Benefits Matrix Model for Transportation Project Evaluation

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A procedure for evaluating proposed urban highway projects that can serve as a framework for establishing statewide construction priorities is described. Guidelines are provided for local officials who need to select and establish priorities for projects on an urban-area basis. The sequential steps followed in the research methodology included evaluation of previously developed priority models, definition of criteria for the model, building the model, and application and testing of the model by using candidate urban highway projects from three North Carolina test cities: New Bern, Kinston, and Durham. A benefits matrix model for transportation project evaluation was developed during the study. The model consists of five elements designed to provide the decision maker with relevant project evaluation information that directly relates to transportation planning objectives. These five elements are user benefits, cost, economic development potential, environmental impact, and relationship of the project to the state arterial system. Evaluation of the model indicated that it can be used at both the local and state levels to analyze a wide range of urban highway projects. The model can also be used to evaluate rural highway projects and, with some modifications, projects involving other transportation modes.

Allocation of funds for capital improvement or physical plant replacement by private enterprise is usually structured to maximize total return on the investment. Anticipated return on investments provides a basis for comparison and selection between alternatives. Allocation of funds for improvements by a public agency, such as a state department of transportation, is not so simple or straightforward.

In most states, the state legislature allocates funds to transportation modes and alternative systems and programs within modes. Funding decisions are based on public desires as indicated by interest group pressure, needs studies, and recommendations by the state transportation agency. Because federal funds are almost always provided on a matching basis, decisions are also strongly affected by funding decisions of the U.S. Congress. Funding decisions by a state transportation agency are usually limited to the establishment of priorities for projects within systems or programs.

One of the more difficult decisions facing a transportation agency is choosing urban highway improvement projects for funding from among many competing projects. Why select a project in one city as opposed to a project in another city?

The primary objective of the research described here was to develop a procedure for evaluating proposed urban highway projects that could be used in establishing statewide construction priorities. A secondary objective was to provide guidelines that would allow local officials to select and establish priorities for projects on an urban-area basis.

A sequential approach was used to develop the priority model. The stepwise process included evaluation of previously developed priority models, definition of criteria on which to structure the proposed model, model building, and application and testing of the model by using three North Carolina test cities: New Bern, Kinston, and Durham.

A benefits matrix model for transportation project evaluation was developed. The model is used to identify and quantify five elements that can be used to evaluate competing urban highway projects: user benefits, costs, economic development potential, environmental impact, and relationship of the project to the state arterial system.

PRIOR MODELS

Methods used to evaluate and select proposed highway projects have evolved over the years from simple economic analyses to highly complex models. The methods can generally be placed in one of four groups: economic analysis techniques, scoring or rating methods, system or network evaluation, and tables-of-benefits methods.

Winfrey (1) perhaps best states the case for economic analysis by observing that it is founded on the philosophy that resources not consumed today are available for use tomorrow and that society benefits more by following an instinct of saving as opposed to following a practice of consumption without economy. The object of economic analysis is to compare input costs and output consequences. Placing valuations on things that cannot be bought or sold in the private market, abstract impacts, and qualitative impacts are the major problems encountered in using economic analysis methods.

The sufficiency rating procedures given in HRB Bulletin 53 (2) and the methods listed by Hall and Hixon (3) and Mak and Jones (4) are examples of scoring or rating methods. These methods were developed to include in the evaluations the many abstract and qualitative impacts that could not be easily measured. An additional objective of several such methods was to better relate the evaluation to transportation goals.

Scoring and rating procedures have major deficiencies. They are typically complicated and not easily understood, and they can easily be biased by including measures that either evaluate the same impact or exhibit a bias toward a given alternative.

Analysis on a system basis is attractive because it can consider the travel interdependencies of a roadway system. The procedures proposed by Spencer (5), Schimpeler and others (6), and Yu and Hawthorne (7) are based on a systemwide approach. The major disadvantage of systemwide evaluations is that they usually restrict the evaluation to changes in only one or two variables, such as travel time saved. In addition, considerable information is usually required concerning travel on the network, and comparisons between urban areas are difficult.

