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Contents

Foreword

The 16 papers in this volume focus on planning and programming, public involvement, transportation–land use interactions, and computer technology in transportation. Most were presented at the 1993 TRB Annual Meeting.

A series of papers on planning and programming focus on new procedures for priority ranking of highway projects; alternative performance measures, with more emphasis on human factors; a statistical appraisal method for programming projects; and a network procedure for the optimization of capital budgeting.

In the area of public involvement in transportation planning, existing practices are discussed and new approaches are suggested for integrating the public into agency decision making; constituency groups and how those groups have affected traditional transportation advocacy groups are examined; one state's approach to public involvement is detailed; and a methodology and its application in a case study of citizen participation are described.

The papers on transportation and land use include an assessment of the concepts of local and regional accessibility to test the implications for shaping travel alternatives of alternative forms of development, an examination of the claim that transportation benefits can be delivered through nontraditional neighborhood design, a test sampling of surveying methodologies for statistically reliable trip characteristic surveys of land development, a study of residential choice to determine whether residents choose to live at densities necessary to support various types of transit service, and a discussion of the effects of proximity to light rail transit stations on the value of single-family homes.

The remaining three papers focus on computer technology, namely, a trial program undertaken by a state department of transportation to use pen-based computers for job-site data acquisition, technology transfer applications using the electronic bulletin board system, and the effect of downsizing information technology on engineering operations.

New Approach to Integrating Engineering, Managerial, and Political Judgment: Development of the Utah Project Prioritization System

LAWRENCE C. WALTERS, GLEN THURGOOD, AND DONALD L. ADOLPHSON

The findings from a research project sponsored by the Utah Department of Transportation (UDOT) between 1989 and 1991 are presented. The goals of the project were to document, formalize, and improve UDOT procedures for prioritizing highway projects. The methods presented here and tentatively adopted by UDOT involve a relatively new approach that integrates and extends traditional engineering measures of reliability in the context of a management science model of productive efficiency. The political priorities of decision makers can be incorporated directly into the model in terms of explicit weights on the relative importance of each dimension being evaluated. In addition, the framework provides a means of assessing the cost of ad hoc revisions in the priority listing.

The deterioration of the level of service offered by the nation's transportation system has become a serious concern. Clearly, pavements and other highway elements make up a significant portion of that infrastructure. Currently, the need for transportation improvements is occurring faster than funds for improvements are being made available. As a result, state departments of transportation (DOTs) face the problem of allocating insufficient funds among numerous highway projects. The Utah Department of Transportation (UDOT) is not immune to these problems. This paper reports the results of a research project carried out in conjunction with UDOT. The purpose of the project was to document and recommend improvements in the procedures used by UDOT in selecting and funding highway projects and to recommend improvements in those procedures (*1*).

In 1989, UDOT's project selection process was largely informal. Consequently, as UDOT staff responded to pressures from local transportation districts, citizen groups, the press, and other public agencies, they often felt vulnerable and unable to convincingly defend their project decisions. Further, when priorities were changed by political forces within the state, it was difficult to assess the effect of these changes on the highway system.

Like any other state, the task of prioritizing highway projects in Utah is both technically complex and politically sensitive. The search for alternative methods of prioritization was guided by these realities. The comparative review of other states focused on how those states systematically program transportation projects within the context of their own technical and political complexities. In pavement management systems, for example, there are commonly five different techniques that are employed in selecting resurfacing and rehabilitation projects:

1. Sufficiency ratings (*2,3*),
2. Quasi-economic analyses (*2,4*),
3. Cost-benefit analysis (*2,4*),
4. Micro- or macro-economic analyses (*2*), and
5. Optimization techniques (*5–9*).

Pavement management systems have been proposed that utilize more than one decision model, often employing at least one kind of optimization technique. One such proposal, termed the "Demand Responsive Approach to Highway and Maintenance Rehabilitation," has been developed through the Department of Civil Engineering, the Massachusetts Institute of Technology (*10*). Another approach that employs optimization techniques along with other decision models has been developed by the Purdue University Department of Civil Engineering in conjunction with the Indiana Department of Transportation and FHWA (*11*). For its bridge management system, the state of Indiana separately utilizes both a ranking model and an optimization model. The ranking model was developed using the analytic hierarchy process technique (*11*).

Another method of optimization is data envelopment analysis (DEA). DEA is a recently developed methodology for measuring the relative efficiency of a set of decision-making units. The seminal paper in DEA was written by Charnes et al. in 1978 (*12*). Since that time over 300 papers have appeared on the topic of DEA (*13*). Although it is not currently used in state transportation agencies, the methodology is nevertheless an extremely useful decision model for prioritizing and programming transportation projects.

DEA was recommended to UDOT as the basis for prioritizing projects. It has strong theoretical foundations, provides the project-level evaluation that is required, and can be fairly readily implemented. Although DEA is not immune to criticism, the same can be said for virtually any approach to the prioritization problem. Each approach has both strengths and weaknesses, but DEA appears to offer great potential for

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addressing the questions raised by UDOT while minimizing other detracting factors. The remainder of this paper details how DEA can be used as the basis for prioritizing and programming transportation projects. The next section outlines the conceptual basis for DEA and explicitly specifies the DEA models. Next, the use of DEA is demonstrated with 49 projects that were either constructed or seriously considered by UDOT. Finally, the integration of DEA into transportation decision making, illustrated by the specific case of UDOT, is discussed.

SPECIFICATION OF DEA MODELS

As discussed previously, the task of prioritizing highway projects in Utah takes place within a context that is technically complex and politically sensitive. To be useful, the prioritization model should to the extent possible reflect and incorporate this complexity and sensitivity. This discussion will begin by focusing on the technical aspects of the problem; political issues will also be introduced.

The major technical components to be included in the model are as follows:

1. *Degradation function (DF).* A functional description that reflects effects such as load, weather, and traffic on existing conditions (EC) and describes the expected deterioration over time without treatment (T). Most researchers agree that DF is relatively flat for some initial period of life and then begins to increase at a growing rate. At some point, performance drops below a minimally acceptable level. The age of the roadway at that point of failure sets the upper limit for expected years of life for a new roadway. DF allows the estimation of both the need for and the impact of any given treatment on a particular segment of road.
2. *Existing conditions.* Central to the modeling effort is a description of current roadway conditions around the state. EC can be described with a large list of indicators, but it is reasonable to group those indicators into five dimensions of concern:

   a. Level of service—the traffic and load-carrying capacity of the existing road;
   b. Pavement condition—the surface and subsurface conditions of the pavement;
   c. Condition of structures—the condition of bridges or other major structures involved in the project;
   d. Ride—the quality of the roadway from the user's perspective; and
   e. Safety—frequency and severity of accidents.

   For the first four dimensions a measure of remaining service life (RSL) or expected years until an unacceptable level of performance is reached can be estimated given existing conditions and the rate of deterioration. Another indicator of need relevant to the first four dimensions is the number of persons served by the roadway in question. To assess the safety dimension, the number and severity of accidents are compared with expected values for similar roads.
3. *Treatments.* The types of projects that might be performed on any given roadway and that operate to mitigate the degradation effects (DF). The issue is how T will improve the level of service, pavement condition, structures, ride, and safety. For level of service, pavement, structures, and ride, this measure of improvement is captured in the additional years of service life (SL) that will result from the project. Again using the degradation function, it is possible to calculate the years of additional life generated by the project and thus a new RSL. To evaluate improvement in safety, the expected reduction in accidents and accident severity is used.
4. *Cost per unit of treatment (C/T).* Preliminary estimates of unit costs for each type of treatment. Project costs can be characterized broadly in terms of UDOT in-house costs, direct contract costs, and user costs resulting from the project.

Each potential project (or project alternative if several alternatives exist for a given site) is thus characterized in terms of need, improvement, and cost variables. The conceptual framework used here assumes that existing conditions (EC) at time t are degraded according to the degradation function (DF). This degradation is mitigated by some treatment. The total costs of the treatment are generated from treatment quantity (T) and the C/T. Conditions at time $t + 1$ result from the interaction of EC, T, and DF.

Figure 1 demonstrates graphically the concepts introduced so far. The vertical axis, labeled *PSI*, represents the present serviceability index or any other measure of roadway conditions. The horizontal axis is time in years. The hypothetical current condition is shown as a dashed line. Given the degradation function, knowing the current service level allows the calculation of the remaining years of life and thus the need for any project. Although Figure 1 shows a single degradation function, a transportation project may change the shape of the function itself. Even if this is true, years of remaining life and years of additional life added by the project remain the relevant indicators of need and improvement, respectively.

Not all dimensions of a given project proposal are under direct managerial control, and this fact must be reflected in the model. Consider, for example, a project to resurface a pavement. In the short run, management has no control over the need for such a project. The level of improvement and the project costs, on the other hand, are under direct managerial control because the scope of the project can be modified and the particular strategy pursued can be changed. The point is simply that the model must show that need is not subject to managerial control, whereas cost and improvement are.

In implementing the approach proposed here, one must also be cognizant of the meaningful direction of the numeric

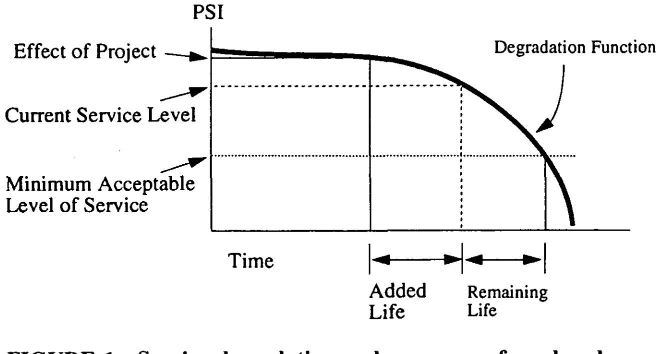

FIGURE 1 Service degradation and measures of need and improvement.

scales used. For example, if the need for a project is measured in terms of expected years of life remaining, then the larger the value, the less the need for attention. If on the other hand the need is measured in terms of traffic volume served, then the larger the number, the greater the need. Both approaches are quite reasonable, but the analyst must keep in mind for each variable in the analysis whether greater attention should be paid to small values or large.

Table 1 summarizes this discussion and lists the variables used in the initial implementation of the model. The table indicates whether the variable is a measure of need, improvement, or cost; whether it is interpreted as being under direct short-term managerial control; and whether large or small values will be emphasized. Variables over which management has no control are considered nondiscretionary and are labeled with an N. Variables scaled so that small values should receive greater emphasis are considered inputs and are labeled with an I, whereas the converse are considered outputs, labeled with an O.

We now turn to a more precise discussion of the DEA model originally outlined by Charnes et al. (*12*). The particular formulation outlined here follows Adolphson et al. (*14*). Data for DEA consist of a set of input measures $X = [x_{ki}]$ and a set of output measures $Y = [y_{kj}]$, where x_{ki} is the amount of input i consumed by project k and y_{kj} is the amount of output j produced by project k. Let $u_j = [u_1, \ldots, u_J]$ and $v_i = [v_1, \ldots, v_I]$ be the vectors of output and input weights. Then the linear programming models to choose weights for a given project, indexed by k, are either of the following:

Input Orientation	*Output Orientation*	
Maximize	Minimize	
$\sum_j u_j y_{0j}$	$\sum_i v_i x_{0i}$	(1)
Subject to		
$\sum_i v_i x_{0i} = 1.0$	$\sum_j u_j y_{0j} = 1.0$	(2)
$\sum_j u_j y_{kj} \leq \sum_i v_i x_{ki}$ for all k	$\sum_i v_i x_{ki} \geq \sum_j u_j y_{kj}$ for all k	(3)
$u_j, v_i \geq 0$ for all i and j	$u_j, v_i \geq 0$ for all i and j	(4)

The duals of the LP models above are computationally more efficient and have a natural interpretation that sheds additional light on the process of DEA:

Input Orientation	*Output Orientation*	
Minimize	Maximize	
Θ	Θ	(5)
Subject to		
$x_{0i}\Theta \geq \sum_k x_{kj}\lambda_k$ for all i	$x_{0i} \geq \sum_k x_{ki}\lambda_k$ for all i	(6)
$y_{0j} \leq \sum_k y_{kj}\lambda_k$ for all j	$y_{0j}\Theta \leq \sum_k y_{kj}\lambda_k$ for all j	(7)
$\lambda_k \geq 0$ for all k	$\lambda_k \geq 0$ for all k	(8)

TABLE 1 Variables Used To Describe Projects in Initial Implementation of DEA Model

Dimension of Concern	Measures of Need	Improvement and Resource Measures
Level of Service	Expected years until actual traffic volume exceeds acceptable level of service (NI)	Additional years added by project until traffic volume exceeds acceptable level of service (O)
	Current Average Daily Traffic (ADT) volume (NO)	Expected change in total traffic (annual ADT) over a 20 year period (O)
	Design Hourly Volume (20 year) (NO)	
Pavement condition	Years of pavement life remaining (NI)	Additional years of life added (O)
	Surface conditions: a. rut depth (NI) b. index of cracking (NI) c. skid index (NI)	Surface conditions: expected improvement resulting from the project. a. rut depth (O) b. cracking (O) c. skid (O)
	Average daily ESALs (NO)	
Ride	Expected years to ride failure (NI)	Estimated additional years of ride life resulting from project. (O)
Condition of Structures	Years until adequacy of structure falls below acceptable standard 1) deck (NI) 2) structure (NI) 3) deck geometry (NI) 4) sub-structure (NI)	Additional years added by project: 1) deck (O) 2) structure (O) 3) deck geometry (O) 4) sub-structure (O)
Safety	Ratio of actual accident rate to statewide accident rate for similar roads (3 year average) (NO)	Expected reduction in accidents as a result of project (3 year average) (O)
	Ratio of actual severity index to statewide severity index for similar roads (3 year period) (NO)	Expected change in the severity index (3 year average) (O)
	Number of accidents occurring over the past 3 years (NO)	
Resources required		Direct project costs (I)
		Indirect UDOT costs (I)
		Estimated user costs during construction (I)
Other relevant factors		Length of project in miles (O) (Optional, used when projects being evaluated have meaningful length)

The input-oriented model contracts input as far as possible while controlling for outputs; the output model expands output as far as possible while controlling for inputs. In both cases, Θ is the contraction or expansion factor, and λ is a vector of weights that defines a comparison point on the frontier. For this discussion the focus will be on the input orientation.

Banker and Morey (*15*) show how to incorporate environmental or nondiscretionary inputs and outputs into a DEA model. Environmental input constraints are shown in Equation 6 for the output orientation, and environmental outputs are shown in Equation 7 for the input orientation. The effect of the nondiscretionary inputs is to limit the feasible comparison points to those with an input less than or equal to the corresponding input for the reference unit being evaluated. The effect of the nondiscretionary outputs is to limit the feasible comparison points to those with an output greater than or equal to the corresponding output for the reference unit.

The basic DEA models, Equations 1 through 4, are unrestricted in selecting nonnegative input and output weights. This approach frees the model user from the necessity of assigning relative weights to inputs and outputs; it also prevents the user from having any control over these weights. Consequently, the model is unable to reflect the political realities of the decision-making process. Fortunately, DEA allows the model user to specify bounds on the relative weights of inputs and outputs. The term "assurance region" was coined by Thompson et al. (*16*) to describe a feasible set of attribute weights. Consider the example of an assurance region in which the model user determines that input i is at least twice as important as input j. This implies that $v_i/v_j > 2$, or $v_i - 2v_j > 0$, in equivalent linear form. The equivalent linear form can be appended to Equations 1 through 4 or it can be expressed as a dual variable and included in Equations 5 through 8. Charnes et al. have given an alternative specification that multiplies the input and output matrixes by the matrix of attribute value constraints. Instead of assurance region, Charnes et al. (*17*) use the term "cone ratio" for the feasible set of weights. By specifying assurance regions or cone ratios, the user can incorporate a significant political component of decision making—the ranking and prioritizing of goals—into the DEA model.

A simple numerical example is now given that permits the discussion of the DEA-based method pictorially. In this example, two measures of outcome and one of input are considered. The measure of improvement is the years of additional life added by the project. A second variable, project length, is intended to reflect the scale of each project. A single measure of cost in thousands of dollars is also provided. These variables for five hypothetical projects are summarized in Table 2, along with the ratio of output per unit cost.

Figure 2 is a graph of the two ratios from Table 2. From both the table and the graph it can be seen that Projects B and C represent the most productive projects in this set. Project B is in the most productive set because it is the largest project per unit cost, and C, because it offers the greatest improvement per dollar spent. The convex envelope defined by Projects B and C thus sets the standard for most productive projects. This envelope is referred to as the best practice frontier. Project A is evaluated by extending a line from the origin through *A* until it intersects the frontier defined by *C* and the convexity assumption. The productivity score for *A* is obtained by taking the ratio OA/OA′ with the result of 0.525. The interpretation of this score is that *A* is slightly more than half as productive as *C*. For *A* to be on the frontier, either project costs would have to be reduced by a factor of 0.525 or improvement and length would have to be increased by a factor of 1/0.525 without changing the cost. A similar story could be told for Projects D and E, with resulting scores of 0.450 and 0.525, respectively. The scores for all five projects are summarized in Table 2 as PPS Score 1.

Reconsider the frontier defined by *B* and *C*. One could readily argue that although it is important to consider project length in evaluating and comparing projects, length of project is certainly not as central to UDOT's mission as is overall improvement to the highway system. Figure 3 shows the new frontier if it is assumed that improvements to the highway system are at least twice as important as the length of the project. Note that whereas Project B was on the frontier in Figure 2 by virtue of having the lowest cost per unit length, in Figure 3 Project B is well off the frontier. Setting the bound or assurance region for the trade-off rate between improvement and size (i.e., improvement is at least twice as important as length) prevents the slope of the frontier from falling below the point labeled *B′* in Figure 3. The revised scores for the five projects are in the last column of Table 2. The resulting score for Project B is 0.611. Notice also that the score for Project D also has changed because the frontier against which it is compared is now different. Project C remains on the frontier and is now the only project on the frontier. Because Projects A and E are still compared only with Project C, the scores for these projects also remain unchanged. Thus the subjective assessment regarding the relative importance of improvement and length has added materially to the analysis.

Score 1 reflects primarily engineering and managerial judgment. Score 2 incorporates political assessment of the relative importance of improvement and project size (i.e., improve-

TABLE 2 Data for Numerical Example and DEA Results

Project	Change in RSL	Project Cost	Length	Length/Cost	Improvement/ Cost	PPS Score # 1	PPS Score # 2
A	3	80	0.2	2.5	37.45	0.525	0.525
B	5	120	1.0	8.3	41.67	1.000	0.611
C	5	70	0.5	7.1	71.43	1.000	1.000
D	8	800	3.0	3.7	10.00	0.450	0.158
E	6	160	0.6	3.7	37.45	0.525	0.525

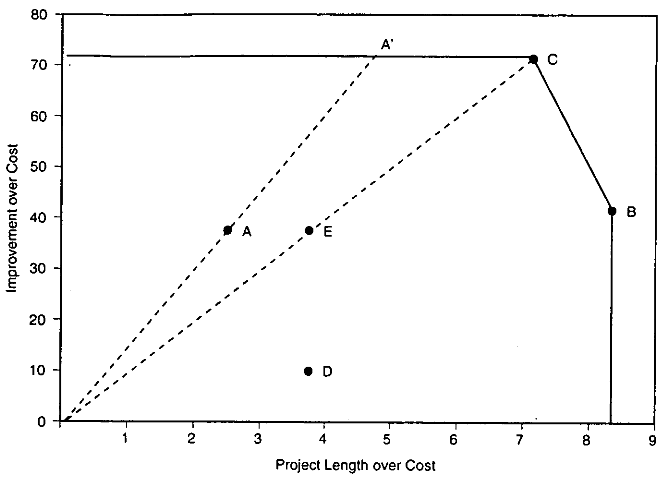

FIGURE 2 DEA Example 1: improvement and length weighted equally.

ment is at least twice as important as size). The DEA-based method proposed here suggests then that projects should be prioritized on the basis of either Score 1 or Score 2 in Table 2, and those with higher ranks should be constructed first. How far the agency is actually able to move down the priority list is a function of funding levels.

Although this simple example was constructed using only two outcome measures, DEA is quite capable of incorporating multiple dimensions as well. A richer demonstration was performed for UDOT to illustrate this more clearly.

DEA DEMONSTRATION USING REAL PROJECTS

To demonstrate the methods, data were obtained from UDOT on 49 projects that either have been recently approved for construction or are currently in design. The project sites lie throughout the state and reflect a broad range of both project size and diversity of scope. Projects included range from relatively small safety improvement proposals to major reconstruction and even new construction. In some instances, UDOT was able to provide reasonable data for current service levels but was unable to provide estimates of remaining service life. In these cases, reasonable but very simple assumptions were made regarding the rate of degradation over the design life for a particular variable. The assumptions yield plausible results that are adequate for this demonstration, even though actual values may vary from those used here.

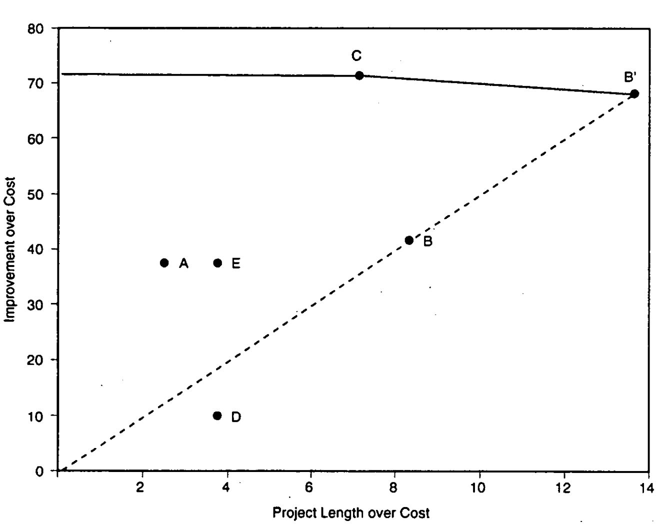

FIGURE 3 DEA Example 2: improvement at least twice as important as length.

To facilitate the demonstration, the projects were first broken down into four categories, on the basis of the expected project components. The categories are

1. Capacity,
2. Safety,
3. Pavement, and
4. Bridge structures.

In the full demonstration, a separate analysis is provided for each class of projects, followed by an integrated analysis including all projects. For the sake of brevity, only the pavement analysis and overall analysis are reported here. The complete demonstration report is available from the authors (*1*).

Pavement

For the pavement part of the demonstration, 23 projects were chosen. The data used to evaluate these projects are shown in Table 3. The 23 projects range in cost from $600,000 to $9 million. In this instance, three measures of need are employed, all measured in terms of remaining service life. The first dimension is a distress indicator that reflects for the most part surface cracking. The second measure is the remaining service life of the roadway structure. The third measure of need is the number of years until the PSI falls below an acceptable level. Although in many instances these dimensions are related, they each capture a different aspect of the pavement condition and expected remaining service. Project outcomes are measured in terms of project length and service life added by the project on each of the three dimensions. Finally, traffic loads are included in the model. Thus the DEA pavement model demonstrated here includes the following variables:

1. Project cost, an input;
2. Remaining service life—distress, a nondiscretionary input;
3. Remaining service life—structural condition, a nondiscretionary input;
4. Remaining service life—PSI, a nondiscretionary input;
5. Project length, an output;
6. Added service life—distress, an output;
7. Added service life—structural condition, an output;
8. Added service life—PSI, an output; and
9. Equivalent single-axle loads (ESALs), a nondiscretionary output.

Table 4 provides the results of the DEA evaluation of these projects. The first two columns following the identification

TABLE 3 Pavement Model Demonstration Data

ID	Project Cost	Service Life: Distress	Service Life: Structural	Service Life: PSI	Project Length	Added Life: Distress	Added Life: Structural	Added Life: PSI	ESALs
27	4,326,257	8.933	17	4.800	0	11.067	3	15.200	1,284.2
28	3,974,031	7.560	16	7.200	0	10.440	2	10.800	1,344.2
29	6,300,000	12.400	12.2	8.667	8.7	7.600	7.8	11.333	1,699.7
30	1,000,000	7.500	16	12.900	3.5	10.500	2	5.100	1,269.6
31	3,910,850	5.667	16	16.667	0	19.333	9	8.333	1,269.6
32	1,000,000	4.947	12.2	5.133	5.30	9.053	1.8	8.867	1,150.7
33	1,700,000	0	10.1	0.000	59.1	15.000	4.9	15.000	34.2
34	9,000,000	0	3.7	1.667	17.5	10.000	6.3	8.333	496.8
35	4,000,000	0	11.3	1.500	13.9	15.000	3.7	13.500	81.4
36	4,000,000	11.733	14.7	7.333	4.2	8.267	5.3	12.667	415.8
37	600,000	0	8.3	0	4.6	13.000	4.7	13.000	9.3
38	3,000,000	0.653	9	3.733	21.4	13.347	5	10.267	63.8
39	4,000,000	0.267	2.2	1.667	11.4	9.733	7.8	8.333	434.2
40	3,000,000	7.280	9.4	0	8.5	6.720	4.6	14.000	22.4
41	4,905,772	1.417	10	5.833	4.5	23.583	15	19.167	652.3
45	3,525,000	25.000	17	15.000	1.40	0	8	10.000	134.3
46	3,300,000	10.333	13.3	6.000	1.5	9.667	6.7	14.000	123.3
47	7,000,000	0	8	8.667	3.5	20.000	12	11.333	77.6
48	4,500,000	0	12.3	5.000	1.1	30.000	17.7	25.000	32.6
49	3,200,000	1.300	16.6	2.000	1.20	28.700	13.4	28.000	391.0
50	4,500,000	0	5.8	9.167	4	25.000	19.2	15.833	274.3
51	1,082,061	14.667	10	5.000	1.98	10.333	15	20.000	122.1
52	1,704,933	15.467	14	1.333	0.8	4.533	6	18.667	141.1

(ID) show the results if no assumptions are made regarding the relative importance of each dimension. In this case 15 of the 23 projects are on the productivity frontier.

Once again, the relative importance of project length to improvement must be considered. Clearly project length is a dimension that should be included in the analysis; otherwise the results will be systematically biased against large projects. On the other hand, it seems unlikely that length is as important as improvement. If assumptions are made regarding the relative importance of the dimensions considered, the rankings change quite noticeably. To demonstrate this, the following relationships were assumed to reflect UDOT priorities:

1. All measures of improvement are at least twice as important as project length.
2. Traffic loads carried are more important than project length.
3. Among the nondiscretionary inputs, structural condition is the most important factor, followed by PSI and distress, in that order.
4. Among the nondiscretionary outputs, structural condition is the most important factor, followed by PSI and distress, in that order.

Using these assumptions, the DEA scores were recalculated and the revised scores are shown in Table 4 in the column headed PPS Index, Weighted. A comparison of the two indexes shows that in 11 of 23 cases the project rank was unchanged. In six cases the rank based on the revised score dropped by as much as 21 places. In the remaining six cases the revised rank increased, although the largest increase was five places. These increases in rank were not caused by higher DEA index scores, since adding relative weights can never increase a score. Rather, the ranks for these projects improved because the scores for other projects fell, whereas the scores for these projects were largely unaffected.

For each project not on the frontier, DEA identifies a set of similar but superior projects on the frontier. These comparison sets are identified in the next two columns of Table 4. Each column is headed by the ID for a project that is on the frontier and that appears in one or more comparison sets. The comparison set for each project not on the frontier is indicated with one or more X's in the appropriate columns.

Comprehensive Model

Thus far, the demonstration has involved only projects of a particular type: safety, bridge structures, and similar projects. One of the decisions confronting UDOT, however, involves the comparison of projects designed to address multiple problems, thus providing differing levels of improvement for each major category. What is essentially a pavement project may include safety concerns, capacity enhancements, and bridge improvements. This demonstration involves the overall comparison of the projects in the data base. To make this comparison, all 49 projects are included, and the variables from the four separate demonstrations are used. Thus, the model

TABLE 4 Pavement Demonstration Results

ID	PPS Index					Comparison Groups for Weighted Model							
	No Assumed Weights	Rank	Weighted[a]	Revised Rank	Change in Rank	30	32	34	37	39	49	50	51
27	1.000	1	0.296	16	-15		X		X				
28	0.299	20	0.296	16	+4		X		X				
29	1.000	1	0.379	14	-13		X			X	X		
30	1.000	1	1.000	1	0								
31	0.645	17	0.375	15	+2	X	X		X				
32	1.000	1	1.000	1	0								
33	1.000	1	1.000	1	0								
34	1.000	1	1.000	1	0								
35	1.000	1	0.439	12	-11			X	X			X	
36	0.203	22	0.194	21	+1		X		X				X
37	1.000	1	1.000	1	0								
38	0.326	19	0.202	20	-1	X			X				X
39	1.000	1	1.000	1	0								
40	1.000	1	0.185	22	-21		X		X				X
41	0.971	16	0.971	11	+5		X		X	X	X	X	
45	0.178	23	0.157	23	0	X							X
46	0.221	21	0.213	19	+2		X		X				X
47	1.000	1	0.246	18	-17				X			X	
48	1.000	1	1.000	1	0								
49	1.000	1	1.000	1	0								
50	1.000	1	1.000	1	0								
51	1.000	1	1.000	1	0								
52	0.544	18	0.435	13	+5		X		X				X

a. Improvement is at least twice as important as project length; Traffic load is more important than length; Structural factors are more important than either distress or PSI; PSI is more important than distress

consists of 22 variables: 1 input (cost), 8 nondiscretionary inputs, 10 outputs, and 3 nondiscretionary outputs.

Initially, no assumptions are made regarding the relative importance of each dimension, with the result that roughly half of the projects are on the frontier. Weighted PPS scores are then calculated on the basis of combining the weighting decisions from each submodel. As noted earlier in the discussion of relative weights, some DEA scores in the revised analysis are largely unaffected by the additional information on relative importance. Others are changed markedly. When they occur, the changes are caused by the project attributes and the imposed restrictions on the nature of trade-offs between the factors used in the analysis.

If the arbitrary assumption is made that only projects on the frontier will be constructed, the overall budget for the 21 projects thus selected will be just under $42 million. The construction program will include projects ranging in size from $50,000 to $9 million (the largest evaluated). Of course this is an arbitrary assumption, because budgets generally are not set after examining projects but are more often determined exogenously by a legislature or other funding agency. In actual practice, projects would be ranked on the basis of the DEA score and then would be selected starting at the top of the ranking and moving down until the budget is exhausted.

One of UDOT management's major concerns is the distribution of transportation resources between urban and rural areas. No attempt was made in evaluating these demonstration projects to distinguish between urban and rural projects, except to the extent that traffic loads were included in some models. It is important therefore to consider whether the DEA approach has any inherent bias in favor of either urban or rural areas. Although the majority of projects proposed came from more urban districts, the selection rate within each district varied from 36 to 50 percent and was fairly comparable. The exception came in one district that "submitted" only three projects, none of which were on the frontier. Even so, there does not seem to be any inherent bias toward either urban or rural areas.

Neither is there any inherent bias for or against any particular type of project. Four safety projects were selected, along with six bridge projects and eleven pavement projects. Again, this distribution appears to be comparable to the distribution of projects submitted, although no effort was made to balance the selection. Clearly one of the strengths of the DEA approach is its inherent balancing of factors considered, within the limits of project attributes and imposed weights.

