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Foreword

The papers in this Record deal with a broad spectrum of topics relating to transportation economics, finance, and administration. The papers are divided into five topics: transportation finance, economic analysis, socioeconomic effects of transportation, transportation education and training, and the conduct of research.

The papers on finance address issues of electronic toll collection systems, highway revenues and expenditures, the use of congestion pricing on new toll roads, local government approaches to financing highway improvements, regional transportation financing, and evaluating THRIFT computer software for financial forecasting.

The papers on economic and socioeconomic analysis in transportation cover a wide spectrum of subjects. Among the topics discussed are comparative performance of highway systems, calculating the economic benefits of increased pavement life, investment requirements for new urban highway capacity, determining truck system costs on interstate highways, relationship between highway infrastructure and economic development, economic techniques for predicting pavement life, economic development resulting from interstate and coastal highways, implementing electronic toll collection and traffic management systems, and road conditions and maintenance input for feasibility studies.

The third section of the Record is focused on the social and economic consequences of transportation improvements. Among the topics presented are effects of elevated rail transit systems on house prices, modeling spatial impacts of transportation facilities, growth around rural highway interchanges, employment effects of highway investment, and methodology for estimating the economic effects of highway improvements.

In a paper on the subject of education and training, transportation engineering and planning education in Europe and the likely direction that it will take in the future are discussed.

In the fifth section, various aspects of managing research programs are discussed. Topics presented include managing technical research, collaborative research programs, and marketing transportation technology.

PART 1

Finance

Consumer Responses to Advanced Automotive Electronics: User Survey on Electronic Toll Collection Systems

YOUNGBIN YIM

To improve toll collection services, toll agencies in California are considering an electronic toll collection system for state-owned toll bridges and toll roads. Potential benefits of this system seem apparent, yet little is known about how consumers respond to the new technology. In October and December 1990, several surveys were conducted among San Francisco Bay Area motorists. The surveys show that Bay Area motorists are highly receptive to electronic toll collection technology. The perceived benefits of the technology include reduced traffic congestion at toll gates and improved air quality. The surveys also suggest that demand for the electronic toll collection service among commercial users is more elastic with respect to cost than it is among motorists.

To improve toll collection, the California Department of Transportation (Caltrans) is considering an electronic toll collection (ETC) system for state-owned toll bridges and toll roads. The ETC system may offer significant benefits to both the users and the operators of toll facilities. Using ETC, motorists would be able to (a) pass through the toll plaza without stopping at a toll booth, unless traffic conditions prohibit it, (b) avoid cash toll payments on each trip or avoid purchasing commute ticket books, and (c) obtain records of all tolls paid for business purposes. The societal benefits expected from ETC include reduced traffic congestion at toll plazas, reduced fuel consumption per vehicle usage, reduced air pollution at toll gates, and a reduction of labor and overhead in toll operation (*1*).

Even though the benefits of ETC are potentially significant, how consumers respond to the ETC technology is largely unknown. In 1990 the Institute of Transportation Studies (ITS) of the University of California at Berkeley, in association with GLS Research, conducted several surveys of toll bridge users in the San Francisco Bay Area. The study was supported by Caltrans.

The objective of the surveys was to determine the level of interest among Bay Area motorists for ETC systems. The concerns were (a) the level of demand in subscriptions to the ETC service, (b) the preferred types of automated vehicle identification (AVI) tags, (c) the preferred mounting location or placement of AVI tags on the vehicle, (d) the desired method of payment for the ETC service, and (e) the perceived benefits of ETC. The surveys included a mail survey of the toll bridge users among Bay Area motorists, a telephone survey of mail survey respondents, and a telephone survey of commercial users. The mail survey, conducted in October 1990, determined the overall interest in subscriptions to an ETC service among motorists who use the Bay Area toll bridges. The follow-up telephone survey, conducted in December 1990, determined the levels of interest in ETC when operational information was provided. A separate telephone survey of trucking firms conducted in December 1990 assessed commercial users' interest in ETC and their sensitivity to its operational aspects.

In the following paragraphs, discussion begins with a review of literature on similar studies. Then the methodology used in conducting the surveys is presented, followed by the findings of the surveys of motorists and commercial users.

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ETC TECHNOLOGY

To use an ETC system, a subscriber opens an account with the toll agency and obtains an AVI tag, or transponder, for the vehicle. The tag is flat, about the size of a candy bar, and can be placed either inside or outside the vehicle. Every time a motorist passes through a toll plaza, sensors read the tag and automatically deduct the toll from the balance in the motorist's account.

A number of ETC systems are currently in operation in states such as Texas, Louisiana, Florida, and New York. The Dallas North Tollway, operated by the Texas Turnpike Authority, has an ETC system covering its entire 14 mi, with another 3 mi under construction. One major advantage has been an increase in the processing capacity of the toll booths. Before implementation of the system, toll booths were processing 350 to 400 vehicles per hour per lane (*2,3*). After implementation, some toll booths were processing 700 to 750 vehicles, with approximately 40 percent of peak traffic motorists using AVI. The Texas Turnpike Authority estimates that dedicating a lane strictly to AVI would result in a processing rate of 1,200 to 1,500 vehicles per hour.

The Texas system uses Amtech Corporation's TollTag, which employs a radio frequency (RF) technology. TollTags are actually small transponders that reflect and modify continuous radio wave signals. Readers receive the signals from the RF module and transmit the data to a computer or some other logging device. The system, operating since 1989, includes 62 toll stations equipped with coin counting and AVI equipment. Amtech Corporation was retained to install and operate the system, shifting the liability from the public agency to the private sector. Demand for the service has grown; in April 1990 AVI represented 13 percent of the transactions on the tollway on a weekly basis. During peak periods, 20 percent of the traffic used the ETC system.

The San Diego–Coronado Bridge was the first ETC system installed in California. It was initiated in October 1988 as a pilot project to test the ETC system and was discontinued in 1990. The Coronado system used AVI technology developed by X-CYTE Corporation. This system was based on acoustical wave technology tags that could be read by remote RF readers (*4*). Each RF tag was assigned a unique number of identifying the vehicle. An electronic tag the size of a credit card was attached to the windshield. The Grosse Ile Bridge in southwest Detroit also uses AVI surface acoustical wave (SAW) technology by X-CYTE. On a typical day, approximately 3,900 (65 percent) of the 6,000 daily transactions on this bridge are by AVI.

The Delaware River Port Authority uses an AVI system on its four toll bridges in the greater Philadelphia area. The system is manufactured by LazerData Corporation and uses an optical laser scanner designed for bar-code reading where a wide scan angle or long reading range is required. A barcoded sticker is attached to the driver's side window. AVI patronage on these four bridges during April 1990 accounted for approximately 30 percent of the total traffic.

PREVIOUS STUDIES

During the past few years, surveys have been conducted by various agencies in other states to learn about consumer attitudes toward ETC technology. These surveys have included the Dulles Fastoll by the Virginia Department of Transportation (VDOT), state toll facilities by the Illinois State Toll Highway Authority (ITHA), the Oklahoma Turnpike by the Oklahoma Turnpike Authority (OTA), the Florida Turnpike by the Florida Department of Transportation (FDOT), and three toll crossings—the Lincoln Tunnel, Goethals Bridge, and George Washington Bridge—by AT/Comm together with the Port Authority of New York and New Jersey (PNYNJ) (*5*). Between October 1989 and May 1990, AT/Comm also surveyed 54 U.S. and two European agencies to determine system designs, market potentials, and pricing structures of ETC (*6*).

In those surveys, toll agencies were concerned with similar issues, such as the level of demand for the ETC system, the preferred payment method, and the demographic profile of potential patrons of the system. Although the sample sizes varied and the return rates differed, similar responses were received. In general, the previous surveys suggested that toll patrons would be highly receptive to ETC technology but would be less receptive to electronic funds transfer (EFT) technology. The majority of the survey respondents (from 56 to 82 percent) expressed an interest in using the ETC system. For the toll payments, the respondents still preferred cash to credit cards or EFT systems. The EFT method was least desired among motorists, possibly because it is not perceived as advantageous. The surveys also suggested that toll users would expect to keep a minimum balance over $20 to open an ETC account and would not mind paying $20 to $25 for the AVI tag deposit.

As expected, the motorists responding to the surveys were mostly commuters who used the toll facilities frequently. In the FDOT survey, 82.7 percent of the trips on the Florida Turnpike were to or from work. The AT/Comm study showed that 83 percent of the respondents traveling on the Lincoln Tunnel and the Goethals and George Washington bridges in New York were driving to or from work. The VDOT survey showed that nearly 75 percent of the respondents were traveling to or from work.

In the previous studies, more men responded to the surveys than women. The respondents were generally between 30 and 50 years of age, had two or more cars in their household, and had an annual household income of between $25,000 and $75,000.

METHODOLOGY

As explained previously, the study was divided into three parts: (a) a mail survey of toll bridge users among Bay Area motorists, (b) a follow-up telephone survey of the mail survey respondents, and (c) a telephone survey of commercial users.

A major concern was whether or not the samples were truly representative. Even though the mail survey questionnaires were distributed randomly at toll gates, they were probably more likely to be returned by those who had a favorable response to the ETC technology. There were no techniques that could guarantee truly unbiased returns nor were there magic numbers that could completely mitigate biased responses. There were ways, however, in which statistical analysis could be made more rigorous to better control response biases.

At the outset of the study, it was recognized that there were at least three ways in which nonrandom samples could be generated: (a) distribution of questionnaires, (b) scheduling of distribution, and (c) nonresponse. Several approaches were used to assess and minimize the impact of these biases.

First, the results of the study were compared with other studies of similar situations, such as the PNYNJ and FDOT surveys.

Second, to control for nonresponse biases, the mail survey data were weighted according to the actual traffic volume and payment methods of individual bridges. In the Bay Area, tolls currently can be paid by several methods, including cash, commute tickets, and scrip tickets. Most of the respondents said they paid tolls either with cash or commute tickets. Only a fraction of respondents (0.5 percent) used methods other than cash or commute tickets. The cash users and commute ticket users were evenly divided. However, Caltrans records show that the ratio between cash users and commute ticket users is 3 to 1, suggesting that commute ticket users may have been slightly overrepresented in the sample data.

Third, for the follow-up surveys, the telephone survey method was chosen over the mail survey to provide better control over nonresponse biases. The Council of American Survey Research Organizations (CASRO) established the minimum standard for an acceptable response rate on the basis of the upper bound calculation formula. CASRO considers a 60 percent upper bound response rate to be acceptable for most opinion research applications. The response rate of the telephone surveys was over 90 percent.

Fourth, the sample size was made large enough to meet accepted standards for statistical precision. For example, assuming an unbiased sample of mail survey responses was obtained, 5,000 survey responses would have given an acceptable error of no more than ±1.4 percent at the 95 percent level of confidence. This level of precision exceeds commonly accepted standards in public opinion research.

Mail Survey

There are a total of eight toll bridges serving approximately 375,000 Bay Area patrons daily, including weekends. In October 1990, 30,000 survey forms were distributed at toll plazas during peak and off-peak hours according to the traffic volume on each bridge. Of the eight bridges, seven (the San Francisco/Oakland, Golden Gate, Richmond/San Rafael, San Mateo/Hayward, Dumbarton, Carquinez, and Benicia/Martinez) were surveyed. Antioch Bridge was excluded because of low traffic volume. Carpool, vanpool, and commercial users were also excluded because of technical difficulties in distributing questionnaires at toll gates. According to the Metropolitan Transportation Commission, 23 percent of the person trips on the San Francisco/Oakland Bay Bridge last year were generated by carpools and vanpools.

To increase the response rate, the mail survey questionnaire was designed to be short and concise, fitting onto one page. The self-administered questionnaire consisted of a short introduction to ETC and six closed-ended questions. Names and telephone numbers of respondents were solicited so that the mail survey could be followed by a telephone interview. Three issues were addressed in the mail survey: (a) general interest in subscriptions to an ETC service, (b) preference in AVI tag types and the placing or mounting locations of tags on the vehicle, and (c) travel characteristics of motorists, including the frequencies of bridge use and the purposes for primary trips.

The sample size of 30,000 for the mail survey was determined according to an expected rate of return of 15 to 20 percent. Even with a 15 percent return, the sample size would have been large enough to obtain statistically precise data for each bridge. The number of survey forms distributed was proportional to the annual average daily peak- and off-peak-hour traffic volume. Questionnaires were color-coded by bridge.

Of the 30,000 survey forms distributed, approximately 6,000, or 20 percent, were returned over a 2-month period. The highest response was obtained from the Dumbarton Bridge (almost 30 percent) and the lowest from the Benicia/Martinez Bridge (less than 10 percent). The response rate at other bridges ranged from 15 to 19 percent. An overwhelmingly large number of respondents (85 percent) expressed their willingness to participate in a follow-up telephone survey. Forms received after the cut-off date—November 2, 1990—were not processed. The number of forms processed was 5,095; a sample size of 5,000 was considered large enough to provide statistically significant results.

The returned questionnaires were edited and manually coded into categorized variables representing the survey questions. A special matrix format was prepared using the StatView statistical package. A numerical case number was assigned to each survey form after checking for errors. The quality of data entry was also checked after completion of the entire matrix.

Telephone Surveys

In December 1990 two telephone surveys were completed—one for motorists and the other for commercial users. The telephone survey of motorists was conducted to follow up on the mail survey. A random sample of motorists was selected from the pool of mail survey respondents who had expressed interest in the ETC service, and 1,000 telephone interviews were completed.

The telephone interviews consisted of 27 dichotomous and multiple-choice questions. These questions were designed to determine (a) the level of interest in ETC if tags were permanently affixed, (b) the preferred tag mounting location for permanently affixed tags, (c) an acceptable tag deposit cost, (d) the desired method of payment, (e) the perceived benefits of ETC, (f) usage of toll bridges, (g) modes of travel, and (h) the socioeconomic profiles of interested toll bridge users. The median interview time was approximately 10 min.

For the commercial users survey, 200 telephone interviews were completed with the owners or managers of trucking firms. The objective was to estimate the level of interest in ETC among current commercial patrons. A random sample of commercial users was selected from the list of approximately 1,200 firms that have existing accounts with Caltrans. In sampling the commercial user population, the firms were classified into three categories—small, medium, and large—according to the size of their accounts. More than 75 percent of the firms interviewed were classified as small firms and had an account size of less than $1,000 a month. Approximately 20 percent of the firms interviewed were medium-sized firms with an account size between $1,000 and $4,999, and 2 percent were large firms that had an account size of $5,000 or more. Three percent of the firms interviewed did not respond. This distribution matched the actual distribution of all commercial accounts with Caltrans. The median length of an interview was 7 min.

Data Analysis

To estimate the overall receptivity of all bridge users to ETC technology, the sample responses were weighted by the actual traffic flows at each bridge. The percentage of traffic volume on each bridge was computed on the basis of Caltrans 1990 traffic transaction data. The weighted frequency distribution for the overall results on each question in the mail survey questionnaire, on the basis of average daily traffic volume, was obtained by the following:

$$w_{1a} = \left(\frac{v_a}{V}\right) \bigg/ \left(\frac{n_{1a}}{N_1}\right)$$

$$r_{1a} = w_{1a}(n_{1a})$$

$$R_{1a} = \sum_{i=1}^{7} r_{1i}$$

for each answer to Question 1, and so on. In the expressions above,

w_{1a} = weighting factor for Question 1 at Bridge a,
v_a = annual average daily traffic volume on Bridge a,
V = total annual average daily traffic volume on all bridges,
N_1 = total number of sample respondents to Question 1 at all bridges,
n_{1a} = number of sample respondents to Question 1 at Bridge a,
R_{1a} = total weighted number of responses to Question 1 at all bridges,
r_{1a} = weighted number of responses to Question 1 at Bridge a, and
i = number of bridges surveyed.

After the sample responses were weighted according to the traffic volume on each bridge, the weighted results were weighted again according to the actual distribution of commute ticket users and cash users. This approach was used to control possible nonresponse biases, because commute ticket users were considered more likely to respond favorably to ETC technology than were cash users. The commute ticket information used in the analysis was prepared by Caltrans and the Golden Gate Bridge, Highway, and Transportation District in 1990. Telephone survey data were not weighted because they represented a unique subset of motorists who expressed an interest in ETC, and comparable population-based data were not available.

FINDINGS OF MOTORIST SURVEYS

The findings of the motorist surveys are presented in three parts: (a) travel characteristics of the toll bridge users among Bay Area motorists, (b) interest in using an ETC system, and (c) a demographic profile of the bridge users. These findings come from the mail and telephone surveys.

Travel Characteristics

The mail survey showed that frequent users or commuters were overrepresented in the sample data. After weighting the survey data according to Caltrans records of toll payments, it was found that there were fewer commuters than shown in the sample data. The weighted results of the mail survey suggested that 46.5 percent of the patrons used toll bridges on a daily basis (five or more times a week), 16.9 percent used them 3 to 4 times a week, and 36.6 percent used them less than twice a week.

The mail survey also suggested that over half the weekday traffic on the Bay Area bridges was generated by trips to or from work. The weighted results suggested that work trips accounted for 67.1 percent of the total daily traffic transactions. Of the total bridge crossings, 10.3 percent were for personal business, 6.5 percent for social and recreational trips, 3 percent for medical or dental reasons, 2.4 percent for school, and 1 percent for shopping trips. Crossings in the "other trip" category accounted for 9.7 percent of the total traffic transactions. This travel pattern was fairly consistent on all bridges surveyed.

Commute tickets were used more frequently by the daily bridge patrons than by those who crossed the bridges once or twice a week. In the Bay Area, commute tickets could be purchased at a discount rate at toll agencies. Discount amounts were about 15 percent of the toll charge, although they varied from bridge to bridge. For example, the Golden Gate Bridge discount rate was 16.7 percent. The method of payment varied slightly among the bridges. On the San Francisco/Oakland Bridge, a higher percentage of motorists used cash than on the other bridges. On the Golden Gate Bridge, the pattern was reversed, with far more motorists using commute tickets than on other bridges.

Ten percent of the telephone respondents used carpool or vanpool service on a regular or semiregular basis (more than three times a week). Approximately 11 percent used it less than twice a week. These respondents were not on the high-occupancy vehicle (HOV) lanes when they received the mail survey questionnaires.

Interest in ETC

The surveys suggested that Bay Area motorists would be highly receptive to ETC technology. According to the mail survey, as many as 82.4 percent of the current Bay Area toll bridge users would be interested in subscribing to an ETC service. However, the follow-up telephone survey suggested that the ETC market would be sensitive to the tag types and tag mounting locations. If tags were to be permanently affixed, ETC interest would drop about 12 percent from the initial interest of 82.4 percent shown in the mail survey.

The interest in ETC varied somewhat from bridge to bridge. Respondents traveling on the Golden Gate Bridge showed a slightly greater interest in ETC than those traveling on the other bridges. The reason could be that there were more commute ticket users on this bridge than on other bridges. As expected, frequent users were more receptive to ETC than were infrequent users. Similarly, commute ticket users were more receptive to ETC than were those using cash. Obviously, frequent users were more likely to use commute tickets than were infrequent users and, consequently, commute ticket users or frequent users would be more receptive to ETC than would infrequent users.

An overwhelmingly high proportion (85 percent) of the mail survey respondents favored transferable tags over permanently affixed tags. The preferred tag type and tag location results were fairly consistent on all bridges. For the transferable tags, the only option given in the survey was inside the windshield. The majority of respondents (82 percent) from all bridges preferred a transferable tag placed inside the windshield. For permanently affixed tags, three placement locations were considered: (a) outside the windshield, (b) on the license plate, and (c) on the underside of the vehicle. If tags were to be permanently affixed, 57.4 percent of telephone survey respondents said they would prefer to have the tags mounted on the underside of their cars. Among the reasons were aesthetics and the possibility of vandalism when tags were placed in a visible location.

The telephone survey also suggested that there was a strong willingness to support the operational requirements of the ETC service. To use an AVI tag, subscribers would pay the toll agency a one-time refundable deposit. The survey showed that imposing a tag deposit would not be a major deterrent. Nearly 9 out of 10 respondents (88.5 percent) said they would be interested in ETC even if a $30 deposit were required. If the deposit were reduced to $15, there would be an increase of 5.3 percent in interest to 93.8 percent. If it were dropped from $15 to $5, an additional 1.7 percent of the respondents would be interested in ETC—an increase to 95.5 percent.

To use ETC, it would be necessary to open an account with the toll agency. The minimum amount necessary to open an account could be as much as $40. This amount was acceptable to 90 percent of the telephone survey respondents. Reducing the minimum amount to $20 would increase interest in ETC to 95 percent. However, if earnings from the float were an important ETC cost recovery consideration, the revenue lost by changing the minimum amount from $40 to $20 would outweigh the revenue gained from an increase in the use of ETC by a ratio of nearly 2 to 1.

Nearly two-thirds of the telephone survey respondents (63.9 percent) said cash was their first choice as a method of payment. The second choice was credit card, and the least desired method was an electronic transfer of funds from bank accounts.

Seventy-two percent of the telephone survey respondents said they would be interested in receiving a monthly log of their bridge crossings because the log would be helpful for accounting purposes. However, if a $1 monthly fee were charged for the service, there would be a 26 percent drop in interest to 46 percent.

Perceived benefits of ETC among the motorists included relief of traffic congestion, improved environmental quality, and increased safety. Nearly 90 percent of the telephone survey respondents believed that there would be less traffic congestion at toll plazas if ETC were implemented (see Figure 1). Of the telephone survey respondents, 77.5 percent said that vandalism would be a problem if the electronic tags could be seen (see Figure 2). Conversely, only 7 percent showed a strong concern that electronic tags would permit the police to track or trace their vehicle (see Figure 3). The general perception of the telephone survey respondents (71 percent) was that ETC would improve air quality because there would be less carbon monoxide produced by vehicles decelerating and idling at toll gates. Telephone survey respondents disagreed (75.2 percent) with the notion that ETC might encourage people to use their cars more often because it would be easier to cross the bridges.

Caltrans is considering discontinuation of commuter discounts. If the commuter discounts on toll charges were discontinued, only half (48.9 percent) of the telephone survey respondents said they would still be interested in ETC. Respondents might have inferred that commuter discounts would still be offered to those not subscribing to ETC. In fact, if the commuter discount were discontinued, all motorists would be affected. Respondents traveling on the San Francisco/Oakland Bridge were more receptive to ETC without the commuter discounts than were respondents on the Golden Gate, Carquinez, and Benicia bridges. One reason for this response could be that the commuter discounts for those three bridges were more than those for other bridges. The Golden Gate Bridge discount is $0.33 for a $2 toll charge, and the discount on the Carquinez and Benicia bridges is $0.25 for a $1 toll. The discounts on other state-owned bridges are $0.15 for $1 tolls. There was a higher proportion of commute ticket users on the Golden Gate (78.1 percent), Dumbarton (59.8 percent), and Carquinez (52.3 percent) bridges than on other bridges.

The Golden Gate Bridge and the seven other Bay Area toll bridges are run by two separate agencies. Therefore, patrons would need to open two separate ETC accounts if they were to use ETC on all Bay Area toll bridges. Of the 205 respondents using all eight bridges, 68.3 percent said they would not be interested in opening two ETC accounts. Patrons of the Golden Gate Bridge appeared to use other bridges more frequently than other bridge patrons used the Golden Gate Bridge. Although nearly half of the Golden Gate Bridge respondents (45.6 percent) said they used other toll bridges at least once a month, only 15.1 percent of other bridge respondents said they used the Golden Gate Bridge that often. No matter how infrequently they traveled on other bridges, patrons did not seem receptive to having two separate accounts for toll payments.

Demographic Profile of Users Interested in ETC

The telephone survey respondents using Bay Area toll bridges were in the upper middle or high income group, had a household income of over $30,000 a year, and had two or more

There will be less traffic congestion at the toll plazas once the ETC system is implemented.

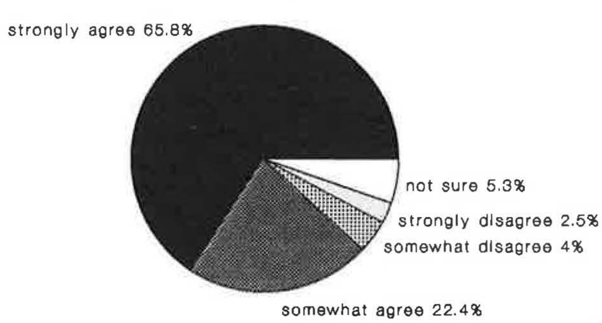

FIGURE 1 Perception about traffic congestion.

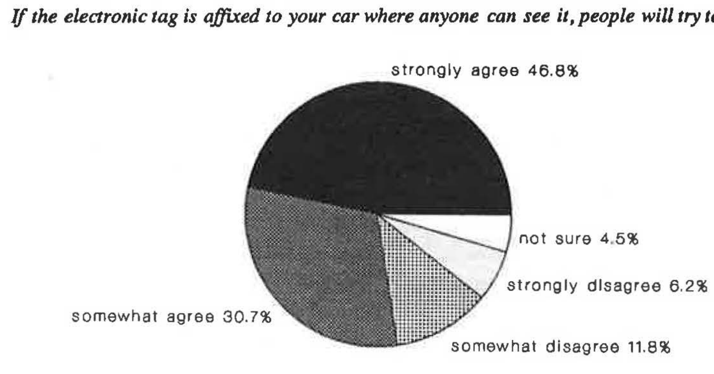

FIGURE 2 Perception about vandalism.

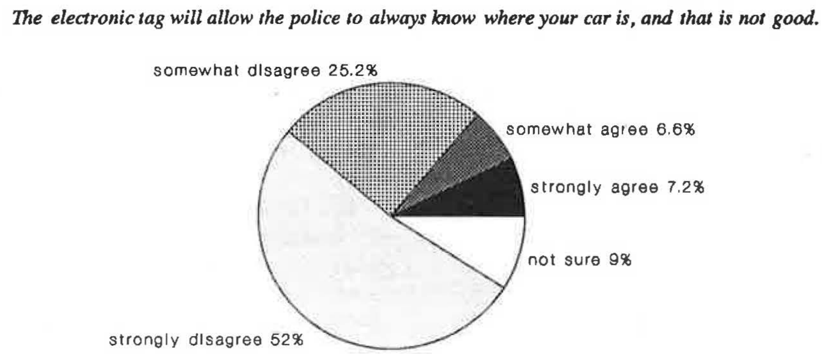

FIGURE 3 Perception about privacy.

cars and drivers in the family. On all bridges, a high proportion of respondents were in the income group between $40,000 and $60,000. The median household income of the sample population was between $40,000 and $50,000. However, the household incomes of respondents appeared to be associated with the individual bridge. Respondents from the Golden Gate Bridge had generally higher household incomes than those from other bridges. Over 30 percent of the sample population traveling on the Golden Gate Bridge had incomes over $100,000 last year. Overall, respondents traveling on the Dumbarton Bridge had higher family incomes than other bridge respondents.

According to the telephone survey, it was estimated that the primary users of the Bay Area bridges interested in ETC would be between 30 and 50 years of age. The median age group was between 30 and 39. The second largest group was between 40 and 49. The San Francisco/Oakland, Richmond/San Rafael, Dumbarton, and Carquinez bridges had their highest proportion of respondents in the age group between 30 and 49. Of the telephone survey respondents, 78.2 percent were employed full time, and 3.6 percent were part-time employees. Only 10.9 percent were self-employed.

Tables 1–9 present the results of this survey compared with the results of surveys conducted in other states. (In the tables, CDOT refers to Caltrans.)

All of the surveys indicate that demand for ETC is a function of the frequency of toll facility use. The ETC technology was most favorably received by those who used the toll facilities frequently. Therefore, it is suggested that ETC be targeted at people who commute to work and at commercial users who frequently use toll facilities. The Caltrans surveys

TABLE 1 Sample Size

	CDOT	VDOT	FDOT	ITHA	OTA	PNYNJ
Distribution	30000	10050	10400	--	30000	12000
Return rate	20%	25%	20%	--	10%	16%
Sample size	5095	--	--	1119	2688	900
Year surveyed	1990	1989*	1990	1989*	1989*	1990

* estimated year where surveys were conducted.

TABLE 2 Gender of Respondents

	CDOT	FDOT	PNYNJ
Men	69.4%	56.7%	77.0%
Women	30.6	42.4	23.0

TABLE 3 Interest in ETC

	CDOT	VDOT	FDOT	ITHA	OTA
Positive	82.4%	65.0%	67.4%	69.0%	56.0%
Negative	17.6	10.0	32.4%	30.0*	--
Not sure	--	25.0	0.2	--	--

* combined both negative and not sure.

TABLE 4 Method of Payment

	CDOT	VDOT	FDOT	PNYNJ
Cash or check	63.9%	60.0%	59.6%	53.0%
Credit card	19.7	--	33.4	23.0
Electronic transfer	14.2	--	7.0	--
Not sure	1.6	--	0.0	--

TABLE 5 Minimum Balance for ETC Account

	CDOT*	PNYNJ
0	1.7	--
$10	1.3	34.1%
$20	2.7	42.0
$30	1.3	13.7
$40	90.0	--
$50	--	10.3

*Percentage of respondents desiring minimum balance between 0-$9, $11-$19, $21-$29, and $30-$39 are not indicated above.

TABLE 6 Tag Price

	CDOT	ITHA	PNYNJ
$50-65	--	4.0%	--
$35-50	--	28.0	47.0%($30-50 with discount toll)
$20-35	($30)92%	50.0	--
0	--	--	48.0 (agency pays for the tag)

TABLE 7 Trip Purpose

	CDOT	FDOT	VDOT	AT/Comm
To or from work	67.1%	82.7%	75.0%	83.0%
Business	10.3	10.1	--	--
School	2.4	1.2	--	--
Medical/dental	3.0	0.7	--	--
Social/recreation	6.5	3.9	--	--
Shopping	1.0	0.7	--	--
Other	9.7	0.7	--	--

TABLE 8 Trip Frequency

	CDOT	FDOT	PNYNJ
>5 times/week	46.5%	79.9%	74%
3-4 times/week	16.9	9.6	--
1-2 times/week	18.0	5.6	--
<once/week	18.6	4.9	--

TABLE 9 Number of Drivers per Household

	CDOT	FDOT
0	0.2%	--
1	14.1	19.5%
2	53.9	57.5
3 or more	31.7	23.0

also suggest that demand for ETC among motorists is elastic with respect to the types of tags offered.

FINDINGS OF COMMERCIAL USER SURVEY

The frequency distribution of the number of tractors or hauling units operated by the commercial respondents was fairly well spread out between 1 and 3,500. However, the median number of all tractors or hauling units was 10. The frequency distribution of the number of all units (including those with a vehicle identification number) operated by the firms interviewed was spread out between 1 and 7,500, but the median number of all units was 30. Over 40 percent of the firms made bridge crossings between two and five times a day. One quarter of the respondents did not know how many crossings they made per day.

Among commercial users, 76.5 percent of the firms interviewed expressed an interest in using the ETC system. Unlike motorists, the commercial users did not seem to be influenced by the types of AVI tags. Rather, their willingness to use the system seemed to be closely associated with its cost. When asked about permanently affixed tags, interest remained the same. However, when asked about the deposit requirement, interest dropped. If a deposit were required to obtain a tag, only 41 percent of the respondents said they would be interested in ETC and 32 percent said it would depend on the cost of the deposit.

The survey also showed that the commercial users' interest in ETC was highly price sensitive. If the cost of the tag deposit were $30, only 54.5 percent said they would be interested in ETC. If the deposit were decreased to $15, interest would increase to 65 percent. If it were reduced to $5, interest would increase to 72 percent. To attract commercial users, it would be highly desirable to keep the cost of the tag as low as possible.

Two payment methods were considered for commercial accounts: prepaid and billed accounts. These accounts could be paid in one of three ways: (a) automatic monthly electronic funds transfer from a company's bank account, (b) automatic monthly charge to a Visa or MasterCard account, or (c) check, cash, or money order. If tolls were paid by check, cash, or money order, there would be a monthly service charge of $7. If they were paid by electronic funds transfer or by credit card, there would be no service charge. Between the two types of accounts, billed accounts (65 percent) were preferred to prepaid accounts (24 percent). Ten percent of the respondents were uncommitted. For either prepaid or billed accounts, cash payments were preferred. The second choice was an electronic transfer of funds from bank accounts. This finding suggests that commercial users are not as reluctant as motorists to use the automated banking system.

Every unit in a company's fleet that has its own vehicle identification number could have its own AVI tag. For instance, a typical tractor-trailer rig is made up of two units: the tractor or hauling unit and the trailer. If both units had tags, sensors at the toll plaza could read both tags and automatically calculate the total toll charge. Because the toll collector would not have to enter the total axles manually, drivers would get through the toll plaza faster. However, some companies frequently haul trailers that arrive from outside the Bay Area. These trailers probably would not have AVI tags. If a firm decided to use the ETC system, all of its hauling or tractor units would need an AVI tag. Tags for its own trailer units would be optional, and many units hauled from outside the Bay Area would not have tags. When asked the percentage of all trips that would be made by rigs that were not completely tagged (i.e., the tractor or hauling unit would have a tag but the trailer unit, or any other unit being hauled, would not), 10 percent of the firms interviewed said trailers would not be tagged most of the time. Only 45 percent of the firms interviewed said the trailers would be tagged at all times. If nearly 55 percent of the trailers were untagged, there could be operational problems for toll agencies.

CONCLUSIONS

According to the surveys, over 82 percent of the toll bridge users in the Bay Area would be interested in using the ETC system. If AVI tags were permanently affixed, interest in ETC would drop to 70 percent. Most of the motorists interested in ETC preferred transferable tags to permanently affixed tags, and the preferred tag mounting location was inside the windshield. If tags were to be permanently affixed because of technological reasons, the most favored location of tag placement was the underside of the car. Mounting the tag on the outside of the windshield was the least desired location, mainly because of vandalism and aesthetics concerns.

The tag deposit of $30 would be a relatively minor issue, and a minimum amount of $40 to open an ETC account would also be acceptable to the vast majority of current toll bridge patrons.

Substantial benefits were perceived as being gained from ETC in at least two areas: (a) reduced traffic congestion at toll gates, and (b) improved air quality. The survey respondents were not concerned with tagged vehicles being more easily located by the police and did not believe that ETC might encourage an increased use of toll bridges.

Demand among commercial users would also be substantial. However, commercial users were more price sensitive to ETC operational issues than were motorists. Commercial users' interests in ETC was highly elastic with respect to the cost of the tag deposit and the method of payment.

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Highway Finance: Revenues and Expenditures

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An overview of the current financing structure for highways is provided. Beginning with public-sector financing, the various highway-based revenue sources, and revenues from these sources that are used for highways, are identified. An analysis of trends for some of these sources is given, focusing on highway user charges. Expenditures for highways are addressed and disaggregated into noncapital and capital outlays. For capital outlays, trends are identified and the source of funds by level of government is shown. A discussion of capital outlay on the federal-aid system by level of government and type of improvement follows. Finally, a brief discussion of private-sector financing is provided. In 1989 the public sector spent $67.7 billion for maintenance and capital improvement of highways. Noncapital highway expenditures, including maintenance and operations of highways, administration, highway law enforcement, safety, and debt service on highway bonds and notes, were $38 billion in 1989—53 percent of all highway expenditures. Capital outlay expenditures by the public sector totaled over $33 billion in 1989. The federal government funded 43 percent of the total highway capital outlay of $33 billion in 1989. Of this total, $25 billion was spent on the federal-aid systems. Private-sector financing includes projects funded and developed by the private sector; it has been estimated that $9.6 billion of highway improvements was financed by the private sector in 1989.

Public-sector financing includes all funding for highways that is managed by the public sector, including projects built with revenue from exactions, development fees, special district assessments, and so on. In 1989 all levels of government together provided $73.6 billion for highway programs. The federal government funded $16.5 billion, the states $36.9 billion, and counties, cities, and other local entities the remaining $20.2 billion. Federal funds, primarily supplied by the Highway Trust Fund, accounted for 22.5 percent of the total funding for highways in 1989, down from 24.8 percent in 1980. The states accounted for half of all funding for highways; a ratio unchanged during the past decade. Since 1980 local governments have almost doubled their funding for highways, raising their share of total funding from 25.7 to 27.4 percent.

Of the total $73.6 billion allocated for highways in 1989, $2.4 billion was placed in reserve and $3.5 billion was used for debt retirement, leaving a balance of $67.7 billion to be spent on highway programs.

In current dollars, highway spending by all governments totaled $10.2 billion in 1960. For 1989 the amount was $67.7 billion. In constant dollars, highway spending increased from $27.5 billion in 1960 to $36.7 billion in 1989. However, as shown in Figure 1, real annual spending actually declined below the 1960 level several times during the 1970s. Since 1980 constant dollar spending has been increasing almost annually.

In constant dollars, per unit of travel, expenditures have dropped by more than half since 1960. Constant dollar expenditures per unit of travel increased slowly from 1980 through 1985 but since then have again begun to decline.

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REVENUE SOURCES FOR PUBLIC-SECTOR FINANCING OF HIGHWAYS

Funding for the $73.6 billion appropriated for highway programs in 1989 came from a number of sources, including user charges, general funds and other non-highway-based revenue instruments, benefit charges, investments and miscellaneous fees, and bond issues. An overview of these revenue sources is presented in Table 1.

User Charges

User charges are the largest single source of revenue for public-sector financing of highways. User charges are imposts levied on owners and operators of motor vehicles because of their use of the public highways. These imposts consist chiefly of motor fuel taxes, registration fees, driver license fees, weight-distance taxes, titling taxes, other fees closely connected to the ownership and operation of motor vehicles, and tolls. For this discussion, user charges are grouped into three categories: motor fuel taxes, motor vehicle taxes and fees, and tolls. Although $54.2 billion was raised from these revenue sources in 1989, only $44.3 billion was used for highways.

Motor Fuel Taxes

Motor fuel taxes are imposed on highway usage of gasoline, diesel, gasohol, and other special fuels, with the largest share of revenue coming from gasoline and diesel fuel taxes. This revenue source is used by all three levels of government. The excise taxes imposed on each type of fuel differ depending on the governmental level and jurisdiction.

Total gasoline excise taxes paid at retail include the federal tax (which was 9.1 cents in 1989 and increased to 14.1 cents on December 1, 1990), state gas taxes, and any local gas tax.

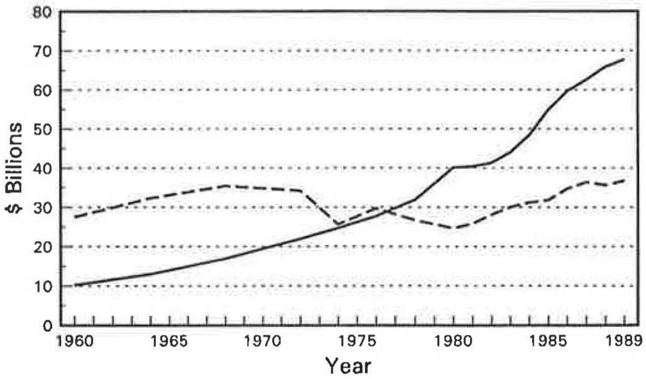

FIGURE 1 Total highway expenditures, 1960–1989.

The average state gas tax weighted by state fuel consumption was 14.19 cents/gal in 1989; it had increased to 15.76 cents/gal by January 1991. Current state gasoline excise taxes range from 7.5 to 23 cents/gal. Some states permit local option gas taxes, and local governments have elected to use this option in 13 states.

The federal diesel tax was 15.1 cents/gal in 1989; it increased to 20.1 cents/gal on December 1, 1990. The weighted national average state special fuel (diesel) tax is 14.76 cents/gal, slightly more than the state gasoline tax.

Total motor fuel tax revenue used for highways was $29.5 billion in 1989—40 percent of revenues. Federal levies were $11.9 billion, states $17.0 billion, and local governments $0.5 billion.

Motor Vehicle Taxes and Fees

This category includes an assortment of taxes and fees on motor vehicles and users. Following is a list of most of these revenue-raising instruments:

- Registration fees,
- Driver license fees,
- Weight-distance taxes,
- Motor carrier taxes,
- Dealer licenses,
- Certificates of title,
- Plate fees or wheel taxes,
- Sales taxes that apply specifically to motor vehicles, and
- Personal property taxes levied only on motor vehicles.

Revenue from these sources used for highways totaled $11.8 billion in 1989—16 percent of the total. Federal revenue from motor vehicles was $2.2 billion, state revenue $9.3 billion, and local revenue $0.3 billion.

Tolls

States and local governments operate toll systems of all sizes, from minor crossings to statewide and regional toll transportation systems. At present, 29 states operate 37 toll roads and 44 toll bridges. In addition, 20 county and 27 municipal toll facilities, mainly bridges, exist nationwide. Toll facilities provided $3.01 billion for highway financing in 1989. State toll facilities generated $2.50 billion, and local toll facilities provided $0.51 billion.

Total Revenues from User Charges

Total revenues used for highways from user charges in 1989 were $44.3 billion, or 60 percent of all revenues used to finance highways. This amount is the same share of highway investments financed from user charges in 1987. Reliance on user charges as a source of revenues reached a peak of 73 percent in 1964.

Non-Highway-Based Financing

Non-highway-based financing includes revenue instruments that have little or no direct connection with the highway user tax base. In some cases, these imposts provide dedicated revenues for highways. However, most of these revenues are placed in the general fund and are subsequently apportioned for highways. The most frequently used revenue instruments in this category include general taxes on property and sales

TABLE 1 Revenue Sources for Public-Sector Financing of Highways, 1989

Revenue Source	Federal	State	Local	Total	Percent
User Charges:					
Motor Fuel Taxes	11.92	17.03	0.54	29.49	40%
Motor Vehicle Taxes	2.20	9.32	0.32	11.84	16%
Tolls	–	2.50	0.51	3.01	4%
Subtotal	14.12	28.85	1.37	44.34	60%
General Funds and Other Non–Highway Based Revenue Instruments	0.99	1.52	8.95	11.46	16%
Benefit Charges:					
Property Taxes and Assessments	–	–	4.54	4.54	6%
Other Taxes and Fees	0.07	1.37	1.01	2.45	3%
Subtotal	0.07	1.37	5.55	6.99	9%
Investment Income and Miscellaneous Receipts	1.36	2.09	2.33	5.78	8%
Bond Issue Proceeds	–	3.06	2.00	5.06	7%
Total	16.54	36.89	20.20	73.63	100%

Note: Revenue values are in billions of dollars.
Source: Highway Statistics, 1989, Table HF–10.

and the income tax. Local governments rely most heavily on non-highway-based revenue sources to finance their highway programs.

Although most of these revenue sources have no specific connection with the highway tax base, some, including general sales taxes that apply to motor fuel and vehicles and personal property taxes that apply to a range of personal property including motor vehicles, are sometimes considered highway-based revenues. In Table 1, any revenues that cannot be attributed to the other revenue categories are assumed to come from this source.

Benefit Charges Including Private Cost Sharing

Benefit charges include charges on activities, usually related to land use, that derive a benefit from highways. Following is a partial list of revenue-raising instruments considered to be benefit charges:

- Real property taxes imposed by single function highway districts,
- Assessments levied for construction and maintenance of roads and streets or for local debt service,
- Impact fees, and
- Severance fees imposed to compensate for the impact of the extraction activity on highways.

The term "benefit charge" implies a requirement to pay. Although not specifically a benefit charge, voluntary contributions from private property owners of land for right-of-way or cash against the cost of a new public facility are also considered benefit charge revenue. Contributions from private property owners are variously referred to as donations, negotiated contributions, developer agreements, and exactions.

The first three revenue-raising instruments listed are a form of institutionalized cost sharing. Local governments (often with required state support) raise funds for specific transportation improvements through systematic and simultaneous cost sharing with multiple private parties whose properties are directly served by a transportation improvement.

In contrast to the ad hoc and usually extremely localized contributions or exactions, these methods require the establishment of a systematic and equitable assessment process within a specific area (district). The specific group of property owners who will benefit directly through transportation improvement–induced changes in economic activity (including property values) is assessed.

Three models are typically used in the United States:

- *Benefit Assessment Districts*. Periodic earmarked fees for transportation that apply to new development in the highway environment.
- *Tax Increment Financing*. Property value increases that apply to all property owners in a transportation-affected area.
- *Traffic Impact Fees*. Fees required of property developers on the basis of specific development attributes and applied as a condition of development.

Funds from direct beneficiaries are thus generated to help pay for public projects that would otherwise place a burden on a local jurisdiction's general tax base.

Funding for projects built by the private sector and turned over to a governmental jurisdiction after completion, with no impact on either the jurisdiction's revenues or expenditures for highways, is not included. Funding for these types of projects is considered private-sector financing and is discussed separately.

These revenue instruments are used primarily at the local level and are difficult to quantify. According to highway statistics data collected from the states, at least $4.5 billion was raised from property taxes and assessments and $2.5 billion from other taxes and fees.

Investments and Miscellaneous Fees

By investing highway funds until needed, many highway agencies are able to realize interest income or profit on the purchase and sale of securities. Other miscellaneous income includes rentals and permit fees. Revenues from this source used for highways were $5.78 billion in 1989, or 8 percent of total revenues—the same share of total revenue as in 1987. This revenue source is used by all levels of government.

Bond Issues

Proceeds from bond issues used for highways were $5.0 billion in 1989. State agencies raised $3.1 billion and local governments $2.0 billion. Revenue from this source was 7 percent of the $73.6 billion allocated to highways in 1989—the same as in 1987.

Highway-Based Revenues Compared with Non-Highway-Based Revenues Used for Highways

Highway-based revenue sources include most bond issues, investments and miscellaneous fees, user charges, and benefit charges. Together they provided approximately $62.16 billion (84 percent) of the revenues used to finance highways in 1989. If revenues from general taxes on property and sales imposed on motor vehicles and motor fuel were included, the share of revenues used for highways derived from highway-based revenue sources would be higher. Non-highway-based revenue sources provided approximately $11.47 billion (16 percent).

REVENUE TRENDS FOR SELECTED HIGHWAY USER REVENUE SOURCES

This section contains an analysis of trends in revenue generated by various user charges from 1960 to 1989. In addition to overall trends, trends in revenue per vehicle mile of travel (VMT) and per vehicle are considered for motor fuel tax revenue and motor vehicle revenue, respectively.

Federal Motor Fuel Tax Revenue Trends

In 1989 federal motor fuel taxes generated $13.5 billion in revenues for the Highway Trust Fund; $11.9 billion of this revenue was spent on highway improvements. Since 1960 revenues from federal motor fuel tax revenues used for highways have increased by $9.6 billion in current dollars and $0.3 billion in constant dollars. Constant dollar revenues from this revenue source reached a peak of $6.9 billion in 1966. The low point in constant dollars for revenue from this source, $2.7 billion, was reached in 1980.

State Motor Fuel Tax Revenue Trends

In 1960 state motor fuel taxes raised $3.3 billion for highway use. By 1989 the yield was $17.0 billion, or 5.2 times greater. The gain in revenue resulted from the compounding effects of a doubling in motor fuel consumption (2.3 times) and state tax rates (2.4 times). However, inflation in highway construction has dramatically reduced the productivity of the state motor fuel tax dollar, resulting in a constant dollar yield in 1989 of $9.2 billion—only $0.4 billion more than the 1960 yield.

Current revenue from state motor fuel taxes used for highways has increased almost annually since 1960. The rate of increase, however, slowed from 1973 to 1980. When expressed in constant dollars, revenues from this source actually declined during this period. Since 1980 real revenue has again increased almost annually, as it did from 1960 to 1973, because of lower inflation and the increase in state motor fuel tax rates.

Federal Motor Vehicle Tax Revenue Trends

Total motor vehicles registered in the nation reached 192 million in 1989. Revenues from vehicle registration used for highways were $2.2 billion in 1989, compared with $0.6 billion in 1960. Current dollar revenues reached a peak of $2.4 billion in 1979, with a per-vehicle revenue of $15.27. Per-vehicle revenue in 1989 was $11.48.

In constant dollars, revenues from this source have declined since 1960, with a low of $0.9 billion being reached in 1983 and 1984. The constant dollar revenue peak of $3.1 billion occurred in 1969.

State Motor Vehicle Tax Revenue Trends

Taxes on motor vehicles produced $15.5 billion in total revenue for the states in 1989; of this, $9.3 billion was used for highways. Current dollar revenue raised for highways in 1989 was more than six times that of 1960, resulting from the combination of an increased number of vehicles (73 versus 192 million) and an increased average fee per vehicle. Together these two factors overcame the effect of inflation in highway construction, resulting in a real increase in revenue from this source of approximately $1 billion from 1960 to 1989. However, constant dollar revenues actually declined below the $4.0 billion level reached in 1960 for several years during the 1970s and early 1980s, with a low of $3.2 billion in 1980.

Toll Revenue Trends

In 1989 state and local revenue used for highways from road and crossing tolls was $3.0 billion in current dollars and $1.6 billion in constant dollars. Since 1960 toll revenues have increased 22 percent in constant dollars; however, this increase has not been steady. From 1960 to 1972, constant dollar toll revenues generally increased, reaching a high of $1.8 billion in 1972. From 1975 to 1980, revenues declined. Since 1980 constant dollar revenues from tolls have increased 61 percent, from $1.0 billion to $1.6 billion, but remain less than constant dollar revenues in 1972. Toll revenue as a share of total revenue for financing highways was 4 percent in 1989—the same as in 1960.

User Charge Revenue Trends

Total revenues from user charges in current dollars have increased from $8.4 billion in 1960 to $54.2 billion in 1989 and in constant dollars from $22.8 billion in 1960 to $29.4 billion in 1989. Constant dollar revenues from this source reached a peak of $29.4 billion in 1969 (see Figure 2). A gradual decline in revenues accelerated in the early 1970s—between 1973 and 1974, real revenue dropped approximately 25 percent. The low point in constant dollar revenues, $15.8 billion, was reached in 1980.

Annual constant dollar revenues per vehicle from user charges were $306 in 1960 and $154 in 1989. Annual per vehicle user charge revenues peaked at $308 in 1964 and reached a low of $103 in 1981.

However, not all revenues raised from highway user charges are used for highways. In current dollars, user charge revenues used for highways were $8.1 billion in 1960 and $44.3 billion in 1989. Comparable revenues in constant dollars were $22.0 billion in 1960 and $24.7 billion in 1989 (see Figure 3).

Annual constant dollar revenues per vehicle used for highways from user chargers were $295 in 1960, the high for the period, and $125 in 1989. Annual per vehicle user charge revenues used for highways reached a low of $85 in 1980.

In 1960, 3.5 percent of constant dollar revenues from user charges was not spent on highways. By 1989 the percent of revenues being diverted from use for highways had increased to 16 percent.

HIGHWAY NONCAPITAL EXPENDITURES AND TRENDS

This section presents a brief overview of noncapital highway expenditures from 1960 to 1989. Noncapital highway expendi-

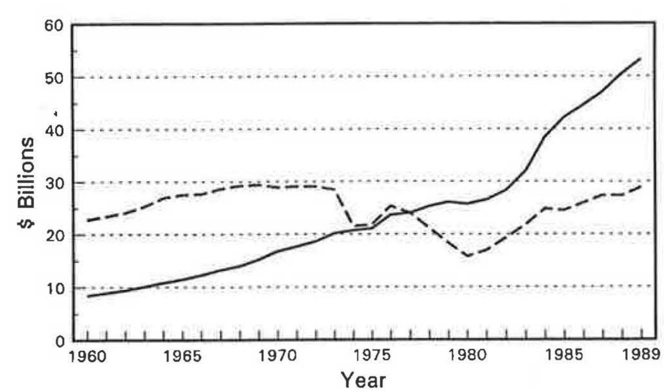

FIGURE 2 Total revenues from user charges, 1960–1989.

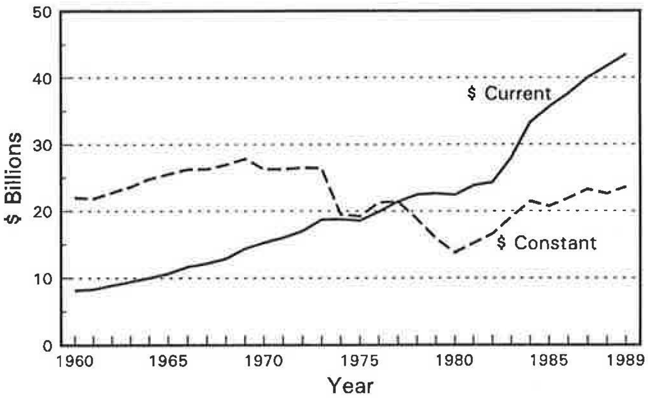

FIGURE 3 Total revenues used for highways from user charges, 1960–1989.

tures include maintenance and operations of highways, administration, highway law enforcement, safety, and debt service on highway bonds and notes. The noncapital highway bill for the public sector was $38 billion in 1989, or 53 percent of all highway expenditures (see Table 2).

Maintenance and Traffic Services

The most expensive noncapital highway activity is roadway maintenance and operations. Maintenance costs include routine and regular expenditures required to keep highways in usable condition (such as patching repairs, bridge painting, and other maintenance-of-condition costs) and traffic service costs (such as snow and ice removal, pavement marking, signs, signals, litter cleaning, and toll collection expenses). Expenditures for maintenance and traffic services are not eligible for federal aid.

A total of $19.7 billion was spent by state, county, and municipal governments in 1989 to keep roads and streets in serviceable condition. The 1989 maintenance and operation spending was 7.5 times that of 1960 and continues to account for about one-fourth of all highway costs.

Administration and Safety

Both highway administration and highway safety expenditures have experienced substantial growth over the past three decades. Spending for administration, including highway planning and research, in 1989 was more than 11 times that of 1960, and its share of all disbursements was up from 4.6 to 7.5 percent. Highway safety expenditures have grown the most, with a 20-fold increase since 1960. Highway safety now commands 9 percent of all spending, compared with 3 percent in 1960.

Debt Service

Highway debt service cost is the only noncapital highway cost showing a reduced share of total outlays. The sum of interest on debt and the annual redemption of bonds accounted for 9.5 percent of all costs in 1960, but debt service required 8.9 percent of all disbursements in 1989.

HIGHWAY CAPITAL EXPENDITURES

Highway capital expenditures are those outlays associated with highway improvements, including land acquisition and other right-of-way costs; preliminary and construction engineering; new construction, reconstruction, resurfacing, rehabilitation, and restoration costs of roadways and structures; and installation of traffic service facilities such as guardrails, fencing, signs, and signals. All of these expenditures are eligible for federal aid.

Governments spent a total of over $33 billion on capital outlay in 1989 (see Table 2). In 1960 capital expenditures accounted for 58 percent of all highway spending; for 1989 the share was 47 percent. For every 1,000 VMT in 1989, $15.80 was spent on highway capital improvements.

Capital Expenditures for Capacity and Preservation

Capital spending on highways can be differentiated on the basis of whether it adds additional capacity or preserves ex-

TABLE 2 Disbursements for Highways by Functions for Selected Years, All Units of Government

Year	Capital Outlay	Maintenance and Operations	Adminis–tration, etc.	Highway Patrol and Safety	Interest on Debt	Subtotal Current Disbursements	Debt Retirement	Total
1960	6,290	2,640	483	327	420	10,160	601	10,761
1964	8,252	3,060	684	474	515	12,985	752	13,737
1968	10,346	4,003	1,017	940	606	16,912	1,071	17,983
1972	12,275	5,443	1,600	1,671	950	21,939	1,270	23,209
1974	13,102	6,573	1,857	2,061	1,079	24,672	1,445	26,117
1976	13,927	7,735	2,209	2,633	1,234	27,738	1,567	29,305
1978	14,938	9,785	2,590	3,160	1,368	31,841	1,593	33,434
1980	20,337	11,445	3,022	3,824	1,456	40,084	1,711	41,795
1981	19,734	12,165	3,439	3,884	1,202	40,424	2,464	42,888
1982	19,052	13,319	3,152	4,068	1,690	41,281	2,046	43,327
1983	20,224	14,240	3,347	4,309	1,872	43,992	2,172	46,164
1984	23,123	15,008	3,604	4,937	1,641	48,313	2,411	50,724
1985	26,647	16,589	4,174	5,241	2,148	54,799	2,737	57,536
1986	29,179	17,643	4,677	5,549	2,505	59,553	2,793	62,346
1987	30,674	18,152	4,973	5,962	2,788	62,549	2,685	65,234
1988	32,883	19,110	4,961	6,108	2,773	65,835	2,755	68,590
1989	33,274	19,679	5,380	6,453	2,871	67,657	3,478	71,135

Note: Values are in millions of dollars.
Source: Highway Statistics, HF–12, various years, and HF–10, October 1990.

isting physical conditions. Capacity improvements include reconstruction with added lanes and wider lanes, and major widening as well as new construction on new right-of-way. Preservation improvements include pavement reconstruction, resurfacing with shoulder or alignment improvements, and resurfacing. As shown in Table 3, capacity improvements account for 53 percent of spending on nonlocal roads; preservation improvements account for 47 percent.

Highway Capital Expenditure Trends

Highway capital outlay by all units of government has grown from $6.3 billion in 1960 to $33.3 billion in 1989 (see Figure 4). In constant dollars, today's spending is comparable to that of the 1960s. The constant dollar low point in capital spending for highways during this period was the $12.5 billion spent in 1980. After 1980 capital outlay increased in constant dollars until 1987, reaching a plateau in the past few years.

Total highway capital outlay per mile of travel has almost doubled since 1960 in current dollars but is down over 60 percent in constant dollars. Inflation increased highway costs nearly five-fold from 1960 to 1989, and real highway spending dropped from over $23 per 1,000 VMT in 1960 to $8.58 per 1,000 VMT in 1989. Since 1980 relative price stability, along with a 64 percent increase in current highway capital spending, resulted in a modest growth in real spending per unit of travel. Still, today's real spending per mile of travel is less than half the 1960 level.

Capital Financing by Level of Government

By law, federal-aid program funds have been legislatively restricted, or earmarked, for capital improvements only. Although the amount spent by state and local governments for capital improvements is known, the source of these funds cannot be accurately determined because they are not necessarily earmarked. The analysis in this section is based on the assumptions that (a) all federal funds are spent on capital outlay and (b) the rest of the funding for capital improvements comes from state and local own-source revenues. No attempt is made to differentiate between state and local revenue sources for capital improvements.

TABLE 3 Spending by Major Improvement Categories on Nonlocal Roads

Major Improvement Category	Percent
System Performance	
Pavement and safety improvements on arterials and collectors	24%
Bridge replacement/rehabilitation on arterials and collectors	16%
Operational improvements to arterials and collectors	6%
Capacity Improvements	
Capacity additions to arterials and collectors	25%
New highway/bridge construction to arterials and collectors	29%
Total	100%

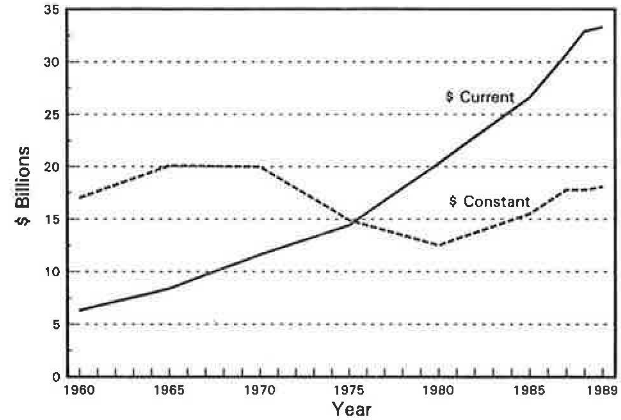

FIGURE 4 Highway capital outlay for all units of government, 1960–1989.

Federal Government

The federal government provided funds for 43 percent of the total highway capital outlay of $33 billion in 1989 (see Figure 5). With the exception of approximately $1 billion provided by other federal agencies, all of these funds came from FHWA. The federal share of highway capital outlay in 1989 was down from a high of 56 percent in 1980. After the 5 cent/gal increase in the federal gas tax took effect, the federal share was 55 percent in 1985; since then it has been going down. The current federal share of 43 percent replicates its 1970 level.

State and Local Governments

State and local governments supplied over half of all funds for highway capital improvements in 1989, as they did during the period from 1960 to 1975. The combined state and local share of capital outlay gradually declined during the late 1970s before leveling off at approximately 45 percent during the early 1980s. Since 1985 the state and local share of capital outlay has been increasing annually.

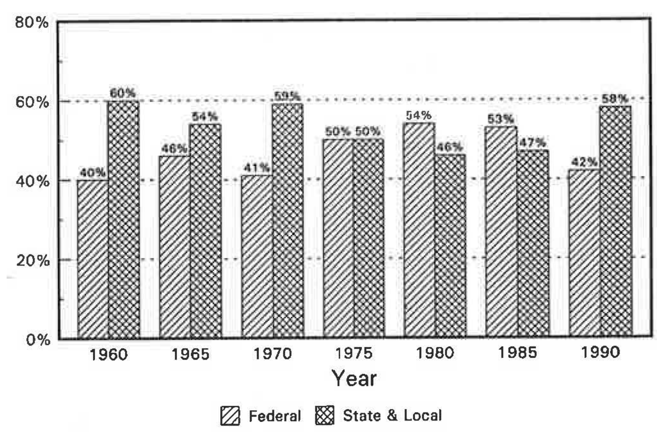

FIGURE 5 Highway capital outlay by level of government.

HIGHWAY CAPITAL OUTLAY ON FEDERAL-AID SYSTEMS

The federal-aid system consists of those roadways that are eligible for federal aid. The federal-aid highway system is divided into four administrative classifications: Interstate, primary, secondary, and urban. Although all roads that are functionally classified as arterials or collectors are eligible, a road becomes part of the federal-aid highway system only when it is designated by a state. Total capital outlay on federal-aid highway systems is estimated to account for $25 billion of the $33 billion expended for capital outlay in 1989 (see Table 4). On the basis of state expenditure data only, capacity improvements account for 54 percent of these expenditures. This amount is comparable to the 53 percent spent on capacity improvements on all nonlocal roads. Highway capital outlay for each federal-aid system is discussed in the following paragraphs.

Interstate System

The federal-aid Interstate system (FAI) capital outlay amounted to $8.2 billion for 1989. As shown in Table 4, expenditures on the rural Interstate were $2.5 billion, or $13.08 per 1,000 VMT. Expenditures on the urban Interstate were $5.7 billion, or $21.06 per 1,000 VMT.

The funding of the Interstate highway system is largely a federal-state activity, with federal funds dominating. In 1989, 79 percent of the funding for capital expenditures on the Interstate system came from the federal government. The remaining 21 percent came from the states. Of this, roughly half was spent to match federal funding on projects in the federal-aid participating program. The other half of state funding was spent on projects with no federal involvement.

Interstate improvements are mainly for system preservation. Less than 30 percent of capital outlay on the Interstate system is spent for new construction.

Federal-Aid Primary System

The next system of national significance is the federal-aid primary (FAP) system. Outlays from all sources on the FAP system were $10.6 billion in 1989. On the rural FAP system, 1989 expenditures were $17.62 per 1,000 VMT; on the urban system, expenditures were $18.76 per 1,000 VMT (see Table 4).

The FAP system is almost totally located on highways under the jurisdiction of the states, making the program essentially a federal-state activity. In 1989 the federal share of spending was 44 percent on the rural FAP system and 54 percent on the urban FAP system. All of the remaining funding for the FAP system came from state and local revenues.

New construction accounts for almost 30 percent of all capital expenditures on the overall FAP system.

Federal Urban and Secondary Systems

The next tier of federal involvement addresses major areawide traffic generators under the federal-aid urban and secondary (rural) systems.

The federal-aid urban system (FAUS) functionally consists of the non-FAP urban principal arterials, most minor arterials, and more than 70 percent of collectors in urban areas. Total capital outlays on the FAUS in 1989 were $3.6 billion. Expenditures per 1,000 VMT were $7.70 in 1989.

State and local governments are the primary funding sources for FAUS improvements. Federal funds account for 33 percent and state and local funds cover 67 percent of all capital costs.

On the basis of state expenditure data only, new construction accounts for approximately 20 percent of capital expenditures on the FAUS. This finding assumes that local spending patterns by improvement type are the same as state expenditure patterns. Because of high land values in urban areas, right-of-way (ROW) and engineering costs account for almost one-fourth of all FAUS costs.

The federal-aid secondary (FAS) system serves basically a rural collector or farm-to-market function. An estimated $2.7 billion was expended on the FAS system by all levels of government in 1989. The federal government provided 29 percent of these funds. Spending per 1,000 VMT was $15.06 in 1989.

Most improvements on the FAS system involve the preservation of roads and bridges. Only one dollar in five goes toward new highways.

PRIVATE-SECTOR FINANCING OF HIGHWAYS

Private-sector financing includes projects funded and developed by the private sector, for example, local roads that are part of a development project or intersection improvements required by a development agreement. Private-sector financing of roads that are part of a development project has been a common practice for a number of years. Projects of this type are often referred to as on-site development. Recently, private-sector financing has expanded to include off-site development, that is, projects outside the boundaries of a spe-

TABLE 4 Total Highway Capital Outlay Per 1,000 VMT, 1989

System	Capital Outlay ($ billions)	Travel (VMT) (billions)	Expenditures per 1,000 VMT
Interstate – Rural	2.5	191.1	13.08
Interstate – Urban	5.7	270.7	21.06
FA Primary – Rural	5.6	317.8	17.62
FA Primary – Urban	5.0	266.5	18.76
FA Urban	3.6	463.3	7.77
FA Secondary	2.7	179.3	15.06
Total Federal–Aid Systems	25.1	1,688.7	14.86
Non Federal–Aid Systems	8.2	418.3	19.60
All Systems	33.3	2,107.0	15.80

cific development project. Projects of this type include improvements to an intersection, widening of an adjacent roadway that is affected by a new development, or a toll road developed by private investors.

Although there is a growing body of anecdotal evidence concerning private-sector financing, there is little hard data. It has been estimated that, in 1989, \$6.4 billion was invested by the private sector for on-site highway improvements and \$3.2 ($\pm$\$2.1) billion off-site. However, these are extremely rough estimates and should be viewed as preliminary. Further effort is needed to gather reliable data on this important and growing area of highway financing.

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Introducing Congestion Pricing on a New Toll Road

ROBERT W. POOLE, JR.

A demonstration project to test the effectiveness of congestion pricing in an urban area is proposed. The general theoretical case for such pricing is reviewed, and recent international interest in congestion pricing is summarized. The need for demonstration projects is outlined, both to add to current knowledge about the effectiveness of congestion pricing and to address political and other public-acceptance barriers to implementation of the concept. A new toll road being planned for Orange County, California, is proposed as a test site for congestion pricing. It is suggested that, instead of charging flat-rate tolls, the transportation agency could charge peak and off-peak tolls, increasing the level of the peak charge each year over a period of up to 10 years, until toll revenues decline below the levels forecast under the flat-rate toll alternative. Measurements of traffic flow and ridesharing behavior would be made, as well as calculations of emission-reduction effects. Finally, a brief discussion of marketing and political considerations involved in conducting such a demonstration is provided.

For more than three decades, economists have urged that direct pricing of road use be implemented to bring demand and supply into balance. To date, pricing for congestion control (as opposed to tolling to pay for road construction and operation) has seen only limited use, and only overseas. Singapore and several Norwegian cities have implemented area pricing to limit vehicular traffic entering the central business district (CBD).

But implementation of congestion pricing, or even serious consideration of that practice, has been held back in the United States both by technical and political problems.

The technical problem has been the difficulty of pricing with conventional methods—either toll booths or access-control stickers. Stickers, used in Singapore, permit only a single price to be charged for access to a certain region or facility. And toll booths, in addition to being unpopular with users and causing additional congestion, do not lend themselves to variable pricing (being set up with fixed-price exact-change lanes, for example). The advent of automatic vehicle identification (AVI) systems makes it feasible to implement sophisticated pricing schemes in user-friendly ways (*1*).

The political problem is at least equally intractable. During the 1970s FTA (formerly the Urban Mass Transportation Administration) offered grants to cities willing to serve as test sites for some forms of road pricing. However, the idea was considered too controversial. Likewise, when California's special task force on transportation proposed the idea in 1976, it was viewed as an anti-automobile measure and dropped as politically infeasible.

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Increased concern over vehicle emissions and congestion levels has made both ridesharing and mass transit popular causes in the past decade. The idea that drivers should pay the full costs of their automobile use has gained increasing respectability, especially in the context of achieving overall air quality goals.

These changes are beginning to affect transportation policy overseas. Norway has begun to use congestion pricing, with Trondheim the first city to implement such a system using electronic toll collection. Bergen and Oslo are converting the existing toll-rings around their CBDs to electronic toll collection (but have not yet instituted peak-hour differentials). The Dutch government has announced plans for electronic congestion pricing in Amsterdam, Rotterdam, Utrecht, and The Hague as part of its national environmental policy plan to reduce urban air pollution. Singapore plans to convert its sticker-based CBD pricing system to a full-fledged congestion pricing system using electronic toll collection. Cambridge and Edinburgh plan to be the first cities in the United Kingdom to implement congestion pricing on city streets (*2*,p.1).

NEED FOR DEMONSTRATION PROJECTS

The idea of charging for freeway use is still unfamiliar to most Californians and their public officials. More foreign, even within the toll-road community, is the idea of using prices as a means of managing traffic demand (as opposed to simply a means of financing the road). The theoretical work carried out to date suggests that regionwide congestion pricing in southern California would have significant impacts on vehicle miles traveled and vehicular emissions (*3*). However, even if the theoretical benefits were overwhelmingly persuasive, it is unlikely that state or local officials could be persuaded to implement such a far-reaching measure on every congested freeway in the region.

Demonstration projects are therefore an attractive next step. There is much that economists and transportation planners still do not know about possible behavioral response to the choices posed by congestion-priced facilities. Also unknown are the political dynamics of congestion-priced projects: which groups will support or oppose such projects and why.

In selecting sites for demonstration projects, the least desirable place to start would be existing freeways, no matter how congested. Putting a price on something that has traditionally been offered free at the point of use risks major public and political resistance, akin to that encountered when an existing freeway lane is taken away to create a high-occupancy vehicle (HOV) lane (e.g., the infamous Diamond Lane episode on the Santa Monica Freeway). The two best types of facilities for introducing the concept are

- Existing toll facilities, where off-peak discounts and peak-hour surcharges can be introduced as fine-tuning the existing pricing to benefit users through reduced congestion and rideshare incentives, and
- Completely new facilities that give users a choice compared with existing, unpriced facilities. New toll roads offer an ideal setting.

Designing and carrying out demonstration projects is important because there is a great deal that the transportation community does not know about user response to congestion pricing. A controversy has developed between traditional toll-road planners and economists over the appropriate modeling techniques to use for congestion pricing (*4*). Thus far, the financial community is cautious about revenue projections based on anything other than traditional analysis using flat-rate tolls; they have no empirical data on which to make judgments about revenue projections for congestion pricing.

Specifically unknown is the response of drivers in automobile-oriented California to peak-hour pricing incentives. What fraction of users will shift their travel to off-peak times? To what extent will time-sensitive drivers be attracted to a less congested highway? What fraction of people will opt for ride sharing or transit, and how will this choice vary by income level and other socioeconomic factors? To what extent will there be displacement of traffic onto nonpriced or conventionally priced facilities? Also, despite the potential environmental benefits (such as reduced emissions and reduced automobile use), to what extent will environmental and pro-transit organizations support congestion pricing?

These significant unknowns can best be assessed by means of carefully designed demonstration projects. Because the potential gains from congestion pricing are enormous, it is important that such experiments be designed and implemented in the near future. If congestion pricing on the entire freeway network would be a more cost-effective way of achieving important transportation goals (e.g., increased vehicle occupancy, reduced vehicle miles traveled, and increased demand for transit), then it is vital to quantify those effects so that this information is available for use in transportation and air-quality planning.

DEFINING THE EXPERIMENT

As noted previously, a new toll road provides one possible venue for demonstrating congestion pricing. The proposed site for such a demonstration is the San Joaquin Hills Transportation Corridor (SJHTC). This 17-mi (14.5-mi tollable) route is an extension of the Corona Del Mar (73) Freeway in Orange County, from Newport Beach and John Wayne Airport southeast to San Juan Capistrano (*5*).

The current design for this tollway is referred to as a 3-2-3 configuration: three lanes southbound, three lanes northbound, and (at a later date) either two reversible HOV lanes or two concurrent-flow HOV lanes in the median. In addition, the median has room for further HOV lanes or a bus or rail transit corridor. The configuration is referred to as the demand management concept, intended to limit the overall width of the tollway to three primary lanes in each direction, plus the median.

The SJHTC corridor has several advantages as a site for the demonstration project. First, the area is affluent, which means objections to pricing based on ability to pay or on equity (rich versus poor) grounds will be fewer for this corridor than for many possible alternatives. (On the other hand, price may be less effective in deterring peak-hour use than it would be in a less affluent area.)

Second, there is some degree of support for the concept on the staff and board of the San Joaquin Hills Transportation Corridor Agency (TCA). On February 14, 1991, the TCA board adopted a resolution supporting its decision to postpone construction of HOV lanes in the median until 2010 by stating, "Tollways provide an inherent financial incentive to encourage HOV usage," and noting, "If additional incentives are necessary [to achieve targeted vehicle occupancy rates], the Board of Directors of the Agency shall adopt appropriate financial toll discounts for high occupancy vehicles in order to achieve equivalent occupancy rates as would occur with construction of the planned HOV lanes" (*6*). The board cited an assessment by Wilbur Smith Associates (WSA) showing that it is possible to decrease tolls for HOV vehicles (in lieu of HOV lanes), and increase them for general use, without a major loss of revenue (*7*).

The proposed controlled experiment on the SJHTC would have three principal purposes:

- To determine the levels of peak-hour price differentials that will produce a given level of net traffic reduction, permitting traffic to flow more smoothly on the SJHTC (Service Level C or better) compared with traffic service levels on the competing parallel routes (Highway 1 and the I-5/405 corridor);
- To compare ridesharing behavior on the SJHTC and the parallel free routes; and
- To quantify the degree of emission reductions brought about by congestion pricing.

Traffic forecasts prepared by the TCA staff (the Corridor Design Management Group) indicate that the SJHTC will experience serious congestion during its initial 15 years. The planned toll rate of $0.138 per tollable mile, though considered high compared with rates charged on most existing toll roads in the United States, appears to be lower than what the traffic would bear.

The planned flat-rate toll is based on demand studies carried out by WSA. WSA used trip tables and link-node traffic networks from the Orange County Environmental Management Agency, revising them to account for the addition of the SJHTC and other new expressways through 2010. WSA then used a capacity-restrained assignment model, with a dual-path choice feature to assign trips to tolled and nontolled segments. For each assignment condition, three separate capacity-restrained assignments were made: a.m. peak, p.m. peak, and off-peak. Separate values of time were used for peak and off-peak conditions and for three types of trip: to and from work, company business, and recreation/other.

The WSA demand studies produced a toll sensitivity curve (toll revenues versus toll rate) with a continued positive slope at the maximum toll rate shown—$0.207/mi. A visual extrapolation of that curve suggests a revenue-maximizing toll of around $0.224/mi (see Figure 1). The shape of the curve suggests that significantly higher tolls than the planned 13.8 cents/mi could be charged without reducing total revenue and that even higher tolls might be feasible for congestion control with only a slight reduction in total revenue. How high might that price level be, and how would the optimum level be established? To take maximum advantage of this experimental setting, a number of different price levels must be tested. Each should be left in place sufficiently long to permit behavior patterns to stabilize—between 6 and 12 months. Because price levels for other goods and services can be expected to continue rising at perhaps 5 percent per year, the experimental design will call for the peak-period toll to be increased by at least 10 percent each period (so that what is being tested are higher charges in real terms).

Perspective on the proposed pricing levels can be gained from the 1975 simulations of congestion pricing in the San Francisco Bay Area by Keeler and Small (*8*). Their estimated optimal (long-run marginal cost) peak-hour charges for urban freeways ranged from $0.145 to $0.343/mi and, on urban-suburban freeways, from $0.033 to $0.091/mi, in 1972 dollars. Converted to 1990 dollars, that would be $0.429 to $1.02/mi for urban routes and $0.0976 to $0.269/mi for suburban routes. Southern Orange County is best described as suburban, so the $0.10 to $0.27/mi should be taken as representative 1990 figures. The proposed peak-hour prices are in line with these numbers derived from simulation modeling.

One possible scheme for the pricing strategy is presented in Table 1. The basic idea is to keep the off-peak toll constant at $0.10/mi while increasing the peak-period toll by 10 percent each period, starting at $0.13/mi (slightly less than the currently planned flat-rate toll). Thus, the differential between peak and off-peak charges would begin at 33 percent and would increase to nearly 100 percent by the 5th period of the experiment. If the experiment continued for another five periods, the differential would exceed 200 percent by the 10th period. A period would be anywhere from 6 to 12 months. If 6-month periods were used, the increase in nominal tolls would be 20 percent per year, large enough to be significant if consumer price inflation continues at moderate levels.

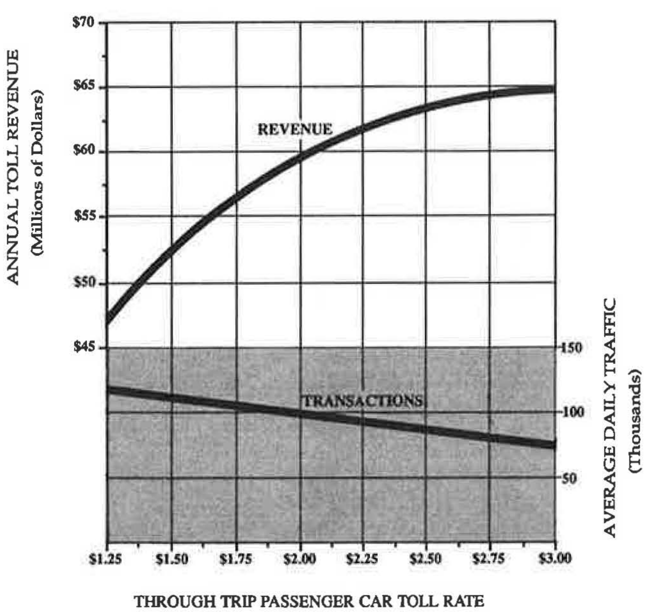

FIGURE 1 Toll sensitivity curve, 1997 levels (*7*).

The financial community has been cautious about the untested idea of congestion pricing. It must be emphasized that, for urban tollways facing competition, a pricing strategy that offers low rates during nonpeak hours and high rates at peak hours is likely to produce more revenue than the conventional flat-rate toll. User sensitivity to price will be quite high at off-peak hours when the parallel free routes are relatively uncongested; by the same token, time-sensitive users will be relatively insensitive to price at peak hours, so it makes sense for the tollway to charge a significantly higher rate then.

To persuade the financial community to consent to this experiment, provisions would still have to be made for deferring or eliminating the next planned increase in any period in which total annual toll revenue was projected to fall below the sum expected from the flat-rate toll. This procedure would ensure that debt-service payments would continue to be made at planned levels.

How realistic are the peak-hour charges proposed in Table 1? The WSA studies for the TCA use average commuter value-of-time numbers of $10.68/hr in 1995, $12.54/hr in 2000, and $15.48/hr in 2005 (*7*). The principal alternatives to the SJHTC are the Pacific Coast Highway (Route 1) and the San Diego Freeway (I-405/I-5). Assume that peak-hour speed on these alternative routes averages 20 mph in 2005 and congestion pricing keeps average peak-hour speed on the SJHTC at 45 mph. For the 14.5-mi tollable length of the SJHTC, the toll road would offer a saving of 24 min during rush hour. On the basis of the WSA figure for 2005, that time saving would be worth $6.23 to the average commuter—well above the highest peak-hour charge of $4.43 in Table 1.

The use of AVI will facilitate this experiment. Toll authorities using coin machines generally price in multiples of $0.25 to maximize the use of exact-change lanes (which have much greater throughput than change-made lanes). AVI will permit fractional prices (such as those shown in Table 1) to be charged, because the charging will take place electronically rather than by means of coin machines. As a further incentive for users to sign up for AVI, the tollway could round each fractional toll to the nearest multiple of $0.25 for cash (tollbooth) customers, thereby giving a small price break to AVI patrons.

The AVI system also greatly facilitates price changes, which is useful when changing from one peak-hour rate to another for each new period of the experiment. It will also be useful on a daily basis in making transitions from off-peak to peak prices. When users know that access conditions will be easier after a certain point in time, they tend to form queues to wait for the transition to easier access. (This phenomenon occurs on Route 66 outside Washington, D.C., when the highway switches from HOV-only to regular access.)

To alleviate this problem, the AVI system can be programmed to make a smooth or stepwise transition between the off-peak and peak rates. If, for example, the peak period is defined as ending at 8:00 p.m., the transition to the off-peak rate of $0.15/mi could be carried out in $0.01 intervals from 8:00 to 10:00 p.m. This transition period would be widely

TABLE 1 Proposed Pricing Schedule for SJHTC Congestion Pricing Demonstration

Period	Peak-Hour Toll	Max. 1-Way Charge	Off-Peak Toll	Peak/Off-Peak Ratio
1	$.13/mi.	$1.88	$.10/mi.	1.33
2	.143	2.07	.10	1.43
3	.157	2.28	.10	1.57
4	.173	2.50	.10	1.73
5	.190	2.76	.10	1.90
6	.209	3.03	.10	2.09
7	.230	3.33	.10	2.30
8	.253	3.67	.10	2.53
9	.278	4.04	.10	2.78
10	.306	4.43	.10	3.06

publicized so that users would know there was little benefit in waiting by the on-ramps until 9:00 p.m., for example, because their savings would only be, say, $0.01/mi for every 3 min they waited. The toll system could also display the current toll rate electronically on roadside or overhead displays at intervals along the route. If the experiment runs for 5 years and the SJHTC opens for traffic in 1995, then by 2000 extensive data will have been collected and analyzed on the effectiveness of congestion pricing. This information will then be available for transportation planning on other southern California facilities and may help in decisions about possible regionwide use of congestion pricing.

This information will also be available well in advance of the planned removal of tolls from the SJHTC in 2010. Level-of-service estimates by the Corridor Design Management Group predict toll-free traffic volumes in 2010 that will result in Service Level F peak-hour conditions along nearly 50 percent of the northbound route and one-third of the southbound route (under the conservative HOV assumption) (*5*). If these projections are correct, service levels by 2015 or 2020 would be even worse, assuming continued traffic growth.

However, if the demonstration of congestion pricing works as well as theoretical models imply, and traffic flows can be maintained at Service Levels C or D during peak hours, then the TCA will have sufficient information to present an argument for the continuing, permanent use of pricing as a basic tool of congestion management from 2010 onward.

MEASURING TRAFFIC FLOW EFFECTS

The proposed demonstration project will compare traffic patterns on the congestion-priced SJHTC with traffic on the unpriced alternative north-south routes: I-405/I-5 and Route 1. Hence, measurements will be needed on all three of these routes at various times during each period of the demonstration project.

Peak and off-peak traffic counts will be needed for all three routes. A simple comparison would contrast forecasted annual traffic levels on these routes (by Caltrans, the TCA Corridor Design Management Group, or other transportation agencies) with the measured levels on each route. On the SJHTC, peak-period traffic volumes should be lower than those forecast and off-peak volumes should be higher than those forecast. Peak-hour traffic volumes on I-405/I-5 and Route 1 may be somewhat higher than those forecast, if there is diversion of some traffic from the toll road because of the higher peak-hour rates. These comparisons may not be highly reliable; many factors (such as changes in local land uses) can affect traffic levels on individual facilities. Nevertheless, to the extent that all three routes serve as substitutes for one another and are affected similarly by corridor-area growth, unemployment levels, and so on, these comparisons will have some validity.

Better estimates of diversion could be obtained from two additional forms of measurement. One would be surveys of random samples of I-405/I-5 and Route 1 users for every period, on the basis of license-plate readings and mail or telephone questionnaires. A second form of measurement could be carried out using AVI technology. If AVI monitoring equipment were installed on I-405/I-5 and Route 1 lanes, that equipment would record the passage of AVI-equipped vehicles on those routes. Presumably, vehicles carrying AVI tags purchased for use on the SJHTC that were operating instead on the alternative routes during peak hours would be vehicles diverted from the SJHTC.

MEASURING RIDESHARING EFFECTS

Increased peak-hour prices will lead to some degree of mode shifting, as some fraction of users who cannot shift to off-peak times or to alternative routes decide to give up the advantages of driving alone. One goal of the demonstration project will be to measure the degree of ridesharing on the SJHTC and the alternate routes as various prices are tested on the former. This goal will be achieved by means of each-period surveys based on license-plate readings and mail or telephone questionnaires.