The methods presented by Thiel (8), Hill (9), and FHWA (10) could be classified as tables-of-benefits methods. In this type of approach the decision maker is presented with a tabulation or listing of the impacts of the various alternatives. The major problems with this method are in determining the impacts that should be listed and having too long a list. Cheslow (11) concluded that an evaluator could reasonably assimilate only six to eight measures.

Criteria for Model Development

Proposed urban highway projects are the result of urban transportation studies or local officials' (public) requests for improvements or both. In making a decision as to whether or not a project should be scheduled for construction, decision makers seek answers to several questions: Is the project worth doing in relation to other possible projects? Will the project meet state transportation system objectives? Are there sufficient funds available to construct the project? Will the project improve system continuity? Does the project involve political commitments, an emergency situation, an area of special emphasis, or a commitment to another agency?

If a decision is made to program the project for construction, it proceeds to the project planning phase. During this phase there is a continual feedback of findings to the decision makers. The option exists to stop or alter the project at any time. The role played by the priority model in the decision-making process is to assimilate sufficient information about the proposed project and present it to the decision makers in a format that helps them to make a sound decision.

Several principles are of critical importance to the acceptance and value of priority models:

1. The model must be capable of presenting optional choices to decision makers.
2. The model output must be responsive to public transportation objectives.
3. The model output must be easily understood by the decision makers and the public.
4. The model should have the flexibility to be used both locally and at the state level.

Public officials responsible for making funding decisions on projects either are elected or are appointed to office by elected officials. They often perceive their most important function to be ensuring that public objectives for transportation improvements are achieved through project selection. Because they make the final decision, the most important function of the priority model is to present the decision makers with adequate information on alternative projects so that an informed decision can be made. The information must relate to the achievement of transportation goals in order to be relevant and it must be easily understood.

The priority model should be adaptable for use by both state officials and officials of local urban areas. Transportation objectives at the urban-area and state levels will most often be the same. However, the weights placed on alternative objectives in making decisions on priorities will undoubtedly differ. Using the same information should help state and local officials to understand each other's viewpoints better. Using the same model would also standardize the technical analysis and make it possible to apply the model gradually as urban transportation studies are completed or updated.

The North Carolina highway program was selected as the basis for developing a priority model for urban highway projects. State highway program objectives were defined through an analysis of objectives identified by administrative studies, an evaluation of program evolution through legislation, and financial analysis of program expenditures. It was concluded that the following objectives were the most important in making funding decisions on urban projects:

1. To improve the state's arterial system to reduce travel costs and improve travel service between urban centers,
2. To improve the level of service and safety of all roads and highways on the state system in a cost-effective manner,
3. To encourage economic development,
4. To preserve the natural and human environment, and
5. To allocate funds to projects in a fair and equitable way.

BENEFITS MATRIX MODEL

In an effort to aid the decision maker in the review of relevant project information, the following five elements were selected for inclusion in the benefits matrix model: user benefits, cost, impact of the improvement on economic development, environmental impacts, and relationship of the project to the state arterial system. The format of the benefits matrix model is given in Table 1.

Quantification of user benefits and comparison with project cost enable the decision maker to evaluate the cost-effectiveness of the project and provide a basis for comparison between competing projects. Cost information is also important for determining whether or not the project can be included in the construction program. Money available for improvement projects will often impose constraints on the number and size of the projects that can be undertaken.

Evaluation of projects on the basis of their probable economic and environmental impacts is in keeping with state objectives to encourage economic development and to preserve and enhance the environment. Analysis of projects as they relate to the state arterial system addresses the state objective of improving statewide travel and communications.

User Benefits

User benefits are computed as total dollar savings resulting from an improvement project through reductions in vehicle operating costs, travel time costs, and accident costs. The savings are accumulated over a 20-year design period. The computational form of user benefits is

$$B = \sum_{i=1}^{20} VCS_i + \sum_{i=1}^{20} TCS_i + \sum_{i=1}^{20} ACS_i \qquad (1)$$

where

B = benefits,
VCS_i = vehicle cost savings for year i,
TCS_i = travel time cost savings for year i, and

Table 1. Format of benefit matrix model.