A final aspect of DEA that can be demonstrated here involves the imposition of a requirement that some particular project be carried out, regardless of its DEA evaluation. Suppose for example that for political reasons all districts must have at least one project. As noted above, none of the projects proposed by one district was selected. The case is made that Project 4 in that district should be constructed. Project 4 is the highest-ranking project submitted by the district, and indeed, in the initial bridge analysis it was on the frontier. If Project 4 is selected for construction, Project 11 is the most logical project to drop (assuming constrained budgets and the impossibility of building both). The data clearly demonstrate that the two projects are very similar. Both are bridge replacements funded from state moneys, with no other pavement or capacity implications, although Project 11 does have safety implications not found in Project 4.

The following are the net effect of replacing Project 11 with Project 4.

1. The state will spend an additional $541,000, the difference in the cost of the two projects;
2. The net improvement to bridge deck service life will be shortened by 1.4 years, the difference in the deck improvement resulting from the two projects;
3. The net improvement to bridge substructure service life will be shortened by 2.9 years; and
4. One additional preventable accident will occur every 3 years.

Thus, the DEA analysis enables identification quite specifically of what the trade-offs are in project substitution.

This comparison does not argue against the substitution of two projects. Such a judgment ultimately must be based on the managerial judgment of political leaders and should include factors that can never be successfully incorporated in a mathematical model. What the comparison does indicate is that constructing Project 4 will have costs, and those costs can be identified and specified with the help of DEA in terms of lost opportunities. If the state constructs Project 4, it likely cannot construct Project 11. The cost of constructing Project 4 over Project 11 can be stated in terms of additional dollars, shortened service life, and additional accidents.

One might argue that Project 11 ought not to be dropped. Rather, some other project should be found that could be replaced with Project 4. One implication of such a decision is that those factors promoted in Project 4 (bridges) are more important than the factors enhanced by the other project that will be dropped from the construction program. If this is true, then the comparative importance of the dimensions involved should be made explicit; otherwise there is no assurance that the resulting DEA priorities accurately reflect UDOT managerial priorities. Rendering these judgments explicit is relatively straightforward. It involves adding to the analysis judgments on the relative importance of broad categories. For example, safety may be judged more important than bridges or pavement condition more important than capacity. The analysis reported above would then be rerun to reflect this additional information.

Again, it should be stressed that DEA will not and should not make final allocation decisions. It is fully expected that UDOT personnel will recommend changes in the DEA rankings, and the final decisions must of course pass the scrutiny of political leaders. But to the extent that decision priorities and criteria can be rendered explicit, they can be incorporated in DEA and thus make the processing of information more efficient. The intent is not to replace expert judgment but rather to aid and enhance that judgment.

PROPOSED INTEGRATION OF DEA INTO EXISTING DECISION STRUCTURES

When the conceptual framework articulated above is linked with the DEA methodology, the result is called the project prioritization system or PPS. PPS allows transportation planners and programmers to incorporate into the prioritization process engineering judgment, sound managerial practice, and political values. The purpose of this concluding section is to describe how PPS can benefit transportation decision making by demonstrating how the methodology can be integrated with UDOT policies and procedures.

It is important to note that there are three different components to the PPS proposed here. First, there is the conceptual framework. In this framework, each potential project is characterized in terms of the need for the project, the improvement that will result if the project is carried out, and the costs associated with project implementation. Second, this framework must be implemented within the context of UDOT's existing data collection activities. Although the existing data sources and evaluation methods will clearly evolve over time, current decisions can be based only on currently available data. The conceptual framework articulated here can be used as a guide in the development and evolution of the data collection and evaluation activity, but it is vital that current data and the conceptual framework not be confused. The individual data items articulated in Table 1 will change over time; indeed entirely new measures may be developed as new technologies emerge. This in no way compromises the power or utility of the conceptual framework for evaluating projects.

Finally, the conceptual framework and the available data are combined and analyzed in the PPS software. Taken by itself, the PPS software is simply an implementation of a fairly generic DEA software package. Neither the conceptual framework nor the individual data items have been hard coded into the software. Should the conceptual framework be modified, and when the data items are improved, there will be no need to modify the software. In conducting any analysis, the user must simply indicate how the software should treat each variable included in the assessment.

As powerful as PPS is, no decision of the magnitude of UDOT's highway construction budget should ever be made solely on the basis of a model. PPS should be thoroughly integrated into UDOT decision procedures, and the output from the model should be carefully reviewed at each stage. There are six points or contexts in which PPS can be of significant benefit to UDOT. These may be summarized as follows:

1. The planning staff can use PPS on system-level data to help identify potential problem sites around the state. In this instance, the only variables available will be measures of current (and projected) utilization and the various measures of need. The output of this stage of the analysis would be a ranking of all sites (e.g., corridors, subdistricts) in the state on the basis of need.
2. Given alternative strategies and conditions for the various corridors around the state, PPS can be used to evaluate and rank corridor plans on the basis of greatest need, and the comparative value of specific proposals.

3. In system preservation planning, given a set of conditions at a particular site or along a corridor, and alternative concepts for improving those conditions, PPS can be used to evaluate and select the most effective strategy. In this case, each alternative concept is considered a separate project. All strategies will likely have the same measures of need, since need reflects current conditions. Each alternative strategy will differ in the amount of improvement it provides and the cost of obtaining that improvement. Thus the output of this type of analysis will be a ranking of all strategies based on the relative cost effectiveness of each. This type of analysis could be carried out by either district or central office personnel engaged in preliminary design work. It is recommended that the results of such analyses be compiled, since it seems likely that relatively superior strategies will emerge over repeated evaluations.

4. A similar application of PPS can be used in capacity planning. Here it may prove more difficult to assess project outcomes, since at least some of the outcomes will occur at the system level. Nonetheless, it is vital for UDOT to estimate such outcomes, whether or not the PPS system is used to evaluate alternative strategies.

5. Given the outputs from the planning activities within each major category (e.g., roadway management, safety, structures), PPS can be valuable in providing an overall assessment and comparison of proposed projects. This assessment can then be combined with public input, funding estimates, and other subjective information to yield the projects that will continue to the next phase of scoping or preliminary engineering.

6. Finally, once need, improvement, and project cost data have been refined, PPS can be used again to evaluate and rank projects before finalizing the transportation improvement program.

It is anticipated that after review, division heads and district directors may wish to modify a priority listing generated by the PPS. The proposed procedure permits such a modification, but it is strongly recommended that the change be justified in some way. Further, the review process should require that consideration be given to which projects will be eliminated if the change in priorities is made. The change may in fact take place, but the costs will, under this proposal, be identified explicitly and considered in the decision to change a priority. Note that at no stage does PPS replace qualified engineering and managerial judgment. Rather, it provides another tool to evaluate complex and often conflicting sets of data and it can provide guidance in considering the inevitable trade-offs involved in managing a contemporary highway system.

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Transportation Service Standards—As If People Matter

REID EWING

The land use–transportation system is just that—a system—but it is seldom planned or managed as such. Instead, roads are viewed in isolation, and system performance is measured by levels of service on individual roadways. Operating speed becomes the essential element in transportation planning. The emphasis on speed encourages excess travel and contributes to urban sprawl, undermining society's environmental, energy, and growth management goals. In Florida and Washington State, the search is on for better ways to measure transportation system performance. Adding impetus is the neotraditional planning movement, which has rejected speed as the ultimate measure of performance but only hinted at what might replace it. A paradigm shift in performance measurement—from speed to personal mobility, accessibility, livability, and sustainability—is argued. Alternative performance measures used around the United States are identified and assessed preliminarily. Growth management systems of the future will almost certainly rely on multiple measures, not discarding speed but giving weight to other considerations as well.

> Now, traditionally, traffic experts have operated with one objective: to move people into and around cities as rapidly and efficiently as possible. . . . Speed becomes uppermost, and the fact that it is never obtained, no matter what contrivances the engineers make, never seems to deter them in their pursuit of it. . . . Cities should be an end, not a means. Rationally one wants to have traffic *stop* there, not go *through*, one wants movement within them to be *slow*, not *fast*. (*1*,pp. 255–256)

Such sentiments have long been expressed by those outside the transportation field (*2*,pp.21–24; *3*,pp.1–2; *4*,p.167). They are beginning to be echoed by transportation professionals. Frequent references are seen to the need for a "paradigm shift" in land-use–transportation planning (*5–7*). If a shift is required in planning, it is equally so in the way transportation system performance is measured. In brief, less emphasis should be placed on how fast vehicles move and more on how well people are accommodated.

THE OLD PARADIGM

The 1985 *Highway Capacity Manual* speaks of levels of service in sweeping terms (*8*,p.1-3), yet when it comes time to operationalize the concept, the manual makes operating speed the essential element in transportation planning.

For urban and suburban arterials, levels of service are measured explicitly in terms of operating speed (*8*, Table 11-1). For other types of facilities, the relationship to operating speed is less direct but no less important. Once a facility's design speed is set, levels of service become a simple function of operating speed (*8*, Tables 3-1, 7-1, and 8-1).

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Growth Management

Roadway levels of service have long been used in facility design, traffic operations, and traffic control. When architects of growth management began looking for ways to measure the adequacy of public facilities and services, roadway levels of service were both handy and legally defensible (*9*).

In designing a facility (intersection, roadway section, etc.), the level of service in the design year is the prime concern. After all, the purpose of the facility is to move traffic efficiently.

Growth management is a different ball game. How to best utilize existing facilities is as important as what to build anew. Public purposes such as downtown preservation and energy conservation vie for priority with efficient movement of traffic.

Speed at What Cost?

One negative consequence of higher speeds is more vehicle miles traveled (VMT). Able to drive faster, motorists drive farther (*10–12*). They also drive more frequently, as discretionary trip making increases (*13,14*).

Although motorists may benefit from more travel, society as a whole does not because the costs of automobile travel are only partially borne by the traveler. When such factors as delay, air pollution, and parking costs are added, automobile use is extraordinarily expensive—an estimated 75 cents/mi. [This estimate represents the sum of midrange cost estimates discussed previously (*15–21*)]. If these costs were fully reflected at the gas pump, a gallon of gas would cost $4.50 or more (*22*).

Urban Sprawl and Automobile Dependence

The emphasis on vehicle speed has other unfortunate consequences. It tends to encourage urban sprawl, with all the attendant costs of sprawl. Under roadway level-of-service standards, infill development is precluded in areas in which roads are already congested. Meanwhile, outlying areas with excess roadway capacity remain developable until they too become congested (*23*).

Even after excess capacity is used up, level-of-service standards may encourage sprawl. Speed can be maintained either by expanding roadway capacity to match the growth of traffic or by moderating the growth of traffic to remain in line with available capacity. The near-universal response to congestion has been to build roads as fast as resources permit. That, in turn, has kept long-distance travel feasible (*24*).

Sprawl leads to automobile dependence, which leads to more sprawl and more automobile dependence. Unfortunately, the ability of some to travel far and fast does not translate into mobility for all. The young, old, poor, and handicapped are worse off now than they were before the automobile. In an automobile-centric society, they suffer from "deprivation of access" (*25*). The negative effects are well documented (*26–30*).

APPLICATIONS IN SEARCH OF STANDARDS

The need for new transportation service standards is immediate and pressing. Localities in at least two states are wrestling with issues of transportation performance measurement as part of second-generation growth management systems. The neotraditional planning movement has rejected speed as the ultimate performance measure but only hinted at what might replace it.

Florida's Change in Direction

Florida is a leader in growth management. New Jersey, Maine, Vermont, Rhode Island, Georgia, Washington State, and Maryland have borrowed concepts or even legal language from Florida's 1985 growth management law.

Yet, after several years of experience, it has become clear that the state needs a paradigm shift of its own. Land use and transportation planning have never been fully integrated, and transit planning has remained incidental to growth management. Roadway levels of service have come to drive the transportation planning process. Urban sprawl and automobile dependence have actually worsened under growth management.

Realizing this, state government has changed the rules of growth management. Cities and counties now have the following options:

- They may designate so-called transportation concurrency management areas (TCMAs) in their comprehensive plans. TCMAs are regions such as downtowns that are geographically compact; have a mix of residential, retail, recreational, and other uses; and offer travelers alternatives to the automobile.
- They may replace separate elements of their comprehensive plans with a unified mobility element. Mobility elements must incorporate policies to reduce VMT and make more efficient use of roadway capacity.

If they choose the first option, cities and counties may, within TCMAs, set their own level-of-service standards for most state highways, without regard to standards of the Florida Department of Transportation. At the same time, localities must adopt policies to guarantee that adequate "levels of mobility" are maintained within TCMAs, even as traffic increases.

How to measure levels of mobility is left up in the air. The rule says only that localities shall establish "numerical indicators against which the achievement of the mobility goals of the community can be judged, such as modal split, annual transit trips per capita, automobile occupancy rates. . .".

Washington's Venture into the Unknown

Washington State modeled its growth management law after Florida's, but unlike Florida, Washington has neither statewide minimum roadway level-of-service standards to which cities and counties must adhere nor methodological guidelines that must be followed in estimating roadway levels of service. Thus, localities are free to innovate.

There is near-universal agreement in the Seattle region that the 1985 *Highway Capacity Manual* is too limiting. King County is developing a four- or five-part transportation adequacy measure. Pierce County is trying to choose between congestion indexes, congestion rates, accessibility indexes, and link level-of-service measures. The city of Bellevue plans to average levels of service across intersections within mobility management areas.

This may be an exception to Mae West's wise observation, "Too much of a good thing is wonderful." All the innovation in transportation performance measurement has left local officials wondering if they can meet the state requirement that level-of-service standards be regionally coordinated. They also wonder if they could defend their chosen measures against a legal challenge.

Neotraditional Planning Movement

The most significant development in the planning field since Radburn and the Greenbelt Town movement is the advent of neotraditionalism—a return to pre-automobile town planning principles. The importance of the movement is illustrated by the dozens of articles on the subject and the dozens of new developments planned according to traditional principles [for a partial bibliography and list of developments, see article by Lerner-Lam et al. (*31*)].

An ITE Committee (5P-8) is charged with developing street design standards for neotraditional neighborhoods (*32*). Design standards are important, but they are not enough. New design standards must be accompanied by new performance standards. Otherwise, neotraditional designs will not make it through the development approval process.

NEW PARADIGMS

If the old "speed" paradigm is ill suited to people's needs, what is to replace it? There are at least four possibilities: mobility, accessibility, livability, and sustainability. The four are distinct but not mutually exclusive. Whereas levels of service relate to facilities, "mobility" generally pertains to populations, "accessibility" to land uses, "livability" to environments, and "sustainability" to communities. These terms have been used interchangeably on occasion, so it is important to be clear about the meaning of each.

Mobility and Accessibility

Mobility refers to the ease with which individuals can move about (*33–35*). Using Reno's seminal work as a guide, a mobile population is one that travels freely because the time and cost of travel are moderate and the travel options are numerous; mobility is reflected in automobile ownership, transit usage, daily person trips, and miles of travel (*36*).

Accessibility refers to the closeness of urban activities to one another (*37–41*). Accessibility can be measured in over-the-road distance, travel time, or travel cost. Thus, accessibility is a function both of land use patterns and the transportation system that serves them. A pithy restatement of the concept is provided by Karlqvist (*42*,p.71): "maximum contact with minimum effort."

Lest there be any inkling that mobility and accessibility are the same, the reader is referred to the literature of the 1970s, when accessibility was a hot topic (*43–45*). Writing in 1979, Dalvi reported that British transport planning had shifted its focus from vehicular mobility to personal mobility. Although he approved of the shift, Dalvi presumed that transport planning would ultimately turn its attention to "accessibility provision":

> It is not enough to focus simply on the characteristics of the transport system. It is equally necessary to consider the spatial distribution of opportunities, so that transport policies might be evaluated not only in terms of moving the people to the opportunities but also *moving the opportunities to the people*. This means that land uses and location planning are as vital to the efficiency of resource use in transport as the management of transport services and the determination of modal split. (*46*,p.640) (emphasis added)

High levels of mobility bring with them high social costs (at least in automobile-dependent America). High levels of accessibility have the opposite effect. Newman and Kenworthy (*47*) have shown traffic to be more fuel efficient in low- than in high-density areas; this is a result of higher running speeds. However, the resulting fuel savings are more than offset by longer trips and more motorized travel. In the tradeoff between fuel-efficient traffic (high mobility) and fuel-efficient land use (high accessibility), the latter wins.

Livability and Sustainability

Livability and sustainability are broad concepts. Focusing on transportation, a livable environment is one that "puts the automobile in its rightful place as one among many options for travel" (*48*,p.5). There are two sides to this. First, automobile traffic must be calmed, that is, reduced in volume and speed. Second, other modes must be enhanced, primarily through changes in land use and facility design. Pedestrians and bicyclists must be given as much priority as automobiles within the street environment (*49,50*).

In the book *Livable Streets* (*51*), the qualities that make a street livable are factors such as safety from traffic, peace and quiet, attractive appearance, and street life; ease of movement by car is only one of many qualities valued by residents and not the most important. A livable street environment is better not only for residents but for pedestrians, bicyclists, transit users, and perhaps even motorists, since it makes for a more pleasant driving experience.

The concept of sustainability had its origins in the environmental movement. Sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs" (*52*,p.8). It does so by conserving natural resources and protecting the natural environment (*53,54*).

In the transportation sector, the principal threats to sustainable development are excessive fossil fuel consumption and the air pollution that results. Both depend on VMT. Both also depend on vehicle trip rates and congestion levels because "cold starts," "hot soaks," and low operating speeds add to air pollution and fuel consumption (*55*).

Among modes, walking and biking rank highest on the sustainability scale, being nonpolluting and non-fossil-fuel consuming. The single-occupant automobile ranks lowest. Transit and ridesharing may rank high or low depending on how these modes are accessed.

> A reduction in commute VMT may not result in a proportional reduction in mobile source emissions. If carpoolers drive to carpool staging areas in single occupant vehicles or if transit riders drive to park-and-ride lots to take transit, auto trips and therefore cold start emissions are not reduced. (*56*,p.160)

MENU OF TRANSPORTATION PERFORMANCE MEASURES

It is easy to call for a paradigm shift in transportation performance measurement, but to move beyond speed, a new set of performance measures will be needed.

Happily, a myriad of measures have been formulated for one purpose or another. Thus, it is mainly a matter of reviewing the alternatives and choosing those that stack up well against appropriate criteria. This paper provides a menu of possibilities and a preliminary assessment of the choices.

Areawide Level-of-Service Measures

In the 1985 *Highway Capacity Manual*, roadway levels of service are defined for individual facilities, not for groups of facilities. By focusing on the condition of individual road facilities at a particular hour, levels of service oversimplify the experience of travelers. Travel is experienced in complete trips. Over the course of a day, a person may travel on scores of roadway segments and dozens of different roads. Even a single peak-hour trip may involve travel on many facilities. Presumably, a traveler's perception of roadway conditions is based on an entire trip or possibly an entire day's worth of travel, not on the delay at one intersection or the congestion on one roadway segment.

Also, travelers have choices. Where a well-developed road network exists, many routes are available for a given trip. For many trips, increasingly even for work trips, a traveler may have discretion in the time of travel. And with the growing number of rail systems and exclusive high-occupancy-vehicle (HOV) lanes on freeways, the traveler may have a real choice of mode.

Must adequate levels of service be maintained for every route, mode, and hour of travel that might be chosen by travelers? That has been the modus operandi of growth management programs. Or is it sufficient that government provide trip makers with acceptable travel options? Only by considering trips in their entirety and looking at alternatives available to travelers can the performance of the transportation system be fairly assessed.

Areawide level-of-service measures have been allowed on an exception basis in Florida's local comprehensive plans (*57*). Areawide measures have been constructed by (a) summing volumes and capacities in overall volume-to-capacity measures, (b) averaging levels of service weighted by lane miles or VMT, or (c) adopting performance summaries that specify the percentage of lane miles or VMT above a given level of service. Areawide measures are used outside Florida by some of the nation's leaders in growth management [Montgomery County, Maryland; San Jose, California; and soon Bellevue, Washington (Figure 1)].

It is a small step conceptually and methodologically from averaging travel speeds for segments that make up arterials (accepted practice since the *Highway Capacity Manual* was updated in 1985) to averaging travel speeds for arterials that make up networks (not accepted as yet but reasonable in the context of growth management). With areawide averaging, local governments will have ample incentive to fix localized traffic problems because travel speeds fall precipitously as capacities are approached and exceeded on individual facilities. Less incentive is provided by other methods of areawide measurement.

IMPACTED by DEVELOPMENT	CAPACITY	VOLUME
River Oaks & Zanker	759	347
N° First & Orchard	1842	1212
N° First & Plumeria	1928	1402
N° First & Bonaventure	1865	1184
N° First & Trimble	3436	3302
N° First & Component	2497	2125
N° First & Charcot	2573	2321
N° First & Karina	2653	2244
N° First & Brokaw	3015	2738
TOTALS	20,568	16,875

WEIGHTED AVERAGE V/C = $\frac{16,875}{20,568}$

= 0.820

= LOS "D"

FIGURE 1 Weighted average intersection level of service (San Jose, California).

Areawide Congestion Indexes

Although new to growth management, congestion indexes have long been used to compare roadway conditions from year to year and place to place. They are sure to play a role in congestion management systems under the federal Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) (*58,59*).

Best known is the roadway congestion index, defined as the number of VMT locally per lane mile of freeways or principal arterials (*60*). The index has been estimated annually since the early 1980s for selected metropolitan areas (Figure 2). Other areawide congestion indexes include the congestion severity index and the lane-mile duration index (*61,62*).

The various indexes are compared by Turner (*63*). Conceptually, all have the same strength or weakness (depending on one's point of view): all measure the degree of roadway congestion for more than just the peak hour. If it is concluded that many travelers have flexibility in their travel hours and that their perceptions of roadway congestion are based on a day's worth of travel, then congestion indexes may be better measures of transportation service than are levels of service. However, like levels of service, congestion indexes measure only one thing—vehicular mobility—with all of its implied limitations.

Ridesharing–Trip Reduction Measures

With the growth of travel demand management (TDM) has come the use of ridesharing–trip reduction measures (*64,65*). Such measures are found in dozens of trip reduction ordinances around the United States and more are to come in states mandating local trip reduction programs (California, New Jersey, and Washington). Trip reduction ordinances set performance standards for large employers, who must then induce enough employees to share rides or switch work hours to meet the standards.

Probably the best known example is the Los Angeles region's Regulation XV, which measures performance in terms of average vehicle occupancies of commuters during the morning peak period. Other measures commonly used include the mode split for non-single-occupant modes and the percent vehicle trip reduction during peak hours (Figure 3).

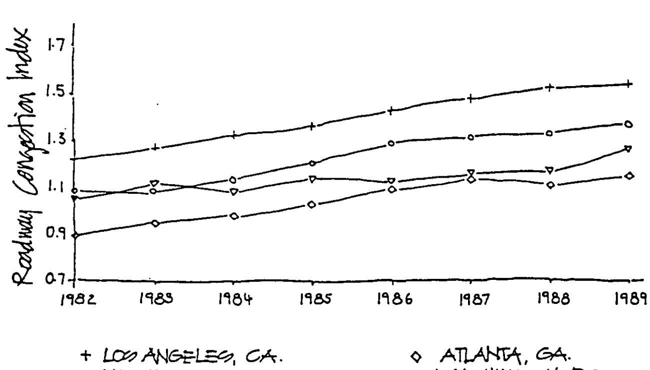


FIGURE 2 Congestion trends in major areas (*60*,p.16).

JURISDICTION	% RIDESHARING/ BIKING/ WALKING	DAILY VEHICLE TRIP REDUCTION	PEAK HOUR VEHICLE TRIP REDUCTION	AVG. VEHICLE OCCUPANCY
Pleasanton, CA			■	
Sacramento, CA	■	■		
Montgomery County, MD	■			■
North Brunswick, NJ			■	
Alexandria, VA			■	
Maricopa County, AZ	■			

FIGURE 3 Measures in trip reduction ordinances.

Such measures are well suited to employer-based TDM programs. Employers have some influence over employees' modes and times of travel through their parking policies, scheduled work hours, and ridesharing programs. But it must be recalled that these measures disregard home-to-work trip lengths (over which employers have no influence). Given that ridesharing is practical only on long commutes, a community that performs well by these measures probably has high VMT to begin with (*66*). Further, given the circuitry of carpool and vanpool trips, an increase in ridesharing may not translate into a significant drop in VMT (*67*).

Multimodal Mobility Measures

Most attempts to measure mobility in multimodal terms have been outside growth management. Examples include Eck's passenger transport index, Polus and Tomecki's level of service of the transportation system, Lomax's speed of person volume, and Courage's personal mobility index (*68–71*).

Within the field of growth management, examples of multimodal mobility measures come from opposite corners of the United States. The city of Miami measures levels of service for automobiles and transit together in transportation corridors. The "practical capacity" of corridors is computed as the sum of automobile and transit capacities (assuming theoretical occupancy and load factors). Person-trip volumes are divided by practical capacities to arrive at volume-to-capacity ratios. Levels of service are then determined with reference to volume-to-capacity standards (Figure 4).

King County, Washington, is developing a transportation adequacy measure for use by its localities. The measure is made up of automobile, transit, nonmotorized, and transportation system management (TSM)/TDM indexes, weighted to reflect local priorities. In urban centers, the transit and nonmotorized indexes may be weighted most heavily; in suburban communities, the automobile and TSM/TDM indexes may be given greatest weight. Facilities will be rated, weights will be applied to the ratings, and an overall transportation adequacy measure will be computed for subareas of the county.

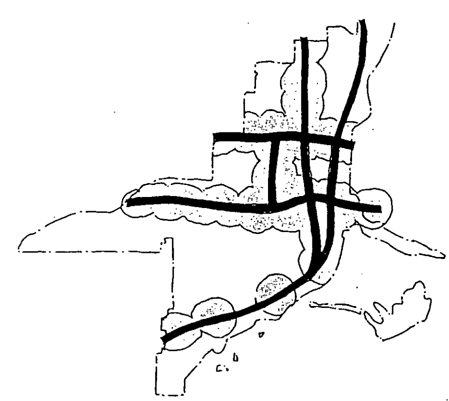
Why measure mobility in multimodal terms when the single-occupant automobile is so dominant? Travelers in some exceptional places such as older central cities still rely on transit and walking for basic mobility. Those without automobiles, regardless of where they live, depend on alternative modes for their mobility. And the rest may become candidates for alternative modes when the full force of federal clean air and congestion management requirements is felt.

Still, there is a certain sense of "adding apples and oranges" with these measures. Modes are not interchangeable for all trips, nor equally valued by all travelers. Service quality is not even measured the same way for different modes (see the 1985 *Highway Capacity Manual*). Any measure that treats modes as interchangeable could have perverse consequences. Buses and sidewalks could be empty and roads gridlocked; yet transportation facilities would be judged adequate and additional development permitted on the basis of excess bus and sidewalk capacity.

Accessibility Measures

The concept of accessibility has been operationalized in measures of varying sophistication and functional form [see previous literature reviews (72–75)]. Accessibility measures may be as simple as average trip length or as complex as "gravity" measures that reflect the regional distribution of jobs, shopping, or other activities.

Simple accessibility standards developed by the American Public Health Association were used by planners in the 1950s



PERSON-TRIP VOLUME/ PERSON-TRIP CAPACITY	LEVEL OF SERVICE
.01 .60	A
.61 .70	B
.71 .80	C
.81 .90	D
.91 1.00	E
1.01+	F

FIGURE 4 LOS standards for Miami's transportation corridors.

and 1960s (*76*). More sophisticated measures were advanced in the 1970s and early 1980s and applied to such diverse areas as travel modeling, siting of public facilities, and analysis of minority employment opportunities [see previous reviews (*77,78*)].

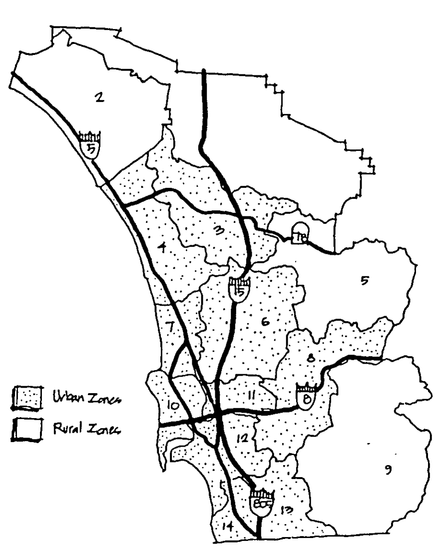
More recently, academic interest in accessibility has waned. Gravity-type models continue to be the workhorse of land use–transportation planning, both in travel modeling and land use allocation (via Lowry-type models). But given the power of accessibility measures, one might have guessed they would amount to more.

Perhaps they will in this new era of growth management, as the emphasis shifts from moving vehicles to moving people to moving opportunities to people. Accessibility standards have been developed for the San Diego metropolitan area and are being considered now by localities in the Seattle region (Figure 5).

VMT and VHT

A class of performance measures includes vehicle trip rates, VMT, and VMT on a per person or per household basis. VMT was chosen in the federal Clean Air Act Amendments of 1990 as the principal performance measure for air quality planning in areas of serious ozone and carbon monoxide pollution (*79*).

VMT has a simple elegance for growth management as well. If development is compact, land uses are mixed, the road network provides direct connections, and transit and ridesharing are well utilized, VMT will be low.



AUTOMOBILE	TRAVEL TIME Minutes	
TRIP PURPOSE	Urban	Rural
Employment	30.	44
shopping	12	21
services	16	25

FIGURE 5 Regional access standards (San Diego Association of Governments).

One approach to VMT standards is suggested by the California Clean Air Act (*80*). Areas with serious pollution problems must bring the growth of VMT, which has been three times the growth of population, in line with population growth. This means that VMT per capita cannot increase as new development is approved (Figure 6).

One thing VMT does not measure is congestion, which, along with VMT, is a major determinant of vehicle emissions, fuel consumption, and time wasted in traffic. It has been suggested that vehicle hours traveled (VHT) might be a better measure of travel demand than is VMT, at least for air quality planning purposes, because vehicle emissions per mile decline with increasing speed (up to about 45 mph), whereas vehicle emissions per hour are essentially independent of speed. Transportation control strategies that reduce VMT may or may not improve air quality, depending on their effect on travel speeds. Strategies that reduce VHT can be counted on to improve air quality.

SELECTING PERFORMANCE MEASURES

How to choose among the many transportation performance measures? Transportation planners are not the first to wrestle with this issue. There is an extensive literature on the measurement of government performance. Even with respect to transportation performance measurement, others have passed this way before (*81–83*).

Performance measures should be easily understood, readily measured, and not too numerous. Whether deserved or not, public agencies have a reputation for fostering needless complexity.

Equally important, performance measures should follow from established goals and objectives. Florida's State Comprehensive Plan calls for energy-efficient transportation systems; easy access to services, jobs, markets, and attractions; and increased ridesharing by public and private employees. Local comprehensive plans establish even more specific goals, objectives, and policies, which may suggest performance measures.

The land use–transportation system is universally acknowledged to be a system (even if it is seldom planned or managed as such). This has implications for the choice of transportation performance measures. Ideally, measures will reflect the efficiency of both land use patterns and transportation network configurations, they will acknowledge the multimodal nature

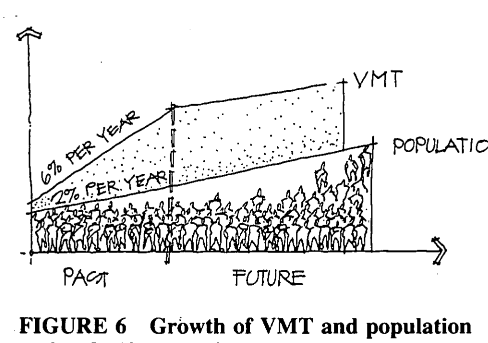


FIGURE 6 Growth of VMT and population under California's Clean Air Act.

of the system, and they will treat the links and nodes as part of a system.

