

PROCEDURE

A comprehensive questionnaire survey was made in the county to provide qualitative and quantitative measurements of current traffic-engineering information regarding organization, administration, personnel and operations, maintenance, budget, and community emphasis. This questionnaire consisted of 70 questions that dealt with the following general categories:

1. Traffic engineering problems—questions designed to elicit subjective opinions concerning perceived community traffic-engineering problems as well as county traffic-engineering problems;
2. Organization and administration—questions that pertained to formal policies and procedures for the initiation, performance, maintenance, and review of traffic-engineering functions;
3. Planning and implementation—questions concerned with the planning priorities and the implementation of highway-safety improvements;
4. Operations—questions that pertained to community traffic-engineering activities, methods of identifying hazardous conditions, management of accident-data inventory, highway features, and traffic-control devices;
5. Maintenance—questions related to methods and level of maintenance performed by the local community for traffic-control devices, highways, and lighting; and
6. Budget—questions directed toward determining how much of the community's total budget should be allocated to traffic-engineering activities.

COMMUNITY SURVEY

A stratified sampling procedure was used to select 30 candidate communities for the survey. In determining the stratifications, we recognized that the majority of traffic-engineering and safety problems occurred in that portion of the county where there is high travel demand and high population density. Thus, the number of samples in each category favored urbanized areas over nonurbanized areas. Table 1 gives the stratification used and the candidate communities selected for the survey.

The survey was administered in each community on a personal-interview basis by the community person who performs the traffic-engineering functions. Although answering the questions required approximately 2 h, most persons interviewed cooperated fully.

SURVEY RESULTS AND RECOMMENDATIONS

A summary of part of the survey results and recommen-

dations is given in Tables 2 and 3. The subjects shown pertain to specific questions used in the survey, but the representation is not all inclusive.

The recommendations generated as part of this study were based on an evaluation of the current status of traffic-engineering activities within the county as determined from the questionnaire survey. The recommendations were aimed at specific problem areas in need of immediate attention to improve traffic-engineering activities. The recommendations were classified into two basic categories: policy and system. Policy improvements generally do not require much cost or personnel and may indirectly affect the accident experience in the entire county. System improvements produce direct results in terms of accident reduction if all other safety requirements are followed; these improvements often require a great deal of funds and personnel. Some of the recommendations, both policy and system, are also given in Tables 2 and 3.

CONCLUSIONS

The survey results and analysis clearly indicate the lack of traffic-engineering sophistication possessed by the majority of the sampled communities in Oakland County. The lack of conformance to highway safety standards may be typical not only of the sampled communities in Oakland County but also of the majority of small urban communities that, because of size or budgetary constraints, do not employ a qualified traffic engineer or technician to handle day-to-day activities. Efforts must be made at the county level or higher to aid agencies responsible for traffic operations.

The survey instrument developed as a part of this study is comprehensive and can be used by other communities. Typical policy improvements as presented here can easily be adopted by other communities to help achieve conformance to the highway safety standards.

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Abridgment

Evaluating Urban Highway Service

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Differences are apparent in the quality of road services between one urban area and another as well as between

one place and another within urban areas. Traffic moves more freely and quickly in some cities. Statistics indi-

cate a wide difference in accident rates among cities. Some urban road systems are in better condition than others. Signal timing, lane striping, signing, and other traffic-control methods vary from city to city. Quantifying these variations, however, is not easy. Both data and standard analysis procedures for judging performance of urban road systems are lacking.

Recognizing these facts, we developed a composite rating system for assessing the quality of service of urban street and highway systems. The method and results of its application to 52 selected urbanized areas, as defined by the Federal Highway Administration, are given in this report. The objective is to stimulate transportation planners and urban officials to develop methods for periodic measurement of the performance of their urban road systems and to establish short- and long-range street and highway performance goals. Because the method has only been tested as a means for comparing street and highway service from urban area to urban area, the data used and the method outlined may not be the most appropriate for monitoring road performance in an individual urbanized area.

DATA BASE

The 1974 National Transportation Study, based on 1972 data, contains the most significant nationwide highway-performance information available. The following information was selected from this inventory to determine the performance of each street and highway network:

1. Total kilometers of street and highway,
2. Total annual vehicle-kilometers of travel on arterial streets and highways,
3. Total hourly capacity-kilometers available on arterial streets and highways,
4. Total land area, and
5. Total annual injuries per 160 million vehicle-km (100 million vehicle-miles) of travel.