Project	User Benefits ($000s)	Cost Type	Cost Amount ($000s)	Economic Development Potential[a]	Environmental Impact Probability[b]	Relation to State Arterial System[c]
1	000.000	R	000.000[a]	1.00	+1.00	5050
		C	000.000[b]		-0.75	
2	000.000	R	000.000	0.50	+0.50	1000
		C	000.000		-0.00	

Note: R = right-of-way and C = construction.

[a]Probability that a project will stimulate economic development.
[b]Probability that a project will have a positive or negative environmental impact.
[c]Estimated design-year average daily through traffic.

ACS_i = accident cost savings for year i.

Future user benefits are not discounted in the model. Stopher and Meyburg (12) recommend that the market discount rate be used to discount benefits but be adjusted downward to account for inflation, upward to account for deflation, and downward to account for taxes that affect the discount rate on the open market. FHWA publications on the cost of owning and operating an automobile (13,14) indicate that for the period 1974 to 1979 operating costs were increasing at an inflationary rate in excess of the market discount rate, which would imply that future benefits should be inflated. Considerable uncertainty continues regarding future interest rates and costs. Future forecases of travel, number of accidents, and other factors required in benefits computations for all projects also contain many uncertainties. All projects will have similar 20-year design periods.

Vehicle Operating Cost Savings

The computational form for vehicle cost savings is

$$VCS = VOC_o - VOC_p \tag{2}$$

where VOC_o is vehicle operating costs for the null alternative and VOC_p is vehicle operating costs assuming construction of the project.

Vehicle operating costs are computed as follows:

$$VOC_i = [(ADT_{bi} + EADT_{di})/2] \times 365 \times 20 \times L_i \times OC_i \tag{3}$$

where

- VOC_i = vehicle operating cost for section i,
- ADT_{bi} = annual average daily traffic estimated or existing on section i in the base year,
- $EADT_{di}$ = estimated annual average daily traffic on section i in the design year,
- L_i = length of section i (miles), and
- OC_i = operating cost for composite vehicle on section i for assumed average operating speed ($/mile).

Vehicle operating costs were compiled from data contained in previous studies and are discussed in more detail by Poole (15). Operating costs included costs for fuel, tires, engine oil, maintenance, and depreciation. Fuel costs were set at $1.18/gal. Costs were developed for a composite vehicle representing a traffic-stream vehicle mix of 1.27 percent 25-ton trucks, 1.44 percent 20-ton trucks, 3.56 percent 6-ton trucks, 10.41 percent 2-ton trucks, 48.33 percent standard automobiles, 24.99 percent compact automobiles, and 10 percent subcompact automobiles. Costs were also developed for operation on freeways, arterials, and collector streets (see Table 2).

It is desirable to divide both the proposed project and the null alternative roadway segment into sections based on traffic volumes and anticipated average operating speeds. Data from traffic assignment phases of urban transportation studies can provide guidance for estimates of ADT and anticipated average speeds. However, it is not recommended that the computations be done by using these data directly. Output of traffic assignment computer programs is not sufficiently precise, particularly with respect to average speeds, and some adjustments will be required in both average speeds and volume assignments. The analyst should develop estimates of average speeds based on volume/capacity (V/C) relationships and study of expected traffic operations on the roadway section.

The computation of vehicle operating costs does not include consideration of variations in average speed on a daily basis or variable growth in traffic during the design period.

Table 2. Average 1979 operating cost of composite vehicle on freeways, arterials, and collector streets.

Average Speed (mph)	Cost (¢/mile) Freeways	Arterials	Collectors
15			24.32
20		23.74	22.76
25	20.00	22.23	21.68
30	19.69	21.26	20.61
35	19.51	20.35	19.67
40	19.41	19.56	
45	19.41		
50	19.44		
55	19.48		

Travel-Time Cost Savings

Placing a proper valuation on travel time has been a difficult problem in economic studies of proposed highway projects for a long time. Most studies have approached the problem from the aspect of the highway user or consumer and his willingness to trade time for cost savings. Most have been empirical studies based on surveys or observations. The approach selected for use in the benefits matrix model is to place a value on individual time as perceived by the state.