At a minimum, two dimensions of performance must be captured. One is traffic congestion, which may be represented by levels of service or congestion indexes. The other dimension is travel volume, which may be represented by ride-sharing–trip reduction measures, accessibility measures, or VMT.

These two dimensions of performance are distinct from one another. To illustrate, one study compared alternative development patterns and found that some patterns generate low VMT and low average speeds, others high VMT and high average speeds, and still others low VMT and high average speeds (*84*). Another study compared transportation control measures and found that some reduce VMT and improve average speed, whereas others affect only VMT or speed, but not both (*55*). By limiting the measures to levels of service, we give away half the farm.

Ideally, a third dimension of transportation system performance would be captured as well: travel opportunity for the transportation disadvantaged. A congestion-free system with moderate travel volumes may still leave those without the automobiles at home without transit, walking, or biking opportunities. This dimension may be represented by multimodal mobility measures, accessibility measures, or simple mode-split measures.

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Cost-Efficient Programming of Road Projects Using a Statistical Appraisal Method

PEDER JENSEN

A statistical appraisal method (SAM) is presented that can undertake cost-efficient programming of road projects in which a large number of projects are to be examined and data are scarce or difficult to acquire. This is often the case in developing countries, and SAM is illustrated by an example concerning appraisal of low-volume rural roads in the Philippines. Most project appraisal methodologies are based on cost-benefit analysis techniques in which costs and benefits for the design life of the projects are estimated and net present values or internal rates of return are calculated. One of the main obstacles to the use of such methods is the tremendous data requirement for the applied benefit and cost estimation models. The use of a statistical regression technique on readily available data or those with a low collection cost is suggested as a method for limiting the requirements for data with a high collection cost. In addition to SAM, a simplified method, budget level test (BLT), is introduced. BLT measures the efficiency of a simplified appraisal method—in this case, SAM—compared with that of cost-benefit analysis. Application of the programming methodology presented indicates that the data requirements in the appraisal type dealt with can be lowered by 50 percent without seriously jeopardizing the quality of the appraisal.

The need for simplified appraisal methods has been pointed out by many writers (*1–3*). By simplified these authors mean methods that do not require the same amount of data as a cost benefit analysis (CBA). This need is especially true for low-volume rural roads, in which the total benefit of a project could be more or less offset by the cost of a comprehensive CBA.

Fricker (*4*) has suggested the use of statistical analysis on available data as a method for limiting the need for an extensive data collection. Fricker's work was based on pavement management systems, but the idea has been found to be useful also in connection with appraisal of low-volume rural roads.

Many projects recommended for implementation in nonvirgin areas have been submitted to several screening processes during several road development studies before the final recommendation for implementation is given (*1*). Therefore, some base data will often exist for many of the individual links in an appraisal study. These data can and should be used to minimize the need for additional data collection, which is often one of the main obstacles and an important cost component in the appraisal process.

The statistical appraisal method (SAM) is an attempt to structure a rational utilization of such existing data.

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The method is based on some basic assumptions regarding the pool of projects to be analyzed and the rationality of the project selection procedure:

- The projects should be independent, meaning that the benefit of one project should not depend on the implementation of another project. This condition is met by most feeder road studies in developing countries.
- The individual projects have to form a rather homogeneous population of projects. This means that the projects have to be of the same order of magnitude and also that they must serve roughly the same aim.
- Some of the same base data have to be present for all projects in question. These data include such factors as length of project, access constraint, approximate cost of construction, approximate existing traffic, and approximate population in the road influence area.
- Only the highest-ranking projects should be implemented, indicating a rational approach. Of course, network consistency should also be taken into account, but mainly to discard projects that require other nonviable projects to be implemented as a prerequisite for their own viability.

Although the presentation of SAM is exemplified by a calculation example concerning low-volume rural roads in a developing country, other applications concerning programming of large numbers of homogeneous projects are also possible by this method.

OUTLINE OF METHOD

The method can be described according to the following five steps, which represent the rationale of SAM.

Step 1: Study Identification

At the first stage the aim of the study must be identified, and on this basis the relevant benefit types are outlined. For each type of benefit a relevant estimation model must be formulated because a formal CBA will have to be carried out for some of the projects.

In addition to the identification of aim and benefits, all projects must be identified. It must be verified that they serve roughly the same aim (e.g., agricultural development) and that the expected impact is of the same type. A 50-km feeder road in a virgin area may induce a shift in agricultural production toward cash crops, whereas an upgrading of a 5-km feeder road will be unlikely to induce such shifts. Therefore it may be necessary to break up the project pool into several subgroups, which can be analyzed separately.

Step 2: Data and Benefit Proxy Variables

For each type of benefit that cannot be estimated on the basis of existing data, a number of proxy variables for these benefits must be identified. Often it will be possible to draw on previous studies. It must be shown that there is a significant relationship between the proxy variables and the actual benefit elements. A significance level better than 10 percent has been used.

All the data for the proxy variables must be collected. Only data that can be collected at low cost should be included here. Also an estimated cost of construction must be found.

Step 3: Initial Subsample for CBA Calculation

A subsample of projects must be selected for comprehensive CBA to establish their actual benefits. The selection of this group of projects can be made in several ways. Because some projects may have been analyzed in an earlier study, it would make sense to start with these as a subsample. If this is not feasible (e.g., because of inconsistencies between studies), a sample might be selected at random, as is the case in the example described later.

The size of the sample should be large enough to remove biases caused by extreme projects but small enough to allow for CBA calculations and further refinement at a later stage. By empirical analysis it has been found that 10 to 15 percent of the total project pool is an adequate initial sample size.

Step 4: Regression Analysis

The fourth step concerns establishing a relationship between the proxy variables and the actual benefits of the selected initial subsample. This relationship is determined by the use of a multiple linear regression technique. All proxy variables found to have a significant relationship to the benefit in question are used as independent variables, and the actual benefit is used as a dependent variable. The regression relationships are then applied so as to calculate benefits for the remaining projects, for which only proxy variables are available.

Step 5: Project Ranking

Step 5 concerns ranking of all projects, both projects with actual benefits and projects with statistically derived benefits. This ranking is made on the basis of a benefit-cost ratio criterion. If the number of projects needed to exhaust the budget can be taken from the top of the ranking, without reaching or including any of the projects that have only regression-based benefits, the analysis can be stopped. Otherwise, an additional subsample must be selected. An additional subsample of projects is determined for CBA analysis, and Steps 4 and 5 are repeated until no further analysis is required. The projects making up this subsample are the highest-ranking projects with regression-based benefits.

It is presumed that it is acceptable to reject a project but not accept one on the basis of a statistical appraisal result. Only projects that have undergone formal CBA are accepted. This corresponds to a general safety principle, in which all actions suggested should be thoroughly analyzed, whereas this may not be completely the case with options that are rejected. In addition to ranking of the projects, CBA calculations also allow for a testing of the absolute profitability of the projects because net present value and internal rate of return can be derived directly from the CBA figures.

BUDGET-LEVEL TEST

In spite of much justified criticism, CBA has survived for many years; there seems to be a consensus that, in spite of flaws and simplifications, CBA is, from a theoretical point of view, the best methodology around. The general CBA framework is an open-ended concept that does not limit the analyst to a limited number of aspects. Anything can in principle be built into CBA. This is not to say that CBA is the perfect tool; quite the contrary. CBA involves a number of problems, of which data requirement is one of the major ones. Cross-sectional or time-series data often do not exist, and even when they do they represent the past, not the future, which is what is really required. Nevertheless, in this context it is justifiable to use CBA as the reference method. Thus CBA will be seen as the correct ranking of projects, and any other method will be judged on its ability to reproduce this ranking. The following concepts are used:

- The prediction ability is the percentage of projects placed correctly by the method in question. Thus a prediction ability of 70 percent indicates that 70 percent of the projects in question have been placed correctly in the ranking. The meaning of correctly will be discussed below.
- The budget level is the percentage of the projects in question that can be financed under the current budgetary conditions. Thus a budget level of 40 percent indicates that funds are available for implementing 40 percent of the projects being examined.
- A good project is a project that under the given budgetary conditions would be accepted. It would be placed in the acceptance stratum by CBA.
- A bad project is a project that under the given budgetary conditions would be rejected. It would be placed in the rejection stratum by CBA.

The rationale of the budget-level test (BLT) is that if funds are available for 40 percent of the projects in question (the budget level is 40 percent), the main point of interest is whether a project belongs to the upper 40 percent of the ranking or the lower 60 percent of the ranking; that is, whether it belongs to the acceptance stratum or the rejection stratum. The essential point is how large a percentage of the projects recommended for implementation by SAM would also have been recommended by CBA. Therefore, the quality of a simplified method such as SAM is defined as the percentage of good projects placed in the acceptance stratum with reference to a formal CBA. This percentage is the prediction ability. Often the budget level is not known in advance; thus all relevant budget levels can be examined, leading to a two-dimensional result shown as a curve on a graph. Such a graph is shown in Figure 1, in which the four curves represent the prediction ability of four simplified appraisal methods when tested against CBA for any budget level between 0 and 100 percent.

The hatched area in the graph represents an area in which the prediction ability is calculated on the basis of very few projects. Therefore, individual projects will have a very large influence on the result. From a statistical point of view, the prediction ability at low-budget levels is uncertain, and the results should be interpreted with great care.

If for a given pool of projects no information is available, one can in principle resort to simple guessing when appraising the projects. With a budget level equal to 100 percent it is a trivial task. All projects can be accepted. Thus the prediction ability is also 100 percent.

The normal situation arises when the budget level is not 100 percent and often is much below. In that case there are four possibilities:

- A good project is placed in the acceptance stratum.
- A bad project is placed in the acceptance stratum.
- A good project is placed in the rejection stratum.
- A bad project is placed in the rejection stratum.

Only the first two possibilities are relevant to the calculation of the prediction ability. If no information whatsoever exists, the probability of these two possibilities can be calculated. They are denoted P_{ga} and P_{ba}.

Because 40 percent of the projects by definition are good projects when the budget level is 40 percent, the probability of selecting a good project (P_g) at any budget level is

$$P_g = BL/100$$

where BL represents the budget level in percentages. Likewise, the probability of randomly selecting a bad project (P_b) at any budget level is

$$P_b = 1 - (BL/100)$$

Knowing the budget level for each run of the test, the probability of placing a project in the acceptance stratum (P_a) is given by

$$P_a = BL/100$$

On the assumption that independence exists between the selection of a project and the assignment of it to a stratum, the compound probabilities can be calculated as follows:

$$P_{ga} = P_g \cdot P_a = BL^2/100^2$$

$$P_{ba} = P_b \cdot P_a = (BL/100) - (BL^2/100^2)$$

The prediction ability (PA) is the percentage of good projects in the acceptance stratum:

$$PA = [P_{ga}/(P_{ga} + P_{ba})] \cdot 100 \Rightarrow PA = BL$$

Thus, a random method will provide a prediction ability equal to the budget level. If the budget level is 40 percent, only 40 percent of the projects recommended for implementation by

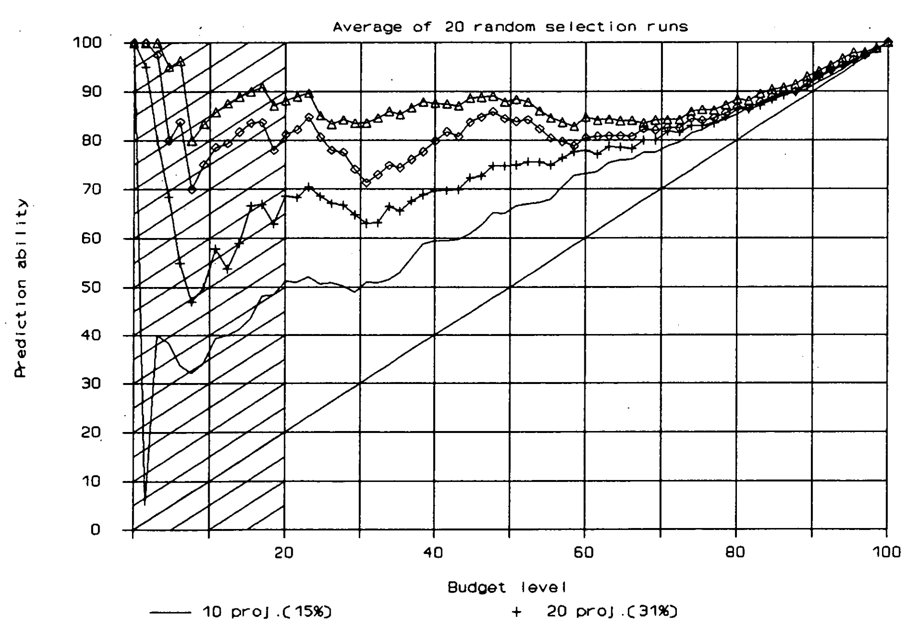

FIGURE 1 Budget-level test on four analytical levels of the statistical appraisal method. Each percentage refers to the percentage of projects used as basis for regression analysis.

a random method will be correct. This can be thought of as a minimum on which any appraisal method should be able to improve. The noncounterintuitive result is shown as a diagonal line in Figure 1.

EXAMPLE

This example concerns low-volume rural roads in the Philippines—so-called barangay roads—where data have been collected by a Danish consulting firm, Hoff & Overgaard A/S, for the Ministry of Local Government in connection with a study (ADB-Assisted Third Road Improvement Project, unpublished data, 1985).

Step 1

On the basis of the study reports, 65 projects were identified as a fairly homogeneous group of road rehabilitation projects. The appraisal of projects described in the reports was based on the four following benefit types:

- Time savings related to nonagricultural traffic.
- Vehicle operation cost savings (VOC) related to nonagricultural traffic.
- Maintenance cost savings.
- Increase in producer surplus in the agricultural sector, which also accounts for benefits related to agricultural traffic.

Step 2

To demonstrate the potential of SAM as compared with the CBA undertaken by the consultant, several possible proxy variables available from the study reports were examined: length of project road, population in road influence area (RIA), population growth in RIA, percentage of unutilized land in RIA, and access constraint. Only three of these showed a significant relationship with the actual benefit types. Significance levels are shown in Table 1. The significance test is used only to select proxy variables, which are as follows:

- *Length of proposed road.* VOC savings depend on length in connection with the amount of traffic on the road. Therefore length could serve as a partial proxy variable for this benefit type. Maintenance cost savings depend largely on the length of the proposed road and can therefore also utilize the information contained in this proxy. Also producer surplus showed a significant relationship, although it is not as strong as the others.

  One might argue that the cost of a project is more or less proportional to its length and that length should therefore be eliminated to prevent both benefits (through regression equations) and cost from being dependent on length. The significance levels, however, indicate that the benefits dependence on length is not total. Instead of cost and benefits per kilometer, in this study length was included as a proxy.
- *Population in RIA.* Population in RIA is an important proxy in the estimation of traffic amounts and can therefore serve as partial proxy for both maintenance savings and VOC savings. Also this proxy showed a significant relationship with producer surplus.
- *Access constraint.* The access constraint factor is a measure of the percent closure of the existing road over the year. If no road exists, the closure is 100 percent. If half of the distance is closed half of the year, the access constraint factor is 25 percent. Time savings are strongly correlated with this factor because after upgrading, high-access constraint often will entail a transport mode shift, for example, from head-loading to small vans. Also maintenance savings showed a significant relationship with this proxy.

The significance of the relationships was tested successively in the regression model by use of a *t*-test on each coefficient in the regression equations (*5*).

Step 3

From the project pool a subsample of 10 projects was selected. The selection criterion adopted was random selection of projects. The size of the initial sample was determined on the basis of empirical testing of SAM.

Step 4

A multiple linear regression analysis was carried out to establish the relationships between proxy variables for the ten projects in the initial sample and the actual benefits found by CBA.

TABLE 1 Significance Levels

	Proxy variables		
Benefits	Length	Population	Access constr
Time savings	-	-	0.022
VOC savings	<0.001	0.012	-
Maintenance savings	<0.001	<0.001	0.002
Producer surplus	0.074	<0.001	-

Step 5

The relationships found were then applied to the proxy variables for the rest of the project pool. With cost and benefits known for all projects (10 with actual benefits and 55 with statistical benefits) a benefit-cost ratio could be calculated and all projects could be ranked. These items are illustrated in Figure 2, in which the project pool is ranked. Column 1 contains the name of each project; Column 2, the ranking achieved by the consultant; Column 3, the ranking on the basis of statistical benefits; and Column 4, an indication of the level at which each project was included in the sample used for regression analysis. An example is the Josefina-Don Mariano Marcos project, which in the CBA study ranked as Number

Projectname	CBA rank	SAM rank	Incl. level
Guinpana-an- Alingasao	30	1	
Tagumpay- Sitio Baran	53	2	
Kiangan- Julongan	2	3	
Bantug- SanGuillermo	1	4	
Lipay - Tubo-Tubo	11	5	
Lagawe- Burnay- Hingyon	6	6	
Josefina Don MarianoMarcos	3	7	10
Sto.Tomas- Sta.Maria	7	8	
Dao - Jct.Maindang- Cuartero	25	9	
Mayoyao- Banao- Alimit	13	10	
Burgos- Iba - Sula	37	11	
Darubba- Runruno	50	12	
Bonifacio- Kanao-Kanao	15	13	
Gamu- Lullutan- SanAntonio	10	14	
BenitoSoliven- SanAntonio	9	15	10
SitioNabilog - Banban	31	16	
Dibuluan- Sta.Isabel	41	17	
Nagdayao- Pis-anan- Bad-as	4	18	
Dibuluan- Bannawag	49	19	
PHILSECO - Cawag	20	20	
Dibuluan- Palasian	24	21	
Jct.East Villaflores - Putian- Astorga	64	22	
Debibi - Tucod	16	23	10
Quirino - Lullutan	22	24	
Nat. Hwy - Gabriela - SitioTapaya	63	25	
NRJ - Katipunan- Sitio Tionggo	17	26	10
Salug- Benoni- Godod	8	27	
Tuburan- Duluan- Parallan	33	28	
Tuburan- Bongbongan	23	29	
Buluangan - Bungsod- Lublub	19	30	
SitioNabilog - Bago	28	31	
NRJ Manjuyod- Cabcaban	52	32	
SanRoque- Sta.Teresa	36	33	
Zamboanguita Calango	40	34	
Debibi - Eden	51	35	
Abaca- Camandagan CasayViejo	39	36	
SitioNabilog - Guincalaban	35	37	
Banga- Taywan	46	38	
Hilaitan - Trinidad	29	39	
Jamindan Tapaz	18	40	
Aritao - Sta.Clara - Canabuan	21	41	
Poblacion- Capaoayan Mangabol	42	42	
Nato- SanRamon- IbangcalC	32	43	
NR - Sampaguita Tamban(incl. NanialanSpur)	14	44	
NRJ - Mapurao- KapanikianSur	48	45	
BatoJct.- Bungot- Itangel	65	46	
T. Fornier - Carmelo- Villar	55	47	
Jct.Bagumbayan Bugo- Bawang	26	48	10
Mabilang- SanCarlos- Mangabol	61	49	
SanGuillermo - Villa Concepcion	27	50	
Jct.S.Roque- S.Agustin- S.Martin	54	51	
Lagawe- Montabiong- Jucbong	5	52	
Salgan- Batabat- East Villaflores	38	53	10
Maindang- Cuartero	56	54	
Tudela- Sinuza- ColambutanSett.	12	55	
SapangDalaga- Concepcion	34	56	
Casiguran- Dilasag	44	57	10
Villa Aglipay - Pao	47	58	10
BenitoSoliven- Villa Concepcion	59	59	
NRJ SanIsidro - Jct.Bug-ang	57	60	
Poblacion- Calipayan- Mababanaba	43	61	
Abbag- Pongo	45	62	
Sto.Niro - Dungao	58	63	
Burgos- SanClemente	60	64	10
Ma-ayon- Maindang	62	65	10

FIGURE 2 Ranking of project pool based on analysis of 10 projects.

3. It was randomly picked as one of the ten projects in the initial sample and was ranked as Number 7. Another example is the Lagawe-Montabiong-Jucbong project, which in the original CBA study ranked as Number 5. This project is strongly misrepresented by the statistical benefits because it was ranked as Number 52.

Steps 4 and 5 Repeated

The next five additional projects were selected for CBA calculation as the five highest-ranking projects with only statistical benefits. These were the projects with the original ranks 30, 53, 2, 1, and 11. Data were collected, benefits were cal-

Projectname	CBA rank	SAM rank	Incl. level
Bantug- SanGuillermo	1	1	15
Kiangan- Julongan	2	2	15
Josefina Don MarianoMarcos	3	3	10
Lagawe- Burnay- Hingyon	6	4	
Sto.Tomas- Sta.Maria	7	5	
Dao - Jct.Maindang- Cuartero	25	6	
Mayoyao- Banao- Alimit	13	7	
Gamu- Lullutan - SanAntonio	10	8	
BenitoSoliven- SanAntonio	9	9	10
Bonifacio- Kanao-Kanao	15	10	
Darubba- Runruno	50	11	
Lipay - Tubo-Tubo	11	12	15
Burgos- Iba - Sula	37	13	
Dibuluan- Sta.Isabel	41	14	
Nagdayao- Pis-anan- Bad-as	4	15	
Debibi - Tucod	16	16	10
SitioNabilog - Banban	31	17	
NRJ - Katipunan- Sitio Tionggo	17	18	10
PHILSECO - Cawag	20	19	
Dibuluan- Palasian	24	20	
Jct.East Villaflores - Putian- Astorga	64	21	
Quirino - Lullutan	22	22	
Dibuluan- Bannawag	49	23	
Salug- Benoni- Godod	8	24	
Nat. Hwy - Gabriela - SitioTapaya	63	25	
Buluangan - Bungsod- Lublub	19	26	
Banga- Taywan	46	27	
NRJ Manjuyod- Cabcaban	52	28	
SitioNabilog - Bago	28	29	
NR - Sampaguita Tamban(incl. NanialanSpur)	14	30	
Hilaitan - Trinidad	29	31	
Abaca- Camandagan CasayViejo	39	32	
Jamindan Tapaz	18	33	
Aritao - Sta.Clara - Canabuan	21	34	
Tuburan- Duluan- Parallan	33	35	
Jct.Bagumbayan Bugo- Bawang	26	36	10
SanGuillermo - Villa Concepcion	27	37	
SitioNabilog - Guincalaban	35	38	
Zamboanguita Calango	40	39	
Guinpana-an Alingasao	30	40	15
NRJ - Mapurao- KapanikianSur	48	41	
Nato - SanRamon- IbangcalC	32	42	
Debibi - Eden	51	43	
Maindang- Cuartero	56	44	
BatoJct.- Bungot- Itangel	65	45	
Mabilang- SanCarlos - Mangabol	61	46	
Salgan- Batabat- East Villaflores	38	47	10
Tuburan- Bongbongan	23	48	
Jct.S.Roque- S.Agustin- S.Martin	54	49	
Tudela- Sinuza- ColambutanSett.	12	50	
T. Fornier - Carmelo- Villar	55	51	
SapangDalaga- Concepcion	34	52	
Poblacion- Capaoayan Mangabol	42	53	
SanRoque- Sta.Teresa	36	54	
Lagawe- Montabiong- Jucbong	5	55	
BenitoSoliven- Villa Concepcion	59	56	
Casiguran- Dilasag	44	57	10
Villa Aglipay - Pao	47	58	10
Abbag- Pongo	45	59	
Poblacion- Calipayan- Mababanaba	43	60	
Tagumpay- SitioBaran	53	61	15
Sto.Niro - Dungao	58	62	
NRJ SanIsidro - Jct.Bug-ang	57	63	
Burgos- SanClemente	60	64	10
Ma-ayon- Maindang	62	65	10

FIGURE 3 Ranking of project pool based on 15 projects.

culated, and new regression coefficients were estimated (Step 4 repeated). With these new relationships benefits were recalculated, and a new ranking was found (Step 5 repeated). This ranking is shown in Figure 3. The Josefina project is now correctly ranked as Number 3. The Lagawe project, on the other hand, is still in the lower end of the ranking scale.

The process was repeated another five times, adding five projects each time. The process was stopped when 40 projects out of 65 were examined by using CBA. The process is illustrated for 20 and 40 projects in Figures 4 and 5. In Figure 4 and especially in Figure 5 it can be seen that more and more projects in the upper part of the ranking have actual benefits,

Projectname	CBA rank	SAM rank	Incl. level
Bantug- SanGuillermo	1	1	15
Kiangan- Julongan	2	2	15
Josefina Don MarianoMarcos	3	3	10
Lagawe- Burnay- Hingyon	6	4	20
Sto.Tomas- Sta.Maria	7	5	20
BenitoSoliven- SanAntonio	9	6	10
Gamu- Llulluten- SanAntonio	10	7	20
Lipay - Tubo-Tubo	11	8	15
Bonifacio- Kanao-Kanao	15	9	
Mayoyao- Banao- Alimit	13	10	20
Burgos- Iba - Sula	37	11	
Debibi - Tucod	16	12	10
Nagdayao- Pis-anan- Bad-as	4	13	
NRJ - Katipunan- Sitio Tionggo	17	14	10
Darubba- Runruno	50	15	
Dibuluan- Sta.Isabel	41	16	
Dibuluan- Palasian	24	17	
Quirino - Lullutan	22	18	
Sitio Nabilog - Banban	31	19	
Salug- Benoni- Godod	8	20	
Nat. Hwy - Gabriela- Sitio Tapaya	63	21	
Banga- Taywan	46	22	
NR - Sampaguita Tamban(incl. NanialanSpur)	14	23	
PHILSECO - Cawag	20	24	
Jct.East Villaflores - Putian- Astorga	64	25	
Hilaitan - Trinidad	29	26	
Aritao - Sta.Clara - Canabuan	21	27	
Jamindan Tapaz	18	28	
Buluangan - Bungsod- Lublub	19	29	
Dao - Jct.Maindang- Cuartero	25	30	20
SanGuillermo - Villa Concepcion	27	31	
Sitio Nabilog - Bago	28	32	
NRJ Manjuyod- Cabcaban	52	33	
Jct.Bagumbayan Bugo - Bawang	26	34	10
Abaca- Camandagan CasayViejo	39	35	
NRJ - Mapurao- KapanikianSur	48	36	
Tuburan- Duluan- Parallan	33	37	
Guinpana-an- Alingasao	30	38	15
Dibuluan- Bannawag	49	39	
Maindang- Cuartero	56	40	
Tudela- Sinuza- ColambutanSett.	12	41	
Sitio Nabilog - Guincalaban	35	42	
SapangDalaga- Concepcion	34	43	
Mabilang- SanCarlos - Mangabol	61	44	
Debibi - Eden	51	45	
Jct.S.Roque- S.Agustin- S.Martin	54	46	
BenitoSoliven- Villa Concepcion	59	47	
Salgan- Batabat- East Villaflores	38	48	10
T. Fornier - Carmelo- Villar	55	49	
Nato- SanRamon- IbangcalC	32	50	
Lagawe- Montabiong- Jucbong	5	51	
Poblacion- Capaoayan Mangabol	42	52	
Zamboanguita Calango	40	53	
BatoJct.- Bungot- Itangel	65	54	
Casiguran- Dilasag	44	55	10
Abbag- Pongo	45	56	
Tuburan- Bongbongan	23	57	
Poblacion- Calipayan- Mababanaba	43	58	
Villa Aglipay - Pao	47	59	10
Sto.Niro - Dungao	58	60	
SanRoque- Sta.Teresa	36	61	
NRJ SanIsidro - Jct.Bug-ang	57	62	
Tagumpay- Sitio Baran	53	63	15
Burgos- SanClemente	60	64	10
Ma-ayon- Maindang	62	65	10

FIGURE 4 Ranking of project pool based on 20 projects.

whereas most of the projects in the lower part of the ranking have statistical benefits.

Even though the acceptance stratum contains only projects that have undergone formal CBA, it may still contain a number of bad projects. This is because a number of good projects have proxy variables that misrepresent them. The socio-economic loss caused by this flaw is small, however, because the projects that replace the misplaced good projects are those that should have been placed just below the budget line, as the best of the bad projects.

Figure 1 shows the BLT for 10, 20, 30, and 40 projects being CBA analyzed and representing successive analytical

Projectname	CBA rank	SAM rank	Incl. level
Bantug- SanGuillermo	1	1	15
Kiangan- Julongan	2	2	15
Josefina Don MarianoMarcos	3	3	10
Nagdayao- Pis-anan- Bad-as	4	4	25
Lagawe- Burnay- Hingyon	6	5	20
Sto.Tomas- Sta.Maria	7	6	20
Salug- Benoni- Godod	8	7	30
BenitoSoliven- SanAntonio	9	8	10
Gamu- Lullutan- SanAntonio	10	9	20
Lipay - Tubo-Tubo	11	10	15
Mayoyao- Banao- Alimit	13	11	20
NR - Sampaguita Tamban(incl. NanialanSpur)	14	12	35
Bonifacio- Kanao-Kanao	15	13	25
Debibi - Tucod	16	14	10
NRJ - Katipunan- Sitio Tionggo	17	15	10
Jamindan Tapaz	18	16	35
Buluangan - Bungsod- Lublub	19	17	40
PHILSECO - Cawag	20	18	40
Aritao - Sta.Clara - Canabuan	21	19	35
Quirino - Lullutan	22	20	30
Dibuluan- Palasian	24	21	30
Dao - Jct.Maindang- Cuartero	25	22	20
Debibi - Eden	51	23	
Tudela- Sinuza- ColambutanSett.	12	24	
NRJ - Mapurao- KapanikianSur	48	25	
Jct.Bagumbayan Bugo- Bawang	26	26	10
SapangDalaga- Concepcion	34	27	
Sitio Nabilog - Bago	28	28	40
Hilaitan - Trinidad	29	29	35
SanGuillermo - Villa Concepcion	27	30	
Mabilang- SanCarlos- Mangabol	61	31	
NRJ Manjuyod- Cabcaban	52	32	
Guinpana-an Alingasao	30	33	15
Sitio Nabilog - Banban	31	34	30
Abaca- Camandagan CasayViejo	39	35	
Sitio Nabilog - Guincalaban	35	36	
Maindang- Cuartero	56	37	
T. Fornier - Carmelo- Villar	55	38	
Tuburan- Duluan- Parallan	33	39	40
Dibuluan- Bannawag	49	40	
Lagawe- Montabiong- Jucbong	5	41	
Tuburan- Bongbongan	23	42	
Jct.S.Roque- S.Agustin- S.Martin	54	43	
BenitoSoliven- Villa Concepcion	59	44	
Poblacion- Capaoayan Mangabol	42	45	
Burgos- Iba - Sula	37	46	25
Salgan- Batabat- East Villaflores	38	47	10
SanRoque- Sta.Teresa	36	48	
Poblacion- Calipayan- Mababanaba	43	49	
Dibuluan- Sta.Isabel	41	50	25
Nato- SanRamon- IbangcalC	32	51	
Abbag- Pongo	45	52	
Zamboanguita Calango	40	53	
BatoJct.- Bungot- Itangel	65	54	10
Casiguran- Dilasag	44	55	10
Sto.Niro - Dungao	58	56	
Banga- Taywan	46	57	35
Villa Aglipay - Pao	47	58	10
NRJ SanIsidro - Jct.Bug-ang	57	59	
Darubba- Runruno	50	60	25
Tagumpay- Sitio Baran	53	61	15
Burgos- SanClemente	60	62	10
Ma-ayon- Maindang	62	63	10
Nat. Hwy - Gabriela- Sitio Tapaya	63	64	30
Jct.East Villaflores - Putian- Astorga	64	65	40

FIGURE 5 Ranking of project pool based on 40 projects.

levels of SAM. It is seen that for each increment in the number of projects used as the basis for the regression analysis the improvement in prediction ability gets smaller. Thus, for each extra dollar invested in additional data collection, the return goes down. This action corresponds with the principle of diminishing marginal return on increased evaluation efforts (*6*).

