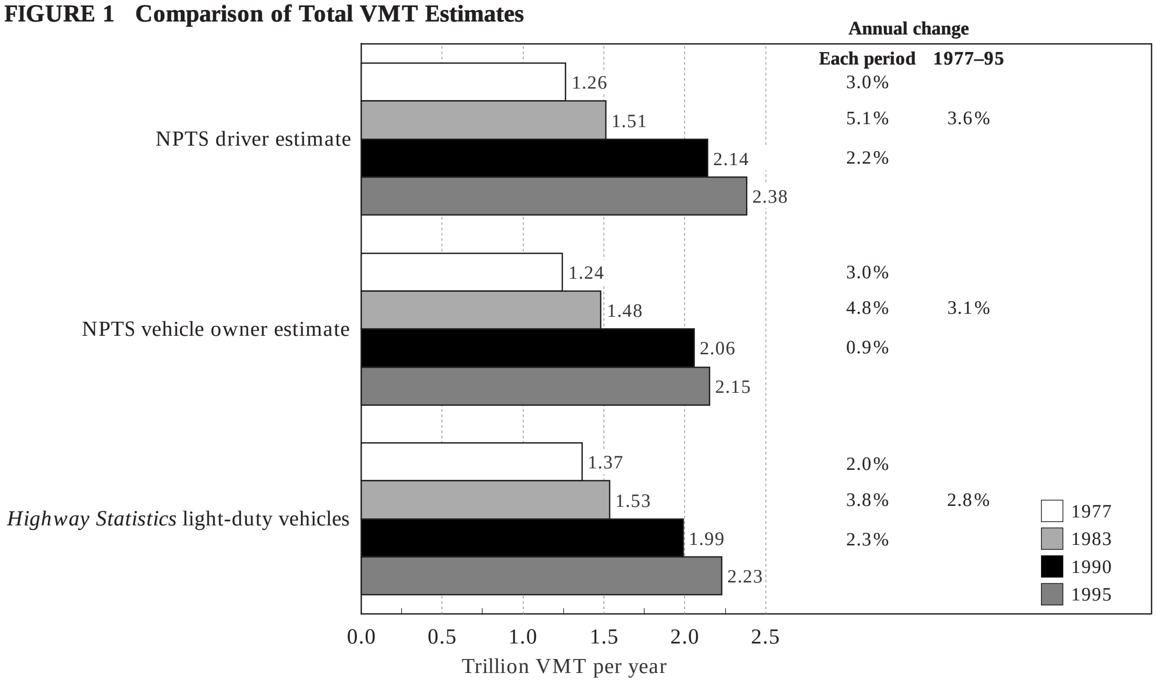
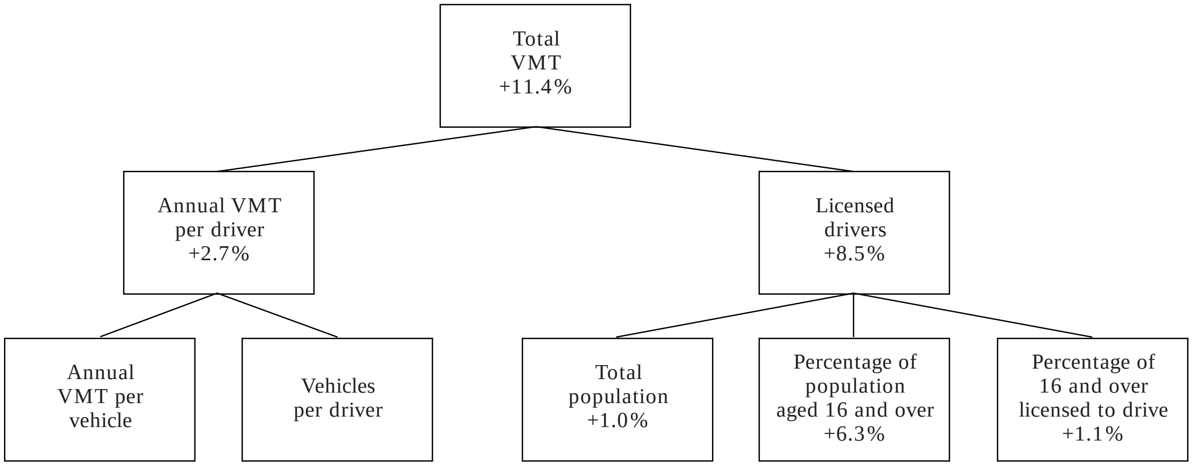


FIGURE 2 Components of Change in Total VMT: 1990–95



Note: Percentages equal product, rather than sum, of the change in individual components.

annual miles driven per licensed driver increased 2.7% over this period, while the number of licensed drivers increased 8.5%; these changes combine to produce the previously reported increase of 11.4% in the driver-based estimate of total travel.[8]

As figure 2 also shows, the change in the number of licensed drivers can be further broken down into changes in the total population, the share of the population of driving age (16 years and above in most states, but higher in a few states), and the fraction of the driving-age population actually licensed to drive. The number of licensed drivers increased between 1990 and 1995 because all three of its components grew, although most of the growth in licensed drivers was accounted for by the increased share of the population of driving age, which rose 6.3%. In principle, it should also be possible to break down the growth in annual miles per driver into changes in annual miles driven per vehicle and in the number of vehicles per driver, but the instruction to survey respondents to include driving as part of work in vehicles garaged outside the household in their estimates of annual driving (see footnote 2) makes this measure inconsistent with the NPTS estimate of the vehicle population, which is limited to household vehicles.[9]

More detailed analysis reveals that the increase in annual VMT per licensed driver occurred primarily among women and older men. Table 2 reports that VMT for the youngest drivers (16 to 19 years old) declined significantly among both men and women, although the percentage decline among males was twice as large as that among females. In contrast, driving increased significantly and fairly uniformly among women aged 20 to 64 years; only among women 65 and older did it fail to change significantly. Table 2 also shows that changes in annual driving among the most active drivers—men aged 20 to 64 years—were mixed, the 20 to 34 age group showed a slight decline, the men 35 to 54 years showed almost no change, and

[8] The percentage change in total travel is equal to the product, rather than the sum, of the change in the individual components.

[9] Ignoring this inconsistency, which was also present in the 1990 survey, results in calculated changes of 4.5% in annual vehicle use and –1.7% in the number of (household) vehicles per driver from 1990 to 1995, which together produce the 2.7% increase in annual VMT per driver reported in figure 2. The calculated increase in annual vehicle use (4.5%) contrasts with the change in respondents' estimates of annual *household* vehicle use reported in the 1990 and 1995 surveys, which is –2.0%. This suggests that much of the growth in total VMT may have been in the use of commercial and other vehicles garaged outside the household. Unfortunately, no estimate of the vehicle population that includes household vehicles plus those others that NPTS respondents are likely to have reported driving is readily available.

TABLE 2 Changes in Annual VMT per Driver by Age and Sex: 1990–95

	Male			Female		
Age	1990	1995	% change	1990	1995	% change
16–19	9,543	8,203	–14.0%	7,387	6,870	–7.0%
20–34	18,310	17,980	–1.8%	11,174	12,001	7.4%
35–54	18,871	18,859	–0.1%	10,539	11,463	8.8%
55–64	15,224	15,844	4.1%	7,211	7,795	8.1%
65+	9,162	10,320	12.6%	4,750	4,788	0.8%
All ages	16,536	16,553	0.1%	9,528	10,143	6.5%

Source: Tabulated from 1990 and 1995 NPTS household files.

those aged 55 to 64 showed a modest increase. Taken as a single group, however, there was little increase in driving, perhaps suggesting some tendency for motor vehicle use to stabilize among those who are already the most active drivers. Older males showed the largest increase in average annual driving between 1990 and 1995, although by 1995 they still drove considerably less than their younger counterparts.

Travel Mode and Vehicle Occupancy

Because the demand for *vehicle* travel ultimately derives from the demand for *person* travel,[10] growth in VMT can also be related to the underlying demand for person-miles of travel (PMT). Specifically, total PMT can be translated into VMT using the share of trips that are made using motor vehicles and the average occupancy of motor vehicles used for each trip. The 1995 NPTS reveals continuing, though modest, growth in the share of trips made using household-owned motor vehicles: from about 84% in 1977 to slightly above 87% during 1990, and up to more than 89% by 1995. The increase in motor vehicle use has come at the expense of walking, public transit, and school bus travel. While the share of bicycle trips increased between 1977 and 1995, it remains under 1%.

At the same time, the survey shows that vehicle occupancy continued to decline: the fraction of vehicle trips made by a single occupant rose from about 60% during 1977 to 67% by 1990 and to 68% by 1995. A more precise indicator of vehicle occupancy is the average number of person-miles per vehicle-mile, which implicitly weights vehicle occupancy for each trip by its distance; this measure declined from 1.89 persons in 1977 to 1.64 during 1990, and further to 1.59 persons by 1995. The combination of a rising share of trips in personal vehicles and declining occupancy of those vehicles means that an increasing number of vehicle-miles are required to meet the same underlying demand for person-miles, so that even the modest recent growth in total *person* trips and miles of travel has been reflected in the significant increases in *vehicle* trips and vehicle-miles noted previously.

HOUSEHOLD VEHICLE OWNERSHIP

The NPTS also provides detailed information about continuing changes in the number, types, and use of motor vehicles owned by U.S. households. The two major developments revealed by the succession of surveys are the trend toward nearly ubiquitous ownership of at least one vehicle among U.S. households, and the rapidly increasing number of households owning multiple vehicles. More recently, the 1990 and 1995 NPTSs highlight the increasing substitution of vehicles classified as light-duty trucks—pickup trucks, passenger and cargo vans, and sport utility vehicles (SUVs)—for automobiles in providing household transportation. While widespread use of pickup trucks as household vehicles significantly predates that of other light trucks (and displays a markedly different geographic pattern), recent purchases of vans

[10] Person travel refers to all trips outside the home by household members made by any means, including on foot and by motorized or nonmotorized vehicles of all types. As employed in the NPTS, vehicle travel includes only household members' trips that are made using personal motorized vehicles owned by that or another household.

and SUVs have substantially increased the share of household vehicles and mileage accounted for by light trucks.

Increasing Vehicle Ownership

Table 3 summarizes changes in the distribution of vehicle ownership among U.S. households from 1977 through 1995. It also shows accompanying changes in the average number of vehicles owned and in the number of household members of driving age.[11] Although the percentage of households without vehicles was not large even at the outset of this period, it declined sharply, while the proportions of households owning two and three or more vehicles rose significantly. Thus, during 1977 the number of carless households almost exactly equaled the number owning three or more vehicles, yet by 1995 the number of households with three or more vehicles was more than *twice* as large as the number without vehicles.

Interestingly, however, these seemingly large changes in the distribution of households among vehicle ownership categories were translated into comparatively modest growth in average vehicle ownership. As table 3 shows, the average number of vehicles per household rose from 1.59 during 1977 to 1.78 in 1995, an increase of only about 12% over a period spanning nearly two decades. But the average number of household members of license-eligible age *fell* slightly, as the effect of continuing declines in household size offset that of the aging of the "baby boom" generation. Thus, as table 3 shows, the number of vehicles per household member of driving age increased from 0.76 in 1977 to 0.89 (17%) in 1990, but remained unchanged in the 1995 survey.

TABLE 3 Changes in Household Motor Vehicle Ownership: 1977–95

Variable	1977	1983	1990	1995
% of households owning:				
0 vehicles	15%	14%	9%	8%
1 vehicle	35%	34%	33%	32%
2 vehicles	34%	34%	38%	40%
3 or more vehicles	16%	19%	20%	19%
Vehicles/household	1.59	1.68	1.77	1.78
Household members 16 or older	2.10	2.06	1.98	2.01
Vehicles/household member 16 or older	0.76	0.82	0.89	0.89

Source: 1990 NPTS, *Summary of Travel Trends,* tables 1, 2, and 4; and 1995 NPTS.

The Increasing Importance of Light Trucks

As indicated previously, a major change in the composition of the household vehicle fleet (i.e., the increasing substitution of light-duty trucks for automobiles) has taken place during the period spanned by the NPTS. Table 4 reports the distribution of household vehicles during 1990 and 1995 by type; it indicates that passenger automobiles represented only about 65% of household vehicles in 1995, a significantly lower share than the more than 71% they accounted for only five years earlier.[12] In contrast, SUVs accounted for 7% of household vehicles by 1995, exactly double their representation in 1990, while the share of passenger vans also increased rapidly, from 5.4% to 7.9% of household vehicles. Table 4 shows that the representation of pickup trucks, the earliest light truck models to be purchased on a widespread basis for passenger transportation, rose only slightly between 1990 and 1995, although the share of pickups, nearly 18%, still exceeds that of all other light trucks.

Because the nation's household vehicle fleet grew rapidly during the period covered by table 4, what may seem like relatively modest changes in

[11] The number of license-eligible household members is used in this analysis because the number of licensed drivers per household is so closely related to the average number of household vehicles. This suggests that the decision by a household member to obtain a driver's license is not separable from the household's decision to acquire an additional vehicle.

[12] Unlike the 1995 NPTS, the 1990 survey did not include a category for sport utility vehicles in its vehicle-type classification. The SUV category was recreated for this paper by using the SUV vehicle make and model codes from the 1995 survey to identify SUVs in the 1990 sample. Unfortunately, we were unable to tabulate the distribution of vehicles among the same type classes shown in table 4 for previous survey years, although the passenger van and SUV categories were probably quite small before 1990.

TABLE 4 Household Vehicles by Type: 1990 and 1995

Vehicle type	1990 Number (millions)	1990 Percentage of total	1995 Number (millions)	1995 Percentage of total	Percentage change 1990–95
Passenger car	117.5	71.2%	113.3	65.2%	–3.6%
Light truck:					
Sport utility[1]	5.9	3.5%	12.2	7.0%	107.6%
Van	9.0	5.4%	13.8	7.9%	53.8%
Pickup	28.4	17.2%	31.1	17.9%	9.6%
Subtotal, light truck	43.2	26.2%	57.1	32.8%	32.1%
Other truck	1.0	0.6%	0.7	0.4%	–27.9%
Recreational vehicle	0.9	0.5%	0.9	0.5%	6.0%
Motorcycle	2.2	1.3%	1.7	1.0%	–24.2%
Other	0.4	0.2%	0.1	0.1%	–57.6%
Subtotal, type known	165.1	100.0%	173.8	100.0%	5.3%
Unknown	0.1		2.3		[2]
TOTAL	165.2		176.1		6.6%

[1] 1990 data retabulated using 1995 definition of sport utility vehicles.
[2] Computed percentage change is extremely large.

Source: Tabulated from 1990 and 1995 NPTS vehicle files.

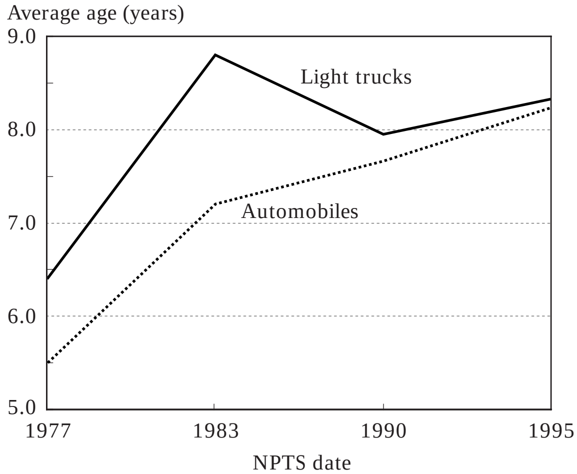
the proportions of vans, SUVs, and pickup trucks obscures significant increases in their *numbers*. The number of vans owned by households increased by nearly 5 million between 1990 and 1995, while the number of SUVs grew by more than 6 million and the number of pickups by nearly 3 million. Thus, in total, the number of light trucks owned by households grew by almost one-third from 1990 to 1995; as a result, they accounted for more than one-third of the household vehicle fleet for the first time in 1995. In contrast, table 4 shows that the number of passenger cars actually declined during this period, suggesting that households were replacing older automobiles with new SUVs and vans. Recent sales figures suggest that the effect of this shift from conventional automobiles to trucks on the composition of the household vehicle fleet has not yet peaked, since truck models currently represent nearly half of all light-duty vehicles sold, with SUVs continuing to exhibit the strongest sales growth of any passenger vehicle category (Another Month 1999).

AGING OF THE FLEET

The 1995 NPTS reveals continued aging of the household vehicle fleet.[13] As figure 3 shows, the average age of household automobiles increased sharply from 5.5 to 7.2 years between the 1977 and 1983 surveys and then more slowly, reaching 8.3 years through 1995. The average age of household-owned light-duty trucks followed a slightly

[13] There is no unambiguously "correct" way to translate the distribution of vehicle model years recorded by the NPTS into a fleet-average vehicle age, partly because the NPTS surveys households over a period that typically includes more than one calendar year. In addition, the difference between the calendar year and most vehicles' model years means that it is not obvious how to code vehicle ages. This paper uses the average ages for 1977, 1983, and 1990 reported as part of the 1990 NPTS (USDOT 1993, 3–40). The 1995 figures were then calculated in a manner consistent with the 1990 data: the most recent model year vehicles (1996 and a very few 1997 vehicles) were assigned an age of one, as were one-year-old vehicles (those with a model year of 1995); model year 1994 vehicles were assigned an age of two, model year 1993 vehicles were given an age of three, and so forth.

FIGURE 3 Trends in Vehicle Age by Type: 1977–95



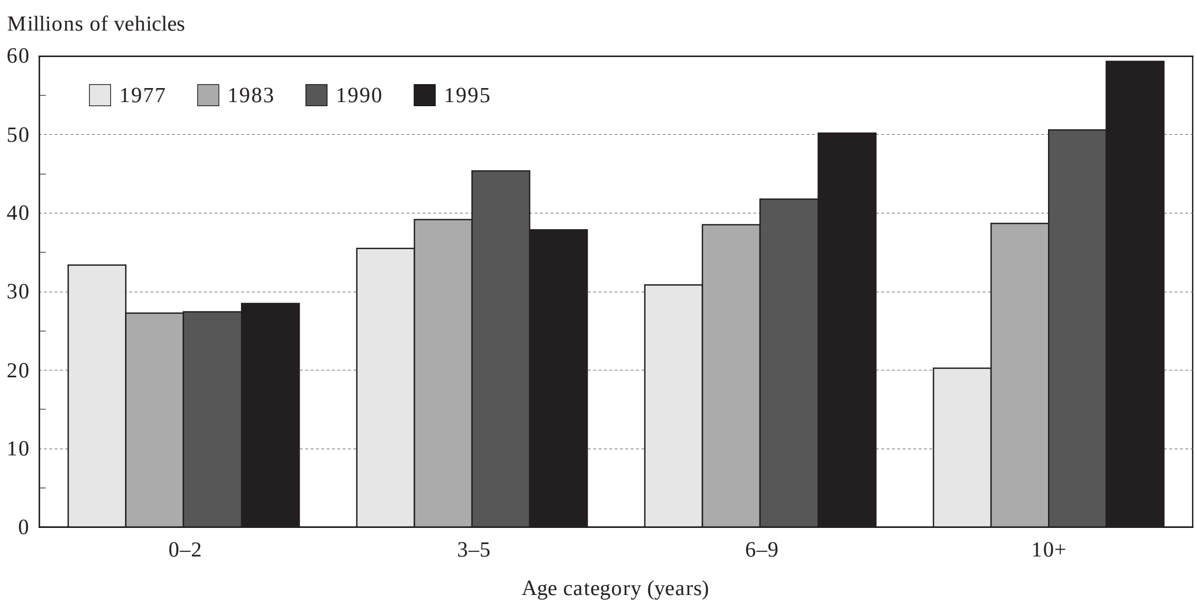
different pattern, as the figure shows: like that of automobiles, it rose sharply between the 1977 and 1983 surveys, but then declined significantly between 1983 and 1990 before increasing again by 1995. The gradual convergence of the average ages of autos and light trucks shown in figure 3 again probably reflects the increasing substitution of light trucks, particularly the more recently marketed models such as minivans and SUVs, for household automobiles.

Because the timing of new vehicle purchases (both to replace aging ones and to expand vehicle availability) is sensitive to macroeconomic conditions, the patterns of vehicle aging shown in figure 3, particularly the sharp increase in average ages of both cars and light trucks between 1977 and 1983, may be partly attributable to the severe recession of the early 1980s, the rapid recovery that followed, and the subsequent slowdown during the early 1990s. Superimposed on this pattern, however, appears to be a gradual longer term increase in the average age of household-owned vehicles that must be explained by other factors. The accompanying changes in the age *distribution* of household vehicles provides some useful suggestions about the underlying causes of fleet aging.

Changes in the Age Distribution of Household Vehicles

Figure 4 displays the age distribution of the nation's household vehicle fleet for each of the four NPTS years. As it shows, the number of U.S. household-owned new vehicles that were up to two years old in 1995 was only slightly greater than the comparable figures for 1983 and 1990 and was well *below* the 1977 number, despite rapid expansion of the total household vehicle fleet throughout this period. After rising steadily from 1977 through 1990, the number of three- to-five-year-old vehicles also declined significantly in the 1995 survey. At the other end of the age distribution, however, the number of six- to nine-year-old vehicles, which had risen only modestly between

FIGURE 4 Distribution of Household Vehicles by Age: 1977–95



1983 and 1990, increased significantly by 1995, while the size of the oldest vehicle age cohort, those 10 or more years old, continued the rapid growth revealed by previous surveys. Thus, by 1995 vehicles that were 10 or more years old accounted for more than one-third of all household vehicles, almost exactly double the 17% share they represented in 1977.

PATTERNS OF VEHICLE USE

The implications of the continued aging of household vehicles for transportation safety, urban air pollution, and energy consumption depend not only on their age distribution but also on utilization of vehicles of different ages. Specifically, if utilization declines rapidly with vehicle age, then the effects of progressively tighter safety, emissions, and fuel efficiency standards for new vehicles will be quickly noticeable. However, if older vehicles are used nearly as intensively as newer ones, the effects of these measures will require many years after they are adopted to be widely felt. The gradual retirement of vehicles of different "vintages" as they age and the changing rates at which vehicles accumulate mileage with increasing age interact to determine the distribution of total household VMT across vehicles of different ages, and the NPTS reveals important information about each of these effects.

A Note on the NPTS Measures of Vehicle Use

As the earlier discussion of total VMT estimates indicated, the NPTS includes two measures of vehicle usage. Households responding to the survey were first asked to estimate the number of miles each of the vehicles available to them were driven during the previous 12 months; respondents provided usable estimates of annual mileage for more than 80% of the 75,000 household vehicles identified in the survey. In addition, odometer readings were obtained for each household's vehicles at the time of the interview, and surveyors subsequently attempted to obtain odometer readings for each of these same vehicles several weeks after the initial interview. The difference in odometer readings between these two dates was then adjusted for normal seasonal variation in household driving activity (the survey period spanned more than a year) and extrapolated to an estimate of each vehicle's annual usage. The paired odometer readings necessary to construct these estimates of annual usage were obtained for about 44% of all household vehicles identified in the 1995 NPTS.

While it might appear that the odometer-based estimates provide a more reliable measure of vehicle use, two considerations complicate the choice between the odometer-based and respondent-reported estimates. First, while there are almost certainly errors in household members' estimates of how much each vehicle was used, there may also be important, if less obvious, sources of measurement error in the odometer-based estimates. Errors could have arisen in reporting a vehicle's odometer readings either during the initial telephone interview or at the time of the followup call. Errors also could have been introduced during the complex process used to convert differences in odometer readings to estimates of annual driving.[14]

Second, the estimates of average vehicle use, and the relationships of vehicle use to other variables that can be inferred from the subsample of vehicles for which the two usage measures are available, are both subject to potential bias. In part because the owner-reported estimates of vehicle use were obtained for such a large fraction of all household vehicles identified by the survey, the typical characteristics of both the vehicles for which these estimates were available and the households who owned them closely mirror those characteristics of all households and vehicles included in the NPTS. In contrast, the vehicles for which odometer-based estimates of annual usage were obtained are significantly newer on average, tend to include a higher percentage of automobiles, and are more commonly owned by households with only one or two vehicles than is the case for all household vehicles identified in the survey.

Thus, it is difficult to choose between the respondent-reported and odometer-based usage estimates, and the two measures do not agree closely. Their simple correlation among the more

[14] See USDOT 1997, appendix K, for a detailed discussion of the procedure for annualizing the odometer reading data.

than 25,000 vehicles for which both were obtained is only 0.64. While the odometer-based estimates seem likely to be inherently more reliable, they may still contain significant measurement errors because of the characteristics of this subsample. Estimates of average usage and of the relationships of use to other variables might be sources of bias for the subsample. Because of the difficulty of choosing between them, this section employs *both* the owner-reported and odometer-based estimates of vehicle use in each of the analyses it reports.

Annual Utilization by Vehicle Age

Figure 5 shows the 1995 patterns of estimated annual usage of different aged household vehicles calculated from the two vehicle-use measures. Both measures indicate that the five newest model years in the household vehicle fleet are driven quite intensively, averaging nearly 14,000 miles annually, according to the owner-reported use estimates, and about 13,000 miles annually, according to the odometer data. Surprisingly, vehicles between 6 and 10 years old seem to be driven nearly as much, averaging 11,000 to 12,000 miles annually, depending on the measure used. Figure 5 shows that according to both measures, it is not until approximately age 12 (model year 1983 in the 1995 NPTS) that annual utilization drops consistently below the 10,000-mile threshold.[15] While the small samples of vehicles older than 15 years from which odometer readings were obtained in both surveys produces considerable variation in the average utilization of individual age cohorts, it appears that usage reaches a "floor" of approximately 6,000 miles annually, even among the oldest vehicles remaining in the household fleet.

The Distribution of Household VMT by Vehicle Age

Figure 6 shows the pattern of usage of household vehicles by age during 1995 derived from the

[15] The customary "model" of individual vehicles' gradually declining utilization with increasing age that is suggested by cross-sectional analysis of the vehicle age distribution and mileage accumulation may be misleading, or at least incomplete. Lave (1994) argues that an entirely different process may be at work, wherein households with high travel demands purchase new vehicles frequently and "wear them out" quickly, while households with low travel demands purchase new vehicles infrequently and retain them for longer periods. Assuming some distribution of household travel demands, this process would produce exactly the same fleet age and mileage accumulation patterns revealed by the 1995 NPTS and its predecessors. In fact, both of these models are probably simultaneously at work within the household vehicle fleet, although their relative contributions to the patterns revealed in the data are difficult to assess. In any case, they have similar implications for the effects of fleet turnover on the age distribution of VMT and on problems such as safety, air pollution, and energy consumption.

FIGURE 5 Vehicle Age and Annual Miles Driven: 1995 NPTS

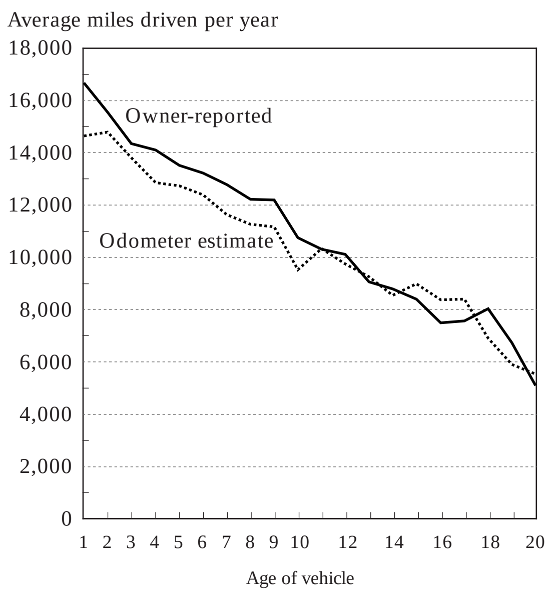
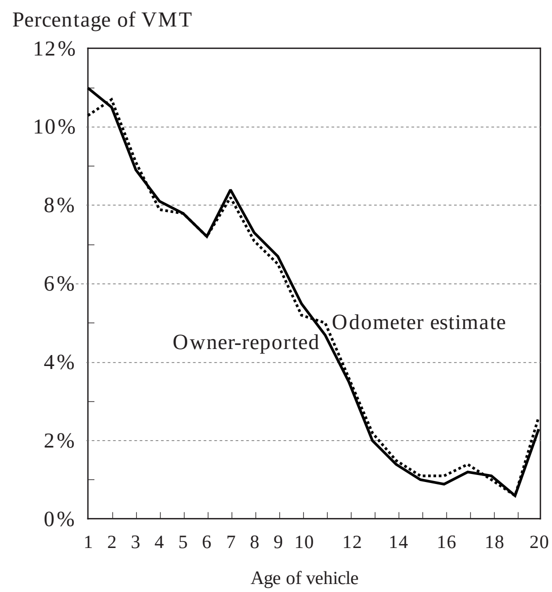


FIGURE 6 Vehicle Age and Percentage of Total VMT: 1995



NPTS to produce the distribution of total household VMT. As it indicates, the effect of declining usage with increasing vehicle age offsets the larger number of older vehicles, so that a higher fraction of total VMT is accounted for by relatively new vehicles than their representation in the fleet would suggest. Thus, according to the NPTS, nearly 50% of all household VMT in 1995 was driven by vehicles that were five years of age or newer, with most of the remainder distributed among vehicles of ages 6 through 15 years.

Annual Utilization by Vehicle Type

Table 5 compares average annual miles driven in different types of household vehicles, again computed from both the owner-reported and odometer-based estimates of vehicle use. The two measures disagree about exactly how much automobiles are typically driven. The odometer figure is about 6% less than owners' estimates, but both indicate that automobiles tend to be less intensively used than other types of household vehicles. Vans are the most heavily used household vehicles, while other light trucks—sport utility vehicles and pickups—fall between automobiles and vans. Since older vehicles of all types tend to be used less than newer models, however, some of the less intensive use of pickups may simply be associated with their much higher average age. The annual use estimates for all household vehicles, which are about 11,800 miles from the odometer-based data and 12,200 miles from owners' estimates, are generally consistent with those reported by other sources.[16]

TABLE 5 Mean Age and Annual Usage, by Vehicle Type

Vehicle type	Mean age (years)	Average annual miles driven: Reported[1]	Odometer[2]
Automobile	8.2	11,988	11,318
Van	6.7	14,256	14,389
Sport utility	6.6	13,853	13,436
Pickup	9.6	12,064	11,826
All household vehicles[3]	8.3	12,226	11,801

[1]Average of vehicle owners' estimates of annual usage.
[2]Average of estimated annual usage for vehicles from which odometer readings were obtained.
[3]Includes other trucks, motorcycles,and recreational vehicles.

Source: Tabulated from 1995 NPTS vehicle file.

A MODEL OF VEHICLE USE

Table 6 shows the results of an analysis designed to clarify the independent effects of age and vehicle type, as well as to explore the influence of household demographic and economic characteristics on vehicle use. The table reports least-squares regression estimates of the parameters of a model relating annual utilization of vehicles to characteristics of the households that own them, their locations, and the vehicles themselves. Changes in vehicle usage can be thought of as a short-run adjustment to changes in factors influencing households' demands for private vehicle travel, such as their demographic composition or the price of fuel, which allows households to respond to such changes without altering their vehicle ownership levels. Households are likely to adjust to permanent changes in these factors by varying their levels of automobile ownership, thereby producing a tendency for average vehicle use to return to some "target" or equilibrium level. Over the longer run, however, this target level may itself rise or fall in response to factors such as additional household members reaching driving age, changing costs of vehicle ownership and use, or improvements in vehicle performance and durability.

[16] For example, the Federal Highway Administration (USDOT 1995, table VM-1, p. V-92) reports average annual mileage of 11,489 for automobiles plus two-axle, four-tire trucks, which corresponds roughly to the definition of household vehicles employed in the NPTS. This number is somewhat below the odometer-based estimate of average household vehicle use reported in table 5. However, the FHWA figure is derived by dividing its estimate of total VMT driven in those vehicles by the number of them registered during the year. The latter measure overstates the actual number of those vehicles in use, because the state registration data used by FHWA to compile it double count vehicles that are sold or moved between states and thus registered twice during the same year. Compared with survey data on the number of vehicles in use reported by R.L. Polk (AAMA 1996), the FHWA vehicle stock estimate appears to be approximately 10% too large. Adjusting to compensate for the double counting of vehicles in state registration data produces an estimate of 12,638 miles per vehicle in 1995, somewhat above the figure derived from NPTS respondents' estimates of vehicles use that is reported in table 5.

TABLE 6 Vehicle Usage Model: Regression Results

Independent variable	Estimated coefficients and t-statistics[1]						Estimated coefficients and t-statistics[2]					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	ß	t	ß	t	ß	t	ß	t	ß	t	ß	t
constant	9.27	27.91	8.45	25.19	8.44	25.17	10.01	21.72	8.84	18.94	8.77	18.81
numadlt	0.10	12.66	0.11	14.00	0.11	13.97	0.17	14.11	0.18	15.12	0.18	15.13
numchild	0.04	8.95	0.04	8.18	0.04	8.36	0.14	21.31	0.14	20.87	0.14	21.03
age	–0.06	–72.51	–0.06	–72.88	–0.06	–59.98	–0.08	–58.16	–0.08	–58.14	–0.07	–45.41
hhvehcnt	–0.15	–24.83	–0.16	–27.44	–0.16	–27.56	–0.09	–9.48	–0.11	–11.78	–0.11	–11.85
linc	0.15	19.27	0.17	20.95	0.17	21.25	0.08	7.12	0.10	8.60	0.10	8.85
lpgas	–0.29	–4.18	–0.08	–1.20	–0.08	–1.21	–0.34	–3.59	–0.05	–0.45	–0.04	–0.41
lbgden		–0.04	–15.44	–0.04	–15.43		–0.06	–13.96	–0.06	–14.16		
van	0.14	7.20	0.13	6.87	0.02	0.59	0.13	5.28	0.13	5.10	0.03	0.83
suv	0.11	5.58	0.10	4.90	0.00	–0.06	0.12	4.43	0.10	3.85	0.16	3.78
pickup	0.09	6.73	0.06	4.08	0.07	3.09	0.04	2.34	0.00	0.11	0.12	3.94
truck	0.16	1.87	0.12	1.37	0.80	4.71	0.06	0.39	0.03	0.21	0.10	0.32
rv	–0.56	–7.98	–0.56	–8.06	–1.09	–7.29	–1.15	–9.41	–1.13	–9.27	–2.24	–8.13
*age*van*					0.016	4.34					0.016	3.12
*age*suv*					0.014	4.12					–0.009	–1.68
*age*pickup*					–0.001	–0.63					–0.015	–4.86
*age*truck*					–0.043	–4.57					–0.006	–0.31
*age*rv*					0.041	4.04					0.083	4.43
Adj. R sq.	0.145		0.149		0.150		0.181		0.187		0.189	

[1] Dependent variable: Natural logarithm of annualized miles driven, derived from vehicle owner estimates (mean = 8.92).
[2] Dependent variable: Natural logarithm of annualized miles driven, derived from vehicle odometer readings (mean = 8.92).

Because the coefficient estimates reported in table 6 are derived from a large cross-section of households and individual vehicles, they theoretically represent the effects of the variables on households' long-run target or desired levels of vehicle use. The coefficient estimates for the categorical or "count" variables included in the model (e.g., *numadult* or number of adults in the household) indicate the proportional or percentage increase in the annual number of miles driven in each of the household's vehicles that is associated with an increase of one in the value of that variable (e.g., the presence of another adult in the household). Because the continuous explanatory variables included in the model are in logarithmic form (e.g., *linc* or the natural logarithm of the household's annual income), their estimated coefficients indicate the percentage change in annual vehicle use associated with a 1% change in the value of each variable.