Southern Orange County poses a difficult challenge to ridesharing. Orange County is one of the most affluent areas in the state, and the service area of the SJHTC is the most affluent portion of Orange County. Affluence is highly correlated with automobile ownership and use, with low-density suburbs poorly suited to bus and rail transit, and with professional and managerial jobs. Surveys of commuters show that individuals with above-average incomes greatly value the door-to-door speed, flexibility, absence of waiting time, privacy, and safety of private automobiles. Conventional transit is unable to compete with the private automobile as the mode of choice for most of these commuters.

Added to this demographic factor is the decentralized pattern of land use in Orange County. The county is renowned for having no downtown, yet it is one of the state's major centers of employment. Census data from 1982 identified nine CBDs in Orange County (defined only in terms of retail centers), compared with just two in 1977. The 1990 census will probably identify many more.

Giuliano and Small (*9*) shed further light on the decentralized nature of Orange County. They identify 32 employment centers in the five-county Los Angeles region. Six of these—Orange County Airport, Santa Ana, Fullerton–Anaheim, Santa Ana South, Orange–Garden Grove, and Garden Grove–Stanton—are in Orange County. However, of the 875,900 jobs (1980 census data) in the county, only 136,000 of them (15.5 percent) are in those centers. The rest are widely dispersed throughout the county.

The low density of employment makes both mass transit and informal ridesharing unusually difficult. In addition, the more affluent the area, the greater the value people put on their convenience, as well as on their time.

A significant incentive would have to be offered to change the behavior of these affluent drivers. This experiment will enable a test of the hypothesis that unusually high prices, especially for nonwork peak-hour trips, may be sufficient to motivate increased ridesharing behavior.

EMISSION-REDUCTION EFFECTS

Air quality is another important consideration. Congestion pricing can be expected to improve air quality in two ways. The first impact comes from the reduced level of congestion on the facility, compared with (a) the level of congestion on the parallel unpriced roads, and (b) the level of congestion forecast by the Corridor Design Management Group for the SJHTC under flat-rate pricing. The California Air Resources Board (ARB) points out that congestion (stop-and-go traffic) significantly increases emissions. As an example, one ARB report (*10*) estimates that a 10-mi trip, using an average 1987 automobile, results in running exhaust hydrocarbon (HC) emissions of 2 g at a speed of 55 mph but that HC emissions would be 7 g at an average speed of 20 mph, typically of stop-and-go conditions.

The second impact on emissions comes from the reduced number of vehicles on the SJHTC. To the extent that higher prices succeed in reducing vehicle miles traveled (rather than simply displacing traffic to the competing routes), there will be fewer vehicles on the road. It is impossible to predict how much of the reduced vehicle miles traveled on the SJHTC will be displacement to other facilities and how much will be true reduction in overall demand. True demand reduction will be less than would be expected in an areawide implementation of congestion pricing, but this is one of the limitations of such a demonstration project.

Between reduced congestion and reduced demand, there would be significant emission reductions from operating the SJHTC with congestion pricing. This reduction cannot be measured directly but will have to be calculated from data on traffic diversion, congestion reduction, and ridesharing increases.

In December 1991 the Southern California Association of Governments issued a finding of conformity with the federal Clean Air Act and the Regional Mobility Plan for the SJHTC. The finding was based on a Memorandum of Understanding with the TCA that the toll-pricing policy will produce HOV equivalency for average vehicle ridership (*11*,p.4).

The current planned removal of tolls from the SJHTC in 2010 would result in significantly increased congestion and the accompanying worsening of emissions—an important additional reason for using the results of this experiment to propose a permanent congestion-pricing regime for the SJHTC for implementation in 2010.

EQUITY CONSIDERATIONS

The equity issue will be less serious for this project than for many other possible demonstration sites, given the demographics of the SJHTC service area. Nevertheless, this issue must be taken seriously in designing the experiment and in explaining it to the public.

Transportation planners should point out that the reduction of congestion levels and increased trip speed on an entire facility will benefit users of transit. It is known that, on average, lower-income individuals are the principal users of public transit in southern California.

Transportation planners and public officials must also explain to the public that congestion pricing represents a step toward a more equitable method of paying for transportation systems. Existing county transportation improvement programs are paid for by a half-cent sales tax—a regressive form of taxation. The gasoline tax, though bearing some relationship to vehicle use, is also regressive in its incidence on income groups. Congestion pricing requires individuals choosing single-occupant vehicles to pay significantly more than those choosing any other form of transportation, and those users tend to be more affluent.

It is critically important that alternatives be provided (and publicized) for individuals who are priced off the SJHTC. As previously noted, the two existing north-south routes—I-405/I-5 and Route 1—are direct substitutes for the SJHTC for many users. Carpools and existing transit will provide alternatives for other residents. But, given the poor suitability of southern Orange County to conventional fixed-route transit, transportation planners should make a concerted effort to bring about traditional transit alternatives for this corridor.

Demand-responsive door-to-door (dial-a-ride) service is available from the Orange County Transportation District only to senior citizens and the handicapped. More generalized minibus and parataxi service could provide both scheduled and demand-responsive door-to-door service, similar to the airport-only service pioneered by SuperShuttle and now offered by numerous firms. Scheduled door-to-door service would overcome the unpredictable waiting times typical of mass transit, and sometimes of carpools and vanpools. Demand-responsive service would provide for the availability of a vehicle whenever the need for an unscheduled trip arose (e.g., for commuters during the day).

A high-demand corridor traversing an affluent area offers a prime location to test door-to-door commercial transportation service, as an adjunct to the tollway. If such commercial services (other than airport shuttles) existed, they would naturally tend to use the toll road during peak hours. In such a business, time is money, and a charge of $5.85 to go the full length of the SJHTC (at $0.39/mi) would be spread over four to eight passengers, adding only a small amount to each person's fare. A reduced toll rate could be given for such vehicles, if further economic incentives were considered necessary. It might be useful to charge a reduced rate until several companies were established and had built up a market in the corridor. But, if the service ultimately proved as popular as airport shuttles, there would be no need for permanent incentives of this sort.

FTA has funded research and demonstration projects on various forms of paratransit and might be interested in aiding such services in Orange County. The TCA could take the lead in encouraging the development of an effective door-to-door paratransit industry in the San Joaquin Hills corridor. Such services would be a natural complement to congestion pricing—offering an additional alternative mode for those tolled off the facility by the higher prices.

MARKETING AND POLITICAL CONSIDERATIONS

How realistic is this proposed experiment? The basic issue of charging tolls is not in question because the SJHTC is already defined as a toll road. The controversial issues will be the environmental acceptability of congestion of pricing instead of earlier implementation of HOV lanes and the fairness of allowing some to pay higher rates for (presumably) better service.

In contrast to a conventional freeway or even a flat-rate-priced toll road, a congestion-priced SJHTC should permit traffic to flow smoothly even at peak hours, thereby producing up to 70 percent less emissions per vehicle trip (*10*) and somewhat fewer trips, as well. These potential environmental benefits, it can be argued, may be greater than those provided by a conventional toll road (or possibly even a conventional toll road plus HOV lanes). The demonstration project is needed to quantify these potential benefits. If the experiment produces evidence to validate the results of the Environmental Defense Fund's recent computer modeling of regionwide congestion pricing (*3*), there will then be a case for considering wider implementation of this pricing policy.

The experiment will also offer an opportunity to introduce a new form of commercial transit service to Orange County. Door-to-door van service, offering attributes superior to that of conventional mass transit and informal ridesharing, may be the breakthrough that finally gets middle-class commuters out of their single-occupant automobiles. But it will take an uncongested, premium-service thoroughfare to make this form of transportation competitively attractive. This, too, is an important reason to test congestion pricing on the SJHTC—and it may be a factor that gains support from environmental and protransit groups.

On the fairness issue, it can also be pointed out that Americans are accustomed to selecting among combinations of price and service in using air travel (which, since deregulation, has become a truly mass-market phenomenon). Paying more to go first class is an ordinary occurrence, whether it is restaurants, hotels, grocery stores, department stores, or airline service. The government-operated postal service now offers Express Mail, a premium-priced alternative to first-class letter mail, to meet the competition of private express services such as Federal Express. Last December the Immigration and Naturalization Service announced that it would test express pay lanes for travelers at selected border crossings with Canada and Mexico (*12*). Those who wish speedier service will be able to pay to get it.

There will certainly be opponents of congestion-pricing experiments. Environmental and protransit organizations have generally opposed the building of the SJHTC. Others have ideological objections to charging tolls, believing that the nation's highways should remain freeways. It is not intended here to make the case for building the SJHTC or for making it a tollway rather than a freeway. The existence of the SJHTC has been assumed, and reasons why this toll road, if built, would be a good place to conduct a demonstration project with congestion pricing have been suggested.

Assuming that the road will be built, and built as a toll road, there is at least a plausible case for diverse interests to support this experiment. Environmentalists should be interested in learning whether peak-hour pricing can significantly reduce vehicle miles traveled and the resulting total amount of vehicle emissions. Transit advocates should be interested in learning whether high prices on roads stimulate demand for new and old forms of transit.

Political support for this experiment may come from several parts of the political spectrum. Political conservatives interested in reducing the need for tax increases may be interested in the potential of highways becoming more self-financing. Liberals seeking a more balanced transportation system, with greater transit alternatives, may also find merit in a system that they would see as creating a more level playing field between automobile use and transit.

In short, the traditional fear that congestion pricing may be a political impossibility may well be overblown. Well-designed demonstration projects, carefully explained and justified, may find diverse support in the search for ways to deal with the serious problem of congestion.

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Emerging Agency Roles in Financing Highway Improvements in Broward County, Florida

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A massive highway construction program has taken place in Broward County, Florida, in the 11 fiscal years spanning the 1980s. Changing agency responsibility for this program is described. Excluding expenditures for preliminary engineering and right-of-way, about $1 billion was spent to construct nearly 1,000 lane-mi of major highway improvements in the urbanized area of the county. This improvement program was the product of many factors, including the accumulated travel demand of an enormous population boom that started after World War II. The hypothesis of a national reversal of federal and state-local roles in financing transportation system improvements during the 1980s is tested in the unique setting of Broward County. A new set of highway players emerged in Broward during the 1980s, including municipal government, the Florida's Turnpike, the Broward County Expressway Authority, and the Port Everglades Authority. These groups joined the Florida Department of Transportation, Broward County, and developers active throughout the 1980s to undertake the construction program described. Revenues from local option gas taxes and tolls helped fund the emerging agency projects. Although Broward County remains a co-leader in lane-mile production with the Interstate program, factors exist that tend to counteract a projected role reversal with the federal government. These factors include the new Florida growth management requirements, which demand more county attention to capacity deficiencies in local road systems, leaving fewer resources for addressing problems on higher level systems. Also there is escalating demand on local transportation revenue to support transit operating costs because of the phaseout of federal transit aids. A ray of hope is the recent emergence of shared-responsibility (jointly funded) projects between the old and new sets of players in Broward highway construction. This activity might be viewed as support for more of a team approach to urban highway improvements compared with the expected federal downshifting of responsibility.

Over the past 11 years, nearly $1 billion from public and private sources has been spent in constructing almost 1,000 lane-mi of major highway improvements in Broward County, Florida. This amount excludes related expenditures for preliminary engineering and right-of-way acquisition. Because this massive highway construction program is reaching its peak and is projected to wind down, some observations can be made about changing agency roles in the program. A variety of agencies have been involved, including the Florida Department of Transportation (FDOT), county and municipal government, individual developers, the Florida's Turnpike, and the Broward County Expressway Authority (BCEA).

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Previous research has suggested the occurrence of a reversal of federal and state-local roles in financing transportation system improvements during the 1980s; a majority of funding now is contributed from state and local sources. It has also been predicted that this role reversal will continue into the 1990s, accompanied by an expected phasing out of major construction of a national highway system and a phasing in of an era of maintenance and rehabilitation. That hypothesis for road improvements in the unique sunbelt setting of Broward County is tested in the following paragraphs.

FACTORS AFFECTING BROWARD HIGHWAY DEVELOPMENT

Approximately 1.25 million people live in Broward County, between Palm Beach and Dade counties (Miami urbanized area) on the southeast Florida coast (see Figure 1). The largest city and the seat of county government is Fort Lauderdale, surrounded by about 400 mi^2 of developable area between the Everglades and the Atlantic Ocean. Almost 90 percent of the population resides within the municipal limits of Broward's 28 cities. Some 5,000 mi of urban streets and highways serve the urbanized area, including just over 100 mi of urban expressway. Broward expressway improvements during the 1980s have helped integrate the expressway system for the tri-county area.

Surface transportation from the outside world originated in 1896 when Henry M. Flagler extended his Florida East Coast Railroad Line south from Palm Beach to Fort Lauderdale, thus providing the initial impetus for development of the Broward County area. World War II resulted in the construction of numerous military bases and military airfields, which eventually became civilian airports, including the Fort Lauderdale/Hollywood International Airport. Commercial air travel made Broward County more accessible than ever, and many servicemen stationed in Broward County during the war chose to return with their families, starting an enormous population boom.

By 1960 the population was one-third of a million, making Broward County the fifth most populous county in Florida. Rapid county growth continued throughout the 1960s (at the rate of about 30,000 persons per year) and increased in the 1970s (at the rate of about 40,000 per year); by 1980 county population exceeded 1 million. Recent population trends indicate that Broward County is entering a period of slower growth, averaging about 25,000 persons a year.

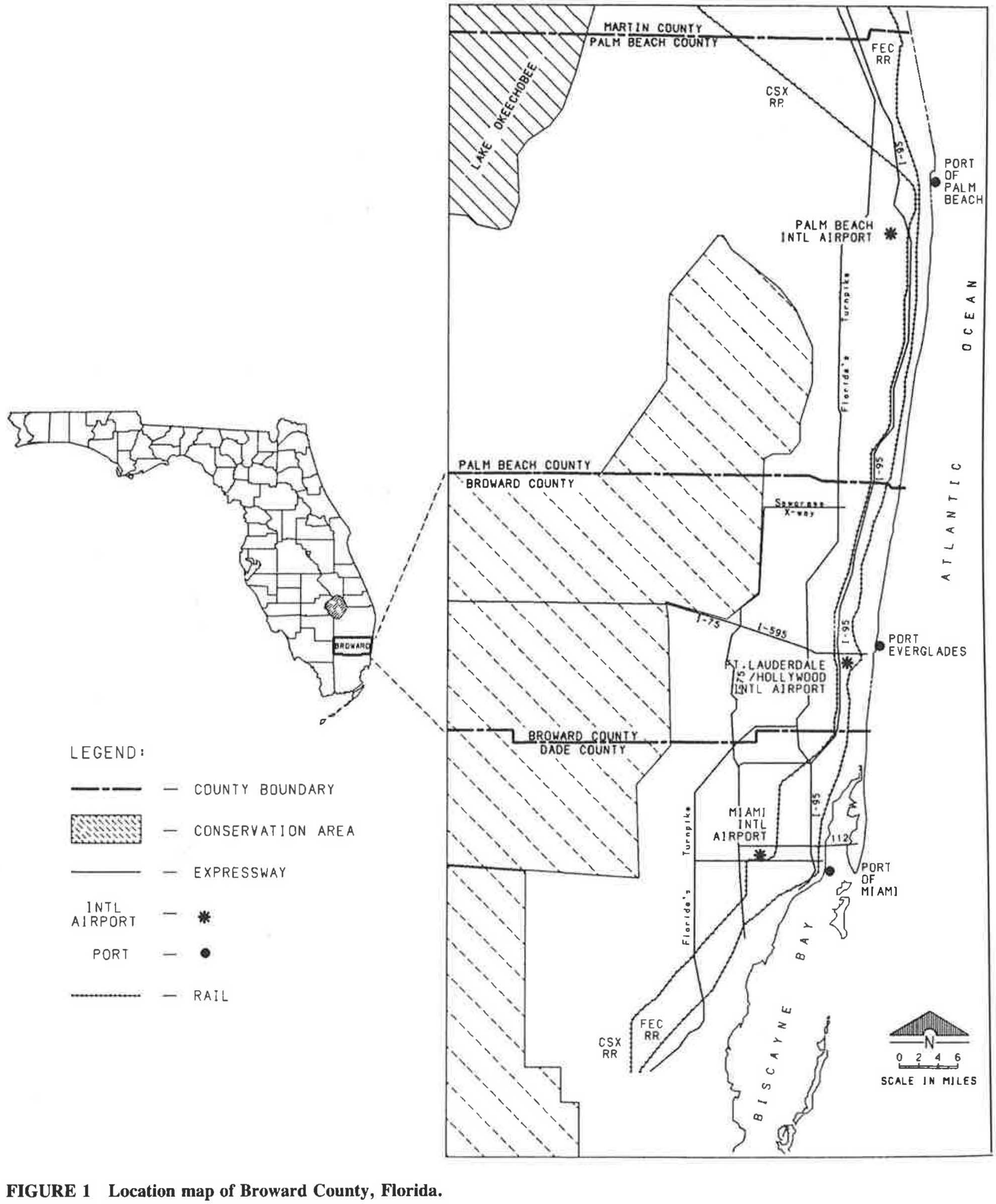

FIGURE 1 Location map of Broward County, Florida.

The context of the Broward County highway experience in the 1980s includes at least two significant factors, which originated at the state level.

First, a chronic backlog of unfunded improvement needs on the state highway system existed throughout the state, caused partly by the accumulating travel demand of locally approved land developments. The adopted 1991 Florida Transportation Plan identifies the 5-year unfunded statewide highway need as more than $7 billion.

Second, the enactment by the Florida legislature in 1985 of landmark growth management legislation culminated in the Local Government Comprehensive Planning and Land Development Regulation Act. The cornerstone of the new Florida growth management process is the concurrency principle—the requirement that the necessary infrastructure, including highway capacity, be in place concurrently with the impact of locally approved developments.

Because of the existing backlog, urban traffic concurrency deficiencies under the new growth management law occur principally on the state highway system. According to the most recent Florida transportation plan, about one-third of all state highways are in urban areas and about half of these urban state highways (both arterials and expressways) are congested. Determining state versus local responsibility for addressing these urban highway deficiencies is a significant issue in Florida today.

FEDERAL-AID CONTRIBUTIONS TO STATE CAPITAL OUTLAY FOR HIGHWAYS

The FHWA annual *Highway Statistics* reports for the 1980s provide a basic perspective on the changing importance of federal highway aid to the FDOT statewide construction program. Table 1 shows a cyclical pattern in the total state capital outlay for highways during the 1980s, which fluctuates from a low of $567 million in 1983 and to a high of $1,406 million in 1988. Table 1 also lists a composite total of the major FHWA payments to the state of Florida in this period that support highway construction: federal-aid primary (FAP), federal-aid secondary (FAS), federal-aid urban (FAU), federal-aid interstate (FAI), and bridge replacement (BRT). This pattern of federal construction reimbursements is more stable than that for state capital outlay but is characterized by less than average annual payments after 1988. The ratio of federal payments to state outlay shows a rather steady decline from 0.517 down to 0.306 during the 1980s if the 1983 low and 1988 high construction years in Florida are disregarded (see Figure 2).

Comparable financial statistics are not readily available for individual counties in Florida to pinpoint the annual federal contribution at this level. Therefore, the following analysis for Broward County is based primarily on construction cost data from highway agencies for completed highway projects.

BROWARD HIGHWAY IMPROVEMENTS IN THE 1980s

Table 2 presents the investment of public and private dollars in constructing completed highway improvements in Broward County over the most recent 11 fiscal years. Eight responsible highway agency types have been identified in the documents and records of the Broward County metropolitan planning organization (MPO). For this analysis, FDOT is subdivided into two categories:

- FDOT/I-SYS represents the urban Interstate highway program in Broward County, including the completion of two new Interstate highways. I-75 and I-595 are the closest approximation to a pure federal-aid system, with a 90/10 matching ratio for participating costs. The table does not contain data relating to the recently completed (fiscal year 1991) addition of 69.2 lane-mi to existing I-95, providing significant capacity improvements. Reconstruction of the last additional 8 lane-mi on I-95 is expected to begin in fiscal year 1992.
- FDOT/NON-I represents all other FDOT completed projects with state or federal funding. Federal participation in these projects ranges from 0 to 100 percent, and the historical records available to the MPO do not readily permit

TABLE 1 Federal Highway Reimbursements in Thousands of Dollars for State of Florida Capital Outlay (*1*)

CALENDAR YEAR	FEDERAL CONSTRUCTION REIMBURSEMENTS FAP	FAS	FAU	FAI	BRIDGE	TOTAL	TOTAL STATE CAPITAL OUTLAY	RATIO OF REIMBURSEMENTS TO OUTLAY
1980	$ 41,985	4,384	30,539	323,672	19,377	$419,957	$811,813	0.517
1981	45,132	2,188	22,107	229,310	26,377	325,114	703,335	0.462
1982	59,351	5,101	22,895	143,213	24,550	255,110	608,078	0.420
1983	55,100	5,185	19,335	211,370	28,345	319,335	567,039	0.563
1984	53,004	7,910	29,283	153,371	22,684	266,252	647,403	0.411
1985	72,871	9,091	31,990	249,771	19,102	382,825	998,532	0.383
1986	78,515	11,792	29,676	217,006	21,728	358,717	1,016,476	0.353
1987	66,561	5,350	31,699	220,898	26,159	350,667	1,194,292	0.294
1988	70,744	3,795	28,692	237,025	29,045	369,301	1,405,645	0.263
1989	56,231	2,498	36,116	200,338	28,362	323,545	1,104,899	0.293
1990	48,933	4,772	28,465	157,025	49,952	289,147	946,156	0.306
	$648,427	62,066	310,797	2,342,999	295,681	$3,659,970	$10,003,668	0.366

Source: Annual "Highway Statistics" Reports, Federal Highway Administration, 1980 through 1990

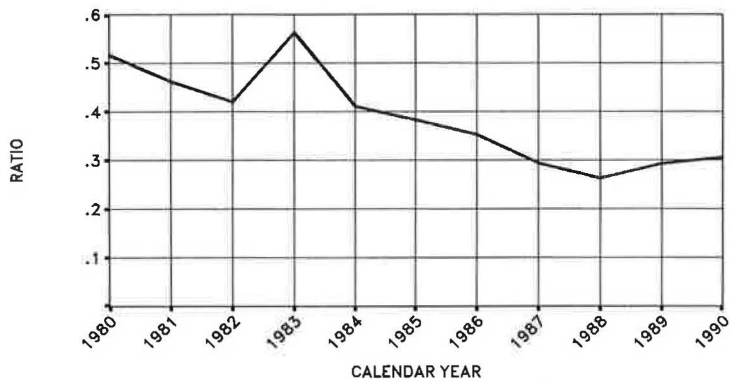

FIGURE 2 Ratio of federal reimbursements to state of Florida capital outlay for highways.

TABLE 2 Estimated Construction Costs of Urban Roadway Projects Completed in Broward County in the 1980s in Thousands of Dollars

	FISCAL YEAR IN WHICH PROJECT WAS COMPLETED											
RESPONSIBLE AGENCY	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	11-YEAR TOTAL
FDOT/I-SYS.	$ 4,988	N/A	N/A	21,366	30,250	18,480	12,430	N/A	38,045	120,124	189,609	435,292
FDOT/NON-I	8,033	1,870	9,099	23,452	N/A	10,276	1,640	2,512	9,379	10,476	33,373	110,110
COUNTY	429	14,060	26,850	1,978	47,632	5,309	13,567	7,132	20,734	4,690	17,401	159,782
MUNICIPAL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	900	500	2,400	1,982	5,782
DEVELOPER	N/A	400	2,250	N/A	1,012	1,400	8,563	3,950	4,256	2,758	29,401	53,990
FTPK	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7,868	27,920	7,205	16,648	59,641
XWAY AUTH.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	94,791	N/A	6,629	N/A	101,420
PORT AUTH.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,750	1,750
	$ 13,450	16,330	38,199	46,796	78,894	35,465	36,200	117,153	100,834	154,282	290,164	927,767

Notes:
- These Estimated Costs do not include Right-of-Way or Preliminary Engineering Costs.
- Roadway Projects Include Improvements to the Expressway, Arterial, and Collector Road Systems.
- The FY 1990 amount for FDOT/I-SYS. does not include the cost of reconstructing I-95, which was under construction but was not completed at this time.
- N/A means Not applicable.

Source: Transportation Planning Division, Broward County Office of Planning

an accurate estimate of the composite federal/state funding split for construction in a given fiscal year.

The Florida's Turnpike (FTPK) was an independent state agency until 1969 when it was consolidated into FDOT. BCEA (XWAY AUTH in the table) is an agency created by state statute to build the Sawgrass Toll Expressway and ancillary facilities in Broward County. The completed 23-mi expressway has been incorporated into the FTPK system. The Port Everglades Authority (PORT AUTH) is a statutory authority that owns and operates Port Everglades on the Atlantic Coast in east central Broward County.

The first observation that can be made from Table 2 is that one set of responsible agencies has been active throughout the 1980s:

- FDOT/I-SYS,
- FDOT/NON-I,
- Broward County, and
- Developers.

This set is joined by a new set of players in 1987:

- Municipal government,
- FTPK,
- XWAY AUTH, and
- PORT AUTH.

Some noteworthy departures from the predicted national role-reversal model are evident from examining Table 2. First, the Interstate highway program is still alive and well in Broward County and remains the major financial contributor to the highway construction program through fiscal year 1990. With the addition of 69.2 lane-mi on I-95, fiscal year 1991 will be the peak year for the Interstate program in Broward. The Broward County MPO, however, is currently programming Interstate highway construction and resurfacing projects through fiscal year 1996.

Second, the next largest contributor after the Interstate program is the county road program. Although the national model would predict an increasingly higher rate of county participation, Broward County government was already making major financial contributions for highway construction at the beginning of the decade. In fact, as Table 2 shows, the county was the major road builder in the early 1980s. Almost $60 million, or about one-third of the county contribution over the 11-year period, was spent for constructing completed projects on the state highway system, a practice that was initiated by county bond issues in the late 1970s. Numerous public surveys conducted at that time identified better transportation as the county's most critical infrastructure need, in response to rapid growth and development. As opposed to the apparent national trend, the county is now spending less on the higher level state highway system and concentrating more on addressing traffic concurrency deficiencies on the county highway system in compliance with the state's new growth management law.

Several patterns of data in Table 2 do conform to the role-reversal model, for example, the recent emergence of municipal government as a contributor to the highway improvement program. This occurrence coincides with the sharing of the proceeds of the county's 6-cent local option gas tax, which is distributed on a 62.5 percent (county) versus 37.5 percent (municipal) basis. In Florida the jurisdictional responsibility for functionally classified arterials is currently limited to state and county government; therefore, the local urban highway program has traditionally been the county road program. City expenditures are now being made on both the collector and arterial system.

In addition, although developer participation in completed road construction has been evident throughout the 1980s, the level of participation is variable. In FY 1990, the $30 million developer contribution exceeds all other categories except FDOT/I-SYS and FDOT/NON-I. This significant increase can be attributed to major road improvements in western Broward, which were required of developers in conjunction with governmental approval of associated developments of regional impact (DRIs).

Table 2 clearly shows an expanding role for toll financing in road construction at both the state and county level. In the early 1980s, the turnpike construction program in Broward was dormant. Recent state legislation authorized up to $425 million in state transportation trust funds and the sale of $1.1 billion in revenue bonds to further expand the FTPK throughout the state. This has been accompanied by an upward adjustment in tolls. BCEA made a $100 million contribution to the overall road program in the late 1980s by building the Sawgrass Expressway around west Broward.

Table 3 also presents the emerging agency roles in Broward highway improvement by listing lane-miles of completed projects (excluding local streets) for the various agencies. Table 3 tends to parallel Table 2 but provides a clearer picture of the actual physical improvements completed in Broward County. Because higher levels of highway facilities are expected to cost more to construct per lane-mile, Table 3 is one way to normalize the described efforts of roadway agencies at various levels. The county is the overall leader in this type of comparison, followed by the Interstate highway program.

TABLE 3 New Lane-Miles of Urban Roadway Projects Completed in Broward County in the 1980s

RESPONSIBLE AGENCY	FISCAL YEAR IN WHICH PROJECT WAS COMPLETED 1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
FDOT/I SYS.	16.4	N/A	N/A	28.8	34.4	17.6	14.4	N/A	14.4	38.6	58.2
FDOT/NON-I	13.8	0.6	16.6	30.0	N/A	13.8	2.0	7.4	2.8	9.3	26.4
COUNTY	7.5	27.4	55.4	6.0	87.1	13.6	25.8	20.0	34.9	22.2	22.7
MUNICIPAL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.1	7.6	2.0
DEVELOPER	0.2	2.0	7.0	N/A	3.0	4.6	23.6	11.8	15.8	6.6	51.8
FTPK	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5.6	14.6	3.2	15.0
XWAY AUTH.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	119.2	N/A	N/A	N/A
PORT AUTH.	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.0
	37.9	30.0	79.0	64.8	124.5	49.6	65.8	164.0	85.6	87.5	179.1

NOTES:
- Roadway Projects Include Improvements to the Expressway, Arterial and Collector Road Systems.
- The reconstruction of I-95 was underway in FY 1990, but the 69.2 additional lane-miles on I-95 were not completed until FY 1991.
- N/A means not applicable.

SOURCE: Transportation Planning Division, Broward County Office of Planning

Private developers rank third in lane-mile production, and a comparison of Tables 2 and 3 suggests they spend the least per lane-mile of roadway constructed.

The dip in lane-mile production for FDOT/NON-I projects in the mid to late 1980s is reflective of the previously mentioned severe funding shortfall at the state level. This change also appears to be caused in part by the channeling of available state funds to maintain the schedule of the Interstate program, including necessary state funding of nonparticipating Interstate system costs.

Table 4 presents a closer look at changing agency participation in the construction of new lane-miles of roadway. Indicated for each agency type are the number of lane-miles, the annual average lane-miles, and the percentage of total lane-miles added for two time periods:

- The entire 11-year period of observation (fiscal year 1980 through fiscal year 1990), and
- The most recent 5-year period of observation (fiscal year 1986 through fiscal year 1990).

For overall lane-mile production, the most recent 5 years were more productive on average (116.40 lane-mi/year) than the entire 11-year period (87.98 lane-mi/year). In terms of the relative importance of roadway agencies in lane-mile production, the following can be noted from Table 4:

- The burden of lane-mile production is spread more evenly in the most recent 5-year period, with developers and BCEA essentially equaling the effort of the Interstate highway program and the county. (These four agencies were each responsible for about 20 percent of the new lane-miles.)
- As previously discussed, the production of FDOT/NON-I lane-miles is down in the most recent 5 years because of the effects of the state shortfall and the need to provide necessary support for the massive Interstate program.
- Other players are emerging to help share the road construction responsibility in a modest but collectively significant way. Together, municipal government, the FTPK, and the Port Authority were responsible for about 10 percent of the new lane-miles in the recent 5-year period.

EMERGING ROLES IN BROWARD HIGHWAY IMPROVEMENTS

Evidence of emerging roles in financing Broward highway improvements exists at all levels of government and provides additional perspective for reviewing the Broward County data set. As with the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, some of these factors are not fully defined. For example, the county is attempting to determine the following:

- Is the Surface Transportation Program of the ISTEA actually a block grant of earmarked funds to MPOs with a population of over 200,000, or is it more like the previous FAU program in which the MPO sets some priorities and everything else is left to the state?
- Who will administer federally aided urban projects off the state highway system, what are the project development requirements, and whose design standards apply?
- What are the actual net increases in federal funding for the urbanized areas, and what is the schedule to make funds available for programming?

TABLE 4 Changing Agency Participation in Construction of New Lane-Miles of Urban Roadway in Broward County

RESPONSIBLE AGENCY	1980 THRU 1990 (11 YEARS) LANE-MILE	ANNUAL AVERAGE	PERCENTAGE OF TOTAL	1986 THRU 1990 (5 YEARS) LANE-MILE	ANNUAL AVERAGE	PERCENTAGE OF TOTAL
FDOT/I Sys.	222.8	20.25	23.0	125.6	25.12	21.6
FDOT/Non-I	122.7	11.15	12.7	47.9	9.58	8.2
COUNTY	322.6	29.29	33.3	125.6	25.12	21.6
MUNICIPAL	12.7	1.15	1.3	12.7	2.54	2.2
DEVELOPER	126.4	11.49	13.1	109.6	21.92	18.8
FTPK	38.4	3.49	4.0	38.4	7.68	6.6
XWAY AUTH.	119.2	10.84	12.3	119.2	23.84	20.5
PORT AUTH.	3.0	0.27	0.1	3.0	0.60	0.5
	967.8	87.98	99.8	582.0	116.40	100.0

Source: Transportation Planning Division
Broward County Office of Planning

At the state level, the Florida legislature is reexamining highway functional classification with an eye to focusing available state resources on certain higher order state interests (which are still in the process of being defined). An issue here has been an attempted capping of the size of the state highway system. (At present, the total public highway and street system in Florida consists of approximately 11,800 mi of state highways, 67,000 mi of county roads, and 28,000 mi of city streets.) As Broward County continues its pattern of urban growth westward from the Atlantic coastline, the Broward County MPO and the County Commission have taken the position that the state arterial system should expand accordingly or, at a minimum, the state should share the responsibility for maintaining and improving the extended arterial system. Mediation of a state-county dispute over who should have jurisdiction of 17 mi of new arterials in west Broward is pending.

In contrast to stated urban highway needs, major state highway expenditures in Florida will apparently be targeted in the foreseeable future onto a new statewide system of highways—the Intrastate Highway System—established by the 1990 Florida legislature. This high-speed, long-distance highway system, according to the 1991 Florida Transportation Plan, will be completed over the next 20 years, incorporating existing Interstate highways, the FTPK, new expressways, and selected arterial roads with highly controlled access. The projection of this policy direction is that FDOT will give lower priority to the nonexpressway portion of the county's existing urban arterial system (i.e., some 380 centerline miles).

On a somewhat more optimistic note, the state legislature has recently amended the FDOT Local Government Cooperative Assistance Program from a 20 percent state versus 80 percent local matching ratio up to a 50/50 ratio for off-system improvements. However, the program is currently unfunded. The MPO is urging the legislature to provide funds for the program, which can help to relieve pressure on the state highway system while taking advantage of local fund contributions to meet mutually agreed upon state and local needs.

Revenues for the Broward County road construction program during the 1980s have come from a variety of sources, including the following:

- State shared gas tax (80 percent of the state's 5th- and 6th-cent gas tax)
- 1976 county bond issue
- 1978 county bond issue ($125 million for 35 projects)
- Four-cent local option gas tax (commencing in fiscal year 1984)
- Bonding the local option gas tax
- State Department of Commerce grant
- County highway impact fees
- Increase to 6-cent local option gas tax (commencing in fiscal year 1986)
- Interest income

Referring back to Tables 2, 3, and 4, these county revenue sources have resulted in a construction budget averaging some $14.5 million/year over the 11 fiscal years spanning the 1980s, adding about 30 lane-mi/year to the public road system in Broward County. The cornerstone of the county road construction program is the local option gas tax, enacted by the 1983 Florida legislature. This tax was the beginning of a clear policy direction by the state of Florida to share responsibility for alleviating urban roadway congestion with local government. The Broward Board of County Commissioners voted in favor of the 4-cent tax permitted at that time. The tax became effective on September 1, 1983, and initially generated a total of about $20 million/year for county and city road and mass transit projects.

Of the local option gas tax proceeds, 37.5 percent is shared by the cities in Broward on the basis of their relative population size. This money must be used for a transportation purpose. By fiscal year 1987, Broward municipalities began their voluntary participation in major roadway construction, as presented in Table 2. Stated city needs also include reconstruction of streets, intersection improvements, road resurfacing, and drainage improvements.

By fiscal year 1986 the Florida legislature permitted an additional 2 cents, or a total of 6 cents, of local option gas tax to be levied. Broward County took immediate advantage of the full 6-cent option and continues to share that with the cities, using the original formula.

This local option tax now generates a total of about $35 million/year for county and city road and mass transit projects. However, Broward County must now use about half of its share of the local option gas tax proceeds, about $13 million annually, to help fund the operating costs of the county bus transit system, brought about in part by the federal government's phased reduction of its transit operating assistance program. Thus, actual role reversal in urban transit funding has been under way for some time and demands an increasing share of available local transportation user fees.

Another highway financing mechanism being made available to local governments in Florida is the toll-funded BCEA, established in 1983 to construct the 23-mi Sawgrass Expressway. A road of this magnitude usually takes from 4 to 7 years to complete, but BCEA accomplished the project in 2 years 10 months because of less cumbersome administrative requirements. To facilitate connecting traffic on and off the Sawgrass Expressway, several feeder roads were also improved by BCEA. BCEA produced 12.3 percent of the new lane-miles of major urban roadway in Broward County during the 1980s, as shown in Table 4. To make this expressway project feasible, the county had to dedicate 80 percent of its state shared gas tax revenue (5th and 6th cents) to help meet toll revenue bond payments in the early years of the project. The Sawgrass Expressway recently became part of the FTPK, and BCEA remains in existence with no current project activity.

Yet another state mechanism in Florida to shift the burden of road construction to the local level and responsible developers is the requirement for them to accommodate traffic impacts for developments that exceed specified thresholds of land use activity. These DRIs must provide a detailed assessment of transportation impacts and enforceable commitments to address those impacts as a condition of permit approval. In the Broward County area, this process is administered by the South Florida Regional Planning Council. The process was a major factor in the increasing developer participation in the Broward road program, which averaged almost 20 lane-mi/year in the most recent 5-year period, according to Table 4. Some Broward developers also construct road improvements instead of making county highway impact fee payments.

SHARED PROJECTS

Table 5 presents some initial evidence of a trend toward the shared project approach. This is somewhat noteworthy in Florida, where the historical practice has been to centralize major road construction responsibilities under the jurisdiction and management of FDOT. Typically, FDOT matches available federal aid and manages the project in accordance with statutory guidelines.

The emergence of shared roadway projects in Broward County began in the early 1980s with developer participation in the western growing areas of the county. The unwritten policy of the County Commission is that the development community must assume a major responsibility in these areas because in-lying road needs far exceed available public financial resources. By 1987 shared projects became more prevalent. For example, BCEA was also working with developers and the county to complete the necessary approach road improvements to interchanges on the toll-funded Sawgrass Expressway.

By 1989 the city government became actively involved in shared projects, working both with the county and developers. Typically these shared projects serve multiple purposes, including satisfaction of developer requirements, improved city traffic circulation, and the filling of gaps in the countywide arterial grid. Working individually, the responsible agencies could only look forward to delayed, underfunded, or incomplete projects.

The pattern illustrated in Table 5 is continuing into the 1990s with the county and cities leading the way in completing and programming joint funded construction projects. The county's newest capital improvement program includes a separate listing of such projects.

CHANGES IN THE PRIORITY-SETTING PROCESS

The changing availability of funding from various levels and sources has been accompanied by adjustments in the Broward MPO's priority-setting process and the nature of projects at the top of the priority list.

For example, the pending completion of the Interstate system in Broward County has brought into focus the need for adequate approach roads and connections to that system. Interstate-system funding for these needed improvements has been supplemented by non-Interstate-system federal aid and state funds to help get this job done. Broward County has suggested to its congressional delegation that the Interstate system is not complete until it is properly connected to the arterial network.

Transportation system management (TSM) projects have received much more attention recently because of the previously discussed state funding shortfall in the mid to late 1980s and the escalating right-of-way costs in built-up areas. Therefore, the MPO has adopted high-ranking projects for accelerating the completion of the countywide computerized signal system, intersection improvements on congested roadways, and preliminary engineering for a reliever route to a state highway that was not feasible to widen. Even when the 1990 session of the Florida legislature enacted the additional 4 cent/gal gas tax to match the 6 cent/gal local option gas tax levied by urban counties, the Broward MPO took the position that available highway revenues should be increasingly targeted to TSM projects. Under growth management laws, the highly demanding traffic concurrency problems along built-up highway corridors in Broward particularly support a higher

TABLE 5 Shared Responsibility for Funding Urban Roadway Projects in Broward County

FISCAL YEAR COMPLETED	NO. OF COMPLETED PROJECTS	SHARED RESPONSIBILITY PROJECTS	MOST INVOLVED AGENCIES
1980	14	0	
1981	7	0	
1982	23	3	County/Private
1983	14	1	County/Federal
1984	18	0	
1985	9	0	
1986	12	1	Developer/County
1987	22	6	Developer/Xway Auth
1988	20	4	County/Developer
1989	21	5	County/City
1990	40	5	County/State

NOTE: Roadway Projects include improvements to the expressway, arterial and collector road systems.

Source: Transportation Planning Division
Broward County Office of Planning

priority for the TSM projects. Recently, the FDOT District Secretary has encouraged the county to take more of a lead role in identifying candidate projects.

The evolving interagency cooperative efforts to expand the highway and transportation network in and around Port Everglades, including contributions by the Port Authority itself, have resulted in a cluster of related projects at or near the top of recent MPO priority lists, some of which have already been funded. This cluster of projects includes Interstate approach road improvements, an Intracoastal Waterway bridge and tunnel replacement, surface arterial intersection improvements along the port boundary, and a study for a major connector road improvement through the port. Funding contributors listed in the Broward MPO's current transportation improvement plan (TIP) for port area roadway projects include FDOT, with federal and state funds, local government, and private developers. A new County Convention Center within the port boundaries has contributed to the urgency of these projects.

PRINCIPAL FINDINGS AND CONCLUSIONS

The following are some findings and conclusions from the Broward experience that may add perspective to the projected national downshifting of responsibility for highway and transportation improvements from the federal government to regional and local agencies (i.e., role reversal).

During the 1980s, the number of responsible highway agency types that completed projects on the collector, arterial, and expressway system in Broward County doubled from four to eight. The new set of players included municipal governments, the FTPK, BCEA, and the Port Everglades Authority. These new agency types joined FDOT (Interstate and non-Interstate), Broward County, and developers who were active through the 1980s to undertake the construction program described here. The new players were responsible for about 18 percent of the funding and new lane-miles constructed over the 11-year period. The applied revenues resulted from shared use of state and local option gas tax, toll funding, and the enlightened self-interest of the port. It is generally acknowledged by responsible highway officials in south Florida that the new players, particularly BCEA, accelerated necessary urban highway improvements in Broward County.

Somewhat deviating from the national role-reversal model, the Interstate highway program is still alive and well in Broward County, and the Broward County MPO is currently programming Interstate highway construction (8 lane-mi) and resurfacing projects through fiscal year 1996. Not examined here, but perhaps deserving further study, is the impact on the state budget to maintain the schedule of the Interstate program, including necessary state funding of nonparticipating Interstate-system costs.

Also deviating somewhat from the national model of the 1980s, Broward County began its significant local participation in the urban highway program in the late 1970s with bond issues to construct highway improvements on all systems, including $60 million of improvements to the state highway system. A variety of revenue sources have funded a county construction budget averaging some $14.5 million/year and adding about 30 lane-mi/year during the 1980s. Even through the peak of the Interstate program, the county remains a coleader in the lane-mile production.

The above findings might be hastily interpreted as documentation of the capability of local government to absorb a national policy to downshift the responsibility for highway and transportation improvements. Other factors need to be considered, however, before arriving at a conclusion. For example, the enactment by the Florida legislature in 1985 of landmark growth management legislation is severely testing the capability of local government to provide required infrastructure, including highway capacity, in a timely manner. Therefore, Broward County is now spending less on the higher level state highway system and focusing on capacity deficiencies on county roads, in compliance with the growth management law.

In addition, the sustaining revenue source for the county road construction program has been the local option gas tax, first enacted by the 1983 Florida legislature. Broward County now levies 6 cents of this gas tax and shares the proceeds with Broward cities in a 62.5 percent county versus 37.5 percent city split. Even though this tax now generates about $35 million annually, the county must use about half of its share to help fund the operating costs of the county bus transit system. This circumstance is mostly caused by the federal government's already implemented phasing out of its transit operating assistance program. The local option gas tax will not be able to accommodate additional county responsibilities for transit or major highway improvements.

A ray of hope that may be evidenced in the Broward County data set is the recent emergence of the shared-responsibility (jointly funded) projects between the old and new sets of players in the highway construction program. This activity appears to have occurred or evolved voluntarily and without mandate to address unique or pressing urban highway needs. It might be viewed as support for more of a team approach to urban highway improvements compared with the expected federal downshifting approach. Three team concepts appear worthy of some exploration from the Broward County experience.

One concept is the increased use of off-system funding approaches, particularly to facilitate adequate connections between various components of the urban highway system. A particular example of this issue in Broward County has been inadequate funding for improved crossroad approaches to the Interstate highway system. It appears that the Surface Transportation Program component of the new federal act may be able to address this problem if agencies can work together to steer the new dollars to these and other needed connections.

A second concept is increased reliance on shared funding sources for use on all key components of the urban highway system, including expressways, arterials, and major collectors. Some natural willingness to do this has already been evidenced in Broward. The state of Florida and Broward County already share their gas tax proceeds with counties and cities, respectively. However, the serious traffic concurrency deficiencies on the urban state highway system demand an intensified level of state-county cooperation. This cooperation might be achieved in a variety of ways, including adequate funding of FDOT's Local Government Cooperative Assistance Program and increased use of county highway impact fees to help fund state projects.

A third concept is federal encouragement and state policy direction to better enable alternate responsible agencies to manage the construction of federally aided roadways in urbanized areas. This process would also require changes to state legislation in Florida. Certainly, new, more locally oriented managers are emerging and would benefit from the substantial technical expertise that exists at the federal and state levels. In return, new local managers should be able to create more opportunities for innovative highway solutions and financing. TSM improvements along urban arterials appears to be one project category in which the county can and should take a lead role.

REFERENCE

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Regional Transportation Financing: The Southwestern Pennsylvania Initiative

RITA POLLOCK AND LORNA PARKINS

Transportation planning is the primary objective of the Southwestern Pennsylvania Regional Planning Commission's (SPRPC) program. During its 29 years as the Metropolitan Planning Organization (MPO) for southwestern Pennsylvania, the commission has documented the region's transportation needs and available resources. Most recently, SPRPC accounted for $10.5-bil in highway, bridge, and transit needs and $4-bil in anticipated funds. In 1990, SPRPC's Transportation Strategy Policy Committee convened a working group to examine transportation financing options. This group's recommendation was deliberated by regional leaders at SPRPC's Fall Policy Conference in November 1990, and resulted in SPRPC's Regional Transportation Finance Initiative. The initiative proposes a multicounty Regional Transportation Finance Authority that would have the principle responsibility of allocating revenues from new, local-option taxes to a specific set of transportation improvements. The authority would work with SPRPC to produce a comprehensive regional transportation and development plan. The plan would identify and rank transportation improvements such as highways, transit, and any other types of improvements that are critical to regional development. After the priority transportation projects are identified, a package of taxes would be proposed for funding. The recommended local option taxes include gas, ad-valorem vehicle, and sales taxes. These taxes would be levied by the participating counties. A mixture of taxes is being proposed so no single tax is inordinately high, and so both user fees, which are perceived as fair, and broad-based taxes can be included.

The Southwestern Pennsylvania Regional Planning Commission (SPRPC) is southwestern Pennsylvania's designated Metropolitan Planning Organization (MPO), which has the responsibility for transportation planning and programming in the six-county region. More than 29 years of experience has given SPRPC a comprehensive understanding of the region's transportation system.

In recent years, SPRPC has developed a growing concern over the magnitude of the region's transportation needs and the limitation of existing federal, state, and local financing programs. SPRPC appointed a Transportation Strategy Policy (TSPC) Committee, comprised of public and private leaders, to assess these needs, to determine the level of available funding, and to develop a strategy for improving transportation.

The committee found that the established state and federal programs will not provide enough resources to significantly improve the region's transportation system. Current programs are also insufficient to maintain existing regional highways, local roads, bridges, and transit systems. The needs over 12 years exceed $10 bil and the funding shortfall is $6 bil.

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The transportation problem has serious economic consequences. There is a growing recognition that improved transportation and good mobility are essential to regional development opportunities. Southwestern Pennsylvania is likely to grow because of scheduled 1992 opening of the new airport, the strategic national location, the environment, and the revitalized economy. Conversely, a failure to provide improved mobility will result in lost economic opportunities, growing congestion, a poorer environment, and deteriorated quality-of-life.

With a predictable local source of funding, the region's leaders would be in a position to make strategic transportation investments that would leverage state and federal funds and support the region's development opportunities.

Accordingly, in the summer of 1990, the SPRPC Transportation Strategy Policy Committee formed a Transportation Finance Working Group (TFWG). The committee gave the group the task of recommending a new financing mechanism that would enable southwestern Pennsylvania to significantly improve its transportation system.

The deliberations and findings of the group may be of interest to other regions. For example, the group sought a financing solution for a sub-state, multi-county area, whereas other models for transportation financing have either been statewide or single-county. The group also proposed a mixture of taxes. While the taxes themselves are commonly found elsewhere, the proposal for enabling and levying them together as local-option taxes for transportation purposes is unique. Finally, southwestern Pennsylvania differs from other regions that have raised local transportation revenues because it is not a high-growth area. San Diego, Phoenix, Houston, and other areas that have provided local solutions to their transportation problems, are generally struggling to keep pace with high levels of growth. In contrast, southwestern Pennsylvania has recently experienced a decade of economic decline and restructuring. Capitalizing on future opportunities for growth depends largely on improving mobility in the region.

TRANSPORTATION FINANCE WORKING GROUP

Overview and Objectives

The group made a comprehensive evaluation of regional transportation financing mechanisms. The assessment included financing mechanisms used in other states and metropolitan areas, powers currently available to county and local governments in Pennsylvania, alternative mechanisms for southwestern Pennsylvania, and alternative organizational arrangements for administering regional transportation revenues. Descriptions of each part of the group's assessment follow.

The group concluded that the finance mechanism should broadly benefit surface transportation. Surface transportation is defined as local, regional, and interregional roadways, guideways, structures, vehicles, and other associated facilities and equipment for the movement of people and goods over land.

The recommended finance mechanism is intended to meet the following objectives:

1. To promote the safe and efficient mobility of people and goods through improved surface transportation and better intermodal linkages,
2. To accelerate the accomplishment of the region's priority transportation improvements in cooperation with the US Department of Transportation (DOT) and the Pennsylvania Department of Transportation (PennDOT),
3. To support the operation and maintenance of the region's surface transportation system,
4. To raise revenues for the improvement of the region's surface transportation system through member governments,
5. To promote the region's economy through strategic transportation investments, and
6. To promote the wise and efficient use of transportation resources.

The group prepared two alternative proposals. Each proposal enables the counties of southwestern Pennsylvania to levy taxes that are dedicated to the improvement, expansion, maintenance, and operation of surface transportation systems and services. The two proposals vary in the administration of the tax revenues and are summarized and compared below.

Examples of Innovative Transportation Finance Mechanisms

A number of counties, regions, and states have developed innovative transportation finance mechanisms to meet growing transportation needs. These mechanisms include user charges, special benefit fees (such as impact fees), non-user related fees (such as sales and property taxes), private financing, debt financing, and special revenues. The group decided to focus on user and non-user fees, specifically tolls and taxes. Specific examples of innovative toll roads, local-option taxes and state taxes for transportation have been identified and researched.

Toll Roads

Four examples of toll roads were researched: the Dulles Toll Road Extension in Northern Virginia; E-470 near Denver, Colorado; the Harris County toll roads near Houston, Texas; and the toll roads in Orange County, Florida. These projects and lessons learned from them are described below.

The Dulles Toll Road Extension is a completely private venture. It will be a 17-mi highway extending from Dulles Airport (the terminus of an existing toll road) to Leesburg, Virginia. The road will pass through mostly undeveloped land completely within Loudon County, Virginia. A small number of large land owners are found in the corridor and most are willing to cooperate with the developers because the road will increase the potential value of their property. In the fall of 1990 right-of-way acquisition and financing arrangements were being finalized.

E-470 is being advanced by a public authority established by the State of Colorado. It is a 48-mi highway that will form an outer, eastern beltway around Denver and will also provide direct access to the new Denver International Airport. The E-470 corridor is currently lightly developed, but it is expected to be actively developed in coming years. Construction of Phase I, a 5-mi segment, is currently underway and permanent financing for the remaining segments was expected by the end of 1990.

The Harris County Toll Roads are financed by the County and administered by a department of the County government. There are two roads totaling 50-mi: the Sam Houston Tollway and the Hardy Toll Road. The Sam Houston Tollway forms a western and northern outer beltway around Houston and the Hardy Toll Road is a north south radial highway that connects with the Sam Houston Tollway and connects with the Houston Intercontinental Airport. Construction of the final segments was completed in July, 1990.

The Orlando toll roads in Orange County, Florida are being advanced by the Orlando-Orange County Expressway Authority. This authority built two major toll roads in the 1960's and '70's and these roads have generated substantially more revenue than needed for debt service. Toll increases were implemented in 1987 and 1990 to raise enough additional revenue to fund construction of 32-mi of new toll roads and to perform major improvements to the existing toll roads. The new toll roads are short segments that extend and or connect the existing toll roads in and around Orlando, Florida. Four of the five new segments are complete. The fifth segment was in the design and right-of-way acquisition stage in the fall of 1990.

These projects demonstrate that publicly or privately financed toll roads are feasible. They have proceeded without federal funds. Importantly, each of these projects is located in a high growth area and coincidentally, each one partially involves airport access. These factors—high traffic volume potential and attractive development locations—are critical for securing financing and generating adequate toll revenues.

Several lessons can be learned from these toll road experiences. First, a totally private project is not advisable; cost savings in construction are outweighed by costs of liability coverage and the problems of securing financing. Second, a mutually beneficial give-and-take between the toll road authority, local land owners and local governments is likely to occur—interchange location, right-of-way donations, and local government concessions to developers are the bargaining chips. Third, accountability is a critical issue with a toll road, particularly with respect to design, safety, and toll rates. Most authorities self-impose established standards (such as state or federal) of design and or environmental protection to limit liability. Also, an authority can be made accountable to the public by creating a board made up of elected public officials. Finally, public support was a prerequisite for each of the toll road projects studied and extensive measures were taken to build and maintain that support.

Local-Option Taxes

Two regions with local-option taxes dedicated to transportation were studied, San Diego and Phoenix. In each case, a county sales tax is used to fund a specific set of transportation improvements. This requires enabling legislation from the state and a local referendum. These regions demonstrate that local citizens are willing to pay for an improved transportation system.

In the San Diego region, MPO both plans and allocates the revenues for approved transportation improvements. The Board of the MPO is the Regional Transportation Commission; the commission uses the MPO's staff. Tax revenues are split evenly between transit, highways and local roads. A referendum was passed for funding a specific set of highway and transit improvements and increasing funds for local roads. Local road projects that are advanced with the tax revenues must be approved by the commission.

In Phoenix, the MPO Maricopa Association of Governments (MAG) plans the projects and the State Department of Revenue distributes the funds. All highways are constructed by the Arizona Department of Transportation. State law requires the local option tax in Maricopa County to fund projects in the MAG Freeway/Expressway Plan. MAG has some flexibility in selecting the projects from the plan that are to be funded. Currently, tax revenues are inadequate to finance the entire plan. The local tax referendum set aside 3 percent of tax revenues for transit. In both regions, the inclusion of transit in the proposals was crucial to passing the referenda.

Targeted State Funding Models

A number of states have raised gas taxes in recent years and specified how those funds should be used. In California, in 1989, the gas tax was increased by 9 cents to finance a 10-year transportation plan. One component of the plan is a Partnership Program that will provide up to 50 percent state matching funds for local highway, road and transit projects. This program rewards counties such as San Diego that have levied special funds for transportation. It enables them to leverage additional state funds for their priority projects.

In Illinois, the state legislature passed a creative piece of legislation in 1989 to increase transportation funding. The legislative package raises the state gas tax by 6 cents, authorizes a local option gas tax in certain counties, and shifts some sales tax revenues from highways to transit. Another provision limits future uses of the gas tax revenues for the state police, thereby dedicating more of the future gas tax revenues to building and maintaining roads.

THE PENNSYLVANIA CONTEXT

Enabling legislation is required in Pennsylvania to raise new transportation revenues. Toll roads are currently the exclusive domain of the Pennsylvania Turnpike Commission. Local option sales, gas or other taxes for transportation, are not permitted at present.

If the legislature authorized local option taxes, these would have to be enacted by elected county commissioners or municipal councils. To raise taxes regionally, there are two basic options: have county and/or local governments act independently but cooperatively to raise the same rate of taxes to fund regional transportation projects; or create a new, elected regional taxing authority to levy the taxes. The group rejected the idea of creating a new, elected authority because there are a multitude of special purpose authorities in existence in the region, and there was mounting evidence that the public is dissatisfied with both the multiplicity and lack of accountability of such authorities. Thus, both alternatives proposed by the group require the counties to levy any taxes.

Pennsylvania's constitution prohibits any highway user fees, such as gas taxes and vehicle registration fees, from funding transit. This fact led the group to propose a mixture of taxes. This mixture includes both user fees, which are considered fair (i.e. those who use the transportation improvements pay for them), and other revenues that can be used for transit.

PROPOSED FINANCING MECHANISMS

The group considered local option taxes to be the best alternative for regional transportation financing. While toll roads might be used (and are included in the group's recommendation), they are feasible only in a few high growth corridors. Local option, rather than state, taxes were chosen to give regional leaders more control and flexibility. The group agreed that higher state transportation taxes should be encouraged in addition to the regional transportation finance proposal. Any opportunities for "piggy-back" taxes that arise in the legislature should be optimized.

The group sought a balance of taxes that would be perceived as fair, raise sufficient revenues, and support both highways and transit. Gas, sales, and personal property tax on vehicles were considered. Table 1 presents a tax evaluation matrix comparing these three taxes.

These three taxes were singled out for different reasons. The sales tax was chosen because of its revenue-generating potential, its ability to fund transit, and its political palatability (versus property or other general revenue taxes). One appealing aspect of the sales tax is that it is paid in part by travelers to and through the region who are using the transportation system. The gas tax was also selected for its political palatability, as well as its perceived fairness. In general, people who travel more in automobiles pay more gas tax. The gas tax, however, is considered regressive with respect to income, as poor people tend to pay a higher percentage of their incomes for the tax than do wealthier people. This is one reason for adding the third tax, the ad valorem vehicle tax. It is a user fee, but the amount paid is related to the number and value of one's vehicle(s). Also, while it functions as a user fee, it is proposed, technically, as a personal property tax. The revenues might be usable for transit (subject to legal opinion).

The local option gas, sales, and vehicle taxes would be authorized by state legislation and levied by the county com-

TABLE 1 Tax Evaluation Matrix

		Sales Tax	Gas Tax	Ad Valorem Tax
Overview		A "Sales and Use" tax enacted by county governments and collected by the Department of Revenue	A tax on the sale of gasoline enacted by county governments and collected by the Department of Revenue	A personal property tax on motor vehicles enacted by city and county governments, and collected by same
Annual Revenue Yield	Low	$ 94.6 Million per 1%	$10.1 Million per 1¢	$4.3 Million per mill
	Medium	$ 97.7 Million per 1%	$11.4 Million per 1¢	$5.4 Million per mill
	High	$101.0 Million per 1%	$12.3 Million per 1¢	$6.7 Million per mill
Legal/ Institutional Issues		• Can be used for transit • Likely to have legislative competition for non-transportation uses	• Cannot be used for transit without a constitutional amendment	• Completely new tax • Could be used for transit
Ease of Implementation		As already exists, it should be easy to collect and administer.	As already exists, it should be easy to collect and administer.	While the information to implement the tax exists in vehicle registration records, programs for computing the tax, billing and collecting would have to be established.
Fairness		Revenues bear no relationship to transportation use.	A user tax; regressive with respect to income; amount paid proportional to use.	A user tax; progressive with respect to income; amount paid not proportional to use.
Stability		Revenues are relatively stable, but fluctuate with the economic cycle (growth, recession, etc.)	Revenues are moderately stable, assuming continued availability of fuels. Erosion occurs with improvements in vehicle fuel efficiency.	Revenues are relatively stable but fluctuate with the economic cycle
Elasticity		• Revenues, based mainly on purchases of durable goods, would generally keep pace with inflation. • Many durable goods are price-elastic; purchases would be affected by high inflation.	• Tax Revenues will not increase with inflation. • Demand for motor fuels is relatively price-inelastic. Thus, consumption is not likely to change in the long term due to the tax.	• Changes in car values tend to keep pace with inflation. • Demand for vehicles is not inelastic; hence tax may influence buyers. (Most likely a one-time effect in the first year of the tax.)
Responsiveness		Source is responsive to economic growth	Source is responsive to fuel consumption, which reflects both vehicle miles travelled and fuel efficiency of vehicles. Historically, this type of tax has not kept pace with need.	Source is responsive to the number and value of registered vehicles (i.e. fluctuations in new car purchases affect revenues); will not necessarily keep pace with need.
Avoidance		An increased tax may result in some sales being exported out of the region ("at the fringes"), unless adjacent counties impose the tax.	An increased tax may result in some sales being exported out of the region ("at the fringes"), unless adjacent counties impose the tax.	Some loss of revenue may occur due to registrations out of the region/state.

TABLE 2 Revenues of Proposed Taxes and Value of 20-Year Bonds

	Tax Rate	Annual Revenues	Bonding Capacity
Sales Tax	1%	$100 Million	$1.1 Billion
Gas Tax	5¢	$ 50 Million	$0.6 Billion
Ad Valorem Tax	4 Mills	$ 27 Million	$0.3 Billion
TOTAL			$2.0 Billion

missioners. The third tax, an ad valorem tax on vehicles, would be an extension of current personal property taxes levied by counties and the City of Pittsburgh.

Gas and sales taxes already exist in Pennsylvania, so systems and procedures for collecting and administering them are in place. An ad valorem tax specifically on vehicles, however, would be new to Pennsylvania. The group did not recommend a particular method for implementing this tax, but models exist in several other states. For example, the tax could be based on the "blue book" or fair market value of all registered vehicles.

Based on revenue estimates and legal constraints, the group recommended the following tax rates: a 5 cent gas tax, a 1 percent sales tax, and a 4 mill ad valorem tax (i.e. $4 per $1000 of value). The latter is determined by an existing limit on personal property taxes in Pennsylvania of 4 mills. In fact, a much higher vehicle tax is levied in other states (for example, 12.5 mills in Minnesota, 20 mills in California, and 25 mills in Massachusetts). The potential to reasonably charge a much higher ad valorem tax, and the legal issues associated with doing so, are important subjects for further deliberation. Table 2 presents revenue projections of the proposed taxes and their potential bonding capacity. As proposed, the sales tax would account for more than half of the total revenues from the tax package. This percentage might be expected to rise over time as the gas tax is unresponsive to inflation.

The anticipated revenues from the proposed taxes would raise $2 billion in bonding capacity. While this is far short of the $6 billion shortfall in the region, it is the maximum amount considered reasonable in terms of taxation. San Diego and Phoenix have both had to make similar compromises between the total transportation need and the level of taxation that is acceptable to the public. This issue is even more compelling in southwestern Pennsylvania, where the reasons for building many of the transportation improvements are related to economic development (i.e. prompting more growth rather than accommodating expected growth).

ADMINISTRATION OF PROPOSED FINANCING MECHANISM

The group considered a number of issues relating to the administration of the regional transportation finance mechanism. First, who levies the tax? The group had already decided that the counties should levy the taxes. Second, who allocates the tax revenues to transportation projects? The group identified two alternatives which are discussed below. Third, who determines which projects will be funded? While those who allocate the revenues are assumed to play a role in selecting projects, this presents the question of transportation planning. This is also discussed below. Fourth, who builds the projects? The group determined that a (non-elected) regional authority, if formed, should not be allowed to construct transportation projects; instead it would allocate funds to other, existing entities (such as PennDOT, transit agencies or counties), who would construct the transportation improvements.

Selection of Projects for Funding

The working group agreed that the selection of projects to be funded with regional dollars should be coordinated with the planning and programming of state and federal transportation funds through SPRPC as the federally designated Metropolitan Planning Organization. The working group agreed that SPRPC's planning process and the planning for regionally-funded transportation improvements should be integrated. The working group recommended a requirement whereby regionally-funded transportation projects must be consistent with SPRPC's Regional Transportation Plan. The group further agreed that a specific set of priority transportation projects should be identified and slated for regional funding before the local option taxes are levied. These projects should be planned and identified by a broadly representative public/private policy committee, possibly a sub-committee of SPRPC's Transportation Strategy Policy Committee.

Allocation of Revenues

The major point of debate was whether a new, regional entity should be formed to allocate the regional transportation revenues. Alternatively, the counties could allocate the revenues. The group decided to bring both proposals before regional leaders at the SPRPC Fall Policy Conference.

Proposal 1 has two distinguishing components: it creates a Regional Transportation Finance Authority and gives the Authority responsibility to allocate the regional transportation revenues. (This would be a non-elected authority with no direct taxing powers.) Proposal 2 also has two distinguishing components: the governments which impose the regional transportation taxes allocate the resulting revenues. In addition, a "banking system" would be created whereby a county government could expend funds for the benefit of another, with or without a promise for future repayment. SPRPC would facilitate these intercounty agreements and maintain an accounting of them. Proposal 1 and Proposal 2 are outlined below.

The group rejected the idea that SPRPC should be the entity that allocates regional transportation revenues. If the revenues were to be allocated by a regional entity, the group favored a small decision-making body having fewer than 10 members. However, the entity's staff and SPRPC's staff should be one and the same to facilitate transportation planning.

The two proposals were fully evaluated by the region's public and private leaders who attended SPRPC's Fall Policy Conference. The participants recognized a number of advantages and disadvantages of both finance mechanisms, and recommended that the regional authority should be pursued.

They chose the authority as the preferred financing mechanism because of its high visibility and its ability to promote intermodal, regional transportation strategies, and to leverage greater funds. Further, the authority would be a strong voice to advocate the region's interest and advance the region's transportation objectives, would be able to allocate funds to projects that best serve the region's long-term interests, and with the financial and political participation of all the counties of southwestern Pennsylvania, would be better able to leverage state and federal grants than any one county acting alone.

PROPOSAL 1: REGIONAL TRANSPORTATION FINANCE AUTHORITY

1. The counties of southwestern Pennsylvania are authorized to create a Regional Transportation Finance Authority.
2. The governing body of the authority includes one member appointed by each board of county commissioners of the member government; one additional member nominated by the Mayor of the City of Pittsburgh and appointed by the Allegheny County Commissioners; and one member appointed by the Governor.
3. The primary purpose of the authority is to allocate locally-generated funds to improve, maintain, operate and expand surface transportation systems and services. Surface transportation includes highways, transit, rail, and new technologies.
4. The member counties of the authority may levy three taxes to specifically benefit surface transportation: a gas tax (up to 5 cents); a sales tax (up to 1 percent) and a personal property tax on vehicles (up to 4 mills). The City of Pittsburgh also may levy a personal property tax on vehicles for the specific benefit of surface transportation. If the City levies this tax, the residents are exempted from a like tax by Allegheny County.
5. The sales tax and gas tax revenues are collected by the commonwealth and remitted to the Regional Transportation Finance Authority; the vehicle tax is collected by the City and counties and also remitted to the authority.
6. The authority allocates the transportation revenues to surface transportation projects within southwestern Pennsylvania. These projects must conform with SPRPC's Regional Transportation Plan and Regional Transportation Improvement Program.
7. The regional transportation revenues will leverage greater federal and state assistance. The transportation revenues may also finance a project in its entirety.
8. The authority is permitted to issue bonds and pledge the regional transportation revenues for security.
9. The member governments are permitted to construct toll roads, and the authority may support such toll roads with the regional transportation revenues.
10. The authority may not construct projects; the authority will financially aid the construction of publicly-authorized transportation projects.
11. SPRPC will staff the Authority to promote conformity between transportation improvements and financing plans using federal, state and regional funds.

PROPOSAL 2: SOUTHWESTERN PENNSYLVANIA TRANSPORTATION FINANCE ACT

1. The SPRPC member governments are authorized to levy specified taxes to benefit surface transportation.
2. These revenues must be used to improve, maintain, operate, and/or expand surface transportation within southwestern Pennsylvania. Surface transportation includes highway, transit, rail, and new technologies.
3. The counties are authorized to impose (a) a gas tax (up to 5 cents); (b) a sales tax (up to 1 percent) and (c) a personal property tax on vehicles (up to 4 mills). The City of Pittsburgh may levy the personal property tax on vehicles for the specific benefit of surface transportation. If the city levies this tax, the residents are exempted from a like tax by Allegheny County.
4. The gas tax and sales tax are collected by the commonwealth and remitted to the county of origin; the city and counties collect the personal property taxes.
5. Each government allocates its transportation revenues for surface transportation projects and services, but must do so in conformance with SPRPC's Regional Transportation Plan and Regional Transportation Improvement Program.
6. The SPRPC member governments may use their transportation revenues for the direct or indirect benefit of another government. A member government may lend its revenues to another member government. SPRPC will develop such intercounty agreements and maintain a complete accounting of such transactions.
7. The transportation revenues will leverage state and federal assistance. The transportation revenues also may finance a project in its entirety.
8. The transportation revenues may be used to secure bonds and other debt instruments.
9. The SPRPC member governments may construct toll roads and use the local transportation revenues to finance such roads.

FINDINGS AND RECOMMENDATIONS

Transportation Financing Needs

Leaders of southwestern Pennsylvania have recognized the need for greater transportation financing. At SPRPC's 1990 Fall Policy Conference, they concluded that these funds must be raised on both the state and local levels. Enactment of a local funding mechanism presents a difficult challenge; it also provides a greater opportunity to accomplish the region's transportation and development objectives. With its own dedicated transportation resources, the region's leaders will be better able to meet the region's needs.

Southwestern Pennsylvania cannot afford not to have a local finance mechanism. In the nineties, those who pay more will get more. Local funding will be key to leveraging federal funds.

The state alone cannot be expected to meet the region's transportation needs. To accomplish our highest priorities, we must form a new partnership with the state. As a partner with independent resources, the region will be able to leverage more state and federal funds than they might otherwise secure. However, regional funding creates a risk of state funds being diverted away from this region, thereby negating the benefits of the regional funds. For example, the state might follow a statewide, priority-based plan for funding. If the highest priority projects in this region were funded locally, the state might ultimately spend more in other regions and less in this region. With safeguards enacted, local resources will not reduce federal and state investment in southwestern Pennsylvania. Rather, local funds will secure more federal and state funding. Safeguards for state funding might include a clause in the authorizing legislation that prohibits a reduction in state funds due to the regional levies, or a policy wherein the regional funds are "last in" on each project (i.e. not committed until after state funds are committed to the project).

Regional Transportation Finance Authority

Reaching broad-based agreement on a Regional Authority is a formidable job. The authority would effect many changes in governmental responsibility, and such changes are made slowly. The county commissioners, who enact the transportation taxes, have responsibility to see that the revenues are wisely used. Under Proposal 1, some of this responsibility would be delegated to the authority. The board composition of the authority must ensure that the county commissioners retain some purview over the use of the tax revenues.

Each county has its own, substantial transportation needs. Each one probably could use all of its tax revenues for its own needs, local roads, bridges, or transit. With pressing local needs, regional needs could become secondary. The authority would provide a forum where regional needs would be more likely to receive attention and emphasis.

The authority, and the related tax measures, are an innovative solution to a longstanding problem. County governments will have more responsibility for transportation than they have ever had. For the counties to assume that responsibility, the public must recognize that the state and federal governments cannot be expected to meet our full needs.

Taxes

The regional financing program should be modest enough to be politically palatable, yet large enough to make significant transportation improvements. A $2 billion regional financial program is appropriate, although it does not meet the entire shortfall.

The proposed 1 percent sales tax, 5 cent gasoline tax and 4 mill ad valorem vehicle tax may not ultimately be the most politically acceptable tax blend. The best tax proposal will evolve in subsequent discussions. A number of interest groups seek a sales tax for their purposes; perhaps, only a portion of the 1 percent tax should be designated for transportation. The ad valorem vehicle tax is strongly supported; it could bear a larger portion of the financing burden.

Ideally, each county should enact the same taxes at the same rate. A uniform level of effort will create an equitable basis for the regional authority. However, there is no mechanism to ensure that the counties do this. This is a potential source of controversy and weakness in the authority. The group recognized that, initially, different counties will have different levels of public support, dictating different tax rates. Some counties might wish to contribute more in order to "buy" more transportation improvements; others might not have as much public support for this type of taxation. The group believed, however, that through achieving results with the funds that are levied, and through a public education process, a satisfactory and workable taxation scheme would ultimately emerge among the member counties of the authority.

Work Program

While the policy conference reached consensus on a regional transportation finance mechanism, that is only a first step. A broader consensus-building process must follow. This process must be led by a coalition of public and private leaders. The private sector, working in cooperation with the public sector, is the most credible advocate of a regional finance mechanism. A public-private partnership is essential to achieve public credibility.

The transportation financing proposal needs to be fully explained and discussed with each board of county commissioners, the Pittsburgh Mayor and city council. Meetings with business and civic leaders are likewise essential. SPRPC should also pursue a public information program that will inform the public of the transportation issue, poll and measure public response, provide input to the planning process, and cultivate support for the finance mechanism.

While this effort proceeds, SPRPC should develop a comprehensive regional transportation plan. The plan will identify projects which the financing mechanism will advance as well as the associated economic benefits. A specific transportation improvement plan is essential to secure support for new tax levies.

STATUS OF THE PROJECT

The southwestern Pennsylvania Regional Transportation Financing Initiative is advancing on several fronts. Legislation based on Proposal 1 and following recommendations from the policy conference has been discussed among legislators and other regional leaders. SPRPC has also begun the public relations effort, introducing the initiative to public and private groups in a wide variety of forums.

SPRPC's objective is to implement the initiative through a two-year work program. In addition to the legislation and the public relations effort, the centerpiece of this work program is a comprehensive planning process. In this process, SPRPC and regional leaders will evaluate transportation options, considering their impacts on growth patterns and the environment. This process will produce a list of priority transportation projects and a specific proposal for financing them. Like a growing number of regions, SPRPC's final transportation plan will be based not on physical expansion of the transportation system to resolve relatively short-term congestion problems, but rather on making strategic, multimodal improvements that will foster a desired vision of regional growth.

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Evaluation of Transit and Highway Revenue Forecasting Template (THRIFT) Software

PAUL ZORN

Transit and Highway Revenue Forecasting Template (THRIFT) software was developed by the Government Finance Officers Association under contract with the U.S. Department of Transportation as a sketch-planning tool. THRIFT allows users to forecast available financial resources for highway and transit financing, evaluate capital projects, and examine the effects of changes in selected financial variables on transportation system funding. Tests of the software at four highway and transit sites in the United States indicate that the software is a useful tool for examining financial scenarios in a sketch-planning context. The key drawback with the software is the level of effort required to collect the historical data needed to conduct the forecasts. Overall, THRIFT was judged to provide a useful framework for examining transportation improvements within the context of current and future financial resources.

The U.S. Department of Transportation (DOT) statement of national transportation policy calls for the federal government to provide technical assistance to state and local governments in the use of alternative or innovative approaches to financing transportation operations and improvements. In order for state and local governments to make informed decisions regarding their financial capacity for constructing and operating capital expansions and improvements, transportation planners must have accurate detailed information about future financial resources, capital costs, and the relative benefits received from capital projects.

Because of the complexity of this information, and the complexity of the underlying calculations, planners have turned to computer software to perform the calculations, store, sort, and display the results of their financial analyses. One such computer package is the Transit and Highway Revenue and Improvement Forecasting Template (THRIFT). THRIFT is a sketch-planning tool that allows users to

- Forecast available financial resources over a 10-year period,
- Determine the adequacy of resources needed to operate, maintain, and construct capital projects for highway and mass transit transportation systems,
- Assign priorities to capital projects using benefit-cost analysis,
- Examine the effects of changes in financial variables (such as tax rates, fares, labor costs, etc.) on a jurisdiction's financial capacity to operate, maintain, and improve its transportation system, and
- Examine the impact of new sources of revenue for financing the transportation system.

Government Finance Officers Association, 1750 K Street, N.W., Suite 200, Washington, D.C. 20006.

THRIFT was developed for DOT with monies from both FHWA and the Urban Mass Transportation Administration (UMTA) (now FTA), and is distributed through FHWA's Office of Planning.

DESCRIPTION OF THRIFT

For more than a decade, state and local governments have assumed a greater share of the responsibility for financing their transportation systems. Because of this increasing responsibility, state and local governments have found it a challenge to manage their resources more efficiently and to find alternative sources of revenue. However, identifying these sources and predicting their potential for generating additional funds is not easy. Furthermore, developing a framework for evaluating alternative financial options in the context of the benefits and costs of highway and transit projects complicates the problem even more.

As early as 1982 FHWA recognized the need to improve the integration of financial planning with transportation planning. In 1985, FHWA began an effort to develop user-friendly computer software to assist state and local governments in forecasting their revenues and expenditures and to integrate this information with the transportation planning process. As one of the products of these efforts FHWA contracted with the Government Finance Research Center, the research arm of the Government Finance Officers Association, to design and construct personal-computer based software for financial forecasting and analysis of capital improvements.

The resulting software, THRIFT, is intended to be used as a tool in the "sketch-planning" process. As shown in Figure 1, sketch-planning is the ongoing process of evaluating (at a summary level) the current state of the transportation network, anticipating the network improvements and expansions required to meet future demand, evaluating the current and future financial condition of the transportation system, and taking the financial and operational steps necessary to implement the plan.

THRIFT can be used to assist in the core financial elements of this process. Although THRIFT does not provide assistance in identifying transportation system needs, once the jurisdic-

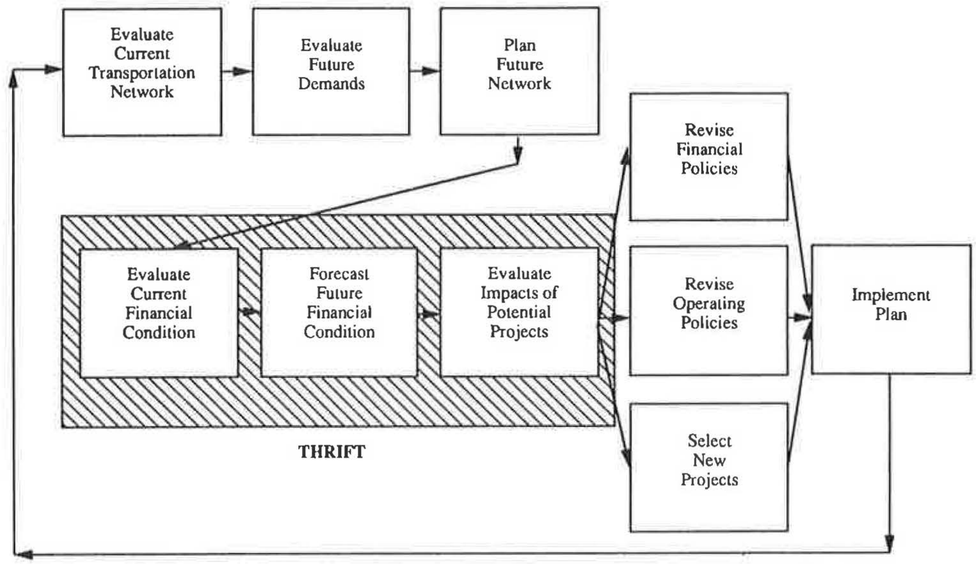

FIGURE 1 Relationship of THRIFT to sketch-planning process.

tion or transportation agency has determined the current status of the network and identified the projects necessary to improve it, THRIFT can be used to test the financial feasibility of the potential transportation improvements. This is done by

- Evaluating the agency or jurisdiction's current and historical revenues and expenditures,
- Forecasting future financial condition based on historical information, using trend analysis and expert judgment,
- Evaluating the financial impact of potential capital projects (including benefit-cost ratios), and
- Evaluating the impact of additional sources of revenues to finance the projects.

The output of THRIFT's analysis is a series of reports that show the net financial impact of highway and transit improvements and expansions on the transportation system. If the analysis shows that resources are unavailable to completely cover costs, THRIFT allows user to examine the impact of

- Revising financial policies by adding new sources of revenue or increasing rates,
- Revising operating policies by cutting back on service, and
- Revising the capital improvement program by changing the ranking of projects based on their benefit-cost ratios.

THRIFT also allows users to conduct sensitivity analyses by examining the impact on the forecasts of changes in the economic and policy variables that underlie the forecasts. In doing so, users have the option of changing any of the underlying demographic and economic assumptions, such as population, income, prices, interest rates, and the like.

REVENUE AND EXPENDITURE FORECASTING USING THRIFT

When examining the current and future financial condition of the jurisdiction or transportation agency, THRIFT is able to forecast a wide variety of revenues and expenditures. On the revenue side, THRIFT allows users to project the potential of a diverse group of revenue sources, including:

- Real and personal property taxes,
- Retail and wholesale sales taxes,
- Income, wage, and payroll taxes,
- Excise taxes on cigarettes and alcohol,
- Utility taxes,
- Motor fuel taxes,
- Driver's license and vehicle registration fees,
- Highway tolls,
- Transit fares,
- Bus charter revenues, and
- Other taxes or fees (e.g., parking, severance taxes, etc.).

On the expenditure side, THRIFT allows users to forecast system operating and maintenance costs, including:

- Labor costs for system administration, operations, maintenance, security, and other workers,
- Non-labor costs for contracted services, utilities, rental property, maintenance materials, and other non-labor costs, and
- Debt service with provisions for user specified interest rates on borrowing.

THRIFT allows users to forecast revenues and expenditures using a number of forecasting techniques, including linear and exponential trend forecasts, disaggregated trend forecasts, and time-series forecasts.

The linear and exponential trend methods use historical trends in the revenues or expenditures as the basis for the forecast, and project these trends using simple linear or exponential rates of change. Disaggregated trend forecasts break the revenues and expenditures down into their economic and policy components and then forecast the economic components using linear or exponential rates. For example, THRIFT disaggregates property tax revenues into the following components:

- Market value of taxable property,
- Assessment ratio,
- Property tax rate,
- Percent of property tax collected, and
- Percent distributed for transportation purposes.

The disaggregated trend method uses linear or exponential trends in the number of households, household income, and housing prices to forecast future market values of taxable property. Property tax revenues are then obtained by applying the policy variables (tax rate, assessment ratios, etc.) to the market value of taxable property. This allows the user to examine the effect that changes in the policy variables will have on available revenues.

The time-series forecasting method uses regression equations to calculate the relationship between the underlying variables and the economic base variable. It is similar to the disaggregated trend analysis, except that the equations linking number of households, household income, and housing prices are calculated using a regression formula, with adjustments for autocorrelation.

Since expert judgment is an essential component of any forecast, THRIFT also allows the forecasts to be modified based on outside econometric analysis or expert judgment.

EVALUATING CAPITAL PROJECTS

In addition to forecasting revenues and expenditures for system operation and maintenance, THRIFT also allows the user to evaluate capital improvements and expansions. To do so, the user enters information about each capital project, including

- Capital costs (including planning, engineering, equipment, vehicles, land and right of way, and construction costs),
- Financing sources (including current (general) revenues, project-generated revenues, grant receipts, and bond proceeds),
- Project operation and maintenance (including labor, utilities, repairs), and
- Benefit-cost variables (including travel time, travel costs, and accident costs with and without the project).

THRIFT then calculates debt service associated with each improvement for the portion of the capital cost financed through bonds, based on a user-entered interest rates and bond maturity.

Benefit-cost ratios are calculated using a procedure similar to that presented in the AASHTO *Manual on User Benefit Analysis of Highway and Bus Transit Improvements* (*1*), with modifications suggested by the procedures described in the FHWA report *Regional Economic Impact Model for Highway Systems* (*2*). For highways, the benefit-cost variables include daily vehicle-miles of travel, vehicle running speeds with and without improvement, accident reduction factors, travel time values, vehicle operating costs, and accident costs. For transit, the benefit-cost variables include number of person-trips, in-vehicle travel time, waiting time, value of travel time, and average fare.

The user can select the projects to be included in the transportation improvement program. These are then added to the financial forecast for operating and maintenance, showing the impact of financing the projects on net resources over a 10-year period. If current resources are not sufficient to finance the improvements, new revenue sources can be explored and/or capital projects may be postponed. THRIFT allows the user to model the effects of these decisions before any action is taken.

USER EVALUATIONS

As part of the development process, THRIFT was beta-tested by four highway and transit systems in the United States: Lane Council of Governments, Oregon; Minnesota Department of Transportation; North Central Texas Council of Governments; and City of Sioux Falls, South Dakota. The systems were selected to represent large and small transportation systems, in rural and urban settings, involving different mixes of highways and mass transit facilities.