The initial sample is selected at random, and the result may depend on which projects are selected. To test if this effect is significant, the total process was repeated 20 times, and the test results shown in Figure 1 as BLTs actually represent an average of these 20 runs. An analysis of the variance derived from the 20 runs shows that when half of the projects are examined, this variation is without practical implications (*7*). On the other hand, the savings in data collection are diminished as more projects have to be examined. Therefore the aim is to find the lowest possible acceptance level of analysis.

The testing of SAM so far indicates that around half of the projects should be examined for practical purposes. This number of projects will result in a satisfactory study outcome defined as an almost correct ranking, achieved by a significant reduction in data collection costs compared with those in a traditional CBA study (*7*).

Last but not least, the procedure enables the analyst to reuse much of the information gathered in earlier studies, which previously went to waste.

CONCLUSION

Conventional appraisal methods of the CBA type are based on data collection and analysis of all projects in question. Because many projects are rejected, high-cost data are collected for projects that are not viable. This becomes particularly clear if only a limited number of the projects competing for implementation can be carried out because of the budget restriction.

The principal feature of SAM is the successive collection and iterative use of data, making data cost savings possible. A major finding is that by application of an SAM instead of a CBA approach, a savings of 50 percent could be obtained without seriously jeopardizing the quality of the appraisal.

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Optimization of Capital Budgeting for Interrelated Capacity Expansion Projects

Ali E. Haghani and Chien-Hung Wei

A network representation procedure for the optimization of capital budgeting problems is proposed. Interrelated capacity expansion projects and discrete time decisions are considered. An alternative-based approach is proposed that yields a very neat formulation by identifying the relationships among alternatives before solving the problem. The most general pairwise interactions are considered, and a 0-1 integer program is formulated with nonlinear objective function and linear constraints. Procedures are demonstrated that convert the nonlinear program into a linear form with an embedded network structure. The out-of-kilter algorithm is applied to solve the resulting network flow problem. Because of the inherent nature of the network structure, this approach enables efficient calculation of optimal solutions for relatively large problems. Computational efficiency is shown that requires less than 3 min of central processing unit time for a system with 372 alternatives.

Capital budgeting problems are of interest in many disciplines. Each field shows unique perspectives and priorities and utilizes different tools and techniques. Because of the application of specific characteristics, the literature on budgeting has tended to divert from, rather than converge toward, a unified perspective. Basically, capital budgeting deals with the evaluation, selection, sequencing, and scheduling of investment projects. Consideration of interrelated projects is particularly challenging because the input or output factors, or both, of one project are significantly affected in magnitude or timing, or both, by the selection or rejection decisions on one or more of the others under consideration. In real-world cases, projects tend to affect each other in terms of costs or benefits. Therefore, consideration of interrelated projects will provide decision makers with more precise information.

The evaluation of projects is mainly an economic issue that heavily depends on the information available about techniques, markets, demands, predicted costs, and benefits, whereas project selection, sequencing, and scheduling basically make up an optimization process. The evaluation stage is often separated from other stages because of different characteristics. Therefore, the objective as well as the scope of this paper, given the full information on project evaluation, is to develop an efficient procedure for making decisions among interrelated projects to meet prespecified goals and objectives over a planning horizon. By applying the proposed procedure, the three major stages in capital budgeting, that is, project selection, sequencing, and scheduling, could be fulfilled in a single stage.

This paper is organized as follows. The problem is described in more detail and a brief literature review is presented in the next section. Then the problem is formulated as a mathematical optimization problem and the solution approach is provided. Numerical results are also presented. Finally, conclusions and future research are discussed.

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PROBLEM STATEMENT

There has been much research concerning interrelated project scheduling. Various fields have a similar problem, and the study methods are diversified [e.g., Erlenkotter (*1*), Gear and Cowie (*2*), Luss (*3*), Czajkowski and Jones (*4*), and Gomes (*5*)]. Most approaches to capital budgeting use integer programming, dynamic programming, or multicriteria formulation to model the interdependencies among projects. To overcome the combinatorial difficulty when more interrelated projects are involved, various heuristic methods are developed. However, studies on project relationships have not yet exhibited a significant breakthrough. For example, the study by Srinivasan and Kim (*6*) was not quite applicable to practical problems.

The solution space of the capital budgeting problems grows exponentially when more projects are considered. However, in most real-world cases, not all of the projects are pairwise interrelated. Hence, decomposing the project set into smaller subsets shows some advantage. Decomposition may be done according to specific applications or by following the more rigorous rules shown by Steuer and Harris (*7*) or Morse (*8*). Prescreening projects to reduce the problem size should be considered whenever possible.

Most of the existing techniques use relatively small illustrative examples. It is thus difficult to assess their capabilities in dealing with large problems. Heuristic approaches, for example, that of Janson et al. (*9*), are developed to handle such large problems. These procedures attempt to reduce the number of projects under consideration systematically or to find "good" solutions to the problems, or both. However, in most cases, it is not possible to verify the quality of the heuristic solutions relative to the optimal solutions. This is because the heuristic procedures usually lack a built-in mechanism to evaluate the quality of each solution obtained. The approach proposed in this paper attempts to overcome such limitations. The proposed model and solution procedure enable the analyst to handle relatively large problems easily and to find the optimal solutions with relatively minor computational efforts.

The capacity expansion problem is similar in many respects to the general project sequencing problem that determines the sizes and facilities to be added. They both are fairly difficult to solve (*10*). A special class of capacity expansion deals with a set of expansion projects according to the demand pattern over time. Then the problem is to select the sequence and appropriate timing of projects to satisfy the time-dependent demand while minimizing the total discounted costs. The resulting expansion path may be defined as the order and timing of implementing a subset of preferred projects. In the work of Martinelli (*11*), a graphical depiction was proposed to sequence inland waterway capacity expansion projects. Each project was viewed as a system generating a common time-dependent output, and a two-dimensional representation was utilized in which costs are plotted on the vertical axis and time is plotted on the horizontal axis. A search algorithm is required in selecting the preferred sequence of projects in the corresponding two-dimensional space. The expansion path could then be identified by the implementation sequence of projects and associated times. This method, named continuous time expansion for convenience, could be a powerful support for decision making because of its visual structure. The expansion paths, however, may not be easily and correctly recognized instantly through the graph, especially for complex project combinations. Hence, direct application of this method may be limited to a small number of projects. Consequently, Martinelli developed a heuristic sequencing algorithm to obtain an efficient solution.

To achieve a sequential expansion path using Martinelli's search algorithm, the cost functions were hypothesized to possess desired properties. Specifically, positive first and second derivatives were assumed with respect to the system outputs. Although it holds in waterway systems, such a requirement might be another limitation of the continuous time approach to more general applications. This type of application-specific restriction is one of the urgent issues to be resolved in capital budgeting.

A good solution for capital budgeting may be easily found by slightly twisting the original problem. Wei (*12*) developed an approach based on discrete time decisions. In that work, the choice of individual projects was the primary decision variable, and a set of supplemental variables was needed to identify the combinations of projects. Because the interrelations among projects are reflected in the cost functions of various project combinations, the transitions between projects and combinations of projects need to be incorporated explicitly as constraints. Consequently, the resulting objective function is quite complicated. That formulation was solved exactly using LINDO.

A comparison between the discrete and continuous time approaches reveals that these two approaches may eventually generate similarly good results for investment purposes. Figure 1 shows a simple example, in which two projects are considered. A total number of three alternatives and corresponding cost functions are identified in the figure. The optimal continuous time decision will start Project 1 at the beginning, switch to 1 + 2 at Year 2.3, and keep on 1 + 2 until the end with a total of 73.48 units. The optimal discrete time decision is to implement Project 1 for the first year and add Project 2 to the system at Year 2 with a total cost of 74.3 units. The expansion paths are highlighted in Figure 1 for the two different approaches. This example indicates that although it might not yield the optimal result, the discrete time decision approach can provide a total cost that is very close to the optimum and good enough for practical applications.

Another property of the discrete time approach is that the selection and sequencing result will be the same as that obtained in the continuous time approach as long as each discrete period is not too long, for example, 1 year. As shown in the following sections, a network solution procedure can

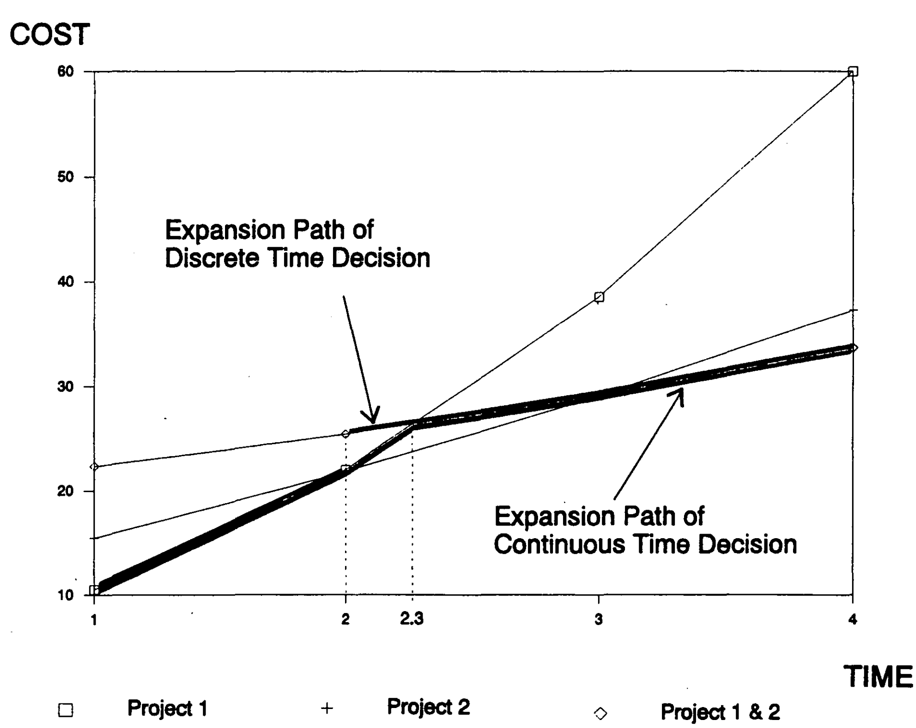


FIGURE 1 Motivating example: comparison of continuous and discrete time project selections.

be applied to the discrete time approach to generate exact solutions.

Because assessing the exact interdependence terms has not been satisfactorily reported in the literature, this paper considers the aggregate effects of interdependent project selection. Therefore, identifying and evaluating interrelations among projects is exogenous to this study, as mentioned earlier. The facility economic service lives are assumed longer than the time horizon of interest. The total discounted costs associated with all combinations of projects are given explicitly as functions of time or demand. These costs include user costs, capital costs, and maintenance costs of projects. The cost functions are usually nonlinear. However, no assumptions are made regarding the functional forms of these costs. It is only assumed that the cost functions are continuous and integrable over the entire planning horizon. Budget constraints are temporarily disregarded. However, they can be incorporated in the model with minor modifications. In fact, considering budget constraints would make the proposed solution method more advantageous, which will be addressed later.

PROBLEM FORMULATION

The problem of choosing projects among candidates for a limited number of periods readily reveals the nature of integer programming. The objective is to minimize total costs while satisfying a certain level of demand. In fact, the example in Figure 1 clearly possesses such a characteristic. For each individual project or combination of projects, it is assumed that implementation may be made either at the beginning of the planning horizon or at the beginning of a later period, depending on the resulting costs. Before formally presenting the formulation, several terms need to be defined. A project combination is referred to as an "alternative." Alternative *j* is an "increment" of alternative *i* if every project in alternative *i* is also in alternative *j*. Alternatives are mutually exclusive if incremental relationships do not hold. For instance, if three projects are considered, alternative 1 + 2 + 3 is an increment of alternatives 1 + 2, 1 + 3, 2 + 3, 1, 2, and 3, and alternatives 1 + 2 and 2 + 3 are mutually exclusive.

To consider full interdependence among projects, pairwise interactions are assumed among all individual projects. Consequently, a small number of projects will reflect a relatively large set of alternatives; for example, five projects represent the consideration of 31 alternatives. This is the most general case possible. However, in reality the pairwise interrelation usually does not exist between every pair of projects; therefore, the number of alternatives would be much fewer.

The primary constraint considered in this paper is the continuity of projects. For research and development industries, projects may be terminated and entirely removed when the outcome is unsatisfactory [Shafer and Mantel (*13*) or Bard et al. (*14*)]. However, in many circumstances no project can be removed once it is implemented or if the cost associated with termination is extremely high. Specifically, decisions at any time should not cause the abandonment of projects that have been implemented in earlier periods through selection of other alternatives.

Because of the complexity of identifying projects and alternatives, the proposed formulation is entirely alternative based. That is, the pairwise interactions among projects are specified explicitly and are not included in the integer program. Consequently, the model presented below has a very neat form and, as shown in the next section, leads to the efficiency of the exact solution procedure.

Assuming that all projects have positive effects on the system under consideration, the underlying idea of the proposed integer programming is to decide which alternative to implement at each period subject to relevant constraints. This means that for the planning horizon only one alternative is selected in each period. As mentioned earlier, interdependencies among projects and corresponding cost functions are specified exogenously. The alternatives may be arranged, for calculation convenience, by the costs at base time such that the lower-cost alternatives will be assigned smaller indexes. The following definitions are used:

I = set of all alternatives;
H = set of periods in the planning horizon;
W_{it} = 1 if alternative i is implemented in period t, 0 otherwise; and
$f_i(t)$ = cost of alternative i as a function of time.

To minimize the total cost associated with all possible alternatives for the entire horizon, the corresponding values of costs for each alternative and time period need to be computed. These values are equivalent to the shaded area under each curve segment shown in Figure 2. Because the cost functions are usually nonlinear, simple algebra is not applicable. Rather, integrating the cost functions for each period is desired. The binary decision variable W_{it} is required to ensure the best choice among alternatives—one that minimizes the associated costs and fulfills relevant restrictions. Using the notations defined above, the objective function is

$$\text{Minimize} \sum_{i \in I} \sum_{t \in H} W_{it} \int_t^{t+1} f_i(u)du \tag{1}$$

Here the flexibility of various types of cost functions with respect to time or demand level is allowed.

Because projects always generate benefits to the system of concern, it is needed to ensure one alternative selected for each period. That is, at least one project should be in service at any time. We then have the following constraint:

$$\sum_{i \in I} W_{it} = 1 \qquad \forall\, t \in H \tag{2}$$

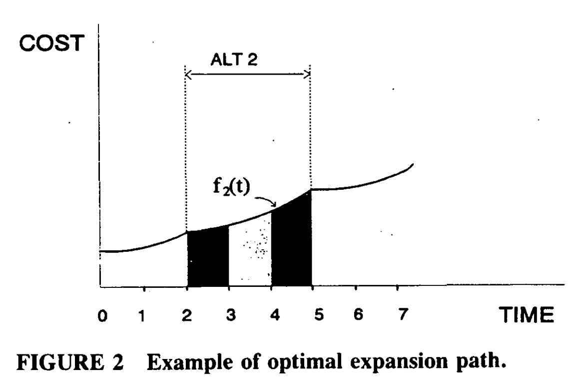


FIGURE 2 Example of optimal expansion path.

Note that Equation 2 also implicitly prevents the conflict of alternatives because one and only one alternative is allowed for each period.

Ensuring the continuity of projects is very important, especially when system capacities are expanded. This condition should hold throughout the entire horizon such that, if alternative i is implemented in period t_0, alternative j must be an increment of alternative i to be implemented in period $t_1 > t_0$. The incremental relationship is easily specified before the formulation. Let J_i be the set of increment alternatives of alternative i. The following constraint satisfies this requirement:

$$W_{it} \leq \sum_{j \in Ji} W_{j,t+1} \qquad \forall\, i \in I,\, t \in H \tag{3}$$

Constraint 3 states that if a project is implemented in a certain period, it should be included in the alternatives chosen in later periods. This ensures the continuity of all projects in any period and is actually a very large set of inequalities.

The alternative-based integer programming for project scheduling is summarized below:

$$\text{Minimize} \sum_{i \in I} \sum_{t \in H} W_{it} \int_t^{t+1} f_i(u)du$$

Subject to

$$\sum_{i \in I} W_{it} = 1 \qquad \forall\, t \in H$$

$$W_{it} \leq \sum_{j \in Ji} W_{j,t+1} \qquad \forall\, i \in I,\, t \in H$$

$$W_{it} = 0 \text{ or } 1 \tag{4}$$

The above formulation is a 0-1 integer programming problem with a nonlinear objective function and linear constraints. Note that no specific assumption is made regarding the functional forms of the costs [i.e., $f_i(u)$]. In fact, as one will see shortly, if these functions are continuous and Rieman integrable, no further assumption is necessary.

As stated before, in previous work the relationship between projects and alternatives was incorporated and resulted in a complicated linear formulation requiring much computation time. Consequently, heuristic and approximation methods were employed to save computational effort. In contrast, the above formulation can be modified into a linear program with a network structure that can be solved exactly by several well-known procedures. This advantage is discussed below.

SOLUTION PROCEDURES

In this section, a procedure is outlined for converting the nonlinear program into a linear program. Then it is shown how the linear program can be reformulated as an out-of-kilter network flow problem and the characteristics of the out-of-kilter algorithm (OKA) are briefly described. Finally some moderate-size numerical examples are presented to test the computational efficiency. The LINDO program is also used to solve these examples.

Linear Programming

Instead of solving the nonlinear program (*4*) directly, a much more efficient solution procedure is achievable through minor transformation of the objective function. This step is desirable to take advantage of the inherent network structure.

Since the known cost functions are continuous and integrable, one could compute the integration portion of the objective function before any other manipulations. Let C_{it} be the cost associated with the decision variable W_{it}. Then the cost of implementing alternative i in period t is

$$C_{it} = \int_t^{t+1} f_i(u)du \tag{5}$$

Note that Equation 5 is applicable to any type of cost function. The resulting values of C_{it} may be treated as scalar coefficients associated with W_{it}. Therefore, the objective function is now transformed into a linear form:

$$\text{Minimize} \sum_{i \in I} \sum_{t \in H} C_{it} W_{it} \tag{6}$$

Given that the magnitudes of C_{it} could always be calculated outside the program, the linear program considered here is

$$\text{Minimize} \sum_{i \in I} \sum_{t \in H} C_{it} W_{it}$$

Subject to

$$\sum_{i \in I} W_{it} = 1 \qquad \forall\, t \in H$$

$$W_{it} \leq \sum_{j \in Ji} W_{j,t+1} \qquad \forall\, i \in I,\, t \in H$$

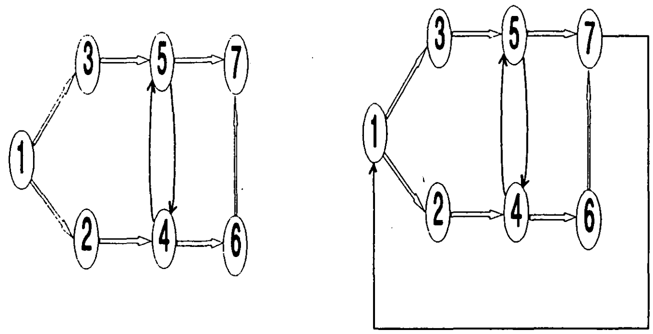
$$W_{it} = 0 \text{ or } 1 \tag{7}$$

Program 7 is found to possess a special structure that could be solved more efficiently by network-flow techniques than the conventional linear programming simplex method. The well-known OKA is demonstrated for this application.

Out-of-Kilter Algorithm

The OKA is developed using the concepts of linear programming duality theory and complementary slackness conditions. The algorithm is especially designed to deal with capacitated network-flow problems. Hence, it is more suitable than the simplex method for linear program problems with network structure.

To apply OKA, a closed network representation is desired that exhibits flow circulation. A circulation is an assignment of flow to arcs such that flow is conserved at each node. The OKA deals with circulations; thus it is often necessary to modify the original networks. A regular network and the corresponding closed network are shown in Figure 3. A return arc is needed from Node 7 to Node 1, as shown in Figure 3*b*. The details of the return arc depend on the problem described by the network.



(a) Original Network (b) Closed Network

FIGURE 3 Network representation.

Associated with each arc in a capacitated network are lower and upper bounds and costs of flow. These may, in fact, be 0 or infinity, as long as constraints are fulfilled. The following notation is defined for OKA:

S = set of arcs,
N = set of nodes,
f_{ij} = flow-through arc (i, j),
L_{ij} = lower bound of flow on arc (i, j),
U_{ij} = upper bound of flow on arc (i, j), and
c_{ij} = cost associated with shipping one unit flow on arc (i, j).

The network-flow problem (or minimum cost circulation problem) is a special linear programming problem that minimizes the total cost subject to four sets of constraints. The general model is

$$\text{Minimize} \sum_{(i,j)\in S} c_{ij} f_{ij}$$

subject to

$$\sum_{j\in N} f_{ji} - \sum_{j\in N} f_{ij} = 0 \qquad \forall\, i, j \in N, i \neq j$$

$$f_{ij} \leq U_{ij} \qquad \forall\, (i, j) \in S$$

$$f_{ij} \geq L_{ij} \qquad \forall\, (i, j) \in S$$

$$f_{ij} \geq 0 \qquad \forall\, (i, j) \in S \tag{8}$$

These constraints represent the requirements on flow conservation, upper bound, lower bound, and nonnegativity, respectively.

The OKA is an iterative procedure to find the optimal circulation in a capacitated network characterized by Program 8. The detailed steps have been described by Phillips and Garcia-Diaz (*15*). Although the OKA procedure seems tedious, it is well defined and can be easily computerized. In addition, because the OKA has very wide application, the procedure and the criterion for optimality will not be altered for various problems. The only changes necessary are the associated network configurations.

A residual benefit to the OKA is that the problem can be easily visualized, a property not present in linear programming formulations in more than two dimensions. Hence, properly presenting the problem as a closed-loop capacitated network-flow problem is essentially the key step. To efficiently solve the discrete time expansion problem, Program 7 may be translated into some equivalent problem that certainly could be solved by the OKA. The typical shortest-path problem is suitable for this purpose.

Each node may be treated as a decision variable (i.e., W_{it}) and each arc as a transition from the current decision variable to the next. In the network, the arc costs correspond to implementing alternatives in a given period (i.e., C_{it}). Because the continuity of projects must hold, nodes may be connected with appropriately selected arcs that satisfy this concern. The resulting network is directed because of the incremental relations between alternatives. The restrictions of implementing only one alternative for each period and nonnegative decision variables imply that flow assigned to each arc will be either unity or 0. In other words, the lower bound of flow is 0 and the upper bound of flow is 1 for arcs connecting with decision variables. To accomplish a closed network, a supersource node and a supersink node are desired to represent the beginning and the end of the time horizon. The supersource and supersink nodes are connected to the first and the last period, respectively, and the return arc from supersink to supersource is created accordingly. The return arc has lower and upper bounds of flow both equal to 1, and the cost is 0 to ensure the flow circulation.

The closed-loop network for Program 7 is shown in Figure 4 in which the triplet on each arc is represented by (U_{ij}, L_{ij}, c_{ij}) for convenience. The visibility property of the network representation is clearly reflected in this diagram. At the termination of the OKA, the shortest path is found by tracing from supersource to supersink nodes over all arcs whose flow is equal to 1. Obviously, the decision variables on such a path are the optimal solution to the capacity expansion problem.

Numerical Examples

To demonstrate various solution procedures for the discrete time formulation, a small, yet representative, numerical ex-

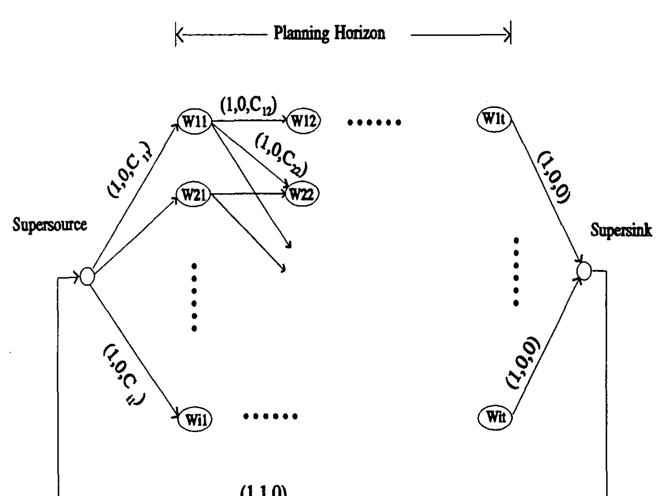


FIGURE 4 Out-of-kilter diagram for discrete time expansion problem.

ample is used. A system with three projects and five periods is considered. There are seven possible combinations of projects (i.e., seven alternatives) under the pairwise interactions assumption, and the increment set is identified in Table 1 for each alternative. It is assumed that the associated cost functions are available and monotonically increasing with respect to time. Quadratic polynomial functions seem appropriate for illustration. For computational convenience, the cost functions are sorted in ascending order of the constant terms and an index from 1 to 7 is assigned to each of them as given in Table 1. These cost functions represent some realistic considerations; for example, the costs of implementing several projects simultaneously are usually lower than implementing them individually, and single projects may be more costly than combinations. These cost functions are plotted in Figure 5.

According to Program 7 the costs of each alternative need to be calculated as the coefficients in the objective function. These values are computed from the area under each curve segment of the functions in Figure 5 and are listed in Table 1.

The OKA can now be applied to this illustrative case. According to the aforementioned procedures, an out-of-kilter

TABLE 1 Cost Functions for the Three-Project, Five-Period Example

Alt i	Project to be implemented	Increment Alternatives	Parameters* a	b	c
1	A only	1,3,5,7	2.5	4	4
2	B only	2,3,6,7	2.0	1	8
3	A & B only	3,7	0.45	5	10
4	C only	4,5,6,7	0.7	5	16
5	A & C only	5,7	1.0	0	18
6	B & C only	6,7	0.35	2	20
7	A & B & C	7	0.2	1.5	25

Alt i	Cost for Alt i in period t (C_{it}) 1	2	3	4	5	Total
1	6.83	15.8	29.8	48.8	72.8	174.03
2	9.17	14.2	23.2	36.2	53.2	135.97
3	12.7	18.6	25.3	33.1	41.7	131.4
4	18.7	25.1	32.9	42.1	52.7	171.5
5	18.3	20.3	24.3	30.3	38.3	131.5
6	21.1	23.8	27.2	31.3	36.1	139.5
7	25.8	27.7	30.0	32.7	35.8	152.0

*The cost function is assumed to be $f_i(t) = at^2+bt+c$

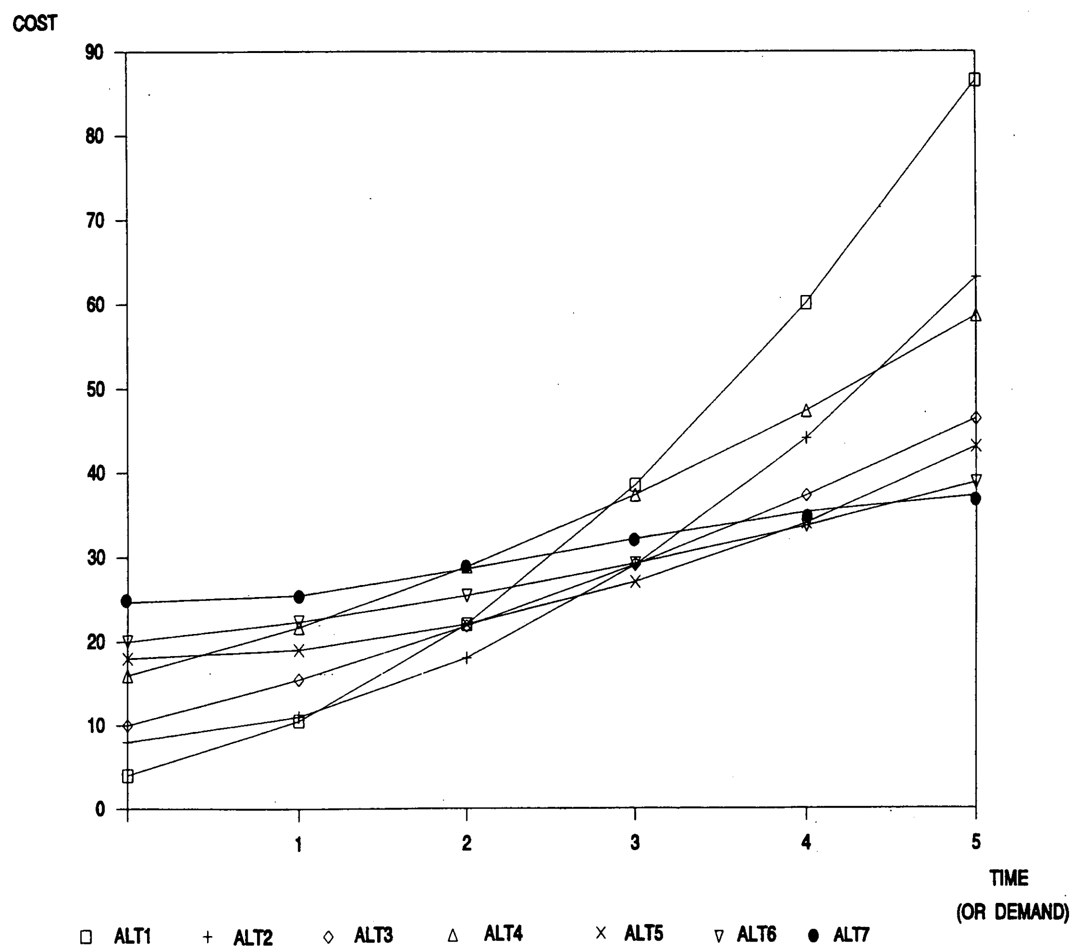


FIGURE 5 Cost functions for three-project, five-period illustrative case.

diagram is drawn in Figure 6. Table 1 provides information enough for this task, that is, nodes and arcs in the network and appropriate connections. The minimum cost path is needed from Node S to Node T in the out-of-kilter diagram, which is equivalent to directly solving Program 7 optimally. Four types of arcs are included in Figure 6, each associated with a vector representing the underlying integer program. The vectors for each arc indicate the allowable upper and lower bounds of flow and corresponding costs for every unit flow. The upper bound of flow is unity for all arcs, and the lower bound is 0 everywhere except for the arc between T and S to induce the flow through the network. Costs of flow on each arc depend on the origin and destination nodes, which correspond to the cost values in Table 1. The four types of arcs and associated vectors are listed in Table 2.

For an intermediate period t, arcs coming from alternative i (i.e., W_{it}) may go into alternative j for the next period (i.e., $W_{j,t+1}$) as long as alternative j is an element of increment set J_i. Because there should be one alternative for the first and last periods, Node S is linked to all variables for the first period and Node T is connected with all last-period variables. As a result, all variables in this diagram are directed to the next feasible decisions throughout the entire horizon. For instance, because $J_2 = \{2, 3, 6, 7\}$, W_{21} can be linked only with W_{22}, W_{32}, W_{62}, and W_{72} in the second period. Note that the structures between columns of W_{it}'s are identical, which is indeed one advantage of such representation, namely, the connections between W_{i2} and W_{i3} are the same as those between W_{i1} and W_{i2}, and so on. This particular structure ensures the project continuity constraint at any period and implicitly incorporates all feasible solutions and corresponding costs. Because of its simplicity, this diagram and associated information can be easily translated into a computer program and then the OKA can be used.