URBANIZED AREAS ANALYZED

To keep the analysis small enough to be manageable and yet large enough to demonstrate clearly the process used and its results, we selected 52 urbanized areas from over 200 that were defined by the 1970 census.

In selecting the 52 urbanized areas, we considered urban size, location, and economy. All urban areas that had over one million people are included. Twenty selected areas had under 500 000 people. State capitals, resort centers, industrial cities, and agricultural trade centers are represented.

The boundaries of each urbanized area were established by federal, state, county, and city officials in the 1974 study. Included in each urbanized area is a central city of 50 000 or more persons and adjacent urban land that is expected to have a population density greater than 400 persons/km² (1000 persons/mile²) by 1990. All system-performance measures are therefore 1972 data for road systems within 1990 urbanized boundaries.

PERFORMANCE MEASURES

Three measures of urbanized area street and highway performance were used in this analysis: accessibility, mobility, and safety.

Accessibility

Access to land is one of two basic functions or service features of roads. The accessibility provided by each urban road network was defined for this study as aver-

age road density, in kilometers per square kilometer (miles per square mile), of land area. As given in Table 1, road density in 1972 for the 52 urbanized areas ranges from 8.9 km/km² (14.3 miles/mile²) of land area in St. Petersburg, Florida, to 2.4 km/km² (3.8 miles/mile²) in Montgomery, Alabama, and Shreveport, Louisiana.

Mobility

Roads must provide for smooth flow of vehicle traffic. One method of evaluating the relative ease of traffic flow is to compare actual vehicle travel on street systems with the theoretical capacity of street systems to carry vehicle traffic. This method is performed by using calculated volume/capacity (v/c) ratios. The higher the v/c ratio is, the more crowded or congested the intersection, road section, or road system is. Arterial systems with numerically small ratios have less congestion, smoother traffic flow, and greater relative mobility. In this analysis an annual v/c ratio was used to represent the mobility factor. This procedure is a variation of the common practice of comparing hourly traffic volumes and capacities.

Annual vehicle-travel data were available from the 1974 study. The motor vehicle carrying capacity of each urbanized area arterial system, in terms of vehicle-kilometers of travel in one direction for 1 h, was converted to an annual basis first by doubling to obtain two-way hourly capacity values and then by multiplying by 8760 h/year. By dividing the reported annual vehicle travel on the arterial street and highway systems by the derived annual capacities of these systems, annual v/c ratios were calculated.

Table 1 gives the calculated annual v/c ratios for the arterial street and highway systems of the 52 selected urbanized areas. Pittsburgh's arterial system is judged the best in terms of mobility because of the calculated 0.073 v/c ratio. The data and calculations indicate the worst arterial street congestion in Madison.

Safety

The third measure of quality of an area's highway network is personal safety. Safety performance of urban roads is measured here as the number of motorists and pedestrians injured per 160 million vehicle-km.

(100 million vehicle-miles) of travel. Table 1 gives the 1972 vehicle injury rate, as reported in the 1974 study, for each of the 52 urbanized areas. The low is 96.9 persons/160 million vehicle-km (100 million vehicle-miles) of travel in Columbus, Ohio; the high is 677.2 in Rochester, New York.

PERCENTAGE-OF-MEAN INDEX

Both planners and researchers would benefit from a technique that combines components of highway service for comparisons of time and areas. Owing to inadequate data and insufficient incentive for such tools, few performance-evaluation techniques have been developed.

Without resolving many of these problems, our analysis establishes a composite index for 52 urbanized area street and highway systems by calculating a percentage-of-the-mean index for each of the three performance factors and then adding those indexes. The mean for each factor always has a value of 100. In this index, bigger is not always better. Positive performance for v/c ratio and for accident rates is represented by low values, so these items have negative signs in the summation. The relation used for this combination is

Table 1. Percentage-of-mean and composite indexes for 1972 performance of urban roads in 52 urbanized areas.