Demographic and Economic Effects on Vehicle Use

The coefficient estimates reported in table 6 suggest that the presence of another adult member of the household increases vehicle use by 10% to 18%, depending on whether the owner-reported or odometer-based estimates of vehicle use are used. Interestingly, the owner-reported use data suggest that this effect is more than twice as large as that of an additional child in the household, while the odometer-based data indicate that the effect of an additional child is nearly as large as than of another adult. Increasing vehicle ownership, as measured by the variable *hhvehcnt*, reduces the utilization of each vehicle, although there is some disagreement about the size of this effect: the owner-reported data suggest that average use declines 15% to 16% with the presence of each additional vehicle, while the odometer data suggest a 9% to 11% decline. The larger effect implied by the owner-reported use data appears to be more consistent with previous estimates, which indicate that a household's ownership of additional vehicles substantially reduces their average use.[17] One possibility is that the explicit controls for the ages and types of household vehicles included in this model capture some effects of increasing vehicle specialization and the matching of vehicles to specific household trip demands that have previously been attributed to a simple count of the number of vehicles a household owns.

The estimated values of the coefficient on the household income variable shown in table 6 indicate that increases in a household's income have only a slight effect on utilization of the vehicles owned. Since there is considerable evidence that rising household income significantly increases members' motor vehicle travel, this result suggests that most of that increase occurs through the mechanism of higher vehicle ownership.[18] In contrast, the estimated coefficient on gasoline prices (*lpgas*) provides some suggestion that the per mile cost of driving may influence households' target levels of vehicle use, although collinearity between this variable and the residential density of the neighborhoods where surveyed households reside (*lbgden*) makes it difficult to tell which of these two variables independently affects vehicle use.[19]

Effects of Vehicle Type and Age

The regression results shown in table 6 also confirm that vans are particularly intensively utilized, but they suggest that much of this greater utilization is explained by a less rapid decline in van usage with age than occurs with other vehicle types. This is evidenced by the fact that when the *age*van* variable is added to the regression, its positive coefficient reduces the negative effect on usage of the *age* variable itself, and the magnitude of the coefficient on the *van* variable declines sharply. The intensive van usage result may be partly an artifact of the different transportation functions served by older passenger and cargo vans (i.e., commercial purposes as well as household travel), and the more recently marketed mini-vans, which more clearly substitute for automobiles and thus tend to serve more limited travel purposes. However, both data sources suggest a tendency for vans of both types to be used more intensively than other types of household vehicles throughout their lifetimes.

The higher average utilization of both SUVs and pickups, as shown by the mostly positive coefficients on the *suv* and *pickup* variables in table 6, may also reflect frequent use of these vehicles for recreational travel, joint household and business use, or other nonpassenger transportation uses. Interestingly, the odometer-based data suggest that the decline in usage of pickups with increasing age is slightly *more* pronounced than for conventional automobiles; since the average age of pickups is significantly higher than other vehicle types, their more intensive utilization seems difficult to explain in light of this result. While it may simply mean that pickups are more readily adaptable to various commercial and nonpassenger household transportation functions than are other vehicles, the effect of introducing the neighborhood density

[17] Using 1990 NPTS data, Walls et al. (1993, 22) estimate that a household's acquisition of each additional vehicle reduces its average annual driving per vehicle by as much as 40%.

[18] For example, Schimek (1997, 88) reports that estimates of the income elasticity of total motor vehicle travel range from 1.2 to 1.4, but that income elasticities of average vehicle use are typically in the range of 0.2 to 0.3.

[19] This collinearity may arise from the procedure used to develop the gasoline price variable, which is the average of monthly retail prices including all taxes over the 15-month survey period, May 1995 through July 1996, in the state where the household or vehicle is located. Most of the variation in this measure among locations is due to differences in state fuel taxes rather than to geographic variation in the pretax price of gasoline. More urbanized states appear to have higher fuel tax rates. As a consequence, households facing higher fuel prices are apparently more likely to reside in higher density neighborhoods, thus making it difficult to disentangle the separate effects of fuel prices and residential density on vehicle use. While it might seem desirable to use gasoline price data for the exact month in which the household was surveyed, the effect of seasonal fluctuations in gasoline demand is significant variation in its price. As a result, using monthly gasoline prices does not allow the specific response we are attempting to measure—movement along the demand curve in response to gasoline price changes—to be separated from the effects of seasonal shifts in the gasoline demand curve itself. In the absence of a structural model of gasoline supply estimated simultaneously with the models of vehicle usage and household travel demand, the resulting "identification problem" can be minimized by using average gasoline prices over the entire survey period, since these can more properly be considered exogenous from the standpoint of households' travel demands and vehicle utilization decisions.

measure on the coefficient of the *pickup* variable suggests that their more intensive use stems partly from their more frequent ownership by households outside urban areas, where longer trip distances increase vehicle use significantly.

CONCLUSIONS

Analysis of the 1995 Nationwide Personal Transportation Survey and its predecessors reveals continuing growth in household vehicle ownership and use, although at somewhat slower rates than prevailed during the 1980s. The 1995 survey reveals only modest growth in annual VMT per licensed driver since 1990, indicating that the growth rate in total driving may ultimately decline toward the rate of increase in the number of licensed drivers. However, rapid increase in the driving-age population provided a significant boost to VMT growth during this period and may continue to do so for some time. In addition, the modest overall increase in VMT per driver obscured rapid growth in driving among women across a broad age spectrum (20 to 64 years) and among older men, developments that may continue to offset the apparent stabilization of driving among young adult and middle-aged men.

The most recent NPTS also shows that vehicle ownership, both per household and per person of driving age, remained virtually unchanged between 1990 and 1995, as did the fraction of households owning multiple vehicles. These developments provide some suggestion that vehicle ownership may be stabilizing, although at levels only slightly below one vehicle per household member of driving age level. Further, the historical decline in average vehicle occupancy slowed markedly during this same period, suggesting that it may also be approaching some floor as vehicle availability becomes virtually ubiquitous among the population of driving age. Combined with a continuing increase in the fraction of household members' trips made by private motor vehicles, the decline in vehicle occupancy meant that even modest growth in *person* travel continued to generate significantly increased *vehicle* travel.

In contrast to the apparent stabilization of these variables, the aging of household motor vehicles accelerated sharply from its historic pace in recent years, primarily as the result of declining retirement rates for vehicles over 10 years of age. The 1995 NPTS also shows that the usage of older vehicles is considerably greater than is generally assumed in the modeling of fleetwide air pollutant emissions and energy consumption levels, raising the possibility that the contribution of older vehicles to these undesirable byproducts of automobile use may be significantly understated. The survey also clearly documents the increasing substitution of light trucks, particularly vans and sport utility vehicles, for passenger automobiles and shows that household-owned light trucks tend to be more intensively utilized than automobiles. While light trucks grew from about one-quarter to nearly one-third of all household vehicles between 1990 and 1995 alone, they continue to represent a still larger fraction of new vehicle sales, so this figure will undoubtedly continue to rise over the foreseeable future.

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APPENDIX

Comparing Survey Methods Using the 1994 NPTS Pretest

The 1995 NPTS uses a different survey method from earlier editions of the survey, making comparisons with earlier NPTS statistics difficult. In order to anticipate the various consequences of this change in survey methods, a 1994 pretest of the 1995 NPTS employed both the 1990 survey method, retrospective recall, and the 1995 survey method, a diary mailed in advance of the travel day; households were randomly assigned to be surveyed using the two different methods.[20] The difference in average measures from each of the two survey methods in the pretest can be used to approximate the difference due to the change in sampling technique alone.

Table A-1 shows average trip length, the number of trips, and their product, total travel, estimated using the two survey methods. These three statistics are shown for all person trips (excluding airplane trips), personal motor vehicle trips (driver and passenger), and motor vehicle trips (using the trip data for drivers only). This third statistic produces an estimate of VMT. The diary method recorded more short motor vehicle trips: the number of vehicle trips was nearly 10% higher using this method, although their average trip length was nearly 8% shorter. The net result is that the diary method revealed only 1.1% more VMT than the retrospective method.

Many more person trips were also recorded when the diary method was used, but these trips were *longer* on average than those already counted using the retrospective method. About 14% more trips in total were counted under the diary method, and these trips were 1.5% longer on average; thus the retrospective method appears to understate the number of PMT by nearly 16%. These differences due to survey method for PMT, VMT, and their components were used in this paper to adjust the 1990 NPTS data to make them more comparable with the 1995 data. Other inconsistencies between the two survey methods were not accounted for, however, such as the treatment of commercial driving. Therefore even the adjusted 1990 data are not completely comparable to the corresponding measures obtained from the 1995 survey.

[20] The 1994 pretest also used a third technique, a memory jogger, which is essentially a simpler form of the travel diary. Since this method was not chosen for subsequent use in the 1995 survey, it is not discussed here.

TABLE A-1 Estimates of Person Trips, Average Trip Length, and Total Person Travel Using Different Survey Methods: 1995 NPTS Pretest

	Retrospective method			Trip diary method			% difference between methods		
Statistic	**Average length (miles)**	**Number of trips (billions)**	**Person-miles (billions)**	**Average length (miles)**	**Number of trips (billions)**	**Person-miles (billions)**	**Average length (miles)**	**Number of trips (billions)**	**Person-miles (billions)**
All person trips[1]	7.77	80.4	625	7.89	91.7	723	1.5%	14.1%	15.7%
Person trips by motor vehicle	8.51	69.9	595	8.75	79.7	698	2.8%	14.0%	17.3%
Motor vehicle trips[2]	8.65	48.6	420	7.97	53.3	425	–7.9%	9.7%	1.2%

[1] Excluding airplane trips.
[2] Trips by drivers only.

The Dimensions of Motor Vehicle Crash Risk

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ABSTRACT

A valid assessment of motor vehicle crash risks and the potential impact of safety interventions requires a precise understanding of the types of crashes involved, the types of vehicles likely to be equipped or otherwise affected, the most relevant *referent* to the intervention (e.g., national annual crash total, vehicle mileage, and vehicle life), and the scope of monetary crash costs to be considered. This paper analyzes the U.S. police-reported, motor vehicle crash problem in four dimensions: crash involvement type/role (e.g., single-vehicle roadway-departure, left-turn-across-path); subject vehicle body type (i.e., passenger cars, light trucks/vans, heavy combination-unit trucks, medium/heavy single-unit trucks, and motorcycles); type of metric (i.e., crashes, involved vehicles, persons killed/injured, and monetary cost); and problem size referent (i.e., U.S. annual, per crash, per vehicle, per driver, and per mile traveled).

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INTRODUCTION

Safety interventions to prevent motor vehicle crashes are often characterized by *specificity;* that is, they are designed to prevent a specific type of crash involvement. In the area of Intelligent Transportation Systems (ITS), for example, vehicle-based sensors are being developed to prevent specific crash types, such as the headway/forward obstacle detection system designed to prevent rear-end crashes (Knipling et al. 1993a; Najm and Burgett 1997). Other safety interventions may target a vehicle type; for example, Federal Motor Carrier Safety Regulations focus primarily on large trucks, particularly combination-unit trucks (CUTs), which include tractor- and semitractor-trailers. These vehicles constitute the majority of interstate commercial vehicles. Thus, there is a need to dissaggregate crash statistics along multiple dimensions, including crash and vehicle type. Further, the analysis of crash consequences may focus on different types of measures (most obviously, measures of injuries and lives lost versus measures of monetary loss) and different frames of reference, such as annually for the nation or per miles of vehicle exposure.

In the area of advanced vehicle-based technology, the National Highway Traffic Safety Administration (NHTSA) (Najm et al. 1995) and others (e.g., Fancher et al. 1994) have conducted research to identify and define promising opportunities for crash prevention. One major NHTSA effort was a multidisciplinary project (Najm et al. 1995) to define the principal ITS crash scenarios and identify effective countermeasures. Associated crash data analyses (Knipling et al. 1993a; Wang and Knipling 1994a, b, c, d) have quantified crashes by type, using metrics such as annual numbers of crashes and injuries and rates of occurrence. In addition, the studies documented significant differences in crash involvement patterns among various vehicle body types—in particular, passenger vehicles (i.e., cars and light trucks), CUTs, and medium/heavy single-unit trucks (SUTs)—also known as “straight trucks” (see box 1).

NHTSA has also assessed the overall economic costs of motor vehicle crashes (Blincoe 1996; Blincoe and Faigin 1992). These studies focused on direct economic losses, and provided estimates of the monetary value society places on the human consequences of crashes, including functional impairment due to injury, “pain and suffering,” and even loss of life. According to Blincoe, in 1994, the average economic cost of a police-reported (PR) crash was approximately $12,360, and the total economic cost of U.S. motor vehicle crashes (PR plus nonpolice-reported (NPR)) was $150.5 billion. On a comprehensive scale incorporating derived valuations for life and pain and suffering (Blincoe 1996), in addition to direct economic loss, the estimates were $34,490 per PR crash and $379.5 billion (PR and NPR) for the national total.

These monetary studies provided analytical breakdowns of various categories of economic

BOX 1 Abbreviations and Acronyms

C	comprehensive cost
CUT	combination-unit truck
E	economic cost
FARS	Fatality Analysis Reporting System
GES	General Estimates System
ITS	intelligent transportation systems
LC/M	lane change/merge
LTAP	left-turn-across-path
LT/V	light trucks/vans
LVM	lead vehicle moving
LVS	lead vehicle stopped
MAIS	Maximum Abbreviated Injury Scale
NASS	National Automotive Sampling System
NHTSA	National Highway Traffic Safety Administration
NPR	nonpolice-reported
OD	opposite direction
PR	police-reported
PAR	Police Accident Report
RE	rear-end
RE-LVM	rear-end, lead vehicle moving
RE-LVS	rear-end, lead vehicle stopped
SI/PCP	signalized intersection/perpendicular crossing path
SUT	single-unit truck
SV	subject vehicle
SVRD	single-vehicle roadway-departure
UI/PCP	unsignalized intersection/perpendicular crossing path
VMT	vehicle-miles traveled

loss, including property damage, economic losses due to lost production, and medical expenses. They also demonstrated the huge proportion of crash costs associated with alcohol—approximately 30% of all crash costs. Recently, Miller et al. (1997) developed estimates of the economic costs and harm associated with crashes of specific geometries. This analysis was based primarily on Crashworthiness Data System statistics, which include only passenger vehicles.

To date, only limited analyses have been performed of the economic costs of various crash scenarios involving specific vehicle body types, which characterize these costs from the standpoint of the expected "per transportation unit" crash experience of vehicles or drivers. Such per unit statistics are likely to be more meaningful than national statistics to regulators, system developers, vendors, and buyers, because they provide a basis for assessing the potential cost-benefits of new safety interventions applied to some part of the vehicle/crash universe. For example, disaggregation by vehicle type is important because marketing strategies for many vehicle-based devices involve initial deployment in a specific vehicle-type fleet (most frequently CUTs) followed by deployment to other vehicle types.

Accordingly, this paper assesses the U.S. motor vehicle crash problem focusing on a number of major crash involvement types/roles and vehicle body types. Both nonmonetary (e.g., crashes, persons killed or injured) and monetary metrics are employed. In addition, this paper analyzes motor vehicle crashes from the perspective of different problem-size "referents"; that is, the U.S. annual national total as well as various "per unit" referents, including per crash, per vehicle, per mile, and even per driver. All four of these analytical dimensions—crash type, vehicle type, problem-size metric, and problem-size referent—are fundamental to a valid assessment of the potential crash amelioration benefits, and thus market opportunities, of motor vehicle safety interventions.

METHOD

Unless otherwise noted, all crash data were retrieved or derived from the General Estimates System (GES) for the five-year period 1989–93 and are intended to be representative of the population of U.S. PR crashes. Fatalities were adjusted to the 1989–93 levels reported in the Fatality Analysis Reporting System (FARS). Four analytical dimensions—crash involvement types/roles, subject vehicle body type, type of metric, and problem-size referent—are discussed below (see table 1).

TABLE 1 Crash Analysis Dimensions and Categories

Crash involvement types/roles:
- All PR crashes
- Single-vehicle roadway-departure (SVRD)
- Pedestrian
- Rear-end, lead vehicle stopped (RE- LVS), striking vehicle
- Rear-end, lead vehicle moving (RE- LVM), striking vehicle
- Lane change/merge (LC/M)
- Backing
- Opposite direction, encroaching vehicle
- Left-turn-across-path (LTAP)

Subject vehicle (SV) body type:
- All vehicles
- Combination-unit trucks (CUTs)
- Single-unit trucks (SUTs)
- Passenger cars
- Light trucks/vans (LT/Vs)
- Motorcycles

Metrics:
- Crashes (equal to SVs in crashes)
- Crash-involved vehicles
- Crash-involved persons
  - Total
  - Not injured
  - MAIS 1–2
  - MAIS 3–Fatal
- Monetary cost
  - Economic (E)
  - Comprehensive (C)
- Fatal equivalents

Referents:
- U.S. annual total
- Per police-reported target crash
- Per mile traveled (or per 100 million VMT)
- Per vehicle annually (or per 1,000 vehicles annually)
- Per vehicle operational life
- Per driver career

Crash Involvement Types/Roles

Crash involvement[1] types and roles are primarily those that have been analyzed and defined in NHTSA-sponsored studies of crash causation and countermeasure applicability (Najm et al. 1995). Note that, with the exception of "all crashes," each category includes an explicit or implicit definition of the crash subject vehicle (SV). The SV is the vehicle regarded as having the critical precipitating role in the crash, such as the striking vehicle in rear-end crashes. While the SV is generally the vehicle whose driver is "at fault" in the crash, there are many exceptions to this general rule. For example, some single-vehicle roadway-departures (SVRDs) are precipitated by an evasive maneuver to avoid an encroaching vehicle, and some left-turn-across-path (LTAP) crashes are associated with a traffic signal violation by the vehicle going straight. Crash involvement type/role categories examined were:

1. All crashes (the universe).
2. SVRD crashes, including struck parked-vehicle crashes.
3. Pedestrian (first harmful event only—not pedestrian impacts occurring as a result of a prior collision).
4. Rear-end, lead vehicle stopped (RE-LVS) crashes (SV is the striking vehicle).
5. Rear-end, lead vehicle moving (RE-LVM) crashes (SV is the striking vehicle). This category includes crashes where the lead vehicle was coded as traveling more slowly than the following vehicle or coded as decelerating at the time of impact. The differentiation of RE-LVS versus RE-LVM crashes is based on police accident report (PAR) information only. RE crashes not identified as either LVS or LVM were distributed proportionately across the two subtypes.
6. Lane change/merge (LC/M) crashes, not including any rear-end crashes (SV is the vehicle making lane change/merge maneuver).
7. Backing crashes, including both "encroachment" and "crossing path" subtypes (Wang and Knipling 1994a) but not including pedestrian impacts (SV is the vehicle making the backing maneuver).
8. Opposite-direction (OD) crashes, including head-on collisions and opposite-direction sideswipes (SV is the encroaching vehicle). For the small number of OD crashes in which the SV was not identifiable, the SV designation was distributed among vehicle types in proportion to their known roles in other OD crashes.
9. LTAP at intersection crashes (SV is the left-turning vehicle).

With the exception of the "all crashes" category, the above crash types were defined in a manner that ensured mutual exclusivity. For example, the lane change/merge category excluded rear-end crashes resulting from such maneuvers. Similarly, the backing crash category excluded backing-into-pedestrian crashes.

Obviously, not all crash types are addressed here. For example, rear-end crashes could be analyzed from the perspective of the *struck* vehicle to provide insights into the potential benefits of safety enhancements to rear brake light or other rear signaling systems (Knipling et al. 1993b). Two key intersection crash types, signalized and unsignalized perpendicular crossing path crashes (Wang and Knipling 1994c), have not been subjected to detailed analysis because of the difficulty of identifying the SV (i.e., the vehicle violating the right-of-way) based on GES-coded variables alone for the five years under study. Limited, nonvehicle-type-specific statistics for these two crash subtypes are provided, however.

Subject Vehicle Body Type

Six vehicle types were addressed: all motor vehicles, passenger cars, light trucks/vans (LT/Vs), CUTs, SUTs, and motorcycles. These vehicle types were defined as in previous reports (Wang and Knipling 1994a, b, c, d) and as suggested by the taxonomy of the GES body type variable. "Passenger cars" here include standard automobiles and derivatives. LT/Vs include van-based light trucks, pickups, utility vehicles, and other light trucks of less than 4,500 kg gross vehicle weight rating (GVWR). The CUT category includes bobtails. For all crash types/roles, the vehicle type was the SV in the crash; for example, the left-turning vehicle in an LTAP crash.

[1] *Crash involvement* in this context refers to a specific role in a specific type of crash, e.g., the left-turning vehicle in a left-turn-across-path crash.

Type of Metric

"Type of metric" refers to what is actually counted in the statistic. The current analysis counted crashes, SVs, involved vehicles, involved persons (classified by injury severity), monetary cost, and fatal equivalents. The term "crashes" is self-explanatory, although it is worth noting that the number of crashes also equals the number of SVs involved in crashes (except for "all crashes," in which no SV is defined). Two levels of "involved vehicles" are quantified: 1) all of the vehicles *of a particular body type* involved in a crash (e.g., all the light trucks/vans involved in LTAP crashes, regardless of crash role) and 2) all of the vehicles involved in a crash regardless of body type.

Involved persons were classified by injury severity level, and include all persons regardless of vehicle role or type (i.e., *not* just those in the SV). The KABCO injury severity scale values—K, killed; A, disabling injury; B, evident injury; C, possible injury; and O, no apparent injury (National Safety Council 1990)—were converted to Maximum Abbreviated Injury Scale (MAIS) values from 0 to 6 (AAAM 1985) using matrices generated for injuries occurring in crashes involving the different vehicle types based on 1982–86 National Automotive Sampling System data. In addition to a count of all persons involved in crashes we assessed, the following three categories are presented: not injured (MAIS 0), minor-to-moderate injury (MAIS 1–2), and serious-to-fatal injury (MAIS 3–fatal). Fatality counts are not presented separately because unacceptably large sampling errors would be associated with the small fatality estimates for specific crash/vehicle types (USDOT NHTSA 1992) and because GES generally undercounts fatalities. These sources of error are reduced by aggregating injury data across multiple severity levels (e.g., MAIS 3, 4, 5, and Fatal).

The GES data on which this study was based provide estimates of the relative frequency of different crash types. Sampling errors associated with GES crash, vehicle, and person estimates are not provided. For some small estimates, these may be significant (USDOT NHTSA 1992), although the use of five-year averages rather than single-year estimates reduces sampling errors.

This paper also contains a number of monetary metrics of the U.S. crash problem size. Unlike the nonmonetary crash statistics based principally on the GES, most monetary metrics used in this paper were adjusted to account for undercounting of PR and NPR crashes. These adjustments were derived from Blincoe and Faigin (1992).

Monetary assessments of crash problem size may be based on narrow economic loss criteria or comprehensive societal value criteria (Blincoe 1996). This paper provides both economic (E) and comprehensive (C) monetary crash problem-size metrics. Unit costs from Blincoe were adjusted to 1997 price levels using Consumer Price Index statistics. E costs represent the value of goods and services that must be purchased as a result of motor vehicle crashes; they include medical care, legal services, emergency services, vehicle repair services, and insurance administration costs. In addition, economic costs include the value of both workplace and household productivity lost due to death or injury, the value of travel delay to noninvolved motorists, and costs incurred due to workplace disruption when an employee is killed, injured, or delayed.

By contrast, C costs incorporate not only economic losses, but a valuation for less tangible consequences such as "pain and suffering" and loss of life. These values have been derived from "willingness-to-pay" studies that examine marketplace behavior to determine the value that people place on reducing risk. There is far more uncertainty involved with these estimates than those based on direct economic costs. These less tangible impacts, however, are often the most devastating aspects of serious motor vehicle injuries, and they should be incorporated whenever a direct comparison is made of costs and benefits or of the potential benefits of competing safety measures. Failure to consider these aspects could result in a serious underestimation of the true harm caused by motor vehicle crashes or the societal benefits associated with proposed safety measures.

In this paper, both E and C costs are expressed in 1997 dollars using a 4% annual discount rate to reflect the decreased value of future economic losses (e.g., lost wages). A 4% annual discount rate was also applied to calculations of expected monetary cost "per vehicle over operational life" and "per driver over driver career." These metrics are defined and discussed later in this section.

One way to simplify the metrics of motor vehicle crash consequences is to express them as "fatal equivalents."[2] This is achieved by dividing the annual monetary cost of any given crash by the cost of a fatality. For example, the annual C cost of all crashes in 1997 dollars is $431.9 billion and the C cost of a fatality is $3,091,420. The total annual fatal equivalents associated with all crashes equals $431.9 billion/$3,091,420 = 139,699.[3] NHTSA uses C costs and this method to derive a cost per-equivalent-fatality for their analyses of proposed safety regulations. For this study, fatal equivalents provide a convenient single-number basis for comparing crash consequences across crash types and vehicle types.

Problem-Size Referent

Crash problem sizes must be expressed in relation to a *referent*; for example, most traffic crash statistics refer to a particular time (e.g., a year) and place (the United States). Six different referents are used in this paper:

1. U.S. annual total (average of 1989–93).
2. Per PR target crash by type.
3. Per mile traveled. To avoid the use of very high or low numbers, crash involvement rates are expressed as the number of crash involvements per 100 million vehicle-miles traveled (VMT); whereas crash monetary costs are expressed in cents per mile. Passenger car and LT/V VMT were obtained from Walsh (1995). All other VMT statistics were obtained from *Highway Statistics* (USDOT Annual releases 1990–94).
4. Per registered vehicle annually (for numbers of crashes, expressed as the number per 1,000 registered vehicles annually). Passenger car and LT/V registrations were based on Shelton (1995). All other vehicle registration statistics were obtained from *Highway Statistics*.
5. Per manufactured vehicle over its expected operational life.
6. Per driver over his/her expected driving career.

[2] Fatal equivalents are the number of fatalities that would be equivalent in cost to all costs associated with crashes including costs for nonfatal injuries and property damage.
[3] The figure 139,699 was calculated before rounding.

The first four of the above referents are self-explanatory and commonly used in traffic safety research. The fifth (per manufactured vehicle over its expected operational life) is relevant to quantifying a crash problem in relation to the average or expected experience of individual vehicles that may, for example, be equipped at the factory or dealership with a particular safety device lasting the life of the vehicle. The expected number of crash involvements over a vehicle's life is derived by the formula:

Expected number = Average annual number of involvements $\times$ Average vehicle life $\div$ Average annual number of registered vehicles

The following values were used for average vehicle life by vehicle type: all vehicles, 13.1 years; passenger cars, 11.8 years; LT/Vs, 16.0 years; CUTs and SUTs, 14.7 years; and motorcycles, 7.5 years (Miaou 1990; Wang and Knipling 1994a).

The referent "per driver over his/her expected driving career" attempts to capture the expected lifetime driving experience of the average driver. It is derived by the formula:

Expected number = Average annual number of involvements $\times$ Average driving career (years) $\div$ Average annual number of registered drivers

The current average life expectancy of a beginning driver (e.g., 17-year-old) is approximately 76 years (USDHHS 1991). Such a person might drive for a total of 55 to 60 years. For example, a person who starts driving at age 17 and stops at age 75 would have driven for 58 years. This "years of driving" value—58 years—is used here although it is an approximation. The extrapolation of five years of crash data (1989–93) across 58 years of driving is also acknowledged to be inexact, since many crash-relevant factors (e.g., driver behavior, road safety, vehicle safety, emergency medicine) may change over such a long time period.

"Per driver over his/her expected driving career" statistics are derived for "all vehicle types" only. Disaggregation by vehicle type would be very difficult, because many drivers operate several different vehicle types during their careers and may drive certain vehicle types (e.g., large trucks, motorcycles) for only a few years.

Statistics: Metric/Referent Combinations

Each metric above could be applied to each referent to constitute a specific crash statistic; for example, crashes (a metric) per year in the United States (a referent). The current analysis includes the statistics listed below. All vehicle, injury, and monetary measures of the crash problem size include all individuals and vehicles involved in the crash, not just those in the SV. All statistics on crashes—involved vehicles and persons, and all "per crash" statistics (monetary value, fatal equivalents)—are based on PR crashes as retrieved from the GES. Monetary and fatal equivalent statistics for the United States, per mile traveled, per registered vehicle, per vehicle over its operational life, and per driver over his/her driving career include both PR and NPR crashes.

1. Annual U.S. number of PR crashes (also equals the number of SVs involved in these crashes)
2. Annual number of vehicles involved (of each body type) in PR crashes
3. Annual number of vehicles involved (regardless of body type) in PR crashes
4. Annual number of persons involved in PR crashes
   - Total
   - Not injured (MAIS 0)
   - Minor to moderate (MAIS 1–2)
   - Serious to fatal (MAIS 3–fatal)
5. Vehicle involvement rate in PR crashes
   - Per 100 million VMT
   - Per 1,000 registered vehicles
6. Expected involvements in PR crashes
   - Per vehicle over its operational life
   - Per driver over his/her driving career ("all vehicles" only)
7. Annual U.S. monetary cost (includes PR + NPR crashes)
   - Economic cost (E)
   - Comprehensive cost (C)
8. Average monetary cost (E and C)
   - Per PR crash
   - Per vehicle-mile (in cents)
   - Per registered vehicle annually (PR + NPR crashes)
9. Expected monetary cost (E and C)
   - Average per vehicle over its operational life (PR + NPR crashes)
   - Average per driver over his/her driving career ("all vehicles" only; PR + NPR crashes)
10. Fatal equivalents
   - Annual national total (PR + NPR crashes)
   - Average per PR crash.

Expected monetary costs over a vehicle's life were calculated using the same vehicle usage-by-vehicle-age projections employed by NHTSA to analyze its safety regulations and, as noted, using a 4% annual discount rate. Motorcycle usage-by-age projections were based on the passenger car pattern, but they were accelerated to reflect the shorter operational life of motorcycles. The "all vehicles" projection was a weighted average of the individual vehicle types. Driver discounting was based on the 1989–93 distribution of crash involvements by driver age. The cumulative discounting for the different vehicle types and for drivers (reflecting their different operational lives) was as follows: all vehicles, 17.45%; passenger cars, 16.73%; LT/Vs, 19.82%; CUTs and SUTs, 18.48%; motorcycles, 11.69%; drivers, 44.56%. For example, the discounted "all vehicles" expected monetary costs over a vehicle's life was derived by first obtaining a gross cost estimate (calculated using the formula shown earlier) and then reducing this gross value by 17.45%.

The "all vehicles" value provided is *not* simply the sum or weighted average of the five specific vehicle types. First, "all vehicles" includes a relatively small number of other vehicle types such as buses. More importantly, for most statistics the crashes, vehicles, injuries, or dollars may be counted under more than one specific vehicle type column. For example, for all crashes (see table 2), those involving *both* a passenger car and an LT/V are counted in both columns. Since many of the statistics provided include all involved vehicles and persons (e.g., injuries to persons in non-SVs), the columns are not additive; such additions would constitute double counting. For all crashes, the per VMT, per registered vehicle annually, and per vehicle over its operational life values for "all vehicles"

TABLE 2 Statistics for All Crashes

Type of statistics		Crashes involving: All vehicles	Passenger cars	Light trucks/ vans	Combin-ation-unit trucks	Single-unit trucks	Motor-cycles
Annual number of PR crashes		6,261,000	5,307,000	2,209,000	214,000	154,000	89,000
Annual number of this vehicle type involved in PR crashes*		10,964,000	7,929,000	2,485,000	221,000	157,000	90,000
Annual number of all vehicles involved in PR crashes*		10,964,000	9,688,000	4,141,000	392,000	287,000	145,000
Annual U.S. number of persons involved in PR crashes*		15,905,000	14,101,000	5,932,000	494,000	376,000	183,000
Not injured (0)*		12,278,000	10,936,000	4,684,000	399,000	307,000	90,000
Minor to moderate (MAIS 1–2)*		3,433,000	3,020,000	1,183,000	85,000	65,000	78,000
Serious to fatal (MAIS 3–fatal)*		194,000	146,000	65,000	9,000	5,000	15,000
Vehicle involvement rate in PR crashes							
Per 100 million VMT		500.41	556.15	415.59	225.52	289.33	927.65
Per 1,000 registered vehicles annually		59.33	64.91	47.87	135.14	36.60	21.54
Expected involvements in PR crashes							
Over vehicle operational life		0.7789	0.7640	0.7684	1.9866	0.5380	0.1615
Per driver over driving career		3.7383					
Annual U.S. monetary cost*	(E)	$164.4B	$146.8B	$57.7B	$9.5B	$5.4B	$6.5B
	(C)	$431.9B	$353.7B	$147.9B	$22.1B	$11.6B	$22.6B
Average monetary cost							
Per PR crash*	(E)	$17,950	$18,650	$17,580	$39,540	$31,870	$57,190
	(C)	$52,610	$50,190	$50,750	$89,400	$66,370	$206,460
Per VMT*	(E)	7.50¢	10.29¢	9.65¢	9.68¢	9.99¢	66.52¢
	(C)	19.71¢	24.81¢	24.73¢	22.57¢	21.50¢	233.05¢
Per registered vehicle annually*	(E)	$890	$1,200	$1,110	$5,800	$1,260	$1,540
	(C)	$2,340	$2,900	$2,850	$13,520	$2,720	$5,410
Expected monetary cost							
Per vehicle over operational life*	(E) d	$9,640	$11,780	$14,310	$69,540	$15,140	$10,230
	(C) d	$25,330	$28,380	$36,660	$162,040	$32,580	$35,830
Per driver over driving career	(E) d	$31,070					
	(C) d	$81,630					
Total annual U.S. fatal equivalents*		139,699	114,423	47,829	7,160	3,763	7,320
Average fatal equivalents per PR crash*		0.01702	0.01623	0.01642	0.02855	0.02120	0.06678

* Inclusive; i.e., includes all crash-involved vehicles and persons, except for the boxed area in "all vehicles" column. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; PR = police-reported; VMT = vehicle-miles traveled.

are less than any of the individual vehicle types, because the aggregation of all vehicles eliminates the possibility of counting "other" involved vehicles. These all vehicle/all crash statistics (see boxed values within table 2), unlike those in other columns and tables, do not reflect consequences to other involved vehicles and their occupants. Similarly, the table 2 values for all crashes "per driver over driving career" do not incorporate consequences to other involved vehicles and their occupants.

The following rounding rules were applied to all the statistics presented in this paper. For crash and injury statistics, values were rounded to the nearest 1,000 if they are 2,000 or greater, or to the nearest 100 if they are less than 2,000. Monetary costs, except for costs per VMT, were rounded to the nearest $10. Costs per VMT were rounded to the nearest 0.01¢. Other statistics, including rates and expected involvements, have been rounded in a manner to ensure that the smallest value in each row contains at least two, and usually three, significant digits. The total annual national fatal equivalent was rounded to the nearest 1. As a result of rounding, some table entries may not sum to the totals. In addition, percentage estimates and the derived statistics in the tables were calculated before numbers were rounded.

RESULTS AND DISCUSSION

Results are shown in table 2 for all crashes and appendix tables A through H (at the end of this paper) for specific crash types. The statistics provided are too numerous to describe completely. This discussion will focus on major findings, caveats, and clarifications of appropriate interpretations.

"All Crashes" Statistics

At the highest level of analysis are the statistics for all crashes and all vehicles types. Between 1989–93, there were an average of 6,261,000 PR crashes annually involving 10,964,000 vehicles and 15,905,000 persons. There were 500 vehicle involvements in PR crashes per 100 million VMT and 59.3 involvements per 1,000 registered vehicles. Each vehicle can be expected to be involved in 0.78 PR crashes during its operational life and each driver can be expected to be involved in 3.74 PR crashes during his or her driving career.

The average annual total economic cost of motor vehicle crashes (PR + NPR) was $164 billion. Average annual national comprehensive costs were $432 billion. The average PR crash resulted in direct economic losses of $17,950 and had a comprehensive cost of $52,610. Not shown in table 2 are the economic costs of NPR crashes; Blincoe and Faigin (1992) estimated that 22% of all injuries, mostly minor, are not accounted for in PARs. In addition, 48% of all property-damage-only crashes are unreported.