In general, the systems found the software to be a useful tool in the sketch-planning process. Once the data was entered, the systems had no trouble carrying out the forecasts, conducting sensitivity analysis, or examining new projects. THRIFT's results were also found to be consistent with the "bottom-line" results of in-house models (*3*).

Using THRIFT, the systems identified periods of potential financial trouble in future years and examined the effects of applying different sources of revenue to relieve the potential deficit. THRIFT was judged to be very useful for conducting sensitivity analyses and developing alternative financial scenarios in a sketch-planning context.

The key drawback to THRIFT was the level of effort required to collect and analyze the historical data required to conduct the forecasts. For THRIFT to make projections based on historical data, the data had to be collected and entered into the program. Testers found that the initial effort to obtain the data and ensure its consistency was time-consuming, and that a high level of expertise was necessary to assess this information. It should be noted, however, that this is a problem inherent in any forecast that requires historical data. Once the data was initially entered, the testers noted that considerably less time was needed to update the data during the next forecast cycle.

CONCLUSION

The THRIFT forecasting software provides a useful tool to assist in the sketch-planning process, and helps transportation planners

- Evaluate the current financial performance of the transportation system,
- Estimate the financial resources required and available to meet needed transportation improvements, and
- Examine alternative means for meeting future transportation needs (either through additional revenues, reduced services, or postponed capital projects).

Perhaps most important, THRIFT provides a framework for examining transportation improvements within the context of current and future financial resources.

ACKNOWLEDGMENTS

The author would like to thank the FHWA Office of Planning and FTA for assistance in the design and development of THRIFT.

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PART 2

Economic Analysis

Procedure To Calculate the Economic Benefit of Increased Pavement Life Resulting from Port of Entry Operations in Idaho

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A calculation procedure has been developed to determine the economic benefit of increased pavement life resulting from operation of a port of entry (POE). Weigh-in-motion data and the AASHTO equivalent single axle load tables are used to evaluate the percentage of overloaded trucks and their equivalents. These values are then used to calculate a reduction of pavement life. The cost of reduced pavement life is based on construction and rehabilitation costs of a typical asphalt highway section with an assumed life of 36 years. The economic benefit of increased pavement life resulting from the Bliss POE ranges from $175,000 to $407,000 depending on the assumed influence of the POE.

Ports of entry (POEs) are operated in the state of Idaho to (a) issue permits and collect fees, (b) enforce truck and axle weight limits and thereby reduce damage to pavement and bridges, and (c) perform other associated tasks, such as regulation of hazardous wastes and agricultural products. Efficient economic management of these ports requires that their costs and benefits be estimated. The objectives of this project are to (a) develop a method to quantify the economic benefit to the state of Idaho that results from prevention of premature pavement failure by the operation of POEs and (b) apply the method to a typical POE. The results for a specific site can be combined with other economic benefits (such as collection of permits and license fees, accident prevention, hazardous waste regulation, and agricultural regulation) and costs (such as personnel, facilities, and reduction in net freight weight per trip) to help determine the economic viability of a POE. A complete economic analysis of POE operations would include all of these benefits and costs. However, these can be considered in further research.

Other economic studies of POEs, the relationships between port operation and truck overloading, and the limitations of weigh-in-motion (WIM) equipment are discussed. The calculation procedure is described and illustrated with examples. The method is then applied to the Bliss POE. A sensitivity analysis is performed to determine how the results change if two key inputs are changed.

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LITERATURE REVIEW

Only a few publications have attempted to quantify benefits of increased pavement life resulting from POEs. Barros (*1*) estimated the cost of overweight trucks to New Jersey highways. He assumed that approximately 20 percent of the trucks were overloaded, on the basis of portable scale results in New Jersey and weights obtained from strain gages on an I-80 bridge in nearby Pennsylvania. Remaining pavement life was calculated from existing highway conditions and a statewide average truck fleet.

Wyatt and Hassan (*2*) estimated that $1.8 million (1982 Canadian dollars) in pavement damages to the southern Saskatchewan provincial highways system was caused by overloaded trucks.

Nielsen (*3*) calculated the cost of reduced pavement life to recommend fines for overloaded vehicles. He assumed an average truck trip length, an average cost per equivalent single axle load (ESAL) per mile of roadway, and a 3-to-1 factor of actual to apprehended overload violators.

In a related study, Halim and Saccomanno (*4*) compared increased pavement and transportation costs under two different load limits. They determined that, where noncommercial traffic is appreciable, increased operating costs for noncommercial vehicles caused by decreases in pavement serviceability and increased repair costs are not offset by gains in efficiency of commercial vehicles arising from higher axle load limits.

A key component of the present study is the estimation of the effect of POEs on truck weights. However, little information relating weigh station operation with weight violation rates has been published. Wyatt and Hassan (*5*) investigated the relationship between enforcement effort and weight compliance at permanent and mobile weigh stations in Saskatchewan. They report that, at permanent weigh stations, zero enforcement results in violation rates that exceed 15 percent for all types of loaded trucks. The violation rate is reduced to about 3 percent when the probability of apprehension exceeds 10 percent. For mobile weigh cars, zero enforcement corresponds to violation rates of about 30 percent, with the violation rate reducing to 9 percent as inspections increase. In both situations, once low violation rates are achieved, additional enforcement effort results in little improvement. These results are expressed as a percentage of loaded trucks and were obtained from violation rate records (static weighing), number of loaded trucks checked, and average percent time the scale is open.

Similar data were taken for short-haul trucks, using WIM equipment. Under normal enforcement (approximately 20 hr/week in the case cited), 31.2 percent of 3S2 trucks (26 percent of all trucks) exceeded legal gross vehicle weights (GVWs). Under zero enforcement 34.5 percent of 3S2 trucks (33.2 percent of all trucks) exceeded legal limits. These violation rates are expressed as a percentage of loaded trucks.

In the past few years, WIM equipment has been used in the state of Idaho. This equipment uses stress-strain relationships to weigh trucks without requiring them to stop. Data from WIM sites are considered here. Shannon and Stanley (*6*) investigated the accuracy of the PAT WIM systems used by the Idaho Transportation Department (ITD). Although the WIM method was not accurate enough to replace static axle weighing for enforcement purposes, good agreement was found between WIM total gross weight and static weights. With the exception of the front axle, the R^2 coefficient of determination between WIM axle weights and static axle weights ranged from 0.7 to 0.95. Shannon and Stanley's results indicate that WIM is acceptable for planning purposes, if its limitations are kept in mind.

Users of WIM data are cautioned that a truck of legal static weight may register as an illegal truck on WIM equipment because of normal weight redistribution at speed and normal truck vibrations (J. L. Hamrick, unpublished data).

The state of Idaho uses a number of criteria to determine if a truck is legally loaded. Following are the maximum legal weights:

- Single axle—20,000 lb.
- Tandem axle—34,000 lb (federal Interstate system); 37,800 lb (if total gross weight does not exceed 79,000 lb allowed on non-Interstate system).
- Total weight—80,000 lb (without permit on Interstate highways).

For this study, a legal truck is defined as one with a gross weight of 80,000 lb or less.

METHODS

The calculation procedure includes several steps. First, after the port has been identified, the road segments under its influence (its influence zone) are identified. Because some trucks on each segment do not route through the port, the percentage of trucks influenced by the port is estimated for each segment.

Second, for each road segment, the percent reduction in pavement life resulting from overloaded trucks is calculated from the percentage of overloaded trucks, axle equivalents and net weights of legal and overloaded trucks, and the percentage of trucks influenced by the port. This calculation is performed for port open and port closed conditions. The percentage of overloaded trucks and their equivalent ratios are estimated from 1989 WIM data.

Third, the cost of building and repairing the road system under decreased lifetimes is calculated for port open and port closed conditions. The difference between these values is the economic benefit that results from operation of the POE. This calculation assumes that the port is either always open or always closed. For this study, the port open condition assumes that the POE is open 24 hr/day, 365 days/year. The port closed condition assumes that the POE is closed 365 days/year. In reality, ITD does not normally operate the ports 24 hr/day.

Selecting Road Segments Influenced by the POE

The preferable method for selecting road segments would consist of an origin-destination study of trucks coming to and going away from the POE being analyzed. An origin-destination study would have the benefit of providing an estimate of the number of trucks on each road segment that are influenced by the POE, as well as the range that the road segment system should extend outward from the port.

Because an origin-destination study was not available for the port being analyzed (Bliss), a geographic zone of influence was identified. That is, road segments were divided between the Bliss POE and neighboring POEs. Figure 1 shows the road system used in the Bliss analysis. As long as the zone of influence is not too extensive, and because every road in the state would not be assigned to a POE, the results of the analysis should be conservative; the POE's influence likely extends past the selected road system.

For each of the road segments considered in the analysis, the average daily truck traffic (ADTT) for 1989 was collected from the ITD MACS/ROSE data base. The ADTT data from ITD was available for road segments much shorter in length

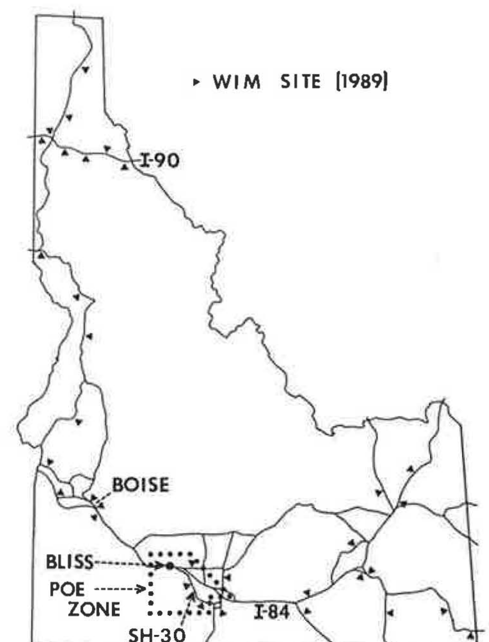


FIGURE 1 Idaho WIM sites and Bliss POE zone.

than the road segments used in this study. The weighted average (by mileage) of the ADTT was calculated for each road segment included in the study area and is used to compute changes in pavement life. Turning volumes are computed using ADTT point data at the intersection rather than the weighted average ADTT of the road segments coming into the intersection.

All of the truck traffic on the POE road segment is assumed to be influenced by the port when it is open, or 100 percent influence (i.e., Segment A in Figure 2). At each branch in the road system leading away from the POE, the influence of the POE on the truck traffic on a given road segment decreases because of the turning traffic. Traffic that travels on road segments influenced by a POE but never passes through the POE is considered uninfluenced traffic.

The number of influenced and uninfluenced trucks on each road segment is estimated using turning movement calculations. In Figure 2, the trucks that follow AC or AB are influenced by the POE, whereas the trucks that follow BC bypass the POE and are uninfluenced by it.

To compute the volume of trucks that follow any of the three possible routes at a three-way intersection, the ADTT for all three segments must be known at the intersection. Equations 1, 2, and 3 are used to compute the turning volumes illustrated in Figure 2:

$$AB = \frac{ADTT_a + ADTT_b - ADTT_c}{2} \quad (1)$$

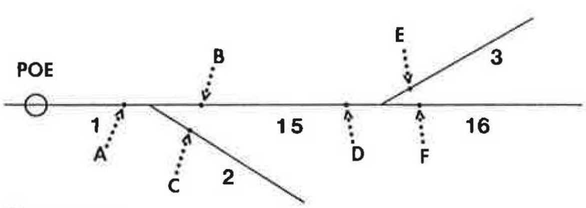
$$AC = \frac{ADTT_a + ADTT_c - ADTT_b}{2} \quad (2)$$

$$BC = \frac{ADTT_b + ADTT_c - ADTT_a}{2} \quad (3)$$

where $ADTT_i$ is the average daily truck traffic on the ith segment.

For the situation illustrated in Figure 2, the truck traffic on Segment C consists of AC influenced trucks and BC uninfluenced trucks. Segment B has AB influenced trucks and BC uninfluenced trucks. Segment A has all influenced trucks.

The influenced truck traffic is found for each road segment by computing the turning volume at each intersection, working outward from the POE. The number of influenced trucks



POINT	ADTT
A	2180
B	2180
C	90
D	2180
E	120
F	2180

FIGURE 2 Road diagram to calculate percent influence for multiple branches.

on a road segment is determined by multiplying the number of influenced trucks at the intersection by the percent of trucks that turn onto the road segment being analyzed. The following example illustrates the procedure used to compute the number of influenced trucks on each segment for the POE shown in Figure 2.

Influenced Traffic on Segment 1

No traffic leaves Segment 1 until the intersection; therefore, all trucks on Segment 1 are influenced by the POE. Hence, 2,180 trucks are influenced by the POE on Segment 1.

Influenced Traffic on Segment 2

$$\frac{2{,}180 + 90 - 2{,}180}{2} = 45$$

On Segment 2, 45 trucks are influenced by the POE.

Influenced Traffic on Segment 15

$$2{,}180 - 45 = 2{,}135$$

On Segment 15, 2,135 trucks are influenced by the POE, or 97.94 percent of the total.

Influenced Traffic on Segment 3

$$\frac{2{,}180 + 120 - 2{,}180}{2} = 60$$

There are 60 trucks on Segment 3 from Segment 15. That is,

$$\frac{60}{2{,}180} \times 100\% = 2.75\%$$

Thus, 2.75 percent of all trucks on Segment 15 turn onto Segment 3.

$$0.0275 * 0.9749 * 2{,}180 = 59$$

On Segment 3, 59 trucks are influenced by the POE.

Influenced Traffic on Segment 16

$$2{,}135 - 59 = 2{,}076$$

On Segment 16, 2,076 trucks are influenced by the POE, or 95.2 percent of the trucks.

This method does not account for the possibility of trucks leaving and entering the system between intersections, which would decrease the percentage of influenced trucks. However, the method also ignores many trucks that go through the subject POE's influence zone and subsequently travel in other POE zones without encountering another POE. This category of truck movement should be counted as a benefit of the subject POE. In this sense, this method can be considered a pessimistic estimate of both the influenced road system and the benefit of the subject POE.

One way of dealing with this underaccounting is to credit any truck traveling in the Bliss influence zone (that routes through only one POE) as being influenced by the Bliss POE, regardless of which POE it came through. Obviously, this procedure misapplies benefits among POEs. However, if done consistently over the state, the correct statewide benefit would be calculated. This additional benefit is determined for the Bliss POE and included separately.

Calculating Percent Loss of Life

The percent loss of pavement life is calculated from the axle equivalents of legal (LEE) and overloaded (OE) trucks, the fraction of overweight trucks in the traffic stream (OL), and the net (freight) weight of legal (LNW) and overweight (ONW) trucks. The difference in net weights must be included so that equal amounts of freight are carried regardless of the percent of overloaded trucks.

The number of legally loaded (3S2) trucks per year (LTPY) assumed during design is

$$LTPY = \frac{TDE}{LIFE \times LEE}$$

where *TDE* is the total design life equivalents of the pavement, and *LIFE* is the design lifetime of the pavement.

The total freight carried per year (TFPY) is

$$TFPY = LTPY \times LNW = \frac{TDE \times LNW}{LIFE \times LEE}$$

To account for the fewer number of trips made by overloaded trucks, it is assumed that the highway carries a constant amount of freight. This total amount of freight is actually carried in legal as well as overloaded trucks.

The equivalents per pound (EQP) of freight when both legal and overloaded trucks are used are

$$EQP = \frac{\text{weighted average equivalents per truck}}{\text{weighted average net freight weight per truck}}$$

$$EQP = \frac{(1 - OL) \times LEE + OL \times OE}{(1 - OL) \times LNW + OL \times ONW}$$

The equivalents per year (EQY) experienced by the pavement are

$$EQY = TFPY \times EQP$$

The total pavement life (TPL) under conditions of overloading is

$$TPL = \frac{TDE}{EQY}$$

$$TPL = \frac{TDE}{TFPY \times EQP}$$

The percent reduction in pavement life is

% years lost

$$= \frac{LIFE - TPL}{LIFE} \times 100\%$$

$$= \left(1 - \frac{TPL}{LIFE}\right) \times 100\%$$

$$= \left(1 - \frac{TDE}{TFPY \times EQP \times LIFE}\right) \times 100\%$$

$$= \left[1 - \frac{TDE}{\left(\frac{TDE \times LNW}{LIFE \times LEE}\right) \times EQP \times LIFE}\right] \times 100\%$$

$$= \left(1 - \frac{LEE}{LNW \times EQP}\right) \times 100\%$$

$$= \left\{1 - \frac{LEE}{LNW \times \left[\frac{(1 - OL) \times LEE + OL \times OE}{(1 - OL) \times LNW + OL \times ONW}\right]}\right\} \times 100\%$$

The percent loss of pavement life is given by

$$\%\ \text{years lost} = \left\{1 - \frac{LEE}{LNW} \times \left[\frac{(1 - OL) \times LNW + OL \times ONW}{(1 - OL) \times LEE + OL \times OE}\right]\right\} \times 100\% \quad (4)$$

Equivalents and Percent Overloads

Equivalents are a measure of pavement fatigue from truck axle loads. The OL is the percent of total trucks with a gross weight greater than 80,000 lb. Only axle weights of trucks with that weight are used to calculate OE.

AASHTO ESAL tables are used here to calculate equivalents, requiring knowledge of the truck axle weights, the terminal serviceability index (P_t), and the structural number (SN) for asphalt concrete or the thickness for portland cement concrete.

The predominant pavement material throughout the study area is asphalt concrete. A 3S2 design truck (five-axle tractor/

TABLE 1 OL and E for Open and Closed POEs

	Location	Total # of Trucks Weighed	Percent Overload	Weighted EQ
Interstate POE Open	Buhl-Hollister	267	9.0	3.26
	Cotteral	903	19.9	3.75
	Lewiston	630	6.8	4.42
	Average		11.9	3.81
Interstate POE Closed	Buhl-Hollister	28	17.9	3.50
	Cotteral	1499	46.5	4.26
	Average		32.2	3.88
Secondary POE Open	Samuels	104	26.7	3.66
Secondary POE Closed	Samuels	387	20.4	4.13
	Ashton	176	38.1	3.76
	Council	172	17.4	3.91
	Payette	278	24.8	3.65
	Cottonwood	151	33.8	3.64
	Average		26.9	3.82

single-trailer truck, one steering axle, and two tandem axles) is used to compute the legal equivalents because the majority of trucks on Idaho highways are of this type. The legal equivalent is computed from the AASHTO tables as follows:

Steering Axle (12 kip) = 1 axle * 0.19 equiv. = 0.19 equiv.

Tandem Axles (34 kip) = 2 axles * 1.09 equiv. = 2.18 equiv.

Total Equivalents = 0.19 + 2.18 = 2.37 equiv. (legal)

It is preferable to conduct a long-term, site-specific survey to obtain the percent of overloaded trucks and equivalents. Because this information is not available, axle weights are obtained from WIM data at locations throughout the state for port open and closed conditions. OL and equivalents were calculated at selected Interstate and secondary WIM sites, both for port open and port closed conditions. The OL and equivalent values applied to Bliss (see Table 1) are based on averages from these WIM sites. If OL and equivalent values are available for a specific site, they should be used instead of these statewide values.

Table 2 presents the calculation procedure used to estimate average equivalents (E) for a group of tandem axles. Adding the average equivalents for the front axle and other tandem axles results in an average equivalent for the group of trucks.

The axle load data available at each WIM site indicate that the average overload equivalent on Interstate and secondary highways for influenced and uninfluenced trucks is approximately 3.80 and is only weakly related to the percent of overloaded trucks. Figure 3 shows the relationship between percent overload and equivalents.

WIM data from 1989 are used to estimate the percent overloads on Interstate and secondary highways for influenced and uninfluenced truck traffic. Again, a long-term survey at each site would be preferable. The OL values used in the benefit calculation are presented in Table 3. The percentages given in the table are rounded averages of the WIM data from Table 1. For convenience, the data reported by Wyatt and Hassan (5) for all truck types is shown next to the values used in the benefit calculation. Unlike the values from this study, the Saskatchewan data are expressed as a percentage of loaded trucks and use static weighing.

TABLE 2 Example Calculation of Average Equivalent for One Tandem Axle

Tandem 1

Axle Load	# of Tandems	Equiv. / Axle, SN=5	Sum of Equiv.
20000	0	0.121	0
24000	0	0.180	0
28000	0	0.364	0
32000	0	0.658	0
36000	2	1.090	2
40000	32	1.700	54
44000	25	2.510	63
48000	8	3.550	28
52000	0	4.860	0
56000	0	6.470	0
60000	0	8.400	0
Sum =	67		148

Average Equivalent = 148 / 67 = 2.2

Note: P_t = 2.5; SN = 5. 1989 WIM data for 352 trucks with GVW ≥ 80,000 lb. All trucks, asphalt concrete.

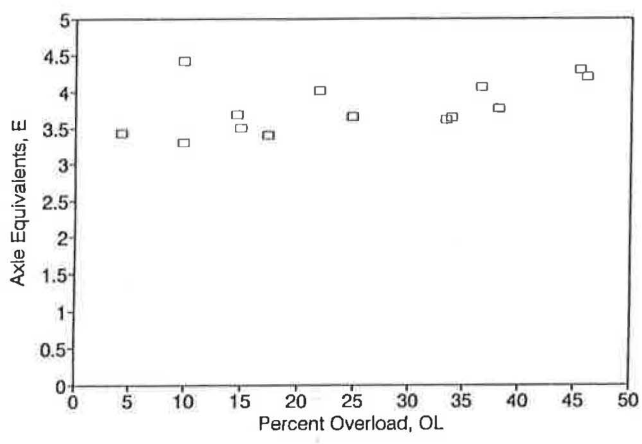


FIGURE 3 Average percent overload versus average axle equivalents for selected WIM sites.

TABLE 3 OL Values

	POE	Used[a] % OL	Saskatchewan[b] % OL
Interstate Roads	Open	10	3
	Closed	30	18.6
Secondary Roads	Open	10	9
	Closed	30	30

a percent of all trucks, WIM
b percent of loaded trucks, static weights

Because of the small size of the secondary open data set, and because secondary ports are frequently closed, it is assumed that 10 percent is a reasonable figure if the port was normally open. The Saskatchewan data indicate a 3-to-1 ratio of percent of overloaded trucks for closed and open ports.

The 1989 WIM data used to estimate E and OL were taken during periods of approximately 1 week or less for each WIM site. Data collected during a relatively short time span may be influenced by short-term local or seasonal events. A more accurate estimate would be possible from a larger data set collected over a longer time span, preferably several times throughout the year. The Wyatt and Hassan data (*5*) were collected over longer periods.

Percent Loss of Life for Continuous POE Operation

If the port was operating continuously, truck traffic on road segments within the study area would consist both of influenced and uninfluenced trucks because of turning traffic not influenced by the port. To account for the difference in percent overloads of influenced and uninfluenced trucks, the percent loss of service life is computed both for port open and port closed conditions for each road segment using Equation 4. Then, a weighted average percent loss of service life is found using the number of influenced and uninfluenced trucks on each road segment. The weighted average percent loss of service life is used to compute a reduced life for the condition of continuous POE operation. The following example illustrates the procedure used to compute the weighted average loss of life.

The following conditions are assumed:

- Influenced traffic, loss of pavement life = 4.06 percent;
- Uninfluenced traffic, loss of pavement life = 11.27 percent;
- POE influenced ADTT = 1,530; and
- POE uninfluenced ADTT = 710.

Then,

Weighted average loss of life

$$= \frac{4.06\% \times 1{,}530 + 11.27\% \times 710}{1{,}530 + 710} = 6.35\%$$

Percent Loss of Life When No POE Is Operating

If the port did not exist or is not operating, it is assumed that all truck traffic in the study area would be uninfluenced. The percent loss of life would then be 11.27 percent.

Reduced Life

ITD uses a pavement design life of 20 years but maintains roads on a 36-year replacement schedule, with maintenance and repairs scheduled at 12 and 24 years after initial construction. It is assumed here that a reduction in pavement service life would reduce the 36-year scheduled lifetime, as well as the 12- and 24-year maintenance schedule.

The reduced service life was computed as follows:

$$\text{Reduced life} = 36 - 36 \times \text{percent years lost} \quad (5)$$

Calculating Present Cost per Mile of Pavement with Reduced Life

ITD uses the following cost estimate for a four-lane highway. The initial cost per mile is $868,600. The 12- and 24-year maintenance costs are $168,200 and $401,100, respectively. The costs of a two-lane road are half these costs. ITD uses a 4 percent interest rate to evaluate its projects.

It is assumed that truck traffic on Interstate and four-lane highways travels in the outside lanes. That is, the inside lanes do not experience any loss of pavement life resulting from overloaded trucks. Therefore, all road segments, Interstate or secondary, are considered to be two lanes wide for allocating costs attributable to pavement damage from overloaded trucks. A cash flow diagram for a 1-mi length of two-lane road would include the following: (a) an initial cost of $434,000, (b) a maintenance cost of $84,000 after a third of its life, and (c) a maintenance cost of $220,550 after another third of its life. The next replacement cycle would begin after the final third of the pavement's life.

The current cost of two-lane road segments per mile is determined using the following equation both for port operating and port not operating conditions:

$$PC = \$434{,}300 + \$84{,}100 \times \left(P/F, 4\%, \frac{\text{reduced life}}{3}\right) + \$200{,}550 \times \left(P/F, 4\%, \frac{\text{reduced life}}{3} \times 2\right) \quad (6)$$

The annual cost (AC) of each two-lane road segment per mile in the study area is found using the following equation both for port operating and port not operating conditions:

$$AC = PC \text{ of segment} \times (A/P, 4\%, \text{reduced life}) \quad (7)$$

The total annual cost of all road segments in the study area is determined by multiplying the annual cost per mile of each road segment by its length (in miles) and then summing the costs of each road segment. The difference between the total annual cost for port operating and port not operating conditions is the benefit derived from operating the port.

RESULTS

An example calculation for the Bliss POE is presented in Table 4, which shows the spreadsheet and procedure used to calculate the annual benefit. The following truck-related val-

TABLE 4 Pavement Life Economic Analysis for Road System Near Bliss POE

SEGMENT	SEGMENT	ADT				100% POE OPERATION			NO POE OPERATION		
CODE	LENGTH	TOTAL	INFL.	UNINFL.	% INFL.	WTD AVE LOSS OF LIFE %	REDUCE LIFE	TOTAL A.C.	REDUCED LIFE	TOTAL A.C.	DIFFERENCE OF A.C.
1010	3.16	2180	2180	0	100.0	5.69	34.0	$98,035	30.5	$105,322	$7,287
2040	42.65	140	45	95	32.1	12.23	31.6	$1,387,299	30.5	$1,421,415	$34,116
2240	8.40	120	60	60	50.0	10.51	32.2	$269,730	30.5	$279,970	$10,240
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
1040	1.41	70	30	40	42.9	11.20	32.0	$45,445	30.5	$46,928	$1,483
1050	0.59	70	40	30	57.1	9.82	32.5	$18,849	30.5	$19,665	$815
TOTALS	159.2 MILES							$5,063,012		$5,304,567	$241,554

ues were used in the Bliss analysis: LEE of 2.37, OE of 3.8, LNW of 51,400 lb, and ONW of 58,400 lb.

In Table 4 the difference between net weights of legal and overloaded trucks is ignored. The percent loss of life as calculated by Equation 4 is 5.69 percent for influenced trucks and 15.33 percent for uninfluenced trucks. Under these conditions, and with the POE open continuously, the net benefit of the POE is $5,304,567 − $5,063,012 = $241,555.

If the difference in net freight weights is included, and the percent of overloaded trucks is 10 percent for influenced trucks and 30 percent for uninfluenced trucks, the percent loss of life is 4.41 and 11.87 percent for influenced and uninfluenced trucks, respectively. With the POE open continuously, and if the difference in net weights is considered, the annual cost is $4,987,627. With no port, the annual cost is $5,163,017. Under the assumptions employed, this second calculation indicates that full-time operation of the port results in an annual benefit of $5,163,017 − $4,987,625 = $175,390. The length of the road system included in the Bliss example is 159.2 mi. The annual benefit of full-time operation of the port is $1,102/mi. This amount represents the minimum benefit of the Bliss POE under the given assumptions; the calculation does not include benefits of the Bliss POE that occur outside of the Bliss zone, which are not included in the benefits of other POEs.

The annual cost of building and repairing the roadways in the Bliss area would be $4,756,300 with no overloaded trucks. The benefit if all overloading could be stopped is $5,163,017 − $4,756,300 = $406,717. This amount represents the maximum benefit possible.

If the Bliss POE reduces the fraction of overloaded trucks to a uniform 10 percent, then the annual benefit is $366,850. Table 5 presents the annual benefit that results from the Bliss POE.

If it is assumed that 90 percent of the trucks on Highway 30 (Segment 2040) are influenced by the Bliss POE (instead of 32 percent), the percent influence on each segment remains as originally calculated in Table 4, and the OL is 10 percent, then the annual benefit is $296,797. Although the port influence calculations show that most (68 percent) of the trucks on Highway 30 are not influenced by the Bliss POE, these trucks have a very high probability of routing through adjacent POEs. Because the adjacent POEs would not have their beneficial influence on Highway 30 attributed to their zone (it is outside of their influence zone), it is reasonable to apply this benefit to the Bliss POE. Consistency requires that any benefits from the Bliss POE that are felt in other zones (and the truck only travels through one POE) should be credited to those POEs, not the Bliss POE. This method would be a consistent way to apply this otherwise ignored benefit. It also results in the correct total statewide benefit.

Because of the uncertainties of OL, OE, and LEE, these factors were allowed to vary to check the sensitivity of the results. ER is the ratio of OE to LEE. Table 6 presents the

TABLE 5 Annual Benefit of Bliss POE

	Condition	Annual Benefit Bliss POE Zone
I.	All Overloading Prevented	$ 407,000.
II.	10 % of Influenced Trucks are overloaded:	
	A. All Trucks Influenced:	$ 367,000.
	B. Percentage of Influenced Trucks calculated by Turning Volumes	
	1. Constant ADTT	$ 242,000.
	2. Constant Net Freight Weight	$ 175,000.

TABLE 6 Sensitivity Analysis for Bliss POE

CONSTANT EQUIVALENT RATIO (ER), COST IN 1000'S OF DOLLARS.

	-50%	-20%	OL 0%	+20%	+50%
POE Open	4864	4929	4972	5015	5079
POE Closed	4947	5062	5140	5217	5333
Difference	83	133	168	202	254

CONSTANT FRACTION OF OVERLOADED TRUCKS (OL), COST IN 1000'S OF DOLLARS.

	-50%	-20%	ER 0%	+20%	+50%
POE Open	4607	4827	4972	5115	5328
POE Closed	4499	4881	5140	5400	5796
Difference	-108	54	168	285	468

results of the sensitivity analysis for OL and ER. If the assumed percentage of overloaded trucks is reduced by 50 percent, the annual benefit is also reduced by about 50 percent. OL and ER have a strong effect on the results. The results confirm that care should be used when estimating them.

CONCLUSIONS

A calculation procedure has been developed to determine the economic benefit of increased pavement life resulting from operation of a POE. The procedure uses WIM data and the AASHTO ESAL tables to evaluate the percentage of overloaded trucks and their equivalent ratio. These values are used to calculate a reduction of pavement life. The cost of reduced pavement life is based on construction and rehabilitation costs of a typical asphalt highway section and an assumed life of 36 years. The economic benefit per mile of increased pavement life resulting from the Bliss POE ranges from $175,390 to $406,717, depending on the assumed influence of the POE.

ITD can use this method to estimate benefits that result from increased pavement life caused by operation of a POE. Other benefits (such as fee collection, accident reduction because of truck inspections, and agricultural inspections) can be added and the sum compared with the cost of operations (facilities, personnel, and reduced net freight weight per trip) to determine the benefit/cost ratio of each POE. This method will help ITD determine the economic viability of POEs throughout the state.

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Nationwide Investment Requirements for New Urban Highway Capacity Under Alternative Scenarios

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A range of new highway capacity needs is defined, including associated capital funding required to maintain 1985 levels of service on nonlocal highway systems in the nation's urban areas through the year 2005, under alternative travel growth scenarios and severity of land/use transportation management strategies. The analysis procedure, which has been computerized, estimates the number of lane-miles that would be required to maintain 1985 average intensities of use (i.e., vehicles miles per lane-mile) in the peak hour. These intensities of use are specified by functional class, location within the urban area (i.e., core, suburbs or fringe), and urban area size. The analysis results indicate that even under a relatively low annual rate of growth (2.36 percent per year), with high levels of land use and transportation management strategies, about 107,000 lane-miles of new capacity will be needed, amounting to a 22 percent increase above the 494,300 existing lane-miles within expanded urbanized area boundaries. This is estimated to cost $375 billion in 1988 dollars or about 1.7 cents per-vehicle-mile of travel.

Procedures are described that were developed to estimate new capacity needs by highway-functional class for the nation's urban highway systems through the year 2005, under alternative travel growth and land use and transportation management scenarios, and capital funding needed to pay for new capacity. The analysis was done to provide background information for the 1991 report to the U.S. Congress on the status of the nation's highways and bridges. The report is prepared biennially by the Secretary of the U.S. Department of Transportation (DOT).

BACKGROUND

A related effort (*1*) identified past trends in supply and use of the nation's urban highways and congestion levels. Another study, *An Evaluation of the Economic Efficiency of New Highway Capacity on Alternative Facility Classes* by FHWA's Planning Support Branch initiated an attempt to identify the best mix of new highway capacity by functional class. An adapted version of this study was published by TRB (*2*).

Other recent efforts (*3,4*) have attempted to assess the magnitude of new highway capacity needs in the future by using FHWA's Highway Performance Monitoring System (HPMS) analytical process (*5*). The HPMS analytical process estimates needs associated with maintaining the existing highway system at or above a defined set of "minimum tolerable conditions" for pavement condition, lane width, vehicular and volume-to-capacity ratio. Improvements are simulated on deficient highway sections, based on design standards and 20-year projected traffic.

In contrast to previous efforts based on the HPMS analytical process, this study considers the effects of policy changes—including land use and transportation system management policies. Three alternative policy scenarios were considered: (a) a base-scenario involving no policy changes, (b) a moderate management scenario involving moderate policy changes, and (c) an extreme, high-management scenario involving major changes in land use and transportation management policies.

The following factors distinguish this research from past studies.

1. The consideration of existing highway capacity outside the current urban area boundaries, which will become available as they expand (the procedure simulates the expansion of boundaries and corresponding conversion of rural lane-miles to urban fringe lane-miles),
2. The inclusion of needs unconstrained by right-of-way availability (i.e., lane-miles of needs are estimated both along existing highway alignments through widenings on available rights-of-way and along new alignments requiring new rights-of-way),
3. Consideration of supply beyond that estimated by the process, needed to provide access for new development and
4. Consideration of the effects of new supply on travel demand and
5. Consideration that service design standards used to determine needs vary across urban area size categories.

The last item is particularly significant in estimating new capacity needs. As we attempt to define this need, we are faced with the problem that "need" for new capacity is a value-laden term and means different things to different people. For the purpose of this study, "need" for new capacity has been defined as the requirement to maintain 1985 levels of service (LOSs) on the urban highway system. These levels of service are expressed as average vehicles per-lane during the peak hour, by functional class and location within the

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urban area (i.e., total vehicle-miles of travel divided by total lane miles). Some planners believe that urban areas of different sizes have different commonly accepted service standards or criteria for highway facility LOS. For example, large urban areas may be willing to accept LOS-D or even LOS-E during peak periods, but smaller urban areas may not be willing to accept such service levels. To account for the differences in LOS acceptability by urban area size, different LOS standards were defined by urban area size group based on 1985 LOS conditions.

The procedure presented in this paper is able to quickly simulate, in an aggregate manner, the effects of peak-spreading (i.e., spreading of traffic from the peak hour to other times of the day either due to congestion or due to nonstandard work hours of service industry workers who are projected to increase in future as a share of the labor force). Route diversion (because of congestion) is also simulated by the procedure in an aggregate manner.

Finally, in this study, the distribution of travel by highway functional class is derived through a rigorous analysis procedure developed as part of a recent study done for FHWA by Oak Ridge National Laboratory (*6*). The distribution procedure considers the interrelationship between highway supply and use and explicitly recognizes the effects of new supply on demand.

PUBLIC POLICIES AFFECTING HIGHWAY NEEDS

There are two types of public policy that can affect new capacity needs in urban areas: (a) land use policies and (b) transportation system management policies.

Land use policies can have significant impacts on new capacity needs. First, new development can be restricted to locations where existing capacity is available, helping to bring about a better match between available highway supply and travel demand. Second, alternative commuting modes can be encouraged by incentives for high density development at both ends of the commute trip—the residential end as well as the employment end. Third, mixed-use developments can be encouraged in the suburbs, both to spread travel throughout the day (since different types of uses have different peak periods) as well as to increase use of carpool, vanpool and transit modes (people will not need their cars during midday if service establishments are within walking distance). Fourth, integration of employment and residential uses can provide opportunities for those who wish to live near their workplaces, shortening trips and encouraging bicycling and walking. Finally, the physical layout and design of new developments can be used to create environments conducive to travel by transit, bicycle, or foot.

Transportation management includes strategies to reduce highway travel demand, as well as enhance its supply. Highway travel demand may be reduced by encouraging people to choose alternative commute modes, change their time of travel to off-peak-periods, and eliminate the need to travel. Peak-period travel demand management techniques include encouraging shifts in time of travel through work rescheduling programs, or peak-period road or transit pricing, discouraging solo commuting through parking management, parking pricing or peak-period road pricing, and encouraging alternative modes through preferential treatment for high occupancy vehicles (HOVs) on highways and at parking facilities, improvements to transit service, transit fare subsidies, and provision of bicycle and pedestrian facilities. Highway supply management techniques increase the effective capacity of existing highways through freeway surveillance and control, restriping of pavements to use shoulders and increase the number of lanes, and traffic signal operation improvements.

ALTERNATIVE FUTURE SCENARIOS

The analysis was done for nine scenarios, each of which was a combination of one of three travel growth scenarios and one of three policy scenarios. The three travel growth scenarios were based on previous work done by the Oak Ridge National Laboratory (*6*):

1. A low growth scenario, reflecting a 2.36 percent annual compound growth rate between 1985 and 2005,
2. A moderate growth scenario, reflecting an annual compound growth rate for total travel of 2.72 percent between 1985 and 2005, and
3. A high growth scenario, reflecting a 3.48 percent annual compound growth rate.

The three policy scenarios were as follows:

1. A base condition, involving no change in travel peaking characteristics and current levels of transportation system management—no increase in supply enhancement, and no increase in current (1985) levels of land use and transportation demand management.
2. A moderate management condition, involving changes in travel demand resulting from moderate increases in levels of land use and demand management and peak spreading, and a transportation system supply management strategy involving freeway surveillance and control, adding lanes by narrowing existing freeway lanes and shoulders, and signal improvements on arterials.
3. A high management condition, involving maximum changes in travel demand resulting from major changes in land use and demand management policies, and a supply management strategy as under the moderate management condition.

ANALYSIS PROCEDURE

The major steps in the estimation process are presented in Figure 1 and are described below. The spreadsheet-model, named NUHICAP.WK3, is available from FHWA's Office of Environment and Planning, Planning Support Branch.

Step 1: Development of Input Data

Using HPMS area-wide and sample data, daily vehicle-miles of travel (DVMT) and lane-mile data were obtained for each individual urbanized area in the United States for the years

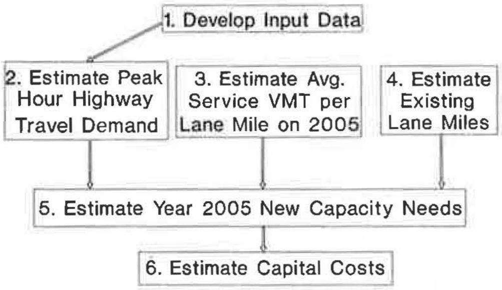

FIGURE 1 Analysis procedure.

1982–1988. The data were cross-tabulated by highway functional class, by location within urban areas, and by urban area size.

Highways were categorized into four classes: (a) freeways and expressways (HPMS Codes 11 and 12), (b) other principal arterials (Code 14), (c) minor arterials (Code 16), and (d) collectors (Code 17). Three urban location categories were used: (a) core (HPMS Codes 1 and 2), (b) suburb (Codes 2 and 3), and (c) fringe (Codes 4 and 5). Urban areas were divided into five population groups: (a) 50,000–75,000, (b) 75,000–200,000, (c) 200,000–500,000, (d) 500,000–1,000,000, and (e) more than 1,000,000.

The socioeconomic data and forecasts for every metropolitan statistical area (MSA) in the United States through the year 2005 were obtained from MSA profiles published by Woods and Poole Economics, Inc. (*7*). The MSA data were used as proxy for the urban area contained within the MSA boundary.

Step 2: Forecast of Future Peak Highway Travel

Using 1982–1988 data for 339 urban areas, a pooled time-series, cross-sectional regression model was developed for forecasting total DVMT for the urban areas. The DVMT/capita was used as the dependent variable. The independent variables were socio-economic variables (number of driver licenses per 1000 persons, household size, real income, and employment) and highway supply deficiency. The supply deficiency of the primary highway system was included as an independent variable to account for the impact of constrained supply on demand for travel.

This regression model was used with forecasts of socioeconomic variables for the year 2005 to estimate future DVMT for each urban area. The dynamics of shift in urban travel, between highway functional classes and locations within urban areas as the area increases in size, were modeled through conditional logit models in which population was used as an explanatory variable. These logit models, together with the forecast population of urban areas, were used to predict the shares of travel by functional class and by location within urban areas in the year 2005. Initially, the current supply (lane-miles) was also included as an independent variable in these models. However, it was found to be highly correlated to population and had very little impact by itself on the distribution of DVMT (*6*).

Traffic demand during the peak hour was estimated by multiplying the forecast DVMT by the peak hour travel shares and directional split percentages. These percentages were obtained by facility class, location within the urban area, and urban area size from NCHRP Report 187 (*8*). The assumption was that no changes in these shares would occur because of peak spreading, either from congestion or continuing increases in the share of service jobs in the economy.

For the scenarios that included land use/transportation policies, reduction in peak-hour, VMT was estimated by urban area size category on the basis of the following:

1. Percent of daily VMT for the work purpose by urban area size, derived from NCHRP Report 187 (*8*).
2. Percent reduction in peak hour work VMT due to modal shifts resulting from institution of land use and travel demand management strategies.
3. Percent reduction in peak-hour VMT because of work rescheduling, peak-period pricing, or spreading of peaks because of either congestion or shifts in the economy from manufacturing to service jobs.

The resulting percent reduction in peak-hour VMT, by urban area size, was entered directly into the spreadsheet used for the analysis and may be modified for alternative policy assumptions. Table 1 presents the procedures, assumptions, and resulting percent reduction estimates for each policy scenario.

Step 3: Estimation of Average Service VMT/Lane-Mile in 2005

The average service volumes per lane at the desired level of service (i.e., 1985 LOS for this analysis) were estimated by functional class, location and urban area size group on the basis of the following:

1. Average intensities of use in 1985 (from 1985 HPMS data).
2. A percentage increase in average intensity of use that can be sustained at a given level of service due to supply enhancement strategies. The increase was based on "enhanceable" mileage (*9*) and average percentage increases in capacity from enhancement strategies based on FHWA analysis (unpublished data from FHWA memorandum from Jeffrey Lindley to Larry Darnes, March 15, 1988). Table 2 presents the procedures, assumptions, and resulting percentage increases in capacity with the supply enhancement strategies for scenarios that included land use and transportation policies.

The procedure assumes a basic relationship between level of service and average intensity of use, which will not change by the year 2005, and that generally the mismatch in the distribution of available capacity and travel demand within the individual urban area will continue. If it can be assumed that the distribution of available capacity throughout the urban area will match more effectively the distribution of vehicular travel demand, average intensities of use could increase without any deterioration in level of service. Changes to average service volumes-per-lane could be made to reflect such alternative assumptions.

TABLE 1 Percent Reduction of Peak-Hour Travel Demand by Urban Area Size Group

	Base	mod mgmt[a]	max mgmt[b]
Work Trips			
A. Percent VMT in PM peak hour[c]:			
50-75K	30	30	30
75-200K	35	35	35
200-500K	40	40	40
500- 1M	50	50	50
> 1M	60	60	60
B. Percent work VMT reduction from management:			
50-75K	0	0	10
75-200K	0	0	11
200-500K	0	4	14
500K-1M	0	12	22
> 1M	0	20	30
Other Trip purposes			
C. Percent VMT reduction from management:			
50-75k	0	0	10
75-200k	0	0	10
200-500k	0	0	10
500k-1M	0	0	10
> 1M	0	0	10
All purposes			
D. Percent VMT reduction from management, i.e. (A*B) + [(100-A) *C]:			
50-75K	0	0	10.0
75-200K	0	0	10.3
200-500K	0	1.6	11.6
500K-1M	0	6.0	16.0
> 1M	0	12.0	22.0

[a] Moderate management policies include primarily travel demand management strategies which affect work trips only, and have significant potential as urban area size increases. Kuznyak and Schreffler (11) suggest that trip reductions in the range of 20% to 40% can be the norm if driving is not subsidized in the form of free parking and travellers are presented with realistic alternative commute modes.

[b] A doubling of the perceived costs of drive alone travel would reduce traffic by 10-30 percent (12).

[c] Based on NCHRP Report No. 187 (8).

TABLE 2 Percent Increases in Peak-Hour Capacity for Policy Scenarios

	Freeway	Other Princ. Art.
A. Number of miles to which "combined" supply management strategies may be applied (9)	1,196	1,611
B. Percent of lane miles "enhanceable" by combined strategies in urban areas:		
(1) 1985 total route miles (source: HPMS)	16,032	36,231
(2) Percent "enhanceable" route miles (A / B-1)	7.5%	4.4%
C. Average percent increase in capacity from combined strategies in urban areas	50% [a]	25%
D. Equivalent overall capacity enhancement (B * C)	3.75% [b]	1.1% 2/

[a] Average based on 64% increase for 4-lane facilities, 42% increase for 6 lane, and 30% increase for 8 lane, assuming 50%, 25%, 25% distribution of such facilities.

[b] These percentages were appropriately distributed by urban area size.

Step 4: Estimation of Existing Lane Miles in Expanded Urban Boundaries

Existing 1985 lane-miles within the 1980 Census urbanized area boundaries were estimated by functional class, location and urban area size group from 1985 HPMS sample data. Additional existing 1985 lane-miles within expanded 2005 urbanized area boundaries were estimated as follows:

1. First, average annual rate of growth in urban land area and average annual rate of growth in dwelling units between 1970 and 1980 were estimated from 1970 and 1980 census data. These rates of growth were used to estimate the excess annual growth rate of urban land resulting from reductions in urban densities.
2. Next, additional land area in 2005 within expanded urban area boundaries was estimated based on projected growth rates for dwelling units and excess land consumption because of reductions in urban densities. It was assumed that the rate of excess land consumption would be half of the 1970–1980 rate, owing to the saturation of demand for suburban life styles.
3. Average existing 1985 lane-miles per-square-mile in the urban fringe, by functional class and urban area size group were estimated from sample data as presented in Table 3.
4. Total existing lane-miles, which would become part of the expanded 2005 urban area, were obtained by multiplying *b* and *c*.

Estimates of lane-miles which would be reclassified from urban fringe to suburban in 2005 were obtained as follows:

1. Suburban dwelling unit growth was estimated by urban area size assuming that 80 percent of the increase in dwelling units would occur in the suburbs.
2. Suburban density estimates by urban area size (i.e., dwelling units per square mile) were derived from the ratio of the increase in dwelling units 1970–1980 to the increase in urban land area 1970–1980 obtained from census data.
3. New suburban land area in 2005 was estimated as $a \times b$.
4. Existing 1985 lane-miles per square mile in the urban fringe as presented in Table 3 were multiplied by *c* to get fringe lane miles reclassified to suburban lane miles.

Step 5: Estimation of 2005 New Capacity Needs

The total inventory of lane-miles needed in 2005 to serve the projected peak hour travel demand (from Step 2) at 1985 levels of service was obtained by dividing projected peak hour VMT by corresponding average service volumes-per-lane (from Step 3) by functional class, location, and urban area size group. New capacity needs for freeways, expressways and other principal arterials, in lane-miles, were obtained by subtracting existing lane-miles (from Step 4) from the total inventory needed to maintain 1985 LOSs.

TABLE 3 Fringe Lane-Miles per Square Mile

	Urban area Size Group				
	50-75K	75-200	200-500K	500K-1M	>1M
A. Lane miles per mile from sample data [a]:					
Freeway	0.087	0.076	0.117	0.093	0.097
Other princ. art.	0.096	0.038	0.120	0.102	0.138
Minor Art.	0.157	0.228	0.206	0.153	0.303
Collector	0.631	0.560	0.899	0.708	0.887
Local	1.942	1.955	2.702	1.768	2.768
Total	2.913	2.857	4.044	2.824	4.193
Total W/O local	0.971	0.902	1.342	1.056	1.425
B. "Smoothed" lane miles per sq. mile [b]:					
Freeway	0.09	0.09	0.10	0.10	0.10
Other princ.	0.10	0.10	0.10	0.10	0.14
Minor Art.	0.16	0.20	0.20	0.20	0.30
Collector	0.60	0.70	0.80	0.80	0.90
Total	0.95	1.09	1.20	1.20	1.44

[a] From HPMS sample data for fringe counties located in the following urban areas:

50-75K: Columbia, Mo; Charlottesville, VA; Medford, OR
75-200K: Tallahassee, FL; Boise, ID; Springfield, IL
200-500K: Toledo, OH; Little Rock, AK; Spokane, WA
500K-1M: Columbus, OH; Birmingham, AL; Salt Lake City, UT
> 1M: Washington, D.C.; Houston, TX; Atlanta, GA

[b] Appropriate adjustments were made for consistency in distribution of proportions of supply by functional class across urban area size groups.

For minor arterials and collectors, new capacity needs were estimated on the basis of access needs for new development. Additional lane-miles needed for access to new developments in the suburbs and the fringe were estimated on the basis of the percentage increase in dwelling units in these locations, assuming that 80 percent of the areawide increase in dwelling units will occur in the suburbs and 20 percent in the fringe. The assumption was made that access needs will increase in the same proportion as dwelling units.

New capacity needs were then divided between widenings on existing rights-of-way and new facilities on new rights-of-way. Feasible widenings by location were estimated on the basis of the following:

- An HPMS analytical process run that provided future constrained lane mile needs (i.e., needed new lane miles that can be provided on existing rights-of-way) by functional class (*3*).
- The distribution by location of new lane-miles actually built between 1982 and 1985 (from HPMS data). The assumption made is that the distribution of actual construction reflects the distribution of future constrained lane-mile needs by location.

Lane-miles to be provided on new facilities on new rights-of-way were obtained by subtracting new lane-miles on existing rights-of-way from total new capacity needs. Lane-mile needs were then distributed by urban area size group based on the distribution of overall lane-mile needs. The assumption is that the breakdown of needs between widenings and new facilities does not differ by urban area size.

Step 6: Estimation of Capital Costs for New Capacity

Capital costs per lane-mile (in 1988 dollars) for added lanes on existing rights-of-way were obtained from data inputs to the HPMS analytical process. Costs for new facilities were derived from nationwide low and high cost estimates and corresponding estimates of lane miles of new capacity needs above constrained needs which can be provided for on existing rights-of-way (*3*). Tables 4 and 5 present the procedures, assumptions and resulting estimated costs per lane-mile for widenings and for new facilities by functional class and urban location. Estimated lane-miles of new capacity (from Step 5) were multiplied by the estimated costs per lane-mile to get total capital costs for new capacity.

ANALYSIS RESULTS

Table 6 presents lane-miles of new capacity needed in 2005 for each of the nine scenarios. Under the base management

TABLE 4 Capital Costs per Lane-Mile for New Capacity

	Core	Suburbs (Built-up)	Fringe (outlying)
A. HPMS data for major widening:			
Freeways:			
construction		2,654	1,583
right-of-way		1,172	867
Total	N.A.	3,826	2,450
Other Divided:			
construction		1,363	899
right-of-way		728	500
Total	N.A.	2,091	1,449
Undivided:			
construction		1,196	832
right-of-way		496	400
Total	N.A.	1,692	1,232
B. Estimated widening costs:			
Freeways	5,100 [b]	3,800 [a]	5,600 [a]
Other Princ. Art.	2,800	2,100	1,500
Minor Art.& Coll	2,300	1,700	1,200
C. Estimated new facility costs [c]:			
Freeways	11,300	8,500	5,600
Other Princ. Art	5,500	4,100	2,900
Minor Art & Coll	4,700	3,500	2,500

[a] HPMS data rounded off to nearest 100
[b] Core costs estimated as 33% above suburban costs
[c] Suburban costs estimated as shown in Table 5. Core and fringe estimates derived based on ratio of core and fringe widening costs to suburban widening costs in line B.

TABLE 5 Average Capital Costs per Lane-Mile for New Facilities

	Freeway	Oth. Pr. Art.	Mi.Art./Coll
Source of data: FHWA (3),pp.17-18.			
A. Lane miles of new capacity needs over and above constrained needs.	45,777	31,674	34,740
B. Minimum additional costs for new capacity, in billions of 1985 dollars.	$113	$39	$33
C. Maximum additional costs for new capacity,in billions of 1985 dollars	$592	$198	$189
D. Average additional costs per lane mile in millions 1985 dollars: (B+C)/(2*A)	$7.7	$3.7	$3.2
E. Cost per lane mile in 1988 dollars [a]	$8.5	$4.1	$3.5

[a] Based on 1988 C.P.I./ 1985 C.P.I.

TABLE 6 Lane-Miles of New Capacity Needed in 2005 for Alternative Policy Assumptions

	GROWTH RATE		
	Low	Moderate	High
A. Base conditions			
Fwy	49,995	59,694	82,273
OPA	64,074	78,266	109,360
MA	34,635	34,635	34,635
Coll	16,238	16,238	16,238
Total	164,942	188,833	242,506
B. Mod mgmt.			
Fwy	39,253	48,155	68,577
OPA	49,547	62,655	90,825
MA	34,635	34,635	34,635
Coll	16,238	16,238	16,238
Total	139,673	161,683	210,275
C. Max mgmt.			
Fwy	26,128	34,057	52,219
OPA	30,404	42,042	67,097
MA	34,635	34,635	34,635
Coll	16,238	16,238	16,238
Total	107,405	126,972	170,189
Existing lane miles	494,300	494,300	494,300

scenario, additional lane-miles needed would range from about 165,000 (low growth) to about 243,000 (high growth), or an increase of 33 percent to 49 percent above the total number of existing lane-miles of about 494,000. With a high level of management, these needs would range from 107,000 (low growth) to 170,000 (high growth) additional lane-miles, or an increase of 22 percent to 34 percent above existing system capacity. New capacity needs for minor arterials and collectors do not change with different scenarios. This is because the population and dwelling unit growth assumptions which determine additional land area developed and access needs are the same for all scenarios.

Table 7 presents the range of new lane miles needed by urban area size group for the low growth scenarios. While the share of needs in the largest urban areas exceeds 50 percent under every policy scenario, the share is significantly lower under a high level of management (down to 52 percent from 59 percent under base policy conditions).

Graphic representations of the variations in new capacity needs are provided in Figures 2 through 4—by policy scenario in Figure 2, by travel growth rate in Figure 3, and by urban area size group in Figure 4. Figure 2 shows that management policies can result in significant reductions in new capacity needs on principal arterials. For low growth scenarios, about

TABLE 7 Lane-Miles of New Capacity Needed in 2005 for Alternative Policy Assumptions with 2.36 Percent Growth

	URBAN AREA SIZE GROUP					
	50-75K	75-200K	200-500K	500K-1M	>1M	Total
A. Base conditions						
Fwy	846	5,568	5,961	5,810	31,811	49,996
OPA	1,335	9,118	7,931	6,559	39,130	64,073
MA	836	5,859	5,713	4,579	17,648	34,635
Coll	529	3,484	2,279	1,726	8,220	16,238
Total	3,546	24,029	21,884	18,674	96,809	164,942
B. Mod mgmt.						
Fwy	846	5,568	5,671	4,899	22,269	39,253
OPA	1,335	9,118	7,472	5,382	26,240	49,547
MA	836	5,859	5,713	4,579	17,648	34,635
Coll	529	3,484	2,279	1,726	8,220	16,238
Total	3,546	24,029	21,135	16,586	74,377	139,673
C. Max mgmt.						
Fwy	580	3,988	3,862	3,381	14,318	26,129
OPA	827	6,057	4,602	3,421	15,497	30,404
MA	836	5,859	5,713	4,579	17,648	34,635
Coll	529	3,484	2,279	1,726	8,220	16,238
Total	2,772	19,388	16,456	13,107	55,683	107,406
Existing lane miles	14,995	75,129	78,833	54,321	271,022	494,300

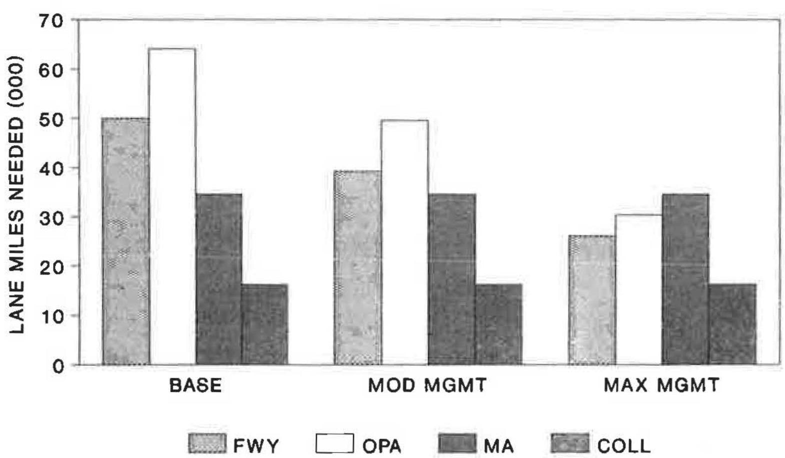

FIGURE 2 Effect of policies on lane-miles of new capacity needed (2.36 percent growth).

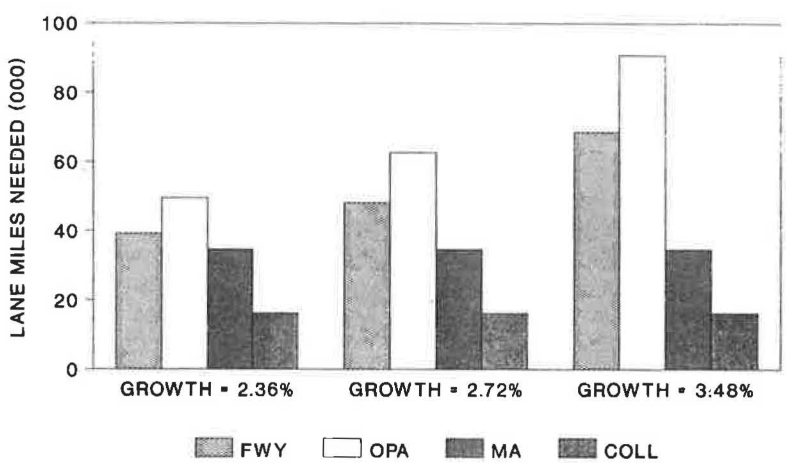

FIGURE 3 Lane-miles of new capacity needed by growth rate (with moderate management).

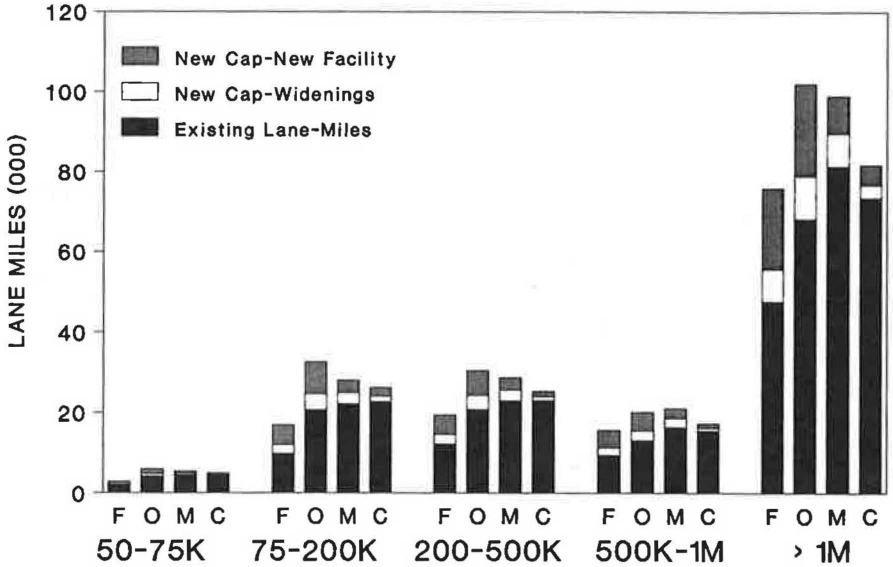

FIGURE 4 Lane-miles of new capacity needed by urban area size (2.36 percent growth/moderate management policies).

a 50 percent reduction from base conditions results from high levels of management. In Figure 3, travel growth rates are shown to have a significant effect on principal arterial needs—about an 80 percent increase in needs for high growth when compared with needs for low growth, when moderate management policies are in place. Finally, Figure 4 suggests that the bulk of new capacity needs will be in the largest urban areas. Even with low growth and moderate management, about 75,000 of the total of 140,000 new lane miles needed will be in areas with a population of more than 1 mil.

Table 8 and Figure 5 show capital investment needs for new capacity by urban area size group for each of the nine scenarios. Total investment needs vary from $375 billion under the low growth scenario with a high level of management to about $1.2 trillion under the high-growth scenario, with base management conditions. Assuming a 20-year-life for new capacity investments and 2005 levels of VMT, these costs equate to about 1.7 and 3.3 cents per vehicle-mile of travel, respectively (based on annual VMT ranging from 1.11 trillion (low growth/maximum management) to 1.76 trillion (high growth/base management)). These costs equate to a fuel tax of 34 cents to 66 cents per gallon, assuming average urban fuel economy of 20 mpg. Nationally, current total state and federal fuel taxes (which are used to fund maintenance and rehabilitation as well as new capacity needs) amount to about 30 cents per gallon on average.

The analysis also indicates larger variations when capital costs are broken down by functional class. On higher func-

TABLE 8 Capital Costs for New Capacity

	GROWTH RATE		
	Low	Moderate	High
A. Base conditions			
50-75K	$15.3	$18.6	$19.1
75-200K	$93.4	$111.3	$128.1
200-500K	$85.9	$105.1	$142.4
500K-1M	$79.2	$94.4	$129.6
>1M	$437.4	$520.0	$744.4
Total	$711.2	$849.4	$1,163.6
B. Mod mgmt.			
50-75K	$14.8	$18.2	$18.8
75-200K	$89.9	$108.3	$126.0
200-500K	$79.1	$98.3	$135.4
500K-1M	$66.1	$80.5	$113.7
>1M	$312.4	$384.1	$579.6
Total	$562.3	$689.4	$973.5
C. Max mgmt.			
50-75K	$10.3	$13.2	$14.1
75-200K	$62.8	$80.2	$97.5
200-500K	$52.0	$69.5	$103.2
500K-1M	$44.8	$58.0	$87.9
>1M	$205.6	$267.7	$438.7
Total	$375.5	$488.6	$741.4

Note: Costs are in billions of 1988 dollars.

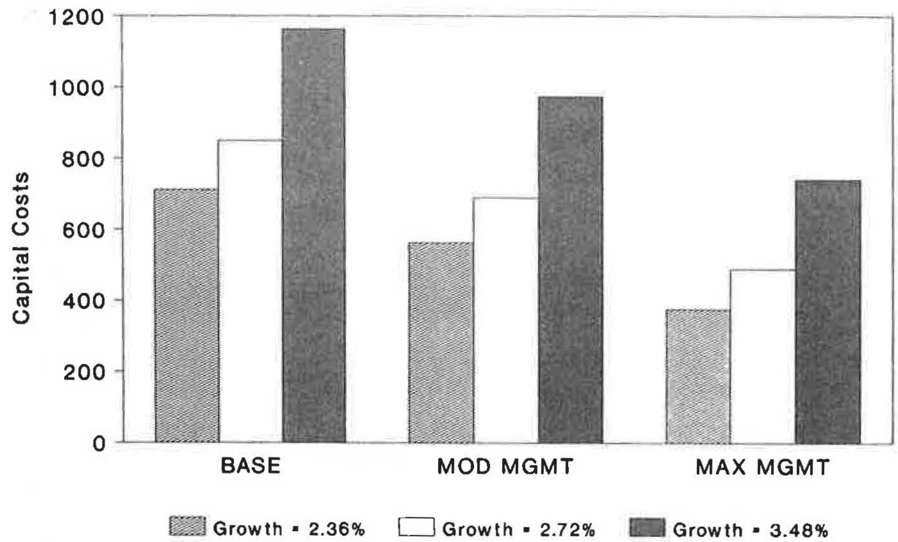

FIGURE 5 Capital costs for new capacity (billions of 1988 dollars).

TABLE 9 Comparison of Lane-Mile Needs and Capital Costs

	GROWTH RATE		
	Low	Moderate	High
A. Max mgmt.			
Lane-mile needs	107,405	126,972	170,188
Ratio with L/M [a]	1.00	1.18	1.58
Capital costs	$375.5	$488.7	$741.4
Ratio with L/M	1.00	1.30	1.97
B. Mod mgmt.			
Lane-mile needs	139,672	161,683	210,275
Ratio with L/M	1.30	1.51	1.96
Capital costs	$562.3	$689.4	$973.6
Ratio with L/M	1.50	1.84	2.59
C. Base conditions			
Lane-mile needs	164,941	188,833	242,505
Ratio with L/M	1.54	1.76	2.26
Capital costs	$711.3	$849.4	$1,163.6
Ratio with L/M	1.89	2.26	3.10

[a] L/M = low growth/max mgmt.

tional classes (e.g., freeways, expressways and other principal arterials), new capacity costs ranged from about 1.6 cents per vehicle-mile to about 4.2 cents per vehicle-mile, based on annual VMT estimates ranging from 0.78 trillion to 1.23 trillion on these functional classes. If these costs could be charged only to peak period users of these higher functional classes (who comprise about 40 percent of daily users) on the presumption that new capacity is needed primarily to serve them, they would equal 4.0 to 10.5 cents per peak-period vehicle-mile. By comparison, average operating costs for an intermediate-sized passenger car (for gas and oil, maintenance and tires) are about 8.4 cents per mile (*10*).

Table 9 presents a comparison of lane-mile needs and capital costs for each of the scenarios with the scenario that requires the smallest capital investment (i.e., the low travel growth scenario with high levels of management). The larger variation in capital costs (relative to the variation in lane-mile requirements) is because of the much higher proportion of new facilities needed on new rights-of-way as total lane-mile needs increase.

CONCLUSIONS

The analysis indicates that significant increases in highway funding will be needed if 1985 levels of service are to be maintained in the nation's urbanized areas. Funding needs for new capacity on the nonlocal highway systems in urbanized areas range from $375 billion, under a scenario representing a low underlying travel growth rate with stringent land use and transportation management strategies, to $1.2 trillion under an extreme scenario representing a high travel growth rate with no significant change in land use and transportation management policies. The moderate management policy scenario, with a low underlying travel growth rate, by historical comparison (i.e., 2.36 percent), is probably the most likely. It would require about $560 billion in new capacity investment. This is equivalent to about 2.4 cents per vehicle-mile of urban travel based on total annual VMT of 1.16 trillion, or a 48 cents per gallon fuel tax assuming average urban fuel economy of 20 mpg.

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Determining Truck System Costs for the Pennsylvania Interstate 80 Corridor

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Public investment in the transportation infrastructure has traditionally been along modal lines with little effort to develop a multimodal approach. Consequently, it is difficult to determine if public transportation dollars have been invested in the most cost-effective manner. Previous research has indicated that modally oriented planning and investment is economically inefficient and generates fewer social benefits than a multimodal approach. A system cost analysis is a prerequisite to any multimodal investment analysis. A component of the system cost analysis is summarized—a through-cost comparison of truck freight on the Pennsylvania I-80 corridor. The system cost analysis includes truck operating costs with a discussion of truck user taxes and their relationship to infrastructure, accident, and other related and environmental costs. The discussion concerning the relationship between infrastructure costs and truck user taxes and fees is important in identifying the system costs that are supported by truck operators and the actual costs incurred by the system. The truck-supported system costs, using a life cycle cost approach, amounts to $1.07 per mile or 8.1 cents per ton-mile on the Pennsylvania I-80 corridor. The costs incurred by the system, excluding exhaust emissions, amounts to $1.30 per mile or 9.8 cents per ton-mile. Annual truck emissions on the I-80 corridor are estimated for hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter. These can be used for comparison with other modal strategies.

The public sector, unquestionably, plays a vital role in the development of transportation infrastructure. Since 1950, with respect to freight, surface transportation has been the largest recipient of public dollars. The transportation system is evolving into a complex multi-modal network, which was encouraged by regulatory changes and has fostered the growth of transportation companies. The new multi-modal environment requires a more thorough examination of public transportation investment, particularly in light of federal and state budgetary constraints. Fundamental questions about the cost effectiveness of public investment in surface transportation, for example, are appropriate. Is it the best use of public resources to finance highway infrastructure for hauling interstate freight? Currently, policy makers have insufficient information to address this basic question. Information on multimodal investment strategies is essential if the U.S. is to maintain a competitive and growing economic posture.

Consolidated Rail Corporation (CONRAIL) contracted Texas Research and Development Foundation (TRDF) in late 1990 to conduct a system cost truck freight analysis specifically for the 311 mi I-80 corridor through Pennsylvania. An examination of truck freight interstate transit costs is likely to provide important information for policy directives on multimodal transportation investment. The preliminary findings of the I-80 corridor study are summarized.

The key objectives of the study were to determine the full-system costs for truck operations, and from these costs, identify truck system costs on a per mile and ton-mile basis. System costs include infrastructure or facility costs, vehicle operating costs, and externalities including property and physical damage from accidents, user delay costs, and environmental costs. Additionally, system costs can be categorized as incurred or supported. Incurred system costs are the true system costs defined above. Supported system costs are the costs currently paid by vehicle operators. The previous definition of system costs is modified to exclude externalities, because they are not paid for directly by operators, and to replace actual facility costs with user taxes and fees that are actually paid by operators. Quite simply, supported system costs are what owners or operators pay for operating their vehicle. Examination of system costs is necessary for evaluating modal options and strategies.

Several inputs are combined to identify the total system costs of truck operations over the I-80 corridor. First, incurred facility costs comprising initial construction, rehabilitation, and maintenance are identified. Then, the various user taxes and fees paid by truck operators to determine the relationship of incurred facility costs and supported facility costs. Next, the full range of operating costs paid by truck operators together with externalities not currently met from freight revenue are determined.

FACILITY COSTS

Initial Construction

Initial construction costs include right-of-way (ROW), bridges, and roadway (or pavement costs). Based on a 1970 report by the Keystone Shortway Association, initial construction costs amounted to $424.2 million (*1*).

Right-of-Way

Based on the initial ROW estimate of $17.9 million, land acquisition costs were approximately $58,000 per mile or about $1,026 per acre for I-80. However, this estimate may be slightly low, because some land may have been donated. There was no convenient way to obtain more precise data within the limits of this study. The average year in which the highway

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was constructed was 1966. Converting ROW to 1989 costs for composite construction yields $236,172 per mile of highway (*2*). The method of cost allocation for ROW, used in the Pennsylvania highway cost allocation study is to allocate ROW costs according to vehicle-miles of travel (VMT) (*3*). Using traffic data from the Pennsylvania Department of Transportation (PennDOT) data base calculated by individual segment, 34 percent of the I-80 real estate costs are allocated to trucks, yielding $80,913 per mile of highway. In this report, final allocated truck costs are in 1989 dollars for all cost categories.

Bridges

The I-80 corridor includes 486 bridges totaling slightly over 16 mi costing $65.7 million (1970 dollars) to construct. Bridge construction costs are 15 percent of total construction costs but account for only 3 percent of the highway length. The average year the bridges were constructed was 1966. Converting the $65.7 million to 1989 dollars yields $913,352 per mile of highway (*2*). The method used for cost allocation of structures and pavements, based on the Pennsylvania highway cost allocation study is 30 percent VMT and 70 percent equivalent single axle load (ESAL). Average rural Interstate truck loading of 98 percent (*2*) yields a 79 percent cost allocation for trucks or $720,452 per mile of highway.

Roadway

The construction, reconstruction, and traffic history were studied to determine the life cycle pavement costs for I-80. The year in which segments of the highway were constructed and the year in which an asphalt or concrete overlay or total reconstruction took place were derived from pavement inventory historical records provided by PennDOT. Based on this data, the average life of the pavements before restoration or reconstruction was nearly 22 years. The entire length of the highway was initially built with 10 in. of reinforced portland cement concrete pavement.

PennDOT does not keep records of accumulated traffic or accumulated ESAL. The Roadway Management System (RMS) data base maintains the current traffic counts by section and calculates current ESAL based on a prior estimate of ESAL per vehicle for the entire statewide network. PennDOT is concerned about underestimating the amount of current ESAL carried on their pavements. Data from the weigh-in-motion (WIM) site on I-80 was used to determine the average ESAL per vehicle for each vehicle class. The historic growth rate of ESAL for the nation's rural Interstates as reported by FHWA and the average historic ESAL growth rate of I-80 in several sections of Western Illinois were averaged to arrive at an annual growth curve used for this study (*4*).

The total cost of the roadway was $340.6 million (1970 dollars) or $1,096,000 per mile (*1*). Using the composite cost indices to adjust for inflation, yields $4,493,838 per mile in 1989 dollars. Application of the 30-70 rule (30 percent allocated by VMT and 70 percent allocated by ESALs) results in 1989 truck costs of $3,544,739 per mile allocated for trucks.

Rehabilitation Costs

A study of the pavement construction and reconstruction history showed that it is possible to combine contiguous segments of the pavement into 25 similar sections with similar construction and rehabilitation histories. These section lengths vary from 2 to 36 mi. The average age of the initial concrete surface and the time of first overlay was determined for each section.

Calculations were then made for each section to determine both the accumulated ESAL for the original concrete surface until overlay and the total accumulated ESAL since that section was placed in service. The average service life of the initial 10-in. concrete pavement is 22.4 years and the sections accumulated an average of 18.7 million ESAL. Most all the surviving original sections are currently scheduled either for restoration or reconstruction.

Since 1979, PennDOT has maintained a project management system for tracking all rehabilitation, restoration and reconstruction projects. This data was used and converted to 1989 dollars on the basis of FHWA correction values for maintenance costs (*2*). For the entire I-80 corridor, total rehabilitation costs from 1978 to 1990 are estimated to be $688 million in 1989 dollars.

The $2,219,355 cost per mile is allocated using the 30-70 rule (30 percent by VMT and 70 percent by ESAL) resulting in $1,750,627 per mile allocated to trucks. Using 300 mil tons average over the average 25-year life of the I-80 system yields approximately 0.59 cents per ton-mile. The rehabilitation costs as a whole are underestimated as a system, since some miles of I-80 are in need of reconstruction or restoration and the monetary resources are not available.

Maintenance Costs

Snow Removal

Data were extracted from the maintenance management system for the last 3 years for each of the 15 counties through which I-80 passes. The average reportea costs of snow removal for all rural Interstate highways in Pennsylvania was $12,000 per mile annually in 1989 dollars or $300,000 over the 25-year life of the highway, according to information in the maintenance management tracking system. However, this figure may be low because current policy doesn't require snow plow operators to identify the specific route for the maintenance management system. Using axle VMT as the allocation basis results in truck life cycle snow removal costs of $161,790 per mile of highway or 53 percent of total snow removal costs.

Routine Maintenance

The average annual routine maintenance costs (excluding snow removal) for rural Interstate highways in Pennsylvania is reported as $17,600 per mile in 1989 dollars. The average annual routine maintenance costs for I-80 for the last 3 years averaged $10,300 per mile in real dollars. Reported routine maintenance costs for I-80 by county varied from as low as zero to a high of $54,000 per mile. Because of the high variability in annual maintenance costs among counties, it was decided to use the average maintenance costs established by PennDOT of $17,600 per highway-mile, or $440,000 over the 25-year life of the highway, for rural Interstate pavements, as the basis for this study. Using the 30-70 rule (30 percent by VMT and 70 percent by ESALs) for allocation of truck costs yields a life cycle value of $347,072 per mile of highway or 79 percent of total routine maintenance.

Truck Weight Enforcement

PennDOT has a law enforcement division for inspecting, issuing citations for fines, and confiscating the trucks of operators who violate the weight limit and back hauling laws. PennDOT's estimate of the department's costs associated only with enforcement of the truck weight laws on I-80 is $393,000 for 1990. Estimating the same amount for 25 years and dividing by 300 million tons over this period results in 0.01 cents per ton-mile, or 84 cents for a five-axle semi-trailer round trip on I-80.

Summary of Facility Costs

Table 1 presents a summary of the average facility costs for trucks. These facility costs are, in principal, recovered in Pennsylvania through user fees and taxes. The facility costs are not recovered within any single year but over the entire life of the facility. The basis of distribution for this analysis is commercial tonnage of freight. Therefore, the life cycle cost of the facility is divided by the total life cycle average of 297,000,000 tons of freight. This converts to a freight cost per ton-mile of approximately 2.2 cents. This equates to 30 cents per mile of travel for a 5-axle semi-trailer based on an average cargo weight of 13.5 tons.

The 25 individual sections of I-80 had fairly large variations in the cost per mile of travel for a five-axle semi-trailer ranging from a low of 18 cents per mile to a high of 51 cents per mile, with an average of 30 cents. The large variations in costs are due to three variables: tonnage on each section, overlayment or reconstruction of the section, and the year in which it was constructed.

USER TAXES AND FEES

One of the basic premises of highway transportation is that vehicle owners and operators pay for the use of highways in direct proportion to the cost of constructing and perpetuating the highway system. User financial support for the highway system is functionally classified according to a three-tiered tax structure. The first consists of fees and charges unrelated to the mileage driven by an operator. It is often considered to be the basic "entry fee" to the road network. The second consists of fees and charges related to miles driven on the highway system. Typically, the second-tier tax is a fuel tax. A third-tier tax introduces weight and distance into the user charge computation. A third-tier tax highlights the difference in road damage attributable to vehicle weight (or more accurately, axle-loadings). Pennsylvania user fees and taxes can be categorized as first- and second-tier taxes. Currently, there are no third-tier taxes in Pennsylvania.

In addition to the functional three-tier classification, user charges are categorized by federal, state, and local jurisdiction. Highway user fees account for most of the financial resources spent on the state highway system, including the federally supported system. Local government funding sources for highways and roads are generally not related to use. Traditional local funding sources include property taxes, general funds, bond proceeds, and the like. This study focuses on the Interstate highway system and therefore excludes local government nonhighway user taxes.

Allocation of State and Federal User Taxes and Fees

Allocation of user taxes and fees involves a three-step process: (a) identification of federal and state sources, (b) allocation of taxes and fees to the I-80 corridor, and (c) determination

TABLE 1 Life Cycle Facility Costs

	Period 1966-1980 (all $ figures are 1989 costs)			
	$ per Mile of Highway		$ per Ton-Mile of Freight[a]	$ per Mile Mile of Travel
	All Vehicles	Trucks	Trucks	5 Axle Comb.
Initial Construction				
Right-of-Way	236,172	80,913	.00027	.00368
Bridges	913,352	720,452	.00243	.03275
Roadway	4,493,838	3,544,739	.01194	.16112
Subtotal	5,643,362	4,346,104	.01464	.19755
Rehabilitation	2,219,355	1,750,627	.00589	.07957
Maintenance				
Snow Removal	300,000	161,790	.00054	.00735
Routine	440,000	347,072	.00117	.01578
Weight Enforcement	32,500	32,500	.00011	.00148
Subtotal	772,500	541,362	.00182	.02461
TOTAL	8,635,217	6,638,093	.02235	.30173

[a] Based on 297 million tons of freight hauled on I-80.

of truck-contributed taxes and fees. The results of this process are discussed in the next two sections. (All taxes and fees are for 1989.)

State User Taxes and Fees

A major source of fees by Pennsylvania highway users are registration fees paid to the Motor License Fund. Registration fees, including vehicles in the International Registration Plan (IRP), are allocated to the I-80 corridor on the basis of daily vehicle-miles of travel (DVMT). Registration fees, statewide, for commercial registration class 7-25 trucks were $59,907,059; $982,417 for registration class 7-25 farm trucks; and $19,617,000 for trucks registered in IRP. Other state first-tier taxes, which include title fees, operator licenses, vehicle code fees, inspection stickers, special hauling permits, and other fees, are allocated on the basis of DVMT. In addition, treasury interest accumulated on the funds are also allocated by DVMT. The distribution of these other state fees and registration fees are presented in Table 2 for I-80 truck operations.

Fuel taxes are the principal source of state revenues for the Motor License Fund, Pennsylvania's transportation fund. The liquid-fuel tax, or gasoline tax, is assessed at 12 cents per gallon on motor vehicles. The fuel-use tax, or diesel tax, is also 12 cents per gallon for motor vehicles. The oil company franchise tax is calculated at 6 percent of the average wholesale price of petroleum products from a 90 cents per gallon minimum to a $1.25 per gallon maximum. This rate is absorbed in the retail price of motor vehicle fuels. The motor carrier road tax is a tax on motor carriers with gross vehicle weights of more than 17,000 pounds. The rate consists of a 12 cents per gallon excise tax, plus the oil franchise tax rate, plus an additional 6 cents per gallon. Credit is allowed for purchases of fuel in Pennsylvania up to the combined excise and oil franchise tax rate. State fuel taxes attributable to truck operations on the I-80 corridor are presented in Table 2. A total of $28 million was collected in 1990.

Federal User Fees and Taxes

Federal user taxes and fees collected from each of the 50 states are allocated to the states on a formula basis that does not necessarily equate to the federal taxes and fees actually collected in that state. Historically, Pennsylvania has received back 114 percent of its payment into the federal fund. However, in fiscal year 1989, the state received only 86 percent. For the purposes of this analysis no distinction is made between payments into the fund and apportionments from the fund, since this is beyond the scope of this study.

Federal fuel taxes consist of a 9 cents per gallon tax on gasoline and a 15 cents per gallon tax on diesel and are the major sources of federal revenues to the Federal Highway Trust Fund. The same procedure for allocating state fuel taxes is used for federal fuel taxes. The distribution of these taxes to the I-80 corridor are presented in Table 2. A total of $18 million was attributed to the I-80 corridor in 1990.

The distribution of the 12 percent federal sales tax on trucks and trailers are allocated to the I-80 corridor on the basis of daily vehicle miles of travel (DVMT). Trucks under 33,000 lbs and trailers under 26,000 pounds are exempt from the federal sales tax. Included in Table 2 is $7.5 million of the federal sales tax attributable to vehicles operating on the I-80 corridor.

The federal tire tax is a variable tax based on the weight of the tire. Tires weighing under 40 pounds are exempt. The tire tax is calculated as follows: 15 cents per pound for tires weighing 40 to 70 pounds, $4.50 plus 30 cents per pound for weight from 70 lb to 90 lb, and $10.50 plus 50 cents per pound for weight over 90 lb. The tire tax is distributed statewide on the basis of annual tire consumption and allocated to the I-80 corridor on the basis of DVMT. Included in Table 2 is $1.4 million of the federal tire tax attributable to trucks operating on I-80.