An individual will alternatively function as a consumer and a worker. From the standpoint of government, which represents the public, both functions are important and of value. Time not devoted to transportation is available for alternative use in production or consumption. Government has encouraged improvements in efficiency through education, research, regulation, and transportation. Government has also placed a minimum value on a person's productive time through the minimum wage and subsidized consumption through unemployment compensation, welfare payments, social security, and other social programs.

Hourly income for a county as established by the Employment Security Commission of North Carolina was used as the most appropriate value of time in the benefits matrix model.

The computational form for travel-time cost savings is

$$TCS = TC_o - TC_p \tag{4}$$

where TC_o is time cost for the null alternative and TC_p is time cost assuming construction of the project.

Time costs are computed as follows:

$$TC_i = [(ADT_{bi} + EADT_{di})/2] \times 365 \times 20 \times (L_i/S_i) \times O_j \times H_j \tag{5}$$

where

- TC_i = time cost on section i,
- S_i = average speed on section i (mph),
- O_j = average vehicle occupancy for urban area j, and
- H_j = hourly value of time for urban area j ($).

Accident Cost Savings

Accident cost estimation information was available in a 1979 manual prepared by the Traffic Engineering Branch of the North Carolina Department of Transportation (DOT) (16). The 1979 costs used by the Accident Studies Unit of the Traffic Engineering Branch were $184,000 for a fatal accident, $18,350 for a nonfatal injury accident, and $800 for a property-damage-only accident. References cited in the manual recommend that estimated accident costs be multiplied by a factor of 1.33 to account for unreported property-damage-only accidents.

Accident cost savings are computed as follows:

$$ACS = 1.33 \sum_{n=1}^{3} aN_n \delta_n \quad (6)$$

where

- a = estimated reduction in accidents (%);
- N_n = estimated number of n-type accidents during the design period; and
- δ_n = average cost of n-type accident (n = 1, fatality; n = 2, nonfatality injury; n = 3, property damage only).

In estimating accident cost savings for the benefits matrix model, the estimating equation is applied as follows:

$$ACS = 1.33\,(AC_o - AC_p) \quad (7)$$

where AC_o is accident costs under the null alternative and AC_p is accident costs assuming construction of the proposed project.

Accident costs are computed as follows:

$$AC_i = \sum_{n=1}^{3} N_{ni} \delta_n \quad (8)$$

where AC_i is estimated accident costs for roadway section i and N_{ni} is the estimated number of n-type accidents during the design period on section i.

The most difficult items to estimate are the number and severity of accidents occurring during the design period. Accident rates used in the model were developed from information given in reports by Modlin and Newnam (17) and Slatterly and Cleveland (18). Table 3 gives the accident rates used for accident cost estimation.

Cost

Costs associated with a highway improvement include construction, right-of-way, maintenance, operation, and administration. Right-of-way costs estimated by the North Carolina DOT include relocation costs of residences, businesses, and utilities as well as land costs. North Carolina DOT project planning reports indicate that usually only construction and right-of-way costs are relevant to the decision on a project. These are the costs used in the benefits matrix model.

Economic Development Potential

A project can be successful by stimulating economic development in the immediate area of the project or by increasing level of service or accessibility to an adjacent area. The probability of a project's success in achieving this objective is affected by the overall potential for economic growth in the urban area. Therefore, the probability (P_e) that a project will stimulate economic development is:

$$P_e = P_{eu}(P_{ei} + P_{ea}) \quad P_{ei} + P_{ea} \leq 1 \quad (9)$$

where

- P_{eu} = probability of economic development in the urban area,
- P_{ei} = probability that the project will stimulate economic development in the area immediately served, and
- P_{ea} = probability that the project will stimulate economic development in the adjacent area.

The estimation of probabilities is a subjective evaluation by the analyst based on his knowledge of the proposed project, urban development characteristics, and land development potential. Land use plans, zoning ordinances, studies of population and economic conditions, annexation studies, and land potential studies can provide guidance.