Each mile traveled by a vehicle is associated with crash costs (PR + NPR) of 7.5¢ (E) or 19.7¢ (C). On average, each registered vehicle annually experiences crash consequences with a value of $890 (E) or $2,340 (C). Over the total operational life of the vehicle, these values are extrapolated to discounted values of $9,640 (E) or $25,330 (C). Extrapolation of the 1989–93 statistics across a 58-year driving career (discounted to current value) indicates that each driver would be expected to be involved in crashes with a value of $31,070 (E) or $81,630 (C). As noted earlier, the per VMT, per registered vehicle annually, and per vehicle over its operational life values for the specific vehicle types are all higher than the "all vehicles" value because they incorporate the consequences to other vehicles involved in the crashes (e.g., LT/Vs involved in passenger car crashes and vice versa).

The statistics indicate an annual national average of 139,699 fatal equivalents associated with motor vehicle crashes. Each PR-crash results in an average of 0.0170 fatal equivalents (the total of all involved persons).

The above statistics can be used to assess potential benefits from the application of safety interventions, whether real or hypothetical, to specific vehicle types. For example, a vehicle-based device lasting the life of a passenger car and capable of reducing all its crash involvements by 5% would have a societal economic value of $11,780 $\times$ 0.05 = $590 (E) or $28,380 $\times$ 0.05 = $1,420 (C) for each equipped passenger car. These represent *time-of-purchase* monetary values because the cost projections were discounted. This monetary benefit would be shared by the occupants of equipped passenger cars and those in other vehicles who would have crashed with the equipped car had the device not been installed.

A new driver education program or similar intervention capable of reducing a driver's lifetime crash involvements by 10% would have a start-of-driving societal economic value of $31,070 $\times$ 0.10 = $3,110 (E) or $81,630 $\times$ 0.10 = $8,160 (C) for each young driver exposed. This benefit would be shared by the driver, his or her passengers, and any nonmotorists (e.g., pedestrians) who would have been affected by these crashes. In addition to this benefit, there would be benefits to other vehicles and their occupants whose crashes with the subject driver were also prevented.

As noted previously, the "per vehicle over operational life" and "per driver over driving career" monetary cost estimates are discounted to reflect the current economic value of future costs. For drivers, this discounting is substantial (44.56%). The *nondiscounted* value of all expected crash involvements during a typical 58-year driving career is $56,050 (E) or $147,250 (C). Applying the cumulative discount of 44.56% yields the discounted value presented in table 2.

Another way of expressing the nondiscounted driver values presented in the paragraph above is to consider per-driver-per-year crash costs. On an annual basis, the driver on average can be expected to be involved in crashes with a total value (*not* including consequences to other vehicles and their occupants) of $970 (E) or $2,540 (C). The potential cost-benefits of ongoing, continuously applied safety programs, such as public service announcements, might be assessed using these values.

Crash-Type Comparisons

Table 3 provides some comparative all-vehicle-type statistics on the eight specific crash types addressed in appendix tables A through H, plus two additional major crash types, signalized and unsignalized intersection perpendicular crossing path (SI/PCP and UI/PCP) crashes (Wang and Knipling 1994c). For each crash scenario, three summarizing statistics are provided: annual U.S. number of PR crashes, average monetary cost (E) per PR crash, and annual U.S. monetary cost. The three statistics represent comparative measures of PR crash frequency, average PR crash severity, and total societal problem size (PR + NPR). Other statistics could have been chosen from the tables to provide essentially the same comparisons.

Table 3 shows that the most numerous crash categories are rear-end crashes (1.45 million annual PR crashes for RE-LVS + RE-LVM), SVRD (1.31 million annual PR crashes), and intersection crossing path crashes (1.30 million annual PR crashes for LTAP + SI/PCP + UI/PCP). The most severe crash types are OD ($50,770 per PR crash) and pedestrian crashes ($42,340 per PR crash). The highest annual U.S. total monetary costs are associated with intersection crossing path crashes ($39.3 billion for the three subtypes combined), RE crashes ($33.8 billion for the two subtypes combined), and SVRD crashes ($33.2 billion).

A specific caveat relating to the backing crash problem size is that of the crashes shown in tables 3 and appendix table F the majority are *crossing path* backing crashes, where a vehicle backs into traffic and is struck by a another vehicle (Wang and Knipling 1994a). Crossing path backing crashes are probably less amenable to technological solution (i.e., rear object detection) than are *encroachment* backing crashes, in which a vehicle backs into a stationary object.

Vehicle-Type Comparisons

For all crashes and for each of the individual crash types, passenger cars and light trucks/vans dominate the statistics for total number of crashes, associated injuries, and monetary costs. For example, a comparison of the annual national total economic

TABLE 3 Crash Type Comparisons
(All vehicle types combined, 1989–93 average)

Crash type	Annual U.S. PR crashes	Average cost (E) per PR crash	Annual U.S. monetary cost
All crashes	6,261,000	$17,950	$164.4B
SVRD crashes	1,310,000	$19,060	$33.2B
Pedestrian crashes	176,000	$42,340	$9.7B
RE-LVS crashes	974,000	$14,170	$22.3B
RE-LVM crashes	480,000	$15,120	$11.5B
LC/M crashes	234,000	$10,080	$4.1B
Backing crashes	171,000	$7,390	$2.4B
OD crashes	190,000	$50,770	$12.7B
LTAP crashes	396,000	$20,500	$11.9B
SI/PCP crashes	266,000	$21,690	$8.4B
UI/PCP crashes	633,000	$20,490	$19.0B

Key: B = billion; E = economic; PR = police-reported.

cost (E) row in table 2 indicates that total costs for all vehicle types combined were $164 billion. The costs of crashes involving the individual vehicle types were: passenger cars, $147 billion; LT/Vs, $58 billion; CUTs, $10 billion; SUTs, $5 billion; and motorcycles, $7 billion. (The individual vehicle types add up to greater than $164 billion, because each vehicle-type statistic includes all vehicles (and people) involved in the crashes.) Thus, from a national perspective, safety interventions are not likely to have dramatic effects unless they address the huge passenger car and LT/V crash situations.

Passenger cars represented more than three times as many vehicle crash involvements than LT/Vs between 1989–93, but otherwise these two large vehicle populations were similar in their crash profiles. Compared to passenger cars, however, LT/Vs have somewhat lower involvement rates, monetary costs per VMT, and average annual monetary costs per registered vehicle.

CUTs are associated with a very different crash-size profile, however. Although they have very low crash rates, their high mileage exposures, long operational lives, and the severity of crashes (Miaou 1990; Clarke et al. 1991) combine to give them very high per vehicle crash costs. Indeed, for "all crashes" and each of the eight specific crash types/roles, CUTs stand out as having the highest per vehicle crash costs and thus the highest potential crash-reduction benefits on a per vehicle basis. For example, in table 2 it is shown that the per vehicle life monetary costs of all CUT crashes is $69,540 (E) or $162,040 (C). These costs are more than four times as great as those for any other vehicle type. From a percentage cost-benefit standpoint, this means that crash avoidance systems can generally afford to be considerably more expensive and/or less effective for CUTs and still be more attractive than the same device installed on other vehicle types. Still, the national impact of such deployments will be limited; only 3.4% of all crashes and 5.8% of associated monetary costs are associated with CUT crashes.

SUTs have a less dramatic crash picture than do CUTs. SUTs represent 1.4% of all vehicle crash involvements and, compared with other vehicles, they have low involvement rates, both on a per mile traveled and per registered vehicle basis annually. Their crashes are more severe, measured by average monetary cost per PR crash, than those of passenger cars or LT/Vs, but they are less severe than those of CUTs or motorcycles. The per vehicle operational life costs of SUT crashes are about 20% of those of CUTs and are only slightly higher than LT/Vs.

Safety interventions for CUTs applied on an annual basis as well as those lasting the life of a vehicle can be very effective. Annually, on average, each CUT was involved in crashes with a monetary value of $5,800 (E) or $13,520 (C). This is four to five times as great as the values for crashes of other vehicle types. Thus, an annual safety intervention (e.g., vehicle safety inspections) would have four to five times the payoff for CUTs as for other vehicle types, assuming equivalent intervention costs and effectiveness.

An important caveat, which bears repeating, is that the current CUT and SUT monetary cost statistics are based on an assumption of zero unreported crash costs. Since in reality there are some such crashes, the current monetary cost statistics understate CUT and SUT crash costs somewhat. This underestimation, however, is not likely to be more than a few percentage points.

The motorcycle crash picture presents another sharp contrast to that of other vehicle types. Motorcycles represent a relatively small percentage of overall national crashes, but their per crash costs are high; for example, $57,190 per PR crash (E) versus $17,950 for all vehicle types combined. Of course, this reflects the relatively high vulnerability of motorcycle riders to crash injuries. The average PR motorcycle crash is associated with 0.067 fatal equivalents—nearly four times the value of all vehicle types combined. In addition, motorcycles have a rate of involvement in crashes per VMT that is nearly twice that of all vehicle types combined. These two factors have a multiplicative effect in making motorcycle travel 6 to 10 times more costly per mile traveled than other vehicle types.

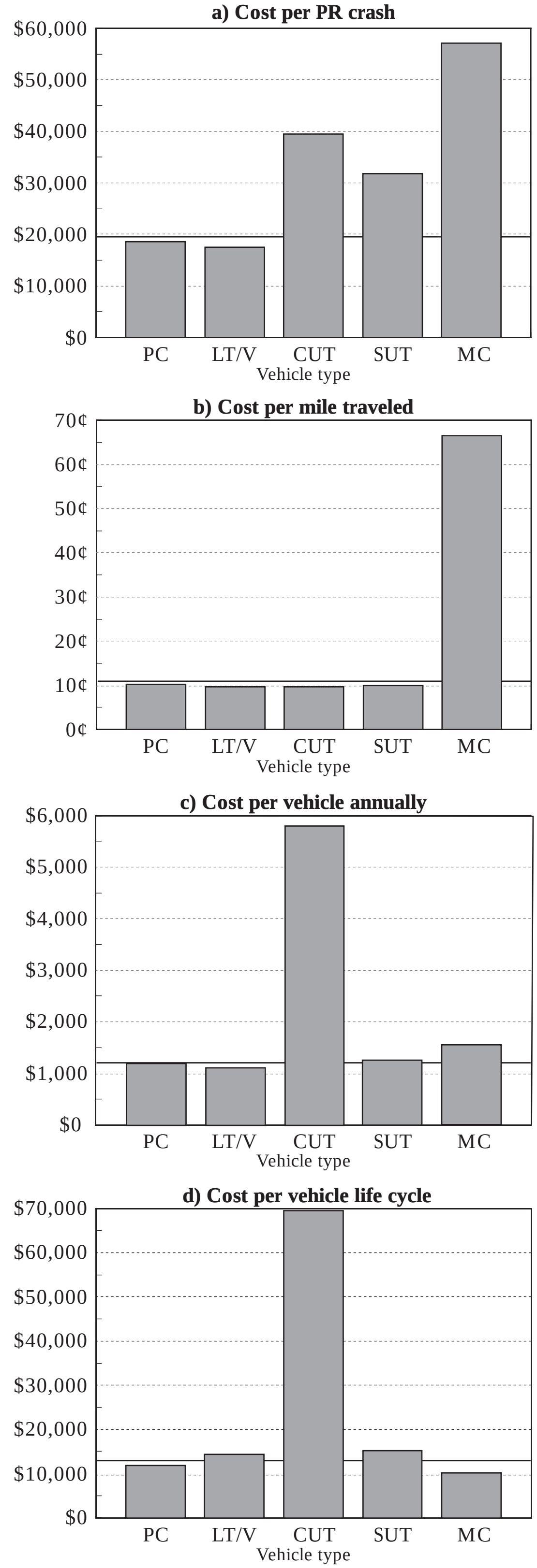
The irony of the motorcycle crash picture—exactly opposite of that of CUTs—is that they have low mileage exposure and relatively short operational lives. These factors make the vehicle operational life crash costs of motorcycles among the lowest of the vehicle types. From a strict per vehicle produced monetary cost-benefit perspective, this makes motorcycles a relatively *unattractive* platform for safety devices lasting the life of the vehicle, assuming equivalent costs and effectiveness levels. On the other hand, this type of vehicle is an extremely attractive platform for safety devices having a limited mileage life. For example, assuming comparable effectiveness, a general safety device (i.e., targeting all crashes) installed for 1,000 miles on an motorcycle would produce more than six times the expected benefit as the same device installed for 1,000 miles on a passenger car.

Figure 1 provides four sets of comparative histograms for four monetary metrics: a) per PR crash, b) per mile traveled, c) per registered vehicle annually, and d) per vehicle life cycle. For each, the horizontal line shows the *weighted average* of the value of the vehicle types, while the vertical bars represent the five specific vehicle types. These relative values are based on the economic (E) monetary values in table 2. Generally, the passenger car and LT/V values are similar to each other and the weighted average across all four comparisons. Since these two vehicle types together represent about 95% of vehicles involved in crashes, they are the principal determinants of the weighted averages for each set. Motorcycles sustain the highest costs per crash, followed by those of CUTs and SUTs, which are also significantly greater than average. In costs per mile of travel, motorcycles are about six times the weighted average; surprisingly, perhaps, both CUTs are SUTs are slightly *lower* than average. In the per vehicle annually set, CUTs are far above the weighted average, while all the other vehicle types are near the average. The per vehicle life cycle set is similar, but not identical since different vehicle types have different average operational lives. In this set, CUTs are again far above average, but motorcycles are now below average reflecting, in part, their short operational lives.

For the individual vehicle types, the current statistics do not provide information to disaggregate "inside" versus "outside" damage, injuries, and associated costs. It is well known, however, that there are major differences across vehicle types in this disaggregation, with CUTs and motorcycles

FIGURE 1 Vehicle-Type Comparisons of Four Monetary (E) Crash Statistics

Weighted costs indicated by reference line



Key: E = economic cost; PC= passsenger car; MC = motorcycle.

representing the extremes. A supplemental analysis (not shown in the tables) indicates that approximately 67.2% of the monetary costs of CUT crashes are associated with damage and injuries outside the truck; for example, occupants of other involved vehicles. In contrast, only 12.5% of the monetary costs of motorcycle crashes are "outside" the vehicle. (The small number of crashes involving multiple CUTs or multiple motorcycles were excluded from this analysis.)

Crash- and Vehicle-Type Interactions

The crash- and vehicle-type statistics provided in appendix tables A through H are too numerous to discuss in detail. For each vehicle type, SVRD and RE crashes (when the RE-LVS and RE-LVM categories are combined) are the most numerous of those shown here. Intersection crossing path crashes are also numerous (Wang and Knipling 1994c), although statistics for only one subcategory of these crashes (i.e., LTAP crashes) are presented here for individual vehicle types.

Comparison of crash statistics across various crash and vehicle types reveals several notable examples of overrepresentation or underrepresentation of particular vehicle types in particular crash types/roles. For example, LT/Vs represent 22.7% of all vehicles involved in crashes but 36.2% of SVs in backing crashes.

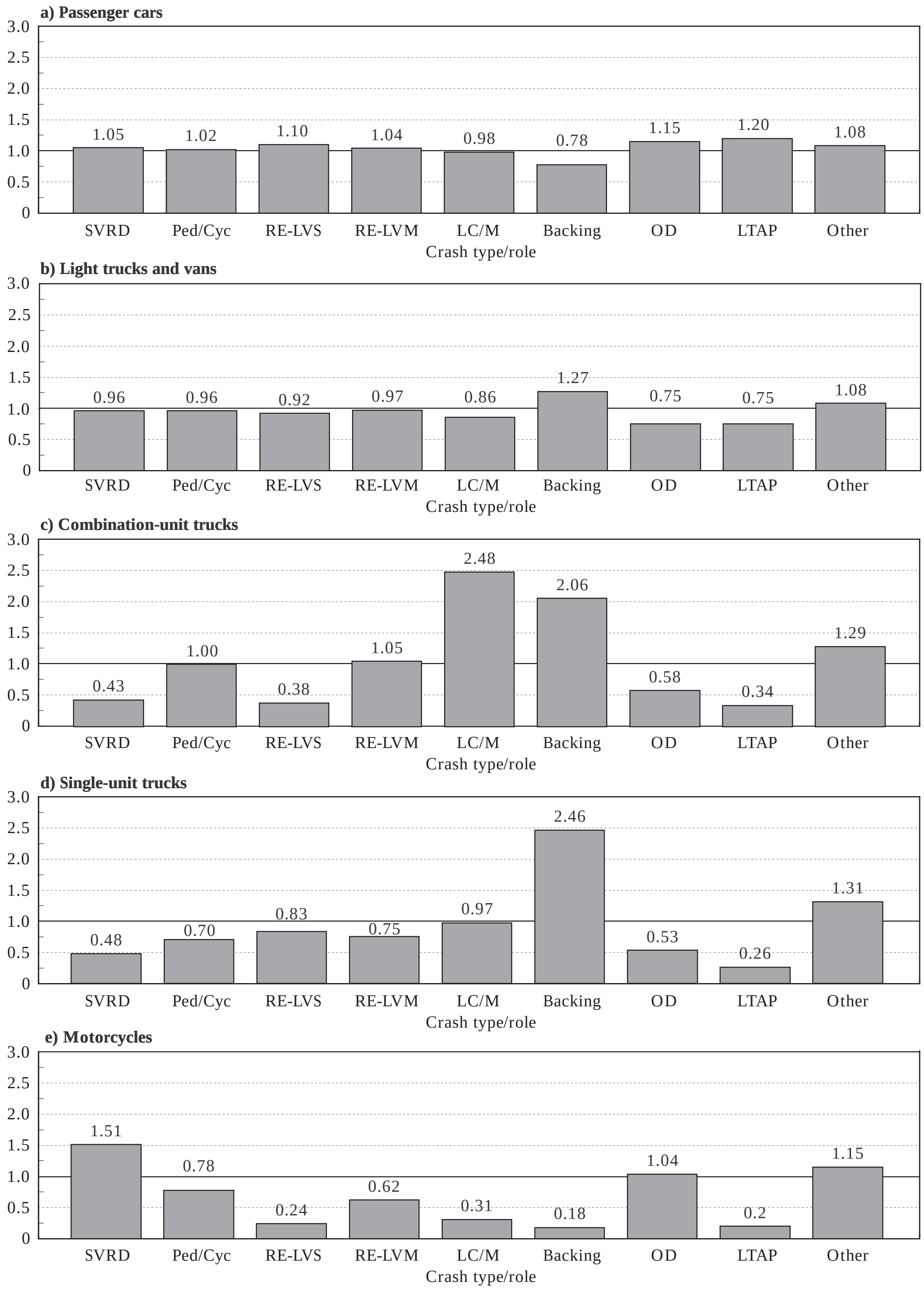
The largest relative overinvolvement of CUTs is in LC/M crashes. CUTs comprise only 2.0% of vehicles involved in crashes, but represent 8.5% of vehicles involved in LC/M crashes as the SV. On a per vehicle life cycle basis, CUT involvements in LC/M crashes are about 12 times as costly as those of SUTs and 14 times as costly as those of all vehicle types combined. CUTs are also relatively underrepresented in certain crash types; for example, they represent only 1.1% of the SVs in RE-LVS crashes and 0.5% of those in LTAP crashes. Nevertheless, for every crash type, CUTs have the highest crash costs per vehicle over the operational life of the vehicle.

The only major overrepresentation of SUTs is in backing crashes; they represent 1.4% of vehicles involved in all crashes, but account for 5.3% of SVs in backing crashes. CUTs and SUTs show a different pattern of SV involvements in RE-LVS versus RE-LVM crashes; CUTs have more RE-LVM crashes, whereas SUTs have more RE-LVS involvements. This likely reflects the different exposure patterns of these two large truck types; CUTs accumulate most of their mileage on highways whereas SUTs accumulate relatively more mileage on secondary/local roads.

Motorcycles are relatively overrepresented in SVRD crashes. They represent 0.8% of all vehicles involved in crashes but 1.2% of SVRD crash involvements. Furthermore, motorcycle SVRD crashes are approximately four times as severe as those of any other vehicle type. On a per mile traveled basis, motorcycle SVRD crashes are an order of magnitude more costly than those of all vehicle types combined. The per vehicle life cycle monetary costs of motorcycle SVRD crashes are actually slightly higher than the "all vehicles" average, an exception to the general rule that motorcycle life cycle crash costs are generally low compared with other vehicle types.

Figure 2 is based on the monetary costs (E) for the different crash type roles and vehicle types. They are shown in terms of *relative* percentage of that vehicle type's crash costs in comparison to a weighted average of all vehicle types combined (the latter statistics are not shown). The horizontal line in each histogram set represents the weighted average across vehicle types for each crash type. The passenger car set (2a) deviates very little from the weighted average of all five vehicle types, since passenger cars dominate these weighted average statistics. LT/Vs (2b) show a relative overinvolvement in backing crashes. For CUTs (2c), there are large relative overinvolvements in LC/M and backing crashes and notable relative underinvolvements in SVRD, RE-LVS, and LTAP crashes. SUTs (2d) show a marked relative overinvolvement in backing crashes. Both CUTs and SUTs show overinvolvements in "other" types of crash roles, since they are very often the non-SV (i.e., nonculpable) vehicle in two-vehicle crashes. For motorcycles (2e), the greatest relative overinvolvements are in SVRD crashes with marked relative underinvolvements in RE-LVS, backing, and LTAP crashes. Recall that the LTAP statistics reflect only SV (left turning) roles in crashes; motorcycles rarely play

FIGURE 2 Relative Distribution of Crash Costs (E) by Crash Type/Role for Five Vehicle-Type Categories



this role in LTAP crashes, but are frequently in the non-SV (going straight), since they are often not seen by other drivers.

"Most-Relevant Referents" for Countermeasure Benefit Assessments

This paper presents crash problem-size statistics that are more specific and heuristic than traditional national annual totals. To perform a meaningful and heuristic benefits assessment, we selected appropriate statistics based on four dimensions of motor vehicle crash risk: crash types/roles, vehicle types, metrics, and referrants. Perhaps the most subtle of these dimensions is problem-size referent. Safety initiatives may vary dramatically in their patterns or "spans" of application and, therefore, in the most appropriate perspective from which to assess their potential benefits. Below are examples of countermeasures with qualitatively different patterns of application and their corresponding most-relevant referents.

For national public information campaigns or other initiatives applied diffusely to the driver/vehicle population, the most-relevant referent would be U.S. annual. Annual program expenditures would be compared with the national annual problem size as measured by various metrics, whether monetary or nonmonetary.

Some safety interventions are applied proportionally to miles traveled; for such interventions, rate-per-mile statistics are most applicable. One example would be improved brake pads with a limited mileage life; benefits would be best assessed by comparing per mile crash rates or monetary cost rates for applicable crash and vehicle types. Another example of a mileage-based safety intervention is roadside inspections for commercial vehicles (primarily CUTs and SUTs). In general, the number of roadside inspections large trucks receive is proportional to their mileage exposure. Recall that CUTs and SUTs have almost identical crash costs per mile of travel (9.7¢ versus 10.0¢ (E), respectively; see table 2 and figure 1b). Assuming that per inspection costs and the crash-reduction effectiveness of inspections are similar for these two vehicle types, the cost-benefits of roadside inspections would also be similar, in spite of the vastly greater per vehicle mileage exposure of CUTs compared with SUTs.

Annual vehicle inspections, in contrast, have a time-based span of application; that is, one year. The most relevant referent would be per vehicle year. From the table 2 per-registered-vehicle-annually monetary cost values and figure 1c, we see that benefits are potentially far greater for CUTs than for other vehicle types. The importance of choosing the most relevant referent is illustrated by the comparison of CUTs with SUTs; unlike the situation above for roadside inspections where the benefits pictures were similar, for annual inspections the per vehicle benefits would be far greater for CUTs than for SUTs.

Most vehicle-based safety devices, whether they are crash avoidance- or crashworthiness-related, are installed at the factory or dealership, or are purchased in the aftermarket for use over the entire life of the vehicle. For example, an ITS crash avoidance device such as a headway/forward obstacle detector would target RE crashes (both LVS and LVM) and would operate over the entire vehicle life cycle. Where the span of application is vehicle operational life, per-vehicle-life-cycle statistics are most relevant to a determination of cost-benefits. Extreme differences among vehicle types are evident in these statistics; for example, assuming equal device cost and effectiveness, a RE-LVM countermeasure installed on a CUT would have 6 times the potential monetary benefits of the same device installed on a passenger car and 12 times that of a motorcycle. As noted earlier, for all crash types studied, the per-vehicle-life-cycle costs for CUTs are higher than for any other vehicle type, even though CUTs generally have low crash rates per mile and are markedly underinvolved in several crash types in relation to their own overall crash picture. The high per-vehicle-life-cycle costs for CUTs reflect their high per vehicle mileage exposure and the great severity of their crashes when they occur.

There do not seem to be any safety interventions with a pure "per crash" span of application. Air bags *deploy* only during crashes (of certain threshold severities), but they are purchased and applied over the vehicle life cycle (albeit they must be replaced after a crash deployment). Costs to government for emergency medical services responding to crashes are not necessarily proportional to the number of crashes to which they respond. Per crash statistics, however, are obviously relevant to any projections of the absolute number of crashes that may be prevented by a safety intervention even if the intervention does not have a per crash span of application.

Finally, there are new driver training/education programs that are conceptualized to affect drivers' entire lifetime driving experience. Here, the intended span of application is the individual driving career. Because drivers are on average involved in multiple crashes over their lifetimes, relatively small reductions in crash risk can be highly cost-beneficial.

CONCLUSION

This paper attempted to dissect the U.S. crash picture in ways that make crash and vehicle type differences more salient and that support realistic assessments of potential countermeasure benefits. Of course, any benefits assessment must include an estimation of the actual crash reduction effectiveness of interventions, which we did not address in this paper, but the above discussion and examples show that identification of the most relevant dimensions of motor vehicle crash risk is even more fundamental to developing a framework for enlightened safety benefits assessment and decisionmaking.

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Appendix Tables

TABLE A Statistics for Single-Vehicle Roadway-Departure (SVRD) Crashes

		Crashes involving					
Type of statistics		**All vehicles**	**Passenger cars**	**Light trucks/ vans**	**Combin-ation-unit trucks**	**Single-unit trucks**	**Motor-cycles**
Annual number of PR crashes		1,310,000	907,000	323,000	31,000	23,000	16,000
Annual number of this vehicle type involved in PR crashes		1,310,000	907,000	323,000	31,000	23,000	16,000
Annual U.S. number of persons involved in PR crashes		1,791,000	1,277,000	435,000	34,000	27,000	19,000
Not injured (0)		1,190,000	849,000	290,000	27,000	22,000	3,000
Minor to moderate (MAIS 1–2)		553,000	397,000	133,000	7,000	4,000	12,000
Serious to fatal (MAIS 3–fatal)		48,000	32,000	12,000	800	300	3,000
Vehicle involvement rate in PR crashes							
Per 100 million VMT		59.79	63.62	53.97	31.64	41.91	167.65
Per 1,000 registered vehicles annually		7.09	7.43	6.22	18.96	5.30	3.89
Expected involvements in PR crashes							
Over vehicle operational life		0.0931	0.0874	0.0998	0.2787	0.0779	0.0292
Per driver over driving career		0.4466					
Annual U.S. monetary cost	(E)	$33.2B	$22.8B	$8.1B			
	(C)	$62,200	$60,870	$62,650	$40,060	$32,190	$263,040
Per VMT	(E)	1.52¢	1.60¢	1.36¢	0.62¢	0.71¢	14.82¢
	(C)	4.67¢	4.88¢	4.24¢	1.44¢	1.54¢	53.76¢
Per registered vehicle annually	(E)	$180	$190	$160	$370	$90	$340
	(C)	$550	$570	$490	$870	$200	$1,250
Expected monetary cost							
Per vehicle over operational life	(E)d	$1,950	$1,830	$2,020	$4,450	$1,080	$2,280
	(C)d	$6,010	$5,580	$6,280	$10,370	$2,330	$8,270
Per driver over driving career	(E)d	$6,280					
	(C)d	$19,360					
Total annual U.S. fatal equivalents		33,125	22,507	8,190	458	269	1,689
Average fatal equivalents per PR crash		0.02012	0.01969	0.02027	0.01279	0.01028	0.08509

* Inclusive, i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; E = economic cost; M = million; PR = police-reported; VMT = vehicle-miles traveled.

TABLE B Statistics for Pedestrian/Cyclist (Ped/Cyc) Crashes

Type of statistics		Crashes involving: All vehicles	Passenger cars	Light trucks/ vans	Combin-ation-unit trucks	Single-unit trucks	Motor-cycles
Annual number of PR crashes		176,000	133,000	37,000	1,200	1,500	2,000
Annual number of this vehicle type involved in PR crashes*		178,000	134,000	37,000	1,200	1,500	2,000
Annual number of all vehicles involved in PR crashes*		178,000	134,000	37,000	1,300	1,500	2,000
Annual U.S. number of person involved in PR crashes*		415,000	315,000	85,000	3,000	3,000	5,000
Not injured (0)*		245,000	188,000	50,000	1,400	1,800	1,400
Minor to moderate (MAIS 1–2)*		155,000	117,000	32,000	900	1,300	3,000
Serious to fatal (MAIS 3–Fatal)*		15,000	10,000	3,000	400	200	500
Vehicle involvement rate in PR crashes							
Per 100 million VMT		8.12	9.39	6.15	1.21	2.79	24.07
Per 1,000 registered vehicles annually		0.96	1.10	0.71	0.73	0.35	0.56
Expected involvements in PR crashes							
Over vehicle operational life		0.0126	0.0129	0.0114	0.0107	0.0052	0.0042
Per driver over driving career		0.0607					
Annual U.S. monetary cost*	(E)	$9.7B	$6.5B	$2.4B	$410M	$162M	$218M
	(C)	$31.1B	$20.3B	$7.8B	$1.1B	$427M	$779M
Average monetary cost							
Per PR crash*	(E)	$42,340	$36,850	$51,020	$287,620	$92,180	$74,660
	(C)	$141,480	$121,410	$171,580	$788,970	$240,720	$271,760
Per VMT*	(E)	0.45¢	0.45¢	0.40¢	0.42¢	0.30¢	2.25¢
	(C)	1.42¢	1.42¢	1.30¢	1.15¢	0.79¢	8.03¢
Per registered vehicle annually*	(E)	$50	$50	$50	$250	$40	$50
	(C)	$170	$170	$150	$690	$100	$190
Expected monetary cost							
Per vehicle over operational life*	(E)d	$570	$520	$600	$3,000	$450	$350
	(C)d	$1,830	$1,630	$1,930	$8,250	$1,200	$1,230
Per driver over driving career	(E)d	$1,840					
	(C)d	$5,880					
Total annual U.S. fatal equivalents*		10,065	6,554	2,523	360	136	252
Average fatal equivalents per PR crash*		0.04577	0.03927	0.05550	0.25198	0.07688	0.08791

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; M = million; PR = police-reported; VMT = vehicle-miles traveled.

TABLE C Statistics for Rear-End, Lead Vehicle Stopped (RE-LVS) Crashes

Type of statistics		Crashes involving vehicle as: All vehicles	Passenger cars	Light trucks/ vans	Combin-ation-unit trucks	Single-unit trucks	Motor-cycles
Annual number of PR crashes		974,000	696,000	229,000	11,000	12,000	3,000
Annual number of this vehicle type involved in PR crashes*		2,144,000	1,331,000	319,000	13,000	14,000	4,000
Annual number of all vehicles involved in PR crashes*		2,144,000	1,532,000	504,000	24,000	27,000	7,000
Annual U.S. number of persons involved in PR crashes*		3,107,000	2,020,000	652,000	27,000	34,000	9,000
Not injured (0)*		2,469,000	1,608,000	523,000	21,000	26,000	6,000
Minor to moderate (MAIS 1–2)*		618,000	401,000	125,000	6,000	7,000	3,000
Serious to fatal (MAIS 3–fatal)*		20,000	11,000	4,000	300	300	300
Vehicle involvement rate as SV in PR crashes							
Per 100 million VMT		44.46	48.85	38.30	10.98	22.98	33.51
Per 1,000 registered vehicles annually		5.27	5.70	4.41	6.58	2.91	0.78
Expected involvements as SV in PR crashes							
Over vehicle operational life		0.0692	0.0671	0.0708	0.0967	0.0427	0.0058
Per driver over driving career		0.7308					
Annual U.S. monetary cost*	(E)	$22.3B	$14.6B	$4.8B	$325M	$400M	$140M
	(C)	$48.0B	$30.0B	$9.9B	$613M	$765M	$443M
Average monetary cost							
Per PR crash*	(E)	$14,170	$12,680	$12,620	$28,480	$29,940	$31,400
	(C)	$35,190	$30,260	$30,640	$51,820	$55,410	$107,430
Per VMT*	(E)	1.02¢	1.02¢	0.80¢	0.33¢	0.74¢	1.44¢
	(C)	2.19¢	2.10¢	1.66¢	0.63¢	1.41¢	4.57¢
Per registered vehicle annually*	(E)	$120	$120	$90	$200	$90	$30
	(C)	$260	$250	$190	$370	$180	$110
Expected monetary cost							
Per vehicle over operational life*	(E)d	$1,310	$1,170	$1,190	$2,380	$1,120	$220
	(C)d	$2,810	$2,410	$2,460	$4,490	$2,140	$700
Per driver over driving career	(E)d	$4,220					
	(C)d	$9,070					
Total annual national fatal equivalents*		15,522	9,705	3,215	198	247	143
Average fatal equivalents per PR crash*		0.01138	0.00979	0.00991	0.01655	0.01770	0.03475

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; E = economic cost; C = comprehensive cost; d = discounted; M = million; PR = police-reported; SV = subject vehicle (striking vehicle); VMT = vehicle-miles traveled.

TABLE D Statistics for Rear-End, Lead Vehicle Moving (RE-LVM) Crashes

Type of statistics		Crashes involving vehicle as: All vehicles	Passenger cars	Light trucks/ vans	Combin-ation-unit trucks	Single-unit trucks	Motor-cycles
Annual number of PR crashes		480,000	329,000	118,000	10,000	7,000	3,000
Annual number of this vehicle type involved in PR crashes*		1,057,000	624,000	165,000	13,000	8,000	4,000
Annual number of all vehicles involved in PR crashes*		1,057,000	724,000	260,000	22,000	15,000	7,000
Annual U.S. number of persons involved in PR crashes*		1,522,000	966,000	341,000	28,000	17,000	8,000
Not injured (0)*		1,212,000	772,000	273,000	21,000	14,000	5,000
Minor to moderate (MAIS 1–2)*		299,000	188,000	66,000	6,000	3,000	3,000
Serious to fatal (MAIS 3–fatal)*		11,000	6,000	2,000	500	200	500
Vehicle involvement rate as SV in PR crashes							
Per 100 million VMT		21.92	23.07	19.76	10.41	12.53	34.14
Per 1,000 registered vehicles annually		2.60	2.69	2.28	6.24	1.59	0.79
Expected involvements as SV in PR crashes							
Over vehicle operational life		0.0341	0.0317	0.0365	0.0917	0.0233	0.0060
Per driver over driving career		0.3603					
Annual U.S. monetary cost*	(E)	$11.5B	$7.2B	$2.6B	$473M	$192M	$187M
	(C)	$25.8B	$15.2B	$5.8B	$1.1B	$361M	$637M
Average monetary cost							
Per PR crash*	(E)	$15,120	$13,390	$13,880	$41,830	$26,800	$43,000
	(C)	$38,960	$32,950	$35,230	$91,530	$48,670	$154,350
Per VMT*	(E)	0.53¢	0.50¢	0.44¢	0.48¢	0.36¢	1.93¢
	(C)	1.18¢	1.07¢	0.97¢	1.09¢	0.67¢	6.56¢
Per registered vehicle annually*	(E)	$60	$60	$50	$290	$50	$50
	(C)	$140	$130	$110	$650	$80	$150
Expected monetary cost							
Per vehicle over operational life*	(E)d	$680	$580	$660	$3,460	$540	$300
	(C)d	$1,510	$1,220	$1,430	$7,810	$1,010	$1,010
Per driver over driving career	(E)d	$2,180					
	(C)d	$4,880					
Total annual U.S. fatal equivalents*		8,347	4,926	1,870	341	115	206
Average fatal equivalents per PR crash*		0.01260	0.01066	0.01140	0.02923	0.01554	0.04993

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; M = million; PR = police-reported; SV = subject vehicle (striking vehicle); VMT = vehicle-miles traveled.