When budget constraints are included, a number of links and nodes in the diagram may be eliminated, most likely the

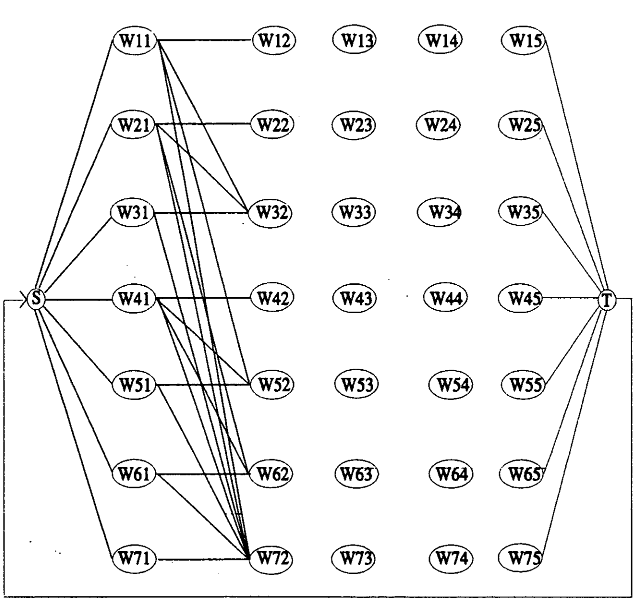


FIGURE 6 Out-of-kilter diagram for the three-project, five-period case.

TABLE 2 Arc Characteristics in Out-of-Kilter Diagram

Arc type	Vector (U, L, c)*
S --> W_{i1}	(1, 0, C_{i1})
W_{i5} --> T	(1, 0, 0)
T --> S	(1, 1, 0)
$W_{i,t}$ --> $W_{j,t+1}$	(1, 0, $C_{j,t+1}$)

*U, L, and c are upper and lower bounds of flow, and cost of unit flow

multiproject alternatives that require higher costs. The resulting diagram could be reduced, thus increasing the efficiency of the OKA.

The optimal solution is $W_{11} = W_{12} = W_{53} = W_{54} = W_{75} = 1$, other W_{it}'s equal 0, and a total cost of 113.03 units. According to Table 1, the optimal investment program is to start Project A immediately, add Project C at the beginning of the third period, and finally add Project B for the last period. The solution for project selection, sequencing, and scheduling may be represented simply by the following expression:

$$A \rightarrow A \rightarrow A + C \rightarrow A + C \rightarrow A + B + C$$

To demonstrate the relative advantage of combining the integer program with the OKA for the project scheduling problem, two much larger examples are generated arbitrarily. The information on these examples is summarized in Table 3, and some representative cost functions are plotted in Figure 7. The curves in Figure 7 represent various subsets of alternatives, each with a different number of projects to be implemented simultaneously. It is clear that these two examples are quite practical. Besides, although the costs all increase over time, the functions in Figure 7*a* have increasing first derivatives, whereas those in Figure 7*b* yield decreasing first derivatives. This may reflect the flexibility of the proposed approach.

The LINDO program is also used to solve the above cases. For the three-project, five-period case, only eight iterations are required to reach the optimal solution. The computational efficiency has been greatly improved, compared with 3,632 iterations for the previous work (*12*). For the two larger examples, the computation times were found to be comparable with those using the OKA. Although such a situation implies that LINDO performs as well as the OKA, it also confirms the effectiveness of the alternative-based formulation. One should note, however, that LINDO is a commercial software and is possibly an order of magnitude more efficient than the OKA code. Therefore, although LINDO can readily be used to solve the resulting linear programs from converting the original nonlinear programs, it may still run into long computation time when problems become larger. On the other hand, an efficient code for the OKA seems especially suitable for the discrete expansion problem and is conceivably more efficient than LINDO for relatively large problems.

CONCLUSIONS

The capital budgeting problem for interrelated capacity expansion projects is discussed in this paper. An integer program

TABLE 3 Information on Two Larger Problems

Example	# Projects	# Alts	# Periods	# Decision Variables	Cost Function	CPU* (seconds)
1	4	15	12	180	$at^2 + c$	29
2	5	31	12	372	$at^{1/3} + c$	172

*Data obtained in IBM PS/2 Model 70 with 20 MHz speed

is proposed and two distinct procedures are used to solve the problem optimally. The interactions among projects are specified before programming to enhance the model efficiency. The alternative-based approach treats alternatives as mutually exclusive decision variables. The project continuity constraint is ensured by defining the incremental relationships among alternatives, which is found to be an underlying advantage of the proposed model.

A network representation procedure is the primary solution method presented. The model is illustrated to be easily translated into a directed network with nice properties. The out-of-kilter algorithm is applied to this network problem, and the results of several examples reveal the computational efficiency of such an approach. Although LINDO yields similar performance for these illustrative cases, relatively large problems could be formulated and solved more efficiently with this network optimization method. Besides, the proposed procedure generates exactly optimal solutions instead of heuristic solutions.

The proposed discrete time alternative-based formulation is likely to result in large integer programming problems as the number of projects increases. However, because the proposed solution procedure is very efficient, it is capable of handling problems with thousands of decision variables. Furthermore, because in the real world it is likely that there exists a limited number of distinct projects with pairwise interactions, the number of alternatives would be manageable. Nevertheless, decomposing the system of interest by any reasonable criteria should be considered whenever possible to reduce the complexity and computational efforts. With small modifications, such as given benefit rather than cost functions, the proposed model could be used when total benefit is the primary concern. Further work may be done that incorporates more precise project interactions with the corresponding cost/benefit functions, and other solution procedures.

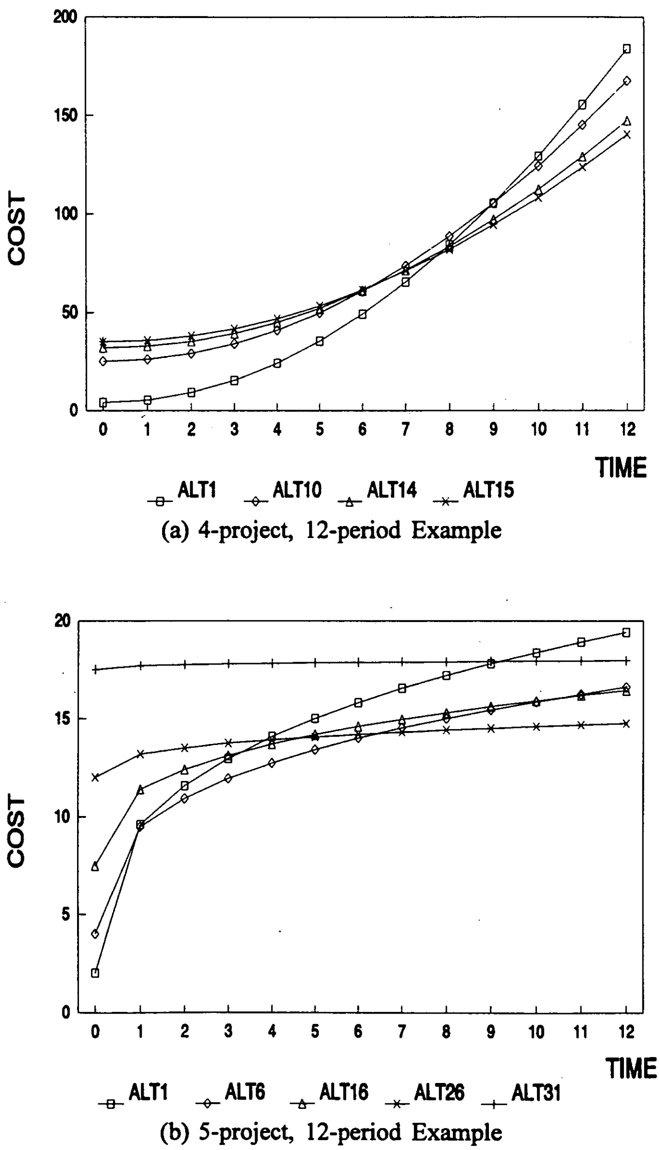


FIGURE 7 Representative cost functions for larger problems.

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Working with New Partners: Transportation Decisions with the Public

JANET HATHAWAY AND LISA WORMSER

Public participation is essential to ensuring that transportation systems serve community goals. Innovative use of a broad array of public relations and communications strategies can help to build public understanding and support for projects and techniques that improve transportation efficiency. Polls, opinion surveys, focus groups, alternative dispute resolution, and media campaigns may helpfully supplement more traditional public hearings, workshops, advisory committees, and task forces.

The new federal surface transportation law directs federal and state departments of transportation and metropolitan planning organizations (MPOs) to "provide citizens, affected public agencies, representatives of transportation agency employees, private providers of transportation, and other interested parties with a reasonable opportunity to comment" on transportation plans and programs. Federal law, through both the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act amendments of 1990, imposes a responsibility to make transportation planning more democratic. The law also provides an opportunity to increase the congruence between transportation investments and community travel needs.

ISTEA requires MPOs to involve the public before approval of their 20-year long-range plans (LRPs) and during the development and approval of their 3-year transportation improvement programs (TIPs). States must create LRPs in cooperation with the MPOs and must give citizens "a reasonable opportunity to comment" in developing the state LRP. In addition, governors are directed to ensure that citizens are involved in developing the state TIP. At both state and metropolitan levels, transportation planning must be coordinated with the plans providing for attainment of national air quality standards.

Some states and MPOs have been creatively involved in expansive contact and communication with community groups. But others may find new and vaguely ominous the notion of soliciting views from the public on plans and process. The purpose of this paper is to review existing public participation tactics and to highlight some innovative approaches to better integrate public participation into agency decision making.

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WHY DO SOMETHING NEW?

Public participation requirements have long been established in laws such as the Administrative Procedures Act and the National Environmental Policy Act, as well as in regulations and guidance issued by federal and state transportation agencies. However, the minimum standards set in such laws do not necessarily result in productive collaboration or partnership.

The phrase "public participation" may conjure up memories of numbing meetings during which dozens of people line up before microphones to complain to officials about projects, plans, or programs. But this is not the best or the only possibility. Neither transportation officials nor the citizens are pleased when public participation is reduced to a procession of gripes and pleas falling on deaf ears. The main value of public hearings is as a safety valve at the end of a long and complex process, which should include many other chances for two-way communication. Public hearings are almost always insufficient to cull good ideas, answer questions, sift through possible alternatives, and explain the reasoning behind projects, plans, or programs. Public hearings are not the grim gatherings that may come to mind. Working with new partners is something entirely different.

PARTNERSHIP WITH THE PUBLIC

What is the significance of the title, "Working with New Partners"? Whereas hearings are one-time events, working implies an ongoing, interactive, iterative connection. Partners are participants with comparable status, with equal legitimacy. The old paradigm was that transportation engineers and officials invite "outsiders," the public, to hear about decisions made by the "experts." The new paradigm establishes transportation decisions as the product of partners' collaborative work. It is the result of debate and choices made jointly by a variety of governmental and nongovernmental parties.

People distrust closed, arcane, or technical processes. This is particularly so when such inaccessible processes result in decisions that directly affect the excluded individuals. Transportation is basic to people. If people cannot travel, their lives are impoverished. People need access and mobility to work, learn, socialize, relax, and challenge themselves. Transportation is so basic that average people, "nonexperts," have very strong views on their travel needs and how well they are being met. A huge amount of the hostility seen at public meetings regarding transportation proposals results from the frustration that people feel when their travel choices are made or constrained by people unknown for reasons unexpressed. Because transportation choices greatly shape people's lives, any process that excludes affected people, limits their input, or fails to provide the necessary information in readily understandable terms will not be effective, no matter how skillfully engineered or technically defensible.

NEW CONCERNS NEED NEW RESPONSES

The broad scope of fundamental issues to be resolved under ISTEA and the Clean Air Act amendments makes it unlikely that any generic approach to public participation will be successful. However, it is possible to identify the key characteristics of successful participation: inclusiveness, early involvement, and clear, accurate information.

Inclusiveness

One measure of the appropriateness of public participation is the inclusiveness of the process: whether it involves the range of people whose interests are affected.

Who are the public? First there are the usual suspects: state transportation officials, MPOs, local elected officials, and public and private transportation providers. Also affected by transportation decisions are environmental groups, developers, business leaders (especially major employers), transportation users (including the disabled, aged, or young), design professionals, and community organizations. No abstract definition will do to identify everyone who uses or may use a transportation system or be affected by it.

The involvement of the public does not mean decision making in a stadium with thousands of people simultaneously expressing views. People have different interests, skills, values, and degrees of commitment to a process resulting in transportation decisions. These differences must be identified and respected for the process to be a civil and productive one. The goal is to build on the strengths of all possible participants. Some people have no background in engineering or design but instead they know of some community needs that may otherwise be overlooked by planners or transportation professionals. Some may have innovative suggestions for investments that could serve multiple goals (such as daycare centers at transit nodes), but they may benefit from the advice and experience of others to refine and implement the ideas. The more participation in the process is limited, the more impoverished proposals will be and the less solid will be the popular support for the goals.

Early Involvement

When should partnerships be formed? The answer is "yesterday." Inclusion of a variety of interests should never be delayed because partnerships take time. The earlier there is concerted outreach, the greater are the prospects for successful outreach.

By requiring that citizens and others with an interest in transportation be involved in developing transportation plans and programs, ISTEA sets the stage for early participation. In this context, a "reasonable opportunity to comment" must be defined in terms of the public's ability to help shape the earliest drafts of the LRP and the TIP, where specific projects are selected. This change in the law marks a departure from the old practice of soliciting public comment before approval of a drafted plan or assembled slate of projects.

Attempts at public participation that occur late in the game often generate hostility and may result in stalled projects. FHWA 1976 guidance on participation in transportation planning remains apt today:

> If too much time elapses between the beginning of the [planning] process and the beginning of public involvement, several problems may develop: it may be difficult to still be flexible, rumors may have spread misinformation, local leaders may feel ignored and become distrusting. Early involvement saves times and agony for the planner. (*1*)

One model for inclusive, early involvement is the "visioning" process, which has been carried out in cities such as Roanoke, Virginia, and Chatham County, Georgia. In Roanoke, an outdated comprehensive plan was the issue; in Chatham County, eight municipalities, including Savannah, shared air and transportation problems but no regional strategy for solving them. Planners brought residents and business and property owners into the planning process through the wise use of public relations and state-of-the-art technology, including electronic town meetings and supplements to local newspapers. Both processes included citizens as facilitators: maitre-d's, schoolteachers, and business people were given training and asked to interview their fellow citizens at the town meetings and throughout the process. Follow through was important to sustaining involvement: planners established benchmarks of progress and made sure citizens knew when their questions would be answered. Early preparation expedited the approval process.

Accessible Information

To accomplish the goal of inclusiveness, information is vital. Many citizens are discouraged by the lack of basic information about how and why transportation decisions are made in their communities. Citizens whose participation has been ignored have grown wary of further involvement. Agency professionals are equally wary that the public will impede their efforts to solve growing transportation problems. Wide availability of clear, accurate, and complete information on transportation procedures can help put both parties on a more equal and cooperative footing.

Effective information should be more than the traditional graphs and charts that accompany studies. Citizens should be helped to visualize the impacts of plans and proposals on neighborhoods, businesses, and the natural environment through the use of maps, models, slides, photographs, computer graphics, and other techniques to visually render the potential effects of transportation decisions.

In Manheim Township, Pennsylvania, located in Amish country in Lancaster County, the land use pattern had become a patchwork in which farms, scenic parklands, and historic resources competed with strip developments and malls at major traffic interchanges. A visual preference survey was undertaken in which citizens were asked to rate photographs of scenes typical to the area: barns and farmhouses, scenic roads, old and new houses, shops, traffic signs and signals, parking lots, and public spaces, including parks and commons. Once citizens determined which sights and patterns they wished to protect and encourage and which they wished to discourage, they were shown how those values translated into design and zoning codes. Using maps and models, citizens were asked to redesign their township with their new preferences and goals in mind. The results were better-informed, more helpful citizen involvement and an accessible plan that reflects the values of the community.

The public needs access to proposals, statistics, and studies with enough time to allow careful review of the material and for the reactions to be incorporated into the process. The last step is crucial. No one wants to waste time thoroughly reviewing and addressing a complex issue only to find that the work will have no influence on the decisions. If there are delays in the production of useful background information, other deadlines must be relaxed to grant the public the time it needs to study and respond to the issue. If people are given less than a month to respond to complex and technical issues, it should not come as a surprise if they are angry and intransigent. People are not at their best and most productive when they are forced to react in a panic.

Finally, it is important not to hide the social and political context that transportation officials assume when developing transportation plans. Many community values and goals may be controversial, but they must be expressed. Many people care about regional development patterns, transportation options, and the consequences these have for employment, economic growth, air quality, livable communities, social justice, and other values.

Almost certainly people will disagree about which goals should be dominant, and they will dispute the means that will best serve the ends. That is to be expected. What everyone will distrust is any pretense that transportation investments are value neutral and somehow promote everyone's interests equally. Honest dialogue and disagreement are more constructive than efforts to avoid the underlying tensions about how jobs, urban design, environment, and transportation are related.

To review, a working partnership means a continuing, respectful collaboration. The new partners are potentially anyone who is affected by these decisions. Outreach and inclusion should begin right away. There is one more crucial element to bring everyone together: information—timely, clear, and accurate information, and above all, accessible information.

THE MOST PROMISING TECHNIQUES

What works? There is no cookbook. Community involvement must be tailored to the community and the issues. The greater the diversity of the interested participants and the greater the controversy, the more necessary is a range of approaches. Following are some of the ingredients, if not the recipe, for success. A variety of these approaches is almost sure to be more helpful than reliance solely on one of these measures. Each technique has both benefits and limitations.

Task Forces

Task forces, reflecting the diversity of a community, can be convened to address transportation planning issues.

The MPOs of the Twin Cities (St. Paul–Minneapolis) and the San Francisco Bay Area have used task forces extensively to increase community involvement. These and other cities have an impressive array of task forces, some of which have regularly met for years, and all of which strive to include members from diverse organizations and perspectives. Task forces seem to work best when their scope is relatively narrow and well defined.

Two successful task forces were convened by the Metropolitan Transportation Commission in the San Francisco region: one was assigned to evaluate transportation control measures and another was created to address the transportation needs of communities with diverse ethnic backgrounds. Many participants found the experience of serving on a task force a positive one, from which there was genuine education as well as communication. However, it was unclear to one participant whether the enhanced understanding shared by task force participants was relayed to other decision makers, particularly those with the greatest authority. Another potential problem was excessive compartmentalization; interaction between task forces was often limited or nonexistent. For example, people with different ethnic backgrounds probably have useful and unique insights into designing and evaluating TCMs, and some TCMs may have greater impacts on minority communities than on the public as a whole. But opportunity for interactive learning may be lost if task forces operate in isolation from one another.

Committees

A common tool for public involvement is the establishment of committees. Citizens' Advisory Committees (CACs) and Technical Advisory Committees (TACs) are two basic types. Although dividing groups according to expertise or technical skills may initially ease communication, it may result in reduced innovation and education. Therefore, some transportation committees mix citizens, business representatives, planners, transportation professionals, and advocates for particular transportation modes (bicycles, rail, transit, trucks). The challenge is to braid the skills and experiences of the various participants in ways that engender creative solutions.

Many communities have used committees to increase public involvement in transportation decisions. Local professional and citizen observers suggest that such efforts result in greater respect for the process and more cohesive support for the ultimate decisions. Even when the final outcome is controversial, broad participation helps prevent the high level of dissatisfaction that may lead to legal challenge and stalemate.

In 1972, for example, the residents of several neighborhoods in Boston united to protest the construction of the Southwest Freeway, an Interstate segment for which the land was already purchased. Through the efforts of city and state representatives, the governor of Massachusetts commissioned a multidisciplinary team to examine alternatives to the highway. The team recommended a new subway line running along the same route as the existing Amtrak and commuter rail lines and uniting three adjacent inner-city neighborhoods via a greenway of parks, sidewalks, and bikeways that follow the subway route. The process was determined and overseen by a citizen's advisory group of residents, business owners, transit officials, and representatives of the city of Boston.

Public Meetings and Forums

A public meeting or forum may be a good way to solicit ideas and discuss transportation alternatives and goals when plans are at an early stage of development. Open forums may include presentations from officials and citizen groups, while inviting response and limited discussion. Portland, Maine, and the San Francisco Bay Area have found such town meetings a useful first step, particularly when focused on the transportation needs of a designated, limited area or corridor.

One of the major difficulties for those who use such meetings is to encourage the going attendance of diverse individuals and groups. The determination and ability to create successful meetings are skills that are relatively rare and often unrewarded. It is essential but insufficient to find a good meeting room in a convenient location, provide broad and timely notice of the meeting, and encourage attendance of interested and affected people. In addition, conveners of public meetings need to be sensitive to the fact that public meetings often are intimidating to both the public and transportation officials. Officials may fear being the targets of blame or vituperative remarks. Citizens may worry that their remarks will be ridiculed or that they will be unable to penetrate the jargon of the experts. Officials will need to be ready to hear criticism but to establish a positive, constructive tone. Civility should be expected of all participants but agreement should not.

Fortunately, respectful treatment of people usually generates polite and respectful responses. Successful meetings depend on airing concerns as well as providing solutions. Public officials should try to avoid promoting a particular outcome, which should be easier if meetings are held early in the process of framing alternatives. Officials should try to avoid defensive reactions to criticisms. Citizens may find that their views are given more respect when they directly note their concerns but refrain from casting doubt on the motives behind proposals. The judicious use of humor is a precious commodity in such settings and can go a long way toward bridging fears and misunderstandings.

Sometimes training seminars in negotiation or alternative dispute resolution are useful for both officials and interested public participants before they embark on an ambitious or controversial series of public meetings. Both transportation officials and the public will benefit from an atmosphere in which people are candid and open to new ideas.

It is also important to encourage that wide-ranging discussion from meetings or forums be folded back into the more traditional planning process. If ideas and suggestions generated are lost or forgotten once the meeting is adjourned, there is a distinct likelihood that the public will perceive such meetings as a sham and a waste of time. Follow-up is essential.

Panel Presentations, Symposia, and Interactive Workshops

Public participation in transportation decisions can be increased by public workshops, presentations, and debates. These can cover a wide range of topics, but they are most useful if tied to issues that have special, explicit relevance to the city or region. Such gatherings can be highly technical. They are obviously more useful to a broad range of the public if panelists avoid or translate acronyms and technical jargon. Topics that may merit such treatment may include how transportation can reduce air emissions, how transportation investments can induce or reduce travel, and the factors that make public transit safer, more attractive, more reliable, and therefore more usable.

Another model for public inclusion is a team effort called a "charette." The term is derived from an intensive, collaborative exercise of architects, operating under deadline pressure, to design a project. A charette was formed for the Puget Sound region in Washington to allow diverse interests to debate and cooperatively discuss development patterns and transportation alternatives. Although it requires a substantial commitment of resources from participants, such an approach fosters consultation and trust while eliciting innovative and collaborative solutions.

Facilitators, Mediators, and Alternative Dispute Resolution Techniques

Particularly when a region is embroiled in controversy over transportation, facilitation and other alternative dispute resolution techniques may help create a positive atmosphere for cooperation and problem solving. Experienced, neutral facilitators and mediators often can establish basic ground rules and reduce the tendency of participants to interrupt, pontificate, ridicule, or intimidate other participants. Such "neutral" experts can often elicit information that might be difficult to obtain during heated exchanges. For example, facilitators may request further information or encourage people to explain confusing or seemingly inconsistent statements without appearing to challenge or disagree with the assertions. As neutral parties, they may be able to guide discussions to include a greater variety of views and help to enable all parties to feel that their insights are being heard. Facilitated meetings can often take less time to result in more productive decisions than meetings that are less structured.

Formal dispute resolution techniques, including regulatory negotiations (or "regnegs"), have been used at the federal and state levels to distill complex legal and political issues into alternatives that more fully integrate the concerns of the affected parties. After a very divisive political campaign, Maine voters passed an initiative that stopped a turnpike widening proposal and required examination of transportation alternatives. A regulatory negotiation was successfully used to develop unanimously supported regulations to implement the new law. Included in the regneg were environmentalists, developers, transportation officials, and community organizations—many of whom had been previously active in the polarized debate concerning the initiative.

Agency-Initiated Outreach

MPOs and state transportation agencies may wish to invite members of the public or representatives of groups to events and meetings to improve rapport with a broader public. Many agencies also develop a mailing list of people interested in the region's transportation issues, and they may regularly send notices of upcoming events to all people on the list. Newsletters, updates, and bulletins can be targeted to people who have attended previous meetings, who have called to request information on transportation planning processes, or who are involved in community activities that indicate an interest in transportation alternatives.

Public Education Campaigns

Partnerships can be heightened by innovative public education campaigns, which may selectively use public service announcements, advertising, the news media, posters, talk shows, and educational television and radio programming. Campaigns can be developed around current transportation problems, transportation solutions, or policy options. Areas with air pollution problems may want to develop an information campaign on the air quality effects of certain transportation practices. For example, the importance of trip-chaining to reduce cold starts emissions from vehicles could be the focus of such a campaign. Practical tips on ridesharing or public transportation services can be presented in ads or public service announcements, following the example of cities such as Seattle and Denver. Ongoing efforts to encourage higher rates of vehicle occupancy can provide the basis of a shift in public attitude about solo driving of the same magnitude as that experienced in the last decade about recycling.

Public Opinion Surveys, Interviews, Focus Groups, and Polls

Maybe there is one lesson that can be learned from politicians: polling and related techniques are basic ways to find out what people need and want. Surveys, interviews, focus groups, and polls are ways to gather public opinion on transportation services, alternatives, and potential improvements. The benefit of surveys or polls is the opportunity to reach a wide audience at relatively low cost. But designing surveys is an art: a survey or poll will be useless if it asks unintentionally or deliberately loaded questions, fails to provide room for "none-of-the-above" answers and unstructured feedback, or otherwise stifles honest response and unbiased results.

Focus groups are another way to involve many points of view. In Bethel, Maine (population 5,000), citizens were catalyzed into a planning process when one of the area's chief employers, National Testing Laboratory (NTL), announced its plans to relocate. The town convened 27 focus groups in a 6-week successful planning process. Participants ranged from loggers to environmentalists, ski resort owners and innkeepers to crafts people and musicians, and old timers to summer people. An unexpected bonus was NTL's decision to remain in the area because of the successful resolution of the conflicts that had motivated talk of relocation.

Competitions

Civic competitions can be held, as they have in some cities, to reward people whose projects or suggestions promise to improve transportation services, safety, accessibility, or efficiency. Competitions could be held, for example, to select the best proposal for a public education campaign to increase transit ridership or reduce single-occupancy travel. In addition to a monetary prize, the reward could include broadcasting the winning advertisements on radio and television.

Technical Support

Community groups may be granted technical assistance funding to enable them to refine, in a technically sophisticated manner, proposals for transportation alternatives. The federal Superfund law provides technical assistance grants so that community groups can hire an expert who can help them analyze and evaluate hazardous waste clean-up proposals. Transportation plans also involve technically complex issues, and transportation decisions may sometimes benefit from the inclusion of independent experts who can help to explain and evaluate the alternatives for community groups. Community groups may be much more informed and engaged if they can rely on the technical advice of a respected consultant, whom they see as serving their interests.

Technical support can also be provided by assigning transportation agency staff to assist in the development of ideas generated by the public. For example, in Tallahassee, Florida, a state bicycle and pedestrian office helps to refine citizen-generated proposals that would expand opportunities for nonmotorized transportation.

People cannot be fully functional in society without mobility, yet mobility is increasingly limited by congestion. Health is threatened by vehicular emissions. No wonder many citizens feel so strongly about transportation policy. Air quality can be improved, transportation can be made more efficient, and transportation investments can be used to revitalize and strengthen communities, but only if diverse communities become true, continuing partners in the transportation planning process. The new partners are full of promise and enthusiasm. The forms of greater public inclusion are limited only by imagination.

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Can Road Builders Join the Public in Influencing Transportation Policy? A Minnesota Case Study

ROBERT C. JOHNS AND FRED J. CORRIGAN

Tremendous changes are occurring in the formulation of transportation policy. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) is revolutionizing approaches to transportation programs, funding, and decision-making authority. These new policies, which emerged and survived against more traditional approaches, are indicators of long-term changes and forces that are affecting transportation in American society. Transportation constituency groups in particular have been affected, with new groups being formed that represent the public's growing influence. This change has been suggested by researchers calling for new coalitions and demonstrated by increased public leadership in transportation projects and the emergence of new voices and groups in transportation policy debates. One constituency group, The Minnesota Transportation Alliance, is examined to see how these forces have affected traditional transportation advocacy groups. The Alliance, formerly called Minnesota Good Roads, is transforming itself from a road builder organization to a broad-based public education and catalyst organization. It is attempting to bring together road builder groups and public representatives in a new coalition that will strengthen the position of transportation in its competition for attention and resources with other public issues. Whether or not it is successful remains to be seen, but its broad-based coalition and participation mechanisms may make it much more prepared for transportation challenges of the 1990s than are groups that are clinging to old traditions or making only small incremental changes.

In the past few years there have been tremendous changes in the formulation of transportation policy and the process of transportation decision making. The most visible indication of these changes is the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), which is revolutionizing approaches to transportation programs, funding, and decision-making authority. The Clean Air Act and the Americans with Disabilities Act also bring new directions to transportation planning and programs.

These new policies were influenced by several factors: changing constituency groups, individual leadership, budget constraints, and last-minute compromises. Although the mix of these factors during policy development influenced the final specifics of the acts, the nature of these policies and the fact that they emerged and survived against more traditional approaches are indicators of longer-term changes and forces in American society that are affecting transportation. The 1991 discussion and debate in Congress reflected similar discussions that have been occurring in states and communities throughout the country.

The focus of this paper is on the changing constituency groups that are influencing transportation decisions. The paper poses the thesis that road builders—the traditional alliance of FHWA, state departments of transportation (DOTs), local government engineers, and construction and supplier industry groups—were ultimately left behind in the ISTEA debate, and that the public—represented by new coalitions of transportation users, planners, and environmental groups—emerged in a leadership role in ISTEA development. Whether or not this is true will be seen during the implementation of ISTEA, but the point is that a shift is occurring. This shift has been suggested in surveys and studies, has been visible in community debates about transportation projects, and is now appearing in state and federal transportation policy development. Evidence of this shift is described below, with a special focus on coalition building in Minnesota.

CALL FOR NEW COALITIONS

In 1988 the Eno Foundation for Transportation published a book by John Hazard, professor of marketing and transportation at Michigan State University, entitled *Managing National Transportation Policy* (*1*). Hazard gives an extensive description and analysis of transportation policy in the United States and reviews the performance of the U.S. DOT (established in 1966) during its first two decades of existence.

In his section on constituent groups, Hazard outlines the increasingly divided constituencies for the U.S. DOT. Before the U.S. DOT was established, initial policies were influenced largely by commercial carrier associations (American Trucking Associations, Association of American Railroads, etc.) that worked directly through their modal administrations. National policy became more complex in the 1960s as social issues came to the fore, the U.S. DOT assumed urban transit responsibilities, and the common carriers industry declined. Hazard outlines three alternatives for future constituency support that the secretary of the U.S. DOT could pursue: (a) continue zigzagging between various constituency groups to find coalitions conceived to be in the public interest; (b) retrieve the active support of carrier groups, leaving equity and external issues to other agencies; and (c) seek out rising constituencies of travelers and shippers as consumers and support

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their broad interests in economically efficient service as a surrogate for public interest in transportation.