As the name implies, the federal heavy-use tax is a fee assessed on heavy vehicles. The fee is $100 plus $22 per 1,000 lbs for vehicles weighing 55,000 to 75,000 lbs. Vehicles heavier

TABLE 2 Truck User Taxes and Fees

	Taxes and Fees, 1989 $								
	State			Federal				State and Federal	
Vehicle Group	Registration Fees	Other Fees & Interest	Fuel Taxes	Fuel Taxes	Sales Tax	Tire Tax	Heavy Use Tax	All Taxes & Fees	Fee Per ton-mile
2 Axle S.U.	340,080	126,855	637,025	475,031	2,195	40,886	10	1,622,082	1.2¢
3 Axle S.U.	118,300	29,021	599,810	391,226	19,314	18,927	498	1,117,096	3.4¢
4 or more Axle S.U.	83,366	16,331	394,036	251,464	69,416	51,930	43,939	910,482	0.6¢
3 Axle Comb.	84,213	39,798	509,051	324,863	12,898	16,297	442	987,562	4.3¢
4 Axle Comb.	567,145	214,032	2,737,685	1,747,120	69,892	56,347	7,291	5,399,512	3.3¢
5 Axle Comb.	6,129,248	1,714,772	21,933,619	13,997,472	6,677,465	1,238,780	3,363,823	55,055,179	0.9¢
5 Axle Multi-trailer	296,838	83,046	1,085,333	692,632	581,816	46,473	261,474	3,047,612	0.8¢
6 or more Axle Comb.	37,909	10,606	141,689	90,422	56,097	4,254	28,154	369,131	1.1¢
ALL TRUCKS	7,657,099	2,234,461	28,038,248	17,970,230	7,489,093	1,473,894	3,705,631	68,568,656	1.0¢

S.U. - Single unit truck
Comb. - Tractor and semi-trailer combination
Multi-trailer - Tractor, semi-trailer, and trailer combination

than 75,000 pounds are charged $550. Farm trucks traveling less than 7,500 mi per year are exempt, as are all commercial trucks with annual VMT of less than 5,000. Federal heavy-use tax calculations are based on I-80 operating weights and allocated on the basis of DVMT. Included in Table 2 is $3.7 million of the federal heavy use tax attributable to trucks using the I-80 corridor.

Summary of User Taxes and Fees Allocation

Total state and federal user taxes and fees attributable to trucks on the I-80 corridor are presented in Table 2. The five axle tractor semi-trailer combination pays 80.3 percent of the truck taxes on the corridor. This compares with 72 percent of the I-80 five-axle DVMT and 87 percent of the total I-80 ton-miles. The five-axle combination pays 12.6 cents per mile or 0.9 cents per ton-mile in user taxes and charges to operate on the corridor. The 0.9 and 0.8 cent per ton-mile for the five-axle combination and five-axle multi-trailer, respectively, are significantly less than other less efficient trucks with smaller average payloads.

VEHICLE OPERATING COSTS

Overview

Vehicle operating costs form a major basis of the prices truckers charge to move commodities across the national Interstate system. Vehicle operating costs are split into two major groups; fixed costs, which are independent of vehicle utilization, and variable costs which vary directly with utilization. Fixed costs are significant and includes items such as depreciation, interest, driver salaries, and general trucking overheads. Fixed costs must be covered by the truck operation if long-term service to customers is to be offered.

Variable costs relate to distance traveled, and include fuel, oil, tire-wear, and vehicle repair and maintenance costs. Considerable knowledge has developed over the last 50 years on the relationship between variable costs and highway design characteristics. However, much of this information is not easily transferable over time. Since vehicle technology (for example, engine and transmission design) changes over time, so do consumption rates, which alters the basic relationships between vehicle costs and highway characteristics. However, work on truck cost model calibration has increased in recent years and is reflected here.

Most highway economic evaluation models are structured to allow highway planners to choose between alternative design strategies. To achieve this they use economic resource prices (net of taxes and social transfers) and not the various financial inputs required for a comparative rate study. However, some of these inputs, like user taxes and fees, have already been calculated in the previous section. Therefore, traditional highway design vehicle operating cost models can be used with a slight modification to reflect overhead costs.

After a comprehensive literature review, two approaches were adopted for the I-80 study. First, a traditional base set of vehicle operating costs using well-known relationships, initially developed by Zaniewski for highway design work, was predicted (*5*). These were first prepared in 1982 and have subsequently been updated as a part of an NCHRP project (*6*). These methods predict both fixed and variable costs and allow a basic operating cost per mile of travel to be determined, excluding profitability and social transfers such as state taxes. As a consistency check, a second approach examined truck costs predicted from a model developed for the Association of American Railroads (AAR) to examine policy tradeoffs between various commodities and modes, particularly truck and rail.

Vehicle Operating Cost Predictions

First examined was a set of vehicle operating costs requiring the geometric characteristics of I-80 as input. The methodology for the calculation of the vehicle operating costs is relatively simple. Each of the vehicle operating cost components (as described below) are calculated for 1,000 mi of travel using the NCHRP equations, which are then multiplied by 1989 unit prices in order to obtain the operating cost per 1,000 mi for each component. The sum of these component costs is the total vehicle operating cost.

Zaniewski's relationships were used to predict four truck types with the following gross vehicle weights: single unit two-axle, 12,000 lbs; single unit three-axle, 35,000 lbs; four-axle semi-trailers, 40,000 lbs; and five-axle semi-trailers, 62,500 lbs. The five-axle semi-trailer (or 18 wheeler) is a critical vehicle in these calculations, accounting for nearly 87 percent of the ton-miles on I-80.

Truck operating costs derived from the Zaniewski relationships were found to be inconsistent for negative grades (*5*). Accordingly, tangent (zero-grade) sections and positive 3 percent grades were averaged to produce an appropriate figure for rolling terrain. The initial results from the basic equations did not report all items, like interest charges and driver salaries. Consequently, revisions were necessary, including removal of user fees and taxes, more accurately estimated in this study for the I-80 corridor. The selected components predict a total cost-per-mile of 58 cents for a two-axle single unit, 79 cents for three-axle single units, 90 cents for four-axle semi-trailers, 93 cents for five-axle semi-trailer units, and $1.13 for five-axle multi-trailer units.

The results from the highway design models were next compared with predictions from the AAR intermodal policy truck cost model. The truck cost model is interactive, allowing the user to select commodity type, shipment size, and length of haul. Model output includes total cost for the selective movement in dollars, dollars per ton, cents per mile, and cents per ton-mile.

A base case was developed using a detailed range of inputs reflecting the differences between company and owner-driver vehicle. Owner-drivers are unable to get the price discounts on new vehicles offered to companies, and also prefer more options, which raises the purchase price ($60,010 for company versus $81,415 for the owner-driver) and, therefore, the cost per ton-mile estimates. There are other significant input differences between company and owner-driver vehicles. As an example, the five-axle semi-trailer driver wages are higher for company than owner-driver operations, $33,583 versus $30,066 per year; fuel consumption is slightly better (5.8 versus 5.4

mpg) for reasons not explained in the model; and tractor maintenance is 2 cents per mile higher for owner-drivers, which again is somewhat unexpected.

The results show that company costs for five-axle single 48-ft trailer units are 96 cents per mile, compared with $1.03 for owner-drivers. These translate into $14.67 and $15.70 per ton, or 4.70 and 5.03 cents per ton-mile, for company and owner-driver operations, respectively. The highway design model predictions for five-axle trucks and those from the AAR models are similar, 93 cents per mile from the highway design models and 96 cents per mile from the AAR models. For the purposes of this research, the highway design vehicle operating cost predictions are reported in the systems cost matrix.

EXTERNALITIES

Economic Cost of Truck Accidents

In evaluating the economic costs of truck related accidents, at least five major cost components need to be addressed: (a) accident damage of all types, (b) time delay costs to other users, (c) fuel and operating costs, (d) clean-up costs associated with accidents; and (e) emergency and police costs attributed to trucking operations.

Accident Costs

Accident costs consist of all property damage and injury-related costs such as lost income, medical expenses, and pain and suffering. The PennDOT accident data base for I-80 is used with annual averages determined from time series data during a 5-year period. There was an average of 488 serious truck accidents per year on I-80 during the period 1985–1989, classified into five categories ranging from property damage only to fatalities. PennDOT costs for each category were used to determine a total 5-year truck cost impact of $139 million. This averages to $27.7 million per year for the entire I-80 route or $89,208 per mile per year.

Examining all reported I-80 accidents during the 5-year period yields a value of $157,000 per mile per year, partly because of the large number of costly fatalities (109) and major injuries (235). Results from other urban studies show that the average annual cost per mile for urban truck accidents was $182,000 compared to this study's estimate of $89,208 for rural interstate travel. This shows the magnitude of rural and urban accident impacts, and demonstrates that the I-80 data appear consistent with national figures.

Delay Costs

Delay costs are defined as the monetary value of occupant time lost as a consequence of delay imposed by truck-related incidents. Only delay created during the accident period or incident is attributable to vehicle related accidents. Thus, delay at normal peak period congestion must be removed from delay calculations. In this study, an adjusted medium value of $4.25 per hour was employed for automobile occupant time, which approximates to the U.S. current minimum wage. This value was multiplied by 1.3 for every vehicle to compensate for average vehicle occupancy. Similar, a value of $25.00 per truck-hour with no occupancy adjustment factor was used, which approximates the national average for driver salary and overhead. An average delay of 13 min per vehicle, per truck accident, was applied to estimates of the affected traffic volume per vehicle category (*7*). The 488 average annual truck accidents on I-80 result in a total delay costs of approximately $1.5 million, which when divided by the route miles gives an annual figure of $4,853 of delay costs per mile of highway attributable to truck accidents.

Vehicle Operating Costs

Additional vehicle operating costs are created when congestion results from incidents. The primary component of additional vehicle operating costs caused by truck accidents, is increased fuel consumption resulting from delay and speed-cycle changes. The estimated increased operating cost of $947 for 17.4 minutes of delay (*7*) was adjusted to reflect the I-80 delay estimate of 13.2 min per affected vehicle, resulting in an operational cost of $718 per truck accident. Taking the average number of accidents (488) and dividing by route-miles results in an average of $1,127 per mile of highway.

Cleanup Costs

Cleanup costs are defined as the costs to public agencies and private organizations for removing accident debris from the roadway and returning the roadway to serviceable condition. The cleanup costs resulting from truck accidents vary drastically according to the type of accident and the cargo being transported and are difficult to determine. The California Department of Transportation estimated that the 6,700 to 8,000 annual truck accidents on the Los Angeles County Freeway System cost from $500,000 to $2,000,000 for cleanup (*7*). Employing these data results in an approximate cost of $250 per accident which for I-80 would give a total of $122,000 for the 488 annual truck accidents, or $392 per mile of highway.

Emergency and Police Costs

There is no dedicated highway patrol system for I-80, so the analysis is based on alternative sources. Costs attributed to the Pennsylvania Turnpike are comparable to the I-80 corridor, and their data reported a cost of $10,898,000 for 1989 Highway Patrol activities, excluding costs associated with truck-weight enforcement. I-80 costs per mile were estimated from the average 1989 cost of $14,022 per mile for the Pennsylvania Turnpike Highway Patrol.

Total Truck-Accident-Related Costs

Total estimated truck-accident costs from the preceding categories amounted to an average cost per mile of highway of $109,602 for I-80. Expanding this annual per mile cost estimate over the 311 mi of I-80 results in a total annual route cost of about $34 million.

TABLE 3 I-80 Truck Emissions[a]

	Emissions	
Pollutant	Grams (ton-mile)[b]	Annual (tons)[c]
Hydrocarbons (HC)	0.292429	2,128
Carbon Monoxide (CO)	0.838110	6,098
Nitrogen Oxides (NOx)	2.585310	18,811
Particulate Matter (PM_{10})	0.358813	2,611
TOTAL		29,648

[a] Based on diesel-powered trucks exceeding 20,000 lbs gross vehicle weight.
[b] From Weaver, C.S., "Feasibility and Cost-Effectiveness of Controlling Emissions from Diesel Engines in Rail, Marine, Construction, Farm and other Mobile Off-Highway Equipment," Radian Corporation, Washington, D.C., 1988.
[c] Based on 6.6 billion annual diesel ton-miles on I-80.

Truck Emissions

Emissions from diesel engines used in motor vehicles have been regulated with increasing stringency since 1980. As an example, federal regulations limited particulate matter (PM) emissions from heavy-duty diesel engines to 0.6 grams per brake horsepower-hour (g/BHP-hr) for the 1988 model year. The nitrogen oxides emissions limit was also reduced to 6.0 g/BHP-hr level. New particulate limits for trucks of 0.25 g/BHP-hr are scheduled to take effect in late 1991, with a revised limit of 0.1 g/BHP-hr for 1994. Because these limits only apply to new units, it will be some time before all vehicles can comply with the cleaner standards. In the meantime, truck engines will show a wide range of emissions performance.

Using the vehicle ton-miles of travel calculated in the traffic section of this study, some broad estimates can be made about I-80 truck emissions for four key diesel truck pollutants: hydrocarbons, carbon monoxide, nitrogen oxides, and particulate matter. These are presented in Table 3, which estimates 29,648 tons of pollutants annually from truck traffic on I-80. Currently, it is difficult to place monetary values on such pollutant levels, particularly as I-80 in Pennsylvania does not pass through a nonattainment area. Air pollution of the type generated by truck traffic has always been treated as an externality, although this view is rapidly changing with the recent federal air quality legislation. Although this study does attempt to value the truck pollution monetarily, it has reported it as a nonmonetary social burden.

CONCLUSIONS

In this final section, system cost inputs from the previous sections are combined to identify both supported and incurred system truck costs over the I-80 corridor. A limitation of traditional highway cost and revenue analyses (as seen in most highway cost allocation methodologies) is that important costs related to transportation operations are excluded. This limitation has significant ramifications when evaluating and comparing the cost of intermodal freight operations. Failure to consider all economic costs associated with transportation operations can lead to inefficient public and private investment in freight infrastructure.

Table 4 presents a summary of the supported system costs for I-80 on the basis of cost per ton-mile of freight and average truck costs per mile assuming a 13.25 average ton payload. Additionally, five-axle tractor and semi-trailer costs per mile of travel (13.5 ton payload) are shown. The five-axle tractor and semi-trailer is the predominant vehicle operating on the I-80 corridor. Under existing policy, supported system costs include vehicle operating costs and user taxes and fees (the vehicle operating costs for using the highway facilities). On average, trucks paid 8 cents per ton-mile or $1.07 per mile of travel in 1989. The predominant five-axle vehicle paid only slight less, $1.06/mile of travel. These supported system costs are the expenses currently paid by truck operators.

Table 5 presents a summary of the incurred system costs. Unlike supported system costs, actual costs to the facilities are used in place of the user taxes and fees paid by truck operators. Additionally, accident externalities are included. (Emissions should be included as a cost, but are reported separately for reasons stated previously.) Not surprisingly, the incurred truck system costs are higher. Actual facility costs are 123 percent higher than the paid truck user taxes and fees. Externalities (i.e., accidents and related costs), amount to 0.5 cents per ton-mile or about 7 cents per mile of highway travel. Comparing the incurred system costs with the supported system costs results in a truck subsidy of 1.7 cents per ton-mile or 23 cents per mile of truck travel. In total dollar amounts, this results in an annual truck subsidy of about $458,741 over the I-80 corridor in 1989 dollars. (Life cycle facility costs are converted to an annual amount based on a 7 percent annuity for 25 years.)

Absent from these monetary results is the issue of emissions, since there is as yet no agreed methodology for calculating such costs. The average five-axle truck emits about 4 g of pollutants (hydrocarbons, carbon monoxides, nitrogen oxides, and particulates) per mile of travel on I-80. Since this

TABLE 4 Truck-Supported System Costs

	Cost per Ton-Mile of Freight	Cost per Mile of Travel	
Cost Category	All Trucks	All Trucks	5 Axle Combinations
User Taxes and Fees	$.0100	$.1325	$.1253
Vehicle Operations	$.0706	$.9355	$.9314
TOTAL	$.0806	$1.0680	$1.0567

TABLE 5 Truck-Incurred System Costs

	Cost per Ton-Mile of Freight	Cost per Mile of Travel	
Cost Category	All Trucks	All Trucks	5 Axle Combinations
Facility	$.0223	$.2955	$.3017
Vehicle Operations	$.0706	$.9355	$.9314
Externalities	$.0050	$.0663	$.0674
TOTAL	$.0979	$1.2973	$1.3005

highway does not pass through an Environmental Protection Agency (EPA) nonattainment area, the dispersion problem is unlikely to be a significant issue, with the important exceptions of global warming and acid rain. It remains an unpalatable fact that trucks produce around 30,000 tons of pollutants annually along the I-80 alignment in Pennsylvania, an issue which may be of growing concern to the state in the 1990s.

To summarize, truck traffic on the Pennsylvania section of I-80 is not paying the full costs of sustaining the system for the operation of heavy vehicles. The key underpayment is in funding the facility costs through user taxes and fees, and this deficit is compounded by operating cost externalities imposed on other users and entities. Operating costs per mile for trucks need to be increased by around 22 percent to maintain the truck freight operations over I-80 in Pennsylvania without subsidies. The increase in truck user contributions is necessary to achieve full economic and equitable modal competition.

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Investigation of the Relationship Between Highway Infrastructure and Economic Development in Indiana

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A study was undertaken to investigate the relationship between highways and economic development in Indiana, using cross-sectional multiple regression analysis of data from 1980 through 1988. Seven highway variables in the broad categories of road conditions, highway mileage, and highway expenditures were used in conjunction with several other variables that were hypothesized to be significantly related to economic growth. Results indicated that highway mileage had a significant association with economic development in most cases. A sectoral model was used to investigate the impact of highways associated with 43 different standard industrial classification groups. Several forecasting models were developed for estimating the economic impact of the construction of two-lane highways, the upgrading of two-lane highways to four-lane highways, and the construction of new multilane highways in Indiana.

An issue that has received much attention in recent years is to what extent highways affect the economy, especially at the state and regional levels. This question becomes important in light of the declining condition of highway infrastructure and where funds for constructing new highways and for the maintenance of existing systems become more limited. Decision makers are increasingly aware of the potential economic development benefits of new or upgraded highways.

Many factors affect the economic development of a region, of which the available highway infrastructure is only one. The extent to which highways actually affect the economic development of a region is a highly debated issue. The literature on this subject uses many methodologies to model this relationship, and results vary, depending on the model, the period, and the unit of analysis.

The purpose of this paper is to investigate how economic development in Indiana between 1980 and 1988, as measured by employment growth, correlated with county-level highway infrastructure in 1980. Such a study does not establish that highways caused growth; it is, however, structured to demonstrate one element of causality: temporal precedence.

LITERATURE REVIEW

Input-output models appear to be the most commonly used methodology to determine the impact of highways on economic development. In most of these models, a distinction is made between the direct, indirect, and sometimes also the induced effects of highway construction (*1*,*2*). Detailed estimation of various economic sector responses to an external impact can be derived from these models. In general, the models are complicated and require detailed data as input, and they can be costly and time-consuming to calibrate and implement. Other limitations include problems with the timeliness of the data and difficulties modeling lagged effects. Several input-output models are in use today at various levels of analysis, such as the Regional Input-Output Model System (RIMS) or its updated successor (RIMS II) (*3*) and the Regional Economic Impact Model for Highway Systems (REIHMS) (*4*).

Regression analysis, using either time-series or cross-sectional data, or pooled time-series/cross-sectioned data, also has been used extensively to estimate the relationship between highways and economic development. An advantage of econometrics is its ability to analyze the simultaneous effect of a large number of variables, lags, and functional forms. Several other methods also have been used. Regression and input-output analysis appear, however, to be the most commonly used methods.

Several studies of the relationship between highways and economic development have been undertaken in recent years. At the national level, the relationship between the highway capacity level and the growth rate of per capita output for the 48 contiguous states between 1960 and 1985 was investigated (*5*). Regression analysis was used, and the results showed that, in general, states with a better highway infrastructure with regard to highway capacity and quality showed a higher per capita income growth over the period.

At the state level, several relevant studies were also performed. An ongoing study in North Carolina investigated the 100 counties in that state and indicated that the strongest growth was situated in urban counties (*6*). In the next part of the study, factor and cluster analysis were used to group counties together according to various factors (*7*). Regression analysis, using cross-section data and lagged variables, was employed to investigate the association between developmental highways and economic development in Georgia (*8*). Two studies were done in Iowa as part of the Revitalize Iowa's Sound Economy (RISE) program. One study (*9*) focused on developing a method to evaluate road projects to attract specific industries to an area. In the second study (*10*), a methodology was developed to determine priorities for primary road corridor development by using a regional analysis meth-

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odology involving the 954 incorporated cities and 99 counties in the state. A study undertaken in Minnesota used regression analysis pooling time-series and cross-sectional data from 1957 to 1982 for the 87 counties in the state (*11*). Granger-Sims causality tests were used to distinguish between the cause and effect of the relationship between highway expenditures and employment.

The four statewide studies mentioned above were typical of economic impact studies. The following are some of the common elements that can be identified. In urban areas, highways seem to have a significant impact on development. Because there are typically better and more extensive highway facilities in these areas, industries and jobs are concentrated in urban areas, thereby providing a bigger tax base and justification for better highway infrastructure. The effect of highway facilities on economic development in rural areas is not clear. There appears to be a significant amount of commuting to urban areas from counties close to urban areas.

The studies also indicated that because of a general decline in manufacturing employment in the United States in the past decade and an increase in service employment, both of these types must be considered in any study of the impact of highways on economic development. Specific service industries can be expected to play an increasing role in economic development in the future. In studies at the disaggregate level, such as within states or regions, counties appear to receive the minimum level of analysis because of data availability.

STUDY DESCRIPTION

In this paper, a study is described that dealt quantitatively with the relationship between highways and economic development in Indiana between 1980 and 1988. Regression analysis was used on cross-sectional data for 92 Indiana counties. The period was determined by the availability of highway data.

Compared with other states in the region and the United States in both 1980 and 1988, Indiana had a relatively strong manufacturing base, although this sector showed a slight decline over the period. The primary metal manufacturing industry in particular showed a large decline. In the service sector, defined as all industries with standard industrial classification (SIC) codes between 40 and 99, the state showed increases in employment and wage-income, similar to those of the East-North Central region and the United States. Almost all service industry groups experienced growth, with the largest actual increase in health services. Because of the larger share of the service sector in the state's economy, the net effect was an increase of over 10 percent in both total employment and wage-income.

For the purposes of this study, multiple cross-sectional analysis was used. A review of the economic development literature identified factors other than highway infrastructure hypothesized to affect economic development:

- Resource costs (*12*);
- Airport accessibility (*13*);
- Facilities that enhance the quality of life (*14*);
- Proximity to metropolitan areas (*15*);
- Relative wage rates and the presence of similar industries in a region (*16*);
- Tax rates; (*17*) and
- Education levels (*18*).

MODEL DEFINITIONS, ANALYSES, AND RESULTS

For the purposes of this study it was assumed that economic development can be modeled as either the change in employment or the change in wage-income over the period. Seven highway infrastructure variables in the broad categories of pavement condition, extent of highway facilities, and highway expenditures were defined. In the analysis, a series of increasingly disaggregate models was defined.

THE LIMITED MODEL

The first model, the limited model, was defined as follows:

$$Y = X'B + e$$

where

Y = The change in a county's employment or wage income in all economic sectors, in the manufacturing sector, or in the service sector between 1980 and 1988;
X = vector of independent variables;
B = vector of estimated parameters; and
e = vector of errors.

The independent variables included the following:

- COND is the road condition variable, defined alternatively as the average weighted road condition of the state highway system in a county (PSR), the percentage of roads with a PSR of 25 or less in a county (POOR), and the percentage of the total highway system that was paved in a county (PAVED);
- MILES is the highway facility variable, defined alternatively as the total mileage per square mile (ROAD80), the multilane mileage per square mile (G2LN80), and the highway facility rating in 1980 (HFR); and
- EXP is the total highway expenditures per square mile in a county from 1980 to 1988 in 1988 dollars (EXP).

The HFR variable was developed to approximate the extent of highway facilities in terms of highway capacity by using the two-lane and four-lane mileages weighed by their respective unconstrained capacities. Highway variables were used individually and in various combinations in separate regressions.

The limited model appeared to explain fairly well the variance in economic development in Indiana from 1980 to 1988 in the total industry and service sectors. It did not explain well the changes in manufacturing employment or wage-income. Road condition appeared to have a significant and positive association with economic development in only a few cases, and highway expenditures were significant with a negative relationship in some regressions. The extent of highway facilities was, however, significant in all instances, with a positive association in the total industry and service sectors. Multilane mileage density (G2LN80) were also associated with higher changes in economic development than were the total mileage density (ROAD80).

THE COMPREHENSIVE MODEL

A more comprehensive model was then defined with the same response variables as those in the limited model. The highway infrastructure variables were included in the same way as those in the limited model, namely each individually and in combination. However, other variables hypothesized to affect economic development were added to the model as explanatory variables. The independent variables in this model included the highway-related variables mentioned in the limited model and the following additional variables:

- ELEC is the industrial or commercial electric rate in a county in 1980, as applicable, in dollars per kW-hour;
- WATER is the availability of water in a county measured on a scale of 2 to 7;
- APT is the straight-line distance in miles from a county to the nearest large airport;
- COLL is the percentage of college graduates in a county in 1980;
- MSA is the distance in miles for a county to the nearest metropolitan statistical area;
- RECR is the acreage of federal, state, and local public recreational facilities in a county in 1988;
- TAXRT is the net property tax rate in a county in 1980;
- WAGE is the average wage rate for the total industry, manufacturing, or service sectors in a county in 1980, as applicable; and
- AGGL is the agglomeration variable, measured as the manufacturing or service sector employment, or both, in a county in 1980, as applicable.

Results from these regressions were as follows:

- Overall, road condition was not a significant variable, except in some instances in the service sector. PSR was positively related to growth, whereas the percentage of poor roads (POOR) was negatively related to growth, as hypothesized. The percentage of paved roads (PAVED) was not significant in any instance.
- Highway mileage was positively related to growth and statistically significant in most cases in the total industry and service sectors. In was not significant in the manufacturing sector, probably because of influences outside Indiana that affected this sector during the period. Parameter values showed consistent behavior in all three models, and, in particular, multilane mileage density had much higher parameter values than the total road mileage density within a fixed configuration of highway variables and agglomeration variables.
- Except for the wage-income manufacturing sector model, highway expenditures were significant in many cases, with a negative association. Expenditures over this period were aimed at localized construction and improvements that may have had only marginal economic impact. In addition, highway expenditures may have been deliberately undertaken in counties with low economic growth because of declining highway conditions.
- The percentage of college graduates and the property tax rate in a county were highly significant, with, respectively, positive and negative associations in most cases, as postulated.
- The adjusted coefficient of determination (R^2) for the comprehensive model increased considerably over that of the limited model. The highest value of this parameter in the total employment sector, manufacturing sector, and service sector, respectively, were 0.75, 0.51, and 0.99. Also, within each specific sector, the employment model attained a higher adjusted R^2 in general than with the same regression in the wage-income model.

SECTORAL MODELS

Industries within the manufacturing and service sectors were identified and divided into 43 groups, according to SIC codes between 1 and 93. For each of these industry groups, the sectoral employment and wage-income data for 1980 and 1988 were obtained. The independent variables in this model were otherwise the same as those in the comprehensive model. The dependent variables varied, however, according to sector.

The results from the sectoral model varied across sectors. In the general industry group, consisting of the four SIC groups with SIC codes from 1 to 17, some conflicting results were obtained relative to highway mileage variables, although the overall models seemed to be fairly "good" in terms of the coefficient of determination. In the manufacturing sector, consisting of SIC groups with SIC codes from 20 to 39, results varied according to sector. Better models were obtained for some industries than had been obtained in the aggregate manufacturing sector model. Some unexpected results pertaining to highway variables were also obtained, with total highway mileage density being significant and positively related to economic development in some manufacturing sector groups, contrary to results from the aggregate model. These sectors were food products, chemical products, and metal industries. In the service industry sector, with 23 SIC groups containing SIC codes from 40 to 93, highway mileage was significant in a majority of sectors, with positive association in the majority of cases, which was consistent with the aggregate model. Also, the adjusted R^2s were high in most sectors.

FORECASTING MODELS

The final part of this study was aimed at the development of models that could be used to estimate the economic impact of highway improvement and expansion projects. Residual analysis was used to investigate the models, and Glejser's test for heteroscedasticity (*19*) was employed when indications of this phenomenon were found in residual plots.

After detecting heteroscedasticity in most models, several measures were attempted to correct for the phenomenon. Deletion of outliers, normalization of dependent variables by county area and population, and weighted least-squares analysis using county population as weights were undertaken. In the total and service industry sectors, several models were

MODEL 1

TEMP = -4,968** + 1,220 ROAD80** - 18,336 ELEC80 + 202 WATER* -17 APT
+ 24,765 PCOLL*** + 26 MSA* -0.00206 RECR + 88 TAX+ 0.0156 TOTWAG80

ADJ. R**2=0.18 SSR=0.09478 SSE=0.27401

MODEL 2

TEMP = 1571 + 7,174 G2LN80** - 71,227 ELEC80*** + 208 WATER*** +9.75 APT
+ 12,883 PCOLL** + 37 MSA*** -0.00537 RECR - 179 TAX - 0.0602 TOTWAG80

ADJ. R**2=0.16 SSR=9.979E-11 SSE=3.153E-10

MODEL 3

TWAGINC = -103** + 26 ROAD80** - 358 ELEC80 + 3.97 WATER* - 0.4075 APT
+ 519 PCOLL*** + 0.5918 MSA* - 3.204E-5 RECR + 1.4237 TAX

ADJ. R**2=0.17 SSR=4.025E-5 SSE=1.28E-4

MODEL 4

TWAGINC = -21 + 164 G2LN80** - 982 ELEC80 + 4.97 WATER** - 0.541 APT
+ 498 PCOLL*** + 0.709 MSA** -0.00013 RECR + 0.7068 TAX

ADJ. R**2=0.14 SSR=3.67E-5 SSE=1.32E-4

MODEL 5

SEMP = 69 + 566 ROAD80** - 12,490 ELEC80 + 106 WATER -14 APT + 30,075 PCOLL***
+ 29 MSA** -0.00422 RECR - 96 TAX - 0.06636 SVCWAG80

ADJ. R**2=0.54 SSR=0.04339 SSE=0.03039

MODEL 6

SEMP = 2234 + 5,003 G2LN80** - 34,539 ELEC80 + 111 WATER - 9.1 APT
+ 29,293 PCOLL*** + 27 MSA** -0.00609 RECR - 89TAX - 0.06731 SVCWAG80

ADJ. R**2=0.54 SSR=0.0431 SSE=0.0304

MODEL 7

SWAGINC = -27 + 15 ROAD80*** - 733 ELEC80 + 2.79 WATER - 0.21961 APT
+ 696 PCOLL*** + 0.72154 MSA*** -0.00007 RECR - 2.4960 TAX

ADJ. R**2=0.65 SSR=2.591E-5 SSE=1.238E-5

MODEL 8

SWAGINC = 44*** + 81 G2LN80*** - 1,459 ELEC80*** + 2.086 WATER***
+ 0.2699 APT***+ 161 PCOLL*** + 0.3697 MSA*** - 0.00002 RECR - 1.616 TAX

ADJ. R**2=0.38 SSR=3.31E-14 SSE=4.26E-14

NOTE : * = VARIABLE DIFFERENT FROM ZERO AT A 10% SIGNIFICANCE LEVEL
** = VARIABLE DIFFERENT FROM ZERO AT A 5% SIGNIFICANCE LEVEL
*** = VARIABLE DIFFERENT FROM ZERO AT A 1% SIGNIFICANCE LEVEL
VARIABLES AS DEFINED EARLIER.

TEMP = TOTAL EMPLOYMENT CHANGE BETWEEN 1980 AND 1988
TWAGINC = TOTAL WAGE-INCOME CHANGE BETWEEN 1980 AND 1988, 1988$, MILLIONS
SEMP = SERVICE EMPLOYMENT CHANGE BETWEEN 1980 AND 1988
SWAGINC = SERVICE WAGE-INCOME CHANGE BETWEEN 1980 AND 1988, 1988$, MILLIONS
OTHER VARIABLES AS SPECIFIED EARLIER.

FIGURE 1 Forecasting models.

identified that had no heteroscedasticity associated with them after transformation, according to Glejser's test. In the manufacturing sector, this problem was still present in all models after transformation.

A total of eight models were identified for forecasting purposes. The models include alternatively the total highway mileage density (ROAD80) and the multilane mileage density (G2LN80), with total and service employment and wage-income change individually as response variables. Figure 1 presents these models with regression parameter values and other pertinent statistical parameter values. It is clear from the table that in each sector, the multilane mileage density parameter exceeded considerably the total highway mileage density parameter. Also the total employment highway parameter values were higher than the values in corresponding models in the service sector. The parameter values for highway infrastructure indicated that mean county employment had an average increase of 1,220 jobs associated with one unit increase in the total highway mileage density per county, all other variables being held constant. This translates into a mean employment increase of three jobs for the mean county with an area of 391 mi^2, over the 9-year period of the study. Using the same assumptions, the following can be derived from the other models:

- The mean county had an average increase of 18 jobs associated with every mile increase in multilane highways;
- The mean county wage-income in 1988 dollars had an average increase of \$66,500 (in 1988 dollars) associated with every mile increase in highways in the total system; and
- The mean county wage-income had an average increase of \$419,000 associated with every mile increase in multilane highways.

In the service industry sector, the associated values were as follows:

- The mean county had an average increase of 1.5 jobs associated with every mile increase in total highway mileage;
- The mean county had an average increase of 13 jobs associated with every mile increase in multilane highways;
- The mean county wage-income had an average increase of \$38,400 associated with every mile increase in highways in the total system; and
- The mean county wage-income had an average increase of \$207,000 associated with every mile increase in multilane highways.

These values are only estimated mean economic development increases associated with increments in highway infrastructure and should not be used for estimating economic growth overall or in individual counties. In Table 1, the 95 percent confidence intervals for the above-mentioned parameters are presented, also adjusted from highway mileage density to highway mileage in the relevant class of total mileage or multilane mileage. The wide intervals of the parameters provide evidence of the large variances associated with the data.

TABLE 1 Confidence Intervals for Estimated Highway Parameters Indicating Wide Range of Estimated Effects of Highways on Economic Development

DEPENDENT VARIABLE	INDEPENDENT VARIABLE	95% CONFIDENCE INTERVAL	
		LOWER LIMIT	UPPER LIMIT
TOTEMP	ROAD80	0.59	5.65
TOTEMP	G2LN80	4.09	32.61
TOTWAGINC	ROAD80	16	116
TOTWAGINC	G2LN80	27	811
SVCEMP	ROAD80	0.32	2.57
SVCEMP	G2LN80	2.88	22.71
SVCWAGINC	ROAD80	18	60
SVCWAGINC	G2LN80	99	315

TOTEMP = TOTAL EMPLOYMENT CHANGE PER COUNTY, 1980-88
TOTWAGINC = TOTAL WAGE-INCOME CHANGE PER COUNTY, 1980-88
SVCEMP = SERVICE EMPLOYMENT CHANGE PER COUNTY, 1980-88
SVCWAGINC = SERVICE WAGE-INCOME CHANGE PER COUNTY, 1980-88

EMPLOYMENT CHANGES IN JOBS PER MILE
WAGE-INCOME CHANGES IN $'000 PER MILE, 1988 $
ROAD80 = TOTAL HIGHWAY MILEAGE PER COUNTY
G2LN80 = MULTI-LANE MILEAGE PER COUNTY

Total employment had adjusted R^2 values that were much lower (0.14 to 0.18) than the service industry's values (0.38 to 0.65). The result is that forecasts using the total industry model will have a wider confidence interval than the service industry model.

The models that were developed for the total employment and service sectors could, however, be used to estimate the economic development impact that the construction of a new two-lane road, the upgrading of a two-lane to a four-lane road, or the construction of a new four-lane road would have on a county in Indiana. The caveats that should be kept in mind at all times are the limitations associated with the data and methodology that were used.

SUMMARY AND CONCLUSIONS

This study was aimed at investigating quantitatively the relationship between highway infrastructure and economic development in Indiana from 1980 to 1988.

The total highway mileage was found to be significantly associated with economic development in most cases. Multilane highways were found to have an association of between 5 and 10 times that of the total highway system. This finding emphasizes the importance of this type of facility, as often addressed in the literature concerning location theory and the attraction of manufacturing industry to a region (*20*).

Highway expenditures were not identified as a good determinant of economic growth in Indiana; this is partly because of the relatively short period of the study. Highway expenditures may not be a good measurement of highway facility availability if the study period does not include the 1960s and 1970s, when massive disbursements were made toward the construction of the highway infrastructure.

Several models were developed in this study that could be used to estimate the economic development impact of constructing new two-lane highways, upgrading two-lane roads to four-lane highways, and the construction of new four-lane highways. The limitations of the methodology—the fact that the models were based on the data for a relatively short period and were subject to specific economic changes in Indiana's history—should be kept in mind when comparing these figures to those of other studies. The models only provide estimates of previous trends; they will not necessarily hold in future years.

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Engineering Analysis of the Economics of Predicted Pavement Life

MICHAEL T. MCNERNEY AND W. RONALD HUDSON

The problem of deteriorating infrastructure—including highways and the cost of proper maintenance—is a major point of debate for policy makers. With continued tight budgets and increasing deficits, policy makers are looking harder at the costs of building and maintaining a viable highway network. Economists and engineers sometimes disagree on pavement maintenance, design, and construction costs. For example, K. Small, C. Winston, and C. Evans, authors of *Road Work* (1989), have proposed that costs of highway maintenance could be reduced by billions of dollars by increasing the thickness of the nation's highways and by imposing a national system of weight-distance taxation. The authors of *Road Work* base their assertion that highway engineers underdesigned the nation's highways on a re-analysis of the AASHO Road Test data using a survival regression analysis. An analysis of the *Road Work* study concluded that the results are similar to those of the original AASHO Road Test when additional traffic is considered. *Road Work* may have used questionable assumptions regarding pavement service life, the role of thickness in pavement performance, and predicted traffic growth. As a result, the estimated savings in the maintenance of the nation's highways seem to be vastly overstated. The analysis concluded that current pavement management economics and thickness design, although not perfect, are reasonable.

Do the nation's pavement and infrastructure problems result from bad economic analysis and poor performance equations? That is the conclusion of *Road Work*, a 1989 publication that suggests that these are the reasons for our crumbling highway infrastructure, estimated to require billions of extra public dollars to maintain and improve (*1*). The book asserts that "the United States can no longer rely on current highway policy to finance and manage its roads" (*1*, p. 114). The book advocates a new national highway policy based on (a) pavement-wear taxes for heavy trucks, (b) congestion taxes for all vehicles and (c) construction of thicker pavements to achieve greater durability (*1*, p. vii). A recurrent theme of the book is that improper economic analyses, along with errors in the AASHO Road Test analysis, have led highway engineers to underdesign the thickness of existing pavements. The book suggests that by increasing the pavement thicknesses by only 1 or 2 in., billions of dollars would be saved.

The *Road Work* proposal for congestion taxes and a national weight-distance tax for each functional class of pavement based on axle loading, but with increased truck weight limits and reduced truck taxes, is of concern to many interested groups. The book is published by the Brookings Institution, noted for its economic studies. It was the work's lack of engineering input, however, that prompted a review of the engineering aspects that were reported. The review of the *Road Work* analysis finds errors in application of pavement engineering principles and questionable assumptions, resulting in conclusions that are not supported by the analysis.

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SCOPE

This paper reports an engineering examination of *Road Work* that compares actual highway engineering data with the assumptions, premises, and observations that led the authors of *Road Work* to their conclusions. This paper covers six main areas in which engineering expertise is required to develop a true economic analysis of the nation's highway pavements:

1. Examination of the reanalysis of the AASHO Road Test data,
2. Assumptions of pavement life and thickness,
3. The role of thickness in pavement life,
4. Routine maintenance costs,
5. Assumptions of traffic growth, and
6. Relative savings of reduced loadings versus increased thickness.

BACKGROUND

In the book and in a previous paper published in *American Economic Review* (*2*), Small and Winston have undertaken the ambitious task of performing a broad-based economic analysis of the nation's highway system with regard to structural pavement design. Their analysis is credible, especially concerning the original AASHO Road Test data. They note that the original analysis in the 1960s overestimated the life of thick rigid pavements because those pavements had not, then, showed distress. Since then, the AASHTO Design Guide has been revised in 1972, 1981, and 1985, with considerable effort to account for environmental factors (*3*).

Road Work articulates challenging and thought-provoking ideas that are worthy of consideration by highway officials in formulating future transportation policy. Several studies have shown that trucks do not pay their fair share of the costs imposed on the maintenance and construction of the highways they use. A recently conducted study by Texas Research and Development Foundation of the I-80 corridor in Pennsylvania concluded that trucks pay only 45 percent of the costs allocated to their use of that facility (*4*). *Road work* estimates that rural and urban truck operations pay only 29 and 14 percent, respectively, of their allocated share of maintenance and then suggests that their system of taxes would recover all costs (*1*, p. 59).

EXAMINATION OF REANALYSIS OF AASHO ROAD TEST

The *Road Work* reanalysis of the original AASHO Road Test data used modern regression analysis techniques with certain limitations and assumptions. Many original AASHO Road Test sections, particularly the thicker ones, never reached a 2.5 serviceability index at the end of the test (1,113,800 axle repetitions). In the *Road Work* analysis, any pavement section that had not yet reached a 2.5 serviceability index was considered a survivor; therefore, the serviceability index of that test section was censored.

In *Road Work*, the authors chose to analyze the data using the Tobit model, an econometric model originally developed by James Tobin in the early 1950s as a tool for the economic analysis of household expenditures (*5*). The model is functionally the same as that in a survival analysis. The model is frequently used when the data (for example the life of laboratory mice) have a measured lifetime, or when they survive the entire length of the experiment. The application of the Tobit-type model to the Road Test data is innovative and worthy of consideration.

TABLE 1 Test Section Data Used for Small and Winston Model

Pavement Thickness (in.)	Number of Test Sections: AASHO	CENSORED	OBSERVED
2.5	12	8	4
3.5	26	14	12
5	42	22	20
6.5	44	24	20
8	56	42	14
9.5	44	41	3
11	28	28	0
12.5	12	12	0
Total	264	191	73

As reported in an earlier paper (*6*), the authors of this paper have duplicated the results of the *Road Work* analysis using the Small data. The data used by Small consist of the original 264 rigid pavement test sections of the AASHO Road Test, but only 73 test sections reached the 2.5 present serviceability index (PSI) failure criteria. A tabulation of the test sections with respect to thickness is provided in Table 1.

Each data point is a recording of the number of axle repetitions when each section reached a 2.5 terminal serviceability index. If the present serviceability index is greater than 2.5, whether it is 2.6 or 4.5 PSI, no PSI value is given to any of these test sections in the Tobit analysis. In Table 1, note that of the 73 observed test sections only 3 of the 44 test sections of 9.5-in. thickness were included, and none of the 11-in. or 12.5-in.-thick test sections were included. Thus, the analysis depended heavily on pavements whose thickness was 8 in. or less. The resulting mean thickness of the observed test sections used in the *Road Work* analysis was only 5.8 in.

In Table 2, a comparison is made showing the Small and Winston results and the AASHO performance equation converted to natural logarithms. The most significant difference is the coefficient of the load term (A_2), which is only 3.24 in the Small and Winston term and 4.62 in the AASHO term. The equations predict the number of equivalent single 18,000-lb axle loads (ESAL) until a 2.5 serviceability index is reached. The significance of these equations for a typical 10-in. rigid pavement is a prediction of 9.3 million ESAL for the Small and Winston equation and 28.6 million for the AASHO equation. In the Small and Winston analysis, the 10-in. pavement would have to be increased to 12.5 in. to predict 26 million ESAL. The authors of *Road Work* believe that the disagreement between these equations caused the AASHO design model to overestimate the life of thick rigid pavements (*2*, p. 563).

SMALL ANALYSIS WITH ADDITIONAL ILLINOIS DATA

At the conclusion of the AASHO Road Test, many thicker rigid test sections were still in excellent condition, and the

TABLE 2 Comparison of AASHO and Small and Winston Performance Equations

EQUATIONS	COEFFICIENTS (STANDARD ERROR) A_0	A_1	A_2	A_3	PREDICTED ESAL (MILLIONS)
AASHO	13.53	7.08	4.53	3.17	28.6
SMALL & WINSTON	13.505 (0.307)	5.041 (0.329)	3.241 (0.260)	2.270 (0.242)	9.3

Note: $\ln N = A_0 + A_1 \ln (D + 1) - A_2 \ln (L_1 + L_2) + A_3 \ln (L_2)$

where D = thickness
L_1 = load in Kips
L_2 = number of axles

remaining sections were rehabilitated as new 10-in. rigid sections constructed in a controlled experiment (7). This rehabilitated roadway was incorporated into Interstate 80 to continue the research on this road test. For inclusion into the new study of the rehabilitated roadway, the rigid test sections had to be at least 8 in. thick and structurally sound, with no visible signs of deterioration. A few 8-in. sections, most of the 9.5-in sections, and all of the 11- and 12.5-in. sections were retained as original test sections. The rehabilitated test facility included 47 original rigid test sections and 37 new 10-in. rigid test sections for a total of 84 experimental rigid sections.

The facility opened to traffic in November 1962 and carried an average daily traffic (ADT) of 3,500 vehicles per day. The traffic consisted of 71 percent passenger cars, 6 percent single-unit trucks, and 23 percent multiple-unit trucks. More than 96 percent of the heavy trucks used the outer lane and therefore only the outer lane was included in the analysis. In 1973 the ADT was 15,700. The average annual growth rate of ADT during the first 10 years was a high 26 percent.

Since the authors of *Road Work* acknowledge the Illinois data by reference, it was assumed that their analysis would also concur with the findings by the Illinois DOT report (*1*, p. 27). The data from the Illinois DOT study of the continuation of traffic on the Road Test sections were added to the *Road Work* data analysis, and surprising results were achieved. As previously reported (*6*), the authors of this paper have calculated new regression coefficients based on this Tobit-type reanalysis of the AASHO Road Test data.

The results in Table 3 show that, revised, the Small and Winston equation is now much closer to the original AASHO equation (using 2.5 terminal serviceability) than it is to the *Road Work* analysis. The coefficient of the load factor term, which was calculated in *Road Work* to be 3.24, is now 4.46. The significance of this change is that a typical 10-in.-thick rigid pavement will now have a predicted lifetime of 24.1 million ESAL versus the 9.3 million ESAL previously predicted by the Small and Winston analysis. Figure 1 shows the

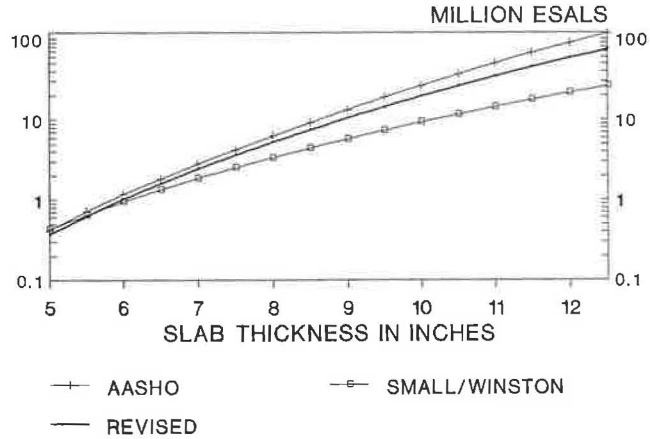

FIGURE 1 Comparison of 18,000 single-axle repetitions by thickness.

differences in the predicted repetitions of an 18,000-lb axle by pavement thickness.

When compared with the performance of the new 10-in.-thick rigid test sections of the Illinois study shown in Figure 2, the *Road Work* equation underestimates the life of thick rigid pavements far more than the original AASHO equation overestimates the life of the same pavements. The foundation of the subsequent *Road Work* economic calculations is based on this limited analysis, which assumes that a four-to-one savings will result for increased cost associated with increasing thicknesses.

ASSUMPTIONS OF PAVEMENT LIFE AND THICKNESS

To complete their economic analysis of the highway system the authors of *Road Work* had to rationalize a pavement thickness and service life for reference, against which in-

TABLE 3 Comparison of Small and Winston and Revised Performance Equations

EQUATIONS	COEFFICIENTS (STANDARD ERROR) A_0	A_1	A_2	A_3	PREDICTED ESAL (MILLIONS)
AASHO	13.53	7.08	4.53	3.17	28.6
SMALL & WINSTON	13.505 (0.307)	5.041 (0.329)	3.241 (0.260)	2.270 (0.242)	9.3
SMALL & WINSTON REVISED	14.02 (0.379)	6.72 (0.277)	4.46 (0.247)	3.09 (0.257)	24.1

Note: $\ln N = A_0 + A_1 \ln (D + 1) - A_2 \ln (L_1 + L_2) + A_3 \ln (L_2)$

where D = thickness
L_1 = load in Kips
L_2 = number of axles

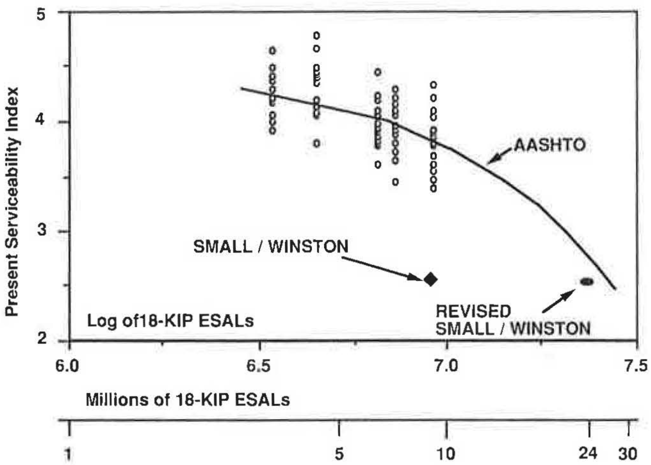

FIGURE 2 Performance of 10-in. rigid sections of rehabilitated AASHO Roadway.

creased thicknesses could be compared to show economic gain. Unfortunately, the thickness and service life values they selected as the basis for the future comparisons were understated, and thus the results are skewed toward higher savings.

Assumed Pavement Life

First, the *Road Work* authors define pavement service life in terms of the time lapse until resurfacing. Although the source of their service life is not clearly referenced, the authors of *Road Work* assume that the service life for rigid freeway pavements is 13.5 years and that for flexible pavements it is 10 years. These assumptions are significant, for most of the "maintenance savings" is achieved by doubling these assumed service lives to "optimum" service lives (*1*).

Based on two case studies that the authors of this paper have completed, it is believed that the *Road Work* assumptions regarding pavement service life are suspect. In a recent study of the Interstate 80 corridor in Pennsylvania, the average age of the original 10-in. rigid pavements was calculated as 22 years until resurfacing or reconstruction (*4*). However, there was no way to determine the serviceability index of those pavements at the time of resurfacing or reconstruction.

A data base for monitoring the long-term performance of CRCP sections in Texas (*8*) was examined for the age of rigid freeway pavements at resurfacing. It was determined that there was an average time lapse of 15.9 years until sections had received their first overlay, or a 17.8 percent greater service life than projected in *Road Work*. If all the unresurfaced pavements 15 years or older were resurfaced today, the average time to resurfacing in the Texas data base would calculate to 18.6 years, or 37 percent more than the *Road Work* assumption.

The authors of *Road Work* reference the source of their data as coming from interviews with highway engineers and their analyses (*1*, p. 39). Resurfacing is often justified for reasons other than loss of serviceability. If the Texas and Pennsylvania data are any indication, the *Road Work* analysis has significantly underestimated the referenced service life.

Assumed Pavement Thickness Based on Pavement Life

Second, the book's authors readily admit that they lack specific data on existing pavement thicknesses. They believe that because of the wide variation in climate and soil type, existing pavements can be more accurately described by the interval between resurfacing than by attempting to identify actual thicknesses. Using their method (which we suggest is faulty) for predicting years of pavement life from road thickness and traffic loadings, they then work backward to estimate the existing national road thickness for given functional classes, pavement types, and traffic level intervals (*1*, p. 39).

Although this circular method of calculation makes for nice, neat, and convenient data for analysis, other variables exist in the real world that also must be considered. The *Road Work* authors' simplification disregards these variables, with the net result that ultimate costs are understated and expected savings are overstated.

Assumed Costs a Function of Thickness

The *Road Work* equation for total pavement cost (TPC), which is optimized in their economic analysis, is

$$TPC = k_2 D + k_m \frac{1}{[e^{rT(D)} - 1]}$$

where

D = thickness,
k_2 = pavement construction cost per lane-mile per unit of road thickness,
k_m = resurfacing cost per lane-mile,
r = interest rate, and
T = time between resurfacing (which depends on D).

The only variables in the *Road Work* equation that affect savings in what the authors term total pavement cost are changes in the assumed pavement thickness, the assumed existing service life, and the optimal service life, determined only by thickness and ESAL (*1*, p. 38). By basing the analysis on an assumed short pavement service life and comparing the results with an optimal service life affected only by thickness and ESAL, the authors argue that significant savings can be realized. But since the assumed values are highly questionable, we suggest that the projected "maintenance savings" are greatly overstated.

ROLE OF THICKNESS IN PAVEMENT LIFE

The authors of *Road Work* exaggerate the role of thickness in the life of a pavement. As has been stated, to simplify their analysis, the authors have consciously excluded all structural terms and factors except pavement thickness. Admittedly, many engineers and nonprofessionals feel that making pavements thicker might have extended the service life of some pavements that did not achieve a 20- or 25-year design life. Rather than as a result of improper thickness design, premature pavement failure is often the result of such factors as

(a) incorrect traffic forecasting, (b) the failure of subgrade support, (c) increased truck weights, (d) lack of proper maintenance, or (e) poor construction practices. Increasing pavement thickness is not a cure-all for each of these problems and may be economically unsound.

Contrary to the assumptions in *Road Work*, thickness is not necessarily the major determinant of pavement service life longevity. Data in Michigan and Texas and from the AASHO Road Test document cases in which thinner rigid pavements—in nearly the same locations, under the same traffic, and in the same weather—have outlasted thicker rigid pavements (*8,9*). Moreover, the decision to rehabilitate pavements is not necessarily based only on the loss of serviceability (roughness), as is the assumption in *Road Work.* In fact, the FHWA Rigid Pavement Distress Model, which is based on empirical data, assigns only 40 percent of the decisions to rehabilitate on loss of serviceability. The remaining 60 percent are assigned to faulting, pumping, loss of skid resistance, joint deterioration, cracking, depression, or swell (*10*). Both loading and environment influence pavement life. Many pavement engineers believe that, in reality, the interaction of heavy truck loadings in combination with environmental conditions has the greatest influence on actual pavement service life.

ROUTINE MAINTENANCE COSTS

Pavements deteriorate with age. The *Road Work* authors assume that a flexible pavement closed to truck traffic will last 25 years, whereas a rigid pavement will not deteriorate at all, since they have found "no evidence of significant aging in rigid pavements" (*1*, p. 28). Although this assumption makes for easy analysis, it ignores what state highway engineers experience throughout their careers: pavements deteriorate with age and require routine maintenance throughout their lifetimes.

If routine maintenance costs were constant throughout the lifetimes of pavements, those costs possibly could be excluded from the economic analysis. In reality, as pavement distress becomes greater, more maintenance is required. Often the forecast cost for continued routine maintenance makes an economic case for early resurfacing. In the Pennsylvania I-80 corridor study, the authors estimated that the cost of routine maintenance over the 25-year lifetime for that rural Interstate highway was equivalent to 10 percent of the life-cycle cost of the initial roadway construction (*4*).

The *Road Work* definition of maintenance savings apparently includes only those costs strictly related to resurfacing; other operations that highway departments normally categorize as routine maintenance are excluded. It is this failure to include these routine maintenance costs in an economic analysis that results in an overstatement of the calculated optimum pavement lifetime and in an inflation of the resultant maintenance savings. This is particularly important in the *Road Work* authors' analysis, since the savings are based wholly on extended pavement service lifetimes. Also, the longer the pavement service lifetime is extended, the greater is the amount of routine maintenance required.

The current AASHTO Design Guide suggests five methods of performing an economic analysis of alternate design strategies. The recommended present worth method, similar to the *Road Work* analysis, describes a method for including the effects of routine maintenance costs as described by Baldock (*11*).

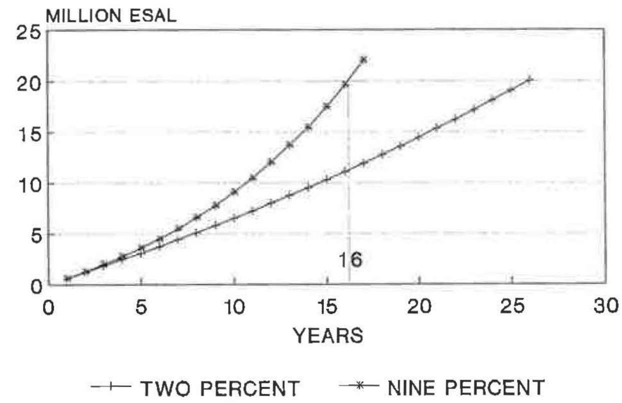

FIGURE 3 Comparison of predicted ESAL growth rate.

TRAFFIC GROWTH FORECAST

The *Road Work* authors acknowledge that their analysis is sensitive to traffic growth (*1*, p. 67). It has been generalized that average daily traffic growth rates are roughly comparable to the growth rate of the gross national product (GNP) (*12*). A conservative ADT growth rate for the assumed existing pavement service life would therefore range from 3.5 to 4 percent. A 3.5 percent ADT growth on rural Interstate highways is equated by the FHWA to a growth rate of 9 percent for ESAL loadings (*12*).

For their model, the authors of *Road Work* have assumed a growth rate of only 2 percent for all vehicles, noting that the number was chosen from the *AASHTO Guide for Design of Pavement Structures* (*1*, pp. 65,68). Yet the AASHTO Design Guide specifically states that a 2 percent growth rate for all vehicles is "a poor assumption" (*3*, p. D-24). The anomaly is that, in comparing costs to show savings, the assumed existing pavement service life reflects a much higher actual growth rate, whereas the calculated optimal 26-year service life uses only a 2 percent growth rate.

Road Work's hypothetical optimal Interstate pavement having a thickness of 10.41 in. would be designed (according to the authors' method) to achieve a service life of 26 years. As shown in Figure 3, if that design were based on 20 million ESAL using a 2 percent annual ESAL growth rate, and if a 9 percent annual ESAL growth rate were actually experienced, the pavement would have accumulated the same 20 million ESAL in only 16 years. The projected source of savings in their model, then, would be reduced from a 12.5-year gain until resurfacing to a gain of less than 3 years.

RELATIVE SAVINGS OF REDUCED LOADINGS VERSUS INCREASED THICKNESS

As mentioned earlier, the maintenance savings purported in *Road Work* are strictly a function of the estimated reduced time until the pavement requires resurfacing. It does not reflect the bulk of traditional state highway maintenance costs, including routine maintenance, lighting and signing, or initial construction (other than the additional asphalt or concrete required to achieve optimal thickness). The *Road Work* findings purport an $8 billion savings in maintenance costs. The source of the savings comes from two areas: (a) reducing truck loadings by shifting freight to trucks with more axles to reduce pavement damage, (b) doubling the assumed existing service life to achieve optimal service life.

As reported in *Road Work*, "The source of the welfare gain is the 38 percent decrease in truck loadings (ESAL-miles) resulting from our policy, almost all of which is due to shifts among truck types" (*1*, p. 53). The reduction of ESAL-miles would be accomplished by replacing current truck-user taxes with marginal cost taxes based on axle-weight per mile of use on each pavement type. Hypothetically, this change would thus induce truckers to use vehicles with more axles on more cost-efficient routes. Considering the tremendous capital investment in present fleets, is it realistic to expect in the distant future the industry to replace the fleets and shift usage to vehicle configurations that offer financial advantages only?

The authors of *Road Work* conduct sensitivity analyses individually of the assumptions of initial pavement life and traffic growth. However, these sensitivity analyses are compared only with the results of their policy, which assumes a 38 percent ESAL reduction of loading. A realistic analysis would be a combination of higher initial pavement life, much higher traffic growth, and the effects of current pricing.

CONCLUSION

New analyses are always valuable, and the authors of *Road Work* are to be complimented on their innovative application of the Tobit model to the analysis of the AASHO Road Test data. Statistically, the Tobit regression analysis procedure can be an effective technique for data analysis in a Road Test-type experiment and potentially could be superior to ordinary least-squares regression analysis. However, when interpreting the results, it is important to look at the data to see what really can be inferred. In this application, because of the small percentage of failed pavements (72 percent censored), the small number of axle repetitions, and the large variance in performance, the Tobit analysis does not yield good prediction equations, especially for thick rigid pavements. However, when it is used with additional data for thicker rigid sections that carry additional loads in the Illinois data, the Tobit analysis produces results very close to those of the performance equations and design guides in current use by professional highway engineers.

The *Road Work* analysis uses questionable assumptions for estimating pavement service life and traffic growth. The questionable assumptions, the exclusions of variables other than thickness, and faulty analysis of thickness design result in overstated maintenance savings. The book presents no credible engineering evidence that increasing the nation's pavement thickness by small amounts would sharply cut overall highway costs.

In summary, although the AASHTO Design Guide analysis may slightly overestimate the life of thick rigid pavements, it is still valid and the prediction equations are reasonably accurate. The current thickness design and techniques of economic analysis of alternate design strategies in use by the nation's highway engineers are satisfactory. Continued emphasis on pavement management systems and techniques have resulted in locally revised performance equations for specific geographic locations. There is no magic cure for offsetting the deterioration of the nation's crumbling highway infrastructure. A practical solution to the problem requires improving understanding and accountability while increasing reimbursement of the cost for the damage caused by axle loads.

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DISCUSSION*

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In discussing our book (*1*), McNerney and Hudson focus mainly on one of its conclusions—that lifecycle pavement costs could be reduced by designing pavements for greater durability.

*This discussion was based on the original paper, which was later revised.

They contest our analysis of pavement wear and a variety of other assumptions. Their own analysis of pavement wear, however, uses data that already have their preferred equation built in, and they neglect to mention that we report extensive sensitivity analyses of the very assumptions they challenge (*1*). In no case does altering key assumptions overturn our findings, and in several cases it strengthens them.

Contrary to the authors' assertion, our book does not advocate increased weight limits.

We discuss the authors' main criticisms in turn.

REANALYSIS OF PAVEMENT WEAR

Current design procedures are heavily dependent on the original road-test analysis by the AASHO. Our reanalysis of the AASHO data introduced survival or Tobit analysis to account for the statistical effects of censored data. "Censored" is a technical term meaning that, for certain observations, the variable being explained is know only to lie in a certain range; here, the number of axle loads to failure is censored for those pavement sections that outlasted the duration of the test. These censored observations still provide valuable information, and McNerney and Hudson are simply wrong to assert here and in their previous paper with Dossey (*2*) that they are omitted from our analysis.

In that paper, the authors approve of our methodology but attempt to apply it to an enlarged sample that merges the AASHO data with supplementary data from in-use Illinois pavements. However, these supplementary data are of a fundamentally different character from the AASHO data. First, in the new data each pavement section received a mixture of various axle weights. The equation being estimated describes the effect of just one axle weight, so it cannot be applied to in-use data without specifying some aggregation rule. What is worse, the supplementary data used by the authors contain no information about the traffic mixture except an aggregate measure of ESALS, calculated from the original AASHO equation (*3*, p. 34).

The results are miraculous. Although the supplementary data can provide no information about effects of various axle loads, the authors claim that including them reinstates the AASHO fourth-power law for their relative damaging power, as compared with a third-power law that we obtained by the same technique without the supplementary data. More generally, one must be suspicious of the remarkable coincidence that the original AASHO equations, which the authors acknowledge to have resulted from faulty statistical analysis on inadequate data, turn out to be about right after all.

There is substantial external evidence that the AASHO equations misrepresent heavy rigid pavements. To cite just two examples, experience with the Illinois Tollway indicates that the AASHO equations overpredicted pavement lifetimes by a factor of three (*4*, p. 39), whereas, on a national sample, the AASHO equations overpredicted average lifetimes in wet-freeze climates (like that at the AASHO test site) by a factor of 1.9 for unreinforced an 2.8 for reinforced rigid pavements (*5*, p. 7). These lifetimes are measured in equivalent axle loads, so the results have nothing to do with the accuracy of traffic forecasts. Widespread concern over rapid pavement deterioration has led many states, such as Pennsylvania and Florida, to strengthen their design standards, and AASHO itself (now AASHTO) to build more conservativism into its revised design guides.

To this evidence we add that the Illinois Department of Transportation (*3*), in its own analysis of the supplementary data used by McNerney and Hudson, reports that the AASHO equations drastically underpredict the lifetimes (in ESALS) of heavy rigid pavements. For example, the 11-in. rigid pavements deteriorated at approximately the rate predicted by the AASHO equations for 10-in. pavements, whereas 12.5-in. pavements performed only as 10.75-in. pavements were supposed to (*3*, p. 32). The Illinois researchers conclude, as we do, that the rigid pavement lifetimes are much less sensitive to thickness than stated in the AASHO equations (*3*, p. 35).

It is worth noting that only a modest portion of the benefits we project from our recommended policies come from our reanalysis of the AASHO data. Another portion comes from increasing the durability of flexible pavements, where our pavement-life equation does not differ much from that of AASHO. The greatest portion comes from using pricing incentives to alter the mix of vehicle types and thereby reduce the pavement-damaging power of trucks. We now turn to the authors' criticisms of our analyses.

ANALYSIS NEGLECTS INFLUENCE OF AGE AND ENVIRONMENT ON PAVEMENT LIFE

Our extensive discussion of the issue of factors affecting pavement life (*1*, pp. 28–31) is based on the same premise as that stated by McNerney and Hudson: it is the interaction between loadings and environmental conditions that determines pavement service life. In the case of flexible pavements, the World Bank has provided quantitative estimates, which are incorporated in our analysis. The effect is to increase the cost-minimizing pavement thickness. The reason is that the World Bank equation, consistent with most evidence, assumes that age has a more deleterious effect if the pavement already has been weakened by heavy use; hence, the stronger the aging effect, the more important it is to forestall such weakening through initial design. In the case of rigid pavements, the evidence for aging effects is inconclusive and no quantitative estimate is available, so we assumed that age-related deterioration is negligible.

ANALYSIS UNDERSTATES EXISTING PAVEMENT THICKNESSES

McNerney and Hudson wrongly state that we lack data on pavement thicknesses of existing roads. As we make clear, FHWA provided such data, but we deemed them unsatisfactory for our purposes (*1*, pp. 19,39–41). Instead, we start with information about the lifetimes of existing pavements. We then calculate (for each road or pavement classification) the corresponding thickness, or more precisely, the corresponding parameter that makes the AASHO equation represent that pavement. There is nothing circular in this and nothing more mysterious than solving a nonlinear equation for a unknown parameter.

In questioning our lifetime assumptions, the authors cite cases that, besides being selective, offer an invalid comparison. Our pavement lifetime is defined as the time taken for the pavement to deteriorate to a predetermined value of the pavement serviceability index, namely 2.5. Times to actual resurfacing may be quite different, especially if maintenance is deferred for budgetary reasons.

Even if actual lifetimes of existing pavements are 30 percent higher than we assumed, our results would be only modestly altered according to one of our sensitivity analyses (*1*, p. 67). The cost-minimizing pavement design would still require an increase in annualized capital expenditures (relative to current practice) of about 62 percent of that in our base case; pricing and revenue implications would be virtually unchanged.

ANALYSIS IGNORES ROUTINE MAINTENANCE

Routine maintenance costs could be incorporated into our model in the same way as are user costs, since both occur in cycles corresponding to periodic resurfacing. In one of our sensitivity analyses (*1*, p. 67), we found that accounting for user costs strengthened all our conclusions considerably: durability should be even greater, prices higher, and overall cost savings larger. Including routine maintenance would have a similar, but much smaller, effect on our results.

ANALYSIS UNDERSTATES TRAFFIC GROWTH

Contrary to the assertion of McNerney and Hudson, our sensitivity analysis showed that the growth rate of traffic loadings has only a small effect on our results [*1*, p. 68)]. The reason is that our data on traffic loadings refer to today, not the date the road was built. Hence, assuming a higher rate of traffic growth implies that traffic was lighter until now and will be heavier subsequently than in the base case. This assumption has offsetting effects on the time of resurfacing.

PRICING INCENTIVES WILL NOT AFFECT TRUCKERS' BEHAVIOR

The authors argue that truckers will not respond to axle-weight-based taxes because they are unwilling to trade extra investment now for benefits realized "only in the distant future." This reasoning is false: to the trucking firm, whose taxes would depend on axle weights, the financial benefits from reconfiguring their fleets would be an immediate reduction in taxes. In Oregon, where such taxes are in effect for trucks exceeding 80,000 pounds, truckers have responded rapidly.

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AUTHORS' CLOSURE

Although we consider the Tobit regression an innovative approach to predicting pavement life, we nevertheless believe, even after further review, that the Tobit analysis is inferior to the AASHO Road Test analysis. The AASHO Road Test analysis of serviceability loss was a complicated two-step process that accounted for the sharp change in the slope of serviceability curve as pavements reached serviceability near 3.5 PSI. The comprehensive analysis performed by the road test staff showed that a direct linear regression of PSI loss was ineffective in predicting pavement loss.

However, the authors of *Road Work* have used a direct Tobit regression, which, in some cases, would theoretically be an improvement over a direct Ordinary Least Squares (OLS) regression when predicting lifetimes. Still, we do not believe it an accepted statistical practice to apply a Tobit regression technique with more than 70 percent of the data as right-censored observations. The Tobit technique is not a full information regression (the serviceability of the censored observations is discarded); rather, it is a bias estimator. Thus, the regression can be highly influenced by only a few observations and the period at which the test ends.

The combination of a Tobit regression that uses only 28 percent full information observations and extrapolates the predicted pavement life more than 10-fold produces fragile results. Using the 12 additional years of real traffic on only a few test sections, our analysis shows that the *Road Work* results are so fragile that, regardless of whether the traffic stream is converted using a *Road Work* or AASHO formula, the results are closer to the AASHO analysis than to the *Road Work* analysis.

Pavement materials and pavement performance are highly variable over time. The AASHO design guide gives specific guidance on how to design pavement to a 90 percent reliability design life using two standard deviations. The AASHO regression has a reported standard deviation of 0.17 on the LOG scale. Therefore, a 10-in. pavement with a 28.6-million ESAL predicted life will have a 90 percent reliability of achieving a 13.1-million ESAL design life. Using this reliability measure, the AASHO Road Test equation does not overpredict design life.

A shortcoming of the *Road Work* analysis is its reported standard deviation of the regression. On initial inspection, the reported standard errors of 0.306 for the intercept, 0.329 for the thickness coefficient, and 0.259 for the load coefficient appear innocuous. However, calculating a 90 percent reliability measure, considering this in a natural log value, makes the analysis seem inappropriate. If the two standard deviations of only the thickness coefficient are used, that alone is enough to change the predicted 18-kip ESAL load on a 10-in. pavement from 9.34 million repetitions to 1.9 million repetitions. If the intercept, load, and thickness coefficients are all taken at two standard deviations at the same time for 90 percent confidence, the design repetitions for a 10-in. pavement is reduced from 9.34 million to 0.22 million. Obviously, this is not a robust regression. Using this reliability measure, the Winston-Small pavement would have to be several feet thick to achieve a 90 percent reliable, 9-million ESAL design life.

A single-step regression of serviceability loss of the AASHO test data is an oversimplification that provides no useful information. The complex analysis of the rigid pavement data performed by Irick at the road test is far superior to any direct regression technique, be it Tobit or OLS. Using the oversimplification of the serviceability loss by direct regression of the AASHO Road Test only shows a lack of understanding of both the complex action of pavement deterioration and the complexity of the original AASHO regression analysis. The direct Tobit regression is definitely not an improvement to the AASHO Road Test analysis.

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I-40 Economic Development Study: Growth Points Analysis

James W. Clay, David T. Hartgen, Tracy H. Newsome, Alfred W. Stuart, and Wayne A. Walcott

A study was undertaken to determine optimal economic development opportunities provided by the opening of the Interstate 40 segment between Raleigh and Wilmington, North Carolina, with an emphasis on strategic locations on the highway within the corridor counties. While providing an overall advantage to the corridor, the highway's opening actually may draw some forms of development from the more rural counties in the corridor to the end-point metropolitan areas of Raleigh and Wilmington, which would accentuate existing disparities between the middle counties and the metropolitan counties. The strategy, built around growth pole theory, is an effort to allow the middle counties to share in the advantages of the highway opening. The study includes a review of the economic structure of the corridor counties in relation to the rest of the state, taking into account future trends likely to affect the corridor. Out of this was developed a growth center strategy that realizes the corridor's greatest economic development potential. The suggested growth center strategy is built around industrial and wholesaling opportunities in the counties closer to metropolitan areas and large retail clusters in the middle, more rural counties. Without strategic planning and cooperation the opportunity to realize the growth potential of I-40 will be lost or reduced.

The purpose of this study was to determine optimal economic development opportunities provided by the opening of the Interstate 40 segment between Raleigh and Wilmington, North Carolina, with an emphasis on strategic locations on the highway within the corridor counties (Figure 1). The study includes a review of the economic structure of the corridor counties in relation to the rest of the state, taking into account future trends likely to affect the corridor. Out of this was developed a growth center strategy that realizes the corridor's greatest economic development potential.

The corridor is composed of ten counties with a metropolitan area at either end. Raleigh, at the northern end, is the state capital and also the center of one of the largest and the fastest growing metropolitan areas in the state. At the southern end lies Wilmington. Neither as large nor as fast growing as Raleigh, Wilmington is also a vigorous metropolitan area, deriving special status from the large state port facility and from its role as a major coastal recreational and historical area. The economies of these metropolitan areas are driven largely by external factors that are causing economic growth nationally to focus on metropolitan areas, especially larger ones. These factors include increasing globalization of the economy, the emergence of the information processing/service economy, and the consequent need for good external communications, especially air service. The office building is replacing the factory as the primary place of work, and white-collar office workers and store clerks outnumber blue-collar factory workers. Conversely, an era of strong industrial growth in rural areas that began in the 1950s peaked in the 1970s and has largely ended. More and more, the fate of rural economies is determined by their relative proximity to metropolitan areas.

The counties lying between Raleigh and Wilmington seem to be very much in that situation. They share the mixed agricultural-industrial economy that is so characteristic of much of nonmetropolitan North Carolina. In addition, two smaller metropolitan areas, Fayetteville and Jacksonville, flank the corridor. They and Wayne county (Goldsboro) are the sites of major military establishments that have a substantial economic impact on the corridor's economy. All three join Raleigh and Wilmington as major North Carolina retail trade centers.

The opening of the I-40 segment is viewed by many as offering the corridor an economic bonanza because of enhanced accessibility and increased traffic flow through the region. The assumption that highway improvements will automatically encourage economic development is subject to debate. Some studies have shown that new highway construction, rather than spreading economic growth, instead tends to benefit major urban centers. A study of Minnesota, for example, found that long-term new highway construction benefits were confined to urban centers (*1*). In rural areas the primary benefits were short-term impacts of the construction phase only. In some instances, it appears that businesses left the rural areas and relocated in the now more-accessible cities.

A Southern Growth Policies Board study (*2*) concluded that "Interstate highways appear to influence growth, particularly when the county with the interstate is also adjacent to a metro area . . . Remoteness from both interstates and metro areas . . . seems to be a deterrent to growth." Forkenbrock and Foster (*3*) detail the lack of consensus on highway construction benefits overall and also point out that highways are more likely to be associated with metropolitan growth than rural growth. This is the situation in the new I-40 corridor, where the more rural "middle" counties may benefit less from the highway than the metropolitan counties at each end.

A 1988 study of North Carolina found that statewide $5,796 per year was spent on new highway construction between 1974 and 1985 for every new job that was created (*4*). Even though

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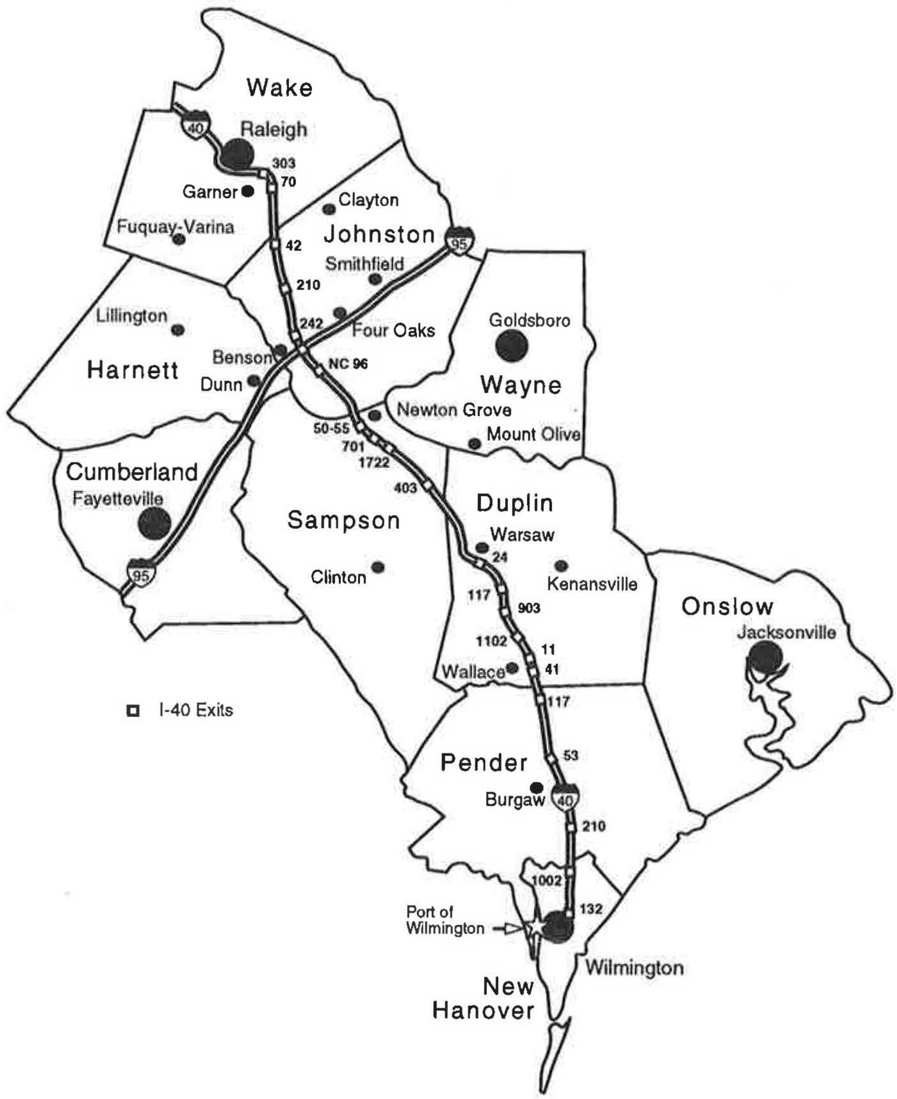

FIGURE 1 Interstate 40 corridor.

the actual cost of highway construction in metropolitan areas was high, the average annual highway expenditure per new job was only $3,276, whereas in the most rural counties the average annual highway expenditure was $11,093, even though highway construction costs per mile were lower in the rural areas. These wide differentials in the relationship between highway construction and economic growth illustrate the point that many more factors than highways are involved in generating economic growth.

These and other studies make it clear that economic growth is not necessarily assured just because a new interstate highway is opened through an area, especially for those parts distant from a metropolitan area. It is possible that vigorous economic growth centering on the end-point metropolitan areas will have an even greater impact on the corridor since a major new highway allows those urban centers greater access to labor and shoppers within the corridor. It is not the intent of this paper to argue the benefits of highway investment, but rather to investigate an appropriate growth strategy for the corridor, given the existence of the new highway and economic trends.

Given the above discussion, an economic development strategy for the I-40 corridor must consider not only the corridor in general but also how to maximize the benefits for those areas (referred to as the "middle counties") that lie between the terminal metropolitan areas. The strategy put forth here for the I-40 corridor arises out of growth pole theory and involves creating growth points (or centers) within the corridor.

Growth pole theory, first suggested by Perroux and discussed by others (*5,6*), is based on the idea that growth or development is not evenly distributed, but instead concentrates around nodes or "poles." Many studies have used interchangeably the terms growth poles, growth centers, and growth points. In the original sense, the poles are not geographical, but rather are industries capable of promoting growth, termed propulsive industries. While Perroux's growth poles skirt the issue of geographic location (*5*), it has become common for the same concept to apply to places as well. Therefore, although the textbook approach to growth pole theory assumes the existence of a propulsive industry as the pole, many studies focus on specific locations as growth poles, centers, or points. Indeed, it is common to use the term growth pole when speaking explicitly of a propulsive industry and growth center or point when introducing the geographical aspect (*5*) or the enhancement of services or physical infrastructure (*7*) in a location.

In general, it is assumed that, even if the geographical concept of a growth center is used, that growth center will include or be built around propulsive industries and firms. Thomas (*6*) provides a good discussion of economic growth theory relative to propulsive industries, including a discussion of the structural changes associated with growth, multiplier effects, and interindustry linkages. The industries often associated with growth pole theory are manufacturing industries (see, for example, Auty's [*8*] study concerning South Korea's heavy industry growth poles), although Thomas (*6*) suggests that some service industries may exhibit high productivity growth and propulsive tendencies. This fact is important to the I-40 corridor because some growth points have more potential to be built around service industries, whereas others will offer more manufacturing or residential potential. These points will be discussed in more detail later.

A final point concerning growth points in the I-40 corridor relates to the issue of size. It is often assumed that larger urban areas will provide the most potential and best return on investments as growth centers because they already have some development in place (*5*). On the other hand, clusters of smaller towns can serve as growth centers, provided a transportation link exists, although Moseley responds that this is true only if a large enough labor pool is encompassed within the cluster (*5*). Obviously, in the I-40 case, a transportation link does exist. Furthermore, North Carolina is unique because the population is spread out over the state rather than concentrated in large cities; this reflects the economic history of the state (*4*) and results in a relatively large labor pool (and market) within the I-40 corridor. These considerations suggest that a growth center approach is feasible along the corridor.

The following section provides an analysis of key elements of the corridor counties' economies. This leads to the formulation of an overall economic development strategy, including a consideration of the major growth centers and their respective "propulsive industries" in and along the corridor.

ECONOMIC OVERVIEW

Population

The counties in the I-40 corridor (Figure 1) contained over 1.3 million residents in 1990, nearly 20.2 percent of the North Carolina total (Table 1). This share increased from 1980 since the corridor growth rate during the decade far exceeded the statewide rate. However, most of this rapid growth was caused by the 40 percent increase in Wake county and the 16.2 percent rise in New Hanover. Otherwise, the eight middle counties grew less vigorously but, at 13.5 percent, they still managed to outperform the state as a whole.

TABLE 1 Population In I-40 Corridor

County	1980	1990	Change 1980-1990
Cumberland	247,160	274,566	11.1%
Duplin	40,952	39,995	-2.3%
Harnett	59,570	67,822	13.9%
Johnston	70,599	81,306	15.2%
Onslow	112,784	149,838	32.9%
Pender	22,262	28,855	29.6%
Sampson	49,687	47,297	-4.8%
Wayne	97,054	104,666	7.8%
Total Middle Counties	700,068	794,345	13.5%
New Hanover	103,471	120,284	16.2%
Wake	301,429	423,380	40.5%
Total I-40 Corridor	1,104,968	1,338,009	21.1%
North Carolina	5,880,096	6,628,637	12.7%

Source: U.S. Census, 1980 and 1990

As shown in Table 1, the middle counties experienced uneven growth, with two actually losing population. Overall, it seems that strong growth counties were either metropolitan or suburban. Otherwise, substantial growth was driven by increases in military employment. Lacking sharp military increases or proximity to an end-point metropolitan area, growth was either modest or even negative.

Employment Change

Table 2 summarizes civilian nonagricultural wage and salary employment in the I-40 corridor, which represented 17.5 percent of the North Carolina total in 1988. Corridor-wide increases in nonfarm jobs were dominated by Wake County's phenomenal surge of 82 percent during the period. Otherwise, the middle counties nonagricultural employment gains average rate was close to the statewide rate, with some variation among them.

These data do not include military employment. However, the U.S. Bureau of Economic Analysis reports that, for 1986, military employment in the corridor totaled 93,370 persons, a 10 percent gain over the 1980 sum of 84,917. The military personnel were concentrated in Cumberland, Onslow, and Wayne counties, which accounted for 96.2 percent of the military personnel in the entire corridor. For once, the statistics were not dominated by either Wake or New Hanover county.