TABLE E Statistics for Lane Change/Merge (LC/M) Crashes

Type of statistics		Crashes involving lane changing/merging vehicle as: All vehicles	Passenger cars	Light trucks/ vans	Combin- ation- unit trucks	Single- unit trucks	Motor- cycles
Annual number of PR crashes		234,000	155,000	55,000	20,000	5,000	1,000
Annual number of this vehicle type involved in PR crashes*		476,000	267,000	65,000	20,000	5,000	1,000
Annual number of all vehicles involved in PR crashes*		476,000	315,000	111,000	40,000	11,000	2,000
Annual U.S. number of persons involved in PR crashes*		689,000	464,000	160,000	53,000	13,000	3,000
Not injured (0)*		595,000	400,000	140,000	46,000	12,000	2,000
Minor to moderate (MAIS 1–2)*		91,000	62,000	19,000	7,000	1,500	800
Serious to fatal (MAIS 3–fatal)*		3,000	2,000	600	400	100	100
Vehicle involvement rate as SV in PR crashes							
Per 100 million VMT		10.68	10.85	9.13	20.04	9.93	10.29
Per 1,000 registered vehicles annually		1.27	1.27	1.05	12.01	1.26	0.24
Expected involvements as SV in PR crashes							
Over vehicle operational life		0.0166	0.0149	0.0169	0.1766	0.0185	0.0018
Per driver over driving career		0.1622					
Annual U.S. monetary cost*	(E)	$4.1B	$2.7B	$947M	$443M	$100M	$38M
	(C)	$7.9B	$4.9B	$1.8B	$757M	$148M	$119M
Average monetary cost							
Per PR crash*	(E)	$10,080	$9,680	$9,940	$21,760	$18,300	$27,380
	(C)	$22,880	$20,990	$22,580	$35,840	$26,170	$93,220
Per VMT*	(E)	0.19¢	0.19¢	0.16¢	0.45¢	0.19¢	0.39¢
	(C)	0.36¢	0.34¢	0.30¢	0.77¢	0.27¢	1.22¢
Per registered vehicle annually*	(E)	$20	$20	$20	$270	$20	$10
	(C)	$40	$40	$40	$460	$40	$30
Expected monetary cost							
Per vehicle over operational life*	(E)d	$240	$210	$240	$3,240	$280	$60
	(C)d	$460	$390	$450	$5,540	$420	$190
Per driver over driving career	(E)d	$780					
	(C)d	$1,490					
Total annual U.S. fatal equivalents*		2,542	1,570	585	245	48	38
Average fatal equivalents per PR crash*		0.00740	0.00679	0.00730	0.01145	0.00836	0.03015

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; M = million; PR = police-reported; SV = subject vehicle (lane changing/merging vehicle); VMT = vehicle-miles traveled.

TABLE F Statistics for Backing Crashes

Type of statistics		Crashes involving backing vehicle as: All vehicles	Passenger cars	Light trucks/ vans	Combin-ation-unit trucks	Single-unit trucks	Motor-cycles
Annual number of PR crashes		171,000	88,000	62,000	10,000	9,000	300
Annual number of this vehicle type involved in PR crashes*		332,000	150,000	73,000	9,000	9,000	300
Annual number of all vehicles involved in PR crashes*		332,000	170,000	122,000	17,000	17,000	500
Annual U.S. number of persons involved in PR crashes*		456,000	235,000	167,000	21,000	22,000	600
Not injured (0)*		406,000	207,000	151,000	19,000	20,000	400
Minor to moderate (MAIS 1–2)*		49,000	27,000	16,000	2,000	2,000	200
Serious to fatal (MAIS 3–fatal)*		1,000	500	200	100	0	0
Vehicle involvement rate as SV in PR crashes							
Per 100 million VMT		7.81	6.17	10.33	9.39	16.35	2.74
Per 1,000 registered vehicles annually		0.93	0.72	1.19	5.63	2.07	0.06
Expected involvements as SV in PR crashes							
Over vehicle operational life		0.0122	0.0085	0.0191	0.0828	0.0304	0.0005
Per driver over driving career		0.1133					
Annual U.S. monetary cost*	(E)	$2.4B	$1.3B	$800M	$208M	$140M	$12M
	(C)	$3.9B	$2.1B	$1.1B	$365M	$177M	$41M
Average monetary cost							
Per PR crash*	(E)	$7,390	$7,660	$6,280	$21,460	$15,910	$34,300
	(C)	$14,180	$15,000	$10,240	$35,780	$19,630	$125,190
Per VMT*	(E)	0.11¢	0.09¢	0.13¢	0.21¢	0.26¢	0.13¢
	(C)	0.18¢	0.15¢	0.19¢	0.37¢	0.33¢	0.43¢
Per registered vehicle annually*	(E)	$10	$10	$20	$130	$30	$0**
	(C)	$20	$20	$20	$220	$40	$10
Expected monetary cost							
Per vehicle over operational life*	(E)d	$140	$100	$200	$1,520	$390	$20
	(C)d	$230	$170	$280	$2,670	$500	$70
Per driver over driving career	(E)d	$460					
	(C)d	$740					
Total annual U.S. fatal equivalents*		1,262	676	361	117	57	13
Average fatal equivalents per PR crash*		0.00459	0.00485	0.00331	0.01143	0.00627	0.04049

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

** Less than 10 dollars.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; M = million; PR = police-reported; SV = subject vehicle (backing vehicle); VMT = vehicle-miles traveled.

TABLE G Statistics for Opposite Direction (OD) Crashes

		Crashes involving encroaching vehicle as					
Type of statistics		**All vehicles**	**Passenger cars**	**Light trucks/ vans**	**Combin-ation-unit trucks**	**Single-unit trucks**	**Motor-cycles**
Annual number of PR crashes		190,000	137,000	44,000	4,000	2,000	1,800
Annual number of this vehicle type involved in PR crashes*		378,000	230,000	58,000	4,000	3,000	1,800
Annual number of all vehicles involved in PR crashes*		378,000	274,000	87,000	7,000	5,000	4,000
Annual U.S. number of persons involved in PR crashes*		557,000	408,000	127,000	10,000	6,000	5,000
Not injured (0)*		386,000	274,000	91,000	7,000	5,000	3,000
Minor to moderate (MAIS 1–2)*		154,000	121,000	33,000	2,000	1,300	1,600
Serious to fatal (MAIS 3–fatal)*		17,000	13,000	3,000	300	200	700
Vehicle involvement rate as SV in PR crashes							
Per 100 million VMT		8.68	9.63	7.30	3.77	4.47	18.21
Per 1,000 registered vehicles annually		1.03	1.12	0.84	2.26	0.56	0.42
Expected involvements as SV in PR crashes							
Over vehicle operational life		0.0135	0.0132	0.0135	0.0332	0.0083	0.0032
Per driver over driving career		0.1289					
Annual U.S. monetary cost*	(E)	$12.7B	$9.7B	$2.5B	$318M	$165M	$388M
	(C)	$39.9B	$30.6B	$7.6B	$795M	$411M	$1.4B
Average monetary cost							
Per PR crash*	(E)	$50,770	$54,130	$42,490	$74,210	$59,910	$177,420
	(C)	$168,190	$178,200	$139,120	$182,040	$146,120	$630,630
Per VMT*	(E)	0.58¢	0.68¢	0.41¢	0.32¢	0.31¢	3.99¢
	(C)	1.82¢	2.14¢	1.27¢	0.81¢	0.76¢	14.02¢
Per registered vehicle annually*	(E)	$70	$80	$50	$190	$40	$90
	(C)	$220	$250	$150	$490	$100	$330
Expected monetary cost							
Per vehicle over operational life*	(E)d	$740	$780	$610	$2,330	$460	$610
	(C)d	$2,340	$2,450	$1,890	$5,820	$1,150	$2,160
Per driver over driving career	(E)d	$2,390					
	(C)d	$7,550					
Total annual U.S. fatal equivalents*		12,918	9,886	2,461	254	131	440
Average fatal equivalents per PR crash*		0.05441	0.05764	0.04500	0.05814	0.04667	0.20399

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics, a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; M = million; PR = police-reported; SV = subject vehicle (encroaching vehicle); VMT = vehicle-miles traveled.

TABLE H Statistics for Left-Turn-Across-Path (LTAP) Crashes

Type of statistics		All vehicles	Passenger cars	Light trucks/ vans	Combin- ation- unit trucks	Single- unit trucks	Motor- cycles
		Crashes involving left-turning vehicle as					
Annual number of PR crashes		396,000	318,000	71,000	2,000	2,000	900
Annual number of this type of vehicle involved in PR crashes*		792,000	571,000	87,000	3,000	2,000	1,000
Annual number of all vehicles involved in PR crashes*		792,000	637,000	141,000	5,000	4,000	1,900
Annual U.S. number of persons involved in PR crashes*		1,178,000	948,000	209,000	6,000	6,000	3,000
Not injured (0)*		865,000	696,000	155,000	5,000	4,000	1,600
Minor to moderate (MAIS 1–2)*		297,000	241,000	51,000	1,400	1,600	800
Serious to fatal (MAIS 3–fatal)*		16,000	11,000	3,000	200	100	100
Vehicle involvement rate as SV in PR crashes							
Per 100 million VMT		18.07	22.34	11.82	2.44	4.09	9.65
Per 1,000 registered vehicles annually		2.14	2.61	1.36	1.46	0.52	0.22
Expected involvements as SV in PR crashes							
Over vehicle operational life		0.0281	0.0307	0.0219	0.0215	0.0076	0.0017
Per driver over driving career		0.2700					
Annual U.S. monetary cost*	(E)	$11.9B	$9.1B	$2.2B	$163M	$74M	$65M
	(C)	$31.2B	$23.2B	$6.0B	$413M	$149M	$218M
Average monetary cost							
Per PR crash*	(E)	$20,500	$19,290	$21,720	$59,880	$30,940	$53,780
	(C)	$59,910	$54,970	$64,720	$148,190	$60,740	$186,810
Per VMT*	(E)	0.54¢	0.64¢	0.37¢	0.17¢	0.14¢	0.67¢
	(C)	1.42¢	1.63¢	1.00¢	0.42¢	0.28¢	2.24¢
Per registered vehicle annually*	(E)	$60	$70	$40	$100	$20	$20
	(C)	$170	$190	$120	$250	$40	$50
Expected monetary cost							
Per vehicle over operational life*	(E)d	$700	$730	$550	$1,200	$210	$100
	(C)d	$1,830	$1,860	$1,480	$3,020	$420	$350
Per driver over driving career	(E)d	$2,250					
	(C)d	$5,890					
Total annual national fatal equivalents*		10,077	7,496	1,927	134	48	70
Average fatal equivalents per PR crash*		0.01938	0.01778	0.02094	0.04733	0.01940	0.06043

* Inclusive; i.e., includes all crash-involved vehicles and persons. For these statistics a crash or injury may be counted in two different columns (e.g., a crash involving a passenger car and a combination-unit truck). Thus, the columns are not additive.

Key: B = billion; C = comprehensive cost; d = discounted; E = economic cost; M = million; PR = police-reported; SV = subject vehicle (left turning vehicle); VMT = vehicle-miles traveled.

Do Environmental Regulations Increase Construction Costs for Federal-Aid Highways? A Statistical Experiment

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ABSTRACT

This paper uses Federal-Aid Highway Program information for 1990 to 1994 to define a natural experiment that evaluates whether compliance with federal environmental regulations increases construction costs. This is accomplished by considering whether indirect measures of the environmental resources in each state affect construction expenditures for federal-aid highways. The test assumes that both positive and negative measures of environmental resources and amenities, such as counts of endangered species and historic sites, and the number of locations with Superfund sites, will serve as indirect indicators of the likelihood that environmental regulations could impact federally supported highway construction. Statistical analyses suggest that the expenditures for federal-aid highway construction and repair were influenced by these factors and by the regulatory activities likely to be associated with environmental mandates. Similar models applied to construction

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expenditures for state roads, which are not subject to the full set of federal regulations, did not find the proxy measures for the potential impact of these environmental regulations as positive influences on construction costs.

INTRODUCTION

Over 20 federal statutes impose a variety of environmental mandates on the construction, repair, and maintenance activities undertaken within the federal highway system.[1] Little is known about the added costs of these requirements.[2] One of the few sources of information, a retrospective set of cost allocations conducted by the Wisconsin Department of Transportation (DOT), suggests the added costs due to environmental regulations may well be 8% to 10% of construction expenditures for federal-aid highway projects (Novick 1995). Unfortunately, these estimates rely on practitioner judgments and not a specific record of the added costs for compliance.

A survey of all the designated environmental officials at state DOTs indicated only a few agencies kept records that would allow the costs arising from compliance with environmental regulations to be distinguished from other costs (see Smith et al. 1997). This response is surprising given the widespread belief that environmental regulations impose large costs and long delays. Indeed, the Wisconsin estimates would imply over $2 billion of the six-year appropriation for the National Highway System under the reauthorization of federal highway support (the Transportation Equity Act for the 21st Century—TEA-21) would be absorbed by compliance with environmental regulations.[3] Environmental regulations also involve a different type of compliance process, relying on negotiation among public agencies to meet the conflicting mandates of different federal statutes.

This study evaluates whether the Federal Highway Administration's (FHWA) statistics on construction expenditures for federal-aid highways provide evidence that environmental regulations have increased construction costs. We use the FHWA definition of construction costs for federal-aid and state-funded highways as reported in *Highway Statistics*. Federal-aid highway projects are subject to all federal environmental regulations. A comparison of the federal-aid construction costs with the construction costs for roads financed exclusively with state funds offers an approximate "natural" experiment to gauge the impacts of different regulations on each type of highway project.[4] To our knowledge, this type of statistical analysis has not been considered before.

Our findings suggest, after controlling for some of the primary characteristics of federal-aid and state roads, proxy measures likely to be related to increased regulatory stringency or the effects of environmental regulations had significant positive influences on construction costs for federal-aid projects. Most of these same variables did not affect the costs for roads completely financed with state funds. The measures of environmental resources included counts of endangered species, the number of historic sites, and the number of National Priority List (NPL) hazardous waste sites, as well as the size of coastal areas.

Our test uses a panel composed of states' construction expenditures (in constant dollars) from 1990 through 1994. It was assembled using

[1] See Smith and von Haefen (1996) and Tarrer (1993) for a summary of the relevant statutes. We have adopted a broad interpretation of environmental impacts that include historic and archeological effects as well as descriptions of more conventional impacts to environmental resources, because this is the framework most often used in the transportation literature.

[2] Carlin et al. (1996) present a summary of the most recent Environmental Protection Agency evaluation of the costs of environmental regulations. The economic literature has focused on three issues: welfare consistent measures of costs (Hazilla and Kopp 1990) and general equilibrium analysis (Jorgensen and Wilcoxen 1990); productivity impacts (Gray 1987; Gray and Shadbegian 1994); and most recently plant-level evaluations of the "net" costs of regulations (Morgenstern et al. 1998).

[3] This estimate is based on the Department of Transportation's summary of TEA-21 at website http://www.istea.ORG/DOCS/tea21/suminves.htm/.

[4] The term "natural experiment" is used in social science research to describe a set of circumstances representing constraints or existing conditions similar to a policy being evaluated. In this type of analysis, selected cases mimic the hypothesis to be tested (a "natural" variation) and it is argued that the results of the analysis will shed light on the effects of the policy. See Moffitt (1991) for discussion of the term in a different policy context.

FHWA statistics on construction expenditures for federal-aid highways and for state roads. The Federal-Aid Highway Program is a grant-in-aid program supported by the federal Highway Trust Fund. It allocates funds to states based on formulas that take account of population, area, mileage, relative costs, and percentage of prior apportioned funds. This fund derives revenues from motor fuel taxes and federal excise taxes on highway users. Federal-aid support to state and local projects generally involves an 80/20% federal/state (or local) share of costs in response to specific apportionment rules.[5]

The next section presents a brief overview of the environmental regulations that can affect highways. We describe the data and results in the following section, and conclude with a summary of the qualifications to and implications of our findings for reforms in the process of implementing environmental mandates.

BACKGROUND

Two statutes are especially important in order to understand the effects of environmental regulations on federal-aid highways: Section 4f of the 1966 Department of Transportation Act, and the 1970 National Environmental Policy Act (NEPA). Section 4f prohibits the use of publicly owned parks, recreation areas, wildlife areas, and historic sites of national, state, or local importance from being used in transportation projects unless the Secretary of Transportation determines there are "no feasible and prudent alternatives." A Supreme Court ruling in 1971, *Citizens To Preserve Overton Park v. Volpe*, made Section 4f and subsequent environmental laws serious concerns for federal-aid transportation projects. Indeed, DOT's Deputy Chief Council noted that in the initial period after this decision senior federal DOT officials felt compelled to review Section 4f provisions personally (Kussy 1996).

The second key statute, NEPA, was intended to enumerate the potential environmental impacts of and mitigation for any federally funded projects before the resources for them were committed. It does not have a direct regulatory role. The Federal-Aid Highway Program has been responsible for about 10% of the approximately 6,000 NEPA cases (Kussy 1996, 12). Three types of actions document the effects of a proposed project: environmental impact statements (EIS); findings of no significant environmental impact (FONSI); and environmental assessments.[6] An EIS is the most extensive documentation NEPA requires.

The set of regulatory mandates for federal-aid projects is complex and overlapping. Table 1 summarizes, by type of resource, a selection of the primary statutes and Executive Orders along with the oversight agency and the regulatory mechanism(s) used in implementation (see Freeman (1978) and Jafee et al. (1995) for a related discussion of environmental regulations). This summary uses a fairly broad definition of what comprises an environmental impact. To some degree, the NEPA requirement for preparing an EIS as well as the documentation required by Section 4f serve to identify the problem areas caused by regulations related to environmental resources. The timing of this coordination, however, has not always assured that the design and planning process will avoid

[5] Table FA-4A of FHWA's 1994 *Highway Statistics* provides an example of these rules. It outlines the apportionment formulas for the Federal-Aid Highway Program for fiscal year 1994. States are keenly aware of their payments into the trust fund in relation to their receipts.

[6] The final product of the NEPA review process is a summary report detailing all the environmental concerns. This can be an EIS, an Environmental Assessment, or a Categorical Exclusion. The latter is associated with a FONSI. For large projects, state DOTs must prepare the EIS and may jointly file it with an interested federal agency. The standard format for an EIS includes the following components: a) purpose and need for the project; b) alternatives considered; (c) description of the effect of environmental resources of the project; (d) nature of the environmental consequences; and e) identification of irreversible commitments of resources.

After the draft EIS is circulated, a public hearing identifying concerns is held and a final EIS is distributed. A Record of Decision issued within 30 days of the final EIS's release signifies project approval.

A final EIS is a record of the final selection and a subset of the alternatives considered along with discussion justifying the decision. Comparison of the final alternative with others reported does not reveal incremental mitigation costs to meet regulations because the EIS records the consensus that was reached, not all the alternatives avoided through the negotiation process. See Smith and von Haefen (1996) for further discussion.

TABLE 1 Selected Environmental Statutes Impacting Highways by Resource[a]

Resource	Statute/Executive Order	Agency	Regulatory mechanism
All resources	NEPA (1970)	Council on Environmental Quality	EIS
Land Public parks	Section 4f, DOT (1966)	FHWA	Documentation and permits
Wildlands	Wilderness Act (1988)	U.S. Forest Service	Land-use restrictions
Historic sites Coastal areas	National Historic Preservation Act (1966)	State Historic Preservation Office	Cultural Resource Assessment
	National Wildlife Refuge Administration Act (1988)	Department of the Interior	Land-use restrictions
	National Forest Management Act (1988, 1993)	Department of Agriculture	Land-use restrictions
	Endangered Species Act (1973) — Habitat	Departments of the Interior and Commerce	Conservation Plan listing
	Coastal Zone Management Act (1988, 1991)	Department of Commerce	Coastal Zone Management Plan Certification; funding restrictions
	Coastal Barrier Act (1982)	Department of Commerce	
Wetlands	Clean Water Act Section 404 (1972)	Corps of Engineers EPA	404 permits
	Executive Order (1977)	FHWA	EIS
	DOT Order 5660.1A (1978)	FHWA	Public review
Navigable waterways	Rivers and Harbors Act (1899)	Corps of Engineers	Section 10 permits
Fish and wildlife, including endangered species	Fish and Wildlife Coordination Act (1988)	Fish and Wildlife Service	NEPA provisions
	Migratory Bird Treaty Act (1918)	Fish and Wildlife Service	Permits
	Endangered Species Act (1973)	Departments of the Interior and Commerce	Biological Assessment Conservation Plan
	National Wildlife Refuge Admin. Act (1988)	Department of the Interior	Land-use restrictions
Rivers	Wild and Scenic Rivers Act (1988, 1993)	Department of the Interior	Prohibits development
Water	Clean Water Act (1972); Clean Water Act Sections 208 and 319 (1978) Safe Drinking Water Act (1988)	EPA State water quality agencies	NPDES permit for point source management plans, Memoranda of Understanding
Air	Clean Air Act (1970, 1977, 1990)	EPA	National Ambient Air Quality Standards for criteria air pollutants; State Implementation Plans; restrictions imposed on activities in nonattainment areas
Noise	Noise Control Act (1972)	EPA	Standards on construction

[a]This table is based on a detailed summary in Smith and von Haefen (1996) and Tarrer (1993). It does not include Executive Orders and statutes governing farmland, floodplains, and Superfund and other hazardous waste sites.

delays and adjustments for environmental regulations. The table also omits additional mandates that could be considered a part of this process. These requirements are related to preservation of private farmlands, liability related to hazardous waste sites, or requirements imposed on projects undertaken in floodplain areas that can be important to the design of highway projects.

The impact of this process on wetlands best illustrates its complexity. While the Army Corps of Engineers has primary responsibility for the Section 404 permitting process, the set of agencies with concerns about a wetlands decision varies with each proposed action and by state. Wetland-related legislation gives six federal agencies responsibilities in this area: the U.S. Army Corps of Engineers and the Environmental Protection Agency (EPA), along with the Natural Resources Conservation Service (previously the Soil Conservation Service) and the Agricultural Stabilization and Conservation Service (both Department of Agriculture), the Fish and Wildlife Service (Department of the Interior), and the National Marine Fisheries Service (Department of Commerce). Thus, substantial coordination with multiple federal and state agencies can be required. With such a diverse group, it is not surprising that one of the key difficulties that has arisen in this process stems from the differences across agencies in the definition of a wetland.[7]

This brief overview suggests that two types of balancing are inherent in the ways environmental regulations impact federal-aid highways. The first is illustrated by the provisions summarized in table 1 and involves compromises across different types of environmental resources, because highways can impact several different resources simultaneously. Here the decisions convey judgments about the relative importance of impacts across different environmental resources. These tradeoffs implicitly assign values to the resources involved, such as wetlands versus historic sites or air quality. The second type of balancing is among the priorities as defined by the statutory mandates of the different agencies for the same class of resources. While these can be linked to the resource balancing process, they need not be.

As part of a larger review of the impact of environmental regulations, we looked at several final Environmental Impact Statements. These EISs confirmed our observations about the process. The alternatives described in each final EIS include a range of different types of resource effects. One example can be found in a 1991 EIS for a project involving a six-mile roadway through downtown Wilmington, North Carolina. The project had wetlands impacts (about 23.1 acres), encountered two landfills with hazardous substances, and had a potential water supply impact due to the possibility of releasing hazardous substances into a nearby aquifer from proposed bridge pilings required to avoid one of the waste sites.[8] Air quality was also likely to be an issue for the Wilmington project, but was not discussed in the supplementary EIS. Finally, the project was in the 100-year floodplain for the Northeast Cape Fear River and three large creeks. This feature alone required elevating the roadway above the 100-year flood level. It also impacted four areas of environmental concern identified in North Carolina's Coastal Management Plan (a requirement of the Coastal Zone Management Act). Adjustments to the final route and the specific design criteria responded to some of these concerns. These adjustments are due to both the project and presumably different agencies' requirements to protect "their" resources.

Cross-agency negotiation can be expected to differ with each project considered. Our statistical analysis is based on annual costs, so it reflects the outcomes of final projects and the negotiation to balance ongoing projects.[9] These aggregates reflect

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[7] After a period of considerable controversy about a proposed reconciliation of definitions, practice has reverted to the Army Corps' 1987 definition for most activities that would affect highways. For a summary of this controversy and of the permitting process see Kusler (1992) and the National Research Council report on wetlands (NRC 1995).

[8] See Smith and von Haefen (1996) for a more detailed summary and USDOT (1991) for the original source.

[9] FHWA is not specific about how the states' construction expenditures for work in progress is reported. Based on what is reported, it would appear to include expenditures related to payments made to states for work in progress.

different mixes of complexities arising from environmental regulations and other mandates related to the projects included in each year's construction expenditures. As a result, the expenditure data do not allow us to isolate the effects of the individual environmental regulations that may have been associated with specific highway projects in a particular state. Instead, the best our approach can recover is whether differences in construction costs, after controlling for the federal-aid system's general characteristics in each state, can be attributed to measures of the environmental resources that are likely to be associated with the regulations relevant to projects in that state.

Clearly, statistical "control" using these types of proxy variables is not as desirable as more detailed information with direct measures of compliance costs. Unfortunately, as we noted earlier, these data do not exist. Thus, this more approximate scheme may result in underestimation of the effects of the regulations. For example, the actual costs of meeting environmental mandates may be temporally shifted or "averaged in" with costs from projects with few impacts. As a result the environmental requirements may appear to have little to do with the temporal and cross-sectional variations in construction costs.

DATA AND RESULTS

Highway construction costs have two primary components. The first arises from the expenditures to support the staff and equipment of state (and local) transportation departments. The second involves public expenditures for the private contractors involved in highway projects. Environmental regulations affect both sets of activities. Our cost measure will not fully reflect both of these effects. As we noted, however, without a special purpose cost study it would be difficult to include a more complete record of the costs. Few states track the environmental compliance costs for construction and repair projects or for their ongoing maintenance programs for highways. Indeed, the General Accounting Office's 1994 review of agencies' practices preparing environmental reviews noted that:

> Although the agencies have developed the integrated processes to expedite NEPA and Section 404 reviews, they have not developed a system to evaluate their success. Specifically, the agencies have not developed baseline data on the time required to complete reviews under the traditional processes, nor have they developed plans to track projects' time frames under the integrated processes. (USGAO 1994, 7)

In describing state's activities the same report observed that:

> FHWA and the American Association of State Highway and Transportation officials (AASHTO) do not collect or track data on all environmental costs associated with highway projects. FHWA has collected information on the costs related to noise barriers, and AASHTO has collected data on the costs of mitigating impacts on wetlands…. In addition, none of 11 states we contacted routinely tracks data on all environmental costs. (p. 10)

Our analysis exploits the ability to construct a panel data set using FHWA's *Highway Statistics* from 1990 to 1994, along with variables designed to represent changes in key environmental resources over this time in each state. The latter data were assembled from a diverse array of sources.[10] Table 2 defines some of the primary variables used (or evaluated for use) in the analysis and documents their sources. Our focus is on the annual federal-aid construction expenditures in each state as the source of our "experiment;" we developed our models using this variable. Models for construction expenditures on state roads are treated as providing a crude "control" relationship.

The statistical model used to evaluate our panel of states' reported experience over the period 1990 to 1994 assumes there are two errors. We follow the simplest form of the random effects framework (see Baltagi (1995) for more details) as in equation (1):

$$y_{jt} = a + b^T Z_{jt} + u_j + \epsilon_{jt} \qquad (1)$$

where a is the intercept, b is a $K \times 1$ parameter vector for the determinants of the dependent variable y_{jt} (in our case an expenditure measure) that is

[10] A more detailed data appendix is available on request from the first author.

TABLE 2 Federal-Aid and State-Funded Highway Expenditure Analysis: Data Description and Documentation

Variable	Description	Source	Notes
construct	Total annual capital outlays for highway construction	From Table SF-12 series, *Highway Statistics*, published annually by the Federal Highway Administration (FHWA), U.S. Department of Transportation, adjusted to 1994 dollars by the Bureau of Labor Statistics' Producer Price Index for intermediate materials, supplies, and component materials.	Costs associated with highway improvements, including land acquisition and other right-of-way costs, engineering, construction and reconstruction, resurfacing, rehabilitation, restoration costs of roadway and structure, and installation of traffic service facilities.
lanemiles	Total estimated lane mileage	Calculated from Table HM-60, *Highway Statistics*.	Number of lanes multiplied by center-lane mileage on the existing roads.
miles	Total public road and street mileage	Tables HM-10, HM-14, HM-15, *Highway Statistics*.	Center-lane mileage on the existing roads.
bridges	Total count of bridges	Table HM-41, *Highway Statistics*.	A continuously updated inventory of vehicle bridges greater than or equal to 20 feet.
eis	Counts of all EISs (draft, final, supplemental, etc.) issued to all federal agencies for each year, 1990–95	These counts were constructed from a computer printout of all EISs issued in the period January 1, 1990 to December 31, 1995. This printout was generated by the EPA Office of Federal Activities' Environmental Review Tracking System.	1995 values inserted for missing 1996 values, and 1990 values inserted for missing 1989 values.
fhw_eis	Counts of all EISs (drafts, final, supplemental, etc.) issued to FHWA for each year, 1990–95	See documentation for eis.	1995 values inserted for missing 1996 value, and 1990 values inserted for missing 1989 values.
spec	Count of federal endangered/threatened species protected by the Endangered Species Act of 1973	A February 29, 1996, snapshot of the counts of endangered species for each of the 50 states was obtained from the Endangered Species Program's Web page, http://www.fws.gov/~r9endspp/listmap.html. This information was combined with a chronological listing of species obtained from the ESP to construct the ES List for the years 1990–95.	

(continued on next page)

TABLE 2 Federal-Aid and State-Funded Highway Expenditure Analysis: Data Description and Documentation *(continued)*

Variable	Description	Source	Notes
npl	Count of Proposed and Final National Priority List Sites for the years 1989–95	These data are compiled annually in the *Statistical Abstract of the United States*, Bureau of the Census, from EPA press releases and proposed rules. Also, *The World Almanac & Book of Facts*, World Almanac Books, compiles the same information from similar EPA documents.	1995 counts were inserted for 1996 missing values.
hist	Count of National Register Sites, Objects, Structures, and Districts in each state for the years 1989 to present	Obtained from John Byrne, Database Manager at the National Register of Historic Places, Department of the Interior, a data set consisting of all National Register Sites as of July 1996, which allowed us to construct these yearly counts.	These data are cumulative counts for each of the years.
coastmi	Miles of coast (counting barrier islands) for each state	Obtained from NOAA's Coastal Zone Management Plan Web page, http://wave.nos.noaa.gov/ocrm/czm/welcome.html.	These estimates were assumed constant across the panel years.
fed/spec	Estimated acres of all federally owned lands for 1989–93, divided by the count of federal endangered/threatened species (i.e., the variable spec defined above)	For years 1989–91, the annually published *Public Land Statistics*, a U.S. Department of the Interior, Bureau of Land Management document. For 1992–93, the publication, *Summary Report of Real Property Owned by the United States Throughout the World*, U.S. General Services Administration, was used.	A comparison of the data suggests that the two data sources are consistent. No estimates were available for 1994–96, so 1993 values were substituted for the missing data.
farm	Estimated acres of farmland where a farm is defined as any establishment from which $1,000 or more of agricultural products are sold or would normally be sold during the year	These data are published annually in *Farm Numbers and Land in Farms*, U.S. Department of Agriculture, National Agricultural Statistics Service.	No estimates were available for 1995–96, so 1994 values were used for these years.

assumed constant across the j and t dimensions and with the levels of the $K \times 1$ vector, Z_{jt} of independent variables. u_j is constant over the t dimension and varies with j. In the analysis of federal-aid expenditures, j will be states. ϵ_{jt} varies with both j and t. The time subscript, t, in this case will be years. Both u_j and ϵ_{jt} are assumed to be classically well behaved. The composite error yields a nonspherical covariance matrix, because the covariance for different time periods in the same state is not zero, $E((u_{jt} + \epsilon_{jt})(u_j + \epsilon_{js})) \neq 0$. One common measure of the importance of u_j is defined by equation (2):

$$\theta = 1 - \frac{\sigma_\epsilon}{\sqrt{T\sigma^2_u + \sigma^2_\epsilon}} \tag{2}$$

where σ_ϵ = standard deviation for ϵ_{jt}
σ_u = standard deviation for u_j
T = the number of time periods observed for each cross-sectional unit.

The measure of importance of states' effects in equation (2) assumes balanced samples. When they are not, the available time periods will vary with the sample of time periods for each state, so T would be replaced by T_j in (2) (see Baltagi and Li 1990). The random effects estimator uses the structure assumed for u_j and ϵ_{jt} to construct feasible generalized least squares (FGLS). Estimates using FGLS are reported for most of the random effects models. The Hausman (1978) specification test compares the ordinary least squares (OLS) fixed effects format with the generalized least squares (GLS) estimator associated with the random effects error structure.[11] This test gauges orthogonality of the random effects with the independent variables. Testing this hypothesis is one way to evaluate whether a random effects specification is superior to a fixed effects approach for taking account of differences in states.

Federal-aid construction costs are deflated to 1994 dollars using the Producers Price Index (adccf) and the dependent variable is expressed in logarithmic form.[12] A semi-log model was adopted after plotting the deflated federal-aid construction costs by year. These plots are reported as figures 1a and b and suggest that the log transformation appears appropriate for these data, especially since our statistical tests rely on the assumption of normally distributed errors. The panel is unbalanced because of missing data for some states.[13]

The second column in table 3 reports a model that evaluates whether compliance costs due to environmental regulations can account for the variation in federal-aid construction costs after accounting for the highway system variables center-lane road mileage, lane-miles, and a count of bridges as control factors. These variables' estimated effects are given in the rows labeled 1 through 3 of the table. The specification of our model avoids two other sources of problems with a test of the effects of environmental regulations. One of these arises from the regulations and a second from the implications of the federal-aid system's funding formula. As we noted, the ultimate form of environmental regulations is the outcome of a negotiated process. Thus, measurement of their impacts would be problematic even if we had access to project-level information. The stringency and form of the regulations at the project level would be endogenous outcomes of the process. At the state level, we do not have records of these resolutions. Instead, our proxy measures indicate the extent of environmental resources (or problems) that would likely be associated with the need for such negotiations on projects. Thus, while these indirect variables make our test more difficult they avoid the

[11] Both are consistent estimates under the null hypothesis and OLS is inefficient. Under the alternative, OLS is consistent and GLS is not. Thus, a failure to reject the null hypothesis provides support for the random effects formulation of the model.

[12] With a neoclassical cost function including factor prices, there would be no need to deflate. Because such cost functions are homogeneous of degree one in factor prices, adjustment for inflation that affects all factor prices equally is unnecessary. One can interpret our deflator as an attempt to use the price index as a control for factor prices over time. This follows because our deflated cost is expressed in logarithmic terms (i.e., ln(adccf) = ln(ccf/PI) = ln(ccf) – ln(PI)). Ideally, one would like to account for differences in factor costs by state, but the required factor price indexes were not available.

[13] The data reporting system is voluntary so that in some years states failed to report some key variables for the model. Rather than impute the missing values for construction cost or the mileage variables, we deleted the observations from the panel.