To systematize the probability estimation process, the following guide was developed for placing success probability values on the subjective evaluation:

Subjective Evaluation	Success or Impact Probability
Excellent/highest	1.00
Very good/very substantial	0.75
Good/substantial/considerable	0.50
Fair/some	0.25
Poor/none	0.00

Environmental Impact

Environmental factors usually considered in highway project evaluation can be separated into three major categories: the physical environment, the social or cultural environment, and the economic environment. Factors included in each of these categories are given in Table 4.

Many of the considerations listed in Table 4 are accounted for in the benefits, cost, and economic development potential elements of the benefits matrix model. Economic environmental factors are all considered to the degree necessary in the three elements. Several elements in the category of the social or cultural environment are also considered to

Table 3. Accident rates for freeways, arterials, and collector streets.

Type of Accident	Roadway Category	Accidents/100 Million Vehicle Miles by V/C Ratio						
		0.4	0.5	0.6	0.7	0.8	0.9	1.0
Fatal accidents	Freeways	0.50	0.66	0.85	1.16	1.60	2.10	2.68
	Arterials	0.86	1.04	1.30	1.76	2.45	3.55	6.00
	Collectors	0.65	0.86	1.10	1.60	2.35	4.00	7.60
Nonfatal injury accidents	Freeways	18.0	25.0	32.0	43.0	62.0	82.0	104.0
	Arterials	88.0	93.0	103.0	130.0	185.0	280.0	460.0
	Collectors	65.0	80.0	110.0	158.0	244.0	395.0	755.0
Property-damage-only accidents	Freeways	106.0	115.0	120.0	124.0	122.0	120.0	115.0
	Arterials	178.0	195.0	120.4	255.0	347.0	470.0	645.0
	Collectors	78.0	100.0	120.8	215.0	325.0	555.0	1100.0

Table 4. Environmental considerations.

Environment	Factors
Physical	Air quality, water resources, soils and geology, wildlife, and vegetation
Social or cultural	Housing, neighborhoods, noise, educational facilities, churches, parks and recreational facilities, historic sites and landmarks, public health and safety, national defense, and aesthetics
Economic	Businesses, employment, economic development, public utilities, transportation costs, capital costs, and operation and maintenance costs

varying degrees. Impact on housing is accounted for in right-of-way cost. The physical impact of a highway project on educational facilities, churches, park and recreational facilities, and historic sites and landmarks is also accounted for in right-of-way costs. However, because these facilities have social connections that extend well beyond the building or physical plant, impacts on the social fabric of the area would not be measured by right-of-way cost. Impacts on public health and safety are partly accounted for in the benefits element. However, other considerations such as fire protection or accessibility to health care facilities would not usually be measured by the benefits element.

The impact of a facility on national defense is accounted for in the fifth element of the model--relationship to the state arterial system. Providing a high level of service on the arterial system, an indicated state objective, will facilitate mobility under emergency situations.

Although many of the environmental factors are accounted for in other elements, a relatively large number remain for inclusion in the environmental impact element. This element of the model assesses the probability that the project will have negative or positive impacts or both on 13 physical and social or cultural environmental considerations that are not accounted for in other elements of the model. These factors are air quality, water resources, soils and geology, wildlife, vegetation, neighborhoods, noise, educational facilities, churches, park and recreational facilities, historic sites and landmarks, public health and safety, and aesthetics.

The evaluation of environmental impacts should be condensed to a single measure or measures easily understood by the decision maker. In the benefits matrix model the approach is to estimate the probability of a positive or negative impact for each of the environmental factors. The summations of both positive and negative probabilities are then measures of the relative environmental impact of a project. The probabilities are computed as follows:

$$P_{+ei} = \sum_{j=1}^{13} P_{+eij} \quad \sum_{j=1}^{13} P_{+eij} \leq 1 \tag{10}$$

where P_{+ei} is the probability of positive environmental impact of a project and P_{+eij} is the probability of positive environmental impact of a project in relation to environmental factor j.

$$P_{-ei} = \sum_{j=1}^{13} P_{-eij} \quad \sum_{j=1}^{13} P_{-eij} \leq 1 \tag{11}$$

where P_{-ei} is the probability of negative environmental impact of a project and P_{-eij} is the probability of negative environmental impact of a project in relation to environmental factor j.