Wage and Income Levels

In the fourth quarter of 1989, private-sector weekly wages in the corridor were substantially below the North Carolina average (Table 3). Wages rose considerably between 1984 and 1989, but most corridor counties did not keep up with the statewide figure. New Hanover almost kept up with the statewide increase and Wake slightly exceeded it. The corridor's per capita income levels were right at the North Carolina mean only because of Wake County's high incomes (Table

TABLE 2 Nonagricultural Wage And Salary Employment

County	1977 Total	MFG	Non-Mfg.	1988 Total	MFG	Non-Mfg.
Cumberland	60,390	10,340	50,050	83,680	12,160	71,520
Duplin	9,470	3,880	5,590	13,220	6,180	7,040
Harnett	13,970	4,970	9,000	17,220	4,560	12,660
Johnston	17,650	7,730	9,920	25,100	9,240	15,860
Onslow	19,090	1,950	17,140	29,080	3,000	26,080
Pender	3,080	350	2,730	5,800	1,070	4,730
Sampson	11,980	5,220	6,760	14,010	5,040	8,970
Wayne	29,330	7,410	21,920	39,180	9,200	29,980
Total Middle Counties	164,960	41,850	123,110	227,290	50,450	176,840
New Hanover	47,890	13,320	34,570	58,420	8,810	49,610
Wake	129,250	18,800	110,450	235,830	26,550	209,280
Total I-40 Corridor	342,100	73,970	268,130	521,540	85,810	435,730
North Carolina	2,170,400	780,900	1,389,500	2,986,600	867,500	2,119,100

	Growth Rates, 1977-1988 Total Employment	MFG Employment	Non-Mfg Employment
Middle Counties	38.8%	20.9%	43.6%
1-40 Corridor	52.5%	16.0%	200.5%
North Carolina	37.6%	11.1%	52.5%

Source: N.C. Employment Security Commission, Civilian Labor Force Estimates, 1987 and 1988

TABLE 3 Average Weekly Wage Private Insured Employment

County	1984	1989	Change
Cumberland	$262.82	330.82	25.9%
Duplin	217.77	279.56	28.4%
Harnett	217.78	288.90	32.7%
Johnston	230.08	309.63	34.6%
Onslow	208.66	249.12	19.4%
Pender	192.12	245.85	28.0%
Sampson	222.41	293.95	32.1%
Wayne	247.77	311.70	25.8%
Average for Middle Counties	238.98	305.64	27.9%
New Hanover	272.49	358.95	31.7%
Wake	312.13	413.96	32.6%
Average for I-40 Corridor	275.90	360.47	30.7%
North Carolina	$294.66	$388.69	31.9%

Source: N. C. Employment Security Commission

TABLE 4 Personal Income

County	1982 Per Capita	1982 % N.C. Average	1988 Per Capita	1988 % N. C. Average
Cumberland	$8,421	90.7%	$12,612	88.2%
Duplin	$6,395	68.9%	$10,595	74.1%
Harnett	$7,059	76.0%	$10,361	72.5%
Johnston	$8,085	87.1%	$12,491	87.4%
Onslow	$7,996	86.1%	$11,262	78.8%
Pender	$7,380	79.5%	$11,677	81.7%
Sampson	$7,464	80.4%	$10,743	75.1%
Wayne	$8,259	89.0%	$12,292	86.0%
Total For Middle Counties	$7,957	85.7%	$11,849	82.9%
New Hanover	$9,377	101.1%	$14,546	101.7%
Wake	$11,944	128.7%	$18,734	131.0%
Total For I-40 Corridor	$9,203	99.1%	$14,300	100.1%
North Carolina	$9,283	100.0%	$14,297	100.0%

Source: U. S. Bureau of Economic Analysis

4). Note that North Carolina ranked 35th nationwide in income, at only 86.7 percent of the U.S. average. Also, average per capita income gained slightly on the North Carolina mean between 1982 and 1988, again because of Wake County. The middle counties declined as a percentage of the statewide average. Performance varied within the middle counties, with all but three counties suffering relative declines in income levels.

Strong job growth, especially in nonmanufacturing, has apparently come at the lower end of the wage scale, with a high proportion of the middle counties' job increases occurring in low-end service and trade jobs; in addition, many jobs are recreationally oriented and thereby seasonal. Conversely, in an area such as Raleigh, growth is largely in high-tech industries, professional occupations, and skilled white-collar areas, as well as in fast-food restaurants and other retail stores.

Manufacturing

In the I-40 corridor, factory jobs grew by 16 percent between 1977 and 1988, well above the statewide average increase of 11 percent. The rise was even more dramatic in the middle counties, where the manufacturing employment total went up 20 percent.

Table 5 offers a detailed view of the corridor's manufacturing structure and points to significant differences between the more urban counties and those in the middle. Overall, about 61 percent of all factory workers in the middle counties are employed in industry groups paying wages below the North Carolina average, which is already one of the lowest in the United States. In Wake and New Hanover counties, by contrast, only about 20 percent of factory jobs are in industries that pay less than the statewide average, whereas over 26 percent are in industries that pay 25 percent or more above the North Carolina mean.

Industrialization historically has served North Carolina well as the leading edge of economic development efforts, but it is becoming an increasingly problematic strategy for the future. For one thing, the types of manufacturing that have been traditionally drawn to rural areas (such as textiles and apparel) are declining, at least as employers. A principal reason for these declines is that many labor-intensive operations have relocated to other countries, either directly as multinational companies redeploy facilities to cheaper labor environments, or indirectly as lower cost foreign producers import their goods and take a larger share of the domestic market.

These declines reflect national trends that also foresee drops in areas such as electrical equipment and industrial machinery. Growth is projected for industries requiring more highly skilled labor forces and that tend to locate in and around major metropolitan areas. Manufacturing generally is expected to drop from 16.4 percent of national employment in 1988 to only 14 percent in 2000. The number of factory jobs is expected to fall by 316,000, with the biggest losses coming in textiles and apparel. The projections for North Carolina call for a steady drop throughout the 1990s, totaling about 43,000 factory jobs. Thus, proponents of an economic development strategy for the I-40 corridor that continues the historic emphasis on industrialization will be attempting to buck strong statewide and national trends.

Nonmanufacturing

Unlike factory employment, strong continued growth is expected in the nonmanufacturing sectors of the economy. Nationally, it is projected that consumer and government services, transportation and trade, business and professional services, hospitality and recreational services, and finance-insurance-real estate will be the strongest employment growth sectors during the 1990s. These sectors will be oriented toward larger metropolitan areas. Only trade, especially retail, recreation-oriented services, and government, among the listed sectors, would seem to have a significant orientation to areas such as the middle counties.

Consistent with these national trends, the largest part of nonagricultural jobs in the corridor is in the nonmanufacturing components, and growth in them was impressive. However, there was a pronounced disparity within the corridor, with the middle counties and New Hanover below the statewide mean, and Wake county recording a gain of 89.5 percent. Wake County accounted for 48 percent of the total corridor nonmanufacturing employment, in constrast with its 31 percent share of factory employment.

Travel and Tourism

Recreational travel is significant in Eastern North Carolina and I-40 is expected to increase accessibility to the state's beaches and other recreational resources. Data in Table 6 show that travelers spent over $1.1 billion in the I-40 corridor counties in 1988. Again, these totals were dominated by Wake and New Hanover counties, which together accounted for nearly 70 percent of the corridor figure. The middle counties' $359 million in traveler expenditures is impressive, but the proportion is far less than the middle counties' 12 percent of population. The number of jobs (6,611) estimated to be supported in the middle counties by travelers' expenditures is also significant but modest in terms of the full employment base of the area.

TABLE 5 Manufacturing Employment, 1988

	Industry (SIC)								
County	Food (20)	Textiles (22)	Apparel (23)	Wood (24)	Chemical (28)	Machinery (35)	Electrical	Other	Total
Cumberland	615	1,131	1,265	483	568	1,178	878	6,042	12,160
Duplin	2,639	2,114	915	334	0	49	0	129	6,180
Harnett	333	1,263	739	447	9	36	985	748	4,560
Johnston	249	564	2,467	434	711	1,515	2,319	3,201	11,460
Onslow	645	3	927	324	3	33	0	1,065	3,000
Pender	140	95	147	220	0	300	16	152	1,070
Sampson	1,220	438	1,109	328	0	35	539	1,371	5,040
Wayne	1,050	740	1,700	710	62	56	720	4,162	9,200
Total Middle Counties	6,891	6,348	9,269	3,280	1,353	3,202	5,457	16,870	52,670
New Hanover	520	130	1,120	430	1,970	867	1,054	2,719	8,810
Wake	1,920	1,220	1,010	860	1,190	3,140	6,200	11,010	26,550
Total I-40 Corridor	9,331	7,698	11,399	4,570	4,513	7,209	12,711	30,599	88,030

Source: North Carolina Employment Security Commission

TABLE 6 Travel Expenditures, 1988

County	Travel Expenditures (thousands)	% N.C. Total	Jobs
Cumberland	166,443	2.7%	3,267
Duplin	3,113	.05%	48
Harnett	25,986	.42%	510
Johnston	42,069	.68%	826
Onslow	53,597	.87%	824
Pender	26,358	.43%	405
Sampson	4,643	.08%	9
Wayne	36,789	0.6%	722
Total Middle Counties	358,998	5.83%	6,611
New Hanover	252,588	3.98%	3,886
Wake	564,585	9.08%	11,081
Total I-40 Corridor	$1,176,171	19.43%	21,578

Source: NC Division of Travel and Tourism, 1988 North Carolina Travel Study

The high levels of traveler expenditures for Cumberland, Onslow, and Wayne Counties strongly suggest that the primary source of traveler expenditures in them is related to military personnel and their visitors. Any change in that impact thus is apt to be more a matter of national defense policy than highway accessibility.

Retail Trade

A major growth sector in the I-40 corridor has been retail trade, reflecting sales to transients, visitors, and residents. Trade employment, in both retail and wholesale trade, rose by 70.6 percent between 1977 and 1988. The rate was only 50.6 percent in the middle counties, whereas higher levels in New Hanover (72.5 percent) and Wake (96 percent) counties raised the overall corridor average to its high level.

The corridor's more rural counties (Duplin, Harnett, Pender, and Sampson) each recorded net retail "leakages" totaling nearly $190 million (Table 7). Leakage is a measure of the extent to which residents shop outside their home counties. It suggests that purchases by travelers and visitors are not sufficient to offset lost sales to residents. Generally, leakage of this magnitude can mean that the range and variety of goods offered by local stores are not sufficient to meet many consumer needs.

The completion of I-40 could augment retail demand in the corridor as more through traffic is channeled onto the new, high-speed, limited-access highway. However, the faster highway may also make it more convenient to travel the length of the corridor without stopping for gas, food, or restrooms. Transients will likely stop at larger, more visible concentrations of stores in either Raleigh or Wilmington with greater selection. A better road will also make it easier for corridor residents to travel major retail clusters in Wilmington, Fayetteville, Jacksonville, Goldsboro, and Raleigh, especially for more expensive "big ticket" items, for which comparison shopping is feasible. Corridor residents also receive heavier television advertising for the larger retail outlets in the endpoint metropolitan areas.

The relatively small "surplus" recorded by Wake county retailers in 1987 suggests underutilized retail capacity in Raleigh stores and that the opening of the northern end of I-40 may expand dramatically the leakage out of those northern counties into the Raleigh area. Additional highway improvements in the corridor will improve access to other urban areas, such as Fayetteville, Jacksonville, and Goldsboro. This suggests that, with these other improvements, I-40 may permit a greater concentration of retailing to occur in a few, highly accessible locations.

SUMMARY AND CONCLUSIONS

The preceding economic analysis points out the corridor's uneven growth, where income and wages in the middle coun-

TABLE 7 Actual And Potential Retail Sales

County	Total Personal Income -1987 (thousands)	Potential Retail Sales (thousands)	Actual Retail Sales - 1987 (thousands)	Net "Surplus" or (Leakage) in Retail Sales (thousands)
Cumberland	$2,971,611	$1,358,026	$1,519,688	$161,662
Duplin	$402,046	$183,735	$152,097	($31,638)
Harnett	$624,890	$285,575	$239,494	($46,081)
Johnston	$922,641	$421,647	$429,977	$8,330
Onslow	$1,343,425	$613,945	$651,671	$37,726
Pender	$280,054	$127,985	$62,331	($65,654)
Sampson	$505,719	$231,114	$185,951	($46,163)
Wayne	$1,146,136	$523,784	$526,772	$2,988
Total Middle Counties	$8,196,522	$3,745,811	$3,767,981	$21,170
New Hanover	$1,568,102	$716,623	$947,902	$231,279
Wake	$6,637,715	$3,033,436	$3,092,724	$59,288
Total I-40 Corridor	$16,402,339	$7,495,870	$7,808,607	$311,737

Sources: Income from Bureau of Economic Analysis.
Retail sales data from 1987 Census of Retail Trade, North Carolina, RC 87-A-34

ties are falling further behind statewide averages. Growth in virtually every category except military employment has been dominated by Wake county and, in some instances, especially retail sales, by New Hanover county. Given recent global changes, future military levels are uncertain in those counties relying on it. Travel expenditures, as well, are dominated by Wake and New Hanover. Potential exists for I-40 to further focus retail sales on existing major retail clusters, thereby draining off a large part of future retail sales. In addition, Wake's increasingly higher wages will attract I-40 workers who will find these jobs even more accessible. Wilmington's role will be similar but less intense. Finally, the outlook for manufacturing is not promising (especially in those industry groups that are dominant in the corridor), making a reliance on industrial growth as an economic development strategy an ill advised option. The following section builds on these findings and presents suggestions for improved development opportunities in the corridor.

The preceding section suggests that the new I-40 segment can be as much of a threat as an opportunity. Without an overall development strategy, especially for the middle counties, the threat of most growth around major urban centers will be stronger and the chance to realize new growth opportunities elsewhere will be diminished. This section provides recommendations for such a development strategy, with specific reference to some of the growth points depicted in Figure 2. This analysis is tentative, and implementation would require further detailed studies. The key point now is to emphasize opportunities available primarily close to the endpoint metropolitan areas and to cluster retail developments to help capture a greater part of the corridor's market potential. Although it is expected to decline as a means of employment, manufacturing will remain a vital part of the state and corridor economy. The key will be to target industry groups that are likely to grow nationally. Generally, companies in these groups will not be attracted to rural locations or supplies of undereducated labor. Rather, they will tend to need more skilled, or at least trainable, workers, proximity to commercial airports and accessibility to urban amenities, and educational resources. The northern and southern ends

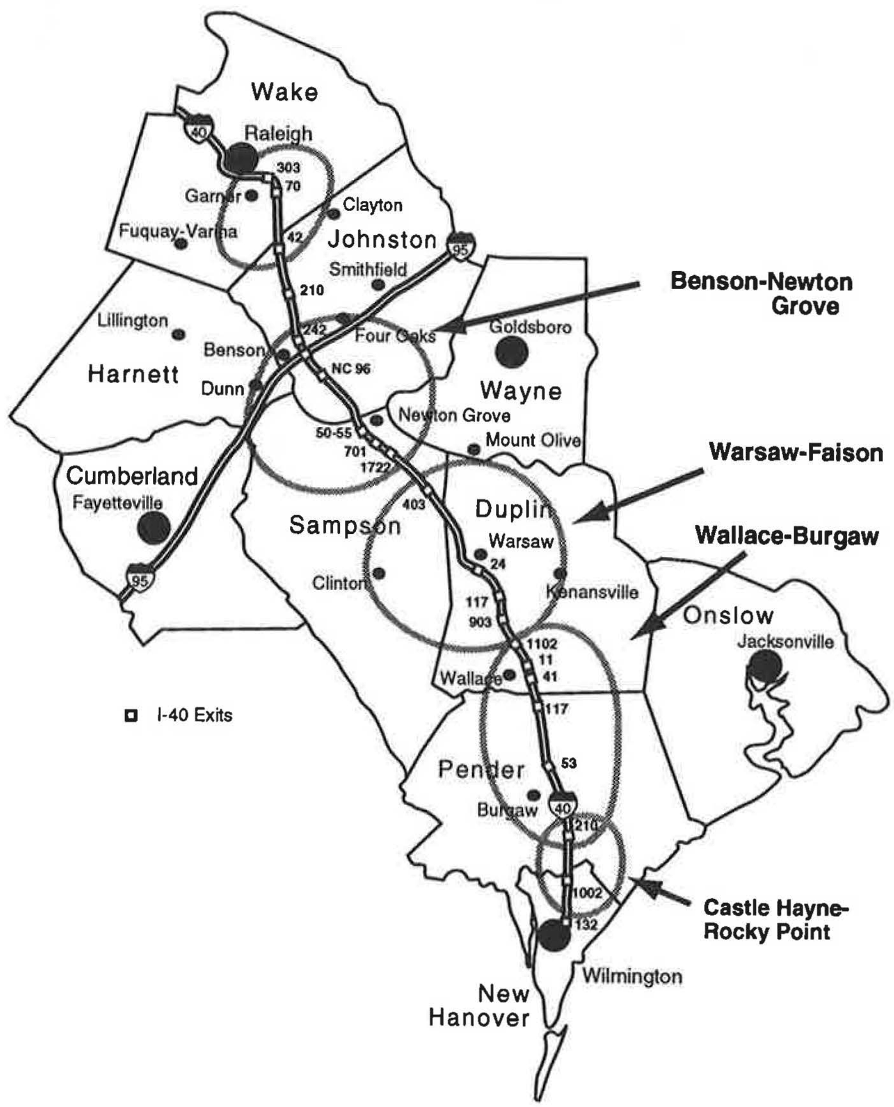

FIGURE 2 I-40 corridor: major growth centers.

of the middle counties could be ideal for such facilities even if the more rural parts might not be. Industrial sites offering easy access to the Research Triangle and to the Raleigh-Durham airport, as well as a large labor supply and less expensive land in areas to the south, could be attractive to companies in these growth industries. The draw will not be as great at the Wilmington end, but the port and the high-amenity quality of that historic city may be an attraction to some companies. Examples of this type of growth point might include Benson-Newton Grove at the Raleigh end and Wallace-Burgaw and Rocky-Point Castle Hayne at the Wilmington end of the corridor. In addition, improved highway accessibility, urban amenities, and business services in Fayetteville, and to some extent in Goldsboro and Jacksonville, may attract additional manufacturing plants to those cities as well. An industrial park would serve well the interests of the entire corridor because it would put jobs within reach of many workers in the corridor. In any event, an industrial development strategy with the best chance for success in the otherwise pessimistic industrial sectors would be one focusing on the advantages of proximity to the two end-point metropolitan areas.

The agricultural resources of the I-40 counties are the basis for a substantial food processing industry, and this should not be ignored. Although that manufacturing sector is expected to decline in employment, it probably will always be important in this area. Every effort should continue to be made to attract further such operations to the corridor. The Warsaw-Faison area has a strong potential for such development.

Just as certain types of manufacturing might find attractive sites in the I-40 corridor near the end metropolitan areas, so might major wholesale distributors. These operations typically require extensive space and ready access to their customers. A location on I-40, especially one near I-95, could be attractive, especially for distributors that need to serve a multicounty or multistate region. For example, Benson-Newton Grove is well situated for this type of development.

The best chance to reduce retail leakage out of the corridor and to capture more trade from visitors and transients will be to cluster new retail space on one or several sites at strategic locations along I-40. The aggregate retail leakage from Duplin, Harnett, Pender, and Sampson counties was estimated to be \$190 million, enough to support 1.3 million ft^2 at \$150 per ft^2. Obviously one or even several shopping centers cannot hope to capture all of those sales, but one or two in the 100,000- to 150,000-ft^2 range could intercept a significant part and, in the process, draw more shoppers off the interstate if the centers are well located, attractive, and visible and offer sufficient shopping variety. Garner, Benson-Newton Grove, Warsaw-Faison all represent potential retail cluster opportunities. The alternative is to have a scattering of retail stores without the mass to support enough variety to hold local shoppers, whereupon the new highway would continue to channel shoppers into Raleigh, Fayetteville, Jacksonville, Goldsboro, and Wilmington.

The imperative to cluster economic development at strategic locations along the corridor is based on economic logic. however, political logic calls for dividing growth equitably among all of the counties and towns in the area. Thus, there is a tension between an economic strategy that calls for clustering and a political strategy that calls for dispersion. Every community-based organization or elected official understandably will want to obtain a piece of the economic pie for its constituency, which could create such an internally competitive environment that some growth opportunities go unrealized. All parties, for example, need to understand that an industrial park located in only one county will provide jobs for workers from a number of counties within the corridor. Furthermore, the best means of developing such a park, obtaining extra state funding for infrastructure for it, and effectively marketing the park would be through a regional organization that presents a unified face to the General Assembly and to others. Therefore, one of the first prerequisites to an effective economic development strategy for the corridor is to develop a sense of regional identity to help overcome any internal competitiveness that may undermine cooperation and coordination. Regular steering committee meetings, held throughout the course of this study, have laid the basis for such a sense of regional identity. They could serve as a prototype for a permanent organization to foster this sense of identity and to lead in the formation of a more specific program of economic development for the corridor.

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Implementation of Electronic Toll Collection and Traffic Management Systems in New England

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The successful efforts that have been achieved to date for the first phase of an operational testing program being developed in New England to investigate and implement electronic toll collection and traffic management (ETTM) Systems are discussed. The New England ETTM Group was formed in 1990 to establish a cooperative effort that will provide a systematic and scientific method for testing and evaluating currently available technologies to determine which one(s) are most effective in New England. Accordingly, uniform standards and specifications are being developed, such as having a set of minimum common data in the tag to capture all the advantages and benefits for both the user and agency in a multiagency situation. The New England ETTM Group includes all the toll collection facilities in the region, the Massachusetts Bay Transit Authority in Boston and Logan International Airport in Boston. The application of a process that might be useful to practitioners seeking to implement ETTM systems is discussed. Future work will document the analytical procedures currently being developed. Many institutional and technical concerns must be addressed before the implementation of ETTM can be successfully achieved. An essential ingredient for successful implementation of such a program in areas such as New England that include many separate, independent agencies is the need to establish a coordinated effort among the agencies in the same region. Significant success has been achieved so far in doing so.

This paper describes the successful efforts that have been achieved to date in developing an operational testing program in New England to investigate the capabilities of automatic vehicle identification (AVI) and electronic toll collection and traffic management (ETTM) technologies for toll collection, for bus operations in Boston, and for the regulation of taxis, limos, common carriers, trucks, and other commercial vehicles at Logan International Airport in Boston. A detailed cost-benefit analysis by the same authors using some facilities in New England as a case study is now under way. That work is expected to provide a more analytical follow-up to this paper at a later time.

The rapid development of AVI and ETTM systems (in this paper referred to as ETTM only) in a number of locations in the United States and elsewhere has helped to illustrate the benefits of using this technology. However, there are still a number of questions to be answered and issues to be resolved before toll agencies and airport and transit managers will be ready to fully implement them. One way of addressing those questions is through carefully designed and monitored operational testing programs.

The use of ETTM technologies represents only one, but an important, element of the programs in the United States, now commonly referred to as intelligent vehicle-highway systems (IVHS). The potential applications of IVHS, however, to address problems of congestion, safety, air pollution, and energy consumption are often misunderstood as being far in the future. The term IVHS is sometimes incorrectly interpreted as being primarily the development of advanced vehicle control systems (AVCS) only. Even AVCS may sometimes be inaccurately viewed as "Buck Rogers," far-out space-age technology, when some near-term advances appear to be feasible. In fact, although it is an important element within the overall framework of IVHS, ETTM deals with available and operational technologies. Automatic toll collection systems are fully operational in the United States in Texas, Oklahoma, Louisiana, Colorado, Florida, and Michigan; and systems are being planned for near-term implementation in the New York City Metropolitan area, elsewhere in New York state, and in other states such as New Jersey and Pennsylvania. Furthermore, ETTM is being used for the regulation of commercial and common carrier vehicles at airports in Los Angeles, San Francisco, and New York, and their application is being planned for use in Boston and other cities. Advanced toll collection systems are also being planned in California, Virginia, Illinois, Georgia, and Florida. There are numerous examples of successful implementation of ETTM in Europe and elsewhere.

The six states comprising New England are relatively small geographically, but they generate substantial congestion and travel needs in urban and rural areas. Because of the high density and compact nature of the region, the six states are somewhat dependent on one another as an integrated economic development region. To a large extent, the quality of New England's transportation system plays a major role in maintaining its economic vitality, both regionally and nationally. Consequently, the states recognize the importance of establishing cooperative efforts as one way to maintain their economic vitality. One example of this recognition was the formation of the New England Transportation Infrastructure Consortium in 1985, which has focused on transportation infrastructure research and development. Massachusetts Institute of Technology (MIT) took the lead in establishing a

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consortium composed of state DOTs, the state universities and MIT's Center for Transportation Studies, together with FHWA and AASHTO. The success of that consortium provided the motivation for establishing the NE ETTM Group.

Given this background, the toll and airport agencies of New England have joined together to establish an interagency agreement for the purpose of jointly evaluating the potential application of ETTM as a region. The NE ETTM Group includes the Massachusetts Executive Office of Transportation and Construction; the Massachusetts Turnpike Authority; the Massport Authority (which includes the Tobin Memorial Bridge and Logan International Airport); the Maine Turnpike Authority; the New Hampshire Turnpike Authority; the Rhode Island Bridge and Turnpike Authority; the Massachusetts Bay Transit Authority (MBTA); The Massachusetts Department of Public Works; and MIT—Region One University Transportation Center. MIT has facilitated its formation and provides technical assistance to the group. MIT has also undertaken extensive research concerning the application of ETTM technologies.

OBJECTIVES AND GOALS

This section describes the three major objectives of the New England program: (a) the objectives of an ETTM research and operational testing program (*1*); (b) the objectives in forming The New England ETTM Group; and (c) the system goals to be achieved as identified by this group.

Objectives of ETTM Research and Operational Testing Program

The motivation for developing and implementing innovative advanced transportation system technologies is based on several important needs to

- Help relieve urban congestion,
- Provide safer vehicle travel,
- Reduce air pollution and other adverse environmental impacts,
- Reduce energy consumption, and
- Provide for more cost-effective urban mobility.

Basic and applied research activities have been under way to develop and apply technologies to meet those objectives for two or more decades. Although there are renewed efforts in the United States and throughout the world to seriously evaluate and implement some of the technologies, there are still many unanswered policy and technical questions to carefully consider and resolve before public and private policy makers can commit the substantial funds required to apply ETTM to deal with the issues summarized above.

Several advanced research activities are under way in the United States designed to test and implement some of the technologies being considered. California, Massachusetts, Minnesota, Michigan, Florida, New York, and Texas are in the forefront of those efforts, in cooperation with the FHWA, FTA (formerly the Urban Mass Transportation Administration), and NHTSA. However, the costs of implementing various innovative technologies are still uncertain because many of those technologies are still evolving and being tested. The benefits to be derived from such technologies are also uncertain. An initial research project sponsored by FHWA undertaken at MIT took the first step toward better describing and analyzing the tangible and intangible benefits to be derived from new highway technologies on a national scale. The purpose of that project as to assess the benefits associated with the development and implementation of new highway technology. An analysis framework that described those costs and benefits in broad qualitative terms was developed. It provided a basis for a more comprehensive and systematic analysis of those benefits, which was undertaken by Mobility 2000 (*2*).

A number of research efforts completed over the past several years have concluded that an essential element in promoting the advancement of new vehicle and highway technologies is to design and implement operational testing programs. Such programs will not only provide the incentives for operational agencies to become actively involved in the development of IVHS, but they will also allow researchers to test the reliability, costs, and benefits of various innovative projects and programs.

A research project undertaken at MIT to develop such operational testing programs was designed as a three-phased program. The objectives for phase one (completed) are the following:

1. Using the research under way or recently completed as a springboard, identify possible technological innovations that are potentially available to make a major breakthrough in developing cost-effective solutions to transportation congestion in New England.
2. Select potential candidate technologies to deal with the most critical transportation problem(s) in New England—such as toll collection and traffic management—using New England as a case study.
3. Develop a planning report with the details required to design a demonstration program to be implemented in New England, but also having broader regional and national implications.

Phase one was funded by a grant under the Region One University Transportation Center program with matching funds from the Massachusetts Turnpike Authority and the Massachusetts Port Authority. It was completed satisfactorily, resulting in the continuation of the project into phases two and three (*1*).

The objectives for phase two (under way during preparation of this paper) are

1. Develop the details of a demonstration program designed to implement at least one cost-effective innovative technological improvement to deal with current transportation issues in New England (as a case study). The selected technologies would have a high probability for successful implementation.
2. Develop the funding package and commitments required to implement this demonstration, which would include state, federal, and private sector funds, and their involvement in this demonstration.

3. Establish a specific schedule for implementing the demonstration program.

The objectives for phase three are

1. To work with the public agencies to implement the demonstration program and evaluate its results.

Objectives In Forming The New England ETTM Group

In carrying out Phase One of this project, the issues related to toll collection and traffic management were identified as being critical in New England. In June 1990, the first informal meeting of officials from the New England Toll Agencies and Logan International Airport was held in Portsmouth, New Hampshire. The purpose of the meeting was to provide an opportunity for the agencies to discuss the plans they were considering for the possible use of ETTM within their agencies.

The New England ETTM Group began as an informal, ad hoc committee that met periodically beginning in June 1990. The central purpose of this group was to establish a cooperative effort that would provide a systematic, scientific method for testing and evaluating currently available technologies to determine which one(s) would be most effective in New England. The members of the group agreed that it is essential to develop compatible systems to provide

- Customer convenience for automobiles, trucks, buses, and other commercial vehicles.
- Congestion relief during peak hours, with the possibility of facilitating mobility improvement measures, such as high-occupancy vehicle lanes.
- Cost reductions and more efficient handling of revenues.
- Enhanced traffic management opportunities.

System Goals To Be Achieved As Identified By The New England ETTM Group

As part of the research project undertaken by MIT concerning ETTM application to New England and with the coordination of the New York, New Jersey, Pennsylvania Interagency AVI/ETTM Technical Committee, the following goals were identified and proposed to the New England Group by the research team (*3*). These goals constitute the minimum achievement to ensure a successful operating system for any group working to implement ETTM. They focus on the need for

1. Single-tag/multiple-agency system;
2. Compatibility of equipment during all phases of any system implementation;
3. Safety and feasibility;
4. Uniform/standard/consistent policies and procedures to minimize customer confusion and safety concerns while maximizing customer acceptance and user friendliness; and
5. Provision of program results to other areas of the country.

All agreed that the only way to achieve the above goals would be through full coordination among the concerned authorities in the same region.

Research and testing conducted in this regard, particularly that of the New York, New Jersey, Pennsylvania Interagency AVI/ETTM Technical Committee has shown the following (*3*):

1. Multiple identification devices or tags on one vehicle would result in a negative public reaction. People would not be encouraged to use ETTM if they knew it might involve placing more than one tag on their vehicle to take advantage of ETTM at toll plazas of various agencies. The need for multiple transponders would also create conflicts regarding suitable mounting locations on vehicles, since it is likely that the identification devices will be required to be physically separated from one another to avoid interference and guarantee operation.
2. Operating different systems in the same region would require unnecessary additional equipment, installation, and maintenance costs, especially if the systems are not compatible, and would lead to non-uniformity of system upgrading and difficulty in coordinating a traffic management system. Any agency operating an ETTM system for toll collection only, and not using it for traffic management would be neglecting important benefits that the system offers. To take advantage of these benefits, the system should be integrated with the region's other transportation systems.
3. Interference caused by multiple tags on a vehicle could result in one or more of the following situations:

- All tags being unreadable.
- Only the strongest or nearest tag being read.
- Incorrect identifications being made.
- Incorrect writes being made in a read/write system.

These situations are possible but not necessary in the case of multiple tags mounted on a vehicle. The technology differs between manufacturers and consequently the degree of "smartness" of readers and tags differ.

4. Non-uniformity of system operational requirements and standards may lead to safety problems and customer nonacceptance. Confusion among users concerning standards and procedures, such as the approach speed to a toll station, or whether it is a stop or non-stop station, could cause accidents and further nonacceptance of the system.

ADVANTAGES OF AN ETTM SYSTEM

Numerous advantages and benefits of ETTM were identified by manufacturers, potential users, and researchers in this field (*4*). The primary benefits are summarized below. (A detailed cost/benefit analysis of implementing ETTM is under way at MIT and is expected to be published soon.)

1. Customer convenience: by reducing travel time for the users and giving them alternatives for paying the tolls that do not involve cash/coins or ticket handling.
2. Additional payment alternative: for users who would find the alternative more convenient.

3. Congestion relief: implementing ETTM decreases the time required to process ETTM-equipped vehicles at toll plazas and thereby increases the throughput efficiency and toll lane capacity. The queuing times at toll plazas are thereby reduced. Thus, total travel time on the highway would decrease for both ETTM users and non-ETTM users. Table 1 shows sample average capacities estimated for several lane types: staffed, automatic coin machines, mixed lanes that would accommodate ETTM and non-ETTM users, ETTM lanes within a conventional toll plaza configuration, and express ETTM lanes allowing vehicles to pass through at highway speeds.

4. Environmental impact: as vehicles stop at toll stations to pay their tolls, excess emissions occur at toll plazas as a result of idling, acceleration, and deceleration (U.S. Environmental Protection Agency, 1978). At a toll station, these emissions are a function of the capacity and productivity of each toll booth. As ETTM improves toll plaza productivity by increasing vehicle throughput, these emissions are reduced (*5*).

5. Traffic management: the implementation of a comprehensive electronic traffic management could be made possible once the basic hardware for a system is installed. All that is required are strategically placed additional reading locations and a supplementary computer system software package to calculate travel times for vehicles traveling between reading stations on the basis of these probe travel times. Consequently, traffic can be directed and diverted according to congestion levels.

6. Improved security: ETTM systems allow transactions to be made without any physical handling of funds in the toll lane, thereby elminating cash handling, fraud, and error, and improving accountability and security.

7. Cost reductions: operating and maintenance costs, land acquisition and construction costs, and user fuel costs are reduced as a result of implementing ETTM. Operating and maintaining toll stations are expected to be less expensive once ETTM is installed. Furthermore, as the implementation of these systems increases the throughput of each lane, fewer lanes and booths need to be built. Eventually all that may be necessary is a bridge above the highway on which to install the reader. Some systems will even allow for the use of reading equipment embedded in the roadway's pavement, thereby eliminating even the need for an overhead mounting structure. Finally, as ETTM can reduce congestion and increase throughput and vehicle speed, fuel savings are expected.

8. Potential for increased public acceptance of toll roads: the use of ETTM will make the use of toll roads (and/or the tolling of new roads and bridges, etc.) more acceptable to the public and increase the acceptability of tolls as a means of funding the construction, operation, and maintenance of new roads, bridges, and tunnels.

TABLE 1 Comparison of Five Sample Toll Station Types

Lane Type	Vehicles/Hour
Staffed (with change making transactions, receipt issuing, etc.)	350
Staffed (only distributing commuter tickets and such)	500
Automatic Coin Machine (only coins--no tokens)	500
Automatic Coin Machine (receiving primarily tokens--few coins)	650
Mixed AVI (includes any of types 1-4 as well as AVI in the same lane)	700
AVI (dedicated AVI lanes in a conventional plaza with barriers)	1200
Express AVI (dedicated AVI lanes in a highway speed pass-through)	1800

Sources: Center for Urban Transportation Research, University of South Florida, Tampa & Ronald Cunningham, Port Authority of New York and New Jersey.

ORGANIZATIONAL REQUIREMENTS AND PROCEDURE FOR IMPLEMENTATION

One of the most challenging aspects of developing an operational testing program for any IVHS related activity will be the organization of the several public agencies that ultimately will be responsible for the design, implementation, and continuing operation of a program such as the one described in this paper.

The experience of the New York, New Jersey, Pennsylvania Interagency AVI/ETTM Committee provides an example that has been beneficial to the New England Group. After several informal meetings, the New England ETTM Group developed and signed an inter-agency agreement that described the potential uses of ETTM technology, the potential benefits to be realized and the importance of considering regional perspectives. The agreement lays out actions to be taken by the group, the role of MIT, and the structure of the regional effort. The agreement formalizes the role of the group and states that meetings will be held as needed, and that decisions will be reached by a consensus of the representatives of each organization. It also identifies the need for regional agreements on a wide variety of necessary subjects such as

- Compatibility questions involving the use of various technologies;
- Standards for noninterfering systems;
- Demonstration and standards for existing testing efforts;
- Performance specifications for ETTM systems;
- Legal issues that may arise;
- Market research possibilities; and
- Operational coordination (tag distribution, account management, etc.)

The process used in developing this agreement included the formation of policy and technical committees. The policy committee consists of the directors of the agencies, as policy representatives from each agency authorized to make decisions, set goals, and monitor the ongoing work in the project. The meetings of this committee are on an as-needed, rather than a regular, basis and usually before and after any designated task for the technical committees. Meetings have occurred about every 6 to 8 weeks. The technical committee could branch into several committees, each dealing with a specific task. At present, one technical committee consists of technical people from each agency, researchers from the Center for Transportation Studies at MIT and engineers from MIT's Lincoln Laboratory, working on the research, design, testing, implementation, and promotion of the project. The first task for this committee is the setting of requirements/standards for ETTM systems to be implemented and tested in the specific sites in New England. Reports including analysis and recommendations prepared by the technical committee are then presented to the policy committee for final decisions.

TECHNICAL AND LEGAL ISSUES FACING IMPLEMENTATION OF ETTM IN NEW ENGLAND

A number of technical and legal issues must be addressed in developing and implementing ETTM in New England. These technical and legal issues are common among most of the authorities in the group.

Technical Issues

Starting with the technical concerns that have been raised, the most sensitive one if the need for the capability of the system to work under the various climatic conditions that are witnessed in New England. In addition to the effect of snow, rain, wind, and humidity, temperatures vary between less than 0°F in the winter to above 100°F in the summer. Previous experiments have shown that the capabilities of some video enforcement systems are limited in the winter. In addition, automatic vehicle classification systems using vertical soundwaves might get distorted as a result of strong wind.

A second concern is the accuracy of the available systems. One must distinguish between the level of accuracy achieved and the level that could be measured. To test for a level of accuracy of 99.95 percent, which is still low at peak periods, one would need to run 40,000 to 50,000 samples. In addition to that, very little performance testing of the various ETTM technologies in various weather conditions has been formally documented. The authorities argue that security and loss of revenue concerns must not be compromised.

A third category of concern involves payment systems. Questions related to payment systems include the existing variation among the agencies in toll structures, prepayment versus postpayment policies, and methods of payment (*4*). Since most of the authorities cannot extend credit to customers, prepayment system methods are most likely to be required. These would include cash, check, use of the credit card to buy future trip entitlement, and electronic funds transfer (EFT). The credit card system or EFT would be ideal since it allows automatic replenishment of a prepaid toll entitlement account. One problem that has not yet been addressed as part of this effort is the issue of creating a system that could act as a clearing house between the various authorities so that toll-paying customers would have to maintain only one account that would be used for tolls from all participating agencies.

A fourth concern is the operation at individual toll stations. These operations will change significantly after implementing ETTM systems. Customer understanding of the system and safety to both the public and the remaining toll collection staff are the main issues. This stresses the importance of a coordinated system for the whole region since having non-uniform standards and operational requirements could have implications on safety and customer acceptance of the system. Pavement markings, adequate signing, channelization, speed limits, and passing areas must be examined to safely and efficiently accommodate ETTM usage (*4*).

Some authorities raised issues that dealt with traffic operation after tolls are paid at stations where a bottleneck situation emerges; in such cases the maximum benefit of throughput increase after installing ETTM might not be captured. This would occur in two situations: the first would be when there are more lanes before the toll station than after it and the toll station assists in merging traffic (see Figure 1a); and the other is when the authority prefers to keep the existing toll station with more lanes at the plaza than before and after (Figure 1b), rather than implement high-speed express ETTM systems (Figure 1c).

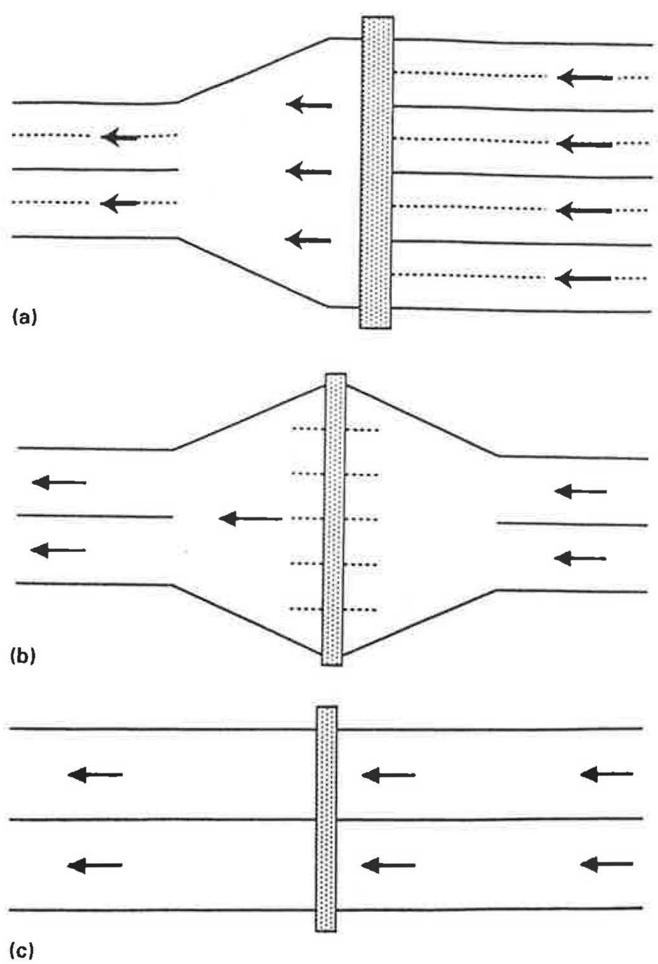

FIGURE 1 Idealized plan of toll station having *a*, more lanes before station than after; *b*, same number of lanes before and after station, with more lanes at station; and *c*, same number of lanes before and after station, with same number of lanes at station.

Legal Issues

Probably the most important issue to address is the one related to privacy. Authorities are concerned that potential customers will not accept it if the system can track people as they move from one place to another. This issue has been addressed in other parts of the country in different ways, such as creating an anonymous user account without requiring the user to give a name. This possibility is still being examined.

A second concern of the authorities is the legal issue involved in issuing violation tickets to drivers of moving vehicles who abuse the ETTM system. A video enforcement system might not be allowed to capture the picture of the offending driver, leaving the vehicle owner as identified by the license plate as the only option. Unfortunately, in some states, such tickets cannot be issued to the owner—only to the driver. Thus, enforcement capability is still unclear.

A third concern about possible customer nonacceptance of the system involves the issue of traffic management and its potential capability of enforcing speed limits in a strict manner. Few people would be encouraged to participate in a program that would put them at high risk of being identified when breaking the speed limit.

The issue of dedicating lanes for ETTM users raises another question. On one hand, some would argue that they cannot justify dedicating one lane for ETTM users unless the proportion of those users would match the proportion of lanes dedicated to them. That is, if 25 percent of the customers are ETTM users and the road in question is a four-lane highway, then it would be justified to dedicate one lane for ETTM users. On the other hand, others argue that if lanes are not initially dedicated to ETTM users, the users would not enjoy the most important benefit from ETTM, which is the savings in time; thus, potential users would be discouraged from using ETTM. Consequently the possibility exists for never getting the desired proportion to dedicate a separate lane.

Finally, officials were concerned about the reaction of toll collector unions toward ETTM. Although toll collectors could be assured of assignment to other jobs dealing with operating and maintaining the system, some collectors are understandably concerned about their long-run future.

SETTING REQUIREMENTS AND TESTING PROCEDURES

One way to resolve the technical issues concerning implementing ETTM systems is through setting requirements/standards and testing systems to determine if they meet those requirements/standards. Some questions that might be answered in a testing program would be

1. Is ETTM appropriate for use in New England?
2. What are the appropriate hardware and software requirements for such use?
3. What system or technology will best serve New England needs?
4. What are the advantages and disadvantages of the options?
5. How will the system operate?
6. What is the reliability of the system?

Furthermore, the answer to "Why have a New England testing and evaluation program?" should be addressed. Five issues (AVI Testing Options, C. Much, T. Hotz, and A. Kanaan, unpublished data) to be further explored include

1. Most operational systems in the U.S. commenced with a testing program. Most of them encountered unexpected problems and recommended a testing phase before implementation.
2. The consequences of a faulty system are severe. They might lead to lost revenue, increased congestion, and public dissatisfaction and distrust in technical solutions for traffic management.
3. Testing would provide opportunities to measure benefits before full-scale operation.
4. Testing will allow for a start-up period to choose the applicable technology, validate the system's reliability, determine the maintenance requirements, monitor the sensitivity to climate, measure background RF environment, and verify that the system can meet all the fundamental operating requirements or standards that are set.
5. Testing would allow for a lead time that is required to demonstrate the benefits to the public, create a sufficiently large user group, and create an infrastructure for tag distribution, data base management, and system failure contingencies.

Accordingly, the most appropriate procedure for a testing and evaluation program would be to design a comprehensive test for the system's operation (AVI Testing Options, C. Much, T. Hotz, and A. Kanaan, unpublished data), use existing or controlled toll stations, use cooperative test vehicles, perform a 9- to 12-month test under a variety of weather conditions, and, if test results meet the requirements/standards, recommend a system to the policy committee for follow-on operational implementation.

So far, the standards that systems have had to meet are not uniform or formal within the United States or anywhere else. Many standards have been developed by various groups and organizations. The New York, New Jersey, Pennsylvania AVI/ETTM Interagency Group has developed a specification for equipment that will eventually lead to a standard. The Heavy Vehicle Electronic License Plate (HELP) program, American Trucking Association, and others have developed or are in the process of developing standards. The problem in creating the standards is that each organization has a different set of requirements from a system. Some organizations need it for toll collection purposes only; some need it for toll collection and weigh-in-motion; others need it for traffic management; and so on. It is possible, though, to set basic requirements or specifications for electronic toll collection and basic traffic management only. If weigh-in-motion, for example, is needed in addition to ETTM, then other requirements could be added to the list.

A set of basic operational requirements is being developed now based on the review of relevant literature and research and analysis of the systems. Many of these are adopted from requirements set by the HELP program, The New York, New Jersey, Pennsylvania ETTM Group, and others (*3,6,7*).

FUTURE NE ETTM GROUP ACTIVITIES

The New Hampshire Turnpike Authority has started an individual testing program that is likely to lead to implementation of an ETTM system by late 1992. The Authority was to test several technologies and examine operational systems between spring 1991 and spring 1992. By that time, it will have decided on the best system for New Hampshire and will begin implementation by the end of 1992.

The MBTA (Boston's transit agency) is currently testing the use of AVI to monitor fuel use for its bus fleet. Tobin Bridge, directed by the Massport Authority, had plans to test various technologies by the spring of 1992. The agencies are formulating plans for possible ETTM applications. MIT will continue working on this research project under sponsorship from the Region One University Transportation Center and will continue to work with the agencies to enhance the design of a testing procedure suggested earlier (AVI/ETTM Testing Methodology, A. Y. Kanaan and T. F. Humphrey, unpublished data). At the same time, MIT will use real data from the various New England agencies and from the authorities operating ETTM systems in the United States to undertake a cost-benefit analysis for ETTM systems. Currently, information about users' reaction to ETTM is being collected by means of a telephone survey. This carefully designed statistical survey will be used to collect data to determine whether implementation of the system is feasible.

The New England ETTM Group's technical committee is currently working on the technical requirements for a system to be considered by each agency. The requirements to be determined by the technical committee will state the minimum operational needs of each agency first; then the general requirements will be developed into detailed specifications.

The technical committee will also review the latest version of the New York, New Jersey, and Pennsylvania Group's specifications. If found appropriate for application in New England, one of the options considered would be to adopt these specifications with necessary modification. This option would be more efficient for the two regions, but especially for New England. The resources that would have to be allocated for testing and setting requirements could be used in other complementary work such as traffic management.

CONCLUSION

The first year of this project has been extremely successful. For the first time, we have been able to generate great interest in New England concerning the possible coordinated application of new technologies to deal with transportation congestion. We have expanded the regional scope of this project to include not only the Massachusetts Turnpike Authority (which was our original intent) but all the transportation agencies in Massachusetts and toll agencies in New England. As we pursue this program, we also plan to undertake an economic analysis of the application of ETTM.

In conclusion, the benefits of ETTM systems for the agency and the user have been documented in various operational systems within the United States and around the world; however, many authorities still have questions and concerns to be answered and resolved. Some concerns can be resolved by proper coordination and agreements between agencies. One way to deal with various constraints is by setting requirements and testing various systems to determine which one best meets those requirements. By doing so, authorities will not compromise security and loss of revenue.

The challenge to be met, however, is the need to develop the appropriate institutional arrangements required to establish compatible systems. It appears we are well on our way in this regard.

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The authors would like to thank the members of The New England ETTM Group, The New York, New Jersey, Pennsylvania Interagency ETTM Committee, Carl Much and Tony Hotz of Lincoln Laboratory, Laura Marmorstein of MIT/Center for Transportation Studies, members of the TRB Committee on Transportation Economics for their constructive comments, and all others who contributed to the material contained in this paper.

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Road Condition and Maintenance Inputs for Feasibility Studies in Developing Countries

Fernando M. Montenegro and Marcelo J. Minc

Guidelines for determining expected road routine and periodic maintenance costs and predicting pavement condition over time are presented. This input is necessary for the economic evaluation of road construction and rehabilitation projects. The developed guidelines, which are presented in the context of a recent project application in Southeast Asia (Rural Infrastructure Fund Project), have direct application in the economic analysis of internationally funded investment projects in developing countries. Proposed techniques and procedures have been adopted from the ones accepted worldwide by international organizations and also according to the authors' experience in the field. One of the objectives was to obtain simple procedures, sensitive to the fast-track nature of road feasibility studies. These guidelines were developed and successfully applied in a project of infrastructure evaluation in the Philippines, sponsored by the United States Agency for International Development.

Road feasibility studies require the forecasting of roadway pavement conditions over time for both the "do" and "do-nothing" alternatives. Pavement condition and, in particular, roughness will determine (together with other factors, such as speed, alignment, cross-section, and traffic) vehicle operating costs (VOCs) (*1,2*). The savings in VOCs between the do and do-nothing alternatives constitute the traffic benefits brought by a project (consumer-surplus approach).

In many instances, roughness, which is a good predictor of pavement condition and has a demonstrated and published relationship with VOCs (*3*), is not measured in the field during fast-track road feasibility studies. More expedient subjective pavement condition surveys are carried out. This paper suggests guidelines for the correlation of roughness and subjective measures of pavement condition by means of a recent application in Southeast Asia [Rural Infrastructure Fund (RIF) Project].

Second to traffic benefits, the other main source of benefits produced by road improvement projects (of all-weather roads) is maintenance savings. Also by means of the RIF example, this paper provides guidelines on how to estimate roadway routine and periodic maintenance costs.

The suggested methodology is simple, quick, and conceptually sound and is particularly appropriate for the economic analysis of road feasibility projects in developing countries.

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PAVEMENT DETERIORATION CURVES

Roughness as Indicator of Pavement Condition

Pavement deterioration curves estimate future values of an index related to pavement condition, such as a pavement condition index or roughness, as a function of current values of that index and time or accumulated axle loads.

The authors recommended roughness as the primary indicator of pavement condition because

- Several internationally accepted studies have demonstrated the high degree of correlation between pavement condition [both user defined as per AASHTO (*4*) and distress defined as per United States Army Corps of Engineers' PAVER (*5*)] and roughness.
- There are readily available models for roughness progression prediction that are applicable in the Philippines.
- Roughness relates directly to vehicle operating costs and estimation of project benefits.

Estimates of road roughness with and without the proposed projects over the analysis period are required to estimate cost savings. The authors have projected roughness progression by means of appropriate roughness progression (pavement deterioration) curves for asphalt, concrete, and unpaved roads that are presented in the following sections. A later section presents the authors' estimate of the correlation between pavement conditions (subjective estimation) with roughness levels.

Asphalt Roads

Because of the recent development, extensive data base, and transferability among developing countries, roughness progression curves derived by the World Bank in its *Highway Design and Maintenance Standards Model* (HDM-III) (*3*) has been selected by the authors.

The World Bank's HDM-III aggregate roughness progression model was developed mainly with data from a United Nations Development Project (UNDP)-funded transportation study in Brazil. The model is based on a relationship between initial roughness, modified structural number, cumulative traffic [in terms of equivalent standard axle loads (ESALs)] and the age of the pavement since construction or last overlay. The relationship is as follows:

$$Rt = [R1 + 725 (1 + SN^1)^{-4.99} * N1] * e^{(0.0153t)} \quad (1)$$

where

- Rt = roughness at time (t) in international roughness index (IRI) m/km,
- $R1$ = initial roughness in IRI m/km
- SN^1 = modified structural number = $0.0394 * n \sum a_i * H_i + SNSG$, $i = 1$
- $N1$ = cumulative standard axles carried since construction or last overlay,
- t = age of pavement (years) since construction or last overlay,
- a_i = strength coefficient of the ith layer (from AASHTO guidelines),
- H_i = thickness of the ith layer, provided that the sum of thickness (H_i) is not greater than 700 mm (mm),
- n = number of pavement layers, and
- $SNSG$ = modified structural number contribution of the subgrade, given by $3.51 \log_{10} CBR - 0.85 (\log_{10} CBR)^2 - 1.43$ where CBR is the California bearing ratio of the subgrade at in situ conditions of moisture and density (percent).

Effect of Seal Coats on Roughness

Following guidelines presented previously (*6*), the authors assumed that a seal coat does not reduce roughness. This is understandable because the coat is a thin layer that follows the contour of the existing pavement. Indeed, if the seal coat is applied badly, roughness may increase.

Effect of Overlays on Roughness

It is useful to know the effect of an asphalt concrete (AC) overlay on road roughness so that the benefit of the overlay may be quantitatively assessed.

Research continuing from the Brazil-UNDP study has related the roughness after overlay to the roughness of the road before overlay as follows:

$$QIA = 19 + (QIB - 19)/(0.602 * H + 1) \quad (2)$$

where

- QIA = predicted roughness after overlay (quarter-car index counts per km),
- QIB = roughness immediately before overlay,
- H = thickness of the overlay,
- A = after the overlay, and
- B = before the overlay.

Note that QI counts/km = 66 mm/km Transportation and Road Research Laboratory (TRRL) roughness units, and 13 QI counts/km = 1 m/km IRI.

Also, an overlay changes a pavement's modified structural number (e.g., the one used in Equation 1) as follows:

$$SN^1A = 0.9 * SN^1B + a_k * D_k \quad (3)$$

where a_k is the overlay strength coefficient and D_k is the overlay thickness in inches.

Portland Cement Concrete Pavements

The authors suggested the use of the HDM-III roughness deterioration model for paved roads as the model for portland cement concrete (PCC) pavement deterioration. A large structural number has been given to the PCC so that the increase in roughness over the life of the road is very small, as would be expected for a well-constructed, well-maintained road. Initial values of roughness for a newly constructed PCC pavement have been estimated and are presented later.

Using a modified structural number of 5 in the HDM-III model yields an increase in roughness from 2.0 m/km to 3.0 m/km over a 20-year period and the passing of 2.5 million ESALs. This increase corresponds to a condition rating bordering good/fair. If a modified structural number of 15 is used, the roughness increases to 2.72 m/km. Little change occurs in the incremental roughness predicted for modified structural numbers greater than 8. For a modified structural number of 15, the roughness after 40 years is 3.70. This value is considered only fair/poor, whereas, considering good construction and good maintenance practices, one would expect the condition to be in the good/fair zone, (i.e., having an IRI value of 3.0 m/km).

Adapting the HDM-III model for bituminous-paved roads to concrete roads does not entirely fit the expected behavior of concrete. However, the model does allow the comparison of concrete roads with bituminous-surfaced roads; the evaluation will be somewhat biased toward bituminous surfaces since the method appears to overestimate the rate of roughness increase for concrete roads. A modified structural number of 8 has been used for concrete pavements in the analysis of RIF projects.

Unpaved Roads

Routine Grading

The purpose of routine grading is to improve surface roughness and minimize the loss of gravel material. It is reasonable to base the frequency of grading on the criteria of limiting roughness. If grading is not carried out, the road condition will become very bad within a short period, even for a traffic level of 100 vehicles per day. With such rapid changes in road roughness, it is not appropriate to determine annual roughness values as it is determined for paved roads. It is, however, viable to approximate average annual roughness values, assuming good maintenance, and this has been done in the RIF study.

Annual average roughness increases between regraveling activities despite the grading interventions. This increase is caused by the gradual loss of gravel, which results in a weaker structure and increased subgrade deformation under traffic.

Regraveling Requirements

The model adopted by the RIF study for determining regraveling requirements was developed by TRRL (*7*) in the Kenya Maintenance Study for Unpaved Roads. The model relates gravel loss to traffic, rainfall, gravel type, and average gradient as follows:

$$GL_A = f[T_A^2/(T_A^2 + 50)] (4.2 + 0.092T_A + 3.5 R_L^2 + 1.88VC) \quad (4)$$

where

GL_A = annual gravel loss (mm);
T_A = annual traffic (thousands) in both directions;
R_L = annual rainfall (m);
VC = average percentage gradient; and
f = constant: 0.94 for lathyritic gravel, 1.51 for quartzitic gravel, 0.96 for volcanic gravel, and 1.38 for sandstone gravel.

Volcanic gravel is the predominant type of soil found in the Philippines, and a value of f of 0.96 for calculating gravel loss has been assumed accordingly.

Roughness Progression Between Regravelings

Variations in gravel road roughness throughout the year are considerable, and only an average annual roughness can be assumed. The annual increase in average roughness is linked to gravel loss. It is assumed that between regravelings the roughness increases as follows:

$$R_t = R_{(t-1)} + 2 \times \frac{GL_A}{100} \quad (5)$$

where

R_t = average roughness for year t (m/km),
R_{t-1} = average roughness for year $t - 1$ (m/km), and
GL_A = annual gravel loss (mm).

ROUGHNESS AND PAVEMENT CONDITION

Described in this section are the procedures used during the pavement condition surveys and the relationship between pavement condition and roughness.

Pavement Condition Surveys

The authors recommended a subjective evaluation of the current road condition of all project roads. This subjective estimation was made by project pavement engineers. The survey team was provided with appropriate guidelines and training (to achieve consistency in ratings) to perform the requested road condition evaluation. Given the short time frame for the reconnaissance survey, a three-category rating scheme was used. A description of each category follows:

- Good: Paved roads substantially free of defects, requiring only routine maintenance; unpaved roads needing only routine grading and spot repairs.
- Fair: Paved roads having significant defects, requiring resurfacing or strengthening; unpaved roads needing reshaping or resurfacing (regraveling) and spot repair of drainage.
- Bad: Paved roads with extensive defects, requiring immediate rehabilitation or reconstruction; unpaved roads that need reconstruction and major drainage works.

Pavement Condition/Roughness Relationships

To translate subjective pavement condition measures from the reconnaissance surveys into pavement roughness in IRI, the authors used previously published relationships (*3,6,9*). A comparison of benchmark roughnesses given in those reports and a point estimation technique were the methods used.

The subjective condition rating data were converted into a numerical scale so that an appropriate comparison of the condition rating categories with published roughness benchmarks could be performed. A point estimation technique exercise (see Figures 1 through 3), in which all pavement raters participated, was applied for the conversion of the subjective category scales used during the field survey on a scale of 0 to 10 (*8*).

The correlation between IRI and pavement condition was derived by a comparison of benchmark roughnesses (e.g., new asphalt, new surface treatment, and new gravel). Since most of the project roads are presently in fair or bad condition, with roughness values generally well over 4 m/km, it is not sufficient to compare pavement condition with measured roughnesses only on new paved roads.

The relationship between pavement condition and roughness at the rougher end of the scale depends on varying and subjective conceptions of pavement condition and failure. For example, the roughness of fair gravel surfaces depends on many factors (such as type of material, its maximum grain size and grading, the time of year, the level of maintenance, the time since the last blading, etc.), and there is no direct way to fix an accurate benchmark for this condition. It is here that the point estimation technique has been useful.

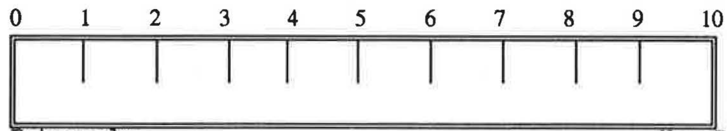
Figure 4 shows the benchmark roughnesses established in the National Roads Improvement Project (*9*) (NRIP) and those in the RFS III study (*10*), measured in in./km, for various surface types and conditions. These benchmarks were compared with the benchmarks established in the World Bank's Brazil study, expressed in IRI. DPWH's pavement condition benchmarks, together with a correlation with roughness values, are presented in Table 1.

The authors estimated the relationships between pavement condition and roughness levels (Tables 2 and 3) based on the relationships presented and the discussion above.

The roughness values assumed for the good, fair, and bad categories for each pavement type in Table 3 fall within the benchmark ranges in Figure 4. Also, the roughness values assumed for failed gravel and earth roads fall within the range of the World Bank's Brazil roughness research data (*3*, Chapter 3, Tables 3 and 4). Values presented in Tables 2 and 3 have been used for pavement deterioration forecasts and for the calculation of vehicle operating costs.

Could you please place an "X" in the following scale at the points that best represent the subjective estimates of pavement condition described below?

PCC ROADS



Extremely bad road, blow-ups, diff. settl., extensive cracking.

New Pav. No cracks smooth surface.

GOOD: Smooth surface, minor cracking, pavement in good condition, allowing running speeds at design speed.

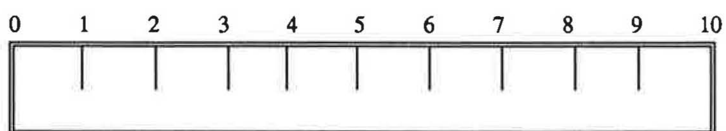
FAIR: Some cracking and joint damage, vehicle running speeds close to design speed.

BAD: Vehicle running speeds are constrained by poor pavement condition. Pavement has failed and is in need of immediate rehabilitation/reconstruction.

FIGURE 1 Point estimation technique questionnaire: PCC pavements.

Could you please place an "X" in the following scale at the points that best represent the subjective estimates of pavement condition described below?

ASPHALT AND OTHER BITUMINOUS PAVEMENTS:



Extremely bad road, extensive open potholes, destroyed pavement.

New Pav. No cracks smooth surface.

GOOD: Smooth surface, minor cracking, pavement in good condition, allowing running speeds at design speed. No potholes.

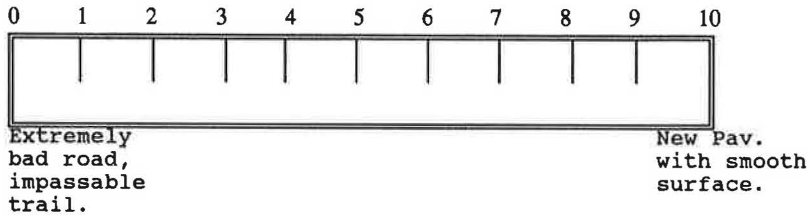
FAIR: Some cracking, vehicle running speeds close to design speed. Few minor open potholes.

BAD: Vehicle running speeds are constrained by poor pavement condition. Pavement has failed and is in need of immediate rehabilitation/reconstruction. Numerous open potholes and surface has disappeared in some sections.

FIGURE 2 Point estimation technique questionnaire: asphalt pavements.

Could you please place an "X" in the following scale at the points that best represent the subjective estimates of pavement condition described below?

GRAVEL ROADS



GOOD: Smooth surface; surface condition allows running speeds at design speed.

FAIR: Tangent speeds of 30 to 50 km/h; surface somewhat rough.

BAD: Road in very poor condition. Uneven surface reduces operating speed to less than 30 and sometimes to only 10 km/h.

FIGURE 3 Point estimation technique questionnaire: unpaved roads.

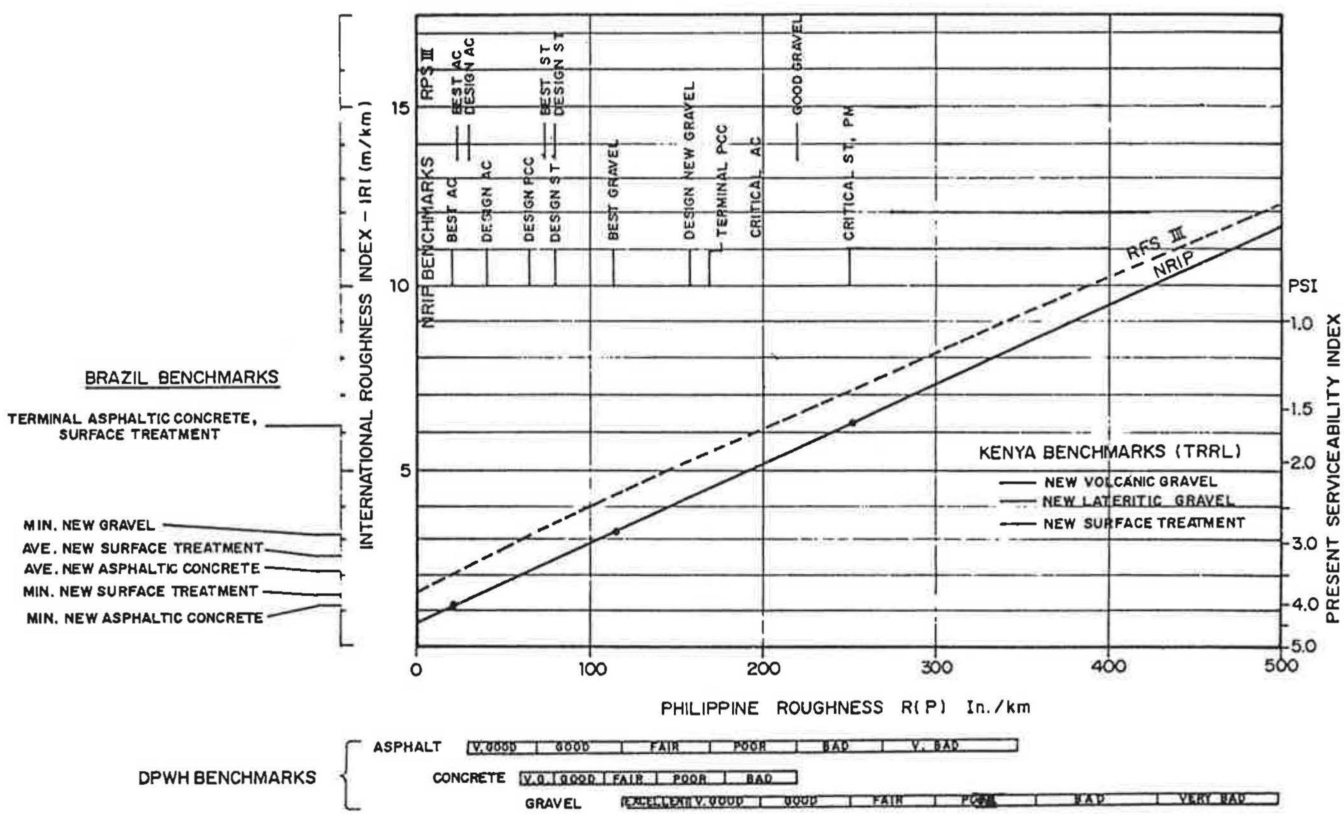


FIGURE 4 Benchmark roughness versus IRI in the Philippines.

TABLE 1 DPWH Pavement Condition Benchmarks

Flexible Pavements (AC, BS)		Roughness (in/km)
1 Very Good	No cracks, as new.	< 70
2 Good	No cracks, low roughness.	70 - 120
3 Fair	Some cracks but no developed pattern, slight surface deformation.	120 - 170
4 Poor	Developed continuous cracking pattern, no loss of material, moderate surface deformations, few potholes.	170 - 220
5 Bad	Extensive cracking pattern with loss of material, large surface deformations, some potholes.	220 - 270
6 Very Bad	Highly deformed pavement, extensive potholing, complete failure.	> 270

Rigid Pavements (PCC)		Roughness (in/km)
1 Very Good	No cracks, as new.	< 80
2 Good	Low roughness, cracks < 100m/100m.	80 - 110
3 Fair	Slight surface deformation, cracks 100 - 200m/100m.	110 - 140
4 Poor	Developed cracking, no loss of material, cracks 200 - 300m/100m.	140 - 180
5 Bad	Extensive cracking with loss of material, deformed pavement, cracks 300 - 400m/100m.	180 - 230
6 Very Bad	Highly deformed pavement, complete failure, high loss of material, cracks > 400m/100m.	> 230

Unpaved Surfaces (G, E)		Roughness (in/km)
1 Very Good	Surface not restrictive to speed.	< 200
2 Good	Surface slightly restrictive to speed.	200 - 250
3 Fair	Slight surface deformations, a few potholes.	250 - 300
4 Poor	Deformed surface, frequent potholes.	300 - 360
5 Bad	Highly deformed surface, continuous potholes, passable only at low speed.	360 - 450
6 Very Bad	Passable only by jeep.	> 450

Note: To convert Philippine Roughness (Rp in/km) to Roughness in IRI in in/km, the following equation has been used: Roughness IRI = 0.7 + 0.0215 * Rp.

TABLE 2 Roughness Values By Pavement Condition and Road Category

Pavement Type	Initial	Critical	Terminal
PCC	2.0[a] (*9*)	—	4.6 (*9*)
AC	1.5[a] (*9*)	4.0 (*9*)	6.0 (*9*)
DBST	2.5[b] (*9*)	4.5 (*9*)	6.5 (*9*)
Gravel	4.0 (*9*)	7.5 (*3*)	10.0 (*9*)
Earth	4.5 (*9*)	8.5 (*3*)	10.0 (*9*)

NOTE: Values are according to IRI (m/km). Initial = pavement condition right after construction. Critical = pavement condition at which major maintenance is appropriate to reduce life-cycle maintenance costs and VOC costs. Terminal = pavement condition at which reconstruction is warranted.

[a]Under a good construction scenario. In the cases of fair and poor construction, these values are 2.0 and 2.5

[b]Under a good construction scenario. In the cases of fair and poor construction, these values are 2.75 and 3.0.

TABLE 3 Roughness Values By Pavement Condition and Road Category

Pavement Type	Good	Fair	Bad	Failed (Very Bad)
PCC	2.7[a]	3.6[a]	4.6[b]	6.0 (*9*)
AC	2.6[a]	4.2[c]	6.0[b]	9.5 (*3*)
DBST	3.4[a]	4.5[c]	6.5[b]	9.5 (*3*)
Gravel	5.5[a]	7.5[c]	10.0[b]	14.0 (*3*)
Earth	6.0[a]	8.5[c]	10.0[b]	16.5 (*3*)

NOTE: Values are according to IRI (m/km).

[a]From a point estimation technique exercise, assuming linear variation of roughness between benchmarks (0 = initial value; 5 = fair; 8 = bad).

[b]Terminal values coincide with the midpoint between the bad and very bad categories (*9*).

[c]Mean roughness observed in the World Bank's International Road Roughness Experiment (*3*).

ROAD MAINTENANCE REQUIREMENTS AND UNIT COSTS

The purpose of this section is to determine appropriate maintenance levels for the project roads under study and, in particular, to determine quantitatively the effect of the various improvement strategies on routine and periodic maintenance expenditures.

Routine Maintenance

Routine maintenance needs and unit rates have been estimated. Although rates vary somewhat throughout the Philippine islands, within the degree of accuracy possible, it is reasonable to use a standard cost per kilometer of road, irrespective of terrain type or location.

Manual routine maintenance is common to any road irrespective of surface type and includes ditch cleaning, culvert cleaning, and general upkeep of structures. Table 4 includes the financial and economic costs per kilometer for these activities. Financial costs are costs measured in market prices, including taxes, subsidies, custom duties, and other tariffs. Economic costs represent real costs for the economy. Transfers, including taxes, subsidies, and duties, are not included; shadow prices for wages, oil, and foreign exchange are considered. The listed activity cost estimates assume 40 m of culvert and 0.2 structures per km.

Shoulder Maintenance

Shoulder grading and regraveling are important maintenance activities necessary for maintaining a shoulder's slope and surface course. The authors have assumed that 5-cm-thick full-shoulder-width regraveling is necessary every 4 years. Grading occurs on an average of 2.4 times per year.

Table 5 presents the financial and economic costs of shoulder maintenance as derived from 1988 NRIP cost data updated by means of consumer price indexes (CPI).

Asphalt Pavement Maintenance

This section presents estimates of routine maintenance costs related to AC and surface treatment (ST) pavements. There are several routine maintenance activities mainly associated with asphalt pavements, such as patching, premix leveling, skin patching, and crack sealing.

Of these activities, shallow patching is the most important in terms of both manpower requirements and cost. Patching is required to repair cracking and potholes. In cases of a

TABLE 4 Annual Manual Routine Maintenance Costs

Activity	Unit	Financial Costs	Economic Costs
Ditch Cleaning	Road Km	10413.9	10413.9
Grass Cutting	Road Km	2083.4	2083.4
Culvert Cleaning	Road Km	778.1	778.1
Minor Structural Repairs	Road Km	1192.2	1192.2
TOTAL (after rounding)		14500	14500

Note: Costs are in February 1990 pesos.

TABLE 5 Shoulder Maintenance

	Economic Unit Cost P/m2	Financial Unit Cost P/m2
Regravelling (10 cm)	21.82	29.60
Regravelling (5 cm)	10.91	14.80
Grading	0.87	1.21

Annual Cost (P/yr-km)

	Shoulder Width					
	0.50m	1.0	1.5	2.0	2.5	3.0m
Regravelling	2730	5460	8190	10920	13650	16380
Grading	2088	4180	6270	8360	10450	12540
Total Economic Cost	4820	9640	14460	19280	24100	28920
Total Financial Cost	6600	13200	19800	26420	33020	39620

Note: P = pesos.

TABLE 6 Annual AC and ST Pavement Maintenance Needs

	Roughness Level (IRI - m/mm)						
	<3	3-4	4-5	5-6	6-7	7-8	>8
Patching Requirements (m^2/km)	0	1.3	3.6	11.3	22.7	42.3	83.3
Patching Requirements (P/yr-km)	0	110	250	780	1570	2930	5760
Other Pavement Activities (50% of patching req.)	0	55	125	390	785	1465	2880
Assumed Total Cost (Economic) (After rounding)	0	0	750	750	3300	3300	8600
Assumed Total Cost (Financial) (After rounding)	0	0	990	990	4340	4340	11320

Note: The assumed economic cost of patching is P 69.17/m2 and the financial costs of patching is P 91.02/m2. P = pesos.

TABLE 7 Annual PCC Maintenance Requirements and Costs

	Economic Unit Cost	Financial Unit Cost
Slab Replacement	279.35 P/m2	347.76 P/m2
Joint and Crack Sealing	15.58 P/m	18.23 P/m

	Roughness Level (IRI - m/km)		
	<4	4-6	>6
Slab Replacement Requirements	0%	0.05%	0.5%
J & C Sealing Requirements	5%	15%	30%
Slab Replacement Economic Cost (P/km year)	0	930	9,300
J & C Sealing Economic Cost (P/km year) (1)	1,040	3120	6,240
Total Economic Cost (P/Km Year)	1,040	4,050	15,540
Total Financial Cost (P/Km Year)	1,220	4,810	18,880

(1) Assuming 20-meter-long 6.70-meter-wide slabs. For example, for roughness < 4 IRI m/km : (6.7 m * 50 joints/km (transverse joints) + 1,000 m/km (longitudinal joint)) * 0.05 / year * 15.58 P/m = 1,039.97 P/km year P = pesos.

TABLE 8 Annual Gravel Road Maintenance Requirements and Cost

	Economic	Financial
Regrading Unit Cost	P 9.070/km	P 12,361/km
Annual Cost (regrade 2.4 times/year)	P 21,770/km yr	P 29,670/km yr

Source: 1988 NRIP Study, updated by means of CPI indices.

TABLE 9 1990 Economic Routine Maintenance Costs (pesos/km-yr) (8,9)

Shoulders (Roughness Shoulders in IRI m/km)				
Shoulder Width	<4	4-6	6-8	>8
0.5m	4820	4820	4820	4820
1.0m	9640	9640	9640	9640
1.5m	14460	14460	14460	14460
2.0m	19280	19820	19820	19820
2.5m	24100	24100	24100	24100
3.0m	28920	28920	28920	28920
PCC Pavements Roughness in IRI m/km				
	<4	4-6	6-8	>8
	15540	18550	30040	30040
DBST/AC Pavements Roughness in IRI m/km				
	<4	4-6	6-8	>8
	14500	15250	17800	23100
Gravel Roads Roughness in IRI m/km				
Roadway Width	<4	4-6	6-8	>8
6m	36270	36270	36270	36270
4m	29010	29010	29010	29010
Earth Roads Roughness in IRI m/km				
Roadway Width	<4	4-6	6-8	>8
6m	36270	36270	36270	36270
4m	29010	29010	29010	29010

surface treatment or asphalt concrete pavement, potholes develop from raveling, wide cracking, or alligator cracking. Factors controlling the initiation and progression of potholes are diverse.

The World Bank HDM-III model (*3*) is a mechanistic model that relates patching requirements to potholes caused by cracking and raveling and to enlargement of existing potholes.

Although the principles behind the HDM-III deterioration model for patching are sound, they are unwieldy in practice because they attempt to rationalize complicated mechanisms into a less complicated, but still complex, set of relationships. Since the authors are considering theoretical maintenance levels in this study, which will be greatly modified by human intervention in actual practice, there is good reason to adopt a more simplistic approach that still allows quantitative comparisons of various maintenance strategies.

The AC and ST pavement patching and total maintenance requirements were tabulated according to roughness level (pavement condition) (see Table 6). Costs were estimated based on NRIP data (updated by means of CPI indexes), assuming average pavement widths of 6.7 meters and pothole depths of 8 cm. The variation of maintenance needs across pavement conditions was estimated according to Montenegro and Sinha (*8*).

PCC Pavement Maintenance

This section presents estimates of routine maintenance requirements and costs for PCC pavement surfaces. The two most important PCC maintenance activities are slab replacement and joint and crack sealing.

Based on NRIP, Volume II, (*9*) it was assumed that an average of 0.05 percent of the paved area is replaced each year. Based on NRIP, Volume II (*9*), and previous data (*8*) it was assumed that joints are sealed every 6 years and that 15 m of cracks are filled every year.

Table 7 presents the authors' estimate of maintenance unit and total costs for PCC pavements.

Gravel Road Maintenance

Many of the roads under study are gravel surfaced. To evaluate upgrading options, it is necessary to determine future maintenance requirements for these gravel roads without the project. Also, some sections of road were evaluated for improvement to gravel standards only and, for these sections, it is necessary to know the future maintenance costs. These estimated costs are presented in Table 8.

Tables 9 and 10 present summaries of the estimated financial and economic routine maintenance costs by road type and condition.

Periodic Maintenance

Paved Roads

One way of scheduling seal coats (pavement resealing) is by assigning a level of distress (e.g., percentage of pavement

TABLE 10 1990 Financial Routine Maintenance Costs (pesos/km-yr) (*8,9*)

		Shoulders Roughness in IRI m/km		
Shoulder Width	<4	4-6	6-8	>8
0.5m	P6600	P6600	P6600	P6600
1.0m	13200	13200	13200	13200
1.5m	19800	19800	19800	19800
2.0m	26420	26420	26420	26420
2.5m	33020	33020	33020	33020
3.0m	39620	39620	39620	39620
		PCC Pavements Roughness in IRI m/km		
	<4	4-6	6-8	>8
	15720	19310	33380	33380
		DBST/AC Pavements Roughness in IRI m/km		
	<4	4-6	6-8	>8
	14500	15490	18840	25820
		Gravel Roads Roughness in IRI m/km		
Roadway Width	<4	4-6	6-8	>8
6m	44170	44170	44170	44170
4m	34280	34280	34280	34280
		Earth Roads Roughness in IRI m/km		
Roadway Width	<4	4-6	6-8	>8
6m	44170	44170	44170	44170
4m	34280	34280	34280	34280

requiring patching) at which the seal is applied. In practice, few highway departments in developing countries undertake seal coating unless the amount of distress has reached critical levels (this often means that the pavement is beyond saving by application of a simple seal). For the purpose of this study, it was assumed that flexible pavements are seal coated every 8 years.

Pavement structures deteriorate and their roughness values increase over time. At certain critical points, it is appropriate to provide an AC overlay (*11*) to

- Prolong the working life of a pavement by increasing the structural strength, and
- Reduce the surface roughness, and in so doing, to increase the VOC benefits derived from the road improvement.

Although it is a universally recommended procedure, AC overlay is rarely carried out in developing countries, resulting in increased roughness for a given traffic loading, which means higher vehicle operating costs and additional capital expenditures (cost of reconstructing a pavement compared with the cost of an overlay).

TABLE 11 1990 Periodic Maintenance Unit Costs

	Economic Cost	Financial Cost
Seal coat[a]	17.39 P/m^2 116,500 P/km	21.82 P/m^2 146,200 P/km
Overlay[b]	2,236.61 P/m^3 1,498,530 P/km	2,856.05 P/m^3 1,913,560 P/km
Regravelling	21.82 P/m^2	29.60 P/m^2
4-m road	87,280 P/km	118,410 P/km
6-m road	130,920 P/km	177,610 P/km

NOTE: Unit costs are based on NRIP data updated by means of CPI indices. P = pesos.
[a]Assuming a 6.70-meter cross section.
[b]Assuming a 6.70-meter cross section and a 10-centimeter overlay.

Unpaved Roads

It is assumed that gravel roads are regraveled every 4 years to replenish the gravel loss caused by traffic and weather. A replenishment thickness of 10 cm has been assumed. Table 11 summarizes the unit periodic maintenance costs assumed in the RIF study.

APPLICATION OF THE PRESENTED METHODOLOGY

As suggested in the previous sections, the proposed methodology was applied successfully by the authors in the evaluation of road construction and improvement projects in the Philippines (financed by the U.S. Agency for International Development).

The proposed methodology provided a quick, technically sound and sensitive (to policy variables) way of assessing the pavement condition (roughness) and road maintenance needs necessary for the analysis of road feasibility projects.

SUMMARY AND CONCLUSIONS

The proposed guidelines provide a framework for the estimation of roadway condition and maintenance needs in the context of road feasibility studies. The guidelines, provided by means of a recent example in Southeast Asia, are simple and conceptually sound. One area of direct application is the economic analysis of internationally funded investment projects in developing countries.

This methodology gathered and adapted in the same framework the latest theories in the areas of pavement deterioration and road maintenance needs estimation from previously published material (*3,6*), as well as the authors' experience in the area. Its use in the Philippines proved to be highly successful, giving a useful tool for estimating necessary factors in the economic analysis of road feasibility projects.

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Transportation and Economic Development of Coastal Areas in the Pacific Northwest

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The role of improved transportation infrastructure in the economic development of coastal areas in the U.S. Pacific Northwest was examined. A quantitative analysis that addressed how future economic development of this region could be stimulated by improved interregional transportation was undertaken. The research sought to understand the economic development potential of the various communities in the study area by identifying the types of businesses that appeared best suited to prosper in these locations. It then examined in detail the specific transportation and environmental needs of the selected target industries, while matching these needs to the infrastructure and quality of transportation services available. A "what-if" analysis was performed to explore whether proposed transportation infrastructure and service improvements would be justified in terms of their resulting direct user benefits and indirect economic benefits, the latter being addressed using input-output modeling. It was concluded that there are substantial economic benefits that would result from improved transportation. However, it is clear that the transportation system provides no magic for generating economic benefits in rural areas of a magnitude needed to offset the costs of a large-scale infrastructure improvement program. On the other hand, many selective infrastructure improvements and generally increased investment in the transportation system are clearly justified economically. The study also concluded that increased spending on transportation infrastructure in rural areas is only a contributing element in permitting these areas to gain the benefits of a vigorous economy and an improved quality of life.

This paper describes a study that examined the role of improved transportation infrastructure in the economic development of coastal areas of the U.S. Pacific Northwest. The study area extends from Mendocino County, north of San Francisco, to the Canadian border (Figure 1). The paper summarizes a quantitative analysis undertaken to address how future regional economic development could be stimulated by improved transportation infrastructure. The paper also reviews the major study conclusions and recommendations. The selected study area is widely perceived as transportation disadvantaged compared with nearby inland areas because it was bypassed by the interstate highway system and has poor or nonexistent rail service, limited or nonexistent air service, and declining intercity bus and domestic marine transportation services. Historically, the local economies of the area have been based on resource extraction—principally timber and fishing. These economies recently have undergone considerable restructuring, because of both production changes in the traditional industries and changes in the character of the local work force and population.

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The communities of the study area are also being affected by broader social and economic trends that include the increasing importance of information processing and management technique as factors of production, increased leisure time and discretionary income, the increasingly footloose character of labor, increased networking among far-flung peer groups, emergence of a unified world economy, and accelerating specialization in economic activities.