FIGURE 1a Real Construction Costs for Federal-Aid Projects: Log Normal Scale

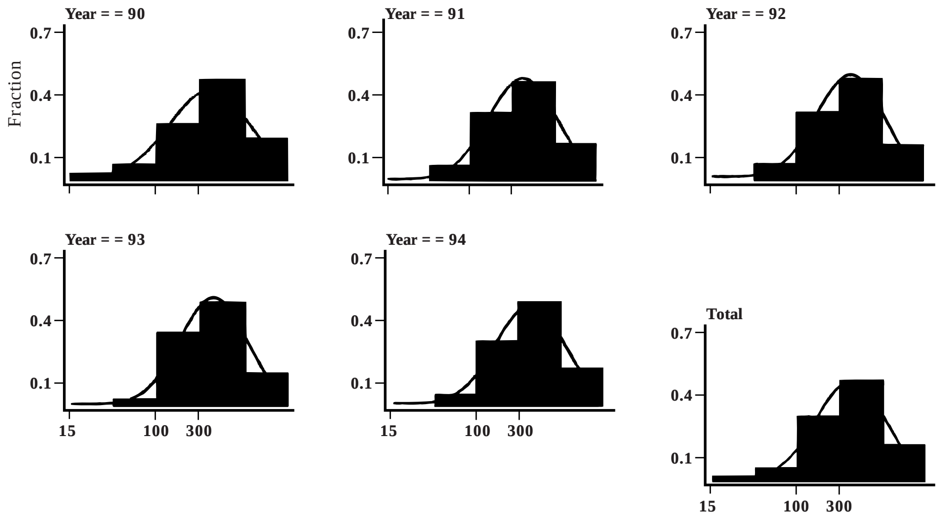
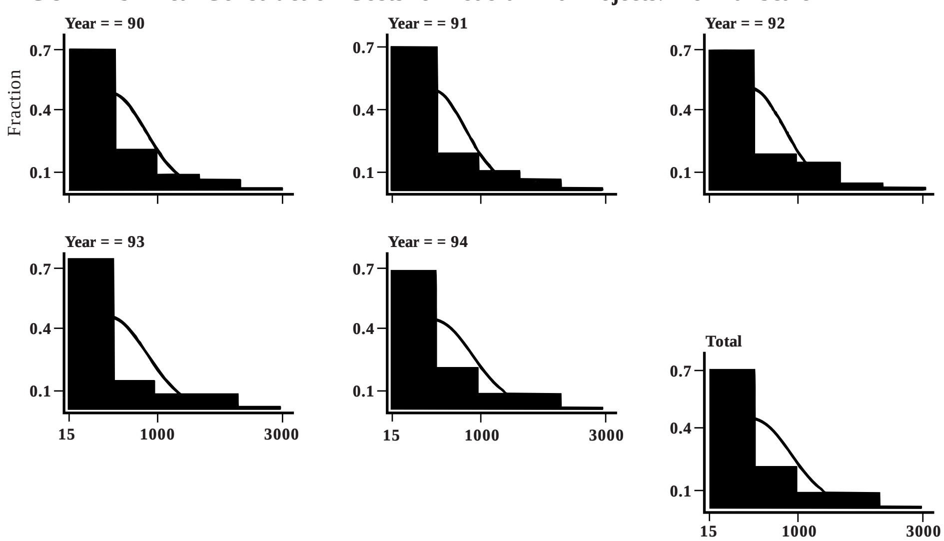


FIGURE 1b Real Construction Costs for Federal-Aid Projects: Normal Scale



potential endogeneity of variables based on the outcome-specific measures of the actual requirements imposed on individual projects.

The second issue arises with the formula funding of the federal-aid system. At one simple level, the cost sharing provides a bound on the added costs of federal environmental regulations. These statutes must add less to highway construction costs than the federal cost-sharing rates, otherwise the states would not participate. This insight is not especially informative as an upper bound estimate with a federal cost share of 80% of the construction costs. Nonetheless, it highlights a somewhat different issue. The features of specific projects will be adapted in other ways to maximize the federal cost share. New federal-aid project characteristics could then be expected to be related to the federal-aid construction costs. We avoided this potential endogeneity by including only the attributes of the each state's existing system. Moreover, FHWA statistical reports do not include specific information on the characteristics of new construction in each year.

TABLE 3 The Determinants of Federal-Aid Versus State-Funded Expenditures on Highway Construction Costs (1994 dollars): Estimated Parameters and t-ratios from Random Effects Models[a]

Row	Dependent-variable: construct	Federal-aid construction cost	State-funded construction cost
1	lanemiles	.017***	-.027
		(2.86)	(-1.32)
2	miles	-.026**	.045
		(-2.45)	(1.26)
3	bridges (scaled by 1,000)	.026	-.010
		(1.34)	(-0.58)
4	eis	-.004*	-.003
		(-1.90)	(-0.43)
5	fhw_eis	.010	.011
		(1.17)	(0.44)
6	spec	.004*	.008
		(1.72)	(1.22)
7	npl	.009***	.002
		(3.05)	(0.18)
8	hist (scaled by 10)	.003***	.008**
		(3.18)	(2.01)
9	coastmi	.046**	.057
		(2.01)	(0.63)
10	fed/spec	-.039*	-.047
		(-1.81)	(-0.59)
11	farm	-.002	.015
		(-0.43)	(0.72)
12	intercept	11.845***	(8.95)***
		(90.59)	(14.55)
	θ	.726	.824
	R^2 within	.054	.027
	Between	.778	.091
	Overall	.727	.090
	Number of observations	238	235
	Hausman test	11.85	7.69
	(p-value)	(0.295)	(0.659)
	Breusch-Pagan test	209.38	186.84
	(p-value)	(0.000)	(0.000)

[a] The numbers in parentheses below the estimated parameters (rows 1–12) are the t-ratios for the null hypothesis of no association. Table 2 describes the sources of definitions of each variable in detail.

Key:
*** p-value of 0.01
** p-value of 0.05
* p-value of 0.10

We conducted a brief telephone survey of each state DOT. Twenty-five states provided some information for some of the years in our sample. The average new miles of federal-aid highway added in each state ranged from 88.1 miles (in 1990) to 61.2 miles (in 1994). It is not clear whether these new miles are reflected in each year's reports, because they relate to miles added during the year. Furthermore, they account for only about 0.5% of the existing system in the average state and thus are unlikely to be an important influence on treating existing mileage as an exogeneous control variable in our tests.

If environmental regulations impact highway construction costs, then we should expect, after controlling for the characteristics of each state's existing federal-aid roadway (and bridges), that the factors likely to increase the stringency of environmental regulations would raise construction costs. By contrast, measures hypothesized to be related to experience and to the resources available for facilitating inter-agency negotiations about the form of environmental regulations would reduce costs. The latter effect occurs because the costs due to delay are reduced. We tested this hypothesis by including measures that (in most cases) varied by state and year for the environmental resources likely to influence the stringency of regulations. These factors are hypothesized to be exogenous influences on the negotiated form of the regulations. We also included measures of the physical characteristics of resources in the state likely to be related to Coastal Zone Management Plans, private farmland, and measures of the level of activity (and experience) in preparing environmental impact statements under NEPA. The estimated parameters for these variables along with their t-statistics are given in row 4 through 11 of table 3.

The estimated coefficients measure the proportionate change in federal-aid construction costs with a change in the respective independent variable. Thus, increases in the count measures for federal endangered and threatened species with habitat in a state or of National Registry sites, all else being equal, increase federal-aid construction costs. Both are statistically significant with at least a 10% p-value. The greater the number of species and historic sites, all else being equal, the more likely they are to be affected by new highway projects in a state. Likewise, a state with a long coastline is likely to encounter issues with the provisions of the relevant Coastal Zone Management Plan important to highways. A large number of NPL hazardous waste sites could mean a greater chance of having to deal with one in a highway project. These factors are general indicators of the effects of increased environmental stringency on highway construction. The EIS for the Wilmington project referred to above illustrated how both of these types of effects can influence the strategy adopted in a project.

Federal land relative to the count of the endangered species in a state, and a large number of EIS's prepared, may be factors that reduce costs. In the first case, federal land may serve as both a restriction on new highways and/or a potential source of habitat for the species affected by a project. In the case of the effects of the total number of EIS's prepared, the reduced costs may result from experience or the cost spreading that can arise when permanent staff are added to state agencies to meet similar mandates in other contexts. The farmland measure has a negative and insignificant effect on costs.

The column in table 3 reporting state-funded construction costs shows estimates of comparable roadway mileage and bridge measures corresponding to features of the state system. With the exception of the count of National Registry sites, none of these factors would be close to being statistically significant determinants of construction costs for roads funded completely by the state (these are not likely to be impacted as much by federal environmental regulations).

Overall, these statistical results are striking. Given the aggregate nature of the analysis as well as the proxy variables used to represent the potential for environmental factors differentially affecting federally funded projects in specific states, regulations could have had a marked influence *at the project level* and yet we might *not* have found significant factors influencing construction costs at the aggregate level. In situations where we must rely on judgment and proxy variables, however, there is an inevitable tendency to question statistical approximations. Three issues seem especially worthy of further consideration. First, it is widely recognized that states differ in their propensities to protect the environment. Would state-specific effects have changed the model? Second, wetlands' effects are the most commonly cited sources of increased environmental compliance cost (see Scodari 1997). We were unable to develop a reliable measure of wetland acreage by state over time. Most of the measures we considered either had incorrect signs, imposed significant restrictions on the available sample, or were highly correlated with other independent variables used to proxy the other resources. None were statistically significant determinants of federal-aid construction costs. In the presence of these data limitations, it is reasonable to ask whether there is any evidence supporting a wetlands effect? Finally, the catchall "omitted variable" concern plagues any effort to detect the effects of unobservable rules hypothesized to influence behavior.

The first and the last questions are partially answered with the Hausman and Breusch-Pagan (1980) test results. As noted earlier, the Hausman test indirectly compares a fixed-effects model (i.e., state-level dummy variables) with a random effects model. By testing the orthogonality of random effects to the independent variables we indirectly gauge whether omitted separate state-specific effects were important enough to cause a rejection in the null hypothesis. Neither the federal-aid nor the state-financed models reject the orthogonality hypothesis. Of course, it could well be the case that state effects were themselves not distinctive. The Breusch-Pagan test rejects this hypothesis. We can conclude based on this test that the variance in the state effect error is not zero for either model. Overall then, while we acknowledge that our model is incomplete, the results of these tests suggest that what may have been "left out" does not appear important enough to influence tests for specification errors and maintained assumptions that could change conclusions on the effects of federal environmental regulations.

The last issue—wetlands effects—is more complex. The only indirect measure we could construct to reflect wetland-related delay costs was the time to process Section 404 permits. The Wilmington, North Carolina, office of the Army Corps of Engineers provided records for over 1,300 permit applications for projects in North Carolina with decisions between 1994 and 1995. This included general and individual permits (see U.S. Army Corps of Engineers (1994); Kusler (1992); and Smith et al. (1998) for descriptions of the various types of permits). The Corps staff identified whether each permit was requested as part of a DOT project (i.e., DOT = 1, otherwise = 0). Our hypothesis is direct. Applications for Section 404 permits for transportation projects are, as a rule, more likely to involve other environmental impacts. Part of the reason for increased construction costs stems from the delay due to multiple, conflicting mandates of the environmental regulations facing highways. The states are required to develop a negotiated "balance" among environmental claims. Using this logic, we would expect DOT applications to take longer after controlling for other influences.

Equation (3) reports our estimated model for delay (days to process and obtain a final decision for a Section 404 permit using the North Carolina sample). The model is estimated as a random effects specification comparable to the description in equation (1). Here each county is treated as the source of the random effect error. Equation (3) reports the estimates. The database does not allow other features of the application to be identified. The numbers in parentheses are the t-ratios for the model and test the null hypothesis of the association.

$$\underset{(17.14)}{\text{Processing time} = 119.08} + \underset{(5.84)}{215.06}\ \text{DOT} \quad (3)$$

R^2

within	.136
between	.259
overall	.160

Hausman $\chi^2(1) = 1.84$
p-value = 0.175
Breusch-Pagan $\chi^2(1) = 7.79$
p-value = 0.005

The estimates are consistent with our expectations. DOT projects on average take 215 days longer to obtain a permit. The Hausman and Breusch-Pagan tests are also consistent with using this simple approach to control for other effects. Thus, to the extent delay adds to compliance costs for environmental regulations and North Carolina's experience is representative, the available data confirm the informal record suggesting that the permitting process associated with wetlands takes more time for transportation projects. This would be consistent with the interactions we outlined, and imply wetlands regulations are part of the environmental compliance cost picture.

CONCLUSIONS AND IMPLICATIONS

This paper statistically compares construction expenditures for highways that address federal environmental regulations to approximate a natural experiment and, in the process, to evaluate whether those regulations impose significant compliance costs on highway construction and repair. The federal-aid system is subject to over 20 different statutes. In addition, states using Federal-Aid Highway Program funding may encounter subsets of the nearly 30 different federal agencies with some oversight responsibilities for the environmental resources covered by these statutes. We have argued the resulting system is one that has public agencies negotiating with other public agencies about the exact nature of compliance on multiple environmental mandates.[14] Our statistical analyses suggest that environmental regulations appear to increase construction expenditures for federal-aid highways. Only the wetlands' effects could not be specifically linked to our cost measures. Permit-level data for one state appears to confirm that when highway projects require Section 404 permits, this factor alone seems to increase permitting delays. Of course, it is also important to note that we do not know much more about these applications and as a result have treated other sources of heterogeneity as random.

There are a number of serious qualifications to these findings. Two are especially important. The federal-aid highway system and the state road systems are quite different. The state road system is likely to be more heterogeneous, with some roadways providing transportation comparable to that of the federal-aid system and others that do not. Thus, one should expect that the construction requirements will be different irrespective of the effects of federal environmental regulations. This implies that direct comparisons of the estimated parameters from the models using the two construction expenditure measures would be inappropriate. As a result, our test considered only the statistical significance and sign of the estimated effects for the proxy variables reflecting the regulations.

Second, and equally important, we do not have direct measures of the stringency of the environmental regulations. Instead, we have variables that reflect the amounts of resources in each state that may be associated with increases in the likelihood that some environmental regulations would apply to projects in that state. This is not the same as knowing that specific projects were affected by the regulations due to specific federal statutes. In short, we are testing our hypothesis using "weak signals" of the influence of the requirements imposed by environmental mandates with "noisy" records of their outcomes for costs.

An optimist reading our results will find the significant effects under these circumstances a clear reflection of the impacts of the regulatory process. This reasoning would suggest that the odds are "stacked against" finding anything. Moreover, our "experiment" implies we should observe influences on federal-aid construction costs and *not* find the associations for state-financed construction costs. The twofold requirement would seem to reduce the chances of nonsense correlations "explaining" the

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[14] New legislation authorizing federal funding for highways recognizes these complications and their effect on compliance costs in its provisions calling for "environmental streamlining" (Section 1309). The legislation encourages development of an integrated decisionmaking process to coordinate permitting and to encourage early consideration of environmental impacts. It encourages the Secretary of DOT to enter into Memoranda of Agreement (MOAs) with the agencies responsible for receiving the environmental documents under NEPA or for conducting other environmental reviews, analyses, opinions, or issuing licenses, permits, or approvals related to highway projects. The expectation is that MOAs will lead to cooperatively determined time periods for reviews and integrated reviews. The Secretary is also given authority to close the record. But this authority to issue a record of decision, closing the record when another agency fails to meet an agreed upon deadline, is limited to matters pending before the Secretary. If projects require a Section 404 permit the Secretary may not restrict the Corps' review with respect to that permit.

The legislation also includes provisions that allow the additional costs associated with this streamlined process to be considered eligible project expenses under the Federal-Aid Highway Program. They are, however, only for federal agencies meeting the deadlines for environmental reviews when these new deadlines are less than the customary time allowed for the reviews.

These details clearly suggest Congress received the informal messages about time delays and compliance costs arising from lack of coordination in the environmental reviews. Nonetheless, to the extent the delays are inevitable, given the conflicting "absolute" mandates, the reauthorized legislation provides no guidance on how a hierarchy of the mandates is to be established.

constant findings for both cases. The pessimist will, by contrast, conclude the experiment is not ideal and our results could equally well reflect a number of omitted variables. State roads are subject to state-level environmental regulations and can, under some conditions, also encounter the federal mandates. Because each construction measure aggregates over several projects, this line of argument would suggest both measures could be influenced by the federal environmental statutes.

We side with the optimistic perspective, but do so cautiously. The primary reason for our acceptance of this perspective is that other independent evidence (e.g., General Accounting Office reports and the ratings of DOT environmental officials (see Smith et al. 1997) confirm the specific sources isolated in the statistical analysis as the most important effects of environmental regulations for highways.

Further progress in evaluating how the environmental mandates impose federal-aid highway impact costs will require a detailed study of individual projects—either reconstructing ex post the adjustments made to accommodate the relevant environmental requirements, or estimating ex ante what appears to be their likely consequences for a specific set of projects. This would be a very significant research effort.

Before undertaking such an effort, it is important to consider why environmental regulations have received so much attention. The regulations seem to be increasing delays and costs, but we do not know whether the modifications to what was best practice in the planning, design, and construction (or repair) of highways are worth at least the added costs. To address this question requires consideration of the net benefits of environmental modifications. While including benefits involves another significant set of complexities, it is important to recognize that the present process is not "neutral" on what these benefits might be. Decisions to set priorities among the absolute mandates associated with each environmental regulation implicitly assign values to the environmental changes that are avoided (or not avoided) by the modifications made to the construction and repair practices for roadways. There is currently no effort to include economic measures of what people would want from these decisions. Thus, even if the benefit estimates are approximate they are likely to help the negotiations of the alternatives. TEA-21 recognizes the need for early coordination and integrated reviews. It does not, however, provide guidance on how to prioritize conflicting environmental mandates. Benefit analysis would offer one way to help set these priorities.

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Rural Transportation Voucher Program for People with Disabilities: Three Case Studies

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ABSTRACT

The lack of transportation is one of the most frequently cited problems facing people with disabilities living in rural areas. This research explores a voucher program for rural transportation. Three case studies of programs implementing a voucher framework, supported in part by volunteers, are presented. These demonstrations were conducted in seven rural, "frontier," counties in two states. The population density of the seven counties averaged less than six people per square mile. One program was administered by an independent living center; two, by developmental disabilities case management service programs. The vouchers themselves provided a measurement method for evaluating the scope and use of transportation. Our analysis shows that 35,000 miles of rides were provided for employment, daily living, evening and weekend social purposes, and non-emergency medical treatment at a relatively low cost.

INTRODUCTION

There are approximately 13.2 million people with disabilities living in rural areas of the United States (Seekins 1995). The lack of transportation is one of the most frequently reported problems facing this population and the rehabilitation providers who

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serve them (Kidder 1989; Page 1989; Tonsing-Gonzales 1989; Nosek et al. 1992). Despite the significance of this problem, few models for delivering transportation to people with disabilities in rural areas have been reported.

Over 20 years ago, Kidder (1989) demonstrated a rural transportation model for people with disabilities that involved forging transportation cooperatives among agencies who had purchased vehicles with federal funds. For example, a senior citizens' program, a mental health center, and a developmental disability service provider could form a cooperative by combining their vehicles and transportation budgets to create a community transportation cooperative serving people with disabilities and not just each agency's clients. Her research demonstrated that such an approach was financially feasible and effective. Unfortunately, her approach has not been widely adopted because, in part, it requires agreement and cooperation between multiple agencies, which often fear loss of control and income. Further, it requires a community of sufficient size to have at least two agencies with access to vans and are willing to cooperate. This means that smaller, more remote, rural areas are often without a transportation option.

In response, a handful of voluntary transportation programs have emerged to address the transportation needs of individuals with disabilities living in sparsely populated rural areas (e.g., Mathews 1992). Forms of this model have emerged in several rural service programs, ranging from agencies that coordinate volunteer rides to those that administer funds to subsidize individuals who seek their own transportation. These programs include organizations operated by statewide support groups for adults with visual impairments (e.g., Visions Northwest, in Oregon) and independent living centers (e.g., SUMMIT, Inc. in Montana). The systems vary in their structure and operation but share the characteristic of transportation provided by volunteers using their personal vehicles, and by public and private providers.

An additional feature of such systems is that they are compatible with an independent living philosophy that calls for maximizing individual control and community integration of people with disabilities (DeJong 1983; National Council on Disability 1997, 19). These programs offer a relatively unexplored alternative to rural transportation for people with disabilities, using community volunteers or local transportation providers to get resources directly to consumers. These models can be referred to in general as Supported Voluntary Rural Transportation Systems (SVRTS). In essence, these projects point to the development of a rural transportation voucher system. However, such projects have received little attention.

Voucher, or user-side subsidy systems, are permissible under the Non-Urbanized Area Formula (Section 5311) of the Urban Mass Transportation Act (USDOT 1992). A variety of individuals and organizations are eligible to apply for these funds, including nonprofit organizations and local transportation districts. Interestingly, voucher systems are also permissible under the Elderly and Persons with Disabilities Program (Section 5310), which is typically used for purchasing vehicles for private nonprofits. These funds may be used for operating and capital expenses for periods of longer than one year.

A review of the use of vouchers systems, however, indicates that fewer than 25 communities around the nation have employed this approach (USDOT 1994). These programs included 6 area agencies on aging, 5 private taxi companies, and 14 fixed-route bus services. Of these, 18 (72%) specifically addressed issues of transportation for people with disabilities.

The goal of this research was to develop and evaluate the practicality of a voucher model for increasing access to transportation for people with disabilities living in rural areas. A secondary goal was to develop measures for monitoring such programs. Specifically, we examined the legal and operational issues of expanding community-based services using trip vouchers supported by existing providers and by volunteer drivers.[1]

[1] The Community Transportation Association of America uses two general administrative categories when assessing the effectiveness of volunteer and other transportation services. Agency-based services are operated by nonprofit groups usually with paid staff. Community-based services are operated by volunteer boards of directors set up specifically for transportation, including services using volunteer staff or drivers (Studebaker 1990).

METHODS

A total of 232 individuals with disabilities were identified as eligible to participate in three projects. Of these, 90 used vouchers for trips during the three studies. The target areas for this research were 7 counties in Montana and South Dakota, comprising some 15,376 square miles with a population of 81,214, which is 5.28 people per square mile. Table 1 lists the three agencies, the counties they serve, and the census counts of the number of people with disabilities in each.

In each of the three major settings, the voucher system was implemented by a private nonprofit agency serving the area. In northeastern Montana, a case management agency, Aware, Inc., took primary responsibility for operating the program in the five counties it served. This program serves adults and children with developmental disabilities. In Ravalli County in southwestern Montana, a local residential and work program for adults with developmental disabilities, Ravalli Services Corporation (RSC), operated the model. In Yankton, South Dakota, an independent living center serving primarily adults with physical disabilities, Prairie Freedom Center (PFC), operated the voucher program.

Each of the transportation systems reported here had both shared and unique features. Unique features of each are described in detail below. Programs shared the following features: 1) each was administered by an established agency that provided liability coverage through volunteer clauses in the agency's insurance,[2] 2) each used vouchers that were given to consumers directly, 3) each agency was a 501 C3 community-based program providing services to people with disabilities, 4) the vouchers were used to purchase rides from independent providers, and 5) the vouchers themselves provided a means for evaluating the system.

Each transportation coordinator received a copy of operating instructions for an SVRTS Program.[3] The manual provides background and guidelines for starting a local voucher program. It includes descriptions of existing voucher programs, examples of vouchers, how to calculate reimbursement rates, how to look for additional funding, and, if necessary, how to apply for vehicles. The observations from each site are reported below.

[2] There are several legal issues involved in providing transportation services. In a system that uses volunteers, one of the major issues is liability insurance. In general, small transportation programs using volunteers can be covered through an agency's liability and excess non-owned auto insurance. For a copy of a legal brief on these liability issues, contact the first author.

[3] This manual is available by contacting the RTC: Rural, 52 Corbin Hall, University of Montana, Missoula, Montana 59812, by calling 1-800-732-0323, or by email at http://ruralinstitute.umt.edu/rtcrural.

TABLE 1 Demographics

Program and state	County	Total 1993 population	People with work disabilities	People with mobility and self-care limitations	Square miles
Aware, Inc., Montana	Daniels	2,266	64	11	1,426
	Richland	10,716	562	148	2,084
	Roosevelt	10,999	541	142	2,356
	Valley	8,239	453	60	4,921
	Sheridan	4,732	216	56	1,677
Ravalli Services, Montana	Ravalli	25,010	1,733	332	2,394
Prairie Freedom Center, South Dakota	Yankton	19,252	1,013	212	518
Total	7	81,214	4,582	961	15,376

DATA COLLECTION AND ANALYSIS

A four-part carbon-copy voucher form was used to facilitate tracking across multiple agencies. Each voucher presents places for the user to record the date of the trip, its purpose, the provider, and (in studies 2 and 3), a mileage estimate. A participant filled out the voucher form and gave it to the driver. The driver kept the original and submitted the rest to the sponsoring agency for reimbursement. A copy went to the case manager for records. The final two copies went to the agency bookkeeper for reimbursement and then on to the two funding sources for evaluation.

Three case studies (Cook and Campbell 1979, 207; Kazdin 1992; Yin 1993) of the use of the voucher system are presented. Data are summarized and plotted as cumulative rates (Skinner 1969, 81) to provide for visual inspection of the time-series data on system performance (Furlong and Wampold 1982).

Study #1: Yankton, South Dakota

Two staff members, the area director and the bookkeeper, of the PFC allocated a small portion of their time to this project and administered the Yankton program. The PFC is an independent living center (ILC)[4] satellite office in Yankton County, South Dakota. First, the PFC staff and a state Department of Transportation consultant conducted an assessment of local transportation needs of their consumers and of several other agencies (Schauer 1994). This assessment of the entire county showed an estimated 16,000 unmet trips per year for 982 potential riders, including people with disabilities, the elderly, and other transportation-disadvantaged groups. Second, the PFC staff took the lead role among agencies for printing and distributing vouchers. Third, the PFC established cooperative agreements with the local taxi service and the local community transportation provider. These providers agreed to honor the vouchers and provide rides when requested at the prevailing rate or fare structure. Fourth, procedures for defining eligibility and for allocating vouchers were developed, based on disability and income. Twenty-six specific disability conditions or characteristics (e.g., SSDI recipient, observable physical impairment, medical report) were used as guidelines. Table 2 shows the sliding scale used to determine voucher allocation.

The Yankton site chose to limit its service area to Yankton County and to use two established transportation providers. In order to avoid issues of organizational liability, the PFC also chose not to use volunteer drivers.

The program began in June 1995. Thirty-five individuals applied for the program, and 32 met eligibility criteria and were accepted. Additional applicants applied over the next several weeks. A total of 59 individuals applied for participation in the voucher program and 55 (93%) met the criteria, were accepted, and received 1,632 vouchers.

After distribution, participants were free to use the vouchers as they needed. Consumers were responsible for arranging their own rides, and providers were responsible for submitting vouchers for payment. Other than processing new applicants and payment, the ILC staff had no other responsibilities.

Of the 1,632 vouchers distributed, 891 (55%) were reimbursed by the ILC. Use paralleled distribution but was consistently lower. This means that either consumers still held a considerable number of vouchers at the end of the project, providers did

TABLE 2 Eligibility Determination Guidelines

Declaration of income	Subsidy per trip
Single individuals	
\$0–\$500 per month	\$1.25
\$501–\$750 per month	\$1.00
\$751–\$900 per month	\$ .75
Married or single applicants with dependents	
\$0–\$700 per month	\$1.25
\$701–\$900 per month	\$1.00
\$901–\$1,200 per month	\$ .75

[4] Independent living centers are typically private nonprofit organizations that provide peer counseling or support, advocacy, and other disability-related services to individuals with disabilities. The majority of the boards of directors of these organizations are required to be individuals with disabilities.

not submit some vouchers for reimbursement, or a combination of both.

Figure 1 presents the cumulative number of rides provided over the 581 days of the project. The rate of utilization remained low for several months but began increasing after about 200 days. A total of 1,143 rides were provided over the 581 days of service for an average of approximately 2 rides per day.

Figure 2 presents the types of rides taken over the 581 days. Of those rides for which a purpose was recorded, 88 (14%) were reported as being for non-emergency medical purposes; 301 (50%) were for daily activities or social purposes; and 215 (36%) were for education or employment.

The total reimbursed cost of rides was $1,278.25 for an average of $1.12 per ride. In this case study, data were not available to calculate the distance of trips or the match of personal resources and vouchers.

FIGURE 1 Cumulative Number of Trips Taken in Yankton, South Dakota

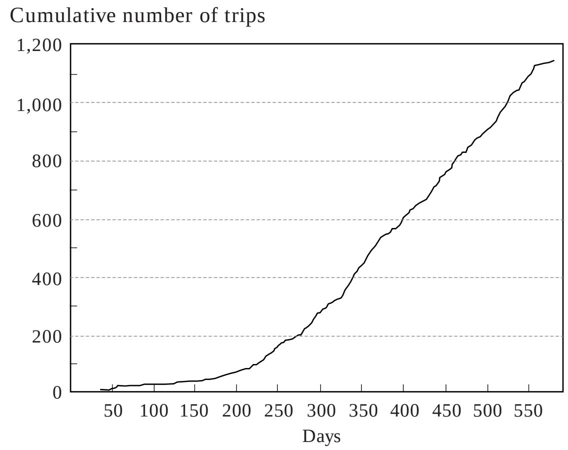
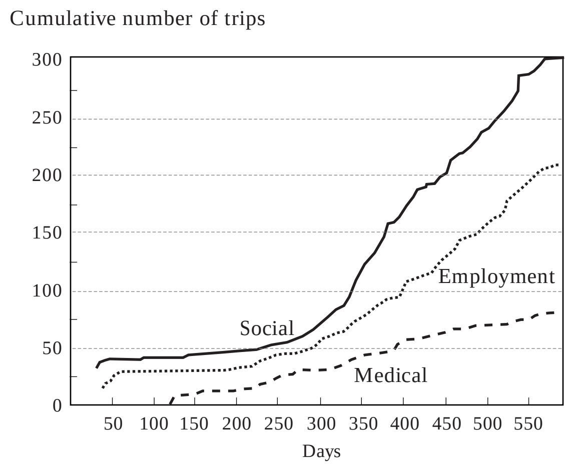


FIGURE 2 Types of Trips Taken in Yankton, South Dakota



Study #2: Northeastern Montana

The northeastern Montana program was administered by Aware, Inc., a case management provider for people with developmental disabilities that serves five counties. One case manager distributed vouchers and monitored their use. The organization's bookkeeper allocated a small portion of her time to making payments to drivers for vouchers.

The Montana Developmental Disabilities Planning and Advisory Council (DDPAC) identified rural transportation as one of the more pressing issues to address. In response, the researchers, in collaboration with Aware, Inc., developed and evaluated a voucher system for addressing the transportation needs of adults and children with developmental disabilities. DDPAC and the University of Montana provided the funds to operate the system. The university-based researchers evaluated the program. Aware, Inc. served as the lead agency for the system's operation. This included providing liability coverage for volunteer drivers through its corporate insurance.

Unlike the Yankton site, this program used volunteer drivers almost exclusively. Aware, Inc. sent a letter to consumers, family members, and other service providers describing the program and soliciting the participation of volunteer drivers. Drivers were required to have valid licenses, the state's minimum liability insurance for their vehicles, and good driving records. These requirements were verified by the case manager. In addition, drivers provided this information on the voucher form. A total of 28 drivers participated over 12 months.

To determine the value for the vouchers and the number each participant could receive, researchers examined average one-way trips based on Section 5311 and 5310 data reported to the Montana Passenger Bureau (Montana Department of Commerce 1990) by the only taxi located in one community of the service area and by bus services in the five-county area. These data suggest that an average trip within limited service areas and times would cost approximately $3. Volunteer drivers were reimbursed at 29¢ per mile with a potentially unlimited service area or schedule. This reimbursement rate for volunteers was set to avoid triggering personal tax consequences.

Aware, Inc. developed criteria appropriate for the region to be served. One criterion was that the voucher recipient be eligible for developmental disability case management services. Additional criteria included people who were receiving no services from existing social or vocational providers, were on waiting lists, were receiving limited services, could not access existing transportation resources from their current provider (e.g., vocational program van services that did not serve the area or did not operate during times when rides were needed), or could not afford to pay for transportation. The transportation coordinator/case manager identified 143 consumers who met these criteria and distributed vouchers to them.

Figure 3 presents the cumulative number of trips taken over the one year of operation. Twenty-nine individuals (20.3%) used the vouchers for a ride at least once. During this time, consumers took approximately 176 trips, totaling 30,957 miles. Employment trips made up 2% of the trips taken, 36% were for non-emergency medical trips, and 63% were used for shopping or visits to family.

Figure 4 presents the cumulative number of miles of travel provided over the year. The distance of trips averaged approximately 176 miles but ranged from 4 to 1,037 miles. Figure 5 presents the cumulative costs for providing rides.

Consumers frequently used vouchers to visit families who lived at great distance. A substantial number of trips were also made to larger towns for shopping and recreational activities not available locally. Most of these trips were taken on weekends and holidays when transportation is often not available from the agencies serving consumers. The total cost of reimbursed rides was $8,978.

Individuals decided how to use their vouchers, where they wanted to go, and when. The case manager, family members, or agency staff provided assistance in arranging rides. After providing rides, drivers submitted the vouchers to Aware, Inc., for payment.

Examining these three figures reveals a general parallel in both trips and miles. These do not necessarily correspond, however, since trips with shorter distances during a given period allowed more total trips during that period.

Figures 3, 4, and 5 show a sporadic start for the program, perhaps because people were unfamiliar

FIGURE 3 Cumulative Number of Trips Taken in Northeastern Montana

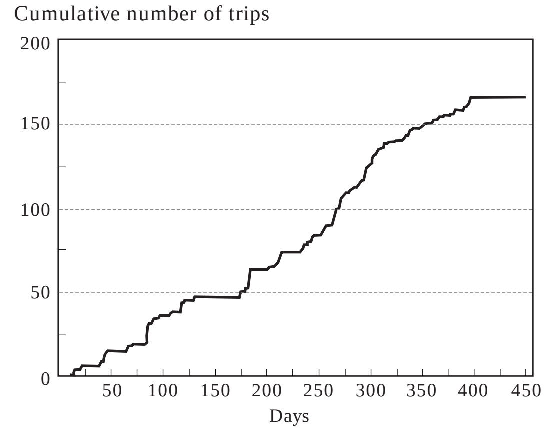


FIGURE 4 Cumulative Miles Traveled by Participants in Northeastern Montana

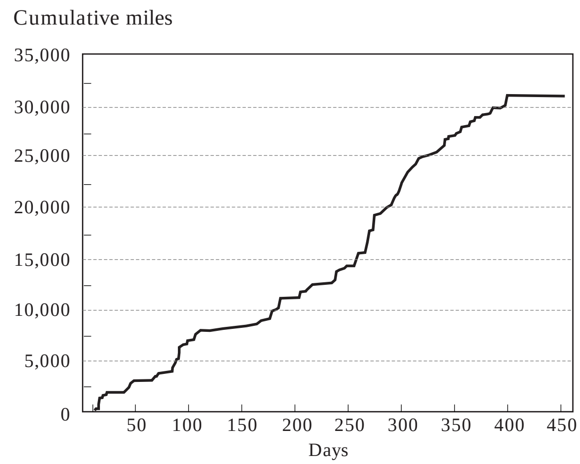
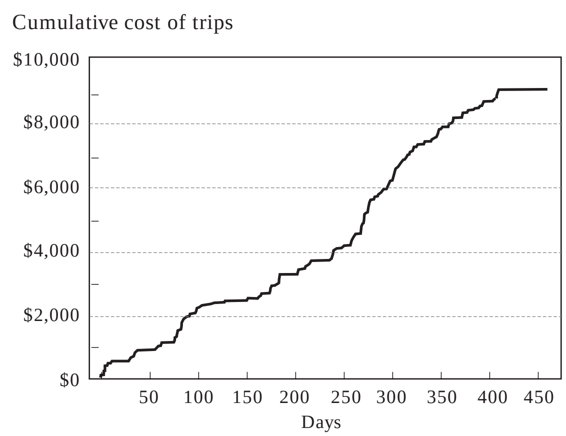


FIGURE 5 Cumulative Costs of Trips Taken in Northeastern Montana



with it. Figure 3 also shows an extended period of no transportation between days 133 and 170 when the demonstration was temporarily suspended. Over time, the rate of trips slowly increased and became more regular. At the same time, the miles of trips began to decline. These patterns provide an interesting contrast with those of the following program.