Information from public involvement and environmental analysis elements of urban transportation studies provides a basis for estimation of probabilities for projects. If no urban transportation studies have been done, it would be necessary to rely on other planning studies and reports or field surveys. The probability estimation guide given previously is used as a basis for assigning probability estimates to the subjective evaluation of project environmental impacts.

Relationship of Projects to State Arterial System

An estimation of the quantity of through travel served by a facility is a measure of the relationship of a project to the state arterial system. Mathematical models developed by Modlin (19) for the estimation of through trips indicate that most through trips are on higher-class facilities--Interstates, principal arterials, and minor arterials.

The benefits matrix model uses estimated average daily through trips on a facility in the design year as a relative measure of the importance of the project to the state arterial system. These data are available from urban planning studies or can be generated by using estimating models developed by Modlin (19).

APPLICATION OF MODEL

To test the application of the model, candidate highway projects from three North Carolina urban transportation studies were selected for evaluation: 15 from New Bern, 3 from Kinston, and 3 from Durham. The 15 New Bern projects provide a basis for evaluation of the ability of the benefits matrix model to evaluate projects on an urban-area basis. A comparison of the three top priority projects in New Bern with the three Kinston projects and the three Durham projects provides a basis for evaluation of the model from a regional or statewide viewpoint.

Assumptions in Applying Model

The New Bern, Kinston, and Durham projects were documented in planning studies that used different base and design years. To ensure comparability it was necessary to convert data on cost and ADT to a common base year and design year. Traffic data were adjusted by assuming a straight-line growth rate. Construction and right-of-way cost data were adjusted based on a highway construction cost index developed by the North Carolina DOT. Projects in the three cities were evaluated with the benefits matrix model according to to the procedures previously outlined. In computing user operating time and accident cost benefits, a number of estimates and assumptions were required for each section of the proposed project and each alternative analyzed. These included (a) base year (1979) and design year (1999) ADT, (b) average operating speeds, and (c) V/C ratios for the base year and design year.

Estimates of base-year and design-year traffic did not present great difficulty because the data were available from urban transportation studies. However, routing traffic for an alternative to a relocation project required careful treatment. Factors considered in assigning traffic to an alternative path were common or logical alternative termini, the minimum path, and the logical origin of junctioning traffic.

Estimates of average operating speeds, which influence operating and time costs, included the geometrics of the street segment, existing and anticipated signal locations, areas of anticipated acceleration and deceleration, and V/C ratios.

Estimates of accidents are sensitive to V/C ratios. To estimate the number of a specific type of accident, the base-year and design-year V/C ratios for a roadway section were estimated and used to obtain appropriate accident rates (Table 3). The rates were then averaged and the average rate was multiplied times the vehicle miles of travel.

Areawide estimates of hourly time costs and vehicle occupancy rates were used in the computation of travel-time costs. Vehicle occupancy (persons per vehicle) was estimated at 1.45 for New Bern, 1.44 for Kinston, and 1.42 for Durham.

Time costs are average estimated 1979 hourly incomes for Craven County (New Bern), Lenoir County (Kinston), and Durham County (Durham) as determined from quarterly reports by the Employment Security Commission of North Carolina. The time costs used in the study were $4.66/hr for New Bern, $5.07/hr for Kinston, and $6.18/hr for Durham.

An areawide estimate of the probability of economic growth is required in order to estimate the probability that a project will stimulate economic development. The areawide probabilities used were 1.00 (excellent) for Durham, 0.75 (very good) for Kinston, and 0.50 (good) for New Bern.

Analysis of Results

The benefits matrix model evaluation of the first three New Bern projects, the three Kinston projects, and the three Durham projects is given in Table 5. The table illustrates how the evaluation would appear to a state decision maker. The three New Bern projects were listed as first-priority projects in the New Bern study (20), and the Kinston and Durham projects were priority recommendations to the state by local officials.

The benefits matrix model evaluation of all 15 New Bern projects is summarized in Table 6. The table shows how the evaluation would appear to New Bern officials.

The benefits matrix model meets the criteria established for the priority model. The model presents the decision maker with project evaluation information related to the achievement of transportation goals. There is considerable flexibility for decision makers to apply their own weights to the evaluation criteria and to consider other factors such as political commitments, legislative mandate, emergency, special-emphasis projects, commitments to other agencies, system continuity and connectivity, and project readiness.