The study sought to understand the economic development potential of the various communities in the study area by identifying the types of businesses that appeared best suited to prosper in these locations. It then examined in detail the specific transportation and environmental needs of the selected target industries, while matching these needs to the infrastructure and quality of transportation services available. A "what-if" analysis was performed to explore whether pro-

FIGURE 1 Coastal study area.

posed transportation infrastructure and service improvements are justified in terms of their resulting direct user benefits and indirect economic benefits. The indirect economic benefits were addressed by using input-output modeling to estimate the impact of transportation system improvements on local income and employment.

The study concluded that there are substantial economic benefits, as well as other types of benefits, that would result from improved transportation. However, it is clear that the transportation system provides no magic wand for generating economic benefits in rural areas of a magnitude needed to offset the costs of large-scale infrastructure improvement programs, such as an expanded interstate freeway system. On the other hand, many selective transportation infrastructure improvements clearly are economically justified. Unfortunately, such improvements are not being made at a sufficient rate to match growing needs because of prevailing financial constraints.

The study also concluded that increased spending on transportation infrastructure in rural areas is only a contributing element to permit these areas to gain the advantages of a vigorous economy and an improved quality of life. In today's world, access to information, ability to participate in peer networks, exchange of new ideas, and increased specialization are the most important factors for economic success. In this regard, infrastructure improvement can play an important role in reducing the sense of remoteness that may discourage innovators and knowledge-sharers from participating in the development of rural areas. Whereas better infrastructure by itself can accomplish little, the role that transportation infrastructure can play in contributing to a balanced program of economic development in rural communities deserves careful attention.

The remainder of the paper contains three sections. The first discusses in greater detail the overall study approach. The second describes how the effects of hypothesized highway system improvements were traced through to their possible economic consequences, measured by direct costs and user benefits, income, and jobs. The last section reviews the principal conclusions and recommendations. The full documentation of the study is found in a three-volume final report (*1–3*).

OVERVIEW OF THE APPROACH

The study work plan included the following tasks:

1. Assemble information on past research dealing with relationships between transportation improvements and economic development.
2. Characterize the current economic and transportation conditions within the study area.
3. Attempt to understand the economic development potential of the various communities in the study area by identifying the types of businesses that seem best suited to prosper in these locations. (This task was aided greatly by the availability of previous target-industry studies performed by several state and local authorities.) Industry selection criteria from previous studies were reviewed, leading to the use of the following criteria by the study:

   - The selected industry offers opportunities to use the skills of displaced timber industry workers.
   - The selected industry can be established in the area through logical expansion of the product lines of businesses already in the area.
   - The selected industry is similar to industries already in the area, offering potential agglomeration economies.
   - The selected industry provides needed input that local businesses now import from outside the area.
   - The selected industry has some special environmental or location advantage, such as tourism and offshore mining.
   - The selected industry increases the value added in the production of goods for sale outside the area.

   These criteria led to the development of a "short list" of industry types, which formed the basis for the subsequent transportation needs analysis.
4. Examine in detail the specific transportation and environmental needs of the selected target industries, and match those needs to the infrastructure and quality of transportation services available.
5. Analyze the strengths and weaknesses of the existing transportation system serving the study area, considering pertinent trends. Whereas all transportation modes were considered, the study focused principally on highways (including trucking and intercity bus) and air. The analysis did not consider rail or coastal maritime transportation in depth, because of both limited resources and the fact that there are several recent, well-founded studies that dealt with these modes in considerable detail (*4–7*).
6. Conduct a "what-if" style of analysis to explore whether alternative transportation infrastructure and service improvements appear justified in light of their associated benefits. Generally, the hypothesized transportation system improvements are similar to those considered in previous studies. However, this analysis tried to explore the frontiers of what could be achieved through better transportation, while attempting to hold capital expenditures to a feasible level. Consequently, many of the infrastructure alternatives are selective spot improvements, implemented on a widespread basis to eliminate delays and other traffic conflicts evident in the existing system.
7. Complete the evaluation of alternatives by estimating the full economic consequences of the hypothesized transportation improvements. This step used conventional engineering economic analysis to estimate on-system costs and benefits and simple input-output modeling to estimate the indirect impact on the local economies and to calculate the associated multipliers.

The last two tasks are discussed in greater detail in the sections that follow.

ANALYSIS OF THE ECONOMIC EFFECTS OF AN IMPROVED HIGHWAY SYSTEM

This section describes the analysis of numerous alternative highway improvements to serve the coastal study area. The consequences of these alternatives are addressed from the perspectives of direct transportation costs and user benefits and indirect benefits to the local economies.

Alternatives

The alternatives that were considered are not all practical proposals to be implemented in the near future. Rather, they are idealized improvements, devised to explore the boundaries of what could be accomplished if financial and political constraints on transportation improvements were relaxed. There is no way that such an ambitious package of improvements could be implemented under today's funding mechanisms. Also, the physical characteristics and effects of the alternatives are quite crudely specified. More in-depth feasibility analysis would be needed before reaching the "go" or "no-go" decisions for any of these proposals or portions thereof.

The transportation alternatives considered in this study are mostly spot improvements to two-lane sections of U.S. Highway 101 and all east-west highways between U.S. 101 and Interstate 5 throughout Oregon, Washington, and Northern California. These improvements are sufficient to provide Level of Service (LOS) B for projected 1990 traffic. Where necessary to achieve LOS B, some sections of U.S. 101 and some east-west highways are proposed for upgrading to four lanes, and U.S. 101 in California is shown as upgraded to a full freeway, as per current state plans. Finally, two new highways were evaluated: a new east-west highway to Gold Beach, Oreg., and a new north-south coastal link through the Quinault Indian Reservation, Wash.

It should be noted that these transportation alternatives do not address long-range opportunities for sweeping technological changes that could substantially change levels of accessibility to the coastal communities, as well as elsewhere in the nation. For example, if highways were automated and electrified employing fusion power, safe vehicle operation at speeds far greater than 55 mph could be achieved along selected access-controlled corridors. However, such possibilities, although important, were beyond the scope of the investigation.

Estimation of Direct User Benefits

Crude estimates were made of the travel time and accessibility consequences of the hypothesized improvements. It was assumed that the improvements would raise most average travel speeds from current levels, between 40 and 50 mph, to a uniform 55 mph. Target speeds were taken as 50 mph through areas with extensive roadside activities.

The fundamental conclusion from the accessibility analysis is that the effects of the improvements are in most locations not very dramatic. Table 1 summarizes the travel time changes between all coastal counties in California, Oregon, and Washington and the nearby major metropolitan areas. As can be seen, most relative improvements are less than 10 percent, and over half are less than 5 percent. The biggest improvements are in the two northernmost California counties, Humboldt and Del Norte, where travel times to San Francisco and the Central Valley improve 14 to 18 percent.

Although not very dramatic in percentage terms, because of the long trip lengths involved, the time savings in Table 1 constitute a significant direct benefit to the traveling public. This benefit is quantified in Table 2. However, this does not alter the fundamental fact that the coastal communities will continue to be physically remote from major metropolitan markets even after substantial improvements in the regional highway infrastructure.

Table 2 presents the full direct and indirect costs and benefits estimated for the highway improvements described above, grouped by highway and geographic area. The direct costs are crude construction cost estimates. User benefits include time savings, at $10 per vehicle-hour, and accident savings, using Caltrans 1987 average value of $28,500 per rural accident avoided, all discounted at 10 percent over a 20-year period (*8*). User benefits for new construction also include vehicle operating cost savings from the next best alternative route, minus annual facility maintenance costs (counted as a negative user benefit for convenience). Vehicle operating costs are not included as benefits on existing highways since the hypothesized improvements would not reduce travel distances significantly, and any operating benefits from reduced delays would be offset largely by increased operating costs from higher speeds. The analysis leading to Table 2 involves many additional assumptions and simplifications, too involved to address here; these are fully documented in the study final report.

Although Table 2 is complex, it provides one fairly simple conclusion. For a substantial portion of the hypothesized highway improvements—about half of the total mileage considered—selective upgrading is economically justified on the basis of direct highway user benefits alone. That is, expected safety benefits combined with estimated travel time savings are sufficient, over a 20-year period, to offset the capital costs of facility upgrading. This is especially true for low-cost spot improvements to mitigate inadequate geometry and improve passing opportunities, but it also applies to some upgrades from two lanes to four lanes, and for one case of new highway construction (the Quinault Tribal Highway in Washington).

In some cases in which the direct user benefits do not cover the costs, the shortfalls are made up through indirect benefits to the local economies.

Estimation of Indirect Benefits to the Local Economies

There are two categories of economic impacts of transportation projects on the affected communities. The first is the short-term consequences of the capital investments themselves, in the form of employment on construction activities and the streams of expenditures for needed materials, supplies, and equipment. (Because of the mobility of construction companies and labor, only a portion of this effect is felt locally.) The second is the permanent improvement to the local economy in the sense that improved transportation reduces some costs of doing business and increases access to customers, thereby increasing local competitiveness and raising the overall amount of economic activity, income, and jobs.

In this study, the full effects of both categories of effects were traced through the economy of each of six county groupings by means of a simple 30-industry input-output model. To drive the input-output model, it first was necessary to make estimates of the immediate (or "first-round") expansion in

TABLE 1 Travel Time Savings from Highway Infrastructure Improvements

	Principal Market Area														
	San Francisco Area			No. Sacramento Valley			Eugene			Portland			Seattle-Tacoma		
County of Production	Current Trip Time (min.)	New Trip Time (min.)	% Gain	Current Trip Time (min.)	New Trip Time (min.)	% Gain	Current Trip Time (min.)	New Trip Time (min.)	% Gain	Current Trip Time (min.)	New Trip Time (min.)	% Gain	Current Trip Time (min.)	New Trip Time (min.)	% Gain
Mendocino	215	195	9%	205	195	5%	530	520	2%	-	-	-	-	-	-
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Humboldt	400	330	18%	370	310	16%	400	390	3%	540	520	4%	-	-	-
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Del Norte	480	410	15%	430	370	14%	300	300	0%	430	430	0%	620	620	-
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Curry	570	480	16%	520	440	15%	275	250	9%	405	385	5%	593	573	3%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Coos	595	560	6%	505	505	0%	190	170	11%	320	310	3%	508	490	3%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
West Douglas	600	590	2%	510	500	2%	150	140	7%	290	280	3%	470	460	2%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
West Lane	620	610	2%	530	530	0%	130	120	8%	250	250	0%	435	430	1%
	0		0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Lincoln	-	-	-	591	581	2%	191	185	3%	201	182	10%	388	372	4%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Tillamook	-	-	-	-	-	-	261	254	3%	162	155	4%	332	323	3%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Clatsup	-	-	-	-	-	-	300	285	5%	160	155	3%	288	270	6%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Wahkiakum	-	-	-	-	-	-	290	290	0%	160	160	0%	230	225	2%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Pacific	-	-	-	-	-	-	320	320	0%	190	180	5%	195	190	3%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Grays Harbor	-	-	-	-	-	-	380	340	10%	251	244	3%	192	180	6%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
West Jefferson	-	-	-	-	-	-	450	440	2%	320	300	6%	255	235	8%
	0	0	0%	0	0	0%	0	0	0%	0	0	0%	0	0	0%
Clallam	-	-	-	-	-	-	500	490	2%	370	360	3%	265	250	6%

each local economy stimulated by the transportation improvements. This is a difficult undertaking.

In theory, for a particular basic industry, it should be possible to relate transportation improvements to reductions in the costs of doing business and then trace those reductions through to their significance for local industry competitiveness, market share, and growth in output. Unfortunately, at least for this study area, it seems the real world does not subscribe to this theory. A cross-sectional investigation of freight transportation rates in the region showed that, for most target industries, freight rates are not affected significantly by highway infrastructure quality. This is because rates are largely distance and market based, rather than cost based. Oversupply and competition for back-hauls keep actual rural trucking charges lower than would appear justified by the costs of providing these services. Also, although travel times and reliability obviously improve with better highways, the dominant service parameters of frequency and flexibility are determined largely by market factors, rather than by the quality of transportation infrastructure.

Despite the tenuous link between transportation infrastructure and economic growth when considered at one point in time, some empirical evidence suggests that, over time, there are connections between improved transportation infrastructure and increased local economic activity (*9–11*). So, what is to be done?

This study adopted and elasticity-based method to estimate the immediate (first-round) permanent economic effects of transportation improvements. The analysis was highly judgmental; however, the judgments in all cases were based on transparent assumptions and were constrained by the findings of the transportation alternatives analysis and by empirical results from other locations.

In the case of target industries in the manufacturing sector, the estimation method was as follows:

1. For each coastal county, determine the improvement in accessibility (travel time) resulting from the hypothesized transportation improvements.
2. In light of the transportation needs of particular target industries, categorize each industry as highly sensitive, moderately sensitive, or fairly insensitive to the accessibility improvement. This characterization was based in part on the results of a survey of local industries and in part on the re-

TABLE 2 Benefit-Cost Summary for Highway Infrastructure Improvement Alternatives

Route	Length of Hgwy. Upgrade (mi.)	Upgrade Type	Total Upgrade Capital Cost(1) ($ mill.)	Total User Benefit(2) (20 yr./10%) ($ mill.)	Local Economic Impact of Capital Spending (1st Five Years Only) Total Sales ($ mill.)	Total Jobs (thous.)	Total Income ($ mill.)	Total Taxes ($ mill.)	Other Local Increases in Economic Activity (After Five Years) Total Sales ($ mill.)	Total Jobs (thous.)	Total Income ($ mill.)	Total Taxes ($ mill.)	Total Local Economic Benefit(3) (20 yr./10%) ($ mill.)
NORTHERN CALIFORNIA COASTAL COUNTIES													
CA 101	99	Freeway (4)	$599.0	$288.5									
CA 299	85	Major imp.	$63.8	$52.7									
	42	Major imp.	$125.7	$17.7									
CALIFORNIA STATE TOTALS			$788.5	$358.9	$143.9	2,046	$21.3	$3.6	$187.3	4,286	$60.2	$7.7	$364.9
SOUTHERN OREGON COASTAL COUNTIES													
OR 101	44	4-lanes	$55.0	$134.3									
(5)	8	4-lanes	$40.0	$29.8									
	55	Major imp.	$41.3	$41.3									
	38	Major imp.	$114.8	$32.5									
	110	Minor imp.	$27.5	$93.4									
	50	Minor imp.	$50.0	$19.8									
OR GB	45	New 2-lanes	$360.0	$76.8									
(6)	30	New 2-lanes	$60.0	$55.4									
OR 42	19	Major imp.	$14.3	$8.8									
	42	Minor imp.	$10.5	$16.5									
SOUTHERN OREGON SUBTOTALS			$554.3	$274.6	$101.6	1,723	$14.3	$2.0	$43.3	1,019	$13.6	$1.6	$118.6
CENTRAL OREGON COASTAL COUNTIES													
OR 38	40	Major imp.	$30.0	$27.9									
	14	Minor imp.	$3.5	$4.4									
OR 126	6	4-lanes	$7.5	$10.2									
	33	Major imp.	$24.8	$23.5									
	14	Minor imp.	$3.5	$8.0									
OR 20	6	4-lanes	$7.5	$10.7									
	15	Major imp.	$45.0	$16.7									
	33	Major imp.	$24.8	$15.5									
OR 18	19	4-lanes	$23.8	$30.1									
	21	Major imp.	$15.8	$29.1									
CENTRAL OREGON SUBTOTALS			$295.5	$293.0	$53.8	901	$7.4	$1.0	$33.5	952	$10.9	$1.3	$79.3
NORTHERN OREGON COASTAL COUNTIES													
OR 6	10	Major imp.	$7.5	$6.6									
	41	Major imp.	$123.0	$29.3									
OR 26	19	Major imp.	$57.0	$9.0									
	27	Major imp.	$20.3	$21.8									
	8	Minor imp.	$2.0	$8.6									
OR 30	4	4-lanes	$5.0	$7.9									
	7	Major imp.	$21.0	$20.2									
	27	Major imp.	$20.3	$35.8									
	6	Minor imp.	$1.5	$5.5									
NORTHERN OREGON SUBTOTAL			$367.0	$261.7	$62.4	1,130	$8.4	$1.2	$18.2	341	$4.4	$0.5	$52.9
OREGON STATE TOTALS			$1,216.8	$829.3	$217.8	3,754	$30.1	$4.2	$95.0	2,312	$28.9	$3.4	$250.8
SOUTHERN WASHINGTON COASTAL COUNTIES													
WA 101	14	4-lanes	$17.3	$54.5									
	123	Major imp.	$92.3	$101.3									
	125	Minor imp.	$31.3	$37.0									
WA 4	11	Major imp.	$33.0	$7.7									
	11	Major imp.	$8.3	$4.8									
	29	Minor imp.	$7.3	$5.0									
WA 6	9	Major imp.	$6.8	$5.2									
	42	Minor imp.	$10.5	$9.3									
WA 109	14	New 2-lanes	$28.0	$60.0									
	14	Major imp.	$10.5	$6.8									
	13	Minor imp.	$13.0	$9.0									
	7	Minor imp.	$1.8	$1.7									
SOUTHERN WASHINGTON SUBTOTALS			$212.8	$238.5	$37.8	560	$5.2	$0.6	$33.5	675	$9.4	$0.9	$64.0

(continued on next page)

TABLE 2 (*continued*)

NORTHERN WASHINGTON COASTAL COUNTIES (7)													
WA 104	19	4-lanes	$23.8	$29.0									
	5	Major imp.	$3.8	$3.8									
NORTHERN WASHINGTON SUBTOTALS			$74.4	$97.3	$12.7	193	$1.7	$0.2	$18.5	388	$5.1	$0.5	$30.3
WASHINGTON STATE TOTALS			$287.3	$335.9	$50.5	753	$6.9	$0.8	$52.0	1,063	$14.5	$1.4	$94.2
GRAND TOTALS FOR 3-STATE AREA			$2,292.5	$1,524.0	$412.2	6,553	$58.3	$8.6	$334.3	7,661	$103.5	$12.5	$709.9

* The six county groups are the following:

Northern California: Mendocino, Humboldt, and Del Norte
Southern Oregon: Curry and Coos
Central Oregon: The western portions of Douglas and Lane, plus Lincoln
Northern Oregon: Tillamook and Clatsop
Southern Washington: Wahkiakum, Pacific, and Grays Harbor
Northern Washington: The western portion of Jefferson, plus Clallam

Notes:
1. All estimates are in 1986 dollars.
2. User benefits include annual travel time savings and accident reduction benefits for twenty years discounted at 10%. For new highways, the benefits include vehicle operating costs and added road maintenance costs (as a negative user benefit).
3. Total local economic benefits are the sum of the annual increases in local income from capital spending for the first five years plus the additional income from increased permanent economic activity for years 6 through 20, discounted at 10%.
4. Includes the remaining rural non-freeway gaps not already programmed for improvement (except the proposed Eureka and Crescent City freeways).
5. The costs and benefits for Hwy. 101 in Or. are split equally among the three county groups in the state. In Wa., the costs are split 2/3-1/3 between the southern and northern groups.
6. Proposed new state highway between Gold Beach and Grants Pass.
7. Cost-benefit analyses of a new Puget Sound crossing and widening the Hood Canal Bridge were beyond the scope of this study.

ported shares of transportation in each industry's cost structure, from census data (*12*).

3. On the premise that, in the long run, transportation costs should track changes in accessibility, use the percentage change in accessibility to estimate the extent to which each industry should increase its future consumption of transportation and, hence, future output and employment. Based on past experience with transportation cost and time elasticities, it seemed reasonable to assume that highly transportation-sensitive industries would have elasticities ($\ddot{Y}$) of about -1.0, that transportation-insensitive industries would have $\ddot{Y} = -0.15$, and that moderately transportation-sensitive industries would have $\ddot{Y} = -0.5$.

Besides numerous empirical studies that give remarkably consistent values for transportation elasticities, in the range suggested here, these assumptions are consistent with the findings of a recent interregional input-output modeling study for a Midwest navigation project. This project found an elasticity between transportation costs and economic output on the order of -0.5 (*13*).

Table 3 shows how this approach is applied in the case of a particular California county. The percentage travel time improvements from Table 1 are weighted by the expected destination market shares for each group of similar industries, and a weighted average accessibility increase is determined. The accessibility increase and the transportation elasticity for each target industry group are multiplied together to develop an industry group growth index. The growth indexes are then averaged in proportion to each industry group's weight for the county to produce an overall estimate of the percent employment increase in the particular manufacturing sector (durable or nondurable goods). The sector employment increases are then distributed back to the groups of target industries in proportion to the products of their growth indexes and "industry weights." The industry weight that reflects each industry group's importance to the local economy is the product of the industry size, measured by 1984 employment, and the proportion of county manufacturing growth expected to come from each industry group, determined by judgment on the basis of target industry considerations.

An important point about this approach is that all growth stimulated by transportation improvements is confined to the target manufacturing industries identified for the study area. This point probably understates the impact somewhat. This was done for convenience and with the understanding that the objective is not really prediction but rather to provide a systematic accounting of the consequences of reasonable assumptions. Because the economic growth that actually occurs will be shaped mostly by nontransportation factors, this simplification seemed appropriate.

The overall results of the analysis showed immediate employment increases in the manufacturing sectors varying from about 1 percent in counties near the Columbia River to around 6 percent in Northern California, where transportation improvements have the greatest relative impact. Through the three-state area, about 1,400 new manufacturing jobs would be created, with over 1,000 in the durable manufacturing sector. This growth is because the counties that enjoy the greatest accessibility increases happen to be those in which durable manufacturing is dominant. The industries showing the greatest immediate employment increases are manufacturers of small metal and mineral products, furniture and fixtures, and packaged food products.

A similar approach was taken in the case of increases in trade and services related to tourism and activities related to

TABLE 3 Sample Estimation of First-Round Employment Increases in the Manufacturing Sectors

	SIC Codes						SIC Codes				
	2541 2599	3441 3533 3535	3299 3499 3544 3549	3732	394	ALL DURABLE MANUF.	2022 2032	2091 2092	275	2851 3079	ALL NON-DUR. MANUF.
Relative Ind. Size	.7	1.6	1.9	.7	.4		2.6	2.6	2.9	.6	
HUMBOLDT, CA											
% Access. Increase	14.5	18.0	18.0	12.2	12.2		18.0	14.5	18.0	18.0	
Elasticity	1	.15	.5	.15	.5		.5	.5	.15	1	
Ind. Growth Index	14.5	2.7	9	1.832	6.105		9	7.25	2.7	18	
Industry Weight	.13	.31	.39	.15	.09		.65	.65	.72	.15	
1986 Employment						4,983					1,592
% Empl. Increase						6.6					7.0
Empl. Increase	90	39	162	13	25	329	43	35	14	20	112

retirement communities. Both of these industries are transportation sensitive, and new output directly stimulated by improved accessibility was therefore assumed to have an elasticity of $\ddot{Y} = -1.0$. Since the outputs in retail trade and services related to tourism and retirees are impossible to distinguish in the available data from outputs consumed by other local residents, it was assumed that 100 percent of the outputs of hotels, motels, eating and drinking establishments, and recreational services are related to tourism, and that 50 percent of the outputs in health services and membership organizations are related to retirees. Although these assumptions probably overestimate the effects involved, this overestimation is balanced by not considering the effects of tourism and retirees in other sectors and in other retail trade and service industries (e.g., purchases at stores and gas stations). The results of the analysis for retail trade and services show immediate employment increases varying between 1 percent and 7 percent, with a similar geographic pattern as manufacturing. Through the three-state area, the estimate is that about 3,800 new retail and service jobs would be created.

Since the permanent employment increases described above are seen as occurring as the result of transportation infrastructure improvements, the analysis assumed a lag of 5 years before any such increases would be realized. Thus, the associated benefits occur only in years 6 through 20 of the analysis period.

In addition to the immediate employment increases in the manufacturing, retail, and service sectors, there are also the short- term employment increases caused by the highway construction itself. It was assumed that 33 percent of the construction labor for these projects would come from the local area and that these effects would occur only during the first 5 years of the analysis period. Also, a share of the direct expenditures on highway capital improvements enters each local economy in the form of local expenditures on materials, supplies, and related items. Construction expenditures were assumed to be 43 percent on structures (bridges, retaining walls, etc.), 36 percent on paving, and 21 percent on earth moving, as assumed by the Federal Highway Administration in developing its national highway construction cost index (*14*).

All of the above immediate (first-round) effects of transportation infrastructure improvements were used as input to the input-output model, customized for each of the six groups of counties within the coastal study area. The particular software used is the Port Economic Impact Kit (PORTKIT), developed for the U.S. Maritime Administration. A detailed description of input-output models in general and the PORTKIT model in particular are available in the associated report (*15*). The full economic effects shown in Table 2 incorporate the effects of the local area economic multipliers, which account for the second, third, and subsequent rounds of growth stimulated by the transportation infrastructure improvements. As expected, the multipliers derived for the six county groupings are small compared with those of most input-output studies, because the small size and relative homogeneity of these economies result in considerable income leakage outside the local areas. All of the multipliers are less than 2.0 and most fall between 1.0 and 1.5.

CONCLUSIONS AND RECOMMENDATIONS

The following are selected conclusions and recommendations reached by this study. Each is discussed in more detail in the study's final report.

1. The greatest potential for growth among the basic industries of the coastal study area lies in presently existing small enterprises and new small businesses started either by current residents or by persons who will move into the region. Adequate transportation is an important, but not a controlling, factor in fulfilling this potential. On the other hand, improved transportation is one of the few points of leverage in local economic development that is controlled primarily by state and federal authorities outside the communities directly affected.

2. A fundamental business problem in the study area—remoteness to large markets—will not be eliminated in the foreseeable future by new highway infrastructure. Fortunately, many basic industries can prosper in the coastal communities, despite their remoteness to major markets, pro-

vided that necessary conditions exist. Among these is access to good-quality air transportation.

3. Transportation infrastructure improvements can provide large user benefits and significant economic development benefits, although the magnitude of these benefits is not large enough to justify massive rural transportation infrastructure development on the scale of interstate freeway extensions.

4. Aggressive local and state efforts are needed to help build a national coalition for national post-interstate highway and bridge infrastructure programs, as well as for complementary state infrastructure programs with the flexibility to address variable local needs and with a greater commitment of resources than is available in current highway programs. It is important for rural political leaders to play an aggressive role to ensure that rural infrastructure receives an adequate share of future funding.

5. Transportation agencies should devote more attention and resources to the need to compete for public resources and support, and they should assemble personnel skills and an organization reflecting market-oriented rather than traditional engineering-oriented strategies. In other words, transportation agencies should learn to sell more effectively the benefits of their products.

6. The potential for dramatic technological change in the interregional transportation system is important to consider in addressing the nation's long-term transportation goals.

7. Finally, there is a critical need for additional basic research, to develop a better quantitative understanding of the relationship between transportation improvements and rural economic development.

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PART 3

Socioeconomic Impacts

Effects of Elevated Heavy-Rail Transit Stations on House Prices with Respect to Neighborhood Income

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There is debate surrounding the effect on the value of single-family homes of elevated heavy-rail transit stations in residential neighborhoods. Some contend that effects are adverse because transit stations impose noise, traffic, and other nuisances on neighborhoods, which reduces house values closer to these stations. Others contend that stations improve accessibility of neighborhood residents to commercial activity centers, which results in increased house values closer to elevated transit stations. Both positive and negative influences can be present. One hypothesis is that transit stations will have a positive effect on the values of homes in lower-income neighborhoods because the benefits of transit station accessibility more than offset any nuisances. On the other hand, transit stations may have a negative effect on values of homes in high-income neighborhoods because the nuisances of transit stations more than offset the benefits. Based on a study in Atlanta, Georgia, it is shown that elevated transit stations have positive price effects on homes in lower income neighborhoods and negative price effects on homes in higher income neighborhoods. Qualifications and policy implications are offered.

ELEVATED TRANSIT STATION EFFECTS ON HOUSE VALUES

Transit stations improve the accessibility of households to the central business district and other modes of urban activity. At first glance, single-family homes should be valued higher the closer they are to transit stations (*1–8*). Alternatively, where transit stations are above ground or elevated they can be associated with nuisances such as noise and increased pedestrian and automobile traffic near the station. Single-family house values can fall the closer they are to transit stations (*9–12*). Burkhardt (*13*) and Dornbusch (*14*) report that residential properties near San Francisco Bay Area Rapid Transit (BART) stations suffered value decreases because of nuisances. Baldassare et al. (*15*) report opinion survey research showing that where transit stations are elevated above residential areas there is reduced preference for living near those stations.

According to Li and Brown (*16*), both views may be correct. Some kinds of land use activities can generate both positive and negative price effects on single-family houses. Only if one influence is greater than another would the observed effect be positive or negative. Where the benefit effects of accessibility offset the nuisance effects, the observed price effects will be positive, but the slope will be dampened by underlying nuisance effects. Where the nuisance effects of accessibility offset the benefit effects, the observed price effect will be negative, but the slope will be dampened by underlying benefit effects.

Lower income households may value differently than higher income households the accessibility to elevated transit stations. Lower income households use public and rapid-rail transit systems more than higher income households (*17*). However, there is no empirical analysis of differential price effects of elevated transit station accessibility on single-family homes with respect to neighborhood income levels. This article helps close this gap in research.

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STUDY AREA

To test the theory, there must be a study area in which the same transit station(s) can be evaluated for their price effects on the value of single-family homes in both lower and higher income neighborhoods. The study can further benefit from transit station planning and design that aims to minimize any adverse effects attributable to noise, traffic, lighting, safety, and general aesthetics or appearance. The conditions are met in one area of the Atlanta, Georgia, area: a portion of the "East Line" of the heavy-rail system run by the Metropolitan Atlanta Rapid Transit Authority (MARTA) (*18,19*).

The study area measures approximately 2.7 mi east to west by 1.7 mi north to south. Major highways define the area. The entire study area is within DeKalb County. The study area is further divided into "north" and "south" subareas divided by the MARTA track. The north subarea is predominantly white, middle class, with affluent sections. The south subarea is predominantly black, lower middle class, with low-income sections. The study area is the largest contiguous segment of the MARTA rail system accessing single-family residential neighborhoods with elevated transit stations. Three elevated stations serve this area. Those stations were constructed and opened in the late 1970s. The study area is also reasonably homogeneous in terms of housing stock age and household socioeconomic characteristics aside from various income levels observed along both sides of the tracks. This allows for relatively uncomplicated analysis of station influences.

Tables 1 through 3 illustrate north and south neighborhood socioeconomic, housing, and transit ridership characteristics. Table 1 shows that less than 10 percent of the population

TABLE 1 DeKalb County East Line Population and Household Profile

Tract	Side of MARTA	1980 Pop.	1980 Households	Black Pop.	Percent Black	Percent Black in Study Area
202	North	2,024	1,150	66	3.26%	0.66%
203	North	3,022	1,380	552	18.27%	5.50%
204	North	2,268	1,163	303	13.36%	3.02%
Summary		7,314	3,693	921	12.59%	9.18%
205	South	4,485	1,515	4,407	98.26%	43.90%
206	South	1,509	539	1,500	99.40%	14.94%
207	South	3,243	1,023	3,210	98.98%	31.98%
Summary		9,237	3,077	9,117	98.70%	90.82%

Source: 1980 Detailed Population and Housing Census, Metropolitan Atlanta, Georgia, US Bureau of the Census.

TABLE 2 DeKalb County East Line House Value and Tenure Profile

Tract	Side of MARTA	Mean Family Income	Median Occupied Unit Value	Owner Occupied	Renter Occupied	Total Units	Percent Units Owner Occupied
202	North	$33,380	$77,500	335	809	1,144	29.28%
203	North	$20,150	$42,900	846	576	1,422	59.49%
204	North	$14,912	$36,800	402	763	1,165	34.51%
Summary		$22,620	$48,673	1,583	2,148	3,731	42.43%
205	South	$12,569	$17,700	665	843	1,508	44.10%
206	South	$13,347	$16,800	176	362	538	32.71%
207	South	$11,452	$18,600	406	618	1,024	39.65%
Summary		$12,334	$17,866	1,247	1,823	3,070	40.62%

Source: 1980 Detailed Population and Housing Census, Metropolitan Atlanta, Georgia, US Bureau of the Census.

north of the MARTA tracks is black, whereas less than 10 percent of the population on the south side is white. Table 2 shows that although house values on the north side of the tracks are more than twice those on the south side, owner occupancy rates are similar. Table 3 shows that both sides of the tracks contribute equally to transit ridership, although slightly more members of the labor force residing in the south use public transit to commute to work.

MODEL AND VARIABLE SPECIFICATION

The study methodology involved collecting sales of single-family homes recorded by the DeKalb County tax assessor during 1986. The universe is composed of 286 arms-length sales of single-family homes with 170 in the north subarea and 116 in the south subarea. The empirical model used is

$$P_i = b_0 + b_j e_i - b_2 TS_i + w$$

where

p_i = market price of a transacted home (i);
e_i = vector of extraneous variables (j) affecting each transacted home (i);
TS_i = value of distance of each transacted home (i) from a neighborhood transit station in 100-ft units; and
w = the stochastic disturbance.

The study evaluates the variation in detached single-family residential property prices with respect to transit station distance. Other variables are considered part of the e_j term,

TABLE 3 DeKalb County East Line Transit Use Profile

Tract	Side of MARTA	Labor Force	Transit Commuters	Percent Transit Commuters To Labor Force	Percent Transit Commuters In Study Area By Tract
202	North	1,249	242	19.38%	16.61%
203	North	1,626	266	16.36%	18.26%
204	North	1,290	214	16.59%	14.69%
Summary		4,165	722	17.33%	49.55%
205	South	1,582	339	21.43%	23.27%
206	South	483	113	23.40%	7.76%
207	South	1,127	283	25.11%	19.42%
Summary		3,192	735	23.03%	50.45%

Source: 1980 Detailed Population and Housing Census, Metropolitan Atlanta, Georgia, US Bureau of the Census.

including

- Square footage of both house and lot;
- Number of bathrooms and the number of stories;
- Presence of basement and foundation, the number of fireplaces, whether the house was situated on a corner lot, the presence of central air conditioning, whether the house was adjacent to a park, and the location inside the city of Decatur; and
- Household income and minority percent status at the census tract level based on the 1980 Census of Population and Housing.

House and lot size are used as controls. A positive association is expected.

Distance to the nearest MARTA station is measured in 100-ft units. The nonlinear term for station distance is computed as the square of distance. The quadratic specification allows one to detect convex or concave relationships. For the south subarea, the functional relationship between transit station proximity and sales price is hypothesized to be concave; the first-order sign will be negative and the second-order sign will be positive. For the north subarea, the functional relationship is hypothesized to be convex; the first-order sign will be positive and the second-order sign will be negative.

Distance to the central business district is typically included in housing price equations as a measure of relative locational advantage (*16*). A variable of the distance to the central business district is not included here because the entire study area lies approximately 3 to 5 mi from downtown Atlanta, making differences between sites small and because the travel time between stations is only 2 to 4 min.

Being adjacent to a park in this study area will be negatively associated with house value. The few parks in this area are large urban parks attracting thousands of users during sunny days. Parking, litter, loitering, and other nuisances affect adjacent homes.

Various house attributes will have a positive association with house values, including the presence of basement and foundation, the number of fireplaces, whether the house was situated on a corner lot, and the presence of central air conditioning.

Income is associated with minority status. In the study area, the higher the median household income of a census block group the lower the percent of households classified as minority by the census for 1980. In the south subarea, census block group incomes ranged from a low of about $9,400 with nearly 100 percent minority households to a high of about $14,000 with seven-eighths minority households. For the north subarea, census block group incomes ranged from a low of about $13,000 with one-sixth minority households to a high of more than $30,000 with 1 percent minority households. Although income is a proxy for both income and minority status, both are considered. The writer hypothesizes that income will be positively associated with house price in both the north and south subareas, but that percent minority population will have a negative association with house price in the north and a positive association in the south. Location inside the city of Decatur is used as a control, although most minority populations of the study area reside there.

Ordinary least-squares regression is used. The linear specification is used except that distance to MARTA stations is specified as quadratic and noninterval relationships are specified as binary (1,0). Except for control variables, only variables performing as hypothesized are used in final regression equations.

RESULTS

Regression results for south and north subareas are presented in Tables 4 and 5, respectively. All coefficients of non-control variables significant at the 0.10 level of the one-tailed *t*-test have the expected signs.

TABLE 4 Regression Results and Equation of South Side Home Sales

DEPENDENT VARIABLE:	Sales Price ($1)
NUMBER OF CASES:	116
MULTIPLE R:	0.622
SQUARED MULTIPLE R:	0.387
ADJUSTED SQUARED MULTIPLE R:	0.342
STANDARD ERROR OF ESTIMATE:	9444.472
F-RATIO	8.455

VARIABLE	COEFFICIENT	STD ERROR	T-Score
Constant	-30543.674	39944.629	-0.765
House Size, square feet	11.446	3.241	3.531*
Lot Size, square feet	0.421	0.276	1.525*
Basement (1,0)	6062.616	2520.597	2.405*
Location in Decatur City	10411.601	3653.165	2.850*
Census Tract Income, 1980 ($1)	0.593	0.307	1.931*
Census Tract Minority %, 1980	590.018	396.849	1.487*
Distance from Station, 100 ft units	-1045.601	227.434	-4.597*
Distance from Station, squared	15.559	3.480	4.471*

*Significant at 0.10 level of one-tailed test.

TABLE 5 Regression Results and Equation of North Side Home Sales

DEPENDENT VARIABLE:	Sales Price ($1)
NUMBER OF CASES:	170
MULTIPLE R:	0.778
SQUARED MULTIPLE R:	0.605
ADJUSTED SQUARED MULTIPLE R:	0.566
STANDARD ERROR OF ESTIMATE:	16357.358
F-RATIO	15.701

VARIABLE	COEFFICIENT	STD ERROR	T-Score
Constant	-4332.749	11823.430	-0.366
House Size, square feet	16.604	4.212	3.942*
Lot Size, square feet	0.200	0.192	1.045
Number of Stories	17896.569	6673.252	2.682*
Adjacent to Park (1,0)	-12051.036	5842.202	-2.063*
Foundation Present (1,0)	7113.912	3619.723	1.965*
Central Air Conditioning (1,0)	7561.525	5064.175	1.493*
Corner Lot (1,0)	-7600.764	4245.001	-1.791*
Number of Fireplaces	3646.128	2734.720	1.333*
Basement (1,0)	3865.805	2995.300	1.291*
Number of Full Bathrooms	4097.538	2694.691	1.521*
Location in Decatur City	-18050.796	4875.782	-3.702*
Census Tract Income, 1980 ($1)	1.921	0.437	4.398*
Census Tract Minority %, 1980	-220.435	126.083	-1.748*
Distance to Station, 100 ft units	965.724	633.330	1.525*
Distance to Station, squared	-23.156	15.600	-1.484*

*Significant at 0.10 level of one-tailed test.

South Subarea

The regression results for the south subarea show the variables performing as hypothesized. They are house size, lot area, house age, presence of a basement, census block group minority percent, and census block group income. Distance from elevated transit stations is significantly associated with house value in the theorized manner. The farther a house is from an elevated transit station, the lower its value. The quadratic terms shows a concave relationship, as hypothesized.

North Subarea

The regression results for the north subarea show the variables performing as hypothesized. They are house size, number of stories, proximity to park, foundation, central air conditioning, location on corner lot, number of fireplaces, basement, number of full bathrooms, percent of census block group population that is minority status, and census block group income. Distance from elevated transit stations is significantly associated with house value in the theorized manner with respect to the first-order relationship. The farther a house is from an elevated transit station, the higher its value. The relation of house value to distance from an elevated heavy-rail station is convex, as hypothesized.

INTERPRETATION AND POLICY IMPLICATIONS

There are two interesting sets of interpretations. The first concerns the condition under which positive and negative price effects can be generated by the same transit stations on single-family homes in neighborhoods of varying income levels. The second concerns the relationship between neighborhood income levels and transit station accessibility in terms of price effects.

Positive Price Effects

Among homes in the south subarea, the results show that elevated heavy-rail transit stations have a positive price effect on houses. Where households depend on rail transit because of income, one could generalize these results to suggest that price effects will be positive. The extent to which the observed price effects are dampened by nuisance effects cannot be determined for reasons explained by Li and Brown (*16*). On the other hand, one must consider that nuisance effects may be minimized because of special design and planning by MARTA to protect neighborhoods from adverse effects (*18,19*).

Negative Price Effects

Results for the north subarea show that transit station proximity is associated with negative price effects on home sales. The analysis suggests that among higher-income neighborhoods, transit stations may reduce values of nearby homes. It is possible that some or all of this effect is associated with distance from minority-dominated neighborhoods. This writer cannot say for sure whether observed effects are related to transit station distance or distance from minority-dominated neighborhoods. On the other hand, a large number of control variables were employed, including census block group income and minority percent and location inside the city of Decatur. Moreover, results are as hypothesized. A final consideration is that both north and south neighborhoods contribute equally to public transit ridership. Nonetheless, more research is needed where interaction between neighborhoods of various minority composition can be controlled. This writer therefore suggests that, until such research is done, one cannot say for sure that results reported here can be generalizable.

Policy Implications

Elevated heavy-rail transit stations will have negative price effects on homes if they are associated with noise, traffic, and other forms of nuisance. They will have positive price effects if they are associated with improving the accessibility of residents to opportunities found throughout the urban area. In lower-income neighborhoods, the price effect will be positive. That is, the closer to a station a single-family home is located, the higher its sales price, all other factors considered. The benefit effects of accessibility more than offset any nuisance effects, at least among lower value homes in lower income neighborhoods. In higher income neighborhoods, transit station proximity may be associated with lower home value. Higher value homes may be more sensitive to nuisance effects than by improvements in accessibility. Rapid-rail transit authorities need to be aware of these differential influences to anticipate the effect of elevated heavy-rail transit stations in residential neighborhoods.

A simple benefit-cost relationship can be constructed from the first-order coefficients on the distance-from-MARTA-station variable. With the use of simplified assumptions and first-order coefficients, total estimated benefits accruing to the south subarea are about $10 million. This is the aggregated value created by improving accessibility through elevated heavy-rail transit. Total estimated losses accruing to properties in the north subarea are in the order of $9 million. However, until there is research that can better control for interaction effects between neighborhoods of varying minority composition, these negative benefits must be viewed with skepticism.

The research suggests that substantial social benefits may be realized by placing elevated heavy-rail transit stations in areas that will positively capitalize on the presence of the facility.

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Modeling Spatial Impacts of Siting a NIMBY Facility

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In the new era of environmental and growth management concerns, the task of locating a socially undesirable facility, such as a solid waste management (SWM) facility, encompasses not only minimizing cost objectives, but also minimizing the effects on and opposition from residential neighborhoods. Survey research on awareness of the existence of such facilities, contemporary attitudes toward solid waste management facilities and their impacts and preferences for various facility attributes, such as number and size, are discussed. In addition, a distance decay effect of people's attitudes toward both existing and to-be-built SWM facilities is identified. These distance-decay results contribute to the literature on the spatial extent of perceived impact of and opposition to undesirable facilities, especially for previously unstudied transfer stations. The data collection and analysis methods selected for this study are discussed. Several binomial and multinomial logit models were developed to model the spatial effects of siting SWM facilities. The most prominent effect of an SWM facility was determined to be the perceived threat to residential property value. Other perceived effects, such as quality of life, traffic accidents, and relocation, did not seem to have a major effect on people.

A solid waste management (SWM) facility, popularly known as a transfer station, can be defined as a NIMBY (not in my back yard) or undesirable facility because people do not want them located nearby. A transfer station is a transshipment point between refuse collection points and final disposal sites. It has been demonstrated in past research (*1*) that a solid waste collection system can be made efficient by locating transfer stations within a city or region in which collection vehicles can transfer their loads to large-size transport vehicles.

The undesirable characteristics of a transfer station primarily affect the individuals in the host community who are located near them. These effects include noisy and possibly dangerous movement of the collection and transfer vehicles, odor pollution at the transfer site, and reduced property value caused by negative perceptions of image or risk or both. These effects depend mostly on the design and operational characteristics of a particular facility.

The location of transfer facilities presents spatial conflicts among the areas served by the facility. For example, a transfer station should typically be located near a given set of refuse collection points to achieve cost-efficiency. Simultaneously, it should be located far enough from the residential areas to minimize real or perceived population impacts and potential opposition. Clearly, these two objectives pose spatial conflict and thus require some trade-offs for finding a compromise location. Rahman (*2*) developed and implemented a model to resolve such facility location problems through the use of multiobjective programming. This paper reports on the part of that effort where distance-based logit equations were developed from survey results, in part to provide input into the opposition-minimizing objective.

This research contributes empirical results to an emerging paradigm in which public opposition is considered in location modeling through maximization of distance-related measures. Erkut and Neuman (*3*) recently published an invited review of the literature on models for locating undesirable facilities. These papers assume a variety of ways to make operational this concept of putting the facilities far from the residential population. Some maximize the average separation distance, some maximize the minimum separation distance, and others minimize the number of people within some critical distance or impact radius. Of the 64 modeling papers reviewed by Erkut and Neuman, none, so far as we know, bases their considerations on any empirical results regarding the spatial extent of negative effects around a NIMBY facility.

A review of existing literature reveals that the empirical studies on the impact of undesirable facilities have thus far focused on estimating actual residential property-value depreciation, with relatively little information concerning perceived effects and their spatial distribution. Also, the impacts of transfer stations have rarely been studied. Zeiss and Atwater (*4*) reviewed 13 empirical studies to determine property value impacts around landfill and incinerator sites. Most of these studies investigated property sale prices around either landfills or power plants and then made comparisons of prices from control locations to identify any trend in property-value differential. One study mentions Price, as quoted in Zeiss and Atwater (*4*), and included transfer stations in an investigation of the property-value depreciation. The findings of these studies are mixed and show no consistent trend of positive or negative effects on property values. In another paper dealing with incinerator impacts, Zeiss (*5*) reported weak correlation between the number of days required to sell properties and the distance from the incinerator. All these studies primarily dealt with the subject of actual property-value impact by investigating actual property sale prices and did not study the perceived property-value impact. However, recent research (*6*) shows that perceived property value impacts exist among

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host community residents, and monetary compensations often may not be enough for acceptance of waste disposal facilities. The research reported in this paper covered the topic of perceived property value impact and its spatial distribution.

Some prior studies (*7*) investigated the spatial distribution of perceived risks and perceived benefits. However, these studies were associated with hazardous waste facilities and industries handling toxic materials. The findings were presented in terms of cumulative percentages of persons willing to live at various distances from the hazardous facilities. No attempt was made to fit any distance-decay equations to the data sets.

Another research direction in undesirable facility location modeling (*8*) has been the effect of facility scale on opposition and the related notion of risk sharing among many smaller facilities. In this paper, we present some preliminary, although inconclusive, empirical results relating to these ideas.

RESEARCH OBJECTIVES

The research reported in this paper was undertaken to gain a sense of contemporary attitudes toward solid waste management facilities and to test some hypotheses on preferences for various facility attributes. The five main hypotheses tested in this research are as follows:

1. People perceive negative impacts of SWM facilities relating to traffic accidents, property values, and quality of life.
2. The negative attitudes people have toward SWM facilities decay with increasing distance from the facilities.
3. Awareness of the existence of SWM facilities declines with increasing distance from the facilities.
4. People would prefer small-sized SWM facilities dispersed in several communities over a single large facility.
5. People would prefer temporary SWM facilities over permanent ones.

The second hypothesis listed above represents the focal point of this research and was intended to explore whether or not a distance decay effect existed for people's negative attitudes toward an SWM facility. The motivation came mainly from the need for an appropriate distance-based objective function for the location problem.

Two attitudinal surveys were conducted to investigate negative public perceptions surrounding an existing small-size (300 tons/day) SWM facility in the city of Glendale and to a to-be-built facility in the city of Phoenix. Two surveys were conducted to offer two tests of the hypotheses.

The Glendale facility is located in the city's office yard and has been operational for the last 15 years. The selected site for the Phoenix SWM facility, known as the Southwest Transfer Station, is near the city's 27th Avenue landfill. Soon Phoenix will use its new landfill, 45 mi southwest of the current landfill.

DATA COLLECTION

The data for this study were collected in two telephone surveys conducted in Glendale and Phoenix, Ariz. The focus population group in Glendale consisted of those living close to the existing solid waste management facility. For the Phoenix survey, the focus was on those living close to the site on which such a facility was to be constructed about 1 year after the survey. Each survey covered six census tracts surrounding the facilities. A demographic profile of these census tracts is presented in Table 1.

The final sample sizes achieved were 294 for the Glendale survey and 254 for the Phoenix survey. These samples provided estimates on population proportions with certain characteristics accurate to within 6 percent at 95 percent confidence level.

Cole's reverse telephone directory (*9*) was used to generate the sampling pool. The sampling method used for this study can be termed "proportionate stratified sampling," in which a strata is a population subgroup defined over census tracts. The sample needed to be stratified by census tracts because separate lists are available in the *Cole's Directory* for each census tract, and it was easier to draw separate samples than to combine the lists.

The items in the surveys can be categorized into the following four groups:

1. Awareness about the facility: one question to determine whether the respondent has previous knowledge of the facility.
2. Measure of potential opposition (MPO) for a new SWM facility: one question measuring perceived comfortable dis-

TABLE 1 Census Tract Statistics

Census Tract No	Wealth Rating	Median Age	Median # Persons per H.H.	% Owner Occupied H.H.	Median Yrs in School	Total Res. H.H.	Total Business
(a) City of Glendale							
926	2	50	2.3	53	12.1	911	317
928	1	42	2.7	45	12.3	1,821	136
923.02	4	39	2.9	79	12.9	3,264	160
925	1	54	2.5	60	12.2	1,149	538
923.01	3	42	2.4	57	12.6	3,999	297
927.02	3	37	3.0	45	12.5	2,324	282
All six	2.3	44	2.6	59	12.4	13,468	1,730
(b) City of Phoenix							
1147	1	43	3.5	38	7.4	750	438
1144	1	46	2.9	48	9.3	1,029	168
1148	1	51	3.0	62	9.0	816	262
1156	2	37	4.3	86	12.5	452	21
1127	1	43	3.2	57	11.5	1,336	221
1125.04	3	43	2.9	78	11.8	2,788	899
All six	1.5	44	3.3	64	10.3	7,171	2,009

SOURCE: COLE'S DIRECTORY, 1990
NOTES:
1. Wealth Rating is based on a 1 to 5 scale, 5 being the most wealthy and 1 being the least.
2. H.H. is Household

tance (PCD) in miles for locating a new SWM facility. MPO was defined to be the square root of PCD [i.e., MPO = SQRT (PCD)].

3. Attitudes: four attitudinal questions regarding how people have felt or experienced the actual effects of an SWM facility, or how people believe or perceive the effects of a to-be-built facility.

4. Opinions: two opinion-type questions regarding people's preferences about size and dispersed location, and temporary versus permanent facilities.

The questions were asked rather than read as statements. It was determined during pretesting of the questionnaire that if an item is written as a statement and read to the respondent and the respondent is asked about the extent to which they agree or disagree, then the respondents' understanding seems to be slower and more error prone. As a result, the attitudinal responses were recorded as binary data (yes or no), but provisions were made for enthusiastic answers such as "strong yes" or "strong no" and for neutral "don't knows."

The response rates for the two surveys were moderate in various census tracts ranging from 20 percent to 47 percent. The average rates were 37.8 percent for the Glendale survey and 41.1 percent for the Phoenix survey. The Phoenix survey was conducted after the Glendale survey. As a result, higher response rates for the Phoenix survey may partly be attributed to interviewer's learning curve and partly to familiarity of local people with the Phoenix project.

The fourteen survey variables that were defined for the purposes of model fitting and data analysis are listed in Table 2. Since the surveys included four questions about negative impacts (ACC, PVAL, QLIFE, and MOVE), three new variables were created by aggregating three of them (PVAL, QLIFE, and MOVE) in various combinations. These "potential opposition measures" (POMs) were created to ascertain a multifaceted attitude toward transfer stations as a function of distance. POM1 represents addition of all three variables together; POM2 represents addition of PVAL and QLIFE; and POM3 represents addition of QLIFE and MOVE. These three variables have multiple ordinal values ranging from 0 to 3, where 0 means no negative attitudes toward an SWM facility, 1 means one negative response, and so on. The variable RDIST was used as an independent variable in the model fitting process. This variable represented survey respondent's rectangular distance from the facility. The rectangular metric was selected for the RDIST variable to emulate the grid street network of Phoenix and Glendale.

The response to the first question—previous knowledge of the facility—was used to divide the respondents into two groups. If the response is yes, answers to the attitudinal questions can be taken as attitudes based on some experience with the SWM facility. On the other hand, if the response is no, answers can be taken as attitudes based mostly on perceptions about an SWM facility. In this paper, the complete set of respondents is designated ALL, whereas those with previous knowledge are called HB (heard before) respondents, and those without previous knowledge are called NHB (never heard before) respondents. These two data sets further facilitated the investigation of the distance decay effect on two population subgroups, classified based on awareness.

TABLE 2 Survey Variables

Variable Name	Description
CT	Census tract
SEX	Gender of survey respondent
AWARE	1 if respondent is aware of the facility, 0 otherwise
ACC	1 for a 'yes' response to the question whether traffic accidents will increase due to a transfer facility; 0 for a 'no'
PVAL	1 for a 'yes' response to the question whether property value will go down due to a transfer facility; 0 for a 'no'
QLIFE	1 for a 'yes' response to the question whether quality of life will go down, 0 for a 'no'
MOVE	1 for a 'yes' response to the question whether one would like to move away due to the facility; 0 for a 'no'
DISPERSE	1 for a 'yes' response favoring dispersed small facilities over a single large one; 0 for a 'no'
TEMP	1 for a 'yes' response favoring the concept of having a temporary or periodic or portable facility; 0 for a 'no' response or favoring a permanent facility
PCDIM	Perceived comfortable distance in miles
POM1	Potential opposition measure 1 defined by aggregating the attitudinal responses to PVAL, QLIFE, and MOVE
POM2	Potential opposition measure 2 defined by aggregating the attitudinal responses to PVAL and QLIFE
POM3	Potential opposition measure 3 defined by aggregating the attitudinal responses to QLIFE and MOVE
RDIST	Rectangular or Manhattan distance of survey respondent from the facility site

METHODOLOGY

Because the response variables were binary (0-1) and the POM variables were integer, logistic regression methods available in the SAS (*10*) statistical software was used. In logistic regression, a discrete variable is converted into a continuous variable by using a cumulative probability function. For example, the discrete response to the property value impact question is converted into a continuous response by taking the probability of getting a positive response. Thus, the main objective in logistic regression is to find an appropriate functional form to estimate this probability. The probability function of a logit model is called the logistic function. In logit models, the dependent variable is the log odds ratio that a particular event will occur given specific values of the explanatory variable.

The logistic function is written as

$$E(Y = 1|x) = p = \exp\{g(x)\}/[1 + \exp\{g(x)\}] \qquad (1)$$

where

$E(Y = 1|x)$ = probability (p) that $Y = 1$, that is, the probability of getting a positive response given the value of independent variable x; and $g(x)$ = logit transformation or link function.

The logit link function is written as

$$g(x) = b_0 + b_1 * x = \ln[p/1 - p] \qquad (2)$$

where

ln = natural logarithm,
b_0 = constant coefficient, and
b_1 = slope coefficient of the independent variable.

In this research, several binomial and multinomial logit models were estimated for various dichotomous and polytomous response variables used in the attitudinal surveys. For most of the models reported here, appropriate logistic functions were used to determine probabilities of getting a positive response to the attitudinal questions.

Once a particular logistic regression model is fitted using the maximum likelihood estimation (MLE) method, the next step in analysis is to assess the significance of the independent variable in the model. This step is performed by checking the p-values of two criteria: the 2 log likelihood, and the score test. These two criteria give statistics and tests for the effects of the independent variable in the model (*11*). In this paper, distance from the facility (RDIST) is the only independent variable considered.

DATA LIMITATIONS

The listing-based sampling usually generates noncoverage bias caused by unlisted numbers or households without telephones. This research assumed that noncoverage bias in the surveys would not significantly alter the results.

The survey questionnaires did not include any socioeconomic type questions for several reasons. First, the main objective of the survey was to complement the facility location modeling process by exploring empirically the nature of a distance decay function representing people's opposition. Second, the surveys were not intended to explore relationships of NIMBY attitudes with demographic variables. Finally, the surveys were not intended to compare the Phoenix with the Glendale case. As such, inclusion of demographic variables in the surveys was not viewed as very critical. However, for interested readers, general demographic data on the two study areas have been provided in Table 1.

The sample sizes of the Glendale and Phoenix surveys provided estimates on population proportions with certain attitudes within an accuracy range of plus or minus 6 percent at 95 percent confidence level. However, two estimates had a higher error range of plus or minus 10 percent because of lower response rates for two specific questions. These two estimates are (a) population proportion in Glendale favoring dispersed small-sized transfer facilities and (b) perceived comfortable distance in Phoenix. These accuracy ranges are based on all surveys responding to a particular question. When the survey samples were divided into HB and NHB groups for regression analysis, the sample size for the HB group was considerably smaller than that for the NHB group. As a result, the HB data sets are treated separately from the NHB sets, then the error range increases to plus or minus 12 percent for the HB data sets and plus or minus 7 percent for NHB data sets at 95 percent confidence level. These error ranges were thought to be acceptable for this exploratory type research.

RESULTS

The Glendale Survey

The Glendale response profile is give in Table 3. Note that 78 percent of the respondents never heard about the facility before, and only 22 percent of the respondents were aware

TABLE 3 Response Summary of Glendale Survey

Survey Questions / Response Categories [1]	Percent of Respondents[a] by Census Tract 926 [2]	928 [3]	923.02 [4]	925 [5]	923.01 [6]	927.02 [7]	All [8]
When did you first hear about the facility?	(85)[a]	(54)[a]	(81)[a]	(23)[a]	(24)[a]	(26)[a]	(293)[a]
Today	68	82	83	91	79	77	78
Heard Before	32	18	17	9	21	23	22
How far in miles would it have to be to feel comfortable?	(85)[a]	(54)[a]	(82)[a]	(23)[a]	(24)[a]	(26)[a]	(294)[a]
0< mi <=3	28	14	16	13	13	16	19
3< mi <=10	35	59	43	48	34	50	44
mi >10	33	25	39	31	45	34	34
Don't Know	4	2	2	8	8	0	3
Do you believe that traffic accidents will increase?	(85)[a]	(54)[a]	(82)[a]	(22)[a]	(24)[a]	(26)[a]	(293)[a]
Yes	17	11	12	23	17	23	15
No	78	85	78	73	62	65	77
Don't Know	5	4	10	4	21	12	8
Is it likely that property values will decrease?	(85)[a]	(54)[a]	(82)[a]	(22)[a]	(24)[a]	(26)[a]	(293)[a]
Yes	47	52	51	50	63	54	51
No	50	46	34	50	17	39	41
Don't Know	3	2	15	0	20	7	8
Do you think quality of life will go down?	(85)[a]	(54)[a]	(78)[a]	(22)[a]	(24)[a]	(26)[a]	(289)[a]
Yes	12	13	5	14	17	8	11
No	83	87	94	77	83	92	87
Don't Know	5	0	1	9	0	0	3
Want to move away?	(85)[a]	(54)[a]	(82)[a]	(22)[a]	(24)[a]	(26)[a]	(293)[a]
Yes	8	15	9	27	13	8	12
No	86	85	89	73	87	92	87
Don't Know	6	0	2	0	0	0	2
Do you favor small dispersed facilities or single large?	(33)[a]	(38)[a]	(2)[a](5)[a]	(16)[a]	(21)[a]	(115)[a]	
Dispersed Small	55	79	50	80	31	29	56
Single Large	24	8	50	20	38	38	23
Don't Know	21	13	0	0	31	33	21
Are you in favor of temporary type facility or permanent?	(85)[a]	(54)[a]	(82)[a]	(22)[a]	(24)[a]	(25)[a]	(292)[a]
Temporary	50	63	47	36	12	20	45
Permanent	23	26	25	50	71	64	34
Don't Know	27	11	28	14	17	16	21

[a] Numbers in parentheses are respective sample sizes.

of the facility. Most Glendale respondents chose a range of 5 to 10 mi for their perceived comfortable distance from an SWM facility. When asked whether traffic accidents will increase because of a transfer station, almost 77 percent of the respondents said no and only 15 percent said yes. On the contrary, when asked whether property values will go down due to a transfer facility, 51 percent said yes and 41 percent said no. For the quality-of-life and move-away questions, a clear majority (87 percent) said no, indicating no perception of stress or threat to their quality of life in the community because of an SWM facility. Glendale respondents preferred the idea of having temporary or periodic SWM facilities over permanent facilities by a 45 percent to 34 percent margin. Again, 56 percent of respondents were concerned about size of the facility and were in favor of small-size facilities dispersed in many communities. Only 23 percent were in favor of a single large facility.

The regression analysis produced a number of significant models. These distance-based logit models, estimated from the Glendale attitude data, are presented in Table 4. The table also presents the p-values of the two criteria of model goodness-of-fit, and the p-value of the slope parameter estimate of the regressor variable RDIST. Low p-value (less than 0.05) for the parameter estimate indicates that the estimate is significant. Low p-values for the -2 log likelihood and the score statistic indicate that the effect of RDIST in the model is significant.

The first two models presented in Table 4 correspond to the response variable PVAL and describe the probability that respondents will show concern regarding the impact of property value given information about the distance of their homes from the existing location of the Glendale transfer facility. The first model was estimated using the data set HB, and the second model was estimated using the data set ALL. Note that the first PVAL model has a larger slope coefficient (0.2833 vs. 0.1336), which indicates that distance causes a higher rate of change in the property value attitude for the HB group. Observe that in both models, the estimated slope coefficient has a positive sign. The positive sign of association indicates that as distance from the transfer facility increases, so do the people's concern about the impact on property value. This association is an interesting finding because typically one would expect to see a negative association between distance and the impact on property value. A possible explanation for this unanticipated result is that most of the survey respondents who live close to the transfer facility either live in mobile trailer home parks or in low property-value areas and thus showed little concern about the property-value impact. In contrast, survey respondents who are far away from the facility live in relatively high property-value areas and logically showed more fear or concern about the property-value impact associated with a transfer facility. This fact provides one explanation for positive association between the two variables PVAL and RDIST, but there may also be other reasons that could not be identified with the survey.

The models for response variable ACC (increased traffic accidents) presented in Table 4 have negative signs on the slope coefficients, indicating a negative association between ACC and RDIST. The negative sign indicates that as the distance from the facility increases, the odds decrease of expressing concern about the impact of accidents. This model along with other distance-decay models estimated from the Glendale survey data are plotted in Figure 1. It is evident that

TABLE 4 Logit Models Estimated from Glendale Data

No	Survey Response Variable	Data Set	Estimated Regression Model	p-value of -2 Log L[a]	p-value of Score[a]	p-value of slope Estimate[b]
			(a) Binomial Logit Models[g]			
1	PVAL	HB[c]	ln [p/1-p] = 0.2833 x RDIST	0.0401	0.0432	0.0498
2	PVAL	ALL[e]	ln [p/1-p] = 0.1336 x RDIST	0.0359	0.0364	0.0376
3	ACC	HB[c]	ln [p/1-p] = -0.4236 x RDIST	0.005	0.0065	0.0102
4	ACC	NHB[d]	ln [p/1-p] = -0.9489 x RDIST	0.0001	0.0001	0.0001
5	AWARE	ALL[e]	ln [p/1-p] = -0.6305 x RDIST	0.0001	0.0001	0.0001
6	QLIFE	HB[c]	ln [p/1-p] = -0.9646 x RDIST	0.0001	0.0001	0.0001
7	QLIFE	NHB[d]	ln [p/1-p] = -1.416 x RDIST	0.0001	0.0001	0.0001
8	MOVE	HB[c]	ln [p/1-p] = -0.8623 x RDIST	0.0001	0.0001	0.0002
9	MOVE	NHB[d]	ln [p/1-p] = -1.1842 x RDIST	0.0001	0.0001	0.0001

[a] Criteria for assessing model goodness-of-fit.
[b] Maximum likelihood estimate of the slope parameter of the logit link function
[c] HB stands for 'Heard Before' referring to the data set which contains only those survey respondents who heard before about the transfer facility.
[d] NHB stands for 'Never Heard Before' referring to the data set which contains only those survey respondents who never heard before about the transfer facility.
[e] ALL refers to the data set which contains all survey respondents.
[f] Intercept estimate p-value.
[g] Probability of a yes outcome is denoted by p.

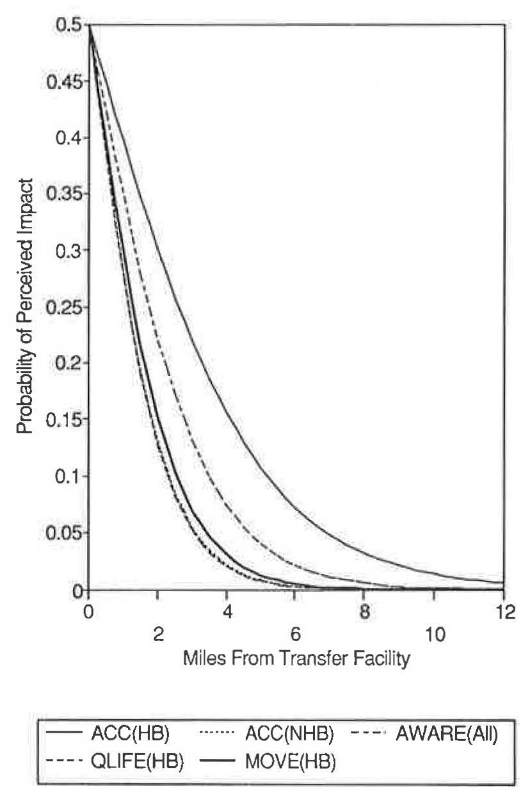

FIGURE 1 Distance-decay models estimated from Glendale survey.

the traffic accident impact to the HB group is mostly significant within 10 mi of the facility, whereas for the NHB group the impact is significant only within 4 mi. Beyond these distance estimates, the accident impacts are relatively constant and small.

The next hypothesis concerned how people's awareness about the facility (AWARE) varied by the distance (RDIST). The estimated binomial logit equation (presented in Table 4) shows that as distance increased, people's awareness seems to have dropped. The public awareness about the facility faded away beyond 6 mi from the facility.

The QLIFE and MOVE impacts are more significant for people who heard about the facility before than for those who never heard before. However, the impacts are not significant beyond 4 mi from the facility.

The Phoenix Survey

The Phoenix response profile is presented in Table 5. The majority (76 percent) of respondents never heard about the Phoenix southwest transfer facility project, and only 24 percent were aware of the project. These statistics on facility awareness are not radically different from those of Glendale. In contrast to Glendale, the Phoenix survey had a higher proportion of respondents who were in favor of a "single large" type facility, and only 18 percent were in favor of "dispersed small facilities." Also, in contrast to the Glendale survey, more Phoenix respondents favored the permanent type facility, and fewer liked the temporary concept. This difference in opinion structure between the two survey areas might partly be attributed to Phoenix respondents' bias toward the recent political decision by the City of Phoenix to have a single large facility. Other contributing factors may well be the differences in demographics between the two cities, which were not investigated in the surveys, or lack of understanding of the tradeoffs involved. The Phoenix responses to the attitudinal questions were similar to those of Glendale in the sense that most people singled out the property value impact as the most negative feeling associated with an SWM facility. Other factors, such as traffic accidents, quality of life, and relocation desire did not prove to be major concerns to the majority of respondents.

The Phoenix data were further investigated using logistic regression analysis to identify general associations between the survey attitudinal variables and RDIST. The logit models that were estimated from the Phoenix data are presented in Table 6. The plots of these equations are presented in Figure 2.

The first regression model presented in Table 6 describes log odds of PVAL as a function of the variable RDIST for the data set HB. Observe that the concern for the property value impact increases as distance from the facility increases. This relationship among the Phoenix survey respondents is similar to that among the Glendale survey respondents. The second PVAL model was estimated from the data set ALL and has a flatter slope compared with that of the first model.

The third and fourth regression models presented in Table 6 describe log odds of the relocation impact (MOVE) as functions of RDIST. The third model has a smaller negative slope coefficient than the fourth model, which implies that the prob-

TABLE 5 Response Summary of Phoenix Survey

Survey Questions / Response Categories [1]	Percent of Respondents[a] by Census Tract 1147 [2]	1144 [3]	1148 [4]	1156 [5]	1127 [6]	1125.04 [7]	All [8]
When did you first hear about the facility site?	(56)[a]	(46)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(253)[a]
Today	82	67	85	74	80	71	76
Heard Before	18	33	15	26	20	29	24
Comfortable with the new site at 27th Ave & Lower Buckeye?	(56)[a]	(46)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(253)[a]
Yes	70	67	61	55	51	58	61
No	30	33	39	45	49	42	39
How far in miles would it have to be to feel comfortable?	(17)[a]	(15)[a]	(13)[a]	(14)[a]	(19)[a]	(20)[a]	(98)[a]
0< mi <=3	0	0	0	7	0	0	1
3< mi <=10	18	27	8	36	10	0	15
mi >10	76	73	92	57	90	100	83
Don't Know	6	0	0	0	0	0	1
Do you believe that traffic accidents will increase?	(56)[a]	(45)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(252)[a]
Yes	20	31	30	35	34	25	28
No	75	64	67	65	51	67	66
Don't Know	5	5	3	0	15	8	6
Is it likely that property values will decrease?	(56)[a]	(45)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(252)[a]
Yes	52	73	55	61	59	56	59
No	36	20	36	32	29	42	33
Don't Know	12	7	9	7	12	2	8
Do you think quality of life will go down?	(56)[a]	(45)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(252)[a]
Yes	9	16	12	7	13	19	13
No	87	84	88	90	82	81	85
Don't Know	4	0	0	3	5	0	2
Want to move away?	(56)[a]	(45)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(252)[a]
Yes	9	2	3	10	10	10	7
No	89	96	94	90	87	88	91
Don't Know	2	2	3	0	3	2	2
Do you favor small dispersed facilities or single large?	(56)[a]	(45)[a]	(33)[a]	(31)[a]	(39)[a]	(48)[a]	(252)[a]
Dispersed Small	21	22	12	16	13	21	18
Single Large	45	47	58	48	46	46	48
Don't Know	34	31	30	36	41	33	34
Are you in favor of temporary type facility or permanent?	(56)[a]	(43)[a]	(33)[a]	(31)[a]	(39)[a]	(47)[a]	(249)[a]
Temporary	29	21	21	29	18	19	23
Permanent	45	63	61	51	61	58	56
Don't Know	26	16	18	20	21	23	21

[a] Numbers in parentheses are respective sample sizes.

TABLE 6 Logit Models Estimated from Phoenix Data

No	Survey Response Variable	Data Set	Estimated Regression Model	p-value of -2 Log L[a]	p-value of Score[a]	p-value of slope Estimate[b]
			(a) Binomial Logit Models[g]			
1	PVAL	HB[c]	ln [p/1-p] = 0.2583 x RDIST	0.0003	0.0006	0.0019
2	PVAL	ALL[e]	ln [p/1-p] = 0.11 x RDIST	0.0011	0.0013	0.0016
3	MOVE	HB[c]	ln [p/1-p] = -0.3655 x RDIST	0.0001	0.0001	0.0004
4	MOVE	ALL[e]	ln [p/1-p] = -0.7272 x RDIST	0.0001	0.0001	0.0001
5	AWARE	ALL[e]	ln [p/1-p] = -0.2506 x RDIST	0.0001	0.0001	0.0001
6	QLIFE	HB[c]	ln [p/1-p] = -0.2959 x RDIST	0.0001	0.0002	0.0008
7	QLIFE	NHB[d]	ln [p/1-p] = -0.2959 x RDIST	0.0001	0.0002	0.0008
			(b) Multinomial Logit Models			
8	POM1	HB[c]	$\ln [p_1/p_4] = -0.2564 \times RDIST$	0.0001	0.0001	0.0004
			$\ln [p_2/p_4] = 0.3746 - 0.2564 \times RDIST$			0.026[f]
			$\ln [p_3/p_4] = 2.163 - 0.2564 \times RDIST$			0.0001[f]

[a] Criteria for assessing model goodness-of-fit.
[b] Maximum likelihood estimate of the slope parameter of the logit link function
[c] HB stands for 'Heard Before' referring to the data set which contains only those survey respondents who heard before about the transfer facility.
[d] NHB stands for 'Never Heard Before' referring to the data set which contains only those survey respondents who never heard before about the transfer facility.
[e] ALL refers to the data set which contains all survey respondents.
[f] Intercept estimate p-value.
[g] Probability of a yes outcome is denoted by p.

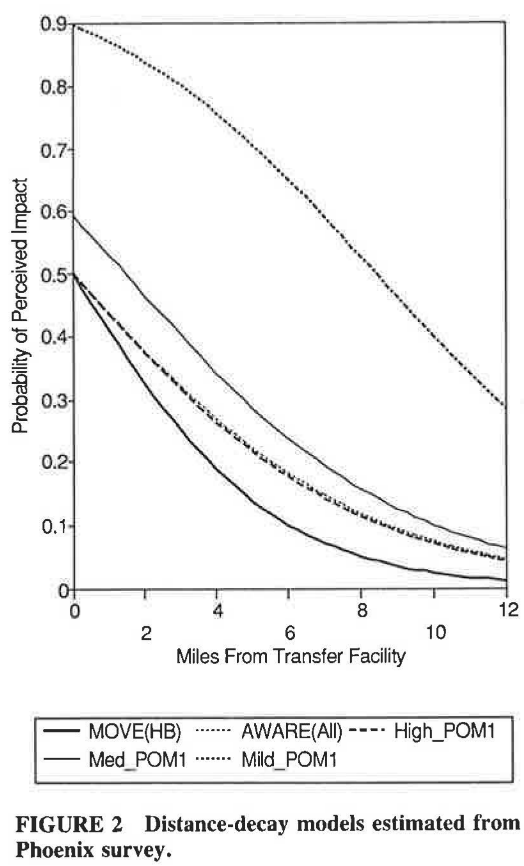

FIGURE 2 Distance-decay models estimated from Phoenix survey.

ability of relocation impact falls off more steeply with increasing distance among HB respondents than among NHB respondents. The probability of relocation impact is prominent within 10 mi of the facility for HB respondents, whereas it is only 5 mi for NHB respondents.

The fifth model presented in Table 6 shows how awareness about the Phoenix transfer facility project varied with the respondent's distance from the facility site. It is evident that the Phoenix facility had a longer range of awareness than the Glendale facility. This result was expected since the Phoenix transfer facility project has been well publicized in the community.

The sixth and seventh Phoenix models describe the log odds of the quality of life impact given the distance from the facility site. The two models are related to two groups of respondents: HB and NHB. The impact on HB respondents is greater than on NHB respondents, and both decrease exponentially with an increase in distance from the facility.

The last model presented in Table 6 is a multinomial logit model for the polytomous response variable POM1. The variable can have four possible values. Thus, three intercepts were estimated. Each equation in the model is called conditional logit and expresses the logarithm of odds of one outcome versus another as a linear function of the explanatory variable RDIST. Plots of these three conditional logit equations are presented in Figure 2. The curve labeled High_POM1 depicts the distance effect on the conditional probability of strong opposition (POM1 = 3); Medium_POM1 depicts the distance effect on medium opposition (POM1 = 2); and Mild_POM1 displays the distance effect on mild opposition (POM1 = 1). As expected, the strong opposition fades away sharply beyond 10 mi from the facility, whereas the medium opposition tends to be significant beyond 10 mi. Within 10 mi of the facility, the mild opposition is not likely to drop as sharply as that of strong or medium opposition. Other conditional logits can be derived algebraically from the given three logit equations. For example, $\ln(p_1/p_2) = \ln(p_1/p_4) - \ln(p_2/p_4)$.

CONCLUSIONS

This research explored empirically the spatial nature of perceived effects of siting solid waste management facilities in urban areas. The results of attitudinal surveys indicate that there are many negative perceptions toward SWM facilities, such as accident hazard and low quality of life and that these perceptions gradually decay over distance.

Both the Phoenix and Glendale surveys supported several hypotheses regarding attitude effects associated with SWM facilities. Several perceived or actual impacts of an SWM facility seem to be affected by people's distance from the facility. These distance effects were successfully modeled using several binomial and multinomial logit equations. Most of the survey variables (awareness, perceived threat of accidents, quality of life, and the combined potential opposition measure) showed statistically significant distance-decay. However, anomalous results were found showing perceived threat to property values increasing with distance, which might be discounted as a result of not controlling for socio-economic variation of various distances from the facility.

In a subsequent stage of this research (not reported here) the distance-decay equations were used for modeling the public opposition objective for the transfer facility location problem. These equations are an important contribution because this methodology can be used by SWM planners in locating facilities in such a way as to minimize perceived negative effects and, by assumption, opposition. These kinds of curves can be used directly in a location model, as in minimizing the systemwide average probability of perceiving any one of the impacts. Alternatively, they can be used indirectly by using them to empirically determine the perceived "impact radius" for a model that minimizes the number of people within the radius.

A majority of Glendale respondents expressed concern about the scale of a facility; they preferred the idea of having temporary SWM facilities dispersed in many communities. However, a majority of Phoenix respondents were in favor of a single, large-type permanent facility. It is suspected that this difference in opinion between the two survey areas can partly be attributed to Phoenix respondents' bias toward the recent political decision by the city of Phoenix to have a single large facility. Other contributing factors may well be the differences in demographics between the two cities, which were not investigated in the surveys. These results are interesting because they relate to the tradeoffs between cost and opposition that SWM facility planners must consider. Recently, Ratick and White (*8*), among others, have argued strongly that equity should be considered when planning for systems of undesirable facilities, where equity is considered to be a function of how many other places are also host sites for undesirable facilities. The survey results presented in this paper do not unequivocally support the notion that people prefer systems of a greater number of dispersed facilities, at least not for transfer stations. Further empirical research is needed to identify people's attitudes toward equity and risk sharing. Also, the ideas of political placation and welfare distribution by use of facility packages (*12*) are fruitful directions for future survey research.

This paper has been concerned primarily with statistical modeling of distance decay effects of siting an SWM facility. Therefore, it has made no attempt to discuss the many wider and complex issues that must be confronted in an actual siting process of a NIMBY facility.

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Growth at Rural Interchanges: What, Where, Why

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Unlike in metropolitan areas, the effects of the Interstate system on economic growth in rural areas are not well understood. There, Interstates have improved accessibility of farm-to-market shipments and significantly increased job opportunities for rural residents wishing to commute to metropolitan regions. In many of these areas, congestion has been reduced and business has improved, whereas in other areas, businesses have deteriorated and economic growth has slowed or declined. Growth at interchanges typically has been limited to a narrow band along the cross streets, or no growth has occurred. The development potential of each of the 22 interchanges on Interstate 40 from Raleigh to Wilmington in North Carolina was assessed. Using a "model-by-analogy" approach, observed growth at presently developed interchanges in North Carolina is related to background data on traffic, site, and situational characteristics. These relationships were applied to the new Interstate 40 interchanges, allowing forecasts for future development pressure. Growth equations were developed using regression, with separate equations constructed for various services and establishment types. Findings indicate that each intersection within the Interstate 40 corridor will experience a different economic pressure. The greatest growth potential is at interchanges near large urban areas and at high-volume roads along the corridor, which have sewer and water service and are near a regional town. Communities and businesses in the corridor must work together to identify appropriate development patterns for each exit, make decisions about utilities provision, and take cooperative action to develop services along the corridor as a group.

Without question, the United States interstate highway system, now completed after over 40 years of construction, has significantly increased accessibility and changed the nature of the U.S. economy. Essentially, the interstate system has produced an integrated economy on the mega-geographic scale. It has tied the regions of the nation together, and has provided for unprecedented availability of consumer goods and products. Without the interstate system it would be difficult to imagine the present modern United States.

The effect of the interstate system on changing travel patterns in metropolitan areas is well documented. Virtually every large city in the country has prepared transportation plans and forecasts using elements of the interstate system as key components of their highway system. The effects of the interstate system on suburban growth and on commuter patterns in metropolitan areas is therefore well understood.

Not nearly so well understood are the effects of the interstate system on economic growth in rural areas. There, the interstate system has improved the accessibility of farm-to-market shipments and has significantly increased job opportunities for rural residents wishing to commute to metropolitan regions. The system has also diverted traffic from other routes, bypassing communities and generating substantial changes in the local business structure. In many of these areas, congestion has been reduced and business has improved. In others, businesses have deteriorated and economic growth has slowed or declined. Typically, growth at rural interchanges has been limited to a fairly narrow band along the cross streets, often extending not more than half a mile on either side of the intersection. At many interchanges, no growth has occurred. In cases in which the interstate passed close to a small town, strip-like developments have often grown up between the community and the interstate exit.

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INTERSTATE 40 COMPLETION

After years of planning, study, and construction, the final 120-mi link of Interstate 40 connecting Wilmington, North Carolina, to Interstate 95 and Raleigh, North Carolina, is finally complete (Figure 1). Officially opened on June 27, 1990, this section of interstate links the Wilmington area, its port, and N.C. beaches to the rest of the state and nation. Along the corridor, there are reports of land speculation at interchanges, rumors of new industrial development, and a belief that the corridor will see new and rapid growth.

The N.C. Division of Community Assistance, in cooperation with the Interstate 40 Steering Committee of local governments and businesses, has initiated a study to determine the effects of Interstate 40 and to develop actions for coping with the expected effects of Interstate 40. The study has several elements, one of which is to assess development potential at each of the Interstate's 22 interchanges. The method used here, essentially "models by analogy," (i.e., observed interchange growth at other presently developed interchanges in North Carolina, is related to background data on traffic, the site, and situational characteristics). The relationships are then applied to the new Interstate 40 interchanges, and forecasts for future development pressure are made.

LITERATURE REVIEW

From the literature, certain variables appear to be critical in determining growth along highways. Eagle and Stephanedes (*1*) noted that there are four ways that highways may affect

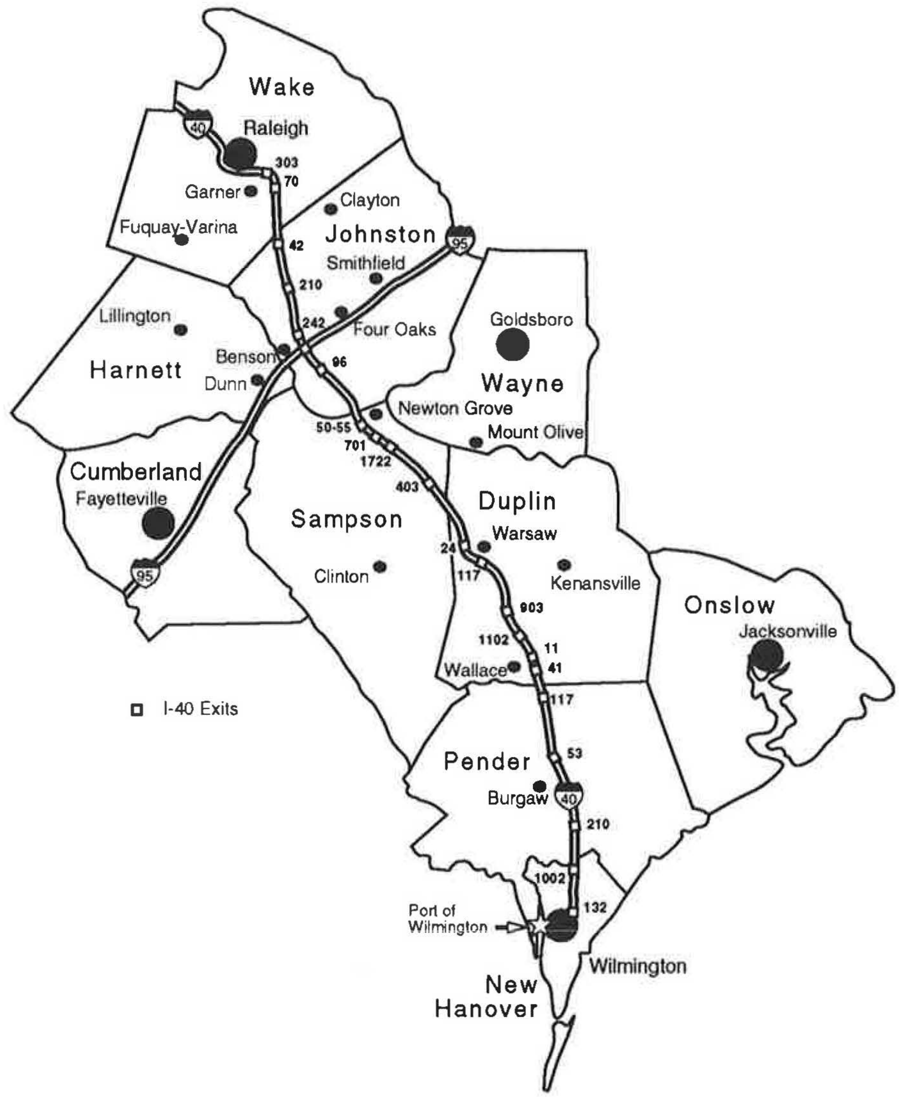

FIGURE 1 Interstate 40 corridor.

economic development, including

1. Residential location,
2. Work place location,
3. Enterprise location resulting from change in labor supply, and
4. Enterprise location resulting from decreased transportation costs.