Hazard clearly prefers the third alternative, focusing on broad-based traveler-shipper consumer constituencies—in other words, on transportation users rather than on transportation producers. He believes that this would result in better-coordinated intermodal services, better long-range planning, increased research and development, and so on—many of which are echoed in the ISTEA language written 3 years after his book.

Another author who has called for new coalitions to influence transportation policy is Nancy Rutledge Connery, former executive director of the National Council on Public Works Improvement. She is eloquent in stating how important the infrastructure is to each person and their community and how the interdependence, mutual accountability, and obligations as humans, citizens, and public works professionals must be recognized (*2*). She is frustrated with the preoccupation of road-builder coalitions simply to find more money and with the common tendency to equate quality of life to greater mobility rather than linking it also to the places in which people work and live.

Connery believes that transportation problems would be better addressed if a broader range of people were brought into public investment decisions, so that public works problems were no longer defined in a vacuum separated from users, operators, and places. She calls for earlier citizen participation to ensure that public investments are understood and supported by the public as well as the experts, and so that the experts do not view the public as a vague enemy when it comes to getting something built. She observes that broad-based collaboration is becoming an important tool in upgrading manufacturing competitiveness and revitalizing public education and believes that infrastructure, the third leg of the foundation of America's economic future, is no less important.

There have been surveys indicating that American citizens may agree with writers such as Hazard and Connery. A national survey in 1989 by Apogee Research for AASHTO found that the public is not happy with their highway and mass transit network (*3*). Although safety, congestion, and road conditions were the leading problems mentioned, the perceived efficiency of the state DOT was the most important factor in explaining satisfaction with the highway system. The public appeared to be interested in better planning and was more likely to have strong negative feelings than strong positive feelings about state DOT efficiency, with a high degree of mistrust over how transportation dollars were spent. This survey and others suggest that the traditional coalitions, which were so effective in the development and construction of the U.S. transportation system, are losing the support of the public and that, unless the old groups change, new coalitions will take leadership roles that respond to the public concerns.

EXAMPLES OF SHIFT IN LEADERSHIP

The call for user coalitions and public involvement by Hazard and Connery and the attitudes documented by the Apogee survey are not new. As Hazard points out, the explosion of social issues in the 1960s led to the development of new constituency groups that were often opposed to transportation development processes. Many highway projects around the country have been slowed, modified, and even stopped by community opposition. Many state DOTs and metropolitan planning organizations (MPOs) have responded with creative, successful public involvement efforts. What is happening today, however, is a radical change, in which traditional coalitions and approaches are not changing rapidly enough. In many cases new groups are taking the lead, in both project development and policy formulation.

Project Development

Changes in public attitudes can first be seen in community reactions to transportation projects. There are many examples of projects that have been changed by public involvement. As Gattis and Stoner find in their research on public attitudes about the creation of frontage roads (*4*), engineers and planners can be expected to have views and concerns that are significantly different from those of businesses and neighborhoods that may be affected by engineering and planning decisions required for frontage roads. When transportation professionals are not aware of or do not prepare for and deal with these fundamental differences in values and perspectives, tension and conflict will result. Many transportation agencies have come a long way in understanding this situation and in implementing participation mechanisms that mitigate conflict. However, these incremental changes are not keeping up with the rising concerns about transportation. Two project examples are described that show radical changes in project development.

In 1984 a study was begun for a new roadway connecting Wilmington to Dover in Delaware. The roadway had been the subject of serious controversy over a period of almost 30 years. Increasing traffic congestion and rising accident rates led to three major studies for a bypass in 1958, 1967, and 1974. Each of these three previous studies took the conventional process of alternatives development on the basis of traffic and engineering consideration, followed by public hearings. Each time, the opposition from farmers, businesses, and residents stopped the proposed project. Alvarez et al. (*5*) describe the approach that finally led to construction of an alternative. This approach turned the traditional process on its head, structured so that the community involvement effort itself drove the engineering design work. The process was based on the premise that every articulated concern warranted attention and that all aspects of the rationale for design decisions should be made clear. Public coalitions helped create and evaluate alternatives, with Delaware DOT (DelDOT) engineers providing data and analysis. Many outreach meetings, surveys, newsletters, project exhibits, slide shows, and individual contacts were employed. Enough consensus was achieved to have environmental impact statements completed and a selected alternative announced 2 years after the study began. Construction began 5 years after the study was started.

In this example, the radical change was in the process, not in leadership. DelDOT, by relinquishing some of its authority and becoming more of a facilitator, actually increased its effectiveness as a leader. It took advantage of the strong user attitudes and formed an alliance with the public to effectively solve a transportation problem. Not many agencies have been willing to be this creative, although perhaps they have not had DelDOT's 30 years of frustration.

A second example demonstrates a shift in leadership as well as in process. Described by Hartgen and McCoy (*6*), the setting for this example is Charlotte, North Carolina, which is at the crossroads of Interstates and other key highways. This is a growing metropolitan area that includes counties in both North and South Carolina. Planning organization roles and responsibilities are disjointed, with multiple DOTs, Councils of Government, and MPOs. In 1985 an ad hoc group called the Carolinas Counties Coalition was formed to pursue regional agendas for the Charlotte metropolitan area and surrounding counties. It quickly identified transportation access as one of its critical issues and generated considerable interest in a second-tier ring road around Charlotte. Ultimately, it formed a transportation task force consisting of elected officials, business representatives, and staff from nine counties, who defined their mission as an advocate for transportation investments as well as a multimodal planning organization. The task force undertook project efforts to study the feasibility of the ring road, a regional transit authority, and rail right-of-way preservation and decided to hire an executive director to be housed at the University of North Carolina-Charlotte.

In this example, the traditional groups that have initiated transportation projects—state DOTs and MPOs—were in a secondary role. In addition, the initial reaction of the two DOTs was one of caution and reluctance, having started their own regional planning efforts for the Charlotte area. Ultimately, they became full partners of the task force and supported the task force efforts; still, this is a case in which a new coalition took the lead because of the lack of response to the growing transportation issues perceived by the public. This is only one of many examples across the country in which this shift in leadership, in defining and advocating transportation projects, has occurred.

Transportation Policy

As they become more widespread, the increasing interest and power of the public in influencing transportation projects ultimately affect transportation policy as well. Local groups that have initiated or changed projects join forces, realizing that they all may gain by influencing the formulation of policy: the state and federal transportation programs, regulations, and funding allocations. It is unclear whether there has been the kind of dramatic shift in leadership for transportation policy as there has been in some communities for transportation projects, but there are clearly new voices and evidence that many people feel as Hazard and Connery do in calling for, and building, new coalitions.

One of the most dynamic places currently for transportation debate is California. The transportation problems are critical: congestion, safety, and air pollution. In the San Francisco Bay Area, traffic congestion has been at or near the top as the most serious metropolitan concern in citizen surveys—above crime, education, taxes, and other concerns that usually outrank transportation in other metropolitan areas. A collection of articles published by the California Institute of Public Affairs in 1990, *The Alternative to Gridlock* (*7*), is an indicator of the new voices that have entered the California transportation debate. Business leaders, environmentalists, and university faculty, as well as government leaders, offer their ideas or solutions. California has also led the way in new methods of financing roads and has experimented with growth management, often initiated by local governments. It is not clear whether one coalition has risen above others in influencing transportation policy, but it is clear that the traditions of other states—gas tax increases influenced by road-builder groups—are no longer workable in California. The public—the transportation users—is demanding a role in setting new transportation directions. Recently, the newly formed San Francisco Bay Area Partnership, a unique intergovernmental and intermodal transportation consortium, has received acclaim for responding to these needs (*8*).

At the national level, a new coalition has risen to a leadership role: the Surface Transportation Policy Project (STPP). By 1991, STPP had grown into an organization whose defined policy goals were supported by over 100 organizations representing a broad spectrum of conservation, environment, planning, transportation, energy, and urban interests (*9*). The STPP is an advocate of public involvement and certainly could be described as a surrogate for the public—a type of user coalition called for by Hazard and Connery. It is interesting to examine STPP's impact on ISTEA, especially since many of STPP's policy proposals were incorporated into ISTEA. The development of ISTEA was influenced by the efforts of U.S. DOT Secretary Skinner to create a national transportation policy and by efforts from a coalition led by AASHTO, the Highway Users Federation, and others to develop a vision called Transportation 2020. These efforts were dominated by traditional groups that have influenced transportation policy in the past. There were certainly new ideas in their efforts—to call them road builders is too narrow—but it is fascinating to see how much impact a new group such as STPP had on ISTEA compared with the impacts of these older, powerful constituency groups. Some observers of ISTEA development will say that Senator Moynihan and his staff were primarily responsible for reversing the more traditional directions. But Senator Moynihan's leadership was supported by his colleagues, whose votes very well could have been reflections of the changing attitudes and rising concerns of the public about the need for new transportation directions.

These examples show that shifts of leadership are occurring in transportation at local, state, and national levels. It is difficult to judge which groups have more power or how shifts will occur in the future. But these shifts have implications for transportation agencies, for existing constituency groups, and for new groups that have transportation interests. One type of constituency group—state coalitions that advocate for transportation—is examined in this paper to see how it is being affected by these changes.

STATE TRANSPORTATION CONSTITUENCY GROUPS

Several states have information and advocacy groups that historically have worked closely with state DOTs and industry groups to influence transportation funding legislation. These groups are usually nonprofit organizations controlled by boards that traditionally have been dominated by road-builder representatives, with significant financing coming from the construction industry. There are several models; some are described below.

- *California.* Californians for Better Transportation is primarily a public information organization that recently has focused on environmental issues.
- *Florida.* Floridians for Better Transportation works to raise public awareness about transportation issues.
- *Georgia.* Georgians for Better Transportation is currently promoting a campaign in support of multimodal transportation in Georgia.
- *Maine.* Maine Better Transportation Association (MBTA) was organized in 1939 as a statewide association of the various interests that constitute Maine's transportation industry. The primary mission of the MBTA is to improve public understanding of the importance of Maine's transportation system.
- *Minnesota.* Minnesota Transportation Alliance conducts programs in advocacy and lobbying, information and communication, and citizen and organization action.
- *Missouri.* Missouri Development Association concentrates mostly on public and media relations, helping the state DOT communicate its message.
- *Pennsylvania.* Pennsylvania Highway Information Association is one of the oldest transportation advocate associations. It is not a lobbying group but was instrumental in the development of the toll road buy-back process that was ultimately included in ISTEA.
- *Virginia.* Virginia Road and Transportation Builders Association recently has been involved in the beginning stages of creating a coalition to pursue increased funding for transportation rather than hold to its historical position of solely supporting highway funding.
- *Wisconsin.* Transportation Development Association (TDA) has identified as its primary goal the establishment and maintenance of a balanced transportation network that meets Wisconsin's present and future mobility needs in the most efficient and effective manner possible. TDA's mission is education. As a nonlobbying entity, the association's prime responsibility is to disseminate credible information on Wisconsin transportation, on the state's current and future mobility needs, and on appropriate solutions to those needs.

To judge how the changes and shifts in influence described above are affecting these organizations, the evolution over the past few years of one of these organizations—Minnesota Transportation Alliance—is examined in more detail.

MINNESOTA TRANSPORTATION ALLIANCE

Reorganization in Minnesota

Almost 100 years ago, in 1893, bicyclists and farmers were leaders in protesting the muddy conditions of Minnesota's roads. Their actions led to the formation of a citizens' organization named Minnesota Good Roads, Inc. (MGRI). This group grew into the largest organization in the state concerned with transportation issues. It became influential as a lobbyist in helping pass gas tax and other state funding legislation. Over time, its core financial supporters were members of the construction industry and Minnesota counties, whose board members were often elected on the basis of their ability to acquire funding for roads.

MGRI worked closely with the state highway department, which became the Minnesota Department of Transportation (Mn/DOT) in 1976, on legislative funding packages. Often, a small circle consisting of legislative committee chairpersons, Mn/DOT officials, and interest group leaders, including the executive director of MGRI, developed highway funding language and formulas that were passed with few changes. In the debates of formula allocations, MGRI competed directly with transit interest groups, protecting highway dollars from being used for transit.

In the late 1980s, the MGRI board of directors faced two challenges. One was the retirement of MGRI's long-time executive director. The second was a realization that the old way of doing business—working with a close-knit group of leaders—was not as effective as it used to be. Newly elected legislators demanded a better understanding of how transportation decisions were made, particularly during a time of budget constraints and federal cutbacks. It also became more difficult to separate highway needs from transit needs, and there was concern that this historical conflict was weakening the overall transportation position in its competition for attention and resources with other public issues such as education and health.

The board believed that MGRI needed a stronger emphasis on public education to help create broader-based support for transportation. It hired a new executive director to implement this direction. Focus group sessions were conducted to determine the types of activities that would be most valuable for MGRI. During these sessions and board meeting discussions, many members proposed that MGRI be renamed to reflect a broader perspective. Although there was no consensus on this, in 1989 the organization was renamed the Minnesota Transportation Alliance to reflect expanded concerns and purposes. The renamed organization established four regional chapters and expanded communication efforts. New members were recruited for the chapters and the board of directors to broaden support for the alliance, bringing in new interest group members such as transit and neighborhood associations. Surveys were conducted of all members to determine the legislative priorities for the alliance, and participation mechanisms were implemented so that regional concerns throughout the state could work their way up for action by the board of directors.

Alliance Policy Task Force

As the transportation alliance began to be active in the Minnesota legislative process, there were concerns that the new directions of the organization were not widely understood. It was perceived by some, particularly in the media, as a road-builder organization with a new name. Others, including some of its contributing members, questioned whether it was losing its focus as it became involved in transit issues. This uncertainty came during a period when transportation was beginning to receive increased attention at both the state and national levels. A Minnesota transportation study board had been established to recommend funding and policy directions to the Minnesota legislature, and U.S. DOT and AASHTO had begun preparing for the transportation reauthorizations due in 1991 in Congress. The alliance needed to participate and respond to these efforts.

Early in 1990, the executive director and the executive committee decided to establish a policy task force that would help prepare the alliance for its involvement in these state and national activities. Its charge was to identify a policy framework and strategic direction for the alliance that could be discussed and adopted by the board of directors and communicated widely to members and interested parties.

Determining what groups would be represented on the task force was a strategic decision because it would be an indicator of the coalition the new organization was trying to build. Seven members were selected in addition to the executive director, as follows:

- An official from the Minnesota Chamber of Commerce,
- The leader of a Minneapolis neighborhood organization that was active in transportation and environmental issues,
- A rural county engineer,
- A retired highway construction executive,
- The former president of the Minnesota Public Transit Association,
- A transportation consultant, and
- A rural community leader who was an advocate for improved transportation from her community to the Twin Cities.

Three members of this task force were from what could be called the road-builder coalition that formerly supported MGRI: the county engineer, construction executive, and transportation consultant. Three other members came from what in this paper has been called the public as users and consumers of transportation—representing Minnesota businesses, urban neighborhoods, and rural communities. The final member represented transit, a group of transportation providers that had not been previously active in the organization. This group met three times in 1990, assisted by an external facilitator, to prepare recommendations for the alliance board of directors.

Recommended Strategic Directions

The task force produced a report of recommendations for the board of directors that presented a new mission for the alliance, a philosophy, policy concerns, recommended programs, and three strategic issue areas that needed to be addressed (*10*). Although there was a great deal of discussion and revision in the preparation of this document, the task force reached consensus and appeared to have a high level of ownership for the product of their efforts. The new mission recommended was as follows:

> The mission of The Minnesota Transportation Alliance is to ensure an effective statewide transportation system for Minnesota. The alliance addresses issues for all modes of transportation through the leadership and active involvement of a broad-based membership. (*10*)

This mission was reinforced through the other recommendations of the task force. The philosophy emphasized an integrated, multimodal transportation system and the active building of coalitions. The programs recommended include (a) advocacy and lobbying with a special emphasis on transportation funding, carrying on the historical strength of the organization; (b) acting as a resource for information, emphasizing communication and education through publications, meetings, and events; and (c) citizen and organization action, acting as a catalyst through four regional chapters to build coalitions and attract new individuals and groups to address transportation issues.

The policy concerns and strategic issue areas identified by the task force distinguished between defining what an effective transportation system is for the state versus ensuring that there are the means available to attain that effective system. The task force believed that the organization had historically emphasized the means—funding—with little comment on what the transportation system should be or do (similar to Connery's concerns). It defined four elements of an effective transportation system:

- Personal mobility and access so that citizens can effectively perform the employment, family, and social activities that contribute to the quality of their lives. The need for access to jobs, housing, education, shopping, health care, and recreation was identified.
- Transportation support of the economy so that the economic competitiveness of Minnesota is enhanced. Multiple industries were identified that need access to suppliers, markets, and labor through efficient transportation systems.
- Transportation support of state and community goals so that community services (fire and police protection, etc.) are effectively provided and transportation services are available to all citizens, including elderly, disabled, and lower-income populations.
- Transportation system characteristics that ensure that Minnesota's transportation system is safe, well planned, well designed, environmentally sensitive, aesthetically pleasing, intermodal, and accessible.

In terms of the means to an effective transportation system, the task force identified three priorities:

- Transportation funding that is adequate, long term, stable, user oriented, and innovative;
- Institution/agency roles that clearly define authority and responsibilities and that link transportation to other state and local goals; and
- Transportation decision-making principles that set high standards for involving the public, planning, protecting the environment, innovation, developing the economy, cost-effectiveness, accountability, and expertise.

The task force recommended that the alliance monitor these seven policy concerns to identify strategic issues that the organization should address through its programs. Potential actions could range from simply providing information about an issue to developing an active lobbying campaign. In addition, the task force identified the internal organization of the alliance as a strategic issue area, recommending that the board ensure that there is agreement on the new mission, develop a membership strategy, evaluate the committee structure, develop program priorities, and establish long-term financing strategies.

Current Status

The Minnesota Transportation Alliance continues to proceed in the directions established by the policy task force in its September 1990 report. The report was adopted by the board of directors and used as a framework for presentations and discussion at the alliance's annual meeting that fall.

The transition to the new organization and new mission has not been instantaneous. There continues to be some uncertainty by traditional members about the role and effectiveness of the new organization. But clearly there have been some successes. The four regional chapters have created a new awareness of the various transportation needs throughout the state. New members have joined these chapters, which offer them forums to address local concerns. Mechanisms have been implemented that allow leaders of the chapters to become board members, bringing new perspectives and a grass-roots component to the organization. This program emphasis has created a new network of contacts that allows the alliance to be up-to-date on public concerns and issues. The two-way communication between the board and the regions has increased the understanding of statewide issues and helped point the Alliance in responsive directions as it prepares its positions for the legislature and Congress.

One result of this increased awareness was the alliance's success in being a sounding board for the Minnesota congressional delegation as ISTEA language was being debated and developed. The annual alliance trip to Washington, D.C., provided members direct access to the delegation, resulting in new information for the delegation that was used in their shaping of ISTEA. Another result of the broader involvement of the alliance was that traditional construction industry members used the alliance to help address their own transportation problems. An aggregate company, for example, has used the alliance's influence to address water transportation issues for barge shipments on the Mississippi River.

The alliance faces challenges, however, in maintaining effective relationships. With a more diverse membership, it runs risks in taking positions that a segment of its membership opposes. Its more effective role may often be that of a catalyst—a group that raises awareness and keeps processes going—as opposed to an advocate. It has had challenges, for example, in defining its role in the expansion debate for Interstate 35W in Minneapolis in which neighborhood groups, light-rail advocates, and proponents for increasing the number of highway lanes are involved in an intense discussion about the future of that corridor.

The alliance also faces challenges in its relationship with Mn/DOT. Formerly, MGRI was often an agent of Mn/DOT, taking positions that Mn/DOT, a public agency, could not take as effectively. Mn/DOT also counted on MGRI to help develop legislative and other support for Mn/DOT proposals. The alliance, by trying to be responsive to its diverse membership, may at times appear to be at odds with Mn/DOT.

The alliance also still faces challenges in the Minnesota legislature. While most legislators perceive the alliance to be a credible voice on transportation issues, there still are some who do not believe it has broadened beyond being a road-builder organization. Although the alliance has been one of the few voices to put forth new ideas, no transportation policy legislation has been passed since the alliance began working towards its new mission. In the 1992 legislative session, for example, the alliance proposed the establishment of a multimodal mobility fund, a concept that had the support of both road-builder and transit groups. The Minnesota Senate supported a bill establishing this fund, but the Minnesota House did not schedule the proposed legislation for a hearing.

There has been some concern about the financial support for the alliance. A few traditional members have drifted away; it is unknown whether this was caused by concerns over the alliance's new direction or by the pressures of the recession. New members, however, have joined since the mission was broadened. The membership is still evolving, and it is too early to predict the results. Currently 30 percent of the members are counties and cities (usually represented by engineers); 50 percent are members of the construction and supplier industry, labor unions, and professional engineer associations; and 20 percent are users of the transportation system and nonhighway modes—businesses, community groups, transit, carriers, and citizens. There are positive signs in the vitality of the new members and in the apparent adoption by these and other members of the task force's recommendations. The words used by the task force keep reappearing in recommendations by regional chapters and in board discussions. The alliance leadership believes that with time and patience the organization is going to grow in membership and influence.

DISCUSSION OF RESULTS

The evolution undergone by the Minnesota Transportation Alliance has been affected by similar forces that brought about ISTEA, led to the formation of STPP, and caused the emergence of the Carolinas Counties Coalition transportation initiative. The changes in American society, the growing concerns about transportation problems, and the perceived lack of response by traditional transportation organizations have led to new groups and new directions that are influenced a great deal by the public, the users of the transportation system.

When one thinks about how transportation decisions were made a few years ago, these are remarkable changes. Although it is uncertain what the end results of these changes will be, it seems that organizations such as the alliance, which are trying to adapt to this new environment, are ahead of those that are clinging to traditional roles and mechanisms. Compared with transportation advocacy and information groups in other states, the alliance is unique in the breadth of its three integrated programs and in its mix of membership. It has both strengths and weaknesses; but it is making midcourse corrections, building a strong network, and taking a patient and optimistic approach in developing capabilities to respond to future challenges. Hartgen and McCoy use the words "uncharted waters" in the title for their paper on the Carolinas Counties Coalition, words that are appropriate in describing the evolution of the alliance. Many organizations are sailing in these waters today, but, as Connery points out, broad-based collaboration can provide direction and vision. The alliance, although facing challenges, seems well positioned to deal with the transportation needs of the public in the 1990s.

The question posed in the title—Can road builders join the public in influencing transportation policy?—does not have a clear answer. Regarding the case study in this paper, although the Alliance seems well positioned and its new funding proposals have found support in the Minnesota Senate, so far no consensus has been developed that has resulted in new transportation policy for Minnesota. There are obstacles to building this type of partnership. The lack of national unity present in the ISTEA development is also present in Minnesota and other states. Transit and environmental groups are often suspicious of road-builder organizations; and road-builder groups that advocate increased highway funding often do so without an understanding of the overall transportation system and without working with other groups that increasingly care about this system. However, the Minnesota Transportation Alliance is one of the few forums in which road builders and public representatives are actively being joined together to bring forth new ideas and to work toward building consensus. It is still an experiment, but a clear rationale was provided by the Alliance Policy Task Force: this direction should ultimately benefit the industry by building coalitions that make transportation more competitive with other public issues.

The changes described in these examples have implications for government transportation agencies. The agencies that will be successful in the 1990s are those that provide the best service to their user constituencies—the public—as called for by John Hazard. State DOTs and MPOs cannot afford to learn the hard way about the strong feelings the public has about the transportation system. Public involvement that drives transportation decisions, as DelDOT finally used to solve its bypass problem, must increase to build the successful coalitions needed today to address critical transportation issues. Creative organizations will take advantage of strong public opinions and benefit from new alliances that help them get needed resources, alliances that conceivably could be even more powerful than the road-builder coalitions of the past.

SUMMARY

Changes in transportation are occurring at a rapid rate. These changes are affecting constituency groups, leading to the formation of new groups and directions. The experience of the Minnesota Transportation Alliance, which is attempting to bring public constituencies together with road-builder groups, may provide a useful approach for dealing with these changes. Whether or not it is successful remains to be seen, but the broad-based coalitions being formed and the participation and communication being provided are indicators of a promising future and also potential models for transportation agencies.

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Public Involvement at the Planning Level: A Case Study of the University of Maryland Eastern Shore Access Road

MOUNTASSER A. RAHMAN

Perhaps the most visible aspect of the Maryland State Highway Administration's commitment to quality in citizen participation is in the administration's forward thinking in the project planning process and in its efforts to assemble locally appropriate and environmentally sensitive solutions to the transportation needs of the state. This is accomplished by the special attention given to public participation and involvement in every aspect of the project planning and development process. Maryland State Highway Administration's public involvement program is highlighted, and the implementation of the program and its positive aspects are described using a case study of the University of Maryland Eastern Shore Access Road.

The University of Maryland Eastern Shore (UMES) Access Road is proposed to serve as a new main entrance into the university, a distance of slightly more than 1 km (less than 1 mi). The UMES Access Road project planning study was initiated on June 7, 1989, and the combined location and design public hearing was held on March 30, 1992. Nine alternatives were developed, five of which were studied in detail and presented at the public hearing. One of the alternatives presented at the hearing was proposed by local citizens. The alternative that will be carried forward for design and subsequent construction is a modification of the one proposed by the local citizens.

PROJECT HISTORY

The town of Princess Anne is located in Somerset County on Maryland's Eastern Shore of the Chesapeake Bay with a 1990 population of approximately 1,700. The town is the administrative center for the county government and is its second largest town (Figure 1). Princess Anne is located approximately 193 km (120 mi) southeast of Baltimore, Maryland, and 161 km (100 mi) north of Norfolk, Virginia.

The town of Princess Anne houses the Eastern Shore Campus of the University of Maryland. The university had its origin on September 13, 1886, and records reveal that 37 students were enrolled by the end of 1886. The expansion projections issues in 1989 by the university show 2,548 students in 1995 and 3,173 students by the year 2000.

The UMES Access Road Study first appeared as a project planning study for MD-362 Extended (Valentine Drive, previously known as Mt. Vernon Drive) in the Maryland Department of Transportation's Consolidated Transportation Program (CTP) for FY 1989–1994.

Inclusion in the 1989–1994 CTP followed its identification as the first priority for Somerset County's secondary highway system. The project is currently included in the draft FY 1991–1996 CTP for the project planning phase only. This project has an extensive Highway Needs Inventory (HNI) history, having appeared in the 1973 HNI and each subsequent biennial HNI update. This proposal is consistent with established land policy in the area and has the identified support of the 1975 Comprehensive Development Plan for Somerset County.

PROJECT PLANNING PROCESS

The Maryland Highway Administration project planning process consists of three phases. Phase 1 consists of engineering, traffic, and environmental assessments; governmental agencies and citizens' groups contact; preliminary design concepts; and preliminary right-of-way, relocation, and construction cost estimates. This phase ends by holding an alternatives public meeting.

Phase 2 of the Maryland Highway Administration project planning process consists of reviewing public comments received at the public meeting, developing detailed engineering and natural and socioeconomic environmental analyses, and preparing and circulating the draft environmental document. This phase ends with a combined location and design hearing.

Phase 3 of the Maryland Highway Administration project planning process consists of reviewing public comments received at the public hearing, evaluating the governmental environmental agency and citizen input, value engineering of the selected alternatives in Phase 2, making a recommendation to the state highway administrator to select an alternative design, and circulating the final environmental document containing the selected alternative. This phase ends with the distribution of the public notice indicating receipt of location approval.

PROJECT NEED

The purpose of the UMES study was to verify and document the need for improved access to the university and to evaluate all feasible alternatives that would accomplish this goal.

Project Planning Division, State Highway Administration, Maryland Department of Transportation, 707 North Calvert Street, Room 501, Baltimore, Md. 21202.

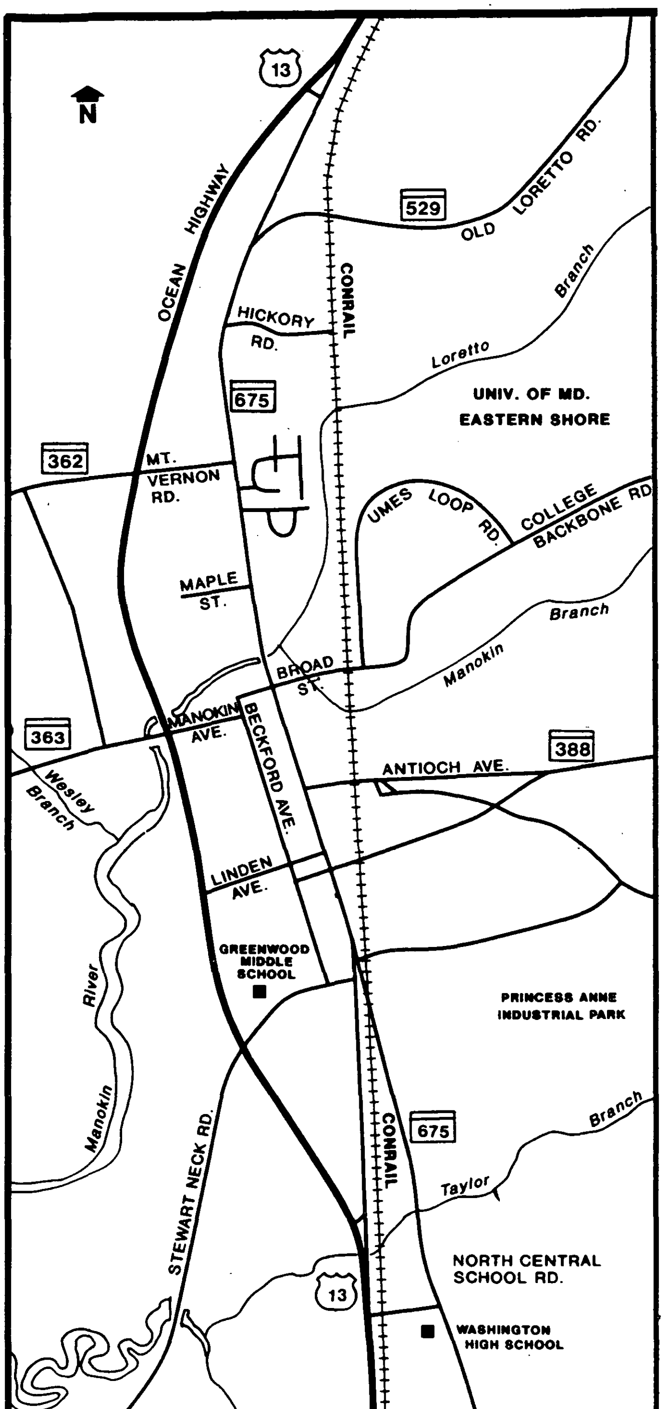

FIGURE 1 Vicinity map of UMES Access Road (not to scale).

Enrollment at UMES has experienced considerable growth in recent years, resulting in increased traffic volumes within the town of Princess Anne. Traffic destined for the UMES campus must negotiate several right-angle turns on local streets, creating turning movement conflicts, particularly in peak hours. By providing more direct access to UMES, some of the campus-bound traffic will be removed from local streets.

The existing entrance route consists of a variable-width two-lane roadway with intermittent curb and sidewalk on one side and earth shoulder on the other. The curb and sidewalk alternate from one side to the other.