Urbanized Area	Accessibility		Mobility		Safety		Composite Index
	Road Density (km/km ²)	Index	V/C Ratio	Index	Injury Rate	Index	
Akron	1.4	82.1	0.155	87.1	139.72	52.4	142.6
Albuquerque	1.8	104.0	0.128	72.0	366.83	137.7	94.4
Atlanta	1.5	83.5	0.226	127.0	107.04	40.2	116.3
Austin	1.0	58.8	0.069	38.8	335.05	125.8	94.2
Baltimore	1.7	98.5	0.173	97.2	358.45	134.5	66.8
Baton Rouge	1.8	101.3	0.174	97.8	360.23	135.2	68.3
Boston	1.7	98.5	0.202	113.5	371.33	139.4	45.6
Charlotte	1.6	89.0	0.166	93.3	255.54	95.9	99.7
Chicago	1.8	101.3	0.227	127.6	302.14	113.4	60.3
Cincinnati	1.4	78.0	0.178	100.0	167.68	62.9	115.1
Columbus	1.3	76.6	0.164	92.1	96.91	36.4	148.0
Denver	2.2	123.2	0.155	87.1	238.63	89.6	146.5
Detroit	1.7	98.5	0.288	161.8	184.65	69.3	67.4
Erie	1.9	108.1	0.125	70.2	238.84	89.6	148.2
Flint	1.5	87.6	0.234	131.5	224.69	84.4	71.8
Fresno	2.5	142.3	0.137	77.0	175.25	65.8	199.5
Grand Rapids	1.8	102.6	0.173	97.2	263.57	98.9	106.5
Hartford	1.6	93.1	0.168	94.4	227.20	85.3	113.4
Honolulu	2.3	131.4	0.271	152.3	305.80	114.8	64.3
Houston	1.5	83.5	0.127	71.4	168.91	63.4	148.7
Jacksonville	1.2	68.4	0.172	96.7	344.63	129.4	42.4
Kansas City	1.8	102.6	0.130	73.0	252.54	94.8	134.8
Knoxville	2.8	160.1	0.185	104.0	147.07	55.2	200.9
Los Angeles	2.4	135.5	0.182	102.2	214.71	80.6	152.7
Madison	1.3	76.6	0.549	308.5	168.08	63.1	-95.0
Miami	2.6	149.2	0.272	152.9	589.61	221.3	-24.9
Minneapolis	1.9	105.4	0.205	115.2	225.20	84.5	105.7
Montgomery	0.9	52.0	0.123	69.1	139.12	52.2	130.7
Nashville	2.0	113.6	0.195	109.6	183.06	68.7	135.3
New York City	2.2	123.2	0.138	77.6	544.38	204.3	41.3
Norfolk	1.4	78.0	0.199	111.8	209.32	78.6	87.6
Omaha	2.0	116.3	0.139	78.1	320.71	120.4	117.8
Philadelphia	1.6	89.0	0.200	112.3	246.84	92.7	83.9
Phoenix	1.6	91.7	0.151	84.9	376.86	141.5	65.4
Pittsburgh	1.7	95.8	0.073	41.0	169.96	63.8	191.0
Portland	2.1	121.8	0.171	96.1	415.72	156.0	69.7
Providence	1.9	106.7	0.187	105.1	351.67	132.0	69.6
Richmond	1.3	73.9	0.197	110.7	190.89	71.7	91.5
Rochester	1.4	80.7	0.112	63.0	677.15	254.2	-36.4
Salt Lake City	1.8	99.9	0.149	83.7	259.46	97.4	119.8
San Diego	1.6	89.0	0.096	54.0	149.31	56.0	178.6
San Francisco	2.5	142.3	0.170	95.6	189.95	71.3	175.4
St. Louis	1.7	97.2	0.164	92.1	242.27	90.9	114.2
St. Petersburg	3.4	195.7	0.190	106.8	327.64	123.0	165.9
Seattle	1.5	86.2	0.206	115.8	287.96	108.1	62.4
Shreveport	0.9	56.1	0.196	110.1	205.84	77.3	68.7
Sioux City	1.7	97.2	0.116	65.2	222.12	83.4	148.6
Spokane	1.9	108.1	0.166	93.3	372.29	139.7	75.1
Tucson	1.3	71.2	0.162	91.0	362.23	136.0	44.2
Tulsa	1.6	90.3	0.108	60.7	128.45	48.2	181.4
Washington	1.4	79.4	0.206	115.8	244.56	91.8	71.9
Wilmington	1.9	105.4	0.206	115.8	205.86	77.3	112.4

Note: 1 km/km² = 0.4 miles/mile².

Composite index = accessibility index - mobility index
- safety index (1)

For a hypothetical, average area, the composite index would be composite index = 100 - 100 - 100 = -100. To translate the composite index scale to correspond to the individual index scales, a linear translation (200) was applied. Therefore, average index for the hypothetical area would be composite index = 100 - 100 - 100 + 200 = 100, and the mean area would still be represented by 100 percent of the mean of all characteristics. The final relationship expressed with variables becomes

Composite index = accessibility index - mobility index -
safety index + 200 (2)

This approach weights each of the three factors equally. This simplification was used because it was the best alternative; other weightings could be used with this system.