Investigators have found that counties with interstate highways have an advantage over other counties with regard to population and employment growth, but only for counties within 25 mi of a metropolitan area. These employment effects are primarily related to industries servicing highway users (e.g., service stations, restaurants, and motels) and are not related to manufacturing or wholesale operations.

Few studies have found a strong correlation between highway and economic development. Wilson (*2*) maintained that, beginning in the late 1960s, efforts to link transportation investments directly to economic growth rarely have been successful. He concluded that the economic development process is far too complex and the role of transportation is not dominant enough for causal relationships to be established. Other studies suggest that economic development would occur in relation to highway investment only if certain other criteria were met. Huddleson and Pangotra (*3*) stressed that net gains from highway investments will occur only if resources (human and otherwise) that were previously not utilized or underutilized are employed. A report from the University of Iowa (*4*) stated that results of industrial location analysis have indicated that investing in better highways will not foster economic growth if other critical factors are not present. Other authors have found that a significant relationship exists between highways and economic growth. Bohn and Patterson (*5*) examined population changes for all U.S. counties between 1960 and 1970 and related them to a number of variables. They found that an interstate had a substantial relationship with relative population growth. Stephanedes (*6*) stated that transportation investments could have an influence on the location of firms, community patterns, and how resources are developed. Later analysis by Eagle and Stephanedes (*1*) indicates that the correlation between highway expenditures and employment is explained by two factors: (a) higher employment levels attract higher levels of highway expenditures, and (b) during the year of construction, employment levels increase.

Another body of literature deals with the locational decisions of firms. These do not generally ascribe much effect to transportation variables. Harrison and Kanter (*7*) concluded that labor costs and availability of appropriate physical space were most important to firms making business location decisions. In a survey of Fortune 500 firms, Schmenner (*8*) found the top factors to be quality of labor, climate, and proximity to markets (which could be directly related to transportation accessibility). More recently, concern for location has focused on the levels of labor skill and public education and on trainability (*9*).

Several studies focus directly on interchange growth. Stein (*10*) discovered that a large portion of development near predominantly rural interchanges consists of highway-oriented businesses such as motels, service stations, and restaurants, and that there was rapid growth in apartments, churches, schools, shopping centers, and industrial parks near predominantly suburban interchanges. Moon (*11*) found that four variables were important in explaining development patterns at interchanges: (a) traffic volume, (b) distance to the nearest city, (c) amount of development before interchange construction, and (d) distance to the nearest interchange. Epps and Stafford (*12*) found that only those interchanges previously designated as complete and unrestricted attracted any appreciable amount of economic development. Within this set, traffic volume and distance to regional centers were key variables influencing the amount of development.

The literature states that highway development will have an impact on the regions through which they run, although there is much disagreement over the type and intensity of the impact. Six variables are believed to have an impact on the amount of development at an interchange (*11,12*):

1. Average daily traffic (ADT) on interstate highway,
2. ADT on crossroads,
3. Location and population of communities within 10 mi of the interchanges,
4. Distances to the nearest major urban center,
5. Amount of development before the interchange construction, and
6. Distance to the next interchange.

In sum, the relationship among factors influencing growth at interchanges is complex. Generally, the amount of business activity observed at an interchange depends on traffic-related factors, particularly traffic volume and truck mix on the interstate and traffic on the cross street. Also likely to be important are locational factors, such as the distance from the interchange to major cities, the distances to the next interchange in each direction, the proximity to rest areas, and competition from other interchanges. Site factors also play a role, particularly sewer and water service, zoning, visibility, ease of access and egress, slope, and advertising. Given the constantly changing nature of such items, it is difficult to predict a growth pattern for a specific interchange in the absence of a complete picture of its site, traffic area, and locational situation.

METHOD

The procedure used in the analysis consists of four steps: (a) a field survey of economic activity at interchanges on North and South Carolina interstates; (b) development of equations relating interchange activity to background factors; (c) application of these equations to characteristics of the intersections on Interstate 40; and (d) forecasting future development pressure at Interstate 40 exits.

The field survey consisted of visits to 103 interchanges on six North Carolina interstates and on two South Carolina interstates, which were completed during the summer of 1990. Because the North Carolina interstate system contains over 270 interchanges, a representative sample with varying terrain, urban-rural traffic, and spacing were surveyed.

A simple field sheet was used to record information on each interchange as well as information describing the location of the interchanges on the system. The interchange survey had 36 items, including distances to towns, the nearest regional center, and rest areas and the distance to other interchanges and other interstates. Also included were traffic counts, availability of water and sewer utilities, and visibility of the interchange from the interstate. Development was categorized as residential, motel, gas station, fast food, sit-down restaurant, truck stop, office, church, bank, and mall. The data were entered into an Excel spreadsheet and uploaded to a mainframe computer data base for further analysis.

Equations for growth were developed by using stepwise regression, with separate equations constructed for residential development, gasoline stations, motels, fast-food and sit-down restaurants, and total interchange. In general, it was found that equations with three or four variables performed satisfactorily.

A careful review of the data showed that growth patterns on Interstate 95, a nearby route, are likely to be most applicable to the Interstate 40 situation. Interstate 95 is a major connector route along the eastern seaboard, connecting the northeast and southeast portions of the country. The section of Interstate 95 running through North Carolina passes through several rural counties and has been complete for nearly 20 years. On opening day 20 years ago, Interstate 95 probably looked the way Interstate 40 looks today. There was little or no development at its interchanges and both interstate and cross-street traffic volumes were only a fraction of what they are today. Twenty years ago it was hard to imagine that some of these interchanges would contain 20 or more units of development. For example, when Interstate 95 first opened, the Highway 53/210 (Fayetteville) interchange was practically empty; today there are nine hotels, two fast food restaurants, six gas stations, and four sit-down restaurants. As Figure 2 shows, development along Interstate 95 ranges from a low of two units to a high of 23 units, with the heaviest development concentrated primarily at major towns or crossroads with the heaviest volumes. Similar development potential exists at some of the Interstate 40 interchanges, provided that certain elements are present.

Growth equations along Interstate 95 were found to best reflect the Interstate 40 situation. Table 1 shows the equations selected. These equations relate development to sewer and water utilities, distance to other interstates and other interchanges, and traffic on the cross street. Generally, the equa-

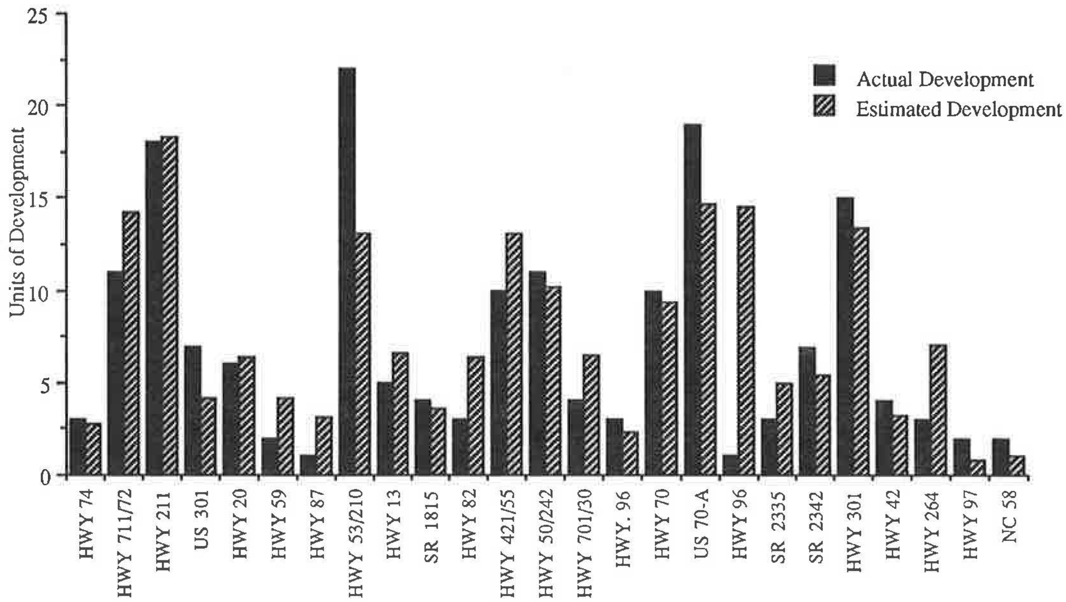

FIGURE 2 Actual versus estimated development on I-95 interchanges in North Carolina, 1990.

tions explained 60 to 70 percent of the variation in observed development. Figure 2 shows that these models generally predict quite well present development on Interstate 95. If the Interstate 40 situation can be described as similar to Interstate 95 20 years ago, then the equations would predict Interstate 40 growth development potential equally well. These equations can be interpreted best by using an example: the development pressure for motels (Table 1) at an interchange is equal to −.34, plus 0.18 motels for every 1,000 cars on the cross street, plus 1.6 motels if the exit has poor visibility, plus 4.53 motels if a sewage system serves the exit, minus .07 motels for every mile of distance from rest areas.

FACTORS AFFECTING DEVELOPMENT

Motels

Locations favoring motel development are those with water and sewer systems, moderate (not high) visibility, cross-street traffic over 4,000 ADT, and proximity to intersecting interstates and rest areas. Sewer availability is the key: on average, sewer availability will generate potential for an additional 4.5 motels. Highly visible sites are more suitable for gas stations and fast-food activities. Cross-street traffic above 4,000 ADT is important, and the exit should be no more than 20 mi from the next interstate or highway's end.

Cross-street traffic seems to be more important to motel development in rural areas and less so in more developed areas. This traffic reflects the motels' need to attract other customers in addition to those that the interstate generates. Motels are also affected by the presence or absence of water and sewer systems but are not as strongly affected by visibility factors. In fact, locations somewhat removed from the interstate itself (but still near the interchange), yet not visible from the interstate, seem to be favored. This factor is probably related to noise from the interstate, or perhaps because of opportunities for site development at locations slightly removed from the interstate. The analysis also shows that, where there is some variability, interchanges occupying relatively flat land tend to have a better chance of attracting motel facilities than those occupying steep slopes.

Gas Stations

Gasoline station clusters are best suited to interchanges with high cross-street traffic volumes (greater than 10,000 ADT) that may require cloverleaf-type interchanges, have good water systems, and are close to both nearby towns and interstate rest areas. For a diamond-shaped intersection, a cross-street volume of at least 5,000 ADT, water service, and a location within 3 mi of town are needed for successful operation. A diamond interchange 10 mi from town on a low-volume cross-street can support at best one to two stations. Since most stations depend on local and interstate traffic for success, they must be close to nearby communities, yet easily accessible from the interstate.

Fast-Food Restaurants

Fast-food restaurants favor sites with high cross-street traffic and water service that are close to intersecting interstates but relatively far from other exits. Essentially they thrive on both local traffic and interstate traffic, particularly at exits isolated from other exits. Sites with water service and traffic above 7,000 ADT and that are more than 10 mi from other exits can support two to three restaurants.

Sit-Down Restaurants

The analysis found that sit-down restaurants favor high local-traffic sites close to intersecting interstates. No strong rela-

TABLE 1 Equations of Development Along I-95 in North Carolina

	Type of Development				
Development Measure	Motels	Stations	Gas Rest.	Fast Food Rest.	Sit-down Residential
Intercept	-0.34	6.76	-0.34	.64	1.07
Traffic:					
mainline traffic (000)					
cross-street traffic (000)	+0.18	+0.097	+0.15	+0.23	-0.021
Visibility:					
visible					
partially visible					
not visible	+1.60				
Terrain:					
flat					
hilly					
steep					
Utilities:					
water system		+1.42	+1.054		
sewer system	+4.53				
Intersection type:					
diamond		-3.50			
cloverleaf					
Locational:					
distance to town		-0.175			
distance to reg. center					
distance to next interchange			+0.114		
distance to rest area	-0.07	-0.069			
distance to intersecting interstate	-0.046		-0.018	-0.024	
R-Square	.65	.67	.67	.58	.39
n	24	24	24	23	24

tionships with other variables were noted. Sites with high volume on cross streets (>10,000 ADT) and within 5 mi of another interstate or the highway's end can support one to two such services.

Single-Family Residential Developments

The least satisfactory of the equations tested were those for residential development. From the analysis, it appears that residential development is not a particularly viable activity at interchanges. Generally, development that does occur tends to be clustered. A negative relationship was found between residential development and traffic on both the interstate and the cross street. Residential development was found to be particularly negatively related to cross-street traffic: cross streets with heavy volumes (>20,000 vehicles per day) were found to have only half the residential development of low-volume cross streets. Most low-volume interchanges can be expected to have some residential development, particularly if they are close to town. Also, contrary to development patterns elsewhere, residential development near interchanges is not strongly associated with other suburban developments, such as malls and hotels. Residential development is more likely in the 1 to 2 mi band beyond the immediate exit.

Notably absent from these relationships are distance to regional centers and interstate traffic volume. The presence of gas stations and fast-food restaurants was found not to be seriously affected by interstate traffic counts. This finding reflects the fact that, along most stretches of the interstate system, there is generally enough traffic to support these facilities. Without exhibiting any variability from one place to another this is not going to be a factor in siting gas stations and fast-food restaurants. Cross-street traffic, on the other hand, is fairly important in those places in which development activity is lacking (i.e., rural areas) and, as with interstate traffic counts, not very important in more urbanized areas in which development is more dense. Other factors that are important, especially for the fast-food restaurants, are the presence of water and sewer systems and, for both gas stations and fast-food restaurants, a degree of interchange visibility from the interstate. Finally, interchanges not requiring extensive grading tend to have more gas stations and fast-food development than those requiring extensive grading.

In contradiction to previous findings of other researchers, there are no strong relationships between shopping development and distance either to the nearest small town or to the nearest regional center. Again, traffic along the interstates has become sufficient in and of itself to make such businesses viable enterprises, even in the absence of large or small population clusters nearby. The only circumstance in which these distance variables seem to be important is, again, in more rural areas, where distance to a small town has some minor impact. These results appear to contradict some of the findings of earlier studies [e.g., Epps and Stafford (*12*)]. But these earlier studies were based on data collected early in the life

TABLE 2 Correlations Among Interchange Measure of Development: I-95 in North Carolina

	Motels	Gas Stations	Truck Stops	Fast Food Rest.	Sit Down Rest.	Malls	Churches	Banks
Motels	-	-	-	-	-	-	-	-
Gas Stations	.67	-	-	-	-	-	-	-
Truck Stops	-.03	-.01	-	-	-	-	-	-
Fast Food Rest.	.60	.53	.09	-	-	-	-	-
Sit Down Rest.	.86	.58	.07	.71	-	-	-	-
Malls	.46	.61	-.17	.56	.64	-	-	-
Churches	.14	.06	.45	.02	.04	-.20	-	-
Banks	.01	.24	.45	.28	.04	-.03	.30	-
Residential	-.34	-.15	.07	-.32	-.62	-.41	.08	.08

n = 25

of the Interstate system, when main-line traffic levels were generally lower and the system was incomplete. Development on Interstate 95 through North Carolina and beyond is now more extensive and traffic levels are higher, making other factors more critical. These findings mean that most counties along Interstate 40 need not wait for rising interstate traffic to "float the boat" of interchange development: if the services are otherwise justifiable, development can be planned now.

There also was considerable correlation between various development types at North Carolina interchanges (Table 2), indicating a symbiotic effect between various kinds of activities at any major interchanges. Motels, gas stations, and fast-food and sit-down restaurants tend to develop together, with sit-down restaurants more closely aligned with malls. All are strongly negatively associated with residential development. Truck stops are generally not correlated with either of these groups, but there is some correlation with certain businesses (banks and churches).

STAGES IN INTERCHANGE DEVELOPMENT

The typical sequence of development at an interchange would seem to be as shown in Table 3. Initially, a rural interstate passes through generally undeveloped lands, some of which may be in agriculture or other light use (Stage 0). There may be a strip residential development along the cross street, particularly if (as is often the case) it is close to a small community. If traffic is low (less than 2,000 ADT), more residential development may occur (Stage 1).

Depending on circumstances, the interchange may then evolve in several ways. A prerequisite for nonresidential economic growth is cross-street traffic volume: traffic levels greater than about 4,000 ADT are needed to support even minimal development (Stage 2). If the interchange has 4,000 ADT on the cross street, is a diamond design, has moderate or good visibility, and is within 10 mi of a small town and an interstate rest area, it will likely be able to support one gas station and one small motel (Stage 2A). The addition of water service will increase gasoline service development to two to three stations. This pattern could be described as "light tourist" because it serves family travel needs.

More extensive economic growth creating a small island of development (Stage 2B) can also develop from light tourist services. This pattern, termed "economically competitive" often occurs when cross-street traffic is greater than 8,000 ADT, both water and sewer service is available, the nearby town is within 3 mi of the site, and the exit is at least 5 mi from nearby exits and has good visibility. In these circumstances, typical development would include two to four gas stations, one to two fast-food restaurants, and two or more motels. This development can challenge businesses in or closer to the small community, creating some tension.

For interchanges closer than 2 mi to the community and on heavy-volume streets (>12,000 ADT), "economic integration" (Stage 2C) can occur, which eventually consolidates the activities of the interchange with those of the community. Development strips are most likely to evolve along such connecting streets, particularly if they are widened to four or more lanes. In these circumstances, typical development would include four or more gas stations, three or more fast-food and motels, and two or more sit-down restaurants. Residential development would generally be pushed out by rising prices and traffic. In extreme cases, malls and other businesses can join this development.

A "heavy tourist-oriented" focus can evolve if circumstances are special: the intersection must be close to intersecting interstates or beltways with cloverleaf intersections, have both water and sewer service, be within 2 to 3 mi of a town, and have moderate visibility. In these circumstances, there is potential for six or more motels, three or more sit-down restaurants, three or more fast-food restaurants, and three or more gas stations (Stage 3A), depending on traffic volume.

Truck stops, a special activity, generally require sites at least 3 mi from a town, at least 20 mi from intersecting interstates, lower cross-street traffic volume (<6,000), and good visibility. Usually one to three stops can be supported in a

TABLE 3 Stages in Interchange Development

Stages	Requirements
0. Minimal development • forest • agriculture • agric.-residential	Initial setting; no requirements
1. Residential • Single family homes medium sized lots	• traffic <2000 ADT • not close to town • rural setting
2.A. Light tourist services • 1+ gas station • 1 small motel	• traffic >4000 • water service • moderate visibility • within 10 mi. of town and rest area • diamond design
2.B. Economically Competitive • 2-4 gas stations • 1-2 fast-food rest. • 2+ motels	• traffic >8000 • water and sewer • town<3 mi. • more than 5 mi. from next exits
2.C. Economic Integration • 4+ gas stations • 3+ fast-food rest. • 3+ motels • 2+ sit-down rest. • no residential • other business/malls	• traffic >12000 • water and sewer • town <2 mi. away
3.A. Heavy Tourist • 6+ motels • 3+ sit-down rest. • 3+ fast-food rest. • 3+ gas	• water and sewer • 2-3 mi. from intersecting interstate • moderate visibility
3.B. Truck Stop • 3+ gas stations/truck stops • 1-2 fast-food rest. • no malls • 1-2 motels	• 3-5 mi. from town • 20+ mi. from intersecting interstate • water service • 1-2 per int. segment (100 mi.) • traffic <6000 • visibility good

100-mi stretch of interstate. At such sites, one typically finds three or more gas stations and truck stops, one to two fast-food sites, no malls, and one to two smaller motels.

POLICY ANALYSIS

The findings from the previous section were used to estimate interchange development pressure along Interstate 40, concentrating on the section between Wilmington and Raleigh (Figure 1). Some of these interchanges have been opened a number of years, and others have just recently opened (in 1990). A baseline estimate of 20-year development pressure was prepared assuming existing site and physical and utility conditions and 1989 traffic. In addition, the effect of selected policies, particularly those relating to sewer and water service and future traffic is shown. Table 4 summarizes the findings by site; Figures 3 through 5 show the data graphically.

Estimates of development pressure should be viewed cautiously: development pressure is not a prediction of what will happen, but instead a relative prioritizing of the possible development on each interchange because of its circumstances. Local governments often have the power to change, control, or accelerate actual development through a variety of policies. This analysis is intended to show which interchanges are likely to come under pressure for future development so that governments will have information for planning.

The analysis shows that the intersections on Interstate 40 between Raleigh and Wilmington each have different development pressures. Some have potential for significant development because of their unique present locations, possibilities for sewer and water, and cross-street traffic, whereas others appear to have less development potential.

In the upper end of the corridor, just south of Raleigh, there are two exits, the first of which (SR-303) has moderate to low development potential. Residential development is more likely because of the close proximity to Raleigh. The second (U.S. 70) interchange has high development potential, with 30 or more units of development potential by the year 2008, if the sewer is extended to the entire intersection (currently water and sewer service some of the interchange). This interchange is especially well-suited for gas stations, fast food, and mall and motel development. U.S. 70 has high traffic volume, which is projected to increase substantially over the next 20 years. An economically integrated development form is likely.

Further south, interchanges at N.C. 42 and N.C. 210 have already begun to experience some growth: currently there are two gas stations with other sites in development. The site pressure was estimated at about four units, under present

TABLE 4 Twenty-Year Development Potential and Character of I-40 Interchanges

	Without sewer/water		With sewer/water	
Interchange	1989 Traffic	2008 Traffic	1989 Traffic	2008 Traffic
Garner SR 303	3.1 LT	3.3 LT	7.0 CE	7.6 CE
Garner NC 70*	21.3 CE	28.3 EI	25.8 CE	32.8 EI
Clayton NC 42	4.0 LT	6.0 LT	10.4 CE	13.7 EI
Smithfield NC 210	3.3 RES	3.6 LT	9.4 CE	9.8 CE
Benson SR 1356	S/W Available		12.6 CE	12.9 CE
Benson I-95	23.7 HT	34.6 HT	30.1 HT	41.6 HT
Benson NC 96	3.5 RES	3.8 RES	9.9 LT	10.3 LT
Newton Grove NC 50-55*	7.1 CE	8.1 CE	10.3 EI	11.7 EI
Newton Grove US 701*	9.1 CE	10.0 CE	12.1 CE	13.3 CE
Newton Grove SR 1722	2.6 RES	2.7 RES	7.2 LT	7.3 LT
Faison NC 403	5.2 LT or T	5.9 LT or T	10.6 CE	11.5 CE
Warsaw NC 24	S/W Available		11.5 CE	12.8 EI
Warsaw NC 117	1.4 RES	2.0 RES or T	3.7 RES or T	4.4 RES or T
Magnolia NC 903	1.1 RES	1.1 RES	2.5 LT	2.6 LT
Rose Hill SR 1102	1.1 RES	1.1 RES	3.1 LT	3.2 LT
Tin City NC 11	1.5 RES	1.7 RES	3.5 LT	3.8 LT
Wallace NC 41	2.7 LT	3.4 LT	5.6 CE	6.6 CE
Willard US 117	3.1 RES	3.7 LT	6.5 CE	7.3 CE
Burgaw NC 53	6.1 LT	6.5 LT	10.4 CE	11.2 CE
Rocky Pt. NC 210	5.0 LT	5.5 LT	10.6 CE	11.4 CE
Castle Hayne	7.3 LT	8.0 CE	14.0 EI	14.9 EI
NC 132	S/W Available		16.0 HT	17.7 HT

* - water only available
RES - Residential
LT - Light Tourist
HT - Heavy Tourist
CE - Competitive Economy
EI - Economic Integration
T - Truck-stop Focus

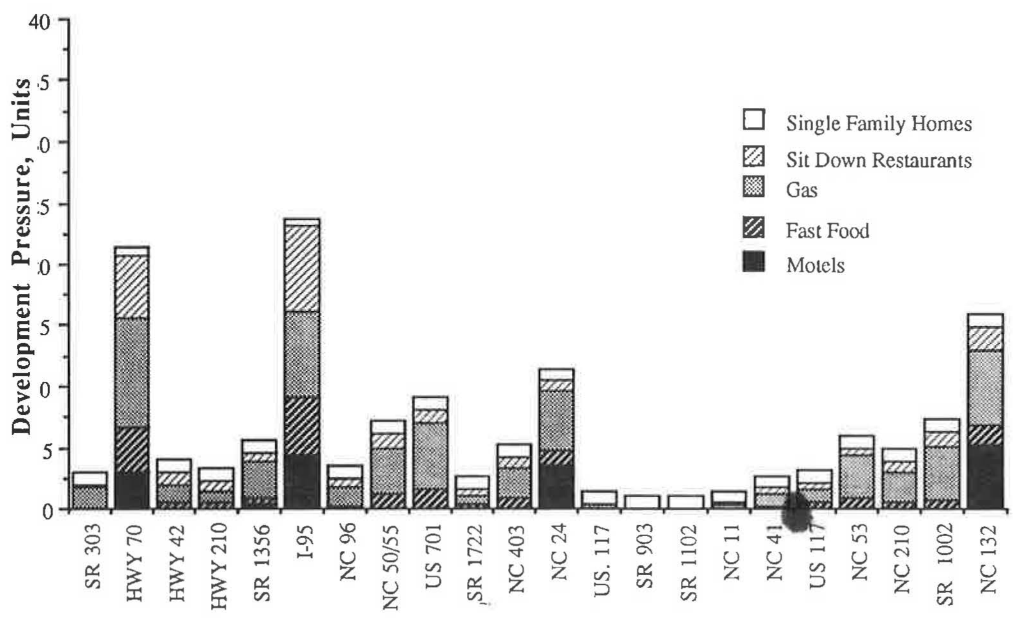

FIGURE 3 Twenty-year development pressure at I-40 exits, 1989 traffic levels.

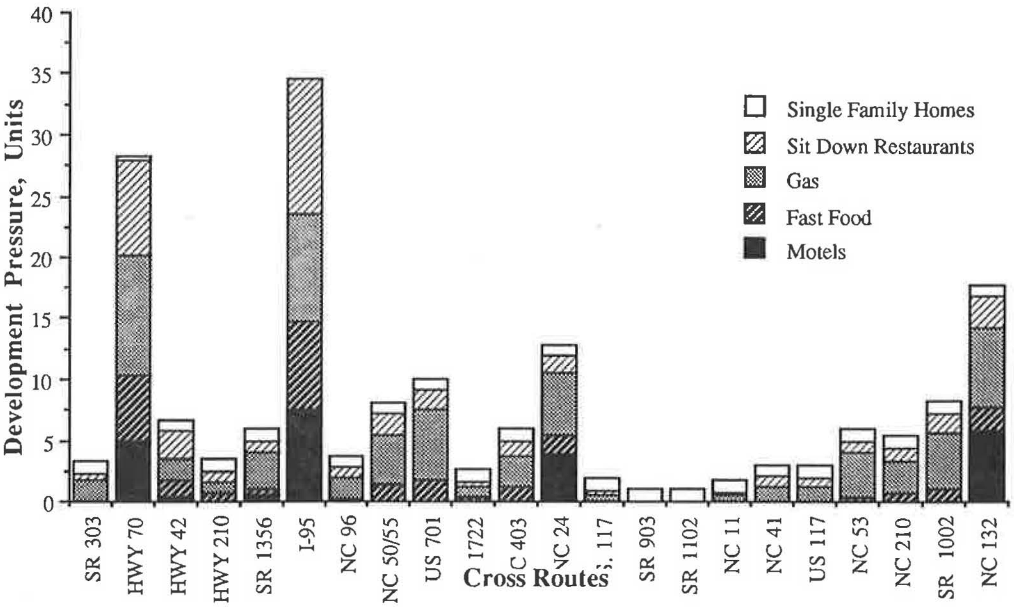

FIGURE 4 Twenty-year development pressure at I-40 exits, 2008 traffic levels.

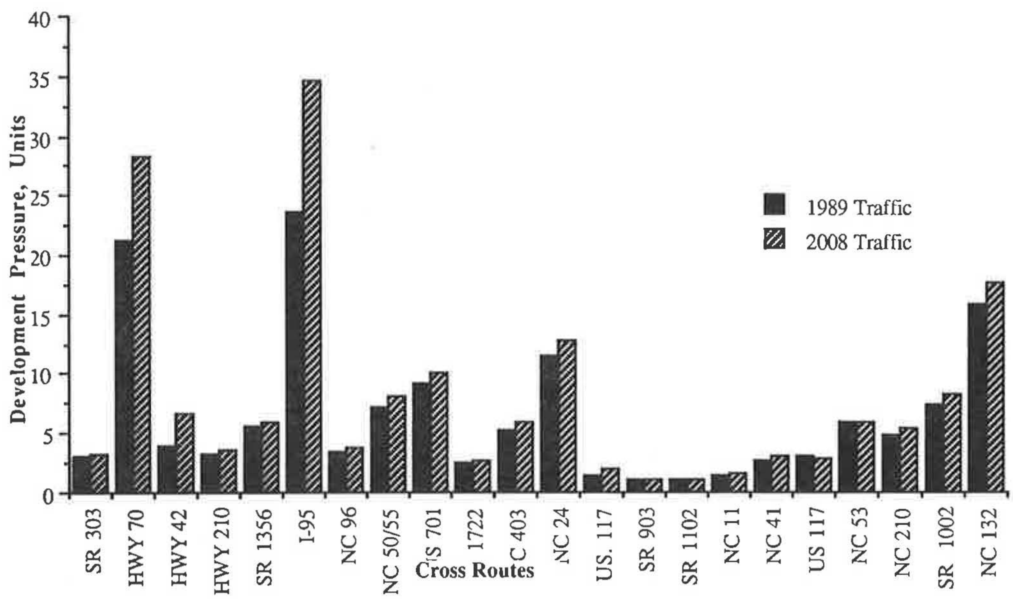

FIGURE 5 Twenty-year development pressure at I-40 exits, 1989 versus 2008 traffic.

circumstances. If sewer and water service is provided, there is a good possibility that the interchanges will experience additional growth.

There are three Interstate 40 interchanges in the Benson area (SR-1356, Interstate 95, and N.C. 96). Interstate 95 carries a large volume of traffic, but, as with most cloverleaf interstate-to-interstate intersections, it does not allow for direct development; the interchanges nearby could receive development instead (see Table 3, Stage 3A). State Road 1356 is also suited to serve traffic coming from Interstate 95, since sewer and water are extended to this location. An estimate of development pressure at the Interstate 95/Interstate 40 location, about 23 units, will show up as increased development pressure at the Interstate 95 Benson exit. The exit at N.C. 96 appears to have only light development pressure.

Toward the corridor center, the Newton Grove area is served by three exits: N.C. 50/55, U.S. 701, and SR-1722. The N.C. 50-55 and U.S. 701/13 exits appear to have some development potential. North Carolina 50-55 has water but not sewer; thus a major element for development is already in place. It is estimated that the interchange could be developed into a standalone economically competitive site, with perhaps eight or more units of development. At the U.S. 701 exit, similar development potential exists. At SR-1722, south of Newton Grove, development potential is light.

The N.C. 24 interchange has considerable development pressure. Water and sewer main lines are in place. The interchange could be developed into a medium tourist site, with the potential to expand to an economically competitive node for the communities. This intersection's rest area enhances its development potential, although visibility may be a problem. Some signing might be required.

There is moderate economic development pressure at N.C. 53 and N.C. 210, with the edge going to N.C. 53. Either the Burgaw or the Rocky Point exit probably could be developed into a competitive economic node if sewer and water were provided. Development may not be cost-effective for the Rocky Point site. If sewer and water cannot be provided, then development would probably remain limited to light tourist service.

North of Wilmington, the exit for Castle Hayne (SR-1002) appears to have quite high development pressure. According to the analysis, SR-1002, which has no sewer or water, has high potential for gas station development. North Carolina 132, the formal end of Interstate 40, has higher development potential; it is heavily residential in character now. Both intersections benefit from their close proximity to Wilmington.

This analysis concludes with a number of general points. First, the importance of providing sewer and water services in both controlling and encouraging development at intersections should be noted. Without sewer and water, the development pressure on most interstate intersections is limited; conversely, with sewer and water services provided, development pressure will be considerable. Provision of sewer and water can generally double the development pressure for most interchanges. Local governments need to understand this linkage and use it in conjunction with other planning tools to encourage the kind of development they seek.

Second, although traffic growth will improve the competitiveness of some intersections, traffic increases alone are not likely to significantly increase development pressure. It was found that development pressure depends more upon site characteristics and the locational positioning of the intersection with respect to its community and the corridor, than it does on traffic.

Most exits in the corridor will not be able to support unlimited economic growth. Since the total economic potential growth for the corridor is limited, communities must work together to plan comprehensively for reasonable expectations at specific interchanges as well as a solid development pattern for the entire corridor.

In summary, it was found that each of the corridor's intersections will experience a different economic pressure, which can be used effectively by local communities and the corridor as a whole. The communities and businesses in the corridor need to work together to identify appropriate development patterns for each exit, make decisions with respect to the provision of utilities, and take cooperative actions to develop the services along the corridor as a group. Such a cooperative process can lead to an environment that is both economically active and aesthetically pleasing and that provides appropriate services at appropriate points.

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Impact of State Highway Investment on Employment Along Major Highway Corridors

KOSTAS G. ZOGRAFOS AND YORGOS J. STEPHANEDES

Prioritization and selection of highway projects may be based, in part, on the expected impact of a proposed investment on the regional economy. Previous studies have shown that the magnitude and significance of the impact of highway investment on a regional economy may be affected by the nature of the economy and the spatial distribution of socioeconomic activity. The question of how highway proximity influences the impact of highway investment on the economic activity of 87 Minnesota counties was examined. The analysis is based on highway construction expenditures and county employment data in conjunction with vector autoregression structural plots and causality tests. The results suggest that, in response to highway expenditures above the trend, counties containing major highway corridors experience a small, statistically significant, increase of their total and manufacturing employment. In contrast, counties not containing major highways experience a small, statistically significant reduction of their total employment.

Urban, transportation, and economic planners often face decisions on the prioritization and programming of highway investments. Decision-making criteria in the evaluation process of state highway construction projects are based, substantially, on benefit-cost analysis. Incremental roadway user savings, measured in terms of vehicle operating cost and travel time, are the project benefits and are compared against the investment cost of highway projects. Although all project benefits are included in the roadway user savings, highway investments have a broader regional economic impact. For quantifying the latter hypothesis, an appropriate criterion is the expected impact of a proposed investment on the economic well-being of the region in which the project is located.

Linkages between economic development and transportation network expenditures have been established in a number of studies (*1-4*). These studies have demonstrated that highway infrastructure investments can affect the level of economic activity of a region by inducing changes in residential location (*1*), work place (*2*), and enterprise location (*3,4*). Furthermore, the relationship between proximity to interstate highway corridors and population and employment growth have been studied in England (*5*) and in the United States (*6,7*).

The objective of this paper is to empirically examine the effect of highway construction expenditures on the employment level of various sectors of the economy in the state of Minnesota. In particular, we seek to determine whether there are differential effects of highway construction expenditures on the employment of a region as a result of proximity of that region to major highway transportation corridors.

The rest of this paper is organized as follows. The second section of the paper presents an overview of previous related work. The third section describes the proposed methodological framework for determining the relationship between highway construction expenditures and employment. In addition, this section summarizes the input data of a case study used to illustrate the proposed methodology. The results of the case study are then discussed and are followed by concluding remarks.

PREVIOUS RELATED WORK

Traditionally, the prioritization of highway construction expenditures has been based, to a large extent, on the consideration of roadway user benefit-cost analysis. A limitation of this approach is that it does not explicitly consider potential effects of highway expenditures on the overall economic well-being of the geographic region in which the investment takes place. Nevertheless, in the United States, 36 departments of transportation consider the economic impact of highway construction expenditures in their project prioritization and selection process (*8*). Further, work in the area of prioritization of highway investments for low-volume rural roadway networks has suggested that low-volume roadway investments should be viewed in the context of regional economic integration and development (*9-14*).

Koch et al. (*9*) proposed a multicriteria framework for the socioeconomic evaluation of rural road projects. The study used the following five criteria for the appraisal of rural road projects: (a) economic benefits, (b) economic costs, (c) distribution, (d) accessibility to social services, and (e) employment. Leinbach and Cromley (*10*) introduced a goal programming formulation for the evaluation of rural roads in Indonesia. Among the considered criteria are total population served by the projects, area of the agricultural land served, connectivity to major corridors, daily market distance, and nature of facilities served. A study of rural road accessibility and development of agriculture and social infrastructure in Ghana (*11*) concluded that improved accessibility resulted in increased social development of rural communities. Analysis of the relationship between the structure of the rural roadway network and accessibility of public facilities (*12*) revealed that

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improvements in the travel times of crucial roadway segments can reduce the number of health care facilities required to effectively serve a given geographic region. However, improved accessibility can also increase the extent of disparities in the local economy (*14*).

The relationship between transportation network investments and level of economic activity has been the subject of a number of empirical studies. However, the results of these studies are inconclusive and often are not in agreement with the hypothesis that the improvement of the transportation infrastructure is a prerequisite to economic development in a region (*13*). For instance, a study of the Ozark region in Arkansas found little correlation between highway investments and economic development (*15*). Further, a study conducted in the Atlantic region of Canada found that investments in the area's transportation infrastructure would attract few industries (*16*).

Sheppard (*14*) and Stephanedes (*17*) suggest that the inconclusive and occasionally contradictory conclusions on the relationship between transportation and economic development are the result of three major factors: (a) variability in the geographical scale across studies, (b) use of methods that are not appropriate to determining the direction of the relationship between the two variables (i.e., the level of economic activity and highway construction expenditures), and (c) failure to consider the hysteresis involved in transportation-economy interactions.

Therefore, in evaluating the impact of highway investments on economic development, it is necessary to use analytical methods that can determine directional effects between the involved variables and account for the time lag between the highway investments and the level of economic activity. Stephanedes (*13*) proposed vector autoregression, causality tests, and structural plots as the most appropriate analytical methods, and these are also adapted in this study.

METHODOLOGY AND DATA SOURCE

The vector autoregression (VAR) formulation for this analysis consists of two equations—one explaining highway expenditures and one explaining employment. Equations 1 and 2 represent mathematically the VAR.

$$H_{i,t} = \gamma_1 + a_{11} H_{i,t-1} + a_{12} H_{i,t-2} + \ldots + a_{1q} H_{i,t-q} + b_{11} E_{i,t-1} + b_{12} E_{i,t-2} + \ldots + b_{1q} E_{i,t-q} + \varepsilon_{i,t} \quad (1)$$

$$E_{i,t} = \gamma_1 + a_{21} H_{i,t-1} + a_{22} H_{i,t-2} + \ldots + a_{2q} H_{i,t-q} + b_{21} E_{i,t-1} + b_{22} E_{i,t-2} + \ldots + b_{2q} E_{i,t-q} + \eta_{i,t} \quad (2)$$

where

$H_{i,t}$ = highway construction expenditures in county i during year t,
$E_{i,t}$ = employment in county i during year t,
a, b, and γ = coefficients, and
ε and η = error terms.

Two sets of data are necessary for the implementation of the VAR method. The first set represents the distribution of highway construction expenditures over time, whereas the second represents the time evolution of employment level.

For this application, state trunk highway expenditure data on the 87 Minnesota counties were obtained from the Minnesota Department of Transportation for the period 1957–1982. Because the objective was to determine whether there is a differential effect of highway proximity on the relationship between highway investment and economic development, the 87 Minnesota counties were divided into two groups. The first group includes the Minnesota counties that contain a major highway transportation corridor; all other counties are placed in the second group. For the purposes of this study, a major corridor was defined by an interstate or one of the most heavily traveled state trunk highways.

Employment data were obtained from the County Business Patterns, spanning the period 1964–1982 for the same 87 Minnesota counties. A study of the distributional effects of state highway investment on local and regional development has shown that, in diversified economies, highway investments affect to a different extent the employment level of various economic sectors (*17*). For instance, the employment impact of highway investments may appear first in the manufacturing sector, and the impact on other sectors (e.g., retail and wholesale) follows. Therefore, it was deemed necessary

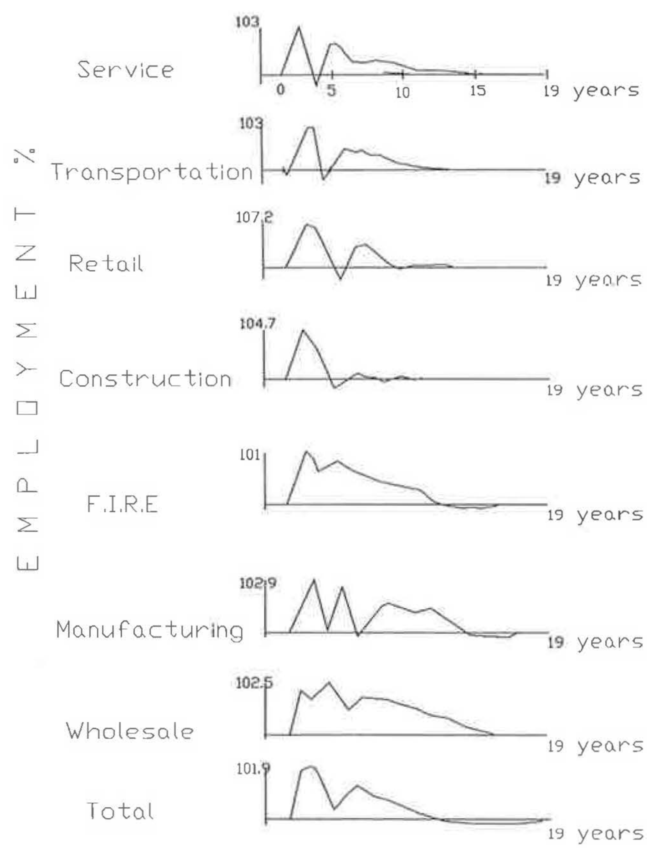

FIGURE 1 Effect of highway expenditures on employment: counties with major highways.

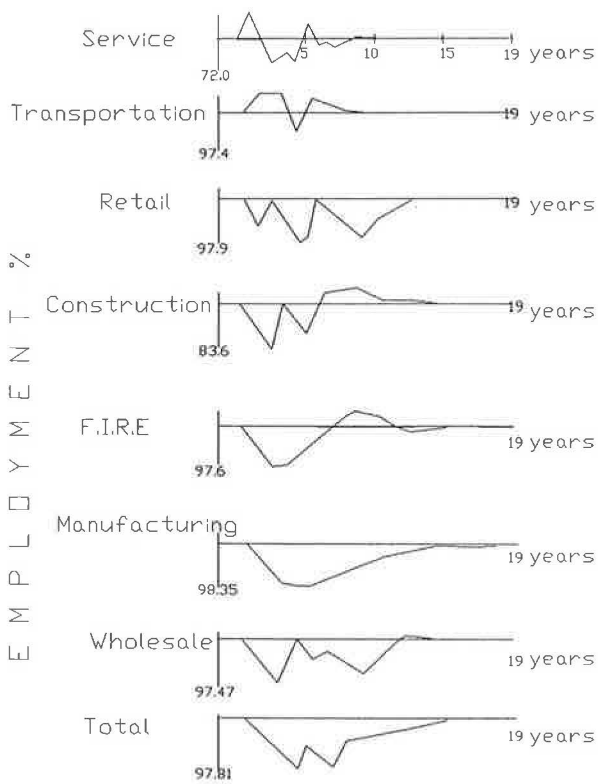

FIGURE 2 Effect of highway expenditures on employment: counties with no major highways.

for this study to examine the effect of highway investments on total employment as well as on sectoral employment levels. For the sectoral employment analysis the following employment categories are used: (a) manufacturing, (b) service, (c) wholesale, (d) transportation, (e) finance insurance and real estate (FIRE), (f) retail, and (g) construction.

Following filtering of panel data (*17*), time series analysis and causality tests were performed for the two groups of counties and the eight employment sectors. Since long-term effects are of primary interest, a 5-year lead was used in the VAR analysis. Furthermore, a 5-year lag was used in VAR to capture the inherent delay in transportation-economy interactions [see work by Stephanedes (*13*) for a detailed description of the method]. The results of the time series analysis are summarized in Figures 1 and 2 in the form of structural plots, and the causality test results are summarized in Table 1.

DISCUSSION OF RESULTS

In this section we discuss the results of the structural plots and the causality tests. First we consider the effect of highway investments on total employment for the two categories of counties; the discussion of the sectoral effects follows. The structural plot of each sector indicates the expected effect of a one-time 10 percent increase in trunk highway expenditures on the employment of that sector.

Total Employment

The employment effect varied between the two county groups. The data demonstrate that, in counties containing major freeway corridors, money spent on improving highways causes an increase in total employment above the normal trend. From Figure 1, a one-time 10 percent increase above the trend in highway expenditures may induce a 1.9 percent short-term increase in total employment. The peak of this increase is observed in the second year. The immediate employment changes that are due to expand business activities during construction last approximately 4 years. This short-term increase is followed by a sharp drop in total employment to its initial level. However, a positive long-term effect of highway investment on the employment of these counties is also indicated over a period of 15 years. From the causality test (Table 1), this impact is statistically significant at the 18.7 level.

For the counties that do not contain major highway corridors, the structural plot of Figure 2 indicates that a 10 percent increase in highway expenditures results in a 2.2 percent decrease in total employment. A long-term reduction in total employment is also manifested over a period of 15 years. In this case, the results of the causality test suggest that the decrease in total employment is significant at the 10.2 percent level.

The total employment results are in agreement with those of other empirical studies (*6,7*), which found that highway

TABLE 1 Effect of Highway Expenditures on Employment

Employment Sectors	Counties with Major Highways	Counties without Major Highways
	F-Test Significance Level (%)	F-Test Significance Level (%)
Service	16.1	>30
Transportation	>30	>30
Retail	>30	>30
Construction	>30	>30
F.I.R.E.*	>30	6.7
Manufacturing	0.7	>30
Wholesale	>30	>30
Total	18.7	10.2

*F.I.R.E. = Finance Insurance Retail Employment infrastructure investments have a positive effect only on the localities in the vicinity of major corridors. The results also indicate that most of these gains are balanced by employment losses in the counties that are further away. Since regional centers tend to be situated along major corridors, this finding is also in agreement with those in earlier studies (*13,17*) that showed that highway investments benefit such centers over other counties.

Manufacturing Employment

The manufacturing employment structural plot (Figure 1) suggests that an increase in highway expenditures causes a 2.9 percent short-term increase in employment in the counties containing a major highway corridor. The peak of manufacturing employment is observed in the third year. The long-term gains in manufacturing employment are substantial. This pattern is common to the manufacturing, wholesale, and FIRE sectors, as well as to the total employment of the state. From the causality test, the effect of highway investment on manufacturing employment of counties containing major highway corridors is highly statistically significant at the 0.7 percent level.

In contrast, the structural plot of manufacturing employment for the counties that do not contain major highway corridors indicates a decrease in employment. The short-term decrease is 2.7 percent and the impact extends over a period of 15 years.

Construction Employment

A 4.7 percent increase in construction employment is indicated by the corresponding structural plot of Figure 1. This increase lasts for 3 years after the highway expenditures. This result suggests that the construction of the highway creates short-term employment opportunities in the counties located in the vicinity of the highway corridor. This positive effect diminishes after the completion of highway construction, as expected. Further, the results of the causality tests indicate that the overall effect on construction employment is not statistically significant.

Other Sectoral Employment Effects

The structural plots for the service, wholesale, retail, and FIRE employment sectors suggest that highway expenditures have a positive effect on the employment level of these sectors in the counties containing major highway corridors. The mirror image of this general pattern (i.e., decrease in employment) is indicated for the counties that do not contain major highway corridors. For the counties without major highway corridors, a FIRE employment short-term decrease of 2.4 percent is statistically significant at the 6.7 percent level, indicating the lack of opportunities in this sector when major corridors do not facilitate interactions with major urban areas.

CONCLUDING REMARKS

In this paper we have examined the time-dependent effect of highway funding on county economic development with an application to the counties in the state of Minnesota. For determining this effect, VAR analysis, structural plots, and causality tests were used with data from trunk highway expenditures and total and sectoral employment. The hypothesis tested is that, in terms of employment gains, counties containing major highway corridors are the primary beneficiaries of highway investment.

When total aggregate employment data were used, it was found that there is a small, positive, long-term effect of highway expenditures on the total employment of counties containing major highway corridors. On the other hand, counties without major highway corridors experienced a small, long-term, statistically significant reduction in their total employment despite the increase of highway expenditures.

When the data were disaggregated to reflect employment for eight sectors of the economy, it was found that sectoral employment increased for all employment categories in the counties containing highway corridors. Further, the increase in the manufacturing sector proved to be highly statistically significant. For the counties not containing highway corridors, highway investment had a small, negative, not statistically significant impact on the employment level of all sectors. The negative effect was significant in the FIRE sector. Although there was a lack of significance, the pattern of long-term employment losses was similar across most economic sectors.

The finding that improved highways tend to help the economy of counties in which the major highways are located but may hurt other counties should not be surprising. In particular, counties that act as regional economic centers tend to be located on major highways, and it has already been suggested in the literature (*17*) that those counties stand to benefit the most from highway expenditures. Counties that are located far from major highways tend to depend on employment opportunities provided by regional centers; better highways allow the residents of these counties to conduct more of their economic activities in nearby centers. These counties can improve their economy if local firms can take advantage of better transportation to expand their activities and improve their competitiveness in the marketplace.

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Methodology for Estimating Economic Impacts of Highway Improvements: Two Case Studies in Texas

JESSE L. BUFFINGTON, LAURENCE M. CRANE, BURTON CLIFTON, AND JOHN SPEED

A methodological procedure that can be used by practitioners in estimating the economic impact of proposed highway improvements is outlined. The methodology is followed in measuring the impact of proposed improvements to U.S. Highway 287 in Wichita Falls and State Highway 199 in Tarrant County. Both have alternative routes that were evaluated. U.S. Highway 287 had two existing route alternatives, elevated and depressed express freeway lanes, and three bypass freeway route alternatives. State Highway 199 had one existing route freeway alternative and two bypass freeway alternatives. The State Highway 199 alternatives would affect Tarrant County and four to five cities, including Fort Worth. A summary of the results from these two case studies is reported. Benefit-cost ratios are calculated for the nonuser effects and the user effects measured in dollars. The objective was to estimate the economic effects resulting from implementing each alternative for each proposed highway improvement. The effects estimated are (a) impact on businesses, distinguishing between traffic-serving and other types of businesses; (b) impact on property values; (c) impact on new development; (d) impact on relocation and employment, including that caused by construction expenditures and loss of clientele; (e) impact on municipal tax revenues, and (f) impact on highway users. Data from previous studies, secondary sources, the Texas Department of Transportation, and the study areas, are used to make these estimates. The results will be used as supporting data in the environmental impact statements that will be presented at public hearings.

Highway improvements, whether for new highways or for existing routes, create changes in the local economy and how it functions. Some of these changes are temporary, lasting only during the construction period; others are long term because they result from the characteristics of the new facility. Rarely is an economic effect clearly all positive or all negative within a community.

PROBLEM STATEMENT AND BACKGROUND

Fort Worth

The Texas Department of Transportation's (TxDOT) District 2 is evaluating the proposed improvement of State Highway 199 in northwestern Tarrant County, Texas. This highway passes through four small "satellite" cities (Lakeside, Lake Worth, Sansom Park, and River Oaks) as it leads into Fort Worth and terminates at Interstate Highway 30 near downtown. Presently, the highway is a four-lane facility with undivided and divided at-grade sections having no access restrictions. The proposed facility is a full limited-access freeway with or without service roads. Three alternate routes are studied, and all three will affect four satellite cities plus Fort Worth and rural Tarrant County.

The following are the route alternatives: (a) Central Route—follows the existing route consisting of a sizeable strip of commercial development sprinkled with random vacant land. This alternative would require the acquisition of additional land, located primarily on only one side of the existing right of way. (b) North Route—would bypass Lake Worth and Sansom Park almost completely and pass mostly through undeveloped land and partially through several residential neighborhoods. (c) South Route—would bypass most of Lake Worth and pass through a large portion of vacant land and several residential neighborhoods. Most of the northern route and nearly half the southern route would pass through the city of Fort Worth.

Wichita Falls

TxDOT's District 3 is evaluating the proposed improvement of U.S. Highway 287 through the midtown of Wichita Falls. The highway segment under study is composed of two, one-way urban arterials in the midtown district, seven blocks long, controlled by a series of sequenced traffic lights at each block. U.S. 287 is improved as a freeway on both ends as it leaves the midtown area, creating a "design gap" in the primary arterial system.

Improvements are proposed to alleviate an unacceptable congestion and accident rate. Accidents are attributable to a violation of driver expectation as freeway traffic approaches the urban street section. There is a need for a continued freeway section for through traffic that will allow only access traffic on the urban section.

To alleviate these traffic problems, several facility options and alternative routes have been proposed. Three of the improvement alternatives are bypass routes. Although these new routes would follow existing streets where possible, extensive

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right-of-way acquisition displacements would be required. Two of these bypass routes would follow along portions of State Highway 240 (Eastside Drive), whereas the third would be a new location. The other two primary improvement alternatives would be to construct either a split elevated or a split depressed one-way section on Holliday and Broad Streets to carry through traffic, leaving a portion of existing roadway to carry local traffic. The elevated section alternative is separated into three secondary alternatives that deal with access ramps to cross streets and the alignment of the project on the north end.

STUDY OBJECTIVE

The study objective is to estimate the economic effects of the proposed route and/or design alternatives for State Highway 199 in Forth Worth and for U.S. Highway 287 in Wichita Falls. The following effects are to be estimated:

1. Impact on existing businesses, distinguishing between traffic-serving and other types of businesses,
2. Impact on new development,
3. Impact on employment, including that caused by construction expenditures and loss of clientele,
4. Impact on municipal tax revenues, and
5. Impact on highway users.

DATA SOURCES

The primary data source is the transportation economics literature (*1–37*). Also, data were collected by TxDOT's District 2 and 3 personnel and the Texas Transportation Institute's (TTI) personnel through personal interviews and mail questionnaires. Limited data were used from the U.S. Bureau of Census, Texas Almanac, chambers of commerce, and city offices.

The literature also contains general studies that estimate the relationship between highway construction expenditures and employment (*38–40*). Findings from the general studies supplement and further support the case study findings.

GUIDELINES FOR ASSESSING ECONOMIC EFFECTS

There are several important guidelines to follow for assessing the effects of highway improvements:

1. Consider all the relevant highway and area characteristics in assessing the economic impacts.
2. Decide which of the above characteristics are significant variables in measuring economic impacts.
3. Consider the techniques available for estimating economic impacts.
4. Collect sufficient data on the characteristics of the proposed highway improvement to use in selecting the most comparable findings of prior studies to estimate economic effects. At a minimum, data from previous studies must be comparable in the following ways:
   - Type of highway improvement (design and route location),
   - Dominant abutting land use, and
   - Stage of land development in area (percent developed).

   When ideally comparable case study findings can't be found, the highway planner is forced to use subjective judgment in adjusting the impact estimates based on the findings of available studies.
5. Adjust the findings of previous case studies to fit the proposed improvement area and route characteristics.

IMPACT ON BUSINESS ACTIVITY

A review of literature was conducted to compile a range of effects experienced by the business communities in various Texas cities where highway improvements have been made. Factors compiled from the comparable literature, such as percentage of changes in the number of businesses, amount of gross sales, and uses and values of property were used to estimate the various effects (*1–35*). Two types of effects needed to be identified: (a) those that occurred during the construction period, and (b) those that occurred after construction was completed and the new highway facility was operational. These two factors affect businesses differently, depending on both location and business type classifications. The effects differ according to the proximity of the business to the construction zone and also to whether the business is primarily a traffic-serving or other type of retail or service business (*1–19*, *36*, *37*).

The methodology most often used in the literature to measure these effects is the before-after approach. Briefly, this procedure analyzes an area under an original set of conditions, constructs a highway improvement, and then reanalyzes the area to determine the impact of the improvement. In the reviewed studies, the before period includes a period 2 to 7 years before construction of the highway. To minimize the effect of factors external to the highway construction, a control area is often used to measure the general economic effects that are occurring, independent of the construction.

Table 1 is a summary of percentage effects on gross sales, as reported in the literature, that resulted from either upgrading or bypassing an existing highway system. This table shows that there is considerable variation between effects among comparable studies. Because the studies considered were not all closely comparable, it was concluded that the comparative weighted mean value was an appropriate measure to use in calculating the estimated gross sales change. The comparative weighted mean is based on a scaled judgment of the characteristics of the types of businesses involved on each route and how they compare with the cases cited in the literature.

An important component of the business analysis was to determine the number of businesses that would close, be displaced either partially or totally, or would open. Table 2 is a summary of business status changes compiled from reviewing published reports. This table was used to estimate the number of businesses that would close or remain open.

No clear procedure was addressed in the literature with regard to determining how many of the opening businesses were new construction as opposed to existing businesses that

TABLE 1 Summary of Abutting Business Gross Sales Impact as Reported in the Literature

BUSINESS ACTIVITY	PERCENTAGE CHANGE OF IMPACT BY TYPE OF IMPROVEMENT							
	UPGRADING EXISTING HIGHWAY SYSTEM				BYPASSING EXISTING HIGHWAY			
	DURING CONSTRUCTION		BEFORE VS. AFTER CONSTRUCTION		DURING CONSTRUCTION		BEFORE VS. AFTER CONSTRUCTION	
	Range	Weighted Mean	Range	Weighted Mean	Range	Weighted Mean	Range	Weighted Mean
Bypassed								
Traffic serving	N/A	N/A	N/A	N/A	N/A	N/A	-65 to +39	-11
Other retail/service	N/A	N/A	N/A	N/A	N/A	N/A	-15 to +55	+10
Remaining								
Traffic serving	-46 to +15	-11	-26 to +27	-6	-46 to +15	-11	-13 to +49	+9
Other retail/service	-32 to +10	-5	-39 to +19	-5	-32 to +10	-5	-13 to +49	+9
Partially								
Traffic serving	-43 to +17	-12	-23 to +5	-11	-43 to +17	-12	-23 to +5	-11
Other retail/service	-35 to +31	-4	-97 to +73	-2	-35 to +31	-4	-97 to +73	-2
Abutting								
Traffic serving	-45 to +16	-11	-25 to +18	-9	-45 to +16	-11	-19 to +26	-2
Other retail/service	-34 to +19	-5	-67 to +48	-4	-34 to +19	-5	-43 to +66	+6
Closed								
Traffic serving	N/A	N/A	-43 to +17	-12	N/A	N/A	-13 to +49	+9
Other retail/service	N/A	N/A	-35 to 31	-4	N/A	N/A	-13 to +49	+9
New								
Traffic serving	-43 to +17	-12	-23 to +5	-11	N/A	N/A	-13 to +49	+9
Other retail/service	-35 to +31	-4	-97 to +73	-2	N/A	N/A	-13 to +49	+9

TABLE 2 Comparative Analysis of Change in Status of Businesses Previously Studied by Route Location[1]

Business Type	PERCENT OF BEFORE CONSTRUCTION BUSINESSES	
	Range	Weighted Mean
OLD ROUTE		
Traffic Serving		
Remaining	64-100	82
Closing	0-36	18
Opening	3-33	17
Nontraffic Serving		
Remaining	75-100	87
Closing	0-25	13
Opening	0-86	34
NEW ROUTE		
Traffic Serving		
Remaining	0-3	.4
Closing	0-3	.4
Opening	0-27	11
Nontraffic Serving		
Remaining	0-8	1
Closing	0-8	1
Opening	0-17	6
COMBINED ROUTE		
Traffic Serving		
Remaining	64-100	82
Closing	0-36	18
Opening	7-60	29
Nontraffic Serving		
Remaining	75-100	88
Closed	0-25	12
Opening	0-88	40

[1] Based on following Texas Transportation Institute by studies: 4,5,7,8,9,10,14 and 15.

were closed but that began operating after the commencement of the study period. Thus, it was assumed that existing businesses that were closed remained closed throughout the study period. The only exception is for those businesses that were vacant or closed at the commencement of the study that would be totally displaced during the construction period. These closed businesses were subtracted from the after closed business totals. Those that were opening were truly new business constructions and not merely existing closed business that began operations or existing businesses that changed ownership.

The findings from the literature review, as summarized in Tables 1 and 2, and data from the sources described in the data section were used to estimate the 1989 gross business sales. The estimating methodology contains several steps:

1. Classify the businesses in the study according to business type based on standard industrial classification (SIC) code. Business type refers to whether they were primarily traffic-serving, or nontraffic-serving retail and/or service-oriented businesses, independent of the proposed routes.
2. Classify each business according to its location, and determine its comparability to the case studies in the literature. This was done for each proposed route alternative. The status of each business is determined according to each route alternate.
3. Estimate the average gross sales per business for all businesses of each SIC code. This was done by using 1989 gross sales data obtained from the State Comptroller's Office.
4. Multiply the number of businesses by type and status, as determined in Steps 1 and 2, by the average gross sales per business of the corresponding type, as determined in Step 3, to generate the total gross sales of all businesses of that type and status.
5. Adjust the gross sales amounts and number of businesses to account for closing businesses and new opening businesses; also for those businesses either totally or partially displaced. The data summarized in Tables 3 and 4 were used to estimate these effects. The number of new businesses generated were allocated according to existing sales volume and adjusted according to the lengths of the old and new highway segments.
6. Apply the appropriate percentage change amounts from Tables 1 and 2 to the gross sales figures calculated in Steps 4 and 5. The result of these calculations is the estimated percentage changes and estimated actual amounts that would occur both during and after construction. This step was repeated for each business classification, alternative route, and status classification.

IMPACT ON LAND USE, DEVELOPMENT, AND PROPERTY VALUES

There is a close relationship between land uses and land values. If land values change, land use usually changes later. Previous studies have shown that a new freeway in an area will change the accessibility to abutting or nearby properties. Increased accessibility causes a change in the during- and after-construction period land values, thereby changing the land uses. The speed of a change will largely depend on the types of abutting and nonabutting use and how densely they are developed. The presence of an adequate cross street or

TABLE 3 Summary of Before- and After-Construction Period Nonuser Effects, and User and Nonuser Benefits and Costs of Proposed U.S. Highway 287 Improvement

NON-USER IMPACTS	ALT. 1	ALT. 2	ALT. 3	ALT.4	ALT.5[2]
Business gross sales ($ mil)	+8.5	+5.9	+17.1	-1.9	+1.2
Improved properties (%)	-3.0	-4.0	+18.0	+8.0	+12.0
Land value ($ mil)	+35.4	+32.9	+37.3	+39.6	+41.7
Tax Revenues ($th)	+209.0	+191.0	+247.0	+189.0	+240.0
Relocation (#)	-45.0	-50.0	-14.0	-6.0	-7.0
Employment (#th)	+5.4	+7.1	+6.2	+4.0	+2.3
Income to economy ($mil)	+407.0	+550.0	+468.0	+298.0	+224.0
BENEFITS AND COSTS					
Users[3]					
Benefits ($mil)	728	658	624	952	952
Costs ($mil.)	114	159	125	78	42
Benefit/Cost Ratio	6.4	4.1	5.0	12.2	22.7
Non-Users[4]					
Benefits ($mil)	451	590	523	435	267
Costs ($mil)	114	159	125	78	42
Benefit/Cost Ratio	4.0	3.7	4.2	5.6	6.4

[1] Impacts of abutting properties, businesses and residents, and the general impacts resulting from highway construction expenditures. Nonabutting impacts are not estimated.

[2] An average of alternatives 5A, 5B, and 5C.

[3] Benefits accruing directly to highway users.

[4] Combined dollar impact on abutting business sales, land values, tax revenues, and income to economy.

TABLE 4 Summary of Before- and After-Construction Period Nonuser Effects, and User and Nonuser Benefits and Costs of Proposed State Highway 199 Improvement

NON-USER IMPACTS	CENTRAL	NORTH	SOUTH
Business gross sales ($mil)	-14	+32	+27
Improved Properties (%)	-48	+4	-19
Land value ($mil)	+14	+10	+12
City/County Tax Revenues ($th)	+68	+185	+212
Relocation (#)	-302	-166	-385
Employment (#th)	+6.1	+7.7	+7.0
Income to Economy ($mil)	+473	+581	+528
BENEFITS AND COSTS			
Users[2]			
Benefits ($mil)	582	545	668
Costs ($mil.)	146	177	176
Benefit/Cost Ratio	4.0	3.1	3.8
Non-Users[3]			
Benefits ($mil)	473	624	568
Costs ($mil)	146	177	176
Benefit/Cost Ratio	3.2	3.5	3.2

[1] Impacts of abutting properties, businesses and residents and the general impacts resulting from highway construction expenditures. Nonabutting impacts are not estimated.

[2] Benefits accruing directly to highway users.

[3] Combined dollar impact on abutting business sales, land values, tax revenues, and income to economy.

road system that frequently interchanges with the new facility will heavily influence the distance from the improved highway that land values and land uses will be affected.

District right-of-way personnel furnished an estimate of the amount of right of way that would be needed for each alternative, and what property improvements that would be taken by type of improved property. Prior studies were used to estimate the number of new improved properties of each type for each alternative. Most of these studies are summarized in other publications (*11,13,21*).

The land value analysis uses the same study strip for each route alternative as defined in the land use analysis. The estimated value of the existing abutting property serves as the base for estimating the proposed route effects on property values and represents the value of the abutting property immediately after the taking of right of way. It is assumed that the land uses and values of the new abutting property are the same as those of the existing abutting property. The value of the property that would be taken for right of way is estimated separately and subtracted from the before-construction value of the newly abutting strip of properties. It is difficult to determine the after-taking use and value of the newly created abutting properties, especially since some of these properties will be remainders of partial takings.

Accordingly, the following procedural steps are used to estimate the existing/new abutting property effects of each route alternate being studied:

1. Estimate the present land value of the existing/new abutting strip of land along each side of the proposed route and the corresponding bypassed portion. The width of the abutting strip is assumed to be 150 ft for residential use and 300 ft for all other uses. The estimated square-foot values of abutting land in each use are based on a compromise between the right-of-way cost estimates made by the district personnel and estimates made by several private appraisers and/or real estate sales persons. The before-construction abutting land values are calculated by multiplying the total square footage of land in each use by the corresponding compromise square-foot values.

2. Estimate the present value of improved properties in each route alternative's abutting strip of land defined in Step 1. These estimates are based primarily on the district's estimated whole taking building values of each land use along each route alternate. The average value of the improved whole taking properties for each land use and route alternative is multiplied by the total number of properties of the corresponding land use group and route alternative to arrive at the estimated total value of the improvements of the property within the study strip.

3. Estimate the total before-construction period value of the abutting strip of properties along the proposed routes and the corresponding bypassed portion of the existing highway by adding the total value of the land calculated in Step 1 to the total value of improvements calculated in Step 2. No adjustment is made for possible damages to small irregular partial takings.

4. Estimate the value of the new improvements for each alternative by type of land use. The average value of existing whole taking improvements estimated in Step 2 is multiplied by the number of new businesses to arrive at an estimated total value of buildings to be occupied by the new commercial/industrial businesses. For new commercial/industrial businesses, it is assumed that such a value is a compromise between the value of a new building and a renovated existing building. Probably 50 percent of these new businesses would

locate in existing renovated buildings. The estimated number of new residences is multiplied by the average whole value of existing residential improvements to be taken to arrive at a total value of all new residential improvements.

5. Estimate the increased value of the vacant land where the new improvements will be placed. It is assumed that only one-half of the new commercial/industrial businesses will need a new lot in which to place a new building. It is also assumed that the size of a commercial lot is 100 ft wide and 300 ft deep. The differential value per square foot between vacant land and commercial land estimated in Step 1 is multiplied by the total lot square footage and then multiplied by the number of new businesses needing a lot, to arrive at the total value of the newly created commercial land. The estimated value of the new residences is assumed to include the lot value. Therefore, no increase in lot value is calculated for new residences. For new public/nonprofit organization buildings, the assumption is made that all will need new buildings and thus need new lots that are 100 ft wide and 300 ft deep. Again, the differential square-foot value between vacant land and the value of public land is multiplied by the total square footage of each new lot and then multiplied by the number of new public/nonprofit lots to arrive at a total value of new public/nonprofit lots.

6. Estimate the total value of new improved properties by adding the total value of the buildings estimated in Step 4 to the total value on the increased value of the land needed for the new buildings estimated in Step 5.

7. Determine the appropriate percentage changes to be used in estimating the expected, before versus after, construction period property values. The results from previous studies were evaluated and the results from the most comparable studies were used to arrive at appropriate range and mean values in which to choose a percentage to use to estimate the before-versus-after effects. These percentages are based primarily on the Texas studies referenced under each table. Most of these studies are summarized in other publications (*11,13,21*). These studies represent a construction period of about 3 years and an after-construction period of from 5 to 8 years. All the chosen percentages, based on the findings of these studies, seemed reasonable and are based on a general comparison of the specific characteristics of each route alternative in relation to the percentage range obtained from the most comparable prior studies (*23,33*).

8. Estimate the total before (instead of after) construction period property effects of each route by multiplying the appropriate percentage change by the total before value of the property abutting the proposed route and/or bypassed portion of the existing route. It is assumed that only one-third of the total impact would occur in the during-construction period. The value of the proposed right-of-way takings is subtracted from the total after-period property value, and the value of the new property is added to the total.

IMPACT ON TAX REVENUES

An indirect benefit to communities whose land values and gross business sales have been increased because of highway improvements is the subsequent effect on the tax base and tax revenues. However, during the construction period, when business accessibility may be adversely affected, the sales tax revenues could be decreased. Also a community's long-term sales tax revenues could be permanently affected if the highway improvement permanently decreased the volume of taxable sales within their boundaries. This report does not account for possible increases in demand on tax revenues caused by increases in growth and development. Consequently, the tax effects in this report are gross impacts.

The data used to estimate the gross taxable sales base are the same as those used previously to generate the gross sales. The percent of gross sales that is taxable was obtained from the state comptroller's office for each SIC code. The gross sales for each business was multiplied by this percentage rate to arrive at the amount of retail sales that were taxable. This amount of taxable retail sales can then be multiplied by the tax rates for the city to estimate the dollar amount of tax revenue. The same procedure is used to calculate the sales tax revenue generated from the wholesale and manufacturing firms operating within the parameters of the study routes.

A similar procedure is followed in estimating the property tax revenues. The data for the property tax calculations are the same as those used to calculate the impact on property values. To estimate the property tax revenue, the property tax base is multiplied by the property tax rate for the city.

IMPACT ON RELOCATION EMPLOYMENT AND INCOME

This section covers the impact of the proposed routes on relocation of businesses and residents and changes in employment and personal income. Each of these types of effects can have a significant effect on the businesses and residents in the study area, especially those abutting the existing or proposed routes. They are discussed separately below.

Relocation Impact

Relocation costs and effects on those displaced by the right-of-way takings of any highway project are of major concern and need to be considered in the decision process. The estimated effects of relocation are obtained from several previous relocation studies done in Texas (*21–23*, *36*, *37*).

Employment Impact

Each proposed route alternative would have a significant employment effect on the area under study. As part of the total impact, a portion would be because of the net change (existing businesses before construction less displaced businesses, plus new businesses after construction) in employment by businesses located abutting the existing and proposed routes. Another portion would be employment resulting from expenditures by the highway contractor to build the new facility and from expenditures by building contractors to build new or renovate old businesses and residences. The abutting businesses and residences are considered to have chosen their locations because of a new highway route (*38–40*).

Estimating Methodology

To estimate the impact on business employment, the following steps were taken:

1. Separate the affected firms (existing, displaced, or new) into two groups: commercial firms and industrial firms. Industrial firms usually have more employees than commercial firms, thus the employment of both groups is estimated separately.
2. Estimate the number of employees of the two groups of firms for the before- and after-construction periods. Use the average number of employees per firm, for each group of firms operating in the city, for each route. Compute this from the latest U.S. Bureau of Census data.
3. Add the estimated number of employees of commercial firms and industrial firms by city for each route.

To estimate the employment impact of highway, residential, and commercial/industrial building construction, the following steps should be taken:

1. Estimate the total construction cost for each route and the total construction cost of commercial/industrial buildings and single-family residences for each route. The route construction cost estimates are broken down based on the miles of each route in each city. For building costs, only whole building values are used to calculate an average building value for commercial/industrial buildings and for single-family residences. It is assumed that half the new businesses will occupy renovated buildings, and half will occupy new buildings. Therefore, the average of whole existing structures is a reasonable compromise value for the buildings occupied by the new businesses. All new residential buildings are assumed to be single-family structures.
2. Estimate the number of employees that might be generated because of each type of construction. The latest (1989) input-output model estimates of the "full-effect" employment multipliers are obtained from a report published by the Texas Comptroller of Public Accounts (*39*). These multipliers are adjusted to 1986 values by the Consumer Price Index. The appropriate adjusted multiplier, which represents the number of employees generated by each 1 million dollars of construction expenditures, is then multiplied by the corresponding total construction expenditures to obtain the estimated number of employees employed. Caution should be exercised not to assume that all the construction employment effects estimated by using the input-output multipliers will occur in the local area. If all the funds for these expenditures come from outside the local communities involved and are spent in those communities to hire local labor and buy locally produced materials, then most of the employment effects may occur in the local area. The employment effects from locally generated funds for building construction are more difficult to measure and trace through the economy.

Construction Expenditure Output Impact

Construction expenditures to build highway improvements and buildings for businesses and residences produce not only an employment impact but also an output, or total demand effect. Total output multipliers have been developed by the Texas Input-Output Model to estimate these effects (*39*). As this construction money circulates through the local, state, and even national economy it may produce three levels of effects: (a) the direct impact of the actual expenditures, (b) the indirect impact in supply industries, and (c) the induced impact of increased consumer spending. If the source of the employment impact expenditures is from outside the local area, most of the final-demand output effects may be realized. The amount of the output impact received locally depends on how much is spent for local labor, services, and supplies. The appropriate multipliers are multiplied by the amount of each expenditure type to yield the final output estimates.

IMPACT ON HIGHWAY USERS

Users of a highway system experience what is called highway user costs. These costs are classified into three types: (a) time or delay costs, (b) vehicle operating costs, and (c) accident costs. One way to justify improving a segment of an existing highway or bypassing the existing segment with a new segment is to show that the money required to pay for and maintain the improvement will produce an even greater dollar amount of user cost savings. The third version of Highway Economic Evaluation Model (HEEM-III) is used to estimate the user cost savings (*41*).

SUMMARY OF FINDINGS AND ACCEPTANCE BY TxDOT

The summary of findings for the case studies shows how estimates of the various nonuser impacts (effects other than those affecting motorists) can be helpful in deciding which route alternative should be selected. They show the extent to which nonuser impact estimates agree with the user, or motorists impact estimates, in selecting a route alternative. The findings for the two case studies are summarized separately below. They are presented in greater detail in the full reports (*42,43*).

Wichita Falls

Table 3 shows the estimates of the nonuser construction effects and the total net benefits and costs for user and nonuser effects for each proposed route alternative for U.S. Highway 287. Alternative 2 would produce the most positive employment and income impact. Alternative 3 would produce the most positive business sales and improved property and tax revenue impact. Alternative 4 would produce the least relocation impact, and Alternative 5 would produce the most positive abutting land value impact.

The user benefits are divided by the highway improvement costs to arrive at a benefit-cost ratio for each alternative. The same procedure is followed for the nonuser benefits. There is considerable agreement among the two sets of

TABLE 5 Estimated Nonuser Benefits to Affected Municipalities and Benefit-Cost Ratios from Proposed State Highway 199 Improvement

MUNICIPALITY	CENTRAL		NORTH		SOUTH	
	BENEFIT	RATIO	BENEFIT	RATIO	BENEFIT	RATIO
Lake Worth ($mil)	65	2.2	31	N/A	88	2.8
Sansom Park ($mil)	88	3.1	67	3.8	104	3.2
Fort Worth ($mil)	232	4.1	417	3.4	263	3.3
Tarrant County ($mil)	53	2.7	57	2.5	55	6.8
River Oaks ($mil)	19	2.8	33	4.1	35	4.3
Lakeside ($mil)	18	3.9	19	9.1	22	3.9

[1] Combined dollar impact on abutting business sales, land values, tax revenues, and income to economy.

benefit-cost ratios (i.e., those representing highway user effects and those representing nonuser effects). The same route alternative, Alternative 5, has the largest benefit-cost ratio for each type of effect. Also Alternative 2 has the smallest ratio and Alternative 4 has the next highest benefit-cost ratio.

Fort Worth

Table 4 shows the estimates of the nonuser construction effects and the total net benefits and costs for user and nonuser effect for each proposed alternative of State Highway 199. Not all nonuser effects select the same alternative. The north bypass alternative would produce the most positive or least negative impact on five of the seven nonuser effects estimated. The central route alternative would most positively affect abutting land values. The south route alternative would most positively affect city and county tax revenues.

User benefits and costs for the south route alternative would produce the most benefits of the three route alternatives, but since the central route alternative would produce the second highest benefits and would cost the least to build, it would yield the highest benefit-cost ratio of the three route alternatives. The north route would produce the lowest benefit-cost ratio. Although it would cost the most to build, the north route would produce proportionately more benefits than the central or the south route alternative.

Since both analyses use the same costs (i.e., right-of-way, relocation, and construction costs), the differences in the magnitude of the user versus the nonuser benefits are responsible for the two analyses having a different route alternative with the highest benefit-cost ratio.

Table 5 presents the results of the nonuser impact analysis on the municipalities affected and the combined dollar benefits and the nonuser ratios of benefits to costs for each proposed route. The cities of Lake Worth, Sansom Park, River Oaks, and Lakeside would be most positively affected by the south route. The city of Fort Worth and Tarrant County would be most positively affected by the north route. The central route alternative would not positively affect any of the municipalities. The south route alternative would produce the highest benefit-cost ratio for the cities of Lake Worth, Sansom Park, and Lakeside. The north route alternative would produce the highest benefit-cost ratio for the city of River Oaks and Tarrant County. The central route alternative would produce the highest benefit-cost ratio for the city of Fort Worth.

CONCLUSIONS AND COMMENTS

The following are conclusions reached from a review of the findings of the two case studies:

1. The findings of the Wichita Falls study support the selection of an existing route, Alternative 5, for improving U.S. Highway 287. The Fort Worth study supports the selection of a bypass alternative, specifically the north route alternative, to improve State Highway 199.
2. The number of business and residential displacements along the existing route significantly affected the magnitude of the effects of existing route alternatives. The existing route alternatives for the U.S. Highway 287 improvement would displace very few businesses and residents. The existing route alternative to improve State Highway 199 would displace more businesses and residents combined than either of the bypass alternatives.
3. The final selection of a route should emphasize minimizing the total number of displacements, especially business displacements.
4. If the proposed improvements are approved for construction, it is recommended that each project be studied to determine the actual construction and after-construction economic affects.

The following are some comments from the two districts:

1. The Wichita Falls District has accepted the findings and conclusions as meeting the criteria necessary for inclusion in the environmental assessment for the U.S. Highway 287 project. The only concern about the methodology has been the difficulty in determining the number of businesses that would simply relocate to an improved route, as opposed to entirely new businesses locating along a new route. This concern is more applicable in an economy like that of Wichita Falls, which is relatively small, isolated, and without significant long-term growth. The findings appeared to be consistent, overall, with observed patterns in the existing Wichita Falls economy.
2. The Fort Worth District is incorporating data from the economic study into the Environmental Impact Statement for the State Highway 199 project. Final selection of the preferred alternative for a project should be based on full and careful comparison of the pertinent data on social, economic, environmental, and engineering considerations related to the project. A choice must be made, and the governing considerations

are a matter of judgment for each specific project, but the process should consider these factors. Engineering considerations are brought into the study during formulation of each alternative, since no tentative alternative would be considered further unless it met minimum engineering requirements. This economic study has provided valuable data on which to base comparison of the alternatives. The conclusions from the economic study may not coincide with the ultimate project conclusions, but the economic data will have a strong influence on the route selection.

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PART 4

Education and Training

Transportation Engineering and Planning Education in Europe

C. J. KHISTY, S. LELEUR, J. G. LAURSEN, W. BRILON, AND F. FUZY

The role of transportation engineering and planning education in Europe and the likely direction it might take in the future are described. The experience of five academics provide information about transportation education in Denmark, Germany, and Hungary with the objective of providing a spectrum of transportation education in Europe that should be of interest to North American educators and practitioners. Comments and broad comparisons, as they relate to programs in North America are discussed. These comments may help educators on both sides of the Atlantic to modify future programs within the constraints of prevailing socioeconomic and academic conditions.

Since the end of World War II, we have witnessed profound changes associated with the transportation of goods and people world-wide, but particularly in Europe and North America. The professional skills required to plan, build, operate, and maintain these extensive transportation systems were developed over the years through educational programs in a variety of disciplines, including transportation engineering and planning. European and North Americans have each, in their own sphere, moved to the cutting edge of technological advancement and innovation. North Americans have enjoyed the benefits of their more-experienced European counterparts who have dealt with such areas as the problem of urban blight, scarce resources, and high energy costs. Europeans have, in a similar way, gained considerably from their American counterparts with solutions to such problems as transportation systems planning, computer applications, signaling systems, and traffic flow theory. Both European and North American advancements in transportation are technically driven, and universities on both sides of the Atlantic have contributed considerably in many ways toward this success. In this new decade, the North Americans are carefully scrutinizing their transportation needs and goals, and there appears to be a new energy at the state and local levels to move ahead. In 1992, Europe is facing a radical change, when the frontiers of its transportation system are being united in a single internal market.

In North America, we know a great deal about our universities through extensive literature published in recent years, e.g., transportation education in the United States (*1*). Comparatively little is known about European universities, particularly in the area of transportation education. This paper combines the experience of five educators to provide a spectrum of transportation education in Denmark, Germany, and Hungary that should be of interest to North American practitioners and educators. It is not the intention of the authors to suggest whether any of the customs, practices, or procedures followed by European universities should be adopted by North American universities. The comments and comparisons offered by the authors indicate some of the advantages of the European universities that may have a bearing on North American universities within the constraints of the prevailing socioeconomic and academic climate.

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TRANSPORTATION ENGINEERING EDUCATION IN DENMARK

General Information

In Denmark, transportation engineers are educated at the Technical University of Denmark (TU), Lyngby, and at the University Centre of Aalborg (AUC). These are the two places where a Master of Science (M.S.) degree in engineering can be obtained. Minor differences exist between the education at TU and AUC. The following concentrates on the education at TU in Lyngby.

TU Denmark was founded in 1829 as "Den Polytekniske Laereanstalt," known today as "Den Tekniske Hojskole," in close association with the University of Copenhagen. The degree awarded to candidates was that of *civilingenior* to distinguish them from the military engineers, as the army until then was the only place where engineers were educated. Currently, TU still awards a *civilingenior* degree in chemical, civil, mechanical, and electrical engineering, which is equivalent to the master's degree in North America.

Students who want to enroll in the education program at TU Denmark must have entrance qualifications equivalent to those at the intermediate level in the Danish upper-secondary school, such as the *abitur* examination from Germany; the General Certificate of Education from the United Kingdom in at least five different subjects, with mathematics and physics at the A-levels; or a high school diploma from the United States, followed by at least 2 years of a 4-year university program in mathematics and physics.

The number of new students every year is close to 1,000. The studies for an M.S. degree normally take 5 years. A modular structure has been adopted, which makes it possible for individual students to compose their own curriculum, within certain restrictions, from a total of approximately 800 courses at TU. A course equivalent to one module consists of 50 to 60 lesson hours in class and 60 to 70 hours of homework. Transportation engineering is one of the subjects covered by several courses. To fulfill their studies, students must pass approximately 50 courses, with 4 compulsory courses in mathematics and 3 in physics. Out of the 50 courses in the basic sciences (mathematics, physics, applied mathematics, and chemistry) students must select 6 optional courses. The study ends with the student writing a thesis with a workload equivalent to that of six courses and a duration of 4 months. Practical training is not a necessary part of the studies at TU Denmark. However, at a period late in their studies, some students may get part-time employment related to their engineering subjects.