Study #3: Ravalli, Montana

Ravalli Services Corporation (RSC) expressed interest in starting an SVRTS program to address transportation problems in its rural service area of southwestern Montana. RSC, a developmental disabilities case management and vocational services provider, served as the lead agency. This included providing liability coverage for volunteer drivers through the volunteer clause of its corporate insurance. The RSC Supported Employment (SE) Coordinator distributed vouchers, monitored their use, and managed payments.

Like the northeastern Montana site, this program used volunteer drivers almost exclusively. This program, however, was used primarily for employment-related transportation. Participants were defined as those who were served by RSC but who were unable to access employment because of transportation problems. The SE Coordinator, who coordinated the voucher program, identified 34 consumers who met this criterion. He recruited potential drivers from the agency and the community. Drivers were required to have valid licenses, the state's minimum liability insurance for their vehicles, and good driving records. These requirements were verified by the Coordinator. In addition, drivers had to provide this information on the voucher form. A total of 17 drivers participated over 3 months.

The SE Coordinator was aware of consumers' work schedules, so he scheduled the trips. The drivers then contacted the consumers to make arrangements for the ride (i.e., pickup place, destinations, etc.). The value of rides was set at 29¢ per mile, based on IRS reimbursement rates for volunteers.

Figure 6 presents the cumulative number of trips taken in the program. To date, of the 34 eligible individuals, six clients (17.6%) have used the

FIGURE 6 Cumulative Number of Trips Taken in Ravalli County, Montana

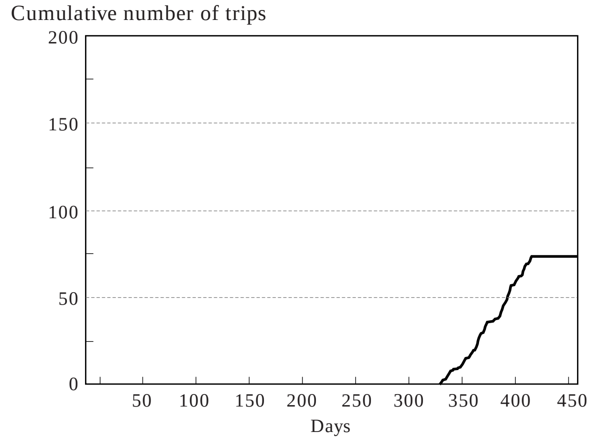
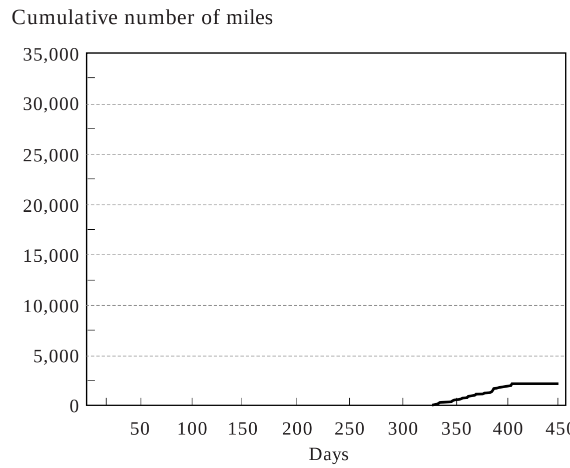


FIGURE 7 Cumulative Miles Traveled by Participants in Ravalli County, Montana



vouchers for trips to work during the program's operation. Some individuals used more than one driver, and some only used their vouchers for one trip. These six consumers took 74 trips over 87 days of operation. Of these, 72 trips (97%) were trips to and from work. Two were trips for medical reasons.

Figure 7 presents the cumulative miles of trips taken over the 87 days of operation. Trips averaged 31 miles but ranged from 14.1 to 283 miles. Figures 6 and 7 are presented on the same scale as figures 3 and 4 to permit ease of comparison. Examination of these graphs shows that the Ravalli program, focusing on employment-related rides, had a faster and more stable rate of trips taken. The slope of the cumulative number of miles traveled shows a stable but slower rate of growth. This is consistent with the substantially shorter average trip distance in the Ravalli case. The contrast makes sense in light of the primary use of vouchers in these two areas. Use of vouchers in the northeast program was mainly for weekend, holiday, and shopping trips, which require longer but intermittent trips. Vouchers in the Ravalli program were used for daily trips to work.

COST COMPARISONS

An important consideration in assessing any transportation program is the efficiency with which it provides services. Ten regular transportation programs in Montana serving rural elderly and disabled people reported the average annual cost per person was $1,054 and ranged from $500 to $1,900. Their cost per mile ranged from 64¢ to $3.20 per mile (e.g., Montana Department of Commerce 1990). The three SVRTS programs had slightly different purposes, consumer bases, service areas, and structures; they averaged less than 29¢ per mile and had an annual cost per person that ranged from $28 to $566. While comparing programs in this manner should be done cautiously, these data suggest that SVRTS programs can be a cost-effective option in rural areas. Also, it is important to note that the Yankton SVRTS program represents a sliding scale subsidy while the other SVRTS programs offered fixed-rate reimbursement. These variations make comparisons difficult.

DISCUSSION

This report summarizes the efforts of three rural communities to expand transportation options available to people with disabilities through the use of a voucher system. The vouchers themselves provided the primary measures for evaluating the program. Over 35,000 miles of transportation were provided to 90 people with a broad range of disabilities living in rural areas. The trips were for employment, medical, daily living, and social purposes at a relatively low cost. Agency staff easily organized and administered the program. Consumers used the vouchers to secure rides to meet their needs. As such, these data suggest that voucher systems can be a viable means of providing transportation to people with disabilities living in rural areas.

The case study approach used here has several advantages. It is relatively easy to organize within one community at a time. Developing interventions in one community at a time permits flexibility in adapting to local circumstances. The small-scale, incremental steps also allow for refinement of procedures and measures. This research method is also relatively inexpensive. It does not provide for direct comparison of models or applications using statistical controls, however. Rather, it requires the accumulation of examples to build understanding and confidence. It can also serve as a preliminary step toward a large-scale study.

An important limitation to the study is that no data were collected about other transportation methods used by participants. Further, no baseline data of transportation used were collected. As such, these data do not allow us to determine whether vouchers increased the amount of transportation, supplanted, or simply supplemented current access. Further research is needed to collect data on the use of various transportation modes and needs for an extended baseline period. Such data would permit an examination of the relative use of modes of transportation by individuals.

Two surprising observations were that fewer people became involved in the SVRTS program than were eligible and, of those involved, fewer people used the vouchers or used fewer vouchers than anticipated. There are many potential explanations for lower participation in the system than expected. Local rehabilitation providers may have overestimated needs. Agencies may not have advertised or recruited eligible individuals outside of their immediate service networks. In those programs where consumers arranged their own rides, some may have been reluctant to participate because of the greater responsibility placed on them. Given the structure of everyday life experienced by many actual and potential riders with disabilities, vouchers may have required more individual responsibility and effort than some were willing to take. Anecdotally, some potential participants also declined to participate when informed of the program and, in fact, objected to it because it was sponsored by a government agency.

For those who did participate, lower use may have been associated with participating in a new program. During site visits some consumers, case managers, and drivers expressed awkwardness in using vouchers or receiving reimbursement. Use clearly increased over time. The fact that each of the programs was in operation for approximately one year suggests that a long-term commitment to making vouchers available may be needed in order to see more extensive day-to-day use.

Another explanation for the lower than expected rates of use may be that some participants were saving vouchers for longer trips or emergencies. Anecdotally, many participants in the northeast Montana demonstration saved their vouchers and used them for trips to cities or for visits to distant family, rather than for local travel.

On the other hand, the lower than expected use may reflect less unmet demand than was assumed by advocates and providers. Service providers consistently report transportation as one of the most pressing problems for people in rural areas. To date, however, little effort has gone into using comprehensive data from multiple sources to document how transportation can be used to meet estimated demand.

Although this review does not offer a detailed cost analysis of an SVRTS program, adding a voucher component to an existing system may not increase the administrative and maintenance costs significantly, since many community agencies provide transportation that people with disabilities might easily purchase with vouchers. Expanding available transportation using vouchers and volunteers may be less expensive than hiring additional drivers or purchasing, maintaining, and insuring a vehicle.

A perennial question when organizing transportation services that involve volunteers is liability and excess non-owned auto insurance. Aware., Inc. and Ravalli Services Corporation each had policies that provided coverage for volunteers who used their own vehicles, which presented no additional costs.

Voucher systems can offer many advantages over traditional systems. First, more hours of service can be available to riders because rides are not necessarily restricted to the time and days of operation of scheduled services. Second, there may be less direct cost to service agencies. Third, vouchers can increase public/private cooperation and business for local bus services or taxis. Fourth, voucher systems can be started incrementally with minimal investment or risk. Finally, the use of vouchers can be monitored with a high degree of detail and accuracy because trips are documented and paid for as they occur, similar to a fee-for-service arrangement.

There may also be disadvantages to voucher systems, including the potential for unexpected increases in trip demand that surpass capacity, unexpected surpluses in available vouchers, limits in the number of subsidized trips available to riders, and the potential for misuse without an adequate monitoring program. Some service agencies may also be reluctant to shift to a voucher system because they fear losing a visible identity in their community (e.g., a van with their name on it).

Transportation remains a significant problem for people with disabilities living in rural areas and for those who serve them. Research into innovative models using small-scale, case-study methods may be a particularly useful approach to exploring alternatives. It also provides a flexible strategy that allows for creative experimentation and the tailoring of projects to community customs and needs.

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The Usefulness of Current International Air Transport Statistics

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ABSTRACT

International air transport is the fastest growing segment of transport. It performs a major function in the globalization process and is a significant feature of the late 20th century. Public policy regarding international air transport has undergone a sea change in recent years as markets liberalized and airlines privatized. New management techniques, partly stimulated by enhanced information technology systems, have resulted in significant changes on the air services supply side. Aircraft and air traffic control systems have improved. These developments pose new challenges for those responsible for overall policy and for those supplying air transport services. Successfully confronting these issues requires a solid and relevant statistical database. This paper sets out to explore the data that are available, highlights their strengths and limitations, and indicates areas where improved statistics may be beneficial.

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INTRODUCTION

Trade in international air transport services is extensive and growing.[1] This trade has an importance in its own right, in terms of balance of payments considerations for example, but air transport also acts as a lubricant for trade in a wide range of other goods and services. It has been instrumental in stimulating many of the globalization trends that have been seen over the past 30 years. It is also a sector that has been, and continues to be, the subject of considerable governmental interventions and one that requires sophisticated management to perform efficiently. Performance indicators are thus of major importance both for public policy formulation and for monitoring internal efficiency.

The late 20th century has also seen a general appreciation of the need for changing how international aviation is controlled.[2] The institutional structure developed in the mid-1940s allowed considerable progress to be realized in international air transport markets during the four decades following World War II, but since then technology has progressed, the demands of air transport users have both changed and expanded, and new markets have emerged (OECD 1997).

Quantitative information is important to this sector. Where tight economic regulation continues, information is needed in the international horse-trading that is an integral part of the bilateral system of air traffic agreements pertaining to such regulations. Where there are efforts to reform, and especially to liberalize the regulatory structure, statistics are needed for both private and government sector use.

Airlines, airport authorities, and suppliers of aircraft and other material inputs require quantitative information to make effective management decisions and to permit longer term planning. Labor unions require data to effectively negotiate with employers. Governments need to monitor the state of the industry to enforce general regulations over such things as anti-trust behavior and to be in a position to conduct international negotiations. Increasingly more data is being demanded on the wider, social implications of air transport as matters of safety and environmental damage attract public attention. Finally, researchers require reliable and consistent data on international air transportation to perform basic analytical as well as policy-relevant research.

This paper focuses on the current availability of international air transport statistics. It looks at the uses made of the available sources and highlights the strengths and weaknesses of current data.[3] To this end, the paper initially provides context by setting out some of the important recent trends in international air transport. It then moves on to look at the main uses made of statistics, both by those concerned with international air transport policy and by those working in the sector or making use of its services.[4] An appendix to the paper critiques the available statistical sources, given the types of current and likely future demands placed on them.

TRENDS IN INTERNATIONAL AIR TRANSPORT

Two forces have helped shape the air transport industry: developments in markets for air transport services and institutional reform. Globalization and internationalization have been major industrial trends of the late 20th century. Part of this pattern is reflected in the significant trade growth that has taken place. Real export growth in the industrialized countries that make up the Organization for Economic Cooperation and Development (OECD) grew at over 7% per year from 1964 to 1992. Comparatively, first world production was

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[1] Air transport is a network industry, and, from a technical perspective, it is somewhat artificial to separate international air transport from domestic air services; not only do they often use the same infrastructure and equipment, but the route networks are themselves interlinked. From many policy points of view and considering institutional structures, domestic services are normally treated differently from international ones.

[2] For instance, on the European side of the Atlantic there was the Comité de Sages for Air Transport (1994); on the U.S. side, the U.S. National Commission To Ensure a Strong Competitive Airline Industry (1993).

[3] The paper is not concerned with the more general attributes of good statistical series, data collection, and presentation, but focuses entirely on the issues peculiar to international air transport.

[4] To provide realistic boundaries, the focus of the paper is almost exclusively on the airline sector, and little attention is paid to the aircraft manufacturers' needs.

up by 9%, exports by 12%, and cross-border lending by 23%. Equally, there has been a significant rise in foreign ownership of assets that are now estimated to total about $1.7 trillion (U.N. Conference on Trade and Development 1994).

Whether these trends are passing fads or genuine long-term adjustments to the way production and trade is conducted is premature to judge. Preliminary indications are, however, that despite short-term problems with some Asian and South American economies, the observed trends are more than transient.

All this has taken place while the institutional structure of air transport services has seen significant developments (Kasper 1988). U.S. economic deregulation of its domestic air freight markets in 1977 and its passenger markets in 1978, combined with subsequent commitments to an "Open Skies" approach to international aviation in 1979, changed the way U.S. policy in this area is conducted. It has also, through both demonstration and direct knock-on effects, affected the ways in which other air transport markets are now regulated (Button 1990; OECD 1993, 1997).

The intra-European market is moving rapidly toward a situation found within the United States. Many European countries unilaterally liberalized their domestic markets, while the European Union (EU) since 1988 has moved, through a succession of "Packages," to a position that has left air transport largely free from economic regulation since mid-1997.[5] There are also indications that the European Union is slowly developing a single external approach to international aviation with the European Commission acquiring rights, albeit limited, to conduct negotiations on some "doing-business" aspects of international agreements.

Outside of Europe and North America, the majority of national markets in South America have been liberalized with a variety of privatization programs. In the Pacific region, the Australian and New Zealand domestic markets have also been deregulated. Additionally, the creation of the World Trade Organization (WTO) brought into play, albeit in an extremely small role,[6] a new and geographically wider policymaking institution to supplement those already in existence, such as the International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) (Katz 1995). Aviation issues are also on the agenda of new regional groupings such as the Asian-Pacific Economic Council.

This combination of market trends and institutional reforms, combined with rising incomes and increased leisure time, have contributed to the steady growth of demand in aviation markets. Additionally, technological advances have allowed aircraft efficiency to rise and air traffic control systems to handle greater volumes of traffic, thus exerting positive effects on the cost side of the international air transport equation. The airlines themselves, partly as a response to these developments, have adopted more aggressive marketing strategies with the introduction of frequent flier programs, yield management, and code-sharing alliances (Gellman Research Associates 1994; USGAO 1995c).

As a result, air passenger traffic since 1960 has grown worldwide at an average yearly rate of 9% with freight and mail traffic growing by some 11% and 7%, respectively. In 1995, for example, some 1.3 billion passengers were carried by the world's airlines (Boeing Commercial Airline Group Annual a). Civil aviation has become a major service industry, contributing to both domestic and international transport systems. It facilitates wider business communications and is a key component in the growth of tourism, which is now one of the world's major employment sectors (World Travel and Tourism Council 1993).

In addition to passenger transport, aviation is an important form of freight transport, with some estimates suggesting it carries over 30% of world trade by value and is forecasted to rise, with some short-term volatility, 400% by 2015 (Boeing Commercial Airplane Group Annual a).

[5] For details of the various "Packages" of reforms, see Button et al. (1998); Vincent and Stasinopoulos (1990); Stasinopoulos (1992, 1993).

[6] A number of countries, especially the United States, have tended to oppose the multilateralism implied in air transport agreements like the General Agreement on Tariffs and Trade (GATT) and have preferred to use their bargaining power within the bilateral structure.

The growth trend has not been even but has exhibited geographical variation. For the period 1982 to 1992, ICAO data show that traffic grew by 11.4% on European-Asian/Pacific routes, but only by 5.0% in mid-Atlantic markets. The European-African traffic hardly grew at all. Airlines have seen a steady growth in their traffic within Europe since 1992. Overall traffic increased by 8.1% in 1994, the biggest annual rise in 15 years, except for a 9.1% increase in 1992 following the drop in traffic recorded in 1991. This trend continued in 1995, with growth reaching 6.1%. This fairly sustained growth in traffic, coupled with a more moderate increase in capacity, is reflected in an improved load factor for all the national carriers which, like productivity improvements, brought many of the airlines back into profitability.

Cargo traffic also exhibits important geographical variations, with the greatest growth in the mid-1990s coming in the Intra-Asian market (20.4% in 1994 and 15% in 1995) and a much more steady expansion in more mature markets such as the European-North American market (5.3% in 1995).

After running a deficit for several years, many airlines managed to get back into the black in 1995. Net profits for the 12 main EU airlines were in the region of US$800 million, against a net overall loss on the same scale in 1994. However, only British Airways, Finnair, and KLM achieved universally favorable results over the entire period from 1990 to 1994. Globally, British Airways, Singapore International Airlines, and Northwest Airlines were the most profitable in 1995, with net incomes of $740 million, $622 million (up to $624 million in 1996), and $506 million ($536 million in 1996), respectively. Some carriers such as Air France (–$581 million) and Canadian Airlines International (–$143 million) continued to report losses in 1995. All major Asian carriers achieved a positive net income in 1995.[7] The financial situation of carriers has tightened more recently, with profit levels declining as Asian markets have been in recession and competition heightened in markets like the North Atlantic.

In line with other sectors, aviation has experienced a significant move toward globalization and internationalization. Indeed, it is the stated objective of British Airways that it intends to become a "global carrier." In pursuit of wider market coverage and in an effort to enhance their own internal efficiency, other airlines have followed a similar course. The most recent development, and perhaps the most controversial, is the formation of various airline alliances.[8]

WHAT DO WE NEED FROM INTERNATIONAL AIR TRANSPORT STATISTICS?

There is no single user of air transport data. Rather, international air transport statistics are collected and analyzed for a variety of purposes. Such statistics are important to various public and private sector groups in their decisionmaking processes. The needs of each group, however, often differ. The use made of data can also vary within a group, according to the issues at hand. Over time these issues can also take on new dimensions. In consequence, compromise is inevitable in the way data is collected and summarized.

The aim here is to look at the current and potential future needs for these statistics. The needs are, therefore, the context for overall medium-term developments in air transport markets, public policy priorities, and commercial requirements. The needs of the public and private sectors inevitably overlap in many instances, requiring similar data.[9]

Policy Analysis

In recent years, there have been significant changes in the institutions governing international air trans-

[7] How much of the net revenue is attributable to international operations is difficult to assess in most cases because of joint operations with domestic services. For example, in 1995, 98.1% of British Airways revenue ton-kilometers was international as was 91.1% of Air France's and 100% of Singapore International Airlines, but only 30.7% of Delta Air Lines', 20% of Continental's, and 7.4% of U.S. Air's were international.

[8] Some indication of the growth in airline alliances can be found in the annual surveys conducted by *Airline Business*. The most recent survey indicates some 502 alliances globally, up 38% from 1997. The data, while indicative use a fairly broad definition of alliances. One thing that they highlight is the volatility of the arrangements that exist.

[9] One area of considerable public concern that is not touched on here is security. Almost by definition, there is limited knowledge of exactly what data are available to the security agencies and to what extent they are exchanged at an international level.

port. International air transport has traditionally been heavily regulated in terms of the fares and cargo rates that could be levied, the level of service that could be offered, and the airlines that could operate. Further, many carriers outside of the United States are state-owned. The situation that emerged from the Chicago Convention of 1944 was that each country retains rights over its own air space, and countries have tended to use this to negotiate bilateral air service agreements with other states. These agreements have varied over time in their detail but generally cover the capacity supplied, specify the permitted carriers, control fares and entry points, and pool revenues. Within this framework, IATA acted as a clearinghouse for information, with fares, capacity, and other features of the market very closely monitored. Data were relatively simple to collect because many key parameters were effectively determined by fiat within the framework of an international cartel.

More recently, many of the bilateral air service agreements have been liberalized. Since 1979, the U.S. government has pursued an Open Skies policy with respect to many of its bilateral negotiations in an effort to remove the more binding restrictions.[10] Within Europe, the Third Package of aviation reforms has led to a multilateral structure in the European Union (Stasinopoulos 1993).

Much of the debate over international liberalization has been conducted in the abstract, with logical argument being deployed in support of regulatory reform.[11] Statistical information has supplemented these theoretical and political arguments, with evidence drawn from a range of studies showing the benefits of freer aviation markets. The post-1978 developments in the U.S. domestic market have formed the bedrock for much of this work, but early lessons were also learned from analyzing some of the liberal bilateral arrangements. Examples include Barrett (1990) and the U.K. Civil Aviation Authority's (1993) work on the European markets. This latter work has provided retrospective assessments of the implications of change and, in doing so, had important demonstration effects for further reform. In general, however, the number of studies of this kind looking strictly at international air transport have been relatively small in number.

Recently, the increased internationalization of airline services has created the need for more current analysis and a longer term need for different types of statistics. As a prerequisite, there are important initial issues of definition. To take two examples of the latter, there is considerable commercial interest, together with accompanying public and legal debate, about the desirability of certain types of airline alliances.[12] Debates of this nature require good data if ultimately they are to prove constructive, but a major problem is that there is no accepted definition of what exactly constitutes an alliance. This has led to the emergence of different sets of statistics.[13] Somewhat linked with this, reforms are resulting in the restructuring of airline service networks, but this leads to major problems in defining what constitutes an air service; simple point-to-point data, for example, provide only a partial picture because most trips involve transit through a hub airport.[14] This definition problem also brings to the fore the important

[10] This was a logical extension of the deregulation of domestic U.S. cargo markets in 1977 and U.S. domestic passenger markets in 1978.

[11] The new attitude toward economic regulation is reflected in the criteria by which regulated markets are now assessed. Regulation, aside from purely protective measures, has traditionally been viewed as containing monopoly power while permitting economies of scale to be enjoyed. The new emphasis focuses on minimizing X-inefficiency and maximizing dynamic efficiency. The result is that the institutional structure shifts to a greater focus on cost minimization and innovation. Inevitably this requires different models and data. Some examples follow: *allocative efficiency* requires first- or second-best pricing of the final product; *scale efficiency* requires possible limitation on sub-optimal entry to industry; *technical efficiency or X-efficiency* require cost minimization by the incumbent firms; and *product choice and dynamic efficiency* require innovation by incumbents.

[12] The majority of airline alliances that have attracted the most public interest have involved one or more European carriers joining with a large U.S. airline. Alliances are certainly not unique to air transport, nor to transport in general, but are one of the most rapidly growing forms of this business practice.

[13] As an illustration, one can compare the number of alliances recorded in recent reports in the *Economist*, *Airline Business*, and *Avmark Aviation Economist*.

[14] This definitional question is important in assessing the degree of competition between carriers when there is a need to delineate the markets being served, e.g., anti-trust immunity matters surrounding alliance approvals.

interface between domestic and international air transport. From a transport perspective, travelers and shippers are concerned about origin to destination characteristics, but the data generally available to policymakers are divided between the local and the trunk elements of a passenger or cargo movement.

The traditional data on physical features of the international airline activities, such as route-miles served, are important for some aspects of the new policy environment; however, they are generally inadequate for the negotiations that take place leading to reform. Negotiations usually focus on the comparative advantage of each nation's airlines rather than with physical parameters. Yet, it is this type of commercial data that is generally lacking, and the adoption of yield management practices makes it difficult to collect.

Freer market conditions, once they are attained, inevitably bring with them concerns about the performance of markets and the conduct of the airlines within them. In the air transport context these take two forms. At one extreme, there is concern that network industries are inherently unstable and, in economic terms, lack a "core."[15] Undersupply is the result. At the other extreme is the fear that given the economies of scale, scope, density, and market presence that are seen as features of the sector, there will be a long-term oligopolization of the sector; again undersupply results. Linked to the latter is a concern that opportunities for new market entry will be further restricted by incumbent airlines pursuing predatory practices.[16]

While tackling these problems may involve individual case studies, background statistics are important as benchmarks against which to assess behavior. This raises questions regarding such things as industrial rates of return in different market types, degrees of rate and service variability, differences in service quality, and comparative cost structures.

The need for more and better data is also likely to be stimulated further in the future by recent broader trends in trade policy. The gradual development of international liberalization of trade in services under the administration of the WTO has to date had minimal effects on the air transport sector, but as the role of WTO expands, the likelihood is that better quantitative information will be sought by those developing policy.[17] It will also become increasingly germane as multilateral policing and monitoring of the regime demand standardization of information.

Forecasting Demand

Often linked to public policy analysis and formation but also extending beyond it is the role of statistical information in predicting demand for international air transport. As a sector, international aviation will continue expanding into the foreseeable future, although at different rates in various geographic submarkets. A number of international agencies, aircraft manufacturers, and airlines regularly produce forecasts of aviation traffic, mainly related to scheduled services (e.g., Airbus Industry Annual; Boeing Commercial Airplane Group Annual b, ICAO Annual a; Daimler-Benz Aerospace 1995; Douglas Aircraft Co. Annual).

While forecasting remains more of an art than a science, it seems likely, taking an overview of these forecasts, that passenger traffic will grow at a rate between 5% and 7% into the foreseeable future, much of it in the Asian-Pacific region (up to 9% a year). Forecasts also show slower growth in the more mature U.S. and European air transport markets.

The nature of the long-term growth trend in air transport is less important than the details about individual markets and fluctuations in medium-term traffic levels. The evidence to date is that many forecasts are not particularly accurate in this

[15] The lack of a core means that because of the features of the market (e.g., decreasing costs) there is no stable equilibrium. If all potential suppliers are aware of this, then none will enter the market because they appreciate that their position is unsustainable. For a technical discussion of these issues see Button and Nijkamp (1998). There may be links between the creation of dominant market actors and concerns over an empty core, because one mechanism for private companies, such as airlines, to internalize the instability problem is to form a cartel or to seek monopoly power.

[16] This has parallels with traditional trade issues like dumping.

[17] The annex to the General Agreement on Trade in Services (GATS) dealing with aviation covers no firm rights and is limited to three doing business issues: aircraft repair and maintenance services, the selling and marketing of air transport services, and computer reservation systems.

TABLE 1 ICAO Seven-Year Forecast and Actual Flights on the North Atlantic (thousands)

	Base-year forecasts 1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1980	127.6	130.2	132.7													
1981	125.7	128.0	130.4	133.0												
1982	125.8	128.1	131.4	131.6	132.0											
1983	127.8	129.1	131.7	131.7	133.6	135.3										
1984	*132.7*	138.3	139.8	142.8	147.9	152.0	153.6									
1985		*140.8*	143.5	144.2	148.5	151.5	156.0	159.5								
1986			*141.4*	149.8	151.9	154.8	159.0	164.0	168.9							
1987				*158.5*	177.2	187.3	195.3	203.4	209.8	215.4						
1988					*175.7*	187.6	197.3	204.5	212.9	221.6	229.1					
1989						*192.0*	205.4	216.4	225.6	235.6	244.4	253.6				
1990							*206.1*	205.0	213.9	224.4	236.7	249.3	263.6			
1991								*213.0*	220.3	233.5	247.0	258.1	268.1	277.6		
1992									*228.2*	238.0	252.2	263.3	278.9	294.3	312.5	
1993										*242.8*	252.8	264.5	277.2	291.2	305.2	320.1

Note: Actual figures in italics.

latter respect[18] (see table 1). These medium-term forecasts are, however, particularly important in many managerial decisions, such as the ordering of new aircraft.

A problem with demand forecasting is that it traditionally has relied on extrapolations of patterns discerned in time series econometric analysis of past events and relationships. Establishing the nature of past and existing relationships between a range of variables and air travel demand is far from easy even with reliable data, but forecasting the future path of independent variables is generally more problematic. Assuming current and past relations will remain constant over the forecast period is also difficult.[19]

More recently airlines such as British Airways and manufacturers such as Boeing have been using various forms of scenario analysis in an attempt to develop strategies to confront uncertain futures (British Airway 1995). These involve less traditional statistical inputs but more qualitative material, and also require a range of forecasts of possible trends in those factors that influence the demand for air services and the costs of providing them.

Cost and Productivity Analysis

Costs of airline services are relevant for policymakers and airlines. The airlines have a commercial interest in having a finger on the pulse of their cost flows, especially as operations are increasingly market driven. Governments require cost data to assess not only legal matters regarding general industrial policy but also for such things as the way taxation policy is applied to the sector. There have been considerable advances in recent years in the ways in which airline costs and their efficiency can be measured.

The conventional accounting procedures and basic econometric models (e.g., using Leontief- or Cobb-Douglas-based functions) deployed until the late 1980s have been supplemented by more rigorous techniques as the understanding of the subtleties of cost functions has advanced, as methods of estimation have developed, and as relevant computer software has become available (e.g., Caves et al. 1987).

On the theoretical side, traditional neoclassical ideas of economies of scale have been supplemented by notions of economies of scope, density, networks, and experience.[20] On the demand side, ideas of economies of market presence have come to the fore in terms of influencing the optimal scale

[18] European Civil Aviation Administration (1994) offers a general discussion of air transport forecasting issues.

[19] Efforts at supplementing these procedures with Delphi and similar techniques do not resolve the problems and can, in some instances, worsen them.

[20] Economies of scale reflect declining costs of production as an airline's output increases; economies of scope are present when one airline can produce two or more services more cheaply than if these services were produced by separate airlines; economies of traffic density occur when the average unit cost of production declines as the amount of traffic increases between any given set of points served; economies of network size exist when the average cost of production declines as the number of city points served by an airline's network increases; economies of experience reflect falling costs with total sales in a market over time.

of activities and largely underlie the development of frequent flier programs and code-sharing alliances. Econometric models accommodate these features and allow parameter estimation through the use of flexible form models. The transcendental-logarithmic (trans-log) function is, for instance, now widely deployed because of its flexibility, although assigning input prices on items such as capital still poses serious problems.[21]

The recognition that inappropriately regulated market structures can lead to intervention failures, with associated high levels of X-inefficiency because carriers are not forced to produce on their lowest cost curves, has led to the adoption both of refined econometric procedures (e.g., the stochastic frontier approach) and programming techniques (particularly, data envelopment analysis) in empirical analysis. While technical disputes continue concerning the validity and usefulness of the alternatives, with institutional change, many of the assumptions of the more traditional ways of treating carrier cost functions are often no longer relevant.

Overall, these developments have implications for the type of data needed to carry out detailed cost and productivity analysis and pose particular problems in policy assessment because much of the data requirement, for example, that regarding yields, has commercial value associated with it. While this is an issue for analysis of any domestic system, it is even more of a problem when international comparisons are being attempted.

Infrastructure

Modern international air transport relies on an extensive infrastructure. This includes not only airports and the navigation and air traffic control systems but extends to the infrastructure required to get passengers and cargoes to and from air terminals. There is also the communications infrastructure necessary to coordinate the activities of customers of airline services and suppliers of services to airlines.[22] Much of this infrastructure is used by both domestic and international airlines, with airports serving as interchange points in the larger air transport network.

The infrastructure data requirements relate to ongoing activities for immediate management and operational planning (e.g., slot, gate, and parking space allocations) and longer term concerns about capacity planning and investments. The latter, given the time it takes to gain acceptance for capacity expansion, can require 30- to 40-year forecasts.[23] In many instances at major international hub airports, the banking pattern of flight arrivals and departures (i.e., flights converging and then departing within narrow timeframes), coupled with the need to integrate domestic and international connections, involves considerable interchange of information between airlines and airport authorities on the local scheduling committee.

In many markets with a large international presence, the available infrastructure is increasingly reaching its technical capacity.[24] While some of the problems lie in the poor management of much of the infrastructure (e.g., X-inefficiencies associated with public ownership and noneconomic pricing), there remain very real capacity issues. Expansion of capacity is, however, difficult because of concern over adverse environmental impacts.[25] In most industrialized countries, investment in more physical capacity requires extensive public inquiry pro-

[21] The standard approach is to estimate the -log cost (or production) function in combination with share equations using Zellner's seemingly unrelated least squares procedures. This increases degrees of freedom and means the estimates are invariate to the share equation omitted and converge to yield maximum likelihood estimates. Oum and Yu (1995) offer an example of this approach.

[22] The research on the role of computer reservation systems and passenger air transport is fairly extensive, but that on the cargo side is more limited (Button and Owens 1999).

[23] These need to be relatively accurate for engineering design purposes, but since costs and benefits are discounted in cost-benefit assessments, they can be less accurate over the longer period. Good short-term data is also required for slot allocation purposes. At present, allocations are usually done administratively (e.g., Castles 1997).

[24] A report published by IATA (1990), for instance, concluded that without further enhancements, capacity of 16 European airports would be severely limited by the turn of the century, with Madrid, Frankfurt, Heathrow, Gatwick, Barcelona and Milan (Linate) the most severely affected. Even if potential measures help to increase capacity, without new runways put into place, 13 airports would still remain constrained by 2010.

[25] It is no accident that perhaps one of the most comprehensive and expensive cost-benefit studies conducted was on the location of a new "Third London Airport." The recommendations of the inquiry team were rejected (Commission on the Third London Airport 1971).

cedures to be conducted. These inquiries are costly and take considerable time to complete.[26]

Safety

Air travel is, by most objective criteria, the safest way to travel. Nevertheless, there are accidents. Between 1987 and 1996, there were 205 commercial jet aircraft losses in the world, 41 by U.S. operators (Boeing Commercial Airline Group Annual a). Over 65% of these were during takeoff or landing. Over the same period, there were 142 fatal accidents involving jet aircraft, of which 108 involved passenger airlines and killed 6,156 people. Globally, data on smaller commercial aircraft accidents are less complete. Aircraft accidents often attract considerable media attention and public concern because of the large numbers of individuals that can be involved in any incident.[27]

The current rate of accidents involving all U.S. carriers has remained fairly constant since the mid-1970s at about 0.05 fatalities per 100,000 departures or 0.0008 per million aircraft-miles. Non-U.S. carriers as a group have slightly worse statistics. The actual number of incidents varies quite considerably year by year because of the unevenness of the fatality incident rate. The problem is that while on a purely mileage-related basis, air transport seems safe, the predicted growth in the sector means the absolute number of incidents will rise unless safety per se is improved. Improving safety, or indeed even convincing the public of the generally good safety record of international air transport, requires a solid statistical foundation.