For example, a state decision maker who has the task of selecting one project for construction from the nine projects listed in Table 5 could decide to base the selection on the maximization of user benefits for funds expended. In this case, the decision maker would choose Durham project D3 (Holloway Street-Liberty Street one-way pair) because the project clearly produces the most user benefits per dollar of funds expended. However, if the decision maker is concerned about the potential negative environmental impact of project D3, his second logical choice is Kinston project K2 (Carey Road extension). If construction funds are not sufficient for project K2, the third logical choice is Durham project D1 (Erwin Road widening). Project D1 is less expensive than project K2, involves no right-of-way cost, provides some potential for economic development, and has a positive environmental impact. If there is a legislative or political commitment to fund a project in each city and the state decision maker chooses to minimize cost, projects N3, K3, and D3 are the logical choices.

A somewhat similar decision process can be outlined for the urban-area official who must make decisions on project priorities. However, the urban-area official, in contrast to the state official, has two distinct purposes for making project selections. The first is to identify and select projects in the urban area that can be recommended to the state transportation agency for construction. For this purpose it is desirable to select a project, or projects, that will be a benefit locally and that will be attractive to state officials by fulfilling state objectives. The second purpose is to select projects for local funding. In selecting projects for this purpose the official is interested in projects that have a low probability of state funding but promise significant local benefits.

Data given in Tables 5 and 6 and the example application illustrate that the benefits matrix model is applicable at both the state and local levels. The model will not ensure that best decisions will always be made. However, it does ensure that relevant information and data on public objectives are considered in project decision making.

The evaluations in Tables 5 and 6 illustrate that the benefits matrix model is capable of evaluating a broad range of projects. The 15 New Bern projects include widening projects, projects on new location, major projects, minor thoroughfare or collector street projects, inner city projects, and projects

Table 5. Benefits matrix model evaluation of top-priority New Bern, Kinston, and Durham projects.

Project	Description	User Benefits ($000s)	Cost Type	Cost Amount ($000s)	Economic Development Potential Probability	Environmental Impact Probability	Design-Year Through-Traffic ADT
N1	First Street loop	13,302	R	678	0.25	+1.00	-
			C	553		-0.75	
N2	New South Front Street	11,772	R	300	0.13	+0.75	-
			C	462		-0.50	
N3	NC-1214 relocation	4,126	R	34	-	-	-
			C	194			
K1	Airport Road widening	19,305	R	0	0.56	+0.25	234
			C	1,486		-0.00	
K2	Carey Road extension	98,956	R	306	0.56	+0.50	-
			C	2,318		-0.00	
K3	Queen Street widening	10,684	R	583	-	+0.00	113
			C	421		-0.50	
D1	Erwin Road widening	37,938	R	0	0.25	+0.50	-
			C	1,190		-0.00	
D2	Alston Avenue extension	81,847	R	1,194	0.75	+0.75	230
			C	4,497		-0.50	
D3	Holloway Street-Liberty Street one-way pair	40,651	R	61	-	+0.25	-
			C	252		-0.25	

Table 6. Benefits matrix model evaluation of New Bern projects.