PUBLIC PARTICIPATION PROCESS

Mailing List and Public Notice

To effectively consult with the public during project planning and development, the State Highway Administration (SHA) maintains a mailing list for each project. Initially, government and elected officials, as well as known community organizations, are included on this list. Persons on the mailing list receive individual copies of all brochures, newsletters, and any other material related to the project.

The intent to initiate project planning activities for the UMES Access Road Study and solicitation for public involvement and inclusion on the project mailing list were blanket mailed to all mailing addresses in the area of the project and published in several newspapers: *The Baltimore Sun* (statewide), *News and Farmer* (regional, Eastern Shore), and *Somerset Herald* (local). The information was also submitted to the local broadcast stations for inclusion in their public bulletins and a press release was issued to the local news media through the SHA Public Affairs Office.

The project planning team developed five alternatives, including Alternative 1, the no-build alternative. Alternative 4 (Figure 2), in particular, received a great deal of attention. On the one hand Alternative 4 facilitated a direct access from US-13 to the UMES campus along the main business district on Mt. Vernon Road (MD-362), whereas on the other it directed the university traffic through a residential area, Princess Anne Estates.

Alternative 4 proposed the extension of existing MD-362 (Mt. Vernon Road) with new roadway construction east from MD-675, Somerset Avenue, to connect with existing Valentine Drive. The new roadway construction was proposed to extend east from the end of Valentine Drive to the UMES loop road. This alternative is documented in the Somerset County Master Plan (1963) and the Comprehensive Development Plan for Somerset County (1975). Valentine Drive was constructed to meet criteria as a part of the future extension of MD-362.

Early in the project around 35 residents of the Princess Anne Estates along Valentine Drive (MD-362 Extended) signed a petition expressing concern that the initial name of the project, MD-362 Extended, indicated a predetermined decision by SHA to extend MD-362, which they strongly opposed. They suggested a new alignment, Alternative 6 (Figure 2), that bypassed the town.

Alternative 6 proposes a UMES entrance road that begins at MD-675 at the approximate location of its existing intersection with Hickory Road, extends east, and curves toward the south, ending at the UMES loop road. In addition to Alternative 6, the project planning team proposed Alternative 6A, which is essentially the same as Alternative 6, except that it would extend Alternative 6 approximately 200 m (650 ft) west from MD-675 to US-13, the major north-south highway in the area. The project name was changed to reflect its broader need and became known as the UMES Access Road Study.

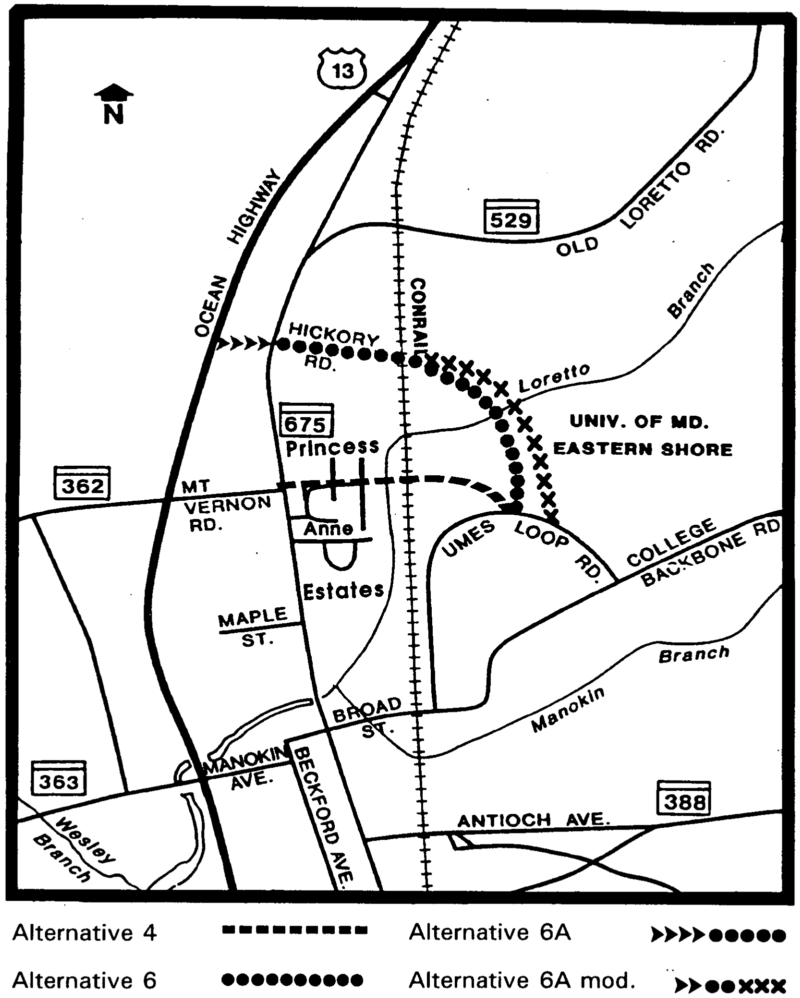

FIGURE 2 UMES Access Road: Alternatives 4, 6, 6A, and 6A modified (not to scale).

Public Meeting

Informal Meetings

To ensure interaction between the SHA project planning staff and the citizens of Maryland, informal public meetings are often held. These range widely in size and format from one-on-one meetings with individual citizens to small groups and special interest organizations to large informational meetings. The meetings are usually located in the project area and are scheduled for the convenience of the public expected to attend.

On January 30, 1990, an informational meeting was held at the Somerset County Library in Princess Anne with residents of the Princess Anne Estates community to provide a clear understanding of the project planning process, to change any preconceived notions that the administration had already chosen an alternative, to provide a forum for interested local citizens to provide comments into the project in the early stages of development, and to present all alternatives developed at that time, including Alternatives 6 and 6A.

On February 1, 1990, an informative meeting was held to brief UMES representatives and county officials on the project and the concerns of the residents of Princess Anne Estates.

Formal Meetings

Alternatives Public Meeting In addition to the informal meetings, the SHA Project Planning Division holds alternatives public meetings approximately one-third of the way through the project planning process. The purpose of these meetings is

- To present to the public the preliminary alternatives developed with preliminary analysis of the advantages and disadvantages of each and the cost, geometric design, and environmental impact associated with each. The right-of-way acquisition process, relocation assistance, and the nondiscrimination in federally assisted and state aid programs are also presented.

- To recommend certain alternatives for detailed analysis.
- To receive public comment on the alternatives presented and suggestions for new ones.

A public notice is published in at least one newspaper, including a map highlighting the area of the study. The notice and a brochure summarizing all the alternatives and their associated environmental, social, and economical impacts are circulated to those on the mailing list before this public meeting. A preaddressed form is included in the brochure for those who choose to submit written comments or request that their names be added to the project mailing list. The brochure is also available at the meeting.

Displays of the conceptual alternatives are available at the meeting, and SHA representatives are available to answer questions and record comments. A formal presentation by SHA staff is given, followed by receipt of public comments.

On March 14, 1990, an alternatives public meeting for the UMES Access Road Study was held at the Greenwood Elementary School in Princess Anne. Public notice was given through the same media used in the project initiation notice. Approximately 50 people attended: 8 requested to speak and 4 more spoke after the registered speakers. All of the opinions expressed, with the exception of one representing the business community along MD-362, were against Alternative 4 (MD-362 Extended).

Alternatives 1 (no-build alternative), 4, 6, and 6A were selected for detailed study, whereas Alternatives 2, 3, and 5 were dropped from further consideration because of adverse environmental and historic impacts.

Public Hearing On the completion of Phase 1 of the project planning activities, a detailed analysis of selected alternatives is conducted. After this analysis, the SHA holds separate location and design hearings or a single combined location/design hearing, depending on the classification of the project and the prospects of the project being continuously scheduled through design. This decision is made by the SHA. In general, two hearings are held on projects that are considered circumferential or bypass corridors, expressways on new locations, or major bridge or tunnel projects.

Two notices of a public hearing are published in at least one newspaper circulated in the project area. The procedure for requesting to speak at the hearing is explained in the notice. The first notice is published at least 30 days before the hearing and a subsequent notice is published within 2 weeks of the hearing. In addition, the public notice and brochure are mailed to those on the mailing list. The notice states the availability and location of a draft environmental document pertaining to the project.

The purpose of the hearing is to provide a means for the public who wish to express on record their views concerning the project. As in the alternatives public meeting, maps depicting the alternatives under consideration are displayed, and SHA representatives are present to answer questions. In addition, the SHA holds informal public meetings as needed or requested by the public to ensure continued interaction between the SHA project planning staff and the citizens of Maryland.

On January 22, 1991, SHA representatives met with members of the business community along MD-362. The business community aired its support for Alternative 4. On September 18, 1991, a meeting was held at the Princess Anne town offices to brief the newly appointed town manager on the history and development of the project planning study. On January 22, 1992, a meeting at UMES was held with university officials to bring them up to date on the development of the project.

The first notice for a combined location and design public hearing for the UMES Access Road project planning study was published on March 18, 1992, followed by a second notice on April 15, 1992. The draft environmental document was on display 15 days before the hearing at the county public library in Princess Anne, the SHA local district office in Salisbury, and SHA headquarters in Baltimore.

A combined location and design public hearing for the UMES Access Road Study was held on Thursday, April 30, 1992, at 7:30 p.m. in Greenwood Middle School. Approximately 80 people attended. Nine people requested to speak. The opinions expressed at the hearing were mixed.

SELECTION OF ALTERNATIVES

On completion of Phase 2 of the project planning process, a review of public and governmental and environmental agencies' comments is conducted, a value engineering team to evaluate the alternatives developed and ensure that the project was not overdesigned is assembled, and a project planning team recommendation meeting is held with the director of the Office of Planning and Preliminary Engineering (OPPE) to select an alternative to be recommended to the administrator.

A team recommendation meeting with the director of OPPE for the UMES Access Road Study was held on June 16, 1992. Alternative 6A modified was selected for recommendation to the administrator. Alternative 6A modified shifts 6A slightly to the east to avoid a major portion of wetlands (Figure 2). A team meeting with the administrator was held on November 17, the team recommendation was accepted, and the location approval notice was circulated in the spring of 1993.

FINAL REMARKS

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) provides an exciting opportunity for the states to manage federal monies for their transportation needs with minimum involvement by the federal agencies. It is believed that the public is well educated enough to act as environmental and socioeconomic watchdogs over the best interests of the local residents. The Maryland SHA has always encouraged active citizen participation. The UMES Access Road project demonstrates the positive outcome of a policy that encourages citizen involvement in the project planning process and helps to identify and implement locally appropriate and acceptable solutions to the highway needs of the state.

Perhaps the most obvious impact of such a simple but effective process was the citizens' increased trust in the process.

The citizens at the initial stages of the project were convinced that a predetermination had been made (Alternative 4), and the only motivation for the project planning team was to go through the motions. A clear change of heart was seen in the citizens from the initial informational meeting where the atmosphere was full of mistrust and was at times chaotic to the public hearing where the citizens demonstrated confidence that the system works. This was shown in the increased attendance from 50 people at the alternatives public meeting to 80 people at the public hearing.

Clearly one of the reasons why Maryland SHA was able to regain the public's trust was the change in the project name from MD-362 Extended to UMES Access Road. Although the extension of MD-362 through the Princess Anne Estates is included in the county's master plan and the reservation of an 80-ft right-of-way was shown on the Princess Anne Estates subdivision plat, the name MD-362 Extended did not reflect the actual need for the project, that is, direct access to the university, and gave the impression of a limited project scope.

A second reason for gaining credibility with the citizens was that SHA took a serious look at the citizens' proposal and gave the citizens full credit for Alternatives 6 and 6A in all of the official correspondence and public contact. It was made clear to the citizens that the modifications proposed by SHA to Alternative 6 were valid engineering and environmental modifications that would maintain the integrity of the concept.

Finally the open-door policy that the administration encourages and supports fosters trust and credibility through direct contact between the project planning team and the citizens of Maryland. These are mainly telephone contact and informal meetings, such as one-on-one discussion at the public meetings and the brief meetings in the residents' back yards when the project planning team was on a field review trip.

The town of Princess Anne suffered a major economic setback when it was bypassed by US-13, the major north-south highway in the area. The planning team believed that another bypass would not be a popular decision nor in the best interest of the residents of the town. The project planning team may not have seen the positive impact associated with Alternative 6 if it had not been proposed by the local citizens, proving once again the value of public involvement in the project planning process.

Publication of this paper sponsored by Committee on Citizen Participation in Transportation.

Citizen Participation Using a Soft Systems Perspective

C. JOTIN KHISTY

Rational intervention in human activity systems such as transportation planning can be achieved through effective citizens' participation. Soft systems methodology provides one such framework and is an inquiring system used to tackle ill-structured problem situations in planning. It enables its users to learn their way to taking action and to improve a problem-ridden situation. This methodology marks a paradigm shift in dealing with complex planning problems. A soft system methodology, formulated by researchers at the University of Lancaster, United Kingdom, is described and this methodology is applied in a case study to demonstrate how it can be used in citizens' participation as applied to transportation planning. This methodology has proved to be effective and easy to use.

Recent years have witnessed an increase in citizen participation (CP) programs, although the overall record of success has been lumpy. Knowledge of CP has also increased over time, and the Advisory Commission on Intergovernmental Relations has identified over 30 different forms of CP used in the United States (*1*).

Trends indicate that the time has arrived for planners to take a good look at all the available methods to match planning styles of transportation agencies to conditions of uncertainty and the status of technology (*2*).

Rational intervention in human affairs in the form of CP needs a well-defined methodological framework. Soft systems methodology (SSM) provides one such framework. SSM is an inquiring system used to tackle ill-structured problem situations in planning. It enables its users to learn their way to taking action and to improve a problem-ridden situation. Checkland and his colleagues at Lancaster University, United Kingdom, have applied SSM in scores of planning applications in recent years and have convinced their clients that it marks a paradigm shift in dealing with complex planning problems (*3*). The purpose of this paper is twofold: first, it sets forth the basic ideas of SSM formulated by Checkland, and second, it applies this methodology to demonstrate how a transportation problem situation in a small city was tackled using SSM.

SOFT SYSTEMS METHODOLOGY

Checkland describes a "system topology" consisting of three basic systems: natural, physical, and human activity. The first two are distinctly defined and can be characterized as "hard" systems, in which the well-established methodologies of systems engineering have been, and continue to be, successfully applied. Essentially, the hard system approach defines the objectives to be achieved and then "engineers" the system to achieve these objectives. The human activity system, however, is usually ill defined and cannot be adequately described by its state, in which case the analyst must concede to its purposeful activity, human values, and nonphysical relationships. This is so because human activity systems can be expressed only as perceptions of people who attribute meaning to what they perceive. There is therefore no single "testable" account of a human activity system—only possible accounts, all of which are valid according to a particular "world view" (or *Weltanschauung*). In contrast to hard systems engineering, soft systems methodology does not seek to mechanically design a "solution" as much as it orchestrates a process of learning (*3*).

The logic behind Checkland's frustration with hard systems methodology can best be described in his own words:

> The real-world client (person, group or society as a whole) is taken to be the owner of the problem; his needs are taken as given and expressed as the objectives to be achieved by a system; there follows a systematic search for an efficient system to achieve the known-to-be-desirable end.

In other words, this hard system methodology tackles the question *how*. By definition, if objectives are themselves problematical, if the questions to be answered are *what* as well as *how* questions, then the system cannot be taken as given, and the approach must be modified (*3*). And this is precisely what Checkland strived to do.

SSM has been developed to aid the understanding of human action by systemic intervention in the situation and is being used extensively in the investigation of problematic organizational and planning contexts through communication processes. Because it is a learning methodology, it has the ability to transform "wicked" problems into tame ones.

Over the last decade, Checkland has crystallized SSM, and his general framework is illustrated in Figure 1. Regarded as a whole, Checkland's SSM is a learning tool that uses the system's ideas to organize four basic mental processes in the analysis: perceiving (Stages 1 and 2), predicting (Stages 3 and 4), comparing (Stage 5), and determining the needed changes and actions (Stages 6 and 7). The output and utility of SSM consist essentially of recognition, learning, and insight. Note the six elements—customers, actors, transformation, *weltanschauung*, owner, and environmental constraints (CATWOE)—that help to structure SSM; the CATWOE mnemonic and the questions raised through the six elements are as follows:

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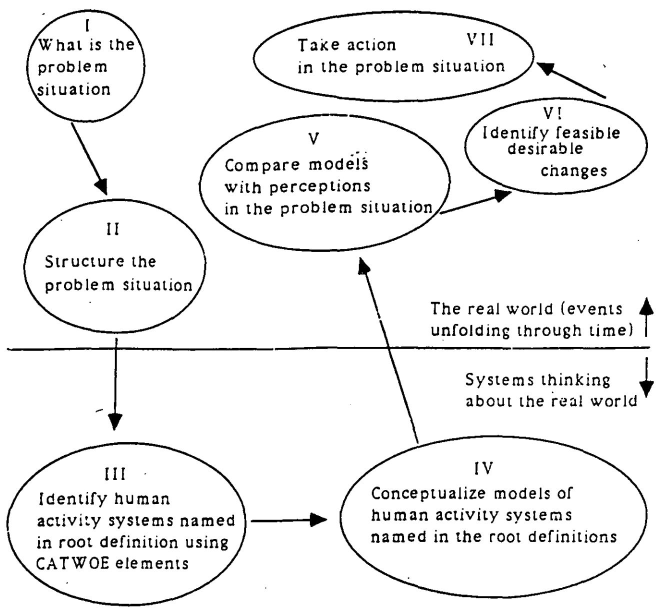

FIGURE 1 Checkland's SSM structure.

C = Customers—Who would be victims or beneficiaries of this system were it to exist (i.e., clients)?
A = Actors—Who would carry out the activities of this system (i.e., agents who carry out the transformation)?
T = Transformation—What input is transferred into what output by this system (i.e., the core of the "root definition")?
W = *Weltanschauung*—What image of this world makes this system meaningful (i.e., world view)?
O = Owner—Who could abolish this system (i.e., ownership)?
E = Environmental constraints—What external constraints does this system take as given (i.e., environmental impositions)?

In SSM, the real-world situation to be analyzed is expressed in nonsystems language using the concepts of structure and process, and the relation between the two. This constitutes a relevant system and encapsulates various specific viewpoints expressed as root definitions (RDs). An RD is a concise description of a human activity system that states what the system is. From the RD a conceptual model of the necessary activities in the system is built. The model building language consists of all verbs. This conceptual model of the human activity system may then be compared with the real world. The model is the formal vehicle for exploring dysfunctions and needed changes in the real world, involving both system analysts and clients.

The products of SSM should provide the basis for needed changes, and such changes can fall into three categories: structural, procedural, and attitudinal. The process is carried out interactively with clients and key informants. The products of SSM provide useful tools from which the clients themselves can tease out deeper insights into their situation, and thereby effect changes responsive to their needs. Four important points need noting: first, each RD makes clear its *Weltanschauung*, the world view from which the system is described; second, SSM is a cyclical process; third, SSM seeks accommodation among conflicting interests; and last, SSM is doubly systemic —it is a cyclical learning process, and it uses systems models within that process.

EXAMPLE OF SSM APPLICATION

Checkland's SSM is applied to a transportation planning problem in this example. A small city (population 30,000) served by a city municipal committee has a problem in deciding whether one of the segments of its regular street network, Jackson Street, deserves to be converted to a "shared street," so as to introduce the concepts of "traffic calming" (*4*). Accidents involving bicyclists, children, and the elderly are on the rise, primarily because of increased through traffic. Accident records maintained by the city appear to be incomplete and inaccurate and are not readily shared with individual citizens.

The shared space concept for pedestrians and motor vehicles is the most recent approach to enhance the safety and environmental qualities of local streets. The major characteristics of this concept are rearranging the street into wall-to-wall sidewalk space that is equally shared by pedestrians and motorists; planting trees, designating play areas for children, and providing benches and flowerbeds; forcing motorists to slow down to speeds of 5 to 10 mph; and providing just enough on-street parking to serve local residents. The idea is to eliminate or reduce to the very minimum conflicts between cars and pedestrians, providing street use for pedestrians, bicyclists, and children, and giving them first preference.

Implementation of a shared street project for Jackson Street is a difficult problem. First, there are citizens in other neighborhoods and communities who believe that automobile mobility reduction on Jackson Street will result in a corresponding overloading of adjacent streets. Second, members of the city council are ambivalent in allowing this change to happen. And last, the city budget is burdened with implementing higher-priority projects according to city officials. Currently, the neighborhood surrounding Jackson Street does not have a citizen advisory committee. Much of the decision-making process is done directly by the city administration on an ad hoc basis. There is little citizen input at any stage. Citizens in general are frustrated with city administrators. The situation was corrected by following the stages in the SSM.

Problem Situation: Stages 1 and 2

The problem from the beginning appears to be complicated because opinions expressed by citizens living in the neighborhood appear at times to be conflicting.

RD and Conceptual Models: Stages 3 and 4

The next stage is to name relevant systems that encapsulate all of the problem themes and then to write a root definition for each one. Two particularly relevant systems emerge; both are normative in that they are expressing a version of what ought to be rather than what is. The first is the Jackson Street Community System (Figure 2). It is obvious that such a system is necessary if the community wants to get anything done. The second is the city council system (Figure 3). People need to be able to communicate with the city administration. The root definitions and the CATWOE mnemonic are used to work out the two conceptual models, as shown below.

Jackson Street Community System

Root Definition: The Jackson Street Community System is a Community Action Committee (CAC) to plan, control, and manage Jackson Street and the neighborhood by introducing improvements to the environment and safety through transformation of Jackson Street to a shared street for convenience of pedestrians, bicyclists, and residents and inhibiting through vehicular traffic.

C = Customers/clients (pedestrians, bicyclists, children, and residents);
A = Actors (elected members of CAC);
T = Transformation (transforming a regular street to a shared street);
W = *Weltanschauung* (a shared street is worth having because of safety and improvement in well-being);
O = Ownership (the elected members of CAC); and
E = Environmental constraints (budget constraints and lack of data).

City Council System

Root Definition: The City Council (including administration and elected members of the council) System develops and enhances a sense of community and uses it effectively to handle issues connected with the development of projects all across the city. This is achieved by setting up and maintaining communication arenas, both formal and informal, that facilitate the negotiation of projects and the participation of all stakeholders in tackling issues connected with prioritizing, funding, and implementing such projects.

C = Customers (the City Council members and administration);
A = Actors (the city engineer and staff);
T = Transformation (ad hoc community development is transformed to organized community development, prioritizing, and funding projects);
W = *Weltanschauung* (issue handling requires being "just and fair" with all communities);
O = Ownership (the City Council); and
E = Environmental constraints (time, staff, and expertise).

Comparison: Stage 5

At Stage 5 a comparison is made between the conceptual models and the problem situation so that one can draw up an

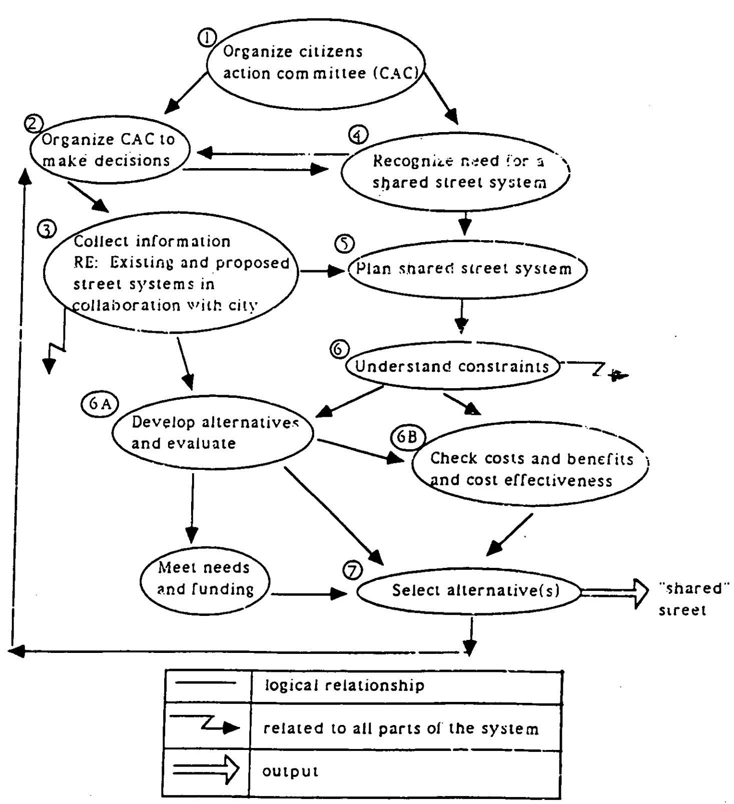

FIGURE 2 Conceptual model: Jackson Street Community System.

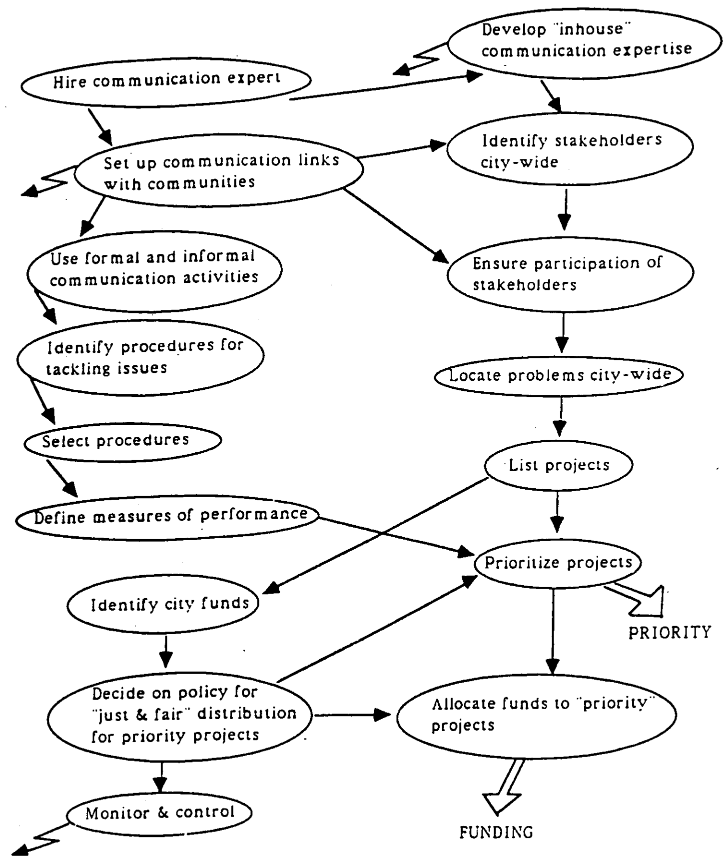

FIGURE 3 Conceptual model: City Council System.

agenda to debate the issues. Comparison of the Jackson Street Community System model with the problem situation indicates that, for example, collection of data is an important issue and should be taken up immediately with the city. Understanding the budget constraints of the city could also be considered an important issue. This interaction is shown in Figure 4.

Comparison of the City Council System model with the real world shows the vital importance of good communication between the city officials and all of the communities involved. Regular reporting procedures as a consequence of monitoring and control would resolve the issues of "secrecy" and "cover-up" leveled against city administrators. Lines of open communication between the city and Jackson Street CAC remove feelings of animosity because funding and priority issues are discussed openly.

Debate: Stage 6

Because the city officials have to decide whether or not to implement this shared street, the questions asked are, "Given the budget constraints, is it possible to provide a shared street, as requested by CAC? How does this project stack up with other priority activities needed to be implemented?" Armed with appropriate data and a cost-effective working plan, CAC

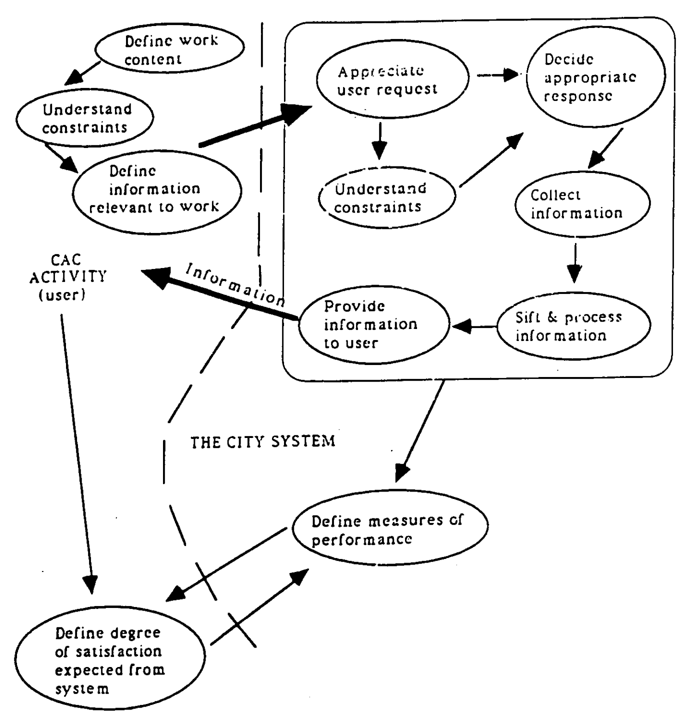

FIGURE 4 Interaction between Jackson Street CAC and city administration regarding the supply of information.

makes a pitch for effecting change. The debate can be widened if necessary.

Implementation: Stage 7

The Jackson Street community is now taking on a new shape and a confidence it can be proud of. The strategies for action developed in the debate with respect to cost effectiveness and priority help CAC in convincing the City Council to include this shared street project for implementation. A decision-making hierarchy is put in place and the process iterated that allows for communication structuring and community development by participative problem solving.

CONCLUSIONS

SSM essentially records the elements of the structure of the situation, the elements of the process, and the relationship between the two or the climate of the situation. It also examines the crucial roles of actors in the situation, the behavior expected in the roles (the norms), and the values by which performance is judged. More importantly, an understanding emerges of how power is acquired, exercised, retained, and passed on. Note that there are no right and wrong descriptions of human activity systems—only multiple possible descriptions based on different images of the world. Also noteworthy is that, in general, conceptual models of human activity systems describe what goes on in the system of concern, whereas at the comparison stage how these "whats" can be achieved becomes a subject for discussion. If necessary, these models are expanded at levels of higher resolution. The process can go through several cycles for further refinement.

It has been recognized that well-structured problems are extremely rare among human activity systems. This experience has brought about emergence of the soft systems approach, developed by Checkland (*3*) in SSM.

The need for SSM in citizen participation for transportation planning has been amply demonstrated by Wachs (*5*) in a paper concerned with a research agenda for transportation. He writes:

> The state-of-the art in transportation research is somewhat unbalanced. In the technical areas of data collection, analysis and forecasting, our field has advanced far beyond the capabilities which exist for the planning of housing, health care and other social services. With respect to the understanding of the political and social costs of transportation planning, and the nature of its institutions, our understanding is no deeper than that gained through research in other sectors. . . . I do not suggest that we should give little attention to the technical side. . .but it is also important, however, to give increased attention to the social and political dimension of transportation planning. . . . Only by improving our understanding of transportation institutions and decision-making processes, as messy and ill-defined as they may be, can we focus the work of the research community on improving the quality of public policy-making and decision-making. (*5*,pp. 521–531)

An example drawn from transportation planning and involving citizen participation demonstrates how SSM can be applied to resolve such problems and how to carry out systemic investigations in complex situations.