Since the courses are taught in Danish, a working knowledge of Danish is necessary. Non-Nordic students must take a Danish test. English-speaking students, however, can be accepted for Master's thesis projects, for some of the specialized courses, and for postgraduate work. The studies are free of tuition fees, but books and study equipment must be purchased by the students themselves (*2*).

Current Program at TU Denmark

The transportation subjects are, with a few exceptions (e.g., vehicle mechanics and internal transport in factories), offered by the Institute of Roads, Transport and Town Planning. Divided into three equally sized divisions, the Institute comprises a faculty of 11 persons. The Transport Division is staffed by a professor and three associate professors.

Courses are not divided into undergraduate and graduate courses as there is really no bachelor degree program. Also, situated on the campus in Lyngby is the Engineering Academy, which offers a program similar to a bachelor's degree program. Students wanting to change from the TU to the Academy or vice versa may do so in accordance with certain rules. This exchange possibility has limited the need for developing a bachelor program within the TU.

Transportation courses within the civil engineering branch are "Town and Traffic Planning" and "Highway and Traffic Engineering." For several civil engineering students these will be the only transportation courses they will take if they are specializing in other fields. In "Highway and Traffic Engineering," students go through a lot of simplified numerical exercises in planning and designing a highway: traffic analysis and evaluation, capacity calculations, road geometry, pavement design, earth work calculation, and traffic economic assessment.

Of the 100 to 120 students taking the introductory courses each year, approximately 20 to 25 will continue with a course entitled "Transport Systems Analysis." This course emphasizes transportation engineering and planning methodology. Some of the major subjects are transport system characteristics; transport modeling; transport networks and flow theory; estimation; assessment of various transportation effects, such as accidents, noise, air pollution, and energy consumption; and transport project evaluation and decision-making. Students can specialize in various transportation subjects if they wish to. Courses offered at the specialized level are "Road Traffic Engineering," "Public Transport by Rail, Road, and Air," and "Urban Traffic, Problems, and Solutions." Transportation problems especially related to third-world countries are treated in "Highway and Traffic Engineering in Developing Countries."

In addition to the above-mentioned semester courses, students also follow more project work-oriented courses covering a 3-week period. These 3-week courses offer students an in-depth study of specific topics and enable them to deliver their results and findings in small professional written reports. Often the students work together in two- or three-person groups, which serve as a preparation for teamwork later on in their professional lives.

The final thesis work is the center of much attention from students, teachers, and possible employers and professionals. Much effort is put into the search and selection of an interesting, relevant, and suitable subject. Some recent M.S. theses have been related to developing countries, such as the Philippines and Indonesia. Around five students per year complete their M.S. theses in transportation. About 1 out of every 10 continues on for a Ph.D. The research topics of the Transport Division are on bicycle traffic, urban transport environment, city and intercity goods traffic, highway capacity and flow studies, safety studies, and assessment of social effects of transport projects.

All transport engineering candidates in recent years have been employed soon after finishing their studies, most of them by major Danish consulting firms, some by ministries and directorates, and others by municipalities and small consulting firms.

Characteristics of the AUC Program

Although the Technical University at Lyngby may be seen as a "supermarket" of various courses within the modular structure, AUC has a project-oriented, group-work-based study program with various topics, following a 1-year basic course. Both bachelor's and master's degrees can be obtained. A major characteristic here is the emphasis on group work, whereas the study at TU Denmark is more individualistic. The project work of groups is evaluated at the end of the semester, and the report is delivered as an end product of the process.

The Future

The transportation programs at TU Denmark, because of their affiliation with the Institute of Roads, Transport, and Town Planning, have a strong connection with town planning and highway construction. In many instances, faculty from all three divisions contribute to the same course. This exchange is felt to be a strength of the transportation program, and this integration is expected to be preserved within the ongoing development of the program.

At this time, an ongoing discussion is in the process at TU Denmark about the future development of *civilingenior* education. One of the issues debated is whether a restructuring of the four-branch structure—mechanical, chemical, electrical, and civil engineering—should be considered. With regard to civil engineering, there is a possibility that a construction branch and a planning/environment branch may be established. In this case, each of these branches might associate with existing institutes that at the moment are not part of the civil engineering department. This restructuring may open up possibilities for new courses and recommended sequences of courses tailored specifically for transportation planning/environment engineers.

Part of the reorganization is also to put a greater emphasis on international relations by getting involved in exchange programs. This is especially important for the transportation program as many of its candidates already are currently employed in part- or full-time jobs outside Denmark (*3*).

TRANSPORTATION ENGINEERING EDUCATION IN GERMANY

General Information

In Germany, every student needs the *abitur* as a basic requirement for the admission to a university. This *abitur* is the final examination that qualifies a student from a *Gymnasium*. A student needs 13 school years to be admitted to this examination, which is conducted by the state. Therefore, a student entering the university is at least 19 years of age. The German *abitur* is equivalent to 2 years of a North American 4-year university program. The universities in Germany do not conduct any entrance examinations.

Programs at the Technical Universities

The full-scale universities or *Technische Hochschule* (technical university) provide a sequence of studies over eight terms plus one term for the diploma thesis. Most students, however, need at least 5 years to finish their studies. Having passed all examinations successfully, the student gets the degree of "Dipl. Ing." (diplome engineer), which is comparable to a master's degree in North America. The examinations must be passed in two stages. After four terms, the student has to apply for prediploma status, consisting of a series of examinations in the basic courses. No special degree is awarded after the student passes these examinations. Therefore, the prediploma is not regarded as a qualification of its own. Its main purpose is to eliminate unqualified students from the university and it is the precondition for continuation toward the main diploma examinations.

In Germany, the universities are operated by the state. This system has two consequences: (a) Studies are free of charge for all students; in addition, students from low-income families are subsidized by the state. (b) The general quality level of courses, lectures, and curricula is more or less the same in all universities. However, professors may put special emphasis on some of the courses they offer. At the university level, a transportation and traffic engineering course is taught within the department of civil engineering. Students are free to select their lectures and their courses and they are also free to attend lectures or not. This freedom allows them to take responsibility for their own careers at a very early stage. Lectures by the professors are accompanied by ungraded exercises that the students perform on their own.

Since transportation is a part of civil engineering, all students have to start their studies with such basic subjects as physics (4 credit hours), surveying (2 hours), geometry (5 hours), chemistry (2 hours) and very comprehensive courses in mathematics (19 hours) and mechanics (16 hours). After the prediploma is completed, special subjects of civil engineering are taught, including courses such as statistics (6 credit hours), concrete construction (8 hours), steel construction (6 hours), materials (7 hours), construction operations (6 hours), soil mechanics (8 hours), hydrology, water supply, water constructions, sewage treatment (11 hours), and transportation and traffic engineering (12 hours). The latter normally is composed of courses on transportation planning, design of highways and railways, and traffic engineering. These are the fundamental courses for all students of civil engineering.

During the last two terms of their studies, students can choose specialized studies and courses. Each faculty of civil engineering provides special courses in construction engineering, water resources, transportation, and environmental engineering. For specializing in the transportation field, courses are provided in land use planning, city and regional planning, transportation modeling, methods of analysis and prognosis, road and highway design and construction, traffic engineering, railway systems, air traffic and waterway operations, operations research, and environmental issues. The emphasis depends on the specialization of the professors and other teaching staff. Experts from outside the universities are brought in for teaching courses on specialized subjects.

One of the most important objectives of the university courses is to educate students to understand the scientific background behind the theory and practices. During their studies, the students have to work on a variety of thesis topics/projects that are designed individually for every student. Sometimes, these theses are closely connected with research projects being performed by the university institutes. Many students are financially supported at university institutes on research projects, and this cooperation contributes significantly to their training as researchers.

After gaining the final diploma, students normally get a job. Only a few of them stay on at the university as full-time research or teaching assistants, and this step is the basis for working toward a Ph.D. dissertation. The Ph.D. is not based on coursework, but on a close cooperation with the professor on some highly specialized research project. On the average, the completion of a Ph.D. takes about 5 years. Transportation engineering and planning can also be areas taught outside the civil engineering department, for example, through the department of mechanical engineering, economics, aeronautics, and psychology.

The Future

The present market for traffic and transportation engineers is excellent. There is a constant demand for such engineers by the state administration and city councils, consulting firms, and private construction enterprises. Because a high percentage of people in the professional field are over the age of 45, there is an increasing demand for younger professionals. On the other hand, a shortage of students in transportation in recent years has resulted in the opening up of the field of transportation to nonengineers as well. This development has made quite popular nonengineering solutions in transportation in the last couple of years, particularly with problems concerning deficiencies in transportation systems and the environmental and socioeconomic effects caused by traffic. One can hope that this public awareness will increasingly attract qualified people to the professional field of transportation engineering, particularly now that a unified Germany has emerged (W. Brilon, personal communication, June 1991).

TRANSPORTATION ENGINEERING EDUCATION IN HUNGARY

General Information

The education of transportation engineers is organized at two levels. One level is similar to the B.S. degree awarded at the Szechenyi Istvan College of Technology (SICT) and the other is the M.S. (called "Engineer") at the Technical University of Budapest (TUB). Although both programs educate transportation engineers, the two institutions have different objectives, durations, and curricula.

Technical University of Budapest

The education of transportation engineers at TUB h as been developed within the civil engineering program. The transportation engineering program originally was set up in 1951 at the Hungarian University of Szeged and was linked to railway operation. In 1969 its faculty merged with the Technical University of Budapest, where a new Faculty of Transportation Engineering was established, absorbing vehicle design from the Faculty of Mechanical Engineering. In 1978 a review of the courses was undertaken; it included the fundamental principles of transport operations, system management and informatics, irrespective of mode. The structure of education is based on transportation technology and transportation system management. Today, the faculty offers two degrees: one in Vehicle Engineering and the other in Transport Engineering.

College of Technology

The education of transportation engineers at the engineering technology level has been developed with an emphasis on road construction, vehicle operation, transport technology, telecommunication technology, and management. The College of Transport and Telecommunication of Budapest was established in 1968. Its establishment in the city of Gyor was undertaken between 1974 and 1977 and named after István Széchenyi since 1986. In 1990 a new curriculum was introduced, including courses in economics and information engineering. Today the College offers eight degrees.

Admission Requirements

The admission requirements are similar for all technical higher educational institutes. All applicants must have a high school certificate and pass an entrance examination. The entrance examination generally includes a written and verbal part in two areas—mathematics and physics. At TUB the capacity is 200 full-time students per year, and in 1990 the number of qualified applicants was 1.7 times the capacity. One-third of this enrollment is in transport engineering. SICT has a capacity of 480 full-time students per year, and in 1990 the number of qualified applicants was 1.9 times the capacity. One-fourth of the enrollment was for the field of transportation.

Educational Process

Technical University of Budapest

The objective of the transportation section is to provide engineering specialists who can design, organize, control, develop, and research transportation systems and processes. The aim of the new structure was to reduce the number of compulsory subjects and to give more opportunity to choose a number of electives in the field of transportation. The course is modular, allowing students to select from a wide choice of courses in transportation engineering. The structure of modules is as follows:

1. The general module includes social sciences and foreign languages.
2. The basic module covers the general engineering subjects and an introduction to transportation. The general and basic modules are mandatory for all students.
3. The main module covers the engineering and scientific aspects of traffic engineering and provides the basis for choosing electives. There are two separate main modules: transportation planning and vehicle engineering. Students choose one of the two modules.
4. The side modules provide the special courses offered in the sixth through ninth semesters, covering the predominant modes of transport, such as railway, road, water, air, and freight transportation.
5. Submodules are special engineering modules that are offered in eighth and ninth semesters. The list of side modules for the transport planning section are development of transportation technology, transportation control informatics, urban transportation, transportation logistics, informatics of transportation control, shipment, water transport, railway automation and vehicles, and vehicle technology.
6. In the last semester students concentrate on their special work. The degree thesis is an exercise based on real-world problems provided by consulting companies and institutions linked to the faculty. During the last semester, students also undertake an 8-wk work experience module with consulting companies. The distribution of modules is given in Table 1.

There can be up to six examinations at the end of each semester. To complete the course, students must also pass a

TABLE 1 Distribution of Modules

Module	Distribution (%)
I. General module	18
II. Basic module	42
III. Main and side module	24
V. Sub module	8
VI. Thesis	8

TABLE 2 Distribution of Time and Effort

Level	Distribution (%)
A	18
B	22
C	29
D	31
Total	100

state examination in a foreign language. Two practical training periods are included in the curriculum. The first is after the fourth semester at any company, and the second after the eighth at a chosen transportation enterprise. Students who have completed their study at SICT can join the TUB program in the fifth semester. Four years ago the faculty started a new program for foreign students (in English) based on the same format as that for Hungarian students. This program has been very successful and the interaction most useful.

The faculty offers a number of postgraduate study options in Transport Engineering and Engineering Economics. The postgraduate program covers four semesters. A doctoral degree from TUB can be conferred on students after a period of 3 years full-time study beyond the M.S. degree by the Hungarian Academy of Sciences.

István Széchenyi College of Technology in Gyor

István Széchenyi College introduced a new course structure in 1989. Presently eight programs are available for engineers, economists, and technical teachers. Engineering courses cover architecture and informatics and civil, mechanical, transportation, and electrical engineering.

The objective of the education provided by the Transportation Engineering program is to provide engineering technology specialists who can direct the solution of technological, organizational, and economic problems in transportation and telecommunication. Although this objective is generally close to what TUB has, it emphasizes the practical applications and needs of transportation. The thrust is similar to the B. Tech programs in North America.

The length of study is 3 years, which is structured into two semesters per year of 15 wks each. The course is modular too. The structure of the modules is as follows:

- "A" level is a general module, covering a foreign language, social sciences, economics, and law.
- "B" level is a basic module that includes general engineering subjects.
- "C" level is a main module in transportation, which covers both engineering and economics courses and is compulsory for all transport students.
- "D" level is a side module covering a specialization in transportation. The list includes roads, railways, transportation, transport packing, shipping, forwarding, and postal management.

In the last semester, students continue their study at the College and work on their theses. This work is on a special transport problem provided by companies and institutions linked to the College. Students have extra consultations and practical training at the company. The time and effort distribution is shown in Table 2.

Practical training after the fourth semester is organized by the Department of Transport and Logistics. The transport program offers postgraduate courses over a length of four semesters in such fields as shipment, railway operation, computer techniques, and railways.

Organization of Institutes

The Faculty of Transportation Engineering at TUB consists of two institutes and five departments in basic subjects and mechanization. The number of the academic staff is about 130. The Institute of Transport Technology and Management is responsible for the transport section. It contains three departments: Transport Automation, Transport Economy, and Transport Operation. At the Széchenyi István College of Technology there are six departments and six divisions. The number of the academic staff responsible for the transport section is composed of divisions of Road Transport, Railway Transport, Postal Management, and Transport Economics. The faculty in both institutions teach and research. Almost all of the research comes from consulting companies and government institutions.

Supply and Demand of Transportation Engineers

At the Faculty of Transportation Engineering at TUB the total number of students is about 850, of which 40 to 50 graduate as transportation engineers out of a total of 150 graduates per year. Also, about 20 to 30 postgraduate students finish their studies. At the Széchenyi István College of Technology, the total number of students is about 2,000. The yearly number of transportation technology engineers in the whole college is about 150 out of a total of 520 undergraduates. Before 1990, the demand for transportation engineers was always higher than the supply; however, the situation has changed since, and the demand has declined somewhat.

Transportation engineers are employed at central and local governments, authorities, municipalities (transport and road departments); planning and research institutes, transport companies (Hungarian Railways, Budapest Transport Company, regional bus and freight transport companies, the Hungarian Shipping Company, Hungarian airlines, etc.) or at other companies with significant transport needs (construction companies, delivery services, trading companies, etc.) (*4,5*).

The Future

There appears to be a need to maintain the two educational levels for transportation engineering. The system has to provide transportation engineers with a wide basic knowledge supplemented with a specialization in a wide variety of fields.

COMMENTS AND BROAD COMPARISONS

Having given a brief description of programs in Denmark, Germany, and Hungary, we now give some personal observations, comments, and comparisons.

In general, the education of transportation engineers and planners in Europe has evolved over several hundreds of years, well before the label of "transportation" was attached to engineers and technicians. In more recent times the European universities established institutes and faculty in *verkerhswesen* (traffic engineering). In North America, particularly in the United States, the education of transportation professionals was closely related to the growth and development of its transportation system.

Students in European universities do not necessarily have to attend formal lectures as is expected of students in North America. The former have the freedom to choose only those lectures they wish to attend. Exercises set by faculty are completed only if a student feels it will help him or her understand the subject. On the other hand, large course projects in senior courses covering both theory and professional practice are the usual methods of introducing students to full-scale design in European schools.

The minimum time required to gain the Dipl. Ing. degree (M.S.) is 8 semesters or 4 years. This is really equivalent to 6 years of study, in North American terms, because entrance to the university is achieved by passing the *abitur* examination, which is equal to 2 years of college. In actuality, the Dipl. Ing. takes anywhere from 5 to 6 years to complete, so the equivalent in North American terms is about 7 to 8 years.

Table 3 provides a rough breakdown of the distribution of course clusters, both at the pre- and final diploma level in German technical universities. The Danish system is not significantly different from its German counterpart. Note that the transportation cluster comprises about 25 percent of the total time and is introduced as early as the fifth semester.

The Hungarian system of educating transportation engineers is quite different from the German or Danish system. Although associated closely with civil engineering, the transportation program by itself comprises about 40 percent of the program. All in all, the European curriculum exposes students to a much broader spectrum of content material in transportation than does the North American counterpart, and the level of coverage is deeper.

Letter grades (e.g., A,B,C, etc.) generally are not awarded to students at the end of each semester in European schools but are awarded at the time of the prediploma or final diploma examination. This system forces students not to "put the knowledge gained in a course behind" but to prepare for a set of examinations covering a wide variety of subjects at the end of the year. In contrast to the North American student, the European student is exposed to a set of more comprehensive and integrated problems.

TABLE 3 Effort Needed to Complete the German Dipl. Ing. Degree (MS)

Prediploma (4 semesters)	Distribution (%)
Physics	10
Surveying	5
Graphics	10
Chemistry	5
Mathematics and statistics	40
Mechanics	30
	100
Final Diploma (4 semesters)	
Concrete construction	10
Steel construction	10
Materials	10
Construction operation	10
Soil mechanics	15
Hydrology, water, sewage	20
Transportation	25
	100
Thesis research (2 semesters)	100

There is no question that major engineering universities in North America with transportation engineering programs are ahead of their European counterparts in computing and equipment facilities. European universities are driven to achieve the best they can, keeping cost and quality in mind.

Although European universities hire students as research assistants, their primary responsibility is to conduct research and not to complete their degree requirements; thus, students pursuing a Ph.D. may find it somewhat more difficult to attain their degrees in a reasonable period of time. The Ph.D. program does not require prescribed course work, and the degree is awarded based on original research work in a highly specialized area. Several years after gaining a Ph.D. instructors (or engineers) must take an oral and written examination called a *Habilitation* dissertation to qualify them to lecture in the university. This qualification reinforces the fact that candidates are able to apply their knowledge to a wide variety of theoretical and practical problems.

As in North America, faculty in Europe have ample opportunity to engage in consulting work, but the general feeling is that teaching and research claim a higher priority over consulting. In some cases a percentage of a professor's consulting fees may be retained by the university. Industry-sponsored research is becoming common in European universities in recent years.

CONCLUSIONS

European universities have a highly specialized and focused transportation engineering and planning program that leads to the North American equivalent of a master's and Ph.D. degree. Because of their long tradition in technical education, the emphasis, at least in the early stages of their programs, is to provide a thorough grounding in mathematics and physics, buttressed further with courses in statistics, probability, and operations research. Although universities in Europe and North America have almost identical objectives in educating the transportation engineer, European-educated engineers are more scientists/engineers than their North American counterparts. This is more obvious at the doctoral level.

In view of the impending single European Economic Commission in 1992, Europe is currently going through a series of rapid and radical changes at all levels, sponsored by the European Conference of Transportation Ministers and the International Road Transport Union. In many areas, their technologies and techniques are equal to, if not ahead of, ours. There is a wonderful opportunity for North Americans and Europeans to derive the potential benefits of learning from the research and technological advancements of one another.

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PART 5

Conduct of Research

Managing the Technical Aspects of a State Transportation Research Program

David L. Huft

During the past 3 years, the South Dakota Department of Transportation has modified its research procedures significantly. The Department has adopted procedures intended to identify its most important research problems and conduct well-designed studies to address them. Under these procedures, large numbers of Department personnel participate in management or conduct of contract and in-house research. Organizational adjustments have been made to accommodate the new procedures. The Department's Office of Research uses a nonhierarchical staff organization that includes engineers from several disciplines. Lines of authority are defined within the context of individual studies rather than by permanent assignment. Individual engineers work with employees of other Department offices to complete in-house research projects and to manage both in-house and contract studies. The revised organization and procedures have allowed the Department to improve technical management of its research effort, even as it has greatly expanded the number of active studies.

The South Dakota Department of Transportation (SDDOT) conducts research to accelerate adoption of new technology to improve its transportation services to the public at reduced cost (*1*). The Department has increased significantly its emphasis on research during the past 5 years, as transportation departments generally have recognized the importance of research and development. The Department's actions are consistent with the recommendations of the American Association of State Highway and Transportation Officials Standing Committee on Research (*2*, p. 6-1): "Member department research activities should be expanded to provide for more effective problem solving at the state level."

The Department's greater emphasis on research is demonstrated tangibly by increased staffing and expenditures. Equally important, the Department has become more willing to address technical problems through concerted research efforts and to adopt research findings in its policies and procedures. As the Department has begun to rely more on research products, their technical validity has become more important.

This paper will describe the organization and procedures that the Department has adopted to promote the technical success of its research program. Many of the ideas are not new; they were taken from other states and modified to fit the Department's specific requirements. Some procedures are still evolving, as perhaps they always should. This discussion is presented in the hope that some of these ideas will prove useful to research managers in other states.

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RESEARCH ADMINISTRATION

The Department's research effort is administered by its Office of Research, which has immediate responsibility for the management and conduct of research. To ensure that research is responsive to the Department's needs, the Research Review Board, composed of managers from throughout the Department, oversees the total research effort. Employees of other offices within the Department assist as members of technical panels that manage individual research projects.

Research Review Board

The Research Review Board's responsibilities include advising the Office of Research, setting research priorities, and approving funding for studies. The Board's membership is broad and includes the following Department and local government representatives:

- Secretary of Transportation,
- Deputy Secretary of Transportation,
- Director of the Division of Planning,
- Director of the Division of Engineering,
- Director of the Division of Operations,
- Materials and Surfacing Engineer,
- Research Engineer,
- Research Staff Engineer,
- Field Operations Representative,
- City Government Representative, and
- County Government Representative.

The Director of the Division of Planning chairs the Board, and the research engineer acts as its secretary. The city, county, and field operations representatives serve 2-year terms, beginning January 1 of even-numbered years. The other representatives serve as long as they hold their respective positions.

Office of Research

The Office of Research is responsible for performing the work directed by the Research Review Board. Its responsibilities include development of annual research programs, administration of research projects, conduct of in-house research, and technical advice to other Department offices. The office is staffed by the research engineer, a secretary, and seven other engineers from several disciplines, including chemistry, civil engineering, computer science, electrical engineering, and geotechnical engineering.

Technical Panels

Individual research projects are managed by small panels of experts in the research topic. Each panel's membership is drawn from the Department's central and field offices and, occasionally, from other public or private organizations. The panel's responsibilities include

- Developing project statements,
- Recommending study funding and duration,
- Recommending in-house or contract research,
- Evaluating research proposals and work plans,
- Selecting research contractors,
- Monitoring research progress, and
- Recommending research implementation.

Every panel is chaired by an Office of Research staff person, whose responsibilities include scheduling panel meetings, maintaining contact with researchers, and monitoring contract compliance. The research staff member is immediately responsible for ensuring the technical validity of the research project.

ANNUAL PROGRAM

In 1989, SDDOT adopted an annual research selection process. With the exception of emergency research needs, the Department intends to select all research topics and to award all research contracts according to the process summarized in Figure 1.

Research Problem Statements

Each May and June, the Office of Research solicits research suggestions from the Department's central and field offices and from the academic and consultant communities. Suggestions are made on research problem statement forms, which name the problem and describe it briefly. Research problem statements suggest research objectives, how those objectives might be achieved, and how the research results might be implemented. The statements provide enough information to allow the Research Review Board to appreciate the significance of the problem, but they do not elaborate on details.

The Office of Research compiles the research problem statements, then presents them to the Research Review Board in early August. The Board evaluates the statements and prioritizes them on the basis of benefit to the Department, likelihood of success, urgency, and probable funding requirements. Studies that are deemed of highest priority are tentatively included in the following year's research program. The others are retained for possible reconsideration in a later year.

Research Project Statements

Management staff from the Office of Research and the Department appoint technical panels to manage each of the selected research problems. Panel membership typically consists of four to six persons knowledgeable of the research topic. To encourage a diversity of viewpoints, field and central office personnel of various classifications and rank are encouraged to participate. In some cases, members are appointed from outside the Department.

A panel's first responsibility is to develop a more specific statement of the research problem. In the Research Project

Task	By whom	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Solicit Problems	Research Office	■	■										
Compile Problems	Research Office			■									
Prioritize Problems	Research Board				■								
Assign Tech Panels	Research Office					■							
Define Projects	Technical Panels						■						
Approve Program	Research Board							■					
Develop RFPs	Research Office							■					
Distribute RFPs	Research Office							■					
Develop Proposals	Researcher								■	■	■		
Evaluate Proposals	Technical Panels											■	
Award Contract	Research Board											■	
Develop Agreement	Research Office												■
Conduct Research	Researcher	■	■	■	■	■	■						
Monitor Research	Technical Panel	■	■	■	■	■	■						
Report Findings	Researcher							■					
Recommend Action	Technical Panel							■					
Review & Comment	Divisions & Regions								■				
Recommend to Secretary	Research Board								■				
Authorize Action	Secretary of Trans.								■				

FIGURE 1 Annual research program.

Statement, the panel defines the scope of the research problem and recommends whether research is justified. If research is deemed necessary, the panel specifies the study's objectives, identifies tasks essential to the study's successful completion, defines the products that the research should produce, and sets the study's budget and duration. The panel also recommends whether the research should be performed by contract or in house.

The panels submit their research project statements to the Research Review Board, which decides which should be retained in the annual research program. If insufficient funding is available to fund all studies, the Board decides which studies should be canceled or postponed until another year.

Contract Research Proposals

For each study approved for contract research, the Office of Research develops a request for proposal (RFP) based on the technical panel's research project statement. RFPs are distributed to prospective researchers, including universities, consultants, and government agencies, around December 1. Proposals are due in mid-February.

In March, each technical panel reviews the proposals submitted for its research project. The panel selects a research contractor to perform the work on the basis of

- The proposer's demonstrated understanding of the problem;
- The merit of the proposed research approach;
- The probability of success in achieving the project's objectives;
- The proposer's record of accomplishment in related problem areas;
- The adequacy of research staff and facilities; and
- The proposer's past record of performance for SDDOT.

The importance of the written proposal cannot be overemphasized; it is the panel's only means of selecting the researcher to conduct the study. The proposal must be concise, clear, and complete. Most importantly, it must convince the panel that a sound research project will follow.

If the panel identifies specific weaknesses in the selected proposal, it may ask the researcher to address them. This negotiation process must produce a modified proposal that is mutually acceptable to the panel and the researcher. Otherwise, another researcher will be selected or the study will be postponed. When the panel and the researcher are comfortable with the proposal, the panel presents its recommendation to the Research Review Board, whose approval is required for project funding.

After the contractor selection is approved, the Office of Research develops a formal agreement for the work. The agreement specifies the standard terms for research funded by federal Highway Planning and Research funds. In certain cases, SDDOT may elect to fund research with state funds. The agreement for state-funded research is essentially identical, except that SDDOT retains the right to inventions and discoveries. The agreement incorporates the researcher's proposal by attachment.

After the agreement is executed, the Office of Research notifies the researcher that work may proceed. Generally, a May 1 starting date is possible. The researcher then performs the research in accordance with the agreement and his or her proposal.

In-House Research Work Plans

If a study is approved for in-house research, the research engineer directly assigns an Office of Research staff member as principal investigator. The assignment is made on the basis of the staff member's expertise, experience, and other workload. Co-investigators may also be assigned to complex projects, but this is not often done.

The principal investigator must respond to the research project statement in much the same way as a consultant responds to a request for proposal. By February 1, the investigator must prepare a work plan analogous to a consultant's proposal. The plan must demonstrate a good understanding of the problem and outline a research methodology appropriate to its solution. The study's technical panel evaluates the work plan as it would a proposal and suggests improvements if necessary. When the panel and researcher have agreed on a sound work plan, the researcher may begin work.

Research Investigation

The study's technical panel monitors the research (both contract and in-house) throughout its duration. It reviews progress reports submitted by the researcher, as well as any interim reports specifically required. The panel may require meetings with the researcher to review progress or provide technical guidance. If desired, the panel may visit the site where the research is being done. It is the panel's responsibility to ensure that researchers fulfill their obligations and that the research objectives are met. Before conclusion of the research, the panel reviews the draft final report and advises the researcher of any changes that are required.

Implementation

Upon completion of the study, the project's technical panel advises the Department how the research findings may be implemented. The panel evaluates the validity of the research and recommends any changes in policy, procedures, or practice that should be adopted. As specifically as possible, the panel defines what actions should be taken and identifies which offices in the Department should be responsible for their completion. The panel's recommendations may include

- Specification changes,
- Policy changes,
- Design changes,
- Training,
- Construction, and
- Additional research.

The Office of Research distributes the panel's recommendations to the Secretary of Transportation and the Department's Region and Division offices for comment. Then the Research Review Board considers the recommendations of the researcher and the technical panel and review comments. The Board recommends to the Secretary of Transportation to what extent the panel's recommendations should be adopted. The Secretary of Transportation evaluates the Board's recommendation and directs appropriate division and region offices to accomplish necessary actions. When the implementation plan is effected, the project's technical panel is dismissed, and the project is considered complete.

TECHNICAL MANAGEMENT

The Department adopted its present research organization and procedures to promote the technical quality of its research. Specifically, the Department strove to improve its

- Project selection,
- Project definition,
- Project design,
- Project execution, and
- Research adoption.

Project Selection

Good project selection is technically important to any research program. Above all, projects must address the needs of the sponsoring agency. Projects that satisfy real needs will be accepted and will earn support for the entire program. Furthermore, projects must fit the agency's willingness to accept risks and change.

Before adoption of the Department's current procedures, research studies were initiated either in response to an emergency or at a researcher's request for sponsorship. Useful studies were performed, but many of the Department's significant needs were never addressed. Unless a problem reached crisis proportions or a researcher took particular interest in a topic, it might never be addressed.

The present process, which involves active solicitation of problem statements within and outside the Department, is more responsive to the Department's needs. All of the Department's central and region office staff are invited to submit suggestions for research. In addition, staff of the Office of Research visit the region and most of the central office managers to discuss research needs and encourage submission of the research problem statement. If necessary, Office of Research staff members prepare written statements from personal interviews. Every effort is made to encourage suggestions from every part of the Department.

Researchers from the academic and consultant communities also have the opportunity to propose innovative solutions to perceived transportation problems. Every prospective researcher on the Department's mailing list is invited to submit research problem statements, which receive the same consideration as statements submitted from within the Department.

Final selection of research topics rests with the Research Review Board, which evaluates all research suggestions in terms of potential value to the Department. Because the Board includes top managers from various Department offices, the selection reflects priorities of the entire Department. City and county representation on the Board encourages an even broader perspective and helps ensure that the topics included in the Department's annual program address significant transportation problems. In practice, this process has broadened the range of investigations. In the past, research focused primarily on materials and design topics, but more recently the Department initiated investigations on information processing, local roads needs, public transportation, and maintenance safety.

Selected studies have involved various levels of risk. Although many of the studies address immediate problems, such as chip seal performance and guardrail design procedures, some address more esoteric topics with less certain payback. Recent topics of investigation have been development of cements that would not promote alkali-silica reactions, field applications of voice-input computers, development of a noncorrosive deicer, and prestressing of bridge decks with composite fibers. The mix of low- and high-payback studies is healthy because products are consistently delivered at the same time that more exciting projects are under way.

Although it is generally successful, the project selection process has one weakness that will require attention. The annual selection process does not of itself encourage multiyear research strategies. Unless special efforts are taken to encourage long-term perspective, the process can focus excessively on short-term projects with lower potential. Projects requiring several sequential phases may not be selected.

Project Definition

Proper definition is essential to the success of every study. The definition establishes the sponsoring agency's expectations for the study and communicates them to the researcher. Unless the study's scope is clearly defined and its objectives are clearly stated, the study will accomplish little and will only disappoint its sponsor.

The Department's project definition process relies on the technical panel's breadth of knowledge and experience. The panel includes both field and central office personnel with various areas of responsibility. A panel assigned to a bridge study, for example, may include a design engineer, a bridge inspector, a maintenance foreman, a geotechnical engineer, and an instrumentation specialist. Whenever possible, personnel of various classifications serve on the panel, but during the panel's activities, rank is explicitly disregarded. The intention is to ensure that all essential aspects of the research problem are considered.

Starting from the brief research problem statement, the technical panel develops a detailed research project statement, which must define a sound research study. As the panel refines the problem description, it may expand, shift, or narrow the scope of the investigation as it sees fit. This privilege is founded in the assumption that a technical panel composed of several members will understand the problem more completely than the individual who first proposed it. Usually, the person who originally proposed the study is also a panel member.

After the problem is defined, the panel sets objectives that will address the problem and then identifies tasks essential to achieving the objectives. The problem, objectives, and tasks must follow a logical progression to ensure that the work that is performed actually addresses the stated problem. At the same time, the panel allows room for the researcher's innovation. In general, the panel specifies what is to be accomplished, but not how.

Project Design

After the technical panel has defined a problem, established research objectives, and identified essential research tasks, responsibility shifts to the researcher, who must propose a method of solution. The researcher's plan must demonstrate a good understanding of the problem and related scientific knowledge and principles. It must also describe a well-considered plan of action.

Research consultants must submit formal proposals explaining how the research will be accomplished. Similarly, in-house researchers must prepare a comprehensive work plan. Researchers prepare proposals and work plans according to published guidelines (*3*) that specify proposal standard format and essential contact. The guidelines require the researcher to provide

- A title page identifying the project and researcher;
- A table of contents for the proposal or work plan;
- A problem statement that not only expresses the technical panel's definition of the problem but also provides insight into the researcher's understanding of it;
- A background summary, which places the problem in a broader context and explains the significance of others' research on the topic;
- A statement of objectives for the study. If objectives other than those specified by the panel are proposed, they must be justified;
- A statement of benefits that can be expected from completion of the study;
- A detailed research plan outlining the tasks and methodology that will be used;
- A list of research products that will be delivered, including reports, software, manuals, data bases, presentations or audio-visual materials;
- An implementation plan envisioned to promote adoption of research results;
- A schedule showing order and duration of research tasks;
- A description of the staffing that will be assigned to the project;
- An assessment of the researcher's facilities essential to the study;
- A description of SDDOT involvement necessary, such as traffic control, information, and materials sampling;
- A detailed budget listing by major expenditure category and fiscal year.

The guidelines are useful to both the researcher preparing the proposal or work plan and the technical panel evaluating it. The panel judges the proposal or work plan against the guidelines, the original research problem statement, and a set of questions designed to force thorough evaluation (*4*) of the researcher's understanding and commitment of resources and effort. If the panel identifies specific weaknesses, it requests necessary modifications to the proposal or work plan.

Although the entire panel works to ensure the proposal's technical quality, there is some difference between the responsibility of the Office of Research staff member who chairs the panel and the responsibility of other panel members. Because they have training and experience in research, staff members have primary responsibility for evaluating the proposed research methodology. The other members are considered to be experts in the topic but not necessarily knowledgeable of research principles, so they contribute more on the general topic and less on research methodology. However, as panel members gain experience by serving on several panels, this distinction is becoming less pronounced.

Inviting competitive proposals has dramatically strengthened contract research proposals. Most studies attract at least one or two excellent proposals, as well as other workable proposals. Since adoption of the Department's procedures, researchers have worked to improve their proposal skills. The result has been proposals that start with a better appreciation of the research problem and that present a more comprehensive plan for the problem's solution.

Project Execution

After a study is initiated, the technical panel's continued involvement is essential to its successful completion. At a minimum, the panel reviews progress reports that the researcher submits quarterly or more often for short projects. Usually, panel involvement is much greater.

Experience has shown that a meeting of the researcher and the technical panel immediately after the study begins is very productive. A face-to-face discussion clarifies the panel's expectations from the project and solidifies the researcher's commitment to the work. The meeting opens communication between the panel and researcher, lessening the probability that the study will die from misdirection or neglect. On-site visits to the researcher's facility increase the panel's interest in and understanding of the work, improving the probability of successful implementation.

Upon completion of the research, the technical panel reviews the researcher's work to ensure that the study's objectives were in fact accomplished. The panel may direct the researcher to address omissions in the work or to better substantiate conclusions. This ongoing review is intended to challenge the work and ultimately contribute to the best possible research product.

Research Adoption

Because the Department involves so many people in the research management process, the chances of successful implementation are great. Four to six persons serve on each technical panel; others may assist with in-house research studies; top Department managers occupy Research Review Board positions. In all, between 80 and 100 of the Department's 1,200 employees participate in an annual research program.

Technical panel members contribute most to successful implementation. The same members who defined the study and monitored its progress are best able to evaluate the work and judge its significance to the Department. Because the panel members were originally appointed by their supervisors, the panel's recommendations enjoy good credibility. Furthermore, members probably occupy positions in the Department in which implementation will occur, which makes it easier to market the results.

The Research Review Board's role is also significant. Because the Board is composed of many of the Department's top managers, the Board's endorsement of research recommendations is persuasive. The Board members who recommend implementation steps to the Secretary of Transportation are in most cases the same managers who will be called on to accomplish them.

INSTITUTIONAL ISSUES

Effective use of the Department's research organization and procedures depends on adequate institutional support. Without sufficient funding and trained staff, sound technical management of multiple research projects is impossible.

Research Staffing

The Department's Office of Research staff totals nine persons—a secretary and eight engineers, one of whom manages the office. This unusual classification mix deserves explanation. First, the staff contains no technicians. Engineers fill every available position to maximize the office's total technical resources. Every position is occupied by a person who can both manage and perform research investigations. Although this arrangement permits the greatest number of active projects, it would be untenable if other Department offices did not contribute support personnel for in-house studies related to their areas of responsibility.

For example, technicians in the Office of Materials and Testing frequently team with an engineer from the Office of Research on studies related to materials. The engineer, acting as principal investigator, supervises the technicians, acting as co-investigators, to accomplish the study. Clearly, this arrangement depends on mutual appreciation of the study's value and good working relationships between the Offices of Research and Materials and Testing. Certain benefits are obtained, however. The technicians' research activity can level seasonal workloads, enhance job quality by stimulating interest in new technology, and actually begin the process of implementation.

Second, the engineers in the Office of Research are not all civil engineers. At present, the staff consists of a chemist, a chemical engineer, two electronics engineers, a physicist, and three civil engineers with different emphasis areas. Several have some graduate-level educational experience. All are computer users and most can write software in multiple languages. This diversity in background has strengthened the office's ability to apply innovative approaches to research problems. It has encouraged application of principles and technologies from other disciplines to the solution of problems in civil engineering.

The third nontraditional aspect of the office's staffing is its organizational structure. Only the office engineer has permanent supervisory authority. All of the other engineers function as heads of technical panels and principal investigators on assigned studies. Authority is project specific, i.e., one engineer may head a technical panel directing another engineer's investigation; on that project, the first engineer has authority over the second. On another project, the engineers' roles may be reversed.

The nonhierarchical organization is reflected in the engineers' classifications. Classifications are assigned on the basis of technical responsibility, not organizational structure. If the engineers perform identical technical functions, they occupy identical classifications. Furthermore, the technical complexity of the engineers' duties justifies high-level classifications. This concept conflicts with the line-of-authority orientation typical of state government classification systems but has been successfully adopted within the Office of Research. The Department's Office of Personnel has recognized the technical demands associated with research investigation and management.

Other advantages result from this organizational structure. Before its adoption, junior engineers tended to assist senior engineers' studies. They often performed specific support tasks and generally did not have responsibility for entire projects. This underutilization of skills prevented the Office of Research from addressing the large number of topics in need of research and was detrimental to staff morale. Under the new structure, individual engineers are responsible for complete studies. They may enlist seasonal workers and personnel from other offices to assist them and may obtain specialized technical assistance from other Office of Research staff, but the ultimate responsibility for the study is their own. Staff members have had to improve their project management skills to function in this manner, but all have welcomed the challenge.

Training

Because the Department's technical panels exercise so much authority over a study, adequate training for the panel's Office of Research staff member is essential. The staff member must deal one-on-one with research consultants and Department managers to coordinate activity on research projects. The person must be able to intelligently evaluate research proposals and reports and maintain credibility with academics, consultants, and peers within the Department. On rare occasions when academics have challenged the qualifications of project managers, a strong defense has been essential. Likewise, when staff members perform research themselves, they must be able to develop a sound work plan and carry it to completion. They must understand and apply scientific and statistical principles to ensure that the research activity is not wasted. Their work must withstand the scrutiny of the Department's technical panels and Research Review Board.

To these ends, the Office of Research obtains training in management skills, research methods, and specific technical subjects. The office sensed an acute need for a research methodology course and, in the fall of 1991, enrolled its entire staff in a two-and-one-half-day course entitled "Transportation Research Methodology." Some other Department employees who serve on multiple technical panels also attended.

Department Support

The commitment of the Department's top management to research is absolutely vital. Without management's support, no technical accomplishments are likely. Even if they occur, they will be wasted. Transportation department research managers often ask the question: "Where should the research office ideally be located in the Department?" In some departments, the research activity is closely associated with the materials group. In others, including the South Dakota Department of Transportation, it is tied to the planning division. Many maintain that the research office should not be a part of any group, but rather should report directly to the chief administrative officer.

The Department's experience indicates that location of the office is not particularly important, if the entire Department is involved in its direction. Although its Office of Research is located in the Division of Planning, studies equally address subjects belonging to the Divisions of Engineering and Operations and recently the Division of Finance. Broad participation in the Research Review Board and technical panels have generated good support, not only among managers, but also among working levels throughout the Department.

Continued support depends on successful delivery of research products. In this context, success is not defined as development of a miraculous new idea or product; rather, success means that a research investigation was well designed and accomplished a set of worthwhile objectives. When managers are informed of a study's objectives and agree to them, they are entitled to a successful project according to this definition. Recently, some have argued that productive research requires large sums of money with minimal restrictions on how it is used (*5*). This may be true of some projects in some environments. In the context of a state transportation department, however, well-defined projects with well-understood levels of risk and realistic promises of benefits will better encourage long-term support for research.

CONCLUSION

The organization and procedures adopted by the South Dakota Department of Transportation have enabled the Department to significantly expand its research activity and broaden its scope of investigation. The Department certainly did not invent most of the concepts described here; rather, it selectively borrowed and modified others' procedures whenever possible.

Adoption of formal research procedures has improved the credibility and productivity of the Department's research effort. Because the procedures rely on broad participation of the entire Department, research results are more readily accepted and Department support is strong.

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Managing a Collaborative State Department of Transportation–University Research Program in Washington State

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The administrative functions of a state department of transportation (DOT) research office are outlined and the way a collaborative, university-based research program interacts with these administrative functions is addressed. Also addressed is how a productive relationship has been established in Washington. The major administrative functions are broken down into funding, program development, program management, and implementation and technology transfer. Issues associated with a collaborative research program between a state DOT and university are identified. DOTs are principally interested in practical, implementable results from a tightly managed program and recognition for their agencies. Universities are interested in supporting students, obtaining access to operating transportation facilities, publishing in recognized academic journals, and funding for hard-to-obtain equipment, travel, and other benefits. With proper communication and interaction between technical personnel and university researchers, both entities can benefit substantially from a joint relationship. The university gains funding, students, equipment, and publications. The DOT gains research results, technical assistance, and training. Because there is substantial common interest and benefit from a collaborative, long-term program, increased emphasis in research at the national level will likely produce additional interaction in the future.

Inside a state department of transportation (DOT), a research program sometimes occupies a rather tenuous position. At times, budget cuts and shifting priorities have caused some states to limit or nearly eliminate their research programs, as recently happened in the state of Alaska. Within this environment, a collaborative research program between a state DOT and a university presents additional challenges and, at the same time, many opportunities. Collaborative research programs involving state DOTs and universities require compromises on both sides. However, once a strong relationship has been developed, the state DOT and university can receive value far beyond the research program. The Washington State DOT (WSDOT) has developed a strong, collaborative relationship and has avoided swings in budget support for research programs noticed in some state DOTs.

The state DOT-university research program puts additional burdens on the administrative aspects of the overall research effort. This paper looks at the administrative functions of the WSDOT program and explores how its relationship with two universities fits into the overall management structure of this research program.

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UNIVERSITY-DOT COLLABORATIVE EFFORTS

Shuldiner and Collura (*1*) studied collaborative research between state highway agencies and universities in 1986. Their findings can be summarized as follows:

> The most successful programs were characterized by the following features:
> a. joint participation by both the university and the highway agency in the initial development of the collaborative program;
> b. a willing commitment by both parties to make the program work;
> c. a truly collaborative rather than arms length relationship;
> d. lots of time, trust, and patience.

On the face of it, universities and state DOTs are very different organizations, staffed by people with different missions. A survey conducted in 1983 by WSDOT showed that of the 50 states and the District of Columbia, 29 preferred to have their research conducted somewhere other than universities, and 22 preferred to have their research conducted at universities (*2*). At that time, about 33 percent of the funding that states spent on research as a whole was conducted by universities (*3*). Although this survey indicated that not every state DOT has seen value in developing a strong relationship with a university, states such as California and Texas have developed long-term, noteworthy collaborative programs. The creation of the University Centers program from the Surface Transportation Act of 1987 has enhanced the contacts and the development of joint projects, if not programs between states and universities.

WSDOT-UNIVERSITY PROGRAM

WSDOT and Washington's two state research universities, Washington State University and the University of Washington, have for years had a research relationship. In 1983, WSDOT management decided to enhance its research program and build much stronger relationships with its state research universities. The Washington State Transportation Center (TRAC) had been formed in 1981 to help foster these relationships, and in 1983 additional emphasis and funding moved the two organizations much closer. At that time, DOT appointed a faculty member from the University of Washington to be its research director on a contract basis. This person was also director of the Transportation Center. This relationship lasted for 4 years, after which the size of both programs justified full-time management. However, this joint directorship provided a unique period during which each group could more clearly understand the others' needs and desires for a research program. As part of these changes, a new research program development process was adopted. It included university faculty participation in writing proposals, many times jointly with WSDOT personnel; evaluation of proposals by technical committees; and management of research projects in close collaboration with WSDOT personnel.

Key to the success of a cooperative program of any nature is the concept of partnerships. In Washington state, this concept is expressed first through the university center director's awareness of DOT needs and concerns and the DOT research director's awareness of university needs and concerns. These individuals believe in the benefits of the partnership and relay that belief to DOT technical and operational staff and university faculty. This leadership enforces the second level of partnership between the individual faculty member and the DOT technical monitor, who is normally a member of a technical staff (e.g., Bridge Office). Further, the DOT research director and the university director/deputy director encourage the joint authorship, and ownership, of the specific research by the particular faculty and DOT technical monitor. This concept adds immeasurably to the usefulness of the research products and to the support of the cooperative programs at both campuses.

ADMINISTRATIVE FUNCTIONS

An NCHRP synthesis provides a review of research programs within state DOTs (*4*). Many of the findings of that document have been incorporated into the Washington State Department of Transportation's research program (*3*). The WSDOT conducted a nationwide survey of research programs to ascertain their structure, mode of operation, and other administrative aspects to help restructure its own program (*2*). The NCHRP synthesis and the WSDOT study, although somewhat out of date, provide excellent background for an examination of typical administrative activities carried out within state DOTs.

The following discussion describes the administrative functions of the collaborative WSDOT-university research program. Program funding, development, management, and implementation and technology transfer are addressed.

Program Funding

The most traditional source of research funding for state DOTs is FHWA Highway Planning and Research Program (HPR), matched with state funds. Some states choose to use all state funds for research and use the HPR funds strictly for planning. These states presumably feel that they decrease their administrative burdens by reducing federal oversight of spending for research. Some states add state money to their HPR research plans and aggressively seek additional research funds from agencies such as FHWA and the former Urban Mass Transportation Administration (UMTA) (now FTA). WSDOT research funding was, for many years, based on HPR funds, state match, and limited state funding supplements. However, in the last 4 years the state has added significantly more state funding to the HPR money and has obtained additional FHWA and UMTA funds to augment its research efforts.

One major advantage of the DOT-university collaborative effort is that DOT can tap university expertise in leveraging research funds to enhance the research program. University faculty are adept at writing proposals for funding. With cooperation from the state DOT, matching funds, and other DOT expertise or equipment, university faculty can develop strong proposals that are likely to be funded by federal agencies.

One example in Washington state is an UMTA grant for a study of the private development of park-and-ride lots. WSDOT provided state funds and in-kind support from staff, and in-kind matching was obtained from a local transit operator (Seattle Metro). UMTA provided the remaining 80 percent of the funding. The proposal was prepared by the university principal investigator. This project illustrates the leveraging of state funds possible through collaborative efforts.

The state DOT research program also needs a constituency that will help fight for its budget. This effort is enhanced if key managers within the DOT view components of the research program as their own and become strong advocates. Within the WSDOT, this advocacy is facilitated by the manner in which the research program is developed and administered. Research topics are identified, discussed, and prioritized in technical committees comprising WSDOT functional staff, university faculty, research office staff, and FHWA experts. This process, described in more detail in the following section, builds an understanding of research needs and priorities among the DOT participants, both in the functional-technical staff and with the executives who participate in each workshop. These executives and technical staff then become advocates for research funding in their area and assist in assuring funding continuity of the WSDOT research program. The collaborative conduct of the research, with WSDOT technical monitors directly involved, further enforces the concept of ownership by others outside the research office.

It is especially important that universities be given enough advance notice to attract high-quality graduate students, whose role on research projects can hardly be overstated, to work on the projects. Although it is difficult to program and select projects far enough in advance to recruit graduate students on a regular basis, some type of commitment between the university and the state DOT can encourage the recruitment of quality students.

In the WSDOT example, this problem is addressed by the establishment of a 2-year research program 7 to 9 months before the start of the next school year. This timing assures a 7- to 9-month notice to university faculty in the odd-numbered years and allows substantial advance planning for even-numbered years. By striving for predictable funding and selection of priority projects as early as possible, the WSDOT provides an opportunity for the universities to maximize planning and thereby maximize the potential for a satisfactory research product.

Program Development

Program development encompasses several factors. The most successful DOT research programs begin the program development process with some type of broad, grass-roots call for research statements or problems. The NCHRP synthesis (*4*) presented a dilemma as follows: "Experience has shown that operational people often do not find the articulation of their research needs an easy matter. Without the solicitation of problems for research, either formally or informally, the research program truly responsive to department needs may be difficult to develop." In other words, although operations people may have trouble expressing their needs, it is important for their needs to be addressed in a meaningful way. One advantage in an ongoing DOT-university collaborative program is that faculty and graduate students who specialize in certain areas can act with practitioners to develop project statements that serve the needs of the department and are also achievable from a research standpoint. This collaboration assists the practitioners in articulating their needs and assists the researchers in understanding those needs.

The WSDOT program involves university faculty in program development. Faculty are part of the call for problem statements early in the program development process and are encouraged to contact department personnel to develop collaborative problem statements; in fact, they are told that without a department sponsor for their statement, the likelihood is small that the research will be funded. This process provides the necessary communications links and also initiates a relationship between the faculty and DOT technical personnel.

The next step in the program development process is the evaluation of the project statements. The NCHRP synthesis (*4*) points out that most states take advantage of some kind of technical committee to select research projects. At WSDOT there are separate technical committees for each major area in the department (e.g., bridge and structures, materials, traffic operations, design, marine operations, and planning). Each technical committee has as its chair a department manager who is responsible for that program within DOT (e.g., the bridge engineer or materials engineer). The district offices are generally represented on these committees, as is a cross section of relevant technical personnel. Also included on the committees are one or more university faculty members whose primary expertise is the relevant subject area, and an FHWA representative. These groups, consisting of approximately 10 people, rank the list of proposed projects within their technical areas and recommend funding levels for each project. At WSDOT, as at most other state DOTs, management has final approval of the research program.

Program Management

In a collaborative research program, management is needed at both the research office at the state DOT and at the university, typically at a university transportation center. The program management functions of these organizations must be closely integrated, but they have specific duties and functions as follows.

Research Office

Contract administration becomes a major activity of a research office that has a collaborative program with a university. Contract administration breaks into four areas:

1. Review, approval, and contracting for a detailed research plan,
2. Progress monitoring and reporting,
3. Expenditure management, and
4. Contract change processing.

Numerous steps can be taken in a collaborative effort to reduce the burden of contract administration. Standardized formats and review processes, editing and clerical support through the university center, and a streamlined but complete contracting process greatly facilitate project initiation. Progress reports that are quarterly rather than monthly, budgets without a burdensome number of line items to manage, and a process that expedites contract changes all help the research office and the researchers concentrate on the quality of the product rather than on contract administration. The research office has primary responsibility for maintaining a liaison between DOT and the university to assure that contacts are maintained and that misunderstandings do not develop. Because these programs are established on a long-term basis, individuals who cannot or will not participate in good faith can be easily identified and prevented from becoming a continuing problem.

Another important role that the research office can play is to broker relationships between the DOT-university researchers and FHWA and other government agencies. Research offices are one main point of contact with federal agencies, and through contacts and the promotion of particular ideas, the research office can assist the university in gaining federal funding.

University Centers

The transportation center at the university, if funded predictably, can provide a stable professional staff that can be counted on to monitor budgets, maintain high-quality reports, assist in reporting requirements, monitor progress and expenditures, and enhance contacts between university people and DOT.

The university center director's role is to direct the center's staff and functions and, more importantly, to represent the collaborative program at the university. This involves continuing the liaison with faculty; explaining DOT needs; recruiting faculty to participate in DOT-sponsored research; explaining the requirements of the collaborative program and contract research; and solving problems that occasionally arise.

The director must also maintain a liaison with the DOT research office and technical monitors to be aware of their needs and of any potential problems that may be developing. The director's advice to DOT on productive research proposals and opportunities, program balance, and university relations is also essential.

The center's word processing, editing, and graphics support staff can provide substantial services to individual research faculty, making the contract research with DOT more attractive to the faculty. The support staff also can provide significant assistance in budget monitoring and progress reporting, to the benefit of both the university researcher and DOT. Joint funding of the center staff, by the university and DOT, assures that both parties will support and utilize the center's services.

WSDOT-TRAC COLLABORATIVE BENEFITS

Once a solid relationship has built up between the university program and the state DOT, opportunities arise that never would have presented themselves in the absence of that relationship. For example, WSDOT recently decided to eliminate a bridge along Interstate 90 in the central part of the state. The bridge was no longer needed because of a railroad abandonment. This bridge presented a unique opportunity for a full-scale test of its earthquake resistance. Collaborative effort allowed researchers at the University of Washington to conduct earthquake experiments shortly before demolition of the bridge. This project required that contract execution, project design, and implementation proceed in an extremely short time so that the project would not impede the contractor's progress. This project could not have been completed without the long-standing, solid relationship that existed between the Washington State Transportation Center and the WSDOT.

The long-term existence of the university center and DOT's participation with that center has facilitated the involvement of a larger number of broader-based faculty at both state research universities. Intelligent vehicle-highway systems (IVHS), environmental legislation, intermodalism, and transit issues are now being productively explored to a much greater degree, building on the successful partnerships established over the years in materials, structures, and traffic operations. This broadening of the WSDOT research program has occurred as university faculty have involved their colleagues in their work, have introduced colleagues to WSDOT research and operational staff, and have seen transportation research productively pursued by their peers. WSDOT executives have also seen the benefits of research in traditional areas and have encouraged their subordinates to pursue research in less traditional areas.

Implementation and Technology Transfer

Perhaps the easiest and most effective way to implement research projects is to involve DOT personnel early in the development of the research program and often during its execution. At WSDOT, where strong relationships have been developed between individual faculty and DOT technical people, research projects have been conducted successfully and with a high degree of implementation. These relationships are beneficial to both DOT and the university because little time is lost in defining the projects and a strong program continues to build. Implementation may take place before the results of a project have been formally distributed in a research report, newsletter, or other technology transfer device. A program manager or engineer who has identified a problem and worked actively with internal or external research personnel to solve that problem is far more likely to adopt the project's conclusions than a person told to adopt a totally external product. This has often been referred to as the "not-invented-here" syndrome. Further, the literature concerning organizational change and innovation contains numerous references to the importance of fully understanding the creative (research) process to effectively use the innovation.

However, the technology transfer process goes beyond the selection and administration of high-quality research projects. It must also include the normal array of information devices such as report distribution, newsletters, seminars, videotapes, and conference presentations.

Once again, universities can assist in the implementation and technology transfer process. Because their primary mission is education, universities have facilities available to help in the production and distribution of technology transfer products. In a collaborative program, faculty and DOT personnel can be encouraged to co-author technical papers presented at national conferences. This joint authorship provides recognition for the contributions of DOT people and also contributes to their professional development.

Short courses and other means of training have been a common outcome of this relationship. The training and short courses have related to both specific research projects and other academic subjects in which the WSDOT has an interest. WSDOT personnel have served on Ph.D. and master's student committees as referees. This service has enhanced the educational process. WSDOT has also located several of its technical personnel at the Transportation Center, where they participate jointly with faculty and TRAC employees on WSDOT research projects and other federal projects that have been developed. WSDOT personnel have taught graduate and undergraduate classes in transportation in the Civil Engineering Department at the University of Washington. They have also been guest lecturers in graduate and undergraduate classes. WSDOT has provided the universities with field trips for students, enhancing their education while gaining valuable research products.

University faculty provide ongoing technical assistance to WSDOT, the Washington State Transportation Commission, and legislative committees. The University has conducted conferences for the WSDOT. Other technology transfer activities have included the development of videotapes and newsletters and the operation of technology transfer vans in rural areas of Washington, Oregon, and Idaho.

WSDOT and the University of Washington have also developed a fellowship program with the cooperation of Transportation Northwest (TransNow), a federally supported, regional transportation center at the University of Washington. This fellowship program has sent as many as ten people per year to the university to obtain master's degrees in transportation planning and traffic engineering. These activities all have been direct outgrowths of the relationship built up through the collaborative research program. The activities have stretched far beyond the research projects to many other areas in education, training, and technical assistance.

WSDOT Executive Involvement

WSDOT executives are not involved in the day-to-day conduct of research, yet their knowledge of, and support for, the research effort is essential to program continuity. WSDOT and TRAC sponsor seminars on emerging issues and on ongoing WSDOT-university research. The day-long seminars feature nationally recognized experts in particular research fields, University of Washington and Washington State University faculty, and WSDOT technical staff. Also invited to the seminars are the university deans for engineering and research and interested private-sector individuals from such transportation companies as Boeing, PACCAR, and Concrete Technology.

These seminars are an important aspect of providing continuing support for the collaborative research programs and of keeping WSDOT executives current on emerging issues, research needs, and research results. The university administrators and faculty gain insight into new work other than their own, and the resultant discussions of issues between the WSDOT and faculty enhance the mutual trust necessary for cooperative programs. In addition, the private-sector experts gain an understanding of WSDOT's problems and of its efforts to resolve these problems through technical research.

WSDOT executives also review and approve the biennial research progress of projects. An internal committee, chaired by WSDOT's deputy secretary and consisting of three other headquarters executives plus a district administrator, reviews the 2-year program of projects. The DOT research director and the university center director jointly present the program, illustrating the balance among functional areas and describing each proposal project. Significant changes proposed to the program are also approved by this committee.

ISSUES IN ESTABLISHING AND OPERATING A UNIVERSITY-DOT RESEARCH PROGRAM

As mentioned previously, universities and state DOTs have very different missions and are driven by different goals and objectives. The following sections examine the points of view of the state and the university. This discussion is not meant to be universally applicable to all states or all universities but is merely illustrative of the compromises that must take place to build a strong relationship.

State Perspective

State DOTs often assert that they need practical research results that can be implemented and are useful within their organization. The mission statement of the WSDOT Research Office specifically says that the research goal is to ". . . increase the effectiveness of transportation systems and programs in the state . . . ." Implementation is often accomplished at the end of several multi-year research projects by asking the project's principal investigator to draft changes to the DOT design manual. This forces the researcher and DOT to agree on the true meaning of the research results, and although it can be a very painful process, it can also be a very practical one. It also helps to demonstrate that the research is being utilized.

Another item of importance is to ensure that everybody involved in the process receives some credit. WSDOT technical reports always identify on the cover with the authors the DOT person who was responsible for project oversight. The encouragement for collaborators to write co-authored technical papers also helps build relationships. DOT personnel sometimes express frustration at not being able to maintain telephone and face-to-face contact with researchers. This is a problem of which all parties need to be aware, and the solution may be as simple as installing electronic voice mail or fax machines to ensure that technical people can reach each other when necessary. Project schedules can be difficult issues in an organization such as DOT, which is very schedule driven. Research projects do not always march to the same drummer. DOT may have to be flexible about research project schedules to gain the highest quality products. Often the reasons for delays are outside the researcher's control. Again, close contact and communication among the technical monitor, the research office, and the researchers is essential.

DOTs may complain that final reports are of poor written and visual quality—not up to the same standards that DOTs have become accustomed to with private consultants. This problem can be overcome by an ongoing relationship that allows the transportation center to maintain continuity in its staff by hiring editors, illustrators, word processors, and other personnel necessary to develop professional products. Inevitably, in a relationship between a university and DOT, a faculty member at the university will be in a position to criticize the operation or some other aspect of DOT management. This always causes a strain on the relationship, which can be overcome only by the overall strength of the relationship itself. All must understand that problems will arise that have to be ignored or overcome in some other way for the relationship to work.

University Perspective

University faculty are driven by the need to attract research support, which funds graduate students and produces publications in academic journals. Faculty gain tenure and promotion through these activities, and DOTs need to understand the reward structure in the university to understand faculty behavior. For many faculty, a grant from the National Science Foundation (NSF) is considered to be of higher value than a contract with the local DOT or other agency. However, NSF provides few grants in the transportation area, which has had the effect of pushing faculty to look for other funding sources, including state DOTs. The need to support students and equipment that is normally not provided by the university and to travel to conferences is important.

Further, the graduate students' education is often significantly enhanced by working closely with DOT practitioners. The students begin to see how their academic training can be applied in the field, in addition to contributing to problem solutions and advancing the state of knowledge. Faculty can also gain insight into new, productive areas of research by interacting with the DOT practitioners in the field. DOTs have facilities and other information that are important to university researchers. The attraction of these facilities, such as the bridge mentioned previously, can provide strong motivation for faculty to interact with state DOTs.

CONCLUSION

This paper examines the administrative aspects of a collaborative DOT-university research program and addresses the mutual benefits of this collaboration. In Washington state, researchers from two universities work collaboratively with technical staff in the Washington State Department of Transportation to develop programs, conduct research, and implement research and technology transfer. This long-term relationship, established in 1983 and refined since that time, has yielded products with a high potential for implementation. The direct involvement of personnel from the WSDOT technical staff offices has resulted in an appreciation for the benefits of research; these people have in turn become advocates for continuing or enhancing research program funding. WSDOT executives are involved in the research program, which, combined with the success experienced in traditional areas, has allowed the research to expand further into emerging areas, such as intermodalism, IVHS, and environmental and transit issues. This expansion has involved new faculty and students at the universities. WSDOT needs practical research results that can be implemented. The universities are interested in supporting students, having access to operating transportation facilities, and publishing and funding. The WSDOT and the universities have made substantial efforts to understand the needs and motivations of the others and to be sensitive to those needs. Both parties have gained substantially from a long-term relationship that has fostered interaction among faculty, students, and WSDOT professionals.

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Marketing Transportation Technology and Programs

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The road and transportation industry in the United States has a long history of seeking out new and innovative technology for the developing transportation infrastructure. Active federal support for the improvement of transportation systems dates from the late 19th century. Assistance from the federal government facilitated access to new technologies and created opportunities for assimilation. Early-model programs of technology demonstration, technical assistance, and training have remained effective tools of technology transfer to the highway community 100 years later. New strategies are required, however, to keep pace with the increasing rate at which new technology and products have become available. In 1990, the Federal Highway Administration defined a marketing process through which highway programs and technologies could be more effectively developed, promoted, implemented, and deployed. The marketing approach incorporates user needs, attitudes, and perceptions into development of new research products. Successful promotion and timely deployment of innovative technology and programs are also dependent on the interest and participation of our partners in the highway community. An historic overview of highway technology transfer in the United States and a description of the evolving marketing program designed to enhance the process are provided. It has been found that successful technology transfer depends on the involvement and support of partners in the domestic and international highway community who help shape the highway program throughout the marketing process.

The prosperity of our nation has depended on the progressive evolution of its transportation infrastructure: a product of partnerships, both private and public, and application of proven technology, both national and international. From the early roads that used successful European pavement techniques, to the sophisticated ribbons of interstate highways built with cooperative effort, the American transportation system reflects an evolution of federal and state roles and application of innovative technology from a multitude of sources.

Early federal involvement in transportation helped the economy grow by linking commercial activities of the states. Thomas Jefferson signed the first federal highway program into law in 1806, creating the National Road (now called U.S. Route 40 in upper Maryland), which connected Ohio to the Eastern seaboard (*1*, p. 1).

The United States led the "turnpike movement" (*2*, p. 11), coordinating the construction of privately financed public works to link up with the National Road. Development of this early road network captivated European interest and investment capital as well as U.S. dollars. States worked cooperatively with each other and private firms to operate toll roads in support of road maintenance.

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Although early highway programs were mostly state functions, a few forms of federal assistance were in place in the 19th century. Federal troops opened up the Western Territories with primitive roads. The federal government also granted free right-of-way for state public roads over unreserved public lands.

The Good Roads Movement of the 1890s shaped the role of state aid for roads and pressured Congress to define a measure of federal assistance. As a result, the Office of Road Inquiry was established in 1893. Throughout this scenario, the focus had been "farm-to-market," dealing with agricultural concerns and rural roads. The new office, within the U.S. Department of Agriculture, collected and disseminated information on roads, primarily serving in an educational and promotional capacity. Later responsibilities expanded to include "object lesson roads," which demonstrated successful road construction techniques, and experimental roads, onsite assistance, and training.

It soon became evident that an enormity of road problems needed to be addressed on a national level. The Federal-Aid Road Act of 1916 addressed the growing responsibilities of roadbuilders beyond construction: considerations of the economy, social and cultural needs, the environment, natural resources, and international relations, where appropriate (*2*, p. 202).

The Bureau of Public Roads, as it was called in 1919, established its role as one of encouragement, leadership, and protection of the national interest. The newly formed American Association of State Highway Officials (AASHO) complemented this role in partnership with federal efforts, consulting on highway construction, legislation, and state issues.

The need for a national program of highway research was addressed through the Highway Research Board (later named the Transportation Research Board). The program coordinated activities in industry, academia, and other organizations for dissemination of information about research to the highway community. These early believers in the open discussion of research also recognized that technical information is "of no value to anyone unless it is learned and put to use by the technical man (*2*, p. 209)."

As the automobile revolutionized transportation technology, the thrust of highway technology shifted along with the population to address concerns of urban centers. A new vision focused on developing a highway system to improve national defense capabilities and link the network of manufacturing centers.

With an increased pace of technological innovation came a greater demand for specialized knowledge and skills. The highway program expanded, interacting with other federal programs and the general public.

Among the significant actions in the Federal-Aid Highway Act of 1956 was development of the Interstate Highway System under the jurisdiction and guidance of the Bureau of Public Roads, then in the Department of Commerce. As the Interstate construction program got under way, the Federal Highway department decentralized for more effective local project management. The interstate system is nearing completion under stewardship of FHWA within the Department of Transportation.

The end of the Interstate construction era provides an opportunity to redirect the focus of FHWA activities and define its leadership role in disseminating transportation technology. An era of system development has been replaced by an era of system performance (T. Larson, unpublished data, FHWA, 1991). The mature highway system now requires preservation, improvement, and enhancement. Increased motor carrier activity and a growing commuter public contribute to congestion, pollution, and loss of economic productivity. The National Transportation Policy (*3*) addresses these issues and proposes new strategies for the 21st century. Budget restraints and deficit reduction, changing demographics, and the urge to innovate are driving future actions. The policy reaches beyond the traditional role of the federal government to involve all parties with a vested interest in transportation and quality of life—state and local governments, academic institutions, the private sector, and the driving public—to work together to improve the safety and efficiency of our transportation system.

The FHWA plays a significant role in the mission to improve the transportation system and to revitalize the domestic economy through its programs of highway research, development, and technology transfer. FHWA has the opportunity to participate in activities of the international highway community, bringing the best of foreign technology and techniques to the United States. A marketing approach not only directs research and refines product development but also enhances the process of technology transfer through strategic planning of activities.

FHWA TECHNOLOGY TRANSFER PROGRAM

Technology transfer is the sum of activities by technology sponsors, developers, and users leading to the adoption of a product or procedure (*4*, p. 1). The traditional technology transfer program starts with a research product or program and develops a strategy of delivery to the appropriate user in the highway community. The program defines potential users, barriers, opportunities, and tools for moving technology from the implementer to the user. FHWA has successfully used its technology transfer program since the 1970s to link technologies and procedures with practical applications in the highway community. Services included hands-on demonstrations, workshops, technical assistance, special studies, and training courses. Other support included distribution of manuals, films, and tapes to appropriate personnel at the state level and development of technical procedures and guidelines. Technology transfer specialists coordinated activities at the regional and division levels and used personal contact as the strategy for successful communication.

However, one-to-one contact is not always an appropriate tactic at every level of the transfer process. Effective transfer is complicated because of the multijurisdictional nature of the highway industry and the need to transfer this technology to users at various levels (*5*, p. 2). Various groups with distinct capabilities, responsibilities, and agendas require a range of unique technology transfer activities. Highway programs often need political visibility and benefit from participation in cooperative activities with highway organizations to rally public support.

A program review study (*6*, p. 7) found that many useful products coming out of research studies were items not predicted in early stages of research. Oftentimes these new products or solutions to problems were lost by the inability to move them out of the laboratory and into use. The 1990 FHWA report, "Marketing Highway Technology and Programs," established a marketing process by which FHWA could more effectively develop, promote, and implement these useful highway products and programs.

A MARKETING PHILOSOPHY

Marketing involves an exchange of values that can be tangible, such as money exchanged for groceries, or intangible, such as the use of seat belts exchanged for passenger safety. To understand how marketing applies to government technology transfer, it helps to explain its evolution as a business philosophy (*7*, p. 37). Business management can be distinguished by four orientations that evolved during significant economic eras in the United States.

A product orientation follows the "better mousetrap" theory: that the major task of an organization is to put out products perceived as good for the public. The public may not need or want a better mousetrap or an Edsel automobile, for that matter. The producer is confident that the product meets the company objectives and does not feel obligated to modify the product to meet customer needs. Historically, this product orientation developed at the turn of the century and highlighted such great products as the electric light, the radio, and the automobile.

According to this approach, research done "for the sake of research" is justified because it creates new knowledge (*8*): "If the knowledge is there a use will be found for it." A product not developed for a specific purpose leads to an ad hoc process of technology transfer, with a product searching for a user.

A production orientation focuses on efficiencies in production and distribution within an organization. Innovations in service and assembly-line production (exemplified by Henry Ford and his first automobiles) often bent the needs of the consumer to fit the system. "You can get this automobile in any color as long as it's black" reflects assembly-line thought. This philosophy is reflected in some government technology transfer efforts as well. To get a new technology in use on the highway, sometimes a product is released before it is thoroughly tested and evaluated. Hot thermoplastic pavement striping is an example of a highway technology not fully developed before release. Although demonstration test sections were already being applied, it was found that further refinements to application techniques needed to be made for proper performance. Giving a new product such a false start creates a skepticism about the value of future improvements.

A sales orientation is often mistaken for a marketing approach. It centers on using persuasion techniques to push a particular product or technology through advertising or personal salesmanship. This approach developed in the Depression era of the 1930s when production exceeded demand. With a glut of mass-produced items on the market, the key to company success (or survival) was salesmanship: convincing the consumer to buy its product over that of a competitor. The term "Madison Avenue approach" is used often to convey a less-than-flattering image of aggressive sales tactics and advertising.

This philosophy goes against the grain of traditional government thought (typically product-oriented), which supports the notion that a useful product sells itself without resorting to glitzy promotion. But good salesmanship is one characteristic of an effective technology transfer agent that is emphasized in FHWA literature on successful technology transfer (*5*, p.8). An outgoing personality and ability to network with the right users are still important and valid characteristics.

A customer, or market, orientation can alleviate the need for aggressive sales tactics. As the U.S. economy rebounded in the 1950s, consumer wealth increased. The demand for high-quality products grew and consumers no longer settled for products pushed on them. This "consumer-centered" philosophy is evident in promotional campaigns for airlines ("the friendly skies") and in improvements in service (solicitous sales personnel at Nordstrom's retail stores).

This systematic study of customer needs, wants, and perceptions can be applied to technical innovation activities in the highway and transportation community. By determining user needs early in the research process and developing the product around those needs, a technology can sell itself to the right users. The product format, promotion and style will be appropriate because these are geared to benefit a particular segment of the user community.

Marketing Highway Technology

A restructured approach to technology transfer was formulated through extensive outreach to the highway community and coordinated by FHWA. Four premises frame the actions of this program (*9*). First, both public and private highway agencies must commit resources to develop and evaluate innovative research and technology in a timely manner. Marketing techniques can streamline this technology transfer process, proving the commitment of personnel, funding, and equipment to be a cost-effective investment.

Second, marketing techniques must be incorporated into the program activities of FHWA. Employees involved in product development and outreach programs should become familiar with the "tools of the trade" described in the marketing process, such as segmenting markets (grouping users by need) and developing marketing plans.

Third, successful marketing efforts are based on involvement and participation of partners in the highway community. Federal and state agencies, local governments, industry, academia, and international groups must all have a role in the marketing process. All these groups should be included in the identification of needs, design of research, and product development. This cooperation ensures that the right issues are addressed in a timely manner and that opportunities for innovation are recognized and acted upon.

The fourth premise incorporates the first three into a strategic process that ultimately links a technology product or program with targeted user groups and tracks its implementation. This marketing process starts with the identification of needs and extends through the deployment, implementation, and evaluation of products developed to meet those needs.

Marketing Process

"Research without implementation is akin to good strategy without execution" (*5*). There is no return on investment if a product stays on the shelf. To facilitate implementation, the FHWA marketing process depends on early input from outside groups to guide research and nurture a receptive audience for a product or program as it develops.

The marketing process begins with identification of needs. Problem areas and definition of research programs are discussed with partners in the transportation community to guide this most critical element. In a marketing approach, research is proactive rather than reactive. Customer needs, wants, and perceptions are anticipated and tracked.

The process continues with product development and monitoring. This is not a discrete step, but a continuous flow of feedback from program offices and partners to ensure that research is on track and is addressing the original issue. Field personnel have a "feel" for how a material can perform (*10*). The goal at this stage is to quantify that feel and feed it back into the product development. The National Society of Professional Engineers developed a similar process for evaluating technology (*11*) that calls for incremental evaluation and redefinition of the problem as required.

Product analysis is an extension of product development, assessing the need for further testing and refinement, making modifications recommended by potential users to enhance implementation. Market analysis is also an ongoing part of the process relating product development to evolving market needs. It defines levels of use and obstacles to overcome in getting a technology on the market and identifies opportunities to enhance acceptance.

These steps can be presented graphically on a technology life cycle, which relates product development to stages of the marketing process (*12*) (see Figure 1). The process is envisioned as a flow of information and positioning rather than discrete steps.

The FHWA life cycle associates with steps in the marketing process. Guardrail development, for example, is at a mature stage of its life cycle. Numerous styles of guardrails are now available. Within the marketing process, ongoing product and market analysis determine the need for cost-effective guardrail improvements. For affordability, new features adapt standard guardrail components. Ongoing needs assessment results in engineering modifications for improved safety. Mar-

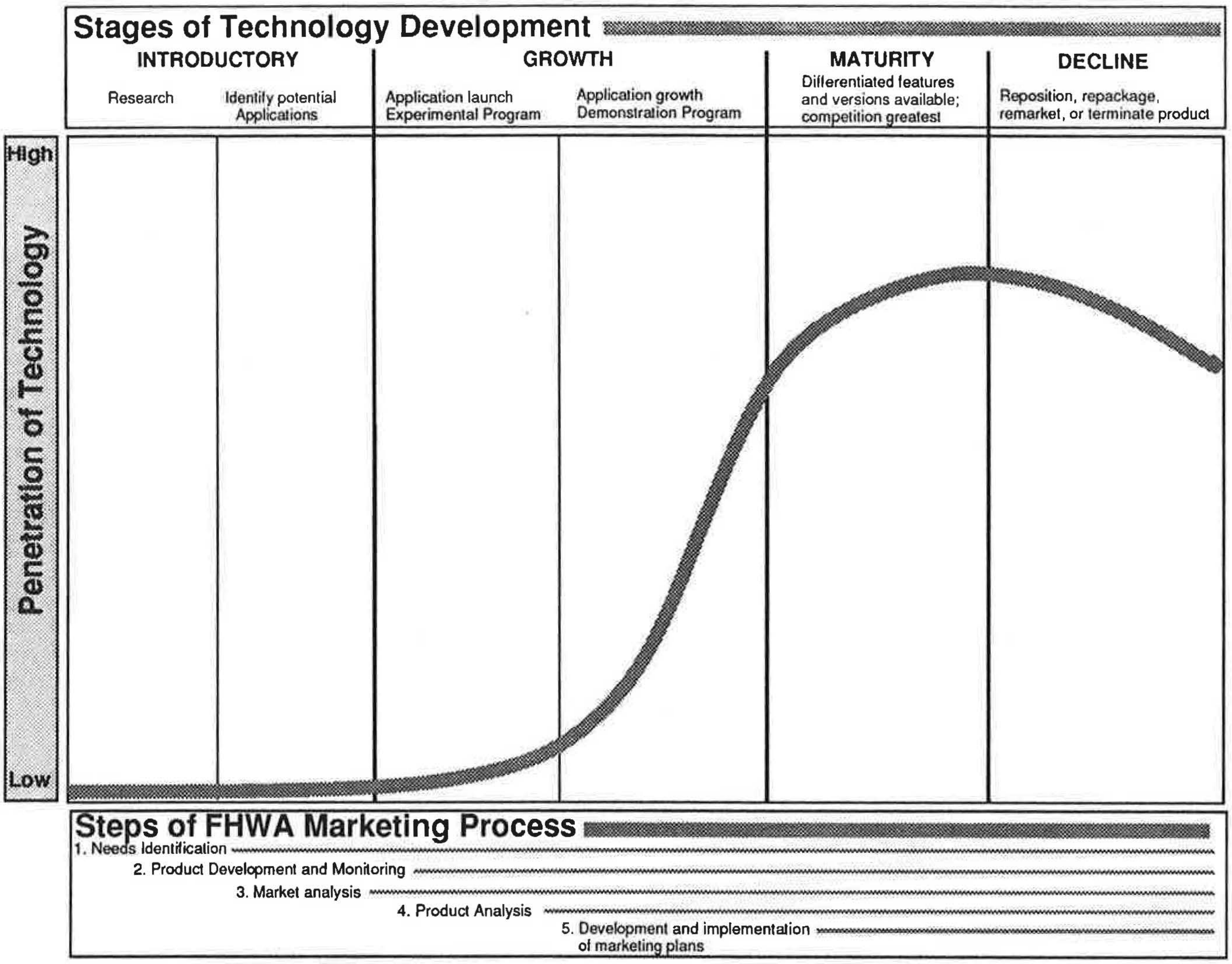

FIGURE 1 Technology life cycle.

keting activities include targeting appropriate levels of users to communicate benefits and information about improved guardrail features.

A marketing plan documents this process of product development and market analysis. The written plan serves to relate the strategic fit of agency goals, resources, and market conditions to developing products and programs. It defines, for a specific planning period, how to allocate resources to a program and how to evaluate performance and effectiveness (*13*, p. 90). Although they may be perceived of as "more paperwork," plans serve an important function in the application of technology.

A formal plan links research with program facilitators and the ultimate user. It coordinates decision making, sets a timetable for program activities, and establishes a "critical path" so necessary steps are not missed. The primary function of a plan is to improve communication among top management, program offices and other players in the program. It systematically presents analysis, assumptions, expected developments, strategy alternatives, and resource needs. This level of planning enables FHWA to focus on its goals and objectives and keep its activities within the scope of the marketing plan.

The Office of Technology Applications (OTA) works with the program offices to generate marketing plans for high-priority products and programs. OTA was established in the fall of 1990 to consolidate and strengthen the outreach activities of demonstration projects, experimental projects, the Rural Technical Assistance Program, and technology transfer efforts of the former Office of Implementation. OTA has three divisions—Technology Management, Engineering Applications, and Safety and System Applications.

OTA provides a coordination function within FHWA for funding and managing technology. The office also provides technology transfer expertise in key technical areas through technology assessment and applications activities. Responsibilities of OTA include

- Identifying and assessing technology requirements in the highway community;

- Assessing new products identified through research and other sources;
- In conjunction with program offices, developing and implementing marketing plans for new technology and programs;
- Evaluating the effectiveness of the technology transfer process; and
- Coordinating and planning a national and international marketing program to facilitate adoption of technology products from the Strategic Highway Research Program.

OTA developed formal training in marketing for FHWA technology transfer personnel at headquarters and regional and division offices. In coordination with the National Highway Institute (NHI), this training under modification for continued presentation to technology transfer counterparts in state and local highway agencies and personnel at state university-based technology transfer centers.

This combination of technical expertise and marketing skills at FHWA enhances agency credibility and streamlines program evaluation. Developing marketing skills at every level of technology transfer ultimately speeds technology to the user.

Application of these marketing skills helps organize complex programs such as incident management. Incident management involves coordinating and mobilizing a response team of police, fire, and medical vehicles, and tow trucks, among others, to clear vehicle collisions and other blockages of traffic in a timely manner. The program requires cooperation and teamwork among diverse groups with firmly established roles in traffic operations. An effective program of incident management addresses the need to redefine these traditional roles.

An incident management marketing program can provide a structure for sharing resources with states and local governments. Demonstration projects, reports, and technical assistance can be scheduled in the action plan, with FHWA program offices assigned responsibility for delivery of associated activities. The activities and information packages described in the program plan can be used to create individual marketing plans tailored to the needs of particular communities. Established incident management programs vary widely in nature, depending on the jurisdictional constraints and cooperative opportunities particular to an area.

FHWA addresses the needs of its constituency by working with its partners to develop and prioritize useful products and innovative technology for the highway community. Sometimes the innovation is just a new way of doing business, involving minor changes in operating procedures, or providing a video for instructional purposes rather than a report. A strong marketing orientation in the field attunes transfer agents to the right communication strategies for getting a technology understood, accepted, and in use. The Rural Technical Assistance Program established a decentralized network of technology transfer centers for this purpose. The centers translate technology into useful formats for the local highway organizations and then pull technology from all sources to solve specific problems.

CONCLUSION

Incorporating innovation into the traditional structure of technology transfer required both a philosophical and physical restructure of FHWA. Adoption of a marketing philosophy acknowledges a change from the traditional inward, product focus to a broad, multifaceted consumer focus. Whereas our original technology transfer program focused on the state as the ultimate target of activities, product and program development now includes a wide base of concerns, from those of the driving public at the local level to interests of the international community at large.

The goal of marketing in this environment is to assist the surface transportation community in seeking innovative solutions to transportation problems through focused research and to ensure that these solutions get put into practical application. All decisions toward this goal should be made in reference to needs of the highway community. FHWA has committed resources to developing a strong marketing orientation among its personnel in the program offices and the field. It has reorganized its technology transfer function to provide a marketing management resource at the headquarters level. Although these internal developments are significant, the successful application of innovative technology ultimately depends on the involvement and support of partners in the highway community who help shape the highway program throughout the marketing process.

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