In practice, aviation safety data are often incomplete, inconsistent, or have serious gaps. This is in part because countries collect data and define terms differently. The U.S. National Transportation Safety Board, for instance, uses a very broad definition of an accident: any incident that involves, for example, a broken bone is classified as an accident. Other countries use tighter definitions. Equally, there are differences in the way air misses are defined and reported.

Efforts have begun to improve the ways in which these safety data are collected across countries. The 33 European Civil Aviation Conference states have followed the U.S. Federal Aviation Administration (FAA) in establishing a system called "Safety of Foreign Aircraft" to collect data on incidents with foreign aircraft. It is intended that the incident database will provide enough evidence to approach the responsible state authority on the operational and technical qualities of its carriers' operations. The practical problem is how to collect these data.[28]

Safety policy involves making tradeoffs. Accidents have a variety of immediate financial costs to aircraft loss and damage, and there are also quantifiable financial costs of preventive policies, though statistics on these are less easily obtained. The costs of lost life and injuries pose more of a challenge. There are techniques available to put monetary values on these derived from both revealed preference and stated preference methodologies that are used in benefit-cost analysis, but they are not free of criticism.

Environmental Issues

Aviation activities impinge on the environment. There is a longstanding concern about aircraft noise nuisance[29] and the local implications of accessing airports by land. Recently, however, the focus has changed to atmospheric pollution around airports and from flights themselves. The change in focus is linked to increased concerns over the emissions of greenhouse gases and the potential damage to the ozone layer, but also reflects the increased marginal utility that societies enjoying

[26] The process is not speeded up by the need in virtually all cases for the decision to be based on entirely new sets of studies. The evidence to date is that there seems to be little capacity to deploy value transfer procedures in this area (Johnson and Button 1997).

[27] Technically, this would seem to imply the need for Bayesian statistical analysis, but Guassian modeling still demonstrates the technical literature. There is some evidence, though, that safety considerations can affect the viability of air carriers (Button 1997).

[28] At present, the United States does not make extensive use of the standard recording devices on aircraft except when a major incident occurs, in contrast to many other countries (e.g., the United Kingdom). In 1998, FAA began seeking ways to make better use of this data to gain insights on situations where incidents have been averted and on the general way crews perform their duties so that a more proactive approach to safety may be developed. The main issues concern an unwillingness of labor to have incidents highlighted.

[29] Nelson (1979) offers some early analysis of these issues.

rising material living standards place on environmental conservation and the well-being of future generations.

Exact calculations are difficult, both because there are gaps in the scientific understanding that we have of the damage done by aircraft emissions and because data on the physical emissions themselves are limited. At the global level, British Airways (1994) estimated that commercial aviation produces some 500 metric tons of carbon dioxide emissions per year and thus contributes 1.25% to 1.5% of the greenhouse gas emissions.[30] The ozone layer may also be affected by nitrogen oxide emissions in the middle atmosphere, and at lower levels it may contribute at the margin to acid rain. Concern has also been expressed about the implications of ice crystals from engine exhausts in the stratosphere. Good data are required to monitor the use of aviation fuel by various types of aircraft in differing operating conditions to provide a more exact estimate of the environmental implications of air transport.

Large aircraft are noisy, and noise complaints are common around international airports. There are various methods of presenting the noise problem in a quantitative form using indices,[31] but in and of themselves are seldom useful for policy debates other than to show changes in the scale of the problem. For policy debates, efforts have been made to provide monetary valuations of the noise measure, based on either hedonic price methods or contingent valuation techniques (Feitelson et al. 1996). However, the consensus has not yet emerged as to a universally applicable figure.

WHAT DO WE KNOW?

There are a variety of statistics available on different aspects of international air transport. Many are simply repetitive and others derivative, but even allowing for this, there are a number of primary and secondary sources that can be used. The goal of this section is not to give a detailed breakdown and commentary on all sources of data relating to international air transport; even a summary description of U.S. air travel would be excessively lengthy. Rather, this highlights the main types of data sources.

Some of the more easily accessible published data series are detailed in the appendix at the end of this paper. In addition to published statistics, there are numerous academic and consultant studies that have collected primary data that may be useful for meta-analysis.[32] The competitive nature of the international air passenger and air cargo sectors, however, means that much of the consultants' material is often confined to the "grey literature."

For a large number of the national agencies, global international air transport statistics are a secondary concern, and most agencies tend to focus their attention on the markets served by their own carriers. International data sets from international organizations are selective and limited. They tend to reflect those areas of activity over which the agency has responsibility. Mainly because of resource constraints and a lack of legal authority, organizations such as ICAO and IATA usually and inevitably rely on airlines and national governments to feed data to them. These data come in at varying speeds, often making full sets of statistics dated by the time of publication. In addition, the data are reduced to the lowest common denominator for comparative analysis. Methods of collection can vary between countries, and data reliability is sometimes suspect.

Those directly responsible for providing air transport offer a range of data sources. The aircraft manufacturers provide technical details of fleets and, in some instances, develop particular data sets to address issues of interest to them. This is particularly true regarding the age of aircraft fleets, their geographical dispersion, the technical reliability of individual types of aircraft, and their safety records.

Airlines provide standardized financial accounts at a national level to meet auditing requirements, but since such requirements differ between countries, comparability is often lacking.[33] In many

[30] Over time, aircraft are becoming more fuel efficient, but this is more than offset by the increased amount of air traffic.

[31] Quinet (1990) offers some examples.

[32] Button et al. (1999) provides a general discussion of the usefulness of meta-analysis in examining microeconomic issues.

[33] There are differences in the type of ownership of carriers, and in the types of information they need to make available for auditing purposes. A state-owned carrier is generally subject to different legal accounting rules from an airline that is a publicly traded or a private company, even within the same country.

countries, in part because of domestic regulations, data relating to service characteristics such as delays are published. Further, the global agencies, such as ICAO, and regional bodies, such as the Association of European Airlines and the Cargo Airlines Association, provide readily accessible compilations of secondary data and also periodic specialized studies using data gathered from members.

Providers of air transport infrastructure are useful sources of network-related information. The air traffic control and navigation systems provide aircraft flow data,[34] while the airports collect and publish data on international passenger and cargo movements through them. The need for customs and immigration clearance at many airports provides supplementary sources of data. Periodically, social and economic impact studies are conducted at individual airports, often as part of a statutory assessment procedure related to expansion programs of one kind or another. Such case studies generate insights into a variety of key parameters that become the bases for subsequent value transfer exercises.

The academic literature provides a range of data sources, parameter estimates, and information useful in value transfer and comparative analysis exercise. While the more general transport journals such as the various *Transportation Research* series, *Transportation Research Record, Journal of Transport Economics and Policy, International Journal of Transport Economics, Transportation, Transport Policy,* and *Transportation Reviews* often carry international air transport-related material, other specialized academic journals such as the *Avmark Aviation Economist* and the *Journal of Air Transport Management*, supplemented by trade-based publications such as *Airline Business* and *Aviation Daily*, are more regular suppliers of data and statistical analysis of international air transport issues.[35]

[34] In some cases, this is collected mainly for long-term planning purposes, but some agencies, such as Eurocontrol, have a major revenue-collecting function, and data is collected for accounting purposes.

[35] One might also add to this list of academic journals the disciplined-based publications in areas such as economics, engineering, and physics that carry pertinent material for many forms of air transport study.

TABLE 2 A General Indication of the Adequacy of International Air Transport Data

	Type of data			
Need	**Physical**	**Economic**	**Social**	**Modeling**
Policy assessment	++	+	+	+
Forecasting demand	++	+*	–	+*
Infra-structure	+	+	+	+
Costing	+	+	–	++
Safety	+	–	–	–
Environment	–	…	…	–

*The weaknesses here concern data availability and modeling procedures suitable for medium-term forecasting.

Scale: The most adequacy is indicated by ++, while the least adequate data are shown with …

WHERE ARE THE GAPS AND WEAKNESSES?

No single set of statistics will ever meet everyone's needs. There will always be gaps in data and the collection of redundant series. Statistics collection involves inevitable compromise and prioritization. International air transport is a complicated sector that can make the collection and subsequent presentation of statistics difficult. While offering a summary of the strengths and weaknesses of what is available is inevitably going to be subjective, and not in small part influenced by personal interests and knowledge, table 2 provides a simplified, normative assessment of the situation. It offers an indication of where data are available to meet the main needs of users, and where there would seem to be important gaps or weaknesses. The aspects of data considered are what might be thought of as basic—physical data, economic data, and social data—but added to this is a "modeling" criterion reflecting the types of technical instruments that are available for each need.[36]

Policy Assessment

In addition to the international sources of data that exist, many countries collect and publish additional statistics for their own, essentially policymaking,

[36] There is no intent to imply that each type of data is of equal importance for all needs.

purposes. This has traditionally been true at the more macro level for negotiating bilateral air service agreement adjustments, and more recently when considering such matters as responding to the emergence of a new strategic airline alliance (Dresner and Windle 1996).

In some instances, however, there have been criticisms concerning the nature of this information and its usefulness. For example, the U.S. General Accounting Office (1995c) has in the past been critical of the amount of suitable economic data available for conducting international bilateral negotiations.[37]

The initial thrust of the Open Skies policy in 1979 and prior de facto initiatives in stimulating the introduction of more liberal bilateral agreements by the United States between 1976 and 1981 were estimated by Dresner and Tretheway (1992) to have generated as much as $325 million in savings in North Atlantic fares alone in 1981. More global analysis was limited by the lack of complete data from less developed countries. Even the routes that were included could only be assessed as either the full economy fare or the lowest minimum fare.

The problems are not that data do not exist but rather that what exists is of limited use in addressing the questions under review. Physical data on passenger flows and flights are available, but these are often only of partial use in addressing what are fundamentally economic questions. While intellectually, for example, there may exist an a priori case for freer trade in international air transport services, in practice, bilateral negotiations are concerned with the costs and benefits of adjusting existing regulatory structures and, as we see below, data here are often lacking.[38]

[37] The USGAO (1995b) has also argued that the U.S. policy response to code-sharing has been hindered by "… such [things] as a lack of detailed data on foreign carriers' code-share traffic traveling to and from the United States" and again, "Data problems handicap DOT's efforts to place a value upon the access rights to the U.S. market that it relinquishes to foreign governments in exchange for improved access or code-sharing. (See also USGAO 1995a.)

[38] In very strict terms, trade is about comparative advantage rather than competitive advantage in a single sector and in this sense the types of negotiations that treat trade in air transport separately from trade in all goods and services is somewhat illogical.

Much of the data is also too aggregate to address key issues. This point was recently made in a study of alliances: "Probably because of the difficulty in obtaining consistent route specific data and the difficulty of separating effects of alliances from other changes, we are aware of only four empirical studies which attempted to measure the effects of airline alliances on carriers and consumers" (Oum and Park 1997).

Forecasting

Forecasting of both supply and demand is important for the effective longer term management of the international air transport system, but the time horizons differ for the various actors. Most major airlines have their own divisions responsible for making use of published statistics and for collecting and analyzing additional commercial material. The advent of computer reservation systems (CSRs) following the creation of Sabre by American Airlines provides for rapid feedback and response on an individual, specific services level. This information is the key to the successful dynamic price discrimination that now characterizes much of the sector. For short-term forecasts, because of this built-in, interactive data-collection/application element, CRSs tend to be efficient.[39]

Longer term planning by airlines and others requires more aggregate levels of information. One source is their own internal market surveys and another the publicly available forecasts of aggregate trends and predictions of change by market segments. Bringing these and other data together at the airline level is, however, not easy, as exemplified by the volatile cycles the sector experiences and the often overreaction of the airlines.

The evidence from the past is that airlines are often rather poor at forecasting the longer term demands that they are likely to encounter. The dramatic swings in profitability of the sector is a man-

[39] The issues here are rather ones of how much information the owner of a CRS should be allowed to keep confidential and the extent to which airlines should be permitted to use their own systems in a competitive air transport market. Good information on revenues and prices is required for public policy and infrastructure policy formulation, but also important is that for competition to be effective, air carriers require that they be allowed to exploit any comparative advantage that they may enjoy.

ifestation of airlines' responses to uncertainty. Little work has been completed looking at just why airlines have been so poor at predicting relatively short-term shifts in their markets and in making decisions about aircraft purchases.

The long-term aggregate market forecasts that the airlines and infrastructure providers use are relatively good at pinpointing broad trends, but much less reliable at foreseeing the turning points in medium-term cycles. The evidence available indicates that one of the difficulties is less the inadequacy of the statistics available within aviation and more the difficulties of predicting determining variables, such as income levels. In the U.S. domestic market, for instance, Morrison and Winston (1995) found that the high levels of excess capacity that existed in the market in 1990 to 1993 were largely due to airlines finding it difficult to predict the future levels of key economic indicators, such as income.[40]

Costing and Productivity

Cost analysis can involve looking at the cost function of either air services suppliers or users. The technical analysis of costing and productivity analysis of supply has advanced a long way in recent years. There is now a plethora of models that can be applied to the costing problem and a range of econometric and programming software available to conduct the empirical estimation. Often the issue is less one of finding a suitable modeling framework than that of selecting the most appropriate from those available.

Problems still remain, however, regarding the data to feed into the models. Some of these were touched on earlier in the discussion of policy. In particular, the greater the commercialization of international air transport as economic regulations are lessened and airlines are increasingly privatized means that cost data are less readily available.[41] Where these data are released it is often done so in very broad categories.

More specific weaknesses have emerged in some recent studies and take a variety of forms. First, outside of the United States few countries have the information required for detailed cost analyses. For example, in his work on international airline productivity using a total factor productivity model, Windle (1991), while having data on U.S. carriers' fuel inputs, had to impute fuel use for non-U.S. carriers.

In other cases, even when some data are available, there is the lack of consistent time series statistics. One example of the problem of point data is seen in the simulation study of European air transport networks conducted by Berechman and de Wit (1996). With only 1992 data on the distribution of business and nonbusiness class passengers, a time series for 1986 to 1992 had to be imputed. The aggregate nature of information on yield and the fact that it was available only for U.S. carriers on North Atlantic routes caused Maillebiau and Hanson (1995) to rely on a partial database in their log-linear estimation that they speculated would produce an error-in-variables bias leading to underestimation of fare elasticities.

The theoretical debates concerning the desirability of competitive international markets are founded on a set of assumptions that imply, for instance, that costs are divisible, demand is relatively elastic, and that suppliers do not all have identical U-shaped cost curves. Violation of such conditions can lead to an empty core and inadequate supply (instability conditions). Button (1996) was forced to rely on variety of proxy variables when seeking to establish whether market stability conditions existed for international air transport within the European Union.

The issue of capital, while conceptually quite straightforward, is always difficult to deal with in applied analysis. Setting aside physical problems such as capacity measurements, there are inevitable difficulties in putting a monetary value on a capital stock and the opportunity costs of using it in its

[40] This is certainly not a problem peculiar to international air transport. In the 1960s, the U.K. statistical authorities attempted to use a logistic curve extrapolation of car ownership to predict future national income trends on the pragmatic basis that, whatever the intellectual problems involved, this could produce more accurate forecasts. This was also prior to Friedman's famous judgments about the criteria upon which to evaluate economic models.

[41] It was not unknown for "creative accounting" to be practiced when government intervention was more widespread.

current activity. Historic costing has now largely been abandoned in analytical work, though official data often include it. Replacement costing, while having an appeal in many sectors, poses particular problems in air transport where technical change is rapid. These general issues are compounded at the international level when different countries pursue different accounting conventions regarding such things as depreciation.[42]

From the perspective of costs to air transport users, there are considerable gaps in our knowledge. Yield management often makes it difficult to conduct analysis beyond that of simply trying to explain average yield and its effects on demand. Even if this were not so, a full analysis of user costs would embrace assessment of the "generalized costs" of using air transport. Such a cost function would entail, in particular, the monetary equivalent of the overall time costs involved. While travel time valuations are available (e.g., they are used by FAA), they seldom reflect such important features as the unreliability of time taken for a trip or differentials for various components of a trip (e.g., travel to the airport, waiting time at the airport, changing planes, and flight time). The evidence available is that different types of air traveler's seek different time attributes from air services,[43] and this needs to be reflected in an appropriate abstract mode model.[44] Related to this is the need to look at trips using a definition that includes travel time to and from airports as part of the overall cost of trip making. There are gaps in the way that user costs are modeled and in the data that are available for estimation.

[42] The concept of depreciation in an expanding network industry is a complex one in itself. While there is a case in engineering terms and with respect to maintenance costs in assuming that links in a network depreciate with time or use, if the network is expanding, the external benefits from being a part of that larger network mean that a link may gain in value. Its economic value is appreciating, and it becomes a negative cost item.

[43] Leisure travelers put a premium on low fares, but business travelers put service quality (including frequency, duration of overall trip, etc.) as their prime concern. For details of the underlying theory of the money value of time, see Sharp (1981).

[44] For an account of the theory of abstract modes, see Quandt and Baumol (1983).

Infrastructure

Airports are diverse, engaging in multifaceted operations, and obtaining comparable data is not easy (Doganis 1992). At the very least, it is difficult to separate the implications of international air transport movements from those of domestic traffic. ICAO (Annual b) is the only agency that collects comparable financial data on airports, but separation of data by various traffic types is not comprehensive. The number of countries participating is also small, and the data provided are limited.[45] Even at the national level, because airports are generally under the authority of local governments or state agencies,[46] data on key economic indicators are often lacking.

One of the practical problems with financial statistics is that airports provide a range of different services, but many of these (e.g., handling of baggage and freight, and aircraft maintenance) are treated as commercial activities separate from the airport itself. The difficulty is compounded because the degree to which these types of service are handled by individual airports differs widely. Airports themselves vary considerably in terms of government involvement and control, and with this come differences in the nature of data disclosed. Differing national accounting practices add to the problem of comparability. The latter is also a major problem when examining air traffic control systems.

There is also the practical problem of deciding what the financial data actually implies; the increasing trend toward privatization and corporatization in many countries means that profit trends may well reflect the degree of monopoly power rather than efficiency. Total factor productivity models (e.g., involving such techniques as nonparametric index number) are now available, offering more useful guidance to efficiency (Hooper and Hensher 1997).

[45] Within Europe, as early as 1984 the European Commission attempted to establish indicators that would provide a basis for inter-airport comparisons as well as international comparisons.

[46] A very small number of major international airports such as Heathrow in the United Kingdom are privately owned, and here conflicts arise regarding availability of data. Commercial considerations point toward a degree of confidentiality, but at the same time the monopoly power of airports such as Heathrow has led to regulation and with it the requirement of public accountability.

Furthermore, there are issues concerning air traffic control and navigation systems. Many systems throughout the world are outdated and considered technologically obsolete. Countries such as the United States are attempting to update their systems and to incorporate new ideas such "Free Flight" into the way air traffic is managed. Elsewhere, most notably the European Union, the effort is on standardizing what are presently a diverse collection of national systems. Overlapping this are new initiatives for stimulating greater efficiency in the management of systems, for example, the Canadian move to corporatizing their system and the United Kingdom's introduction of private financing. Efficient use of resources in this rapidly changing environment requires not only good physical data but also reliable models and carefully constructed financial data. The financial data are particularly important if economically based charging is to be more widely adopted, both from a strict accounting perspective and as insurance at the international level that there is no exploitation of systems.

Safety

Safety statistics at the aggregate level are extensive and available in long time series. There is a need for greater international consistency, especially regarding the developing nations and the former communist states of Europe, but even here the international agencies are making progress. Safety data are sparse; incidents are infrequent and, increasingly because of improved technology and regulatory controls, often unique. As a result, the emphasis tends to be increasingly on looking at conditions where a potential for a serious incident existed but was avoided. Data on air misses has a long pedigree, but at the international level there are problems in that definitions of air misses vary between countries, and reporting of incidents is not always consistent.[47] As noted above, there are also major national differences in the way that cockpit recorded data are collected and used, in part because of labor relations problems and because insensitive collection could lead to adverse feedback on cabin crew behavior. These microdata are important, however, since the cause of many accidents is not known (e.g., flying into terrain) or results of a series of actions may not be immediately clear from the currently available data.

Presentation and explanations of safety data pose serious problems. It is generally agreed by economists that from a cost-benefit point of view, air transport may be too safe, that is, resources devoted to airline safety would yield a higher social return in some other use. Media coverage of incidents is part of the explanation (accidents involve a spatial and temporal concentration of deaths and injuries that make for spectacular journalism),[48] as is a general lack of education on the nature of probabilities. How this problem could be resolved is uncertain, but public knowledge of transportation safety is, in general, inadequate.

Environment

Concern about the environmental damage associated with air transport, beyond issues of noise nuisance, is comparatively recent and growing (USGAO 1992). It is not surprising that there is still considerable uncertainty about the physical links involved, let alone the economic and social implications. The gaps in this area are, thus, considerable. Part of the problem lies in the need for more pure scientific analysis to ascertain how various pollutants associated with air transport adversely affect the environment. Before this issue is fully clarified, it is impossible to place viable monetary values on environmental effects.[49]

In many ways, broad criticisms of environmental data transcend any discussion of the air transport sector. Many of the issues are new, the impacts often long term, and the underlying relationships

[47] Domestically in the United States, there have been periodic changes in rules of reporting with, for example, immunity from liability being given when incidents were reported between 1968 and 1971 but removed after 1971. Rates of reported incidents were found to go down significantly after 1972 (McKenzie and Shughart 1988). There was a dramatic drop in the number of air misses recorded in the period immediately following President Reagan's dismissal of striking air traffic controllers in the early 1980s, possibly because the there were not enough controllers available to take reports.

[48] As a personal aside, I have often wondered what the situation would be if newspapers were legally forced to give the same number of column inches to a transport death irrespective of the mode involved.

[49] There are additional problems in that aviation fuel can be bought at various points on an aircraft's flight itinerary, and hence, the amount of fuel burned on any particular flight is difficult to ascertain.

not fully understood (Button 1993; Levinson et al. 1998). The issues often have more to do with a need for basic scientific research than with large-scale data collection. What is missing, however, is a systematic effort to bring together existing knowledge and to ensure that ongoing and future analyses present findings and data in ways that allow for viable synthesis. There are many ways in which quantitative information and empirical findings may be brought together, but for full efficiency common reporting procedures are generally required.[50]

CONCLUSIONS

Reliable statistics are important both for public policymaking in international air transport and for the commercial vitality of operators. The world in which air transport operates is, however, a rapidly changing one. There are major technological advances not only in aircraft but also in the information and control systems that control their use. Institutional adjustments mean that the role of government is now different from what it was 20 years ago, with market forces, privatization, and commercialism playing a much stronger part in the way the sector functions. This produces new challenges in terms of information requirements.

It is not only the airlines' component of the sector that is undergoing transformation. Airports are being privatized or are being required to operate in a more commercially oriented manner, and air traffic control is in some instances being put on a more accountable basis. Successful change requires reliable and germane data if ex ante policy decisions are to meet specified criteria and ex post operations are to be efficient. At the international level, greater transparency will inevitably be needed if liberalization is to continue and not be thwarted by concerns of market manipulations at the infrastructure level.

What is encouraging is that international air transport statistics are in many ways improving and becoming more consistent. The coming together of national groupings, such as the European Union, to develop consistent "internal" air transport policies has necessitated this in some cases. The major international agencies in air transport, such as IATA and ICAO, have new roles to play in this respect, as the traditional structure of the industry changes and as new markets, particularly in the Pacific rim area and in Eastern and Central Europe, grow, albeit at a rather stuttering pace. The emergence of more competitive markets and greater commercialism in the sector as a whole poses additional challenges but equally stimulate actors to participate more fully in internalizing their data needs.

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APPENDIX

International air transport data are available from a number of national and international organizations and commercial undertakings. While not an exhaustive inventory of data sources, this listing represents most of the major sources of data and what they attempt to show.[51] They are divided by the national or international agency source. Much of the data summaries from U.S. sources are adapted from the *Directory of Transportation Data Sources, 1996*, produced by the Bureau of Transportation Statistics, U.S. Department of Transportation.

U.S. Department of Transportation, Bureau of Transportation Statistics

Name: *North American Transportation Statistics on Canadian, Mexican, and United States Transportation*
Frequency: Biennial
Summary: This source provides data on the size, scope, and use of the various transportation modes in the three nations. Most of the data pertain to land modes (rail, highway, etc.), but there are some aviation data.

Name: *Combined T-9 and Service Segment (Data Bank 27T)*
Frequency: Monthly
Summary: This databank shows point-to-point international traffic data between the United States and the originating/terminating nation. It does not show final passenger destinations; such data would be covered by domestic sources. This data set was replaced by Form 41 Schedule T-100 in 1990.

[51] The author is indebted to Kirk Johnson for his assistance in compiling the list of data sources. What this list makes no attempt to cover are series that normally appear in a more general data series (e.g., in National Income Accounts, Labor Statistics, etc.). Data from these sources are often used in meso-level comparative analyis.

Name: *Schedule P-12(a) Fuel Consumption by Type of Service and Entity*
Frequency: Monthly
Summary: This source reports fuel consumption by aircraft operations by geographic area and service type (scheduled vs. nonscheduled).

Name: *T-100 International Segments (Data Bank 28IM and 28IS)*
Frequency: Monthly
Summary: All relevant data are collected relating to particular nonstop international flights for U.S. air carriers. Data are embargoed for three years before release.

Name: *Origin and Destination Survey (Data Bank 1A)*
Frequency: Quarterly
Summary: This database is derived from a 10% survey of air carriers. It provides a full itinerary of the air travel for all large U.S. certificated air carriers. The data sample all travel, so not all are international in nature.

Name: *American Travel Survey*
Frequency: 5 years
Summary: This survey provides limited long-distance international travel data.

U.S. Customs Service

Name: *U.S. Exports of Domestic and Foreign Merchandise (EM-545)*
Frequency: Monthly
Summary: This database shows the weight, quantity, nation of destination, and assessed valuation of merchandise leaving the United States.

Name: *U.S. General Imports and Imports for Consumption (IM-145)*
Frequency: Monthly
Summary: This source contains data on the net quantity, valuation, and nation of origin for imports.

U.S. Department of Commerce, International Trade Administration

Name: *Canadian Travel to the United States*
Frequency: Annual
Summary: This sample details tourism from Canada to the United States (by individual state). Data include visitor nights, mode of transport, purpose, spending patterns, lodging, and seasonality.

Name: *Historical Arrivals Database*
Frequency: Annual
Summary: The data show annual arrivals from over 100 nations and regions.

Name: *In-Flight Survey of International Air Travelers; Overseas Visitors to the U.S.; U.S. Travelers to Overseas Countries*
Frequency: Annual
Summary: These data sets provide information on travel and spending patterns both to and from the United States. The data include places visited, demographics, means of booking, and duration stayed. The data summarize other sources.

Name: *International Air Passenger Database*
Frequency: Monthly (with both quarterly and annual summaries)
Summary: This data set shows international flight characteristics such as arrival/departure, class of aircraft, date of flight, flight number, and total number of U.S. nationals and foreigners.

Name: *Outlook for International Travel to and from the United States*
Frequency: Annual
Summary: This data set forecasts international travel to and from the United States, taking into account economic and political factors (e.g., recession, war, fluctuating currencies).

United Nations, International Civil Aviation Organization (ICAO)

Name: *Civil Aviation Statistics of the World*
Frequency: Annual
Summary: Provides summary data for a variety of air transportation sources, such as arrival/departure information, scheduled services, and the like.

Name: *The World of Civil Aviation*
Frequency: Annual
Summary: This publication provides an accounting of the major developments and trends in the international air transport arena over the past couple years and forecasts some of the potential trends in the short-term future on both a global and regional basis. It also discusses economic influences, policy issues, and the role of air carriers and airports in current and future industry trends.

Name: *Accident/Incident Reporting (ADREP)*
Frequency: Annual
Summary: This source reports annual statistics of accidents and incidents occurring within the ICAO reporting area.

Name: *Surveys of International Air Transport Fares and Rates*
Frequency: Annual
Summary: This source discusses the differences in international airfares. A separate publication exists to discuss regional differences in rates and costs.

Name: *Outlook for Air Transport to the Year 2005*
Frequency: Annual
Summary: This report forecasts broad trends in air transportation on a variety of topics into the middle of the next decade.

Name: *Digests of Statistics*
Frequency: Annual
Summary: This is a set of reports that discusses air travel demands, financial data for the industry, origin and destination statistics, and the like.

International Air Transportation Association (IATA)

Name: *North Atlantic Report*
Frequency: Annual
Summary: The database shows information on changes in traffic for individual airlines and the total route market.

Name: *Monthly International Statistics*
Frequency: Monthly
Summary: This shows traffic and capacity results from 85 major, scheduled airlines in the survey. The reporting delay is only about four weeks for these data.

Name: *World Air Transport Statistics*
Frequency: Annual
Summary: This annual report shows 10-year trends in traffic, capacity, finance, and fleet for IATA's member airlines, of which there are currently 85.

Name: *ASIA/PACIFIC Air Transport Forecast (1980–2010)*
Frequency: Annual
Summary: This publication forecasts travel demand between the Asian-Pacific and the rest of the world, assessing various traffic areas. It analyzes passenger traffic volumes and past growth, and discusses current hub activities and congestion.

Name: *European Air Transport Forecast (1980–2010)*
Frequency: Annual
Summary: This report forecasts air travel demand for European markets, much like the previous Asia-Pacific report, and includes statistics, albeit limited, on air travel in the former Soviet Union states.

Name: *North America Air Transport Forecast (1980–2010)*
Frequency: Annual
Summary: This publication forecasts air travel demand for the United States, Canada, and Mexico.

Name: *Passenger Forecast (1996–2000)*
Frequency: Annual
Summary: This report gives an aggregated view of the world's major airlines to forecast passenger demand for 66 countries. The report also disaggregates trends to 17 different world regions. Although not comprehensive, the statistics cover approximately 86% of the world's total international air traffic demand.

Australian Department of Transport

Name: *AVSTATS—International Scheduled Air Transport*
Frequency: Monthly and annually
Summary: This data set includes figures on revenue passenger, freight, and mail data, airline market shares, seat utilization, and the like for operations to and from Australia. The publication contains trend analysis from the previous year for comparison.

Airports Council International

Name: *Worldwide Airport Traffic Report*
Frequency: Annual
Summary: The data show passenger, freight, mail, and aircraft takeoffs/landings for major world airports.

European Union

Name: *New Cronos*
Frequency: Annual
Summary: Contains data on international passenger characteristics, origin/destination by country (especially within the E.U. member states) with aggregation for world regions (e.g., South America and the Indian Subcontinent). Also, arrival/departure data are available from major airports within E.U. member states.

Air Transport Association

Name: *ATA/Gallup Air Travel Survey*
Frequency: Annual
Summary: These data summarize a Gallup poll on American air travel for those 18 and older. It shows percentages of both domestic and international flights.

Name: *Passenger and Cargo Traffic History*
Frequency: Annual
Summary: This report shows aggregated figures on revenue passenger-miles and cargo capacity for U.S. carriers flying internationally.

Name: *Passenger Load Factor History*
Frequency: Annual
Summary: This source shows load percentages for U.S. carriers flying internationally.

Name: *Monthly Passenger Traffic Statistics*
Frequency: Monthly
Summary: These data include revenue passengers, load factors, enplanements, etc. for the international operations of U.S. carriers.

Name: *Monthly Cargo Traffic Statistics*
Frequency: Monthly
Summary: These data include international freight and mail delivery for U.S. carriers.

Reed Travel Group

Name: *Official Airlines Guide (OAG)*
Frequency: Monthly
Summary: The OAG is a set of publications that describe the flights available for all major airlines on both a domestic and international basis, including information on fares.

Office Development, Parking Management, and Travel Behavior: The Case of Midtown Atlanta

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ABSTRACT

The effects of special parking provisions in zoning ordinances are assessed based on a case study of Midtown Atlanta. The study results indicate that it is somewhat easier to promote increased office development around rail transit stations than it is to reduce parking construction associated with such office development. It also appears that spill-over parking is a much more likely commuter response to parking pricing than is alternative mode use, especially where the private automobile is the dominant mode of commuter transportation and reasonably priced alternative parking lots are conveniently located.

INTRODUCTION

Zoning ordinances often require more parking than is required to serve the access needs of new development (Shoup and Pickrell 1978). The result in most suburban office settings is ample free parking or, from a different perspective, the absence of parking pricing needed to discipline travel markets (Shoup 1982). Even in central business districts

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(CBDs), where parking pricing is the rule rather than the exception, as much as half or more of all employees may receive free parking, either directly provided or reimbursed by their employers (Roche and Willson 1986).

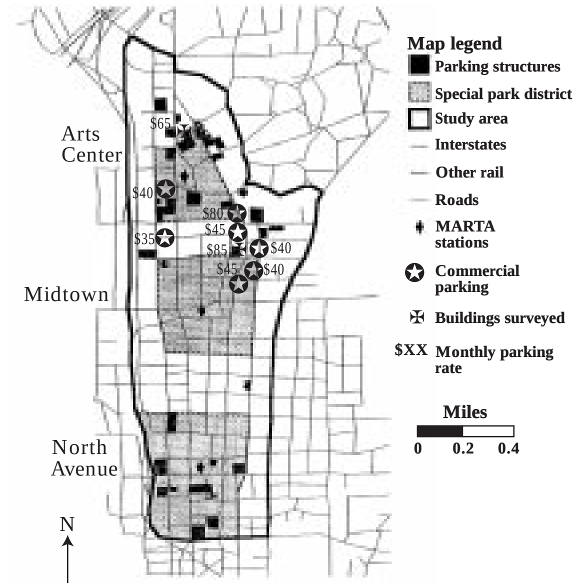
Transportation influences land use by allowing higher density development as greater accessibility is provided (Giuliano 1989). Beltways have transformed many urban areas. Suburban highway junctures can develop into employment centers rivaling the CBD in terms of both size and influence (Payne-Maxie and Blayney-Dyett 1980). Rapid rail transit is posited to have similar effects, though perhaps on a somewhat smaller scale (Cervero and Landis 1993).

Local communities often attempt to steer development through zoning ordinances, providing tax breaks, density bonuses, and other incentives to attract certain types of development activity to specific locations within their jurisdiction (Forkenbrock 1990; Cervero 1994). Atlanta, Georgia, is one such city. The city of Atlanta modified its zoning ordinance in 1981 to promote economic development by easing restrictions on building construction near rapid rail stations. An example of this is the elimination of all parking requirements in redevelopment zones called Special Public Interest Districts (SPIDs). This paper will analyze the local effects of SPIDs on land development and travel behavior in Midtown Atlanta.

Data

The data used in this analysis were derived from a case study of Midtown Atlanta, a major employment center in the city of Atlanta, located just four miles north of the traditional CBD (Nelson et al. 1995). For the purposes of this study, a cordon line was draw around three nearly contiguous SPIDs in the Midtown area: the North Avenue, Midtown, and Arts Center rail stations. Preliminary data on availability, occupancy, and pricing were collected for all high rise office buildings and commercial parking facilities located in the study area through a combination of telephone interviews and windshield surveys. Two sites were identified within the study area's boundaries for further analysis, based on detailed employer and employee surveys. Each site selected was composed of two adjacent buildings. The first site was located just inside, the second site just outside, Midtown's SPID boundaries (see figure 1).

FIGURE 1 Midtown Study Area



Employers located at both sites were surveyed regarding employee parking policies. Of the 74 tenants in the 4 buildings surveyed, 29 returned surveys for an overall 39% response rate. Employees of all building tenants were surveyed simultaneously regarding mode of travel to work, parking, and related issues. Of the 74 tenants resident in the 4 buildings, 36 (49%) returned 1 or more employee surveys. Of the 674 employees of these 36 responding firms, 350 (52%) returned employee surveys. This response rate is adequate to ensure a representative sample of employees and employers within the sites selected.

Methodology

The methodology employed here is simple and straightforward. We have a single study area composed of a unified land market in a fairly homogeneous neighborhood commonly recognized as such and therefore called Midtown. Within the study area there are three SPIDs. Buildings, building tenants, and their employees must be either inside or outside an SPID.