Project	Description	User Benefits ($000s)	Cost Type	Cost Amount ($000s)	Economic Development Potential Probability	Environmental Impact Probability	Design-Year Through-Traffic ADT
N1	First Street loop	13,302	R	678	0.25	+1.00	-
			C	553		-0.75	
N2	New South Front Street	11,772	R	300	0.13	+0.75	-
			C	462		-0.50	
N3	NC-1214 relocation	4,126	R	34	-	-	-
			C	194			
N4	Elizabeth Avenue extension	2,715	R	0	0.13	+0.50	-
			C	267		-0.00	
N5	Pembroke Road widening	3,776	R	67	-	+0.35	-
			C	826		-0.00	
N6	Airport Road connector	11,389	R	157	0.38	+0.75	158
			C	146		-0.00	
N7	Trent Boulevard widening	3,202	R	219	0.13	+0.35	-
			C	729		-0.00	
N8	I Street-Beaufort Street minor thoroughfare	1,761	R	968	-	+1.00	-
			C	534		-0.50	
N9	National Avenue-Oaks Road widening	7,047	R	0	-	+0.25	-
			C	1,008		-0.50	
N10	Pembroke Road relocation	3,822	R	177	-	+0.00	-
			C	279		-0.25	
N11	Pembroke Road-Trent Boulevard connector thoroughfare	1,940	R	432	0.13	+0.25	-
			C	540		-0.25	
N12	NC-1214 extension to Racetrack Road	111	R	102	0.25	+0.25	-
			C	996		-0.25	
N13	Craven Street realignment	872	R	170	-	+0.00	-
			C	24		-0.50	
N14	Oakland Avenue extension to Oaks Road	694	R	117	0.25	+0.60	-
			C	389		-0.00	
N15	US-70 widening	30,821	R	0	-	+0.25	8,680
			C	911		-0.00	

on the fringe of the urban area that would serve new development. New Bern project N13 (Craven Street realignment) and Durham project D3 (Holloway Street-Liberty Street one-way pair) are traffic operations improvements.

The evaluation of the 15 New Bern projects indicates that the benefits matrix model provides additional project evaluation information that can result in a reordering of priorities for an urban area. Priority recommendations listed in the New Bern thoroughfare planning study (20) were staff recommendations that considered existing and projected capacity deficiencies, improvement of system service, land development needs, and input from local officials and the public. The evaluation indicates that project N6 should probably be moved to the top of the priority listing. Other changes in the listing also appear desirable.

The benefits matrix model provides considerable information that can be of secondary benefit to local officials. Right-of-way costs and negative environmental impacts work against the implementation of a project. Knowing this, local officials can work to reduce the magnitude of these adverse effects through mechanisms such as advance purchase of right-of-way, park relocations, and urban renewal. Reductions in these impacts will improve a project's ranking in relation to other projects. The model also identifies those projects that have a small payout of benefits in relation to cost. These projects would be strong candidates for local implementation via subdivision regulations as land development occurs.

SUMMARY

A significant finding of this research effort was that a priority model must be capable of presenting optional choices to decision makers but should not make decisions on project priority. The decision maker must retain the freedom to make decisions on projects. The role of the priority model is to provide the decision maker with adequate information on alternative projects so that an informed decision can be made.

A second important finding is that a priority model must be structured around public objectives for the transportation system. Projects must be evaluated in terms of how well they achieve desired objectives.

The benefits matrix model meets the criteria established in the study for a priority model. The model presents relevant project evaluation information concerning transportation objectives to the decision maker and the public and presents the information in a format that is easily understood. Information related to the effect of the project on economic development, on the environmental impact of the project, and on the through travel served by the project is new information in a new format.

The model is applicable for project evaluation at both the state and urban-area levels. At the state level it provides a common basis on which decision makers can evaluate proposed projects from many urban areas. The model can be used by urban-area decision makers to select projects for local construction and for submission to the state as candidate projects for state construction.

The model can evaluate a broad range of urban highway projects. It is easy to apply and calculations are relatively simple, but professional engineering expertise is required in estimating V/C ratios, operating speeds, and impact probabilities.

It should be possible to extend the model to the evaluation of rural highway projects and transportation projects involving other modes. Estimation of through travel served may be more difficult for rural highway projects than for urban areas because in the case of urban areas the information either is readily available or can be obtained from estimating models. In the case of transportation projects involving other modes, through travel served may or may not be a valid evaluation criterion.

The concept of the benefits matrix model appears to be applicable to other states and jurisdictions. However, transportation objectives may be different and it may be necessary to make changes in evaluation criteria.

Some difficulty was encountered in the study in obtaining good data on vehicle operating costs, and a number of references and data sources were used to compile the vehicle operating cost information. Additional research to update vehicle operating costs would be quite helpful in the quantification of benefits.

Another problem area was encountered in estimating accidents for the user benefits analysis. The study used a relationship between V/C ratio and number of accidents to make this estimate. When compared with empirical data the resulting estimates appear to be reasonable, but additional research is needed to update these relationships.

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