Also, our study implies that each variable continues to contribute to system performance as its value continues to increase. Clearly, an indefinite number of

kilometers of road per square kilometer of land would be neither optimal nor desirable. For this analysis, optimum values for each variable were assumed to be outside the ranges studied, and linear relationships were assumed to be within each range.

PERFORMANCE OBSERVATIONS

The resulting composite index of highway performance measures for the 52 selected urbanized areas is given in Table 1. The observations listed below indicate the type of information a nationwide analysis of performance measures would yield.

1. The larger urban areas that have grown rapidly in recent years generally have higher highway-performance factors. San Diego, Los Angeles, and Houston are all in the top 10 of the composite index. However, fast-growing Phoenix ranks low mainly because this city has a poor highway-safety record.

2. Most old, large urbanized areas have low composite scores. New York, Boston, and Chicago have poor highway-performance ratings. Pittsburgh, how-

ever, ranks high because of its good safety record and excellent mobility rating.

3. The urban area rated high most consistently in terms of street and highway performance is Fresno, which ranks fifth in accessibility and twelfth in both safety and mobility and therefore has the second highest score in the composite index.

4. Grand Rapids, most nearly typical of the urban areas analyzed, scores 102.6 in accessibility, 97.2 in mobility, and 98.9 in safety and has a composite score of 106.5.

5. No single urbanized area ranks consistently low in all the indexes.

6. Columbus, highest scoring in the safety index, has an injury rate of less than half the arithmetic mean of the 52 selected urbanized areas, indicating a street and highway system that was designed and is being operated with strong emphasis on safe movement of motor vehicles and pedestrians.

7. St. Petersburg, which has an accessibility score of 195.7 and is the leader of that index, has almost twice the road kilometers per square kilometer of land of the average urbanized area and an accessibility score four times that of the lowest ranked city, Montgomery. The St. Petersburg urbanized area is apparently highly compact; most of its urbanized area is fully developed and well served by streets and highways. The Montgomery urbanized area apparently contains much underdeveloped land not well served by roads.

Since all urbanized areas are not included, the resulting indexes of highway service cannot be interpreted as national rankings. No doubt other urbanized areas have highway service characteristics both superior and inferior to those of the cities selected.

NEEDED RESEARCH

Traffic volume and roadway capacity data, as reported in the 1974 National Transportation Study, were used to assess mobility. However, average speed data segregated by various functional classes of urban road would more directly indicate vehicle mobility. Unfortunately, such data are not as yet universally available, and volume-to-capacity ratios are used instead.

Further study might show that other features of road

performance in addition to accessibility, mobility, and safety might prove to be useful in analyzing urban road performance. An engineering appraisal of road surface might be included in further study because of the importance of road surface to travel comfort and to vehicle maintenance cost. But again such data are not generally available.

More study is required to translate performance measures into standards against which urban street and highway performance can be compared. Lacking standards for accessibility, mobility, and safety, we relied on the arithmetic mean for the selected cities as a basis for judging the comparative road performance. Further research might define, for example, an optimum road density as a benchmark for accessibility.

The question of weighting the performance measures is raised because the relative importance of the measures used in the analysis is unknown. For instance, the importance of mobility relative to accessibility is not clear. Lacking such information this analysis gave equal weight to each measure. Further research might reveal that accessibility, for example, is a relatively minor consideration, and safety and mobility are the primary measures of urban road performance. Particularly useful in this regard would be factor-analysis techniques applied to existing data.

CONCLUSIONS

This analysis of urban highway performance confirms the assumption that there are differences in quality of highway service in urbanized areas and that methods can be devised to assess urban road performance. However, lack of adequate data is a serious impediment to use of any method in comparing or monitoring urban road performance.

REFERENCE

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Methodology for Evaluating Bus-Actuated, Signal-Preemption Systems

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The objective of this research was to model the impact of bus-actuated, signal-preemption systems on delay experienced by buses at signalized intersections and to develop a methodology to evaluate these systems by location. The model developed is green-extension strategy that quantifies the effect of the system on bus and other traffic at intersections depending on the characteristics of the intersections. Based on random arrivals, equations quantify the travel-time savings and losses experi-

enced. Then, the cost of the preemption system is developed, and a revenue-cost ratio for any location is developed. The application of this revenue-cost methodology to a local bus route resulted in a 14:1 revenue-cost ratio. Transportation planners who reviewed this result and methodology expressed the desire to emphasize the ability of this system to reduce bus running times enough to remove at least one bus from the route. This criterion was applied and a bus was removed in the test cor-