We will look at the dynamics of speculative high rise office development inside and outside SPIDs within the Midtown study area. In addition, we will also analyze travel behavior and parking utilization among employees inside and outside SPIDs within the Midtown study area.

The following hypotheses will be tested:

Group I
1. SPIDs increase development
2. SPIDs reduce parking supply
3. SPIDs increase parking pricing

Group II
4. SPIDs modify travel behavior
5. SPIDs encourage transit use

The first three hypotheses can be tested explicitly based on analysis of a full inventory or a census of the local market for commercial office space before and after SPID implementation. The last two hypotheses require the use of statistical methods applied to a survey sample of employees inside and outside SPIDs. The statistical methods used here include categorical analysis based on cross-tabulation and non-linear regression analysis using the logit model.

The mode choice model used is a basic logit model of the following form:

$$P = e^U / (1 + e^U)$$

where

P = probability of mode choice, and

U = utility of mode choice

for the binary mode choice case. Most of the choices modeled here are binary. Mode choice for work trips is modeled as three mutually exclusive levels of alternative mode use: a) never, b) occasional, and c) regular. Mode choice for non-work trips is modeled as four non-exclusive binary choices: rail, bus, walk, and bicycle. Parking location is modeled as a single binary choice: a) onsite and b) offsite.

These dependent variable specifications are quite simple and largely data driven. Further breakdowns by specific alternative modes for work trips or specific trip purposes for non-work trips were hindered by the limited variability available in this particular data set. The results presented here are, for the most elaborate models, consistent with the initial construction of implicit hypotheses as embodied in the original survey instrument and the limitations inherent in the actual data.

Parking location and mode choice can be modeled simultaneously (Westin and Gillen 1977). In this analysis, these two elements of travel demand are treated separately, mainly because of limited variability in mode choice among the few regular users of alternative modes found in Midtown Atlanta. In order to model parking location and mode choice together, it would be necessary at the very least to separate travel modes into those that require parking and those that do not. The overwhelming reliance of Midtown Atlanta commuters on the solo driven private automobile creates a lot of statistical power sufficient to model parking location.

THE BUILT ENVIRONMENT

The Atlanta metropolitan region, with a population of more than 3½ million in 1997, is one of the 10 largest urban areas in the United States, as well as one of the fastest growing. The city of Atlanta, with a population barely exceeding 400,000, is one of the smallest central cities in the United States and among the most stagnant in terms of population growth. The city of Atlanta actually declined in population in the 1970s, stabilizing somewhat only after 1980. Meanwhile, the surrounding Atlanta suburbs have grown by leaps and bounds. Annexation is not a serious option for Atlanta, due to special provisions of the state constitution that make both local annexation efforts and the incorporation of entirely new cities unusually difficult to accomplish.

The Midtown area was one of Atlanta's first true residential suburbs. It was laid out by upscale developers in the early part of the 20th century, just four miles north of the original CBD. The Midtown area was annexed by the city of Atlanta after World War I and grew to maturity as one of its most prestigious residential neighborhoods. The first office boom in Midtown occurred in the late 1960s, with 7 buildings of 8 to 24 stories going up between 1964 and 1974. Midtown developed a bad reputation in the late 1970's as the aging housing stock suffered a serious decline. In the 1980s, Midtown residential property values rebounded as Yuppies moved in, becoming urban pioneers of sorts. Meanwhile, Midtown's second office boom ran from 1986 to 1994, with 10 new office towers of 10 to 50 stories augmenting the Midtown skyline.

The Midtown area has excellent access to both highways and public transit (see figure 2). The "Connector," a short, merged link of I-75 and I-85, runs directly adjacent to the area on the west side, with two full-service Midtown exit ramps, including partial access roads both north and south. The Metropolitan Atlanta Regional Transportation Authority (MARTA) is a combined rail and bus transit system. Over 90% of MARTA's bus passengers are routed to the rail system by design, making MARTA one of the most rail-dominated transit systems in the world. There are three MARTA rail stations in the Midtown area, strung together like beads on a string and closely spaced along Peachtree Street, the central traffic artery running from the CBD through Midtown and Buckhead all the way out to the farthest northern suburbs.

MARTA was created by an act of the Georgia State Legislature in 1965, with a mandate to operate existing bus service while planning and implementing a proposed rapid rail system in and around Atlanta. The rail system plan was completed in 1971. A referendum to support construction of the rail system through the institution of a regional 1¢ sales tax was approved by voters in Fulton and DeKalb counties but rejected by voters in Cobb and Gwinnett counties. Portions of the east-west rail line opened for service to the general public in 1979. The north-south rail line opened shortly thereafter, with service to the three Midtown rail stations starting in 1981 and 1982.

Special Public Interest Districts

In 1981, the city of Atlanta established SPIDs around MARTA rail stations in three sections of the city: Downtown, Midtown (the study area), and Buckhead (see figure 2). The purpose of all three of these SPIDs was to promote high-density

FIGURE 2 MARTA Service Area

commercial office development in conjunction with the location of MARTA rail stations:

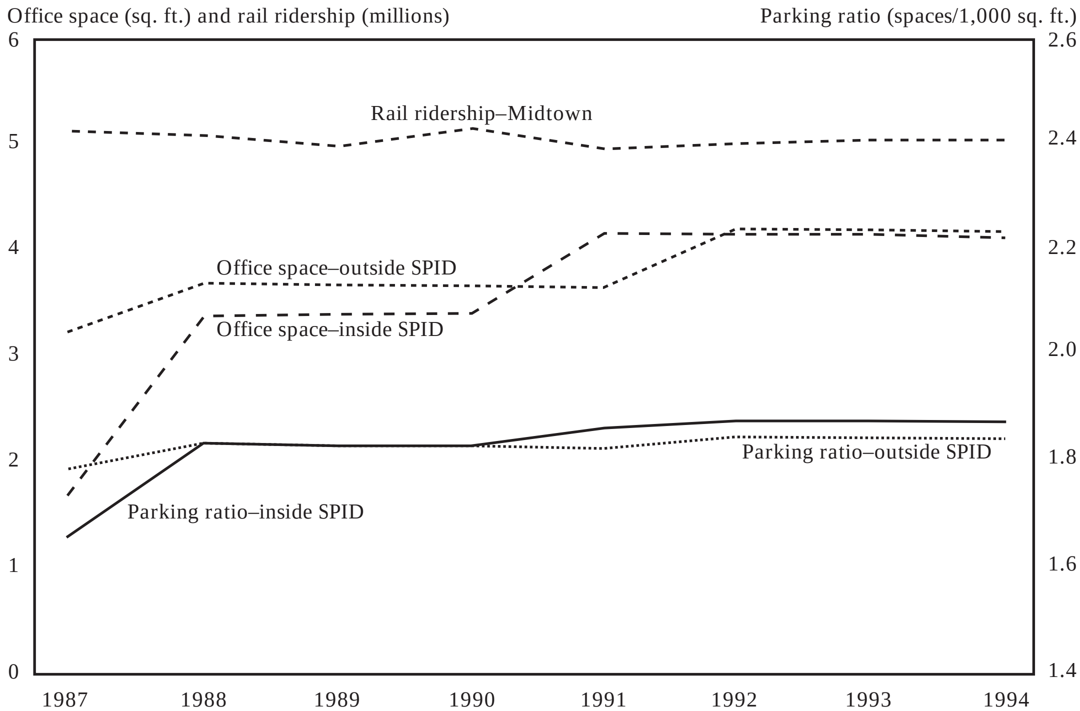
1. Developments inside SPIDs were freed from any parking requirements whatsoever, and were allowed to build to any height desired under permissible density restrictions.
2. Developments outside SPIDs were required to construct a minimum of 2 parking spaces per 1,000 square feet of commercial office space, and existing height restrictions effectively limited buildings to 30 stories or less.

SPID boundaries were drawn approximately 1,000 feet around each MARTA rail station, with major street thoroughfares used as the actual dividing lines. Walking distance to MARTA was thus the default criterion used to determine whether any particular proposed development project fell inside or outside the domain of SPID provisions (see figure 1).

Office Development

The Midtown office market was dormant both during and after the deep economic recession that struck the nation in the early 1980s. It was not until 1986, five years after SPIDs were first put in place, that the Midtown office market began to revive. At the beginning of this new office development cycle, there were 4.8 million square feet of

FIGURE 3 Midtown Office Development



commercial office space available in Midtown, two-thirds of which was located outside SPID boundaries (see figure 3). Parking ratios for preexisting office developments were 1.65 inside and 1.78 outside SPIDs.

During the occasionally frenzied land speculation and office development activity that occurred in Midtown in the late 1980s, a net 3.5 million square feet of office space was added to the preexisting stock. Just over 70% of this new office development occurred inside rather than outside SPID boundaries. Given more than sufficient availability of vacant and underutilized land in the Midtown area, SPIDs, it seems, had been successful in promoting office development within comfortable walking distance of MARTA rail stations.

There was one problem. New Midtown developments outside SPIDs built an average of 2.07 parking spaces per 1,000 square feet of commercial office space, barely above the minimum requirements set by the city. Interestingly, however, new Midtown developments inside SPIDs built an average of 2.03 parking spaces per 1,000 square feet of commercial office space, barely distinguishable from new developments outside SPIDs and certainly well above the city's requirement of zero. Far from building no new parking, Midtown developers inside SPIDs added parking at virtually the same rate as did their local competitors outside SPIDs. Based on this evidence, one cannot conclude that SPIDs resulted in any decrease in the availability of Midtown parking at all.

Building Management

Building managers influence employee travel behavior primarily through parking policies. Building managers may choose to charge for parking, provide it free of charge, or include it in signed lease agreements. They may restrict parking to tenants, employees, and their visitors or open it up to anyone who happens to pass by. Building managers can reserve some, all, or no parking for tenants and their employees. Building managers who charge for parking may do so on an hourly, daily, weekly, or monthly basis.

Shoup (1982) found that free employee parking is almost always bundled with long-term office leases, at least in Southern California. Building managers in Midtown Atlanta generally provide no free parking, either to tenants or their employees, with or without long-term office leases. This practice seems to be a basic condition of the local market, applicable to all Midtown office buildings, not just those included in the present study. Midtown tenants are given the option to reserve parking for their employees, up to a limit of 2 parking spaces per 1,000 square feet of leased office or retail space. Any such "reserved" spaces must be paid for separately and in addition to the office lease, either by the tenant or the employee.

Commercial parking rates in Midtown Atlanta varied widely in 1995, from $1.25 to $8.50 on a daily basis, and from $22.50 to $85 on a monthly basis depending on location and site-specific amenities. The four buildings included in this analysis were toward the high end of this scale, with maximum daily rates of $6 and $7.50 and regular monthly rates of $65 and $85, inside and outside SPIDs, respectively. Commercial parking lots with daily rates of $2 to $4 and monthly rates of $30 to $40 were concentrated mainly in the central Midtown area (see figure 1). Several inexpensive surface commercial parking lots were immediately adjacent to Site 2, located just outside the central Midtown SPID, while only one such lot, located just inside the northern Midtown SPID, was within convenient walking distance of Site 1.

EMPLOYEE DEMOGRAPHICS

The demographics of the two sites surveyed were reassuringly similar (see table 1). Employees inside SPIDs were significantly more likely than those outside to hold professional job titles and to have attended some graduate school. Employees inside SPIDs were slightly older than those outside, with higher incomes and more autos, and more likely to live in the suburbs. None of these latter differences were statistically significant, even at the 0.10 level, though age and auto availability bordered on statistical significance.

Overall, it appears that the demographics of the two sites were almost, but not quite, identical. It appears that employees inside SPIDs were perhaps slightly more "upscale" than those outside, but this tendency, if one can even call it that, was mathematically weak, and therefore unlikely to skew the numerical results or invalidate the experimental design. Midtown employee demographics were comparable to both the Atlanta region and the United States as a whole. Major differences includ-

TABLE 1 Demographics by Site

Demographics	Percentage of employees: Inside SPID	Percentage of employees: Outside SPID	χ^2 (d.f.)†
Profession:			
Manager/supervisor	20.3	29.6	
Professional/technical	46.0	30.3	9.23 (2)***
Other	33.7	40.2	
Age:			
Under 30	32.6	33.3	
30–39	28.8	37.3	3.88 (2)
40+	38.6	29.4	
Gender:			
Male	34.2	38.7	
Female	65.8	61.3	0.74 (1)
Race:			
White	85.4	81.0	
Non-white	14.6	19.0	3.10 (1)*
Education:			
Some graduate school	45.7	31.2	
Some college	47.3	60.4	
No college	7.0	8.4	7.56 (2)**
Annual household income:			
<$30,000	33.9	39.1	
$30,000–74,999	27.1	23.9	0.98 (2)
>$75,000	39.0	37.0	
Household auto availability:			
N cars < N adults	8.7	11.2	
N cars = N adults	66.7	72.4	3.53 (2)
N cars > N adults	24.6	16.4	
Residential location:			
Fulton/DeKalb counties	59.8	62.5	
Cobb/Gwinnett counties	25.7	24.3	0.27 (2)
Other	14.5	13.2	

† level of significance
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

ed a higher proportion of women than the national average and a lower proportion of minorities than the Atlanta average.

Working Conditions

Unlike demographics, which varied consistently if slightly, working conditions varied either tremendously or not at all by site location (see table 2). Length of employment and the average amount of time spent at work in an average day were virtually identical inside and outside SPIDs. Workers inside SPIDs had greater flexibility in choosing when to start their work day and were more likely ever to have worked at home. It appears that the slightly more upscale workers inside SPIDs had much greater autonomy in selecting key aspects of their employment conditions.

TABLE 2 Working Conditions by Site

Working conditions	Percentage of employees: Inside SPID	Percentage of employees: Outside SPID	χ^2 (d.f.)†
Length of employment:			
< 12 months	32.8	28.9	
12–35 months	35.5	40.1	0.90 (2)
> 36 months	31.7	30.9	
Average time spent at work:			
< 9 hours	28.1	28.1	
9–9.5 hours	42.7	41.1	0.12 (2)
> 9.5 hours	29.2	30.8	
Flexibility in arrival time:			
< 15 minutes	20.9	35.7	
15–30 minutes	51.6	54.5	19.23 (2)***
> 30 minutes	27.5	9.8	
Ever worked at home:			
No	42.9	62.4	
Yes	57.1	37.6	13.11 (1)***
Who pays for parking:			
Employer pays	56.8	25.5	
Shared cost	15.1	6.4	55.71 (2)***
Employee pays	28.1	68.2	

† level of significance
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

The most significant difference in working conditions had to do with who pays for employee parking. Employees inside SPIDs were more than twice as likely to receive free parking from their employers. Employees outside SPIDs were more than twice as likely to have to bear the full burden of their own parking costs. The slightly more upscale and much more autonomous workers inside SPIDs were significantly more likely than those outside SPIDs to receive parking subsidies from their employers. This effect, although unanticipated from an experimental design perspective, seems reasonable on its face, given the employee demographics and working conditions found in Midtown Atlanta. The slightly higher parking rates outside SPIDs may also have contributed to this phenomenon.

Travel to Work

Over 90% of Midtown employees drove alone to work on a regular basis (see table 3). About a third had tried carpooling, and a quarter had tried MARTA rail at least once in their lives as an alternative mode of transportation for the journey to work. Only 1 in 10 Midtown employees regularly commuted using any mode of transportation other than driving alone. Half of those who did use alternative modes sometimes also drove alone on a regular basis. Driving alone is thus not only the dominant mode of transportation for work travel in Midtown Atlanta, it is overwhelmingly dominant. There were no significant differences between employees inside SPIDs and those outside, in terms of mode choice for the journey to work on either a regular or an occasional basis.

There may have been virtually no difference between sites in terms of how Midtown employees got to work. There was a major difference in where they parked their cars once they got there, however. Midtown employees outside SPIDs were 10 times as likely as those inside to park their cars offsite rather than onsite, a very significant difference. Employees outside SPIDs in this particular instance faced higher parking fees onsite, were less likely to receive parking subsidies from their employers, and had more convenient access to competitively priced commercial parking than did their confreres inside SPIDs (see figure 1).

TABLE 3 Travel to Work by Site

Travel to work	Percentage of employees: Inside SPID	Outside SPID	χ^2 (d.f.)†
Use of alternative modes:			
Never use	36.5	34.4	
Occasionally use	54.7	54.1	0.70 (2)
Regularly use	8.9	11.5	
Regular modes of travel:			
Drive alone	94.3	93.0	0.24 (1)
Carpool	5.2	5.7	0.05 (1)
MARTA bus	1.0	1.9	0.46 (1)
MARTA rail	2.6	3.2	0.10 (1)
Walk	1.0	3.2	2.02 (1)
Occasional modes of travel:			
Drive alone	2.1	5.7	3.21 (1)*‡
Carpool	30.7	33.8	0.36 (1)
MARTA bus	9.4	8.3	0.13 (1)
MARTA rail	29.7	24.2	1.31 (1)
Walk	0.5	1.3	0.57 (1)
Bicycle	5.2	1.9	2.62 (1)
Taxi	1.0	3.2	2.02 (1)
Where park:			
Onsite	96.4	63.7	
Offsite	3.6	36.3	61.52 (1)***

† level of significance
‡ statistical artefact
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

Non-Work Travel

Only one in five vehicle trips are made for commuting purposes these days (Pisarski 1992). Non-work trips, when chained together with work trips, may interfere with the ability of commuters to adopt alternative modes of travel (Bhat 1996). Midtown Atlanta employees were asked if they ever used MARTA bus or rail, walked, or rode bicycles for six varieties of non-work travel:

1. work-related business
2. personal business/errands
3. shopping/dining
4. recreation/entertainment
5. education/school
6. social/visit friends

There were few statistically significant differences between employees inside and outside SPIDs in their use of alternative modes of transportation for such non-work travel (see table 4). Overall, employees inside SPIDs were slightly more likely to use MARTA rail for non-work travel, a reasonable finding given the relative proximity of these employees to the Arts Center MARTA station. Interestingly, most of the observed difference in MARTA rail travel for non-work trips is accountable by one trip purpose, namely work-related business, though personal business/errands also contributes to the phenomenon.

PARKING PRICING

The effects of SPIDs should not be felt directly by commuters but rather indirectly. Thus, parking construction requirements, limitations, or freedoms should translate directly into parking prices, whether higher or lower. Higher parking prices associated with reduced parking supply might then result in measurable shifts in mode choice for the work trip, an indirect effect. Atlanta's SPIDs had no effect on parking supply, at least not the expected negative effect, but even this should not diminish the independent contribution of parking pricing to mode choice changes in any way. About half of the Midtown employees surveyed had to pay some or all of their parking costs (see table 2).

Oddly enough, however, paying for parking did not seem to translate into mode choice changes of any significance in Midtown Atlanta (see table 5). This is naturally somewhat disappointing, given the literature on the subject, which constantly reiterates that parking price elasticities are indeed very significant (Shoup 1995), and that demand management strategies based on parking pricing are the ones most likely to achieve measurable changes in travel behavior under normal circumstances (Higgins 1990).

Midtown Atlanta employees who paid for parking were slightly less likely to use alternative modes of transportation to get to work and slightly more likely to use three out of four alternative modes for non-work travel, but none of these measured differences were even close to being statistically significant. Furthermore, while employees who paid for parking were significantly more likely to park offsite

TABLE 4 Non-Work Travel by Site

Non-work travel	Percentage of employees: Inside SPID	Percentage of employees: Outside SPID	χ^2 (d.f.)†
Any trip purpose:			
MARTA bus	8.3	10.2	0.36 (1)
MARTA rail	64.6	55.4	3.04 (1)*
Walk	39.1	40.1	0.04 (1)
Bicycle	22.9	18.5	1.03 (1)
MARTA bus:			
Work-related business	4.2	3.8	0.03 (1)
Personal business/ errands	3.1	3.8	0.13 (1)
Shopping/dining	1.0	2.5	1.16 (1)
Recreation/ entertainment	5.2	6.4	0.22 (1)
Education/school	0.5	0.6	0.02 (1)
Social/visit friends	1.6	3.2	1.01 (1)
MARTA rail:			
Work-related business	40.6	17.2	22.54 (1)***
Personal business/ errands	26.0	15.9	5.24 (1)**
Shopping/dining	9.9	6.4	1.41 (1)
Recreation/ entertainment	44.8	42.0	0.27 (1)
Education/school	3.1	2.5	0.10 (1)
Social/visit friends	4.7	5.1	0.03 (1)
Walk:			
Work-related business	8.3	8.3	0.00 (1)
Personal business/ errands	14.1	15.9	0.24 (1)
Shopping/dining	13.5	18.5	1.58 (1)
Recreation/ entertainment	25.5	30.6	1.10 (1)
Education/school	2.1	0.6	1.28 (1)
Social/visit friends	14.6	14.6	0.00 (1)
Bicycle:			
Work-related business	1.6	0.0	2.47 (1)
Personal business/ errands	2.1	6.4	4.12 (1)** ‡
Shopping/dining	2.6	2.5	0.00 (1)
Recreation/ entertainment	20.8	17.2	0.74 (1)
Education/school	0.5	0.0	0.82 (1)
Social/visit friends	6.8	3.8	1.46 (1)

† level of significance
‡ statistical artefact
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

TABLE 5 Employee Behavior by Employer Parking Payment

Travel behavior	Employer pays for parking: No	Employer pays for parking: Yes	χ^2 (d.f.)†
Work travel: Alternative modes			
Never use	37.0	34.6	
Occasionally use	53.0	55.3	0.46 (2)
Regularly use	10.0	10.1	
Non-work travel: Alternative modes			
Bus	10.1	10.0	0.25 (1)
Rail	62.5	57.7	0.82 (1)
Walk	41.5	36.9	0.75 (1)
Bicycle	21.0	20.8	0.00 (1)
Parking location:			
Onsite	68.0	100.0	
Offsite	32.0	0.0	58.39 (1)***

† level of significance
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

than those who were entitled to receive free parking, this finding is not surprising and contributes little to science. If simple cross-tabulations cannot produce the anticipated results, it is possible that a more powerful statistical tool, such as multiple linear regression, may succeed where others have failed.

LOGISTIC REGRESSION

Preliminary results based on bivariate hypothesis testing seem to suggest that the choice of parking location varies with parking management strategies, but mode choice does not, at least not in Midtown Atlanta. These results, although mathematically quite convincing, are at least partially counterintuitive from a purely theoretical point of view. In addition, we have not yet controlled for either working conditions or demographic variables, both of which might conceivably alter some or all of these findings.

Logistic regression was performed on all dependent variables (parking location and mode choice for the work trip and for non-work travel) using a partial stepwise technique (see table 6). Building location (inside or outside SPIDs) and parking price (or rather, the level of employer parking subsidy, an inverse function of parking price) were forced into each of the equations for hypothesis testing purposes. All remaining variables (both working conditions and demographics) were forced into each equation at first and then removed one at a time until only those variables that were at least marginally statistically significant ($t \geq 1$) remained. This procedure limited mul-

TABLE 6 Employee Travel Behavior by Site, Working Conditions and Demographics

Variable	Park offsite	Use of alternative modes					
		Work trips		Non-work trips			
		Regular	Occasional	Bus	Rail	Walk	Bicycle
Intercept	2.75** (1.30)	0.23 (1.40)	0.40 (0.90)	–0.41 (1.50)	2.56** (1.03)	1.52 (0.95)	0.33 (0.94)
Outside SPID (1 = yes, 0 = no)	2.35*** (0.48)	–0.46 (0.47)	0.34	0.25 (0.46)	–0.41 (0.30)	0.22 (0.27)	–0.40 (0.31)
ln (length of employment)	–0.38** (0.17)		(0.27)** (0.10)		0.22* (0.12)		
ln (arrival time flexibility)					0.28** (0.11)		
ln (employer parking subsidy)	–0.53*** (0.12)	–0.09 (0.12)	0.04 (0.06)	–0.13 (0.11)	–0.12* (0.07)	–0.01 (0.06)	–0.01 (0.07)
Managerial (1 = yes, 0 = no)	–0.59 (0.51)					–0.64** (0.32)	
Professional (1 = yes, 0 = no)				0.64 (0.47)		–0.81*** (0.31)	
Male (1 = yes, 0 = no)	–0.50 (0.44)					–0.51* (0.28)	
Black (1 = yes, 0 = no)		1.71*** (0.52)	–0.49 (0.40)				
Graduate school (1 = yes, 0 = no)		–1.19** (0.56)	0.42 (0.27)		0.80*** (0.30)	0.49* (0.27)	
ln (income)	–0.95*** (0.32)	–0.43 (0.35)	–0.28 (0.22)	–0.60* (0.35)	–0.74*** (0.25)	–0.38* (0.22)	–0.37* (0.22)
Live outside core (1 = yes, 0 = no)		–1.84*** (0.64)	–0.32 (0.25)	–1.12** (0.53)	0.60** (0.27)		
Log likelihood—initial	–209	–209	–202	–208	–194	–216	–218
Log likelihood—at convergence	–90	–77	–194	–81	–166	–202	–160
N observations	302	301	292	300	280	311	315
Percentage correctly predicted	88	91	61	91	70	62	79

Note: Standard errors are in parentheses.
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

ticollinearity while providing maximum information on the overall statistical power of the model and each of the independent explanatory variables thus considered.

Site Effects

The regressions reaffirm the significant contribution made by building location to choice of parking location. The building site surveyed outside SPIDs was actually closer to the heart of Midtown, while the building site surveyed inside SPIDs was perched on the northern fringe of Midtown (see figure 1). The building site surveyed outside SPIDs had a somewhat higher monthly parking rate onsite ($85 vs. $65), far fewer employees who received free parking from their employers (25% vs. 57%), and much more convenient access to lower priced commercial parking (four lots within one block vs. one lot within two blocks). The site variable captures the effects of differential parking rates and availability simultaneously. Parking subsidies are treated as a separate variable in this analysis.

There was no statistically significant relationship found between building location and mode choice. There was not even a strongly identifiable pattern to the marginally significant or clearly insignificant signs in the equations. Employees outside SPIDs were less likely to commute regularly but more likely to commute occasionally via alternative modes, less likely to use MARTA rail but more likely to use MARTA bus, less likely to ride bicycles but more likely to walk for non-work travel purposes. The results shown in table 4, then, remain as a more useful guide than these insignificant regression findings.

Parking Subsidies

The elasticity of demand for offsite parking with respect to employer parking subsidies in Midtown Atlanta is both high (–0.50) and very significant ($t > 4.00$). The elasticity of demand for alternative modes of transportation with respect to employer parking subsidies is both low (circa –0.10) and barely significant ($t < 2.00$) in just one out of six cases. Removing the site variable from the equations has little effect on estimated mode choice price elasticities but increases the offsite parking price elasticity to an even higher –0.70. Thus, –0.50 is a conservative estimate of the price elasticity of demand with respect to parking location, based on these data.

Shoup (1995) identified seven case studies in which the elasticity of demand for solo automobile commuting with respect to parking price varied from a low of –0.08 to a high of –0.23, with an average of –0.15. An average of 67% of employees receiving free parking drove alone to work, versus 42% of those who had to pay for parking across Shoup's seven cases. Four of Shoup's cases are traditional CBDs, while the remaining three are large, high-density urban and suburban employment activity centers not unlike Midtown Atlanta, in terms of urban design and the built environment. The parking price elasticities measured here for regular commuting and rail and bus transit use for non-work travel are not statistically very powerful but are clearly within the range of previous studies, albeit at the low end of that range.

Feeney (1989) found that parking price elasticities can be even lower than those reported by Shoup in suburban enclaves, with a range of –0.01 to –0.05 based on the limited European examples he provides. The results found here suggest that Midtown Atlanta, with highway and transit access similar to many CBDs, in addition to a physical location just four miles north of the original Atlanta CBD, exhibits travel behavior characteristics that are perhaps a bit more like what one would expect to find somewhere out on the exurban periphery of the metropolis. The overall transit mode share in Midtown Atlanta is estimated to be about 7% (Nelson 1995). There was no increase in transit ridership observed during the second office building boom of 1986–94, however, indicating that office workers may not be the best market for transit ridership in mixed use Midtown Atlanta (see figure 3).

The upshot of these findings is that Midtown Atlanta employees are far more likely to park offsite than to stop driving alone to work in response to parking pricing. The only requirement for offsite parking is that reasonably priced, conveniently located parking alternatives must exist. Such parking alternatives might include onstreet parking in adjacent streets or offstreet parking in lots or garages. Onstreet parking can be controlled using time limits, parking meters, or residential permits. Offstreet parking can be controlled using pricing, gates, or guards. Where parking is limited in supply or high in price, spillover parking may quickly become a problem unless all parking in both the public and private sectors is controlled in one way or another to restrict access to those for whom that parking was originally intended.

Other Working Conditions

Some working conditions fared better than employer parking subsidies in the equations; others, worse. Neither average length of time spent at work (a measure of job commitment, perhaps) nor ever having worked at home (another measure of job commitment as well as work autonomy) remained in any of the equations once the stepwise regression procedure was completed, showing just how strongly insignificant these two variables were.

Length of employment was negatively associated with parking offsite, showing that walking in the rain eventually becomes a nuisance. Length of employment (i.e., seniority) surprisingly was not associated with the level of employer parking subsidies provided. In fact, other than choice of parking location, employer parking subsidies were not associated with any other variables in the analysis, with the minor exceptions of gender and race, discussed below.

Length of employment was positively associated with ever using a) any alternative to driving alone to get to work, and b) MARTA rail for any non-work travel. This presumably is a simple matter of probabilistic chance associated with longevity, as well as car reliability and job commitment. Individuals with greater flexibility in arrival time at work were more likely to have used MARTA rail for non-work travel, particularly work-related business and personal business and errands.

Demographic Effects

There were a variety of interesting demographic effects on travel behavior to complement those previously reported. Income appeared with a negative sign in all seven equations. Income was not significantly related to mode choice for the work trip, however. Income was significantly related to a lower probability of alternative mode use for non-work travel.

Residential location operated very much like the income variable in the equations, with all negative signs. Residential location appeared in only four equations, however; significantly, in only three. Midtown workers who lived outside the urban core and the MARTA service area defined by Fulton and DeKalb counties were significantly less likely to use alternative modes of transportation to get to work on a regular basis and were also significantly less likely to use MARTA rail or bus for non-work travel. The estimated effect on regular commuting, however, was much larger than the one for non-work travel using MARTA.

Age was significantly related to a few of the dependent variables, but was highly correlated with many of the other independent variables as well. This led to multicollinearity, excessively large standard errors for age and other variables, and wide fluctuations in the estimation of model parameters with and without the age variable in the model. As a result, age was eliminated from the model on an a priori basis and does not appear in any of the final equations. If age had been allowed to remain in the model, it would have appeared as a significant variable in the same equations with the same signs but larger coefficients than length of employment, a variable that does appear in the model. Thus, length of employment may be viewed as a proxy for age.

Education betrayed some interesting effects in the model. Highly educated persons were significantly less likely to use alternative modes for commuting, but significantly more likely to use MARTA rail and to walk for non-work trip purposes. Education has been shown to be negatively associated with the use of alternative modes for commuting (Ferguson 1997) and positively associated with the number of trips generated on a daily basis and with average trip length (Lave 1998).

Occupation barely made it into any of the equations. The primary finding was that managers and professionals alike were significantly less likely to walk during non-work travel. Managers' principal trips involved socializing and visiting friends; professionals' trips were for personal errands, shopping, and dining.

Within the equations, men acted much like managers and professionals, which is not surprising, given that almost 90% of Midtown men held managerial or professional job titles, as compared with 50% of Midtown women. In addition, men were significantly more likely to receive employer parking subsidies than were women in Midtown.

Blacks were significantly more likely than non-blacks to use alternative modes of travel to get to work on a regular basis. Blacks were significantly more likely to use MARTA rail to get to work on an occasional basis but significantly less likely to carpool to work on an occasional basis, producing an overall effect on the occasional use of alternative modes for commuting that was not significant.

Blacks were significantly more likely to get parking subsidies than were non-blacks in Midtown Atlanta, but this was probably a statistical artefact. A large proportion of blacks employed in Midtown Atlanta worked for building managers rather than building tenants. Building managers were among the few firms to offer free parking to all employees, for the fairly obvious reason that they had complete control of all onsite parking and relatively few employees.

MODE OF TRAVEL AND PARKING LOCATION

There may be a deeper and more significant relationship between choice of parking location and mode choice for the journey to work. If one is at least a partial substitute for the other, does this make these two apparently independent choices related to each other as extended travel behavioral alternatives? It appears that the answer to this question is yes, at least in part. With no inference regarding causality intended, it appears that alternative mode users are significantly more likely to park offsite than are dedicated solo drivers, and this propensity increases with the regularity of alternative mode use (see table 7).

The observed relationship is fairly weak but always consistent. It is statistically significant only when controlling for parking pricing. These results would be substantially improved if the sample of regular alternative mode users was larger, but this cannot be helped in the present instance. The percentages would not have to change, only the sample size on one end of the distribution, in order for most of these conditional probabilities to be significantly different from each other.

A full model of parking location would explicitly treat tradeoffs between parking price differentials, walk access times, and other characteristics of parking amenities (e.g., covered parking vs. parking exposed to the elements and parking attendant always on duty vs. empty lot). For a relatively large number of alternative parking facilities, such a model has more in common with destination choice than with mode choice models, and might benefit from the formulation of a gravity-type model interface for the more accurate estimation of model parameters.

TABLE 7 Parking Location by Work Travel, Parking Payment, and Site

	Percentage of employees who park offsite by use of alternative modes			
Conditional statements	**Regular**	**Occasional**	**Never**	**χ^2 (d.f.)†**
All employees	22.9 n = 35	20.0 n = 190	14.5 n = 124	2.04 (2)
Employee pays full cost of parking	50.0 n = 16	38.4 n = 86	23.7 n = 59	5.32 (2)*
Employee pays full cost of parking and building is located outside SPID	72.7 n = 11	51.7 n = 60	38.9 n = 36	4.11 (2)

† level of significance
* significant at 0.10 level
** significant at 0.05 level
*** significant at 0.01 level

Combining a gravity-type destination choice model for parking location with a logit-type mode choice model for work trips is certainly possible, but would not be particularly easy to accomplish and would require a much larger and more elaborate database than provided here. Consider that parking location is relevant for solo commuters, carpoolers, and bicyclists, but not for transit users and walkers. Bicycle parking is an entirely separate issue from automobile parking in most instances. Developing such a model and finding the data required to estimate its parameters might be a very worthwhile future research undertaking.

CONCLUSIONS

It appears that SPIDs were more effective in promoting commercial office development around MARTA rail stations than in promoting the use of MARTA rail for commuting to and from Midtown Atlanta. The parking provisions of SPIDs appear to have been more successful in increasing parking supply and thereby reducing spillover parking than in increasing the price of parking or inducing mode choice changes for the journey to work among Midtown commuters.

Parking price elasticities with respect to driving alone appear to be on the order of –0.10 in Midtown Atlanta. This number is somewhat on the low side perhaps but is clearly in line with previous research, at least with respect to suburban operating environments. Parking price elasticities with respect to parking location appear to be on the order of –0.5, a very significant finding in and of itself. It appears that concerns about spillover parking are not unwarranted, given the much greater elasticity of demand for parking somewhere else, as opposed to finding another way to get to work in an automobile-dominated employment environment. Spillover parking is often illegal, and where it is not illegal, it is often considered to be illicit, except where approved markets have been established, as is the case of commercial parking lots in Midtown Atlanta. Because of the illicit nature of many kinds of spillover parking, there are few, if any, previous studies that estimate the effect of parking pricing on the use of alternative parking facilities, as has been done here.

There appears to be a weak substitution effect between parking location and mode choice. That is to say, those people who are more willing to park offsite appear to be more willing to use alternative modes of travel and vice versa. On the one hand, the elimination of spillover parking might thereby induce greater use of alternative modes. On the other hand, attempts to forcibly encourage alternative mode use might easily result in spillover parking instead.

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