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Regional Versus Local Accessibility: Implications for Nonwork Travel

SUSAN HANDY

The question of how alternative forms of development affect travel patterns has recently been the focus of a heated debate, much of which centers on the effects of suburbanization in particular. The concept of accessibility provides an important tool for resolving this question. By measuring both the accessibility to activity within the community, or "local" accessibility, and the accessibility to regional centers of activity from that community, or "regional" accessibility, the structure of a community is more fully characterized. The research summarized uses the concepts of local and regional accessibility to test the implications for shopping travel of alternative forms of development in a case study of the San Francisco Bay Area. The results show that higher levels of both local and regional accessibility are associated with lower average shopping distances but are not associated with differences in shopping frequency. As a result, higher levels of both local and regional accessibility are associated with less total shopping travel. However, the effect of high levels of local accessibility is greatest when regional accessibility is low and vice versa. These findings suggest that policies should be directed toward enhancing both types of accessibility, but that the effects may work against each other to some degree.

The question of how particular forms of metropolitan development affect travel patterns has long been of concern to planners but has recently been the focus of a heated debate. Much of this debate has centered on the effects of suburbanization in particular, with some arguing that the decentralization of housing and jobs reduces overall travel (*1*,*2*) and most others arguing that the low-density development that is associated with decentralization leads to more automobile travel and gasoline consumption (*3*,*4*). At this level, it is a macroscale debate, centered on the overall structure of metropolitan regions and on total travel within those regions.

Within this discussion, the concept of neotraditional development has engendered more acceptance than true debate. Proponents of this concept suggest that the proper design of a suburban community can reduce the amount of automobile travel by its residents, particularly for nonwork travel, although little hard evidence has been presented to support the claim (*5*). At this level, it is a microscale debate, centered on the structure and travel patterns of a particular community. The broad question is to what degree—if at all—alternative types of suburban development create differences in travel patterns. The practical question is whether suburban form can be shaped to reduce automobile travel and mitigate the problems associated with it.

The concept of accessibility provides an important tool for resolving these questions, which demand a more comprehensive view—one that combines the micro- and macroscales. The amount that a person travels is influenced by both the character of the particular community in which he or she lives and the spatial structure of the region of which that community is a part. To test the implications for travel of alternative forms of suburban development it is necessary to characterize both the community and its region and to compare alternative forms in light of this dual characterization. Further, the structure associated with various types of activity and hence various types of travel—particularly work versus nonwork travel—may be vastly different. The measures that have typically been used to characterize development—population density and the jobs/housing ratio—have proved inadequate for this task. By measuring both the accessibility to activity within the community, or "local" accessibility, and the accessibility to regional centers of activity from that community, or "regional" accessibility, the necessary dual characterization is achieved.

The first goal of this research was thus to develop and refine definitions of local and regional accessibility as a way of describing the spatial structure of a metropolitan region and differentiating between specific communities within the region. The second goal of this research was to use these definitions to test the degree to which differences in nonwork travel patterns can be attributed to differences in the structure of communities. The basic hypothesis was that both local and regional accessibility would have significant correlations with nonwork travel patterns in a particular community and that the balance between the two would be important determinants of the amount of travel by residents of that community.

This paper presents the results of the first stage of research, an aggregate-level analysis of the San Francisco Bay Area for 1980 using existing data and simple measures of local and regional accessibility. First, basic definitions of regional and local accessibility are outlined. Second, the methodology used to calculate regional and local accessibility for the region is presented. The patterns of accessibility that these calculations generate are then compared to expectations on the basis of qualitative knowledge of the character of the San Francisco Bay Area. Finally, the relationship between accessibility levels and travel patterns for the region is tested in a variety of ways. This analysis generated several interesting, although preliminary, conclusions.

DEFINITIONS

Accessibility as generally defined consists of two parts: a transportation element or resistance factor and an activity

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element or motivation factor (*6,7*). The transportation element reflects the ease of travel between points in space as determined by the character and quality of service provided by the transportation system and as measured by travel distance, time, or cost. The spatial element reflects the distribution of activities, such as residences, employment, stores, offices, and so on. This distribution is characterized by both the amount and location of various types of activities. The spatial element is alternatively called the "attractiveness" of a particular location as a trip destination.

There is thus a substitutability between the transportation system and the distribution of activities in determining the level of accessibility (*8*). A given place may be very far from a few large activity centers or close to several small activity centers and have the same level of accessibility. Yet the implications for travel patterns may be very different. As a result, it is important to distinguish between types of accessibility, in particular to differentiate between regional accessibility and local accessibility. Local accessibility depends on close proximity to locally oriented centers of activity, whereas regional accessibility depends on good transportation links to large, regionally oriented concentrations of activity. By evaluating both the local and the regional accessibility of a community, both the character of the community itself as well as the character of the region and the quality of the links between the community and the region have been accounted for.

Three interrelated variables are thus combined to distinguish between local and regional accessibility. The first approach is to differentiate based on the size and location of the commercial concentration. For example, activities located within a certain distance contribute to local accessibility, whereas activities beyond that distance contribute to regional accessibility. In the first case, activity concentrations are likely to be small, whereas in the latter only large concentrations of activity will be relevant. A second approach is to differentiate by type of activity. For example, a grocery store contributes to local accessibility, whereas a department store contributes to regional accessibility. The two approaches are linked in that the willingness of an individual to travel a certain distance depends on both the type of activity and the amount of activity at the destination, according to the shopping and travel behavior literature (*9,10*).

Local accessibility is thus defined with respect to "convenience" establishments, such as supermarkets, drugstores, and dry cleaners. Only such establishments that are nearby or that are nearest to the community are included, and usually these establishments will be found in small centers or in stand-alone locations. Local accessibility should be associated with short and relatively frequent "local" trips, whereas the choice of particular destinations will depend to a large degree on the distance to that destination. Regional accessibility is defined with respect to regional retail centers, such as suburban shopping malls or downtown commercial areas, which offer a wide range of "comparison" goods. These centers may be close to the community or relatively far, but they attract customers from a wide geographic area. Regional accessibility should be associated with longer and less frequent "regional" trips, where distance is less of a concern in destination choice.

However, these distinctions are not entirely clean. While serving primarily comparison shopping needs, regional centers may also include convenience establishments. Similarly, comparison establishments, such as a clothing or furniture store, may be located within a primarily residential community. Thus, there may be some substitutability between local and regional accessibility. A high level of local accessibility may reduce the frequency of regional trips, whereas a high level of regional accessibility may reduce the frequency of local trips. The possibility of this substitutability is particularly important in resolving how the design of a particular community within a metropolitan region influences the travel patterns of its residents.

METHODOLOGY

The method used to calculate local and regional accessibility levels for the San Francisco Bay Area and to test the relationship between these measures and travel patterns was driven by two goals. The first goal was to keep the analysis as simple and straightforward as possible. This way, the effectiveness of a simple approach was tested before more time and resources were expended—perhaps unnecessarily—for a more complicated approach. The second goal, which is related to the first, was to make use of existing data. Again, this approach either proves sufficient or suggests that additional data are needed. This phase of the research thus provided guidance for detailed case studies that were conducted in the second phase of research and are described elsewhere (*11*).

The primary data source for this phase of the analysis was the Metropolitan Transportation Commission's (MTC) travel forecasting data base, which includes land use data as well as travel data. The data are provided at the zone level for 550 zones that have been aggregated from census tracts or at the superdistrict level for 34 superdistricts that have been aggregated from zones, or both. The original source of the land use data is the Association of Bay Area Governments' forecasts based on the 1980 census. Travel data are from MTC's 1981 Travel Survey, which covered 7,235 Bay Area households and was aggregated to the zonal level using 1980 census data; this survey provides some disaggregate data that can also be used. Although now a decade old, these data are the most recent currently available. Beside the obvious disadvantage of using dated data, its age meant that it was difficult to even find all of the data needed in the appropriate form.

Given the stated goals of keeping the analysis simple and using existing data, an exponential form of the gravity model was used for calculating both regional and local accessibility. This is probably the most widely accepted form of accessibility measure, at least at the aggregate level, and has the strongest theoretical basis of such measures (*7,12*). In addition, this form of accessibility measure was found to have the strongest correlation with travel patterns, and hence the strongest empirical basis, at least for this case study. The calculation of local accessibility will be described first, followed by a description of the calculation of regional accessibility.

Local Accessibility

For the purposes of this analysis, local accessibility was defined with respect to both the type of activity and the location of activity because only nonindustrial activity within a zone was included. The calculation of local accessibility using an exponential form of the gravity model required data on the attractiveness of local commercial activity and the impedance between residential areas and commercial areas. The measure of attractiveness was defined as retail, service, and other employment within the zone. Off-peak, automobile intrazonal travel times, computed by MTC as the average of the travel times to the three closest zones, was used for the impedance. The parameter is based on MTC's gravity model parameter for shopping trips, adjusted using data from the 1981 MTC survey on the trip length frequency distribution for convenience shopping trips.

The resulting formula for local accessibility was thus:

$$LA_i = \frac{(\text{retail} + \text{service} + \text{other employment})_i}{\exp\,(\text{time}_{ii} \times 0.1813)} \quad (1)$$

where i is the origin zone.

After local accessibility was calculated for each of the 550 zones, normalized values were calculated by dividing each zone's value by the mean value (weighted by population) for the region as a whole, excluding San Francisco zones. These normalized values allow for a focus on relative differences between zones, rather than the absolute values, which are largely meaningless except in a relative sense. Because the focus here is on suburban development, the highly urbanized San Francisco zones do not provide an appropriate comparison and hence were excluded from the calculation of relative levels of accessibility. All results presented will be based on these relative accessibility levels.

For the purposes of the analysis of travel patterns presented below, averages of local accessibility for superdistricts were needed. When averaged to the superdistrict level, zonal local accessibilities were weighted by population. By weighting values by population, those zones with an abundance of employment but very little population had a proportionately smaller effect on the superdistrict average. The superdistrict average thus reflects the level of local accessibility that residents in the district experience on average. Nevertheless, such averaging may mask very great differences within a superdistrict (just as using zonal accessibilities may mask great differences within a zone).

Regional Accessibility

Regional accessibility was defined in terms of access to specific regional retail centers. Definitions of centers were taken from the 1982 U.S. Census of Retail Trade. These centers included central business districts (CBDs) of the three major cities plus the smaller downtowns of the older suburban communities, regional shopping malls, and some areas of strip development. The census provided data on the number of establishments by type and on employment, although not by type of establishment, for each center. Centers ranged in size from a low of 17 establishments and 78 employees (in downtown Richmond, in the East Bay) to a high of 2,527 and 15,705 (in downtown San Francisco).

Unfortunately, the set of centers included in the census does not appear to be particularly consistent, with retail centers in some areas better represented than in others. For this reason, only centers that were clearly either a CBD or an identified regional shopping center, termed a "planned center" by the retail census, were included. Thus, many of the areas of strip development were screened out. In general, these screened-out centers were much smaller than those that were included. This approach is consistent with the definition of regional accessibility, which focuses on concentrations of retail activity that have a potential drawing power from a large subarea of the region. In addition, the sizes of the San Francisco centers were dampened, to reflect the extra cost and difficulty of reaching these urban centers, relative to suburban centers.

Travel times were taken from MTC's 1980 estimates of off-peak zone-to-zone travel times by automobile, where off-peak times are based on assumed free-flow travel speeds. Regional accessibility was calculated at the zone level, using average travel times from each zone to the zone of each center. The following measure was used:

$$RA_i = \sum_j \left[\frac{(\text{retain employment}_j)}{\exp\,(\text{time}_{ij} \times 0.1302)}\right] \quad (2)$$

where i is the origin zone and j is the destination regional center.

The parameter is based on MTC's gravity model parameter for shopping trips, adjusted using data from the 1981 MTC survey on the trip length frequency distribution for comparison shopping trips. As for local accessibility, normalized values were calculated by dividing each zone's value by the mean value for the region as a whole. Results will be reported using these relative accessibility levels.

CHARACTERIZATION OF SUPERDISTRICTS

To test the appropriateness of the local and regional accessibility measures, the calculated values for the San Francisco Bay Area were evaluated with respect to how well they matched qualitative knowledge about differences between subareas of the region. In addition to demonstrating the strengths of the accessibility measures, this evaluation highlights several limitations.

The San Francisco Bay Area is a fast-growing metropolis of roughly 6 million people—over twice the population of only 3 decades ago. The area encompasses 9 counties and nearly 100 cities, including San Jose (now the largest), San Francisco, and Oakland. Whereas population and industry are concentrated on the flatlands around the bay itself, new development is increasingly found in surrounding valleys extending in strips to the north, south, and east because the area is geographically constrained by the bay and several mountain ranges. As a result, several relatively distinct subareas are often referred to: the Peninsula, stretching south from San Francisco (Figure 1; Superdistricts 5–7); the South Bay, better known as Silicon Valley (Superdistricts 8–14); the East Bay, including Oakland and Berkeley (Superdistricts 16–20); the North Bay, including Marin County and the wine country (Superdistricts 25–34); and the Inland East Bay, consisting of San Ramon and Livermore valleys, over the hills, and to the east of the East Bay (Superdistricts 15 and 21–24).

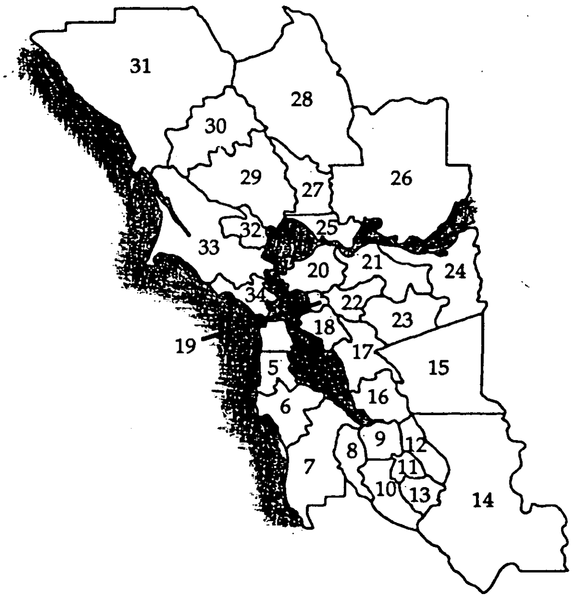

FIGURE 1 San Francisco Bay Area superdistricts.

Calculated values of regional accessibility ranged from a low of 0.03 times the regional average for Superdistrict 28 (St. Helena) in the North Bay to a high of 2.22 times the regional average for Superdistrict 9 (Sunnyvale) in Silicon Valley (Table 1). Values of local accessibility ranged from 0.38 times the regional average in Superdistrict 28 to 2.13 times the regional average in Superdistrict 8 (Palo Alto). Regional accessibility was found to vary more between than within superdistricts, whereas local accessibility was found to vary more within than between superdistricts. This makes sense, given that regional accessibility should be relatively equal among zones in particular sections of the Bay Area, whereas local accessibility levels may vary greatly from one zone to the next, depending on the distribution of activities. Thus, the remainder of this section looks at each measure in turn and considers first how regional accessibility differs between subareas and, second, how local accessibility differs within subareas. In general, patterns of regional accessibility match with expectations to a greater degree than do patterns of local accessibility.

TABLE 1 Regional and Local Accessibility Levels by Superdistrict

		Accessibility*	
Number	Superdistrict	Local	Regional
5	Daly City/San Bruno	0.75	0.85
6	San Mateo	1.29	1.04
7	Redwood City	0.81	1.35
8	Palo Alto	2.13	2.08
9	Sunnyvale	1.23	2.22
10	Saratoga	1.24	1.95
11	Central San Jose	1.47	1.68
12	Milpitas	0.66	1.42
13	Southern San Jose	0.64	1.10
14	Gilroy	0.73	0.11
15	Livermore	0.71	0.52
16	Fremont	0.78	0.92
17	Hayward	1.37	1.03
18	Oakland	1.08	0.93
19	Berkeley	1.28	0.92
20	Richmond	0.85	0.57
21	Concord	0.92	1.06
22	Walnut Creek	0.97	1.11
23	Danville	0.53	0.77
24	Antioch	0.49	0.42
25	Vallejo	0.90	0.55
26	Fairfield	1.15	0.18
27	Napa	0.69	0.17
28	St. Helena	0.38	0.03
29	Petaluma	0.64	0.09
30	Santa Rosa	1.07	0.30
31	Healdsburg	0.51	0.06
32	Novato	0.57	0.11
33	San Rafael	0.83	0.19
34	Mill Valley	0.63	0.22

* normalized to regional average

Regional Accessibility Characterization

The pattern of regional accessibility levels matches well with the distribution of regional retail centers and transportation facilities. Superdistricts with high levels of regional accessibility are concentrated in the South Bay or Silicon Valley area. This area is less geographically constrained than other parts of the Bay Area. The area encompasses many regional shopping malls as well as several important CBD areas—20 of the 67 regional centers identified in the retail census. In addition, the area is served by both north/south and east/west freeways. The Peninsula includes superdistricts of both high and medium levels of regional accessibility. This area is more geographically constrained than Silicon Valley and is characterized by a linear concentration of development along the bayshore, served by two north/south freeways.

East Bay superdistricts also have medium levels of regional accessibility, ranging from 0.57 (in Richmond) to 1.03 (in Hayward) times the regional average. This area is similar to the Peninsula, in that development is concentrated along the bay and is served by two north/south freeways. The superdistricts in the Inland East Bay have a similar range of levels of regional accessibility, from 0.42 to 1.11 times the regional average, but have lower levels on average than those in the East Bay. Finally, the North Bay superdistricts tend to have very low levels of regional accessibility, ranging from 0.03 to 0.55 times the regional average. This area is much more sparsely developed than the rest of the Bay Area and contains very few regional shopping centers.

Local Accessibility Characterization

Two basic types of suburban development, from different eras of the Bay Area's growth, can be identified. As the region expanded over the last century, many previously separated and outlying communities were absorbed into the regional fabric. Although now overwhelmed by what has become a continuous ring of development around the bay, their structure can still be distinguished from that of newer development. In particular, these older communities were built on traditional rectilinear grids and had central commercial areas that provided shopping and services for residents. Although their importance declined because of competition from regional shopping malls beginning in the 1950s, many of these commercial areas have been revitalized in recent years. Quite often, residential areas continue to border the downtowns, so that the mixing of commercial and residential uses is better than that in the newer suburban areas. In this way, these older communities resemble designs for neotraditional communities, although the reverse is more accurate. These older communities are concentrated on the San Francisco Peninsula and along the East Bay, with some found in outlying areas in the Livermore Valley and the North Bay.

Areas of the region that developed after World War II have a distinctly different structure. These areas are characterized by the separation of residential and commercial activities typical of post-World War II residential and commercial development practices. Large residential subdivisions that have limited links to the major arterials that flank them, if they are not in fact closed in by solid walls, are the norm. Commercial activity lines the arterials or is concentrated in strip malls or large regional malls and is highly automobile oriented. In short, it is this sort of development that the neotraditionalists are reacting against. These communities have been built on the fringes of the developed region as it has pushed outward over time, beginning in the South Bay, and are now pervasive in the inland East Bay and in many parts of the North Bay. Although significant commercial and industrial activity has followed the residential development in these areas over time, the character of these communities remains distinctly different from that of the older communities.

The pattern of local accessibility at the superdistrict level is not entirely consistent with the distribution of each type of community (Figure 2). The South Bay superdistricts have the highest average levels of local accessibility, despite the fact that this area consists of a mix of newer and older suburbs. The Peninsula, which consists more exclusively of older suburbs, has lower average levels of local accessibility, perhaps because many of these suburbs were traditional bedroom communities for San Francisco. The Oakland and Berkeley superdistricts (18 and 19) in the East Bay have average levels of local accessibility only 1.37, 1.08, and 1.28 times the regional average, respectively. Yet these superdistricts also contain some of the highest local accessibility zones. Berkeley and Oakland's highest local accessibility zones are both higher than those of Palo Alto, although Palo Alto has a higher superdistrict average. Superdistrict averages are more consistent with expectations in the Inland East Bay and in the North Bay, where development is generally sparser and lower in density.

The characterization of local accessibility patterns is difficult, given the degree to which local accessibility can vary between neighboring zones. Two problems were evident when the pattern of local accessibility by zone for a particular community was analyzed. First, the local accessibility measure does not reflect the degree of mixing of land uses within the zone. Two zones may have the same distribution between residential and commercial land uses, yet in one zone, the uses are well mixed and in the other, they are completely segregated, with residential in one half and commercial in the other. Second, the measures are dependent on the definition of the zones. In some cases, zones may have been defined such that only residential development is included, whereas in others, both residential and commercial areas may be included. Or a zone may contain primarily residential uses, but be surrounded by zones with commercial uses. The fact that a different zone system may lead to very different results points to the importance of a disaggregate evaluation of local accessibility.

RELATIONSHIPS TO TRAVEL PATTERNS

The relationships between regional accessibility, local accessibility, and travel patterns for shopping trips were tested in a variety of ways. The available data on travel patterns consisted of data aggregated from MTC's 1981 survey to the superdistrict level, rather than the zone level, and the raw survey data from which the superdistrict averages were ag-

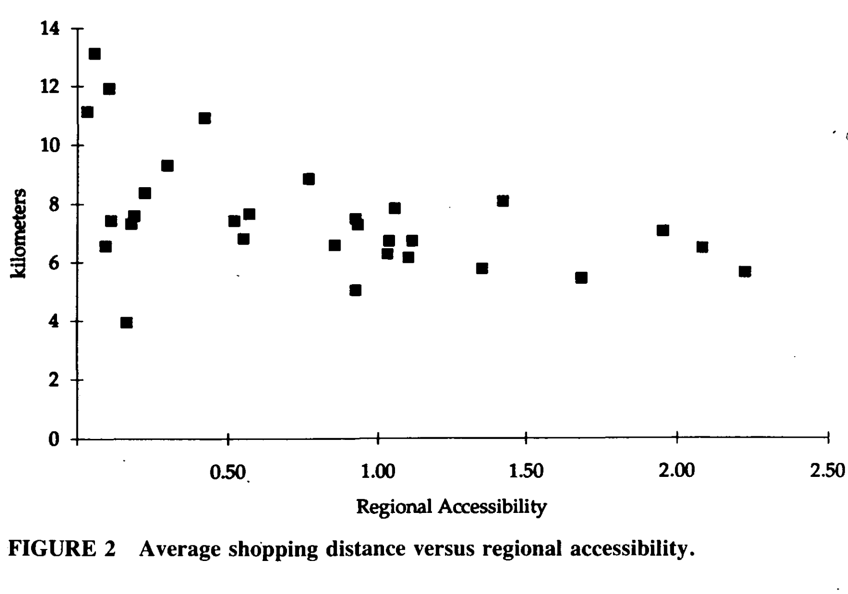

FIGURE 2 Average shopping distance versus regional accessibility.

gregated. Thus, relationships at the aggregate, superdistrict level were first tested using both plots and simple correlations. For this analysis, data were available for all shopping trips, with no distinction between comparison and convenience shopping. This is a particularly important limitation, in that accessibility measures should match the type of travel being analyzed. Then, the relative importance of local versus regional accessibility and the balance between the two were evaluated.

Hypotheses

The first hypothesis to be tested is that accessibility levels will be negatively related to travel distances: high levels of accessibility imply that activities are closer to residences so that minimum distances to activities are shorter. The second hypothesis is that there will be a positive relationship between trip frequency and accessibility: residents will compensate for low levels of accessibility—regional or local—by taking fewer trips but accomplishing more on each trip (by visiting more establishments, for example) or will take advantage of high levels of accessibility by taking more trips because they are relatively easy to make. If these two hypotheses are put together, then the third hypothesis is that accessibility levels will have little impact on total travel, as the higher trip frequencies and shorter distances associated with high levels of accessibility will balance out.

Although these hypotheses apply to both regional and local accessibility, slight variations are expected to apply for both, and the relationships are expected to be much more complicated than the basic hypotheses would imply. For example, very high local accessibility may be associated with more walking and thus less travel by automobile. But part of the expected complication is driven by the fourth basic hypothesis; that the balance between regional and local accessibility of a community significantly influences the travel patterns of its residents. In particular, high levels of local accessibility will encourage fewer trips to regional centers, whereas high levels of regional accessibility will encourage more trips to bypass local commercial centers for regional centers. In other words, those areas with high local but low regional accessibility should induce the least amount of travel, whereas those with low local but high regional accessibility should induce the most.

Findings

Significant relationships were found when superdistrict averages of local accessibility and regional accessibility were compared with average superdistrict travel characteristics. Shopping distance is plotted versus regional and local accessibility in Figures 2 and 3, respectively. In both cases, shopping distance decreases with increasing accessibility. The correlations (excluding San Francisco superdistricts) are −0.48 and −0.47, respectively, significant at the 10 percent level. This finding is consistent with expectations, given the definition of accessibility; a high level of accessibility implies that more opportunities are located close by. If Superdistrict 8, which has much higher average local accessibility than any other superdistrict, is removed, the correlation increases to −0.71.

The relationship between regional accessibility and shopping trips per person was virtually nonexistent ($r = -0.00$), as was the relationship between local accessibility and shopping trips per person ($r = -0.03$). These findings do not support the initial hypothesis that higher levels of accessibility are associated with higher trip frequencies. In other words, residents in areas with poor accessibility do not compensate by taking fewer trips, whereas residents in areas with good accessibility do not take advantage of this fact by taking more trips.

Combining trip frequency (trips per person per day) with trip length (kilometers) to estimate average person kilometers traveled (PKmT), significant correlations are again found for both regional and local accessibility, with values of −0.45 and −0.47, respectively, for shopping (Figures 4 and 5). Thus, the amount of nonwork travel is significantly lower in areas

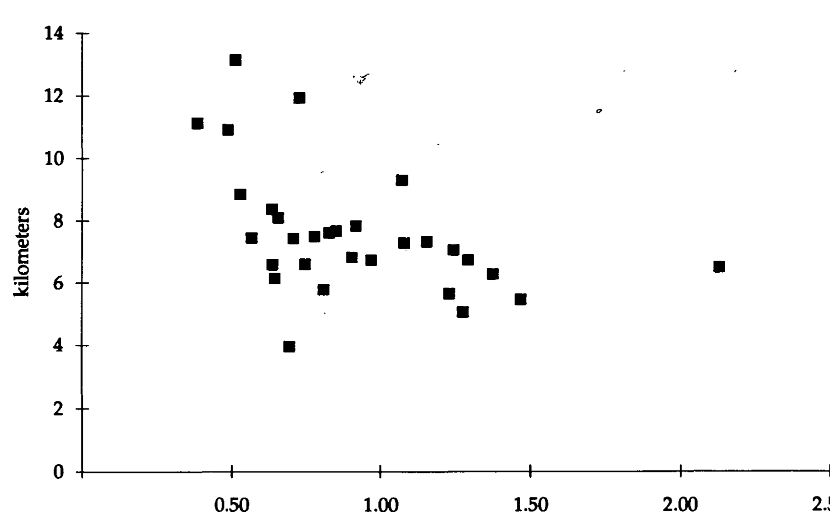

FIGURE 3 Average shopping distance versus local accessibility.

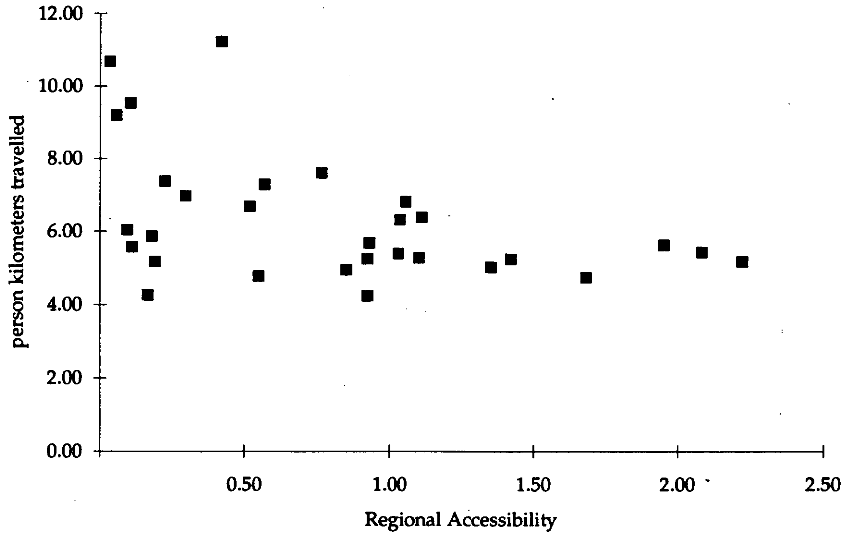

FIGURE 4 Average shopping travel versus regional accessibility.

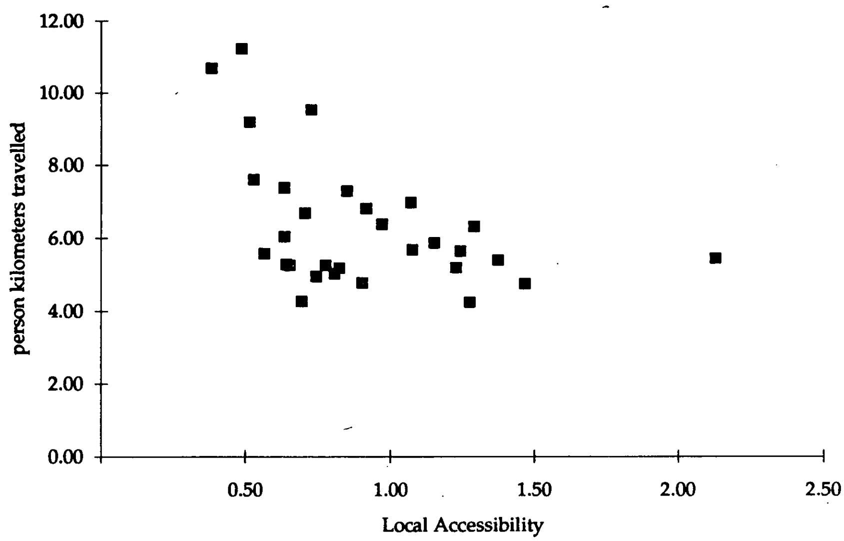

FIGURE 5 Average shopping travel versus local accessibility.

that have higher levels of accessibility, both regional and local. For example, the Hayward superdistrict, with high regional and local accessibility, has an average PkmT for shopping of 3.34, whereas the nearby Danville superdistrict, with low accessibility of both types, has an average PkmT for shopping of 4.73, or 42 percent more travel.

Regional Versus Local Accessibility Balance

To test the importance of the balance between regional and local accessibility and their relative influence, superdistricts were grouped according to accessibility levels. Superdistricts were divided into types, as follows: high (>1) or low (<1) local accessibility; high (>1.5), medium (0.75 to 1.5), and low (<0.75) regional accessibility. Average values of local accessibility and regional accessibility as well as travel characteristics for each of five types (not six because there are no superdistricts with high regional accessibility and low local accessibility) are shown in Table 2. Note that the number of each type of superdistrict is quite small, so that the results are mostly suggestive, rather than conclusive.

Clearly, average shopping distances increase as levels of both types of accessibility decrease. Type 1 superdistricts, with high local and regional accessibility, have an average distance of 6.17 km (3.83 mi) versus 8.59 km (5.34 mi) for Type 6, with low local and regional accessibility, a difference of 40 percent. On the other hand, there does not seem to be a clear relationship for travel time or trips per person consistent with results presented earlier. As a result, PKmT appears to increase as levels of accessibility decrease: Type 1 has an average PKmT of 5.27 versus an average of 7.33 for Type 6, also a difference of 40 percent.

A comparison of specific types of superdistricts helps to show the relative importance of regional versus local accessibility. First, local accessibility is held constant, whereas changes

TABLE 2 Travel Characteristics by Superdistrict Type

	Accessibility Level		Average Accessibility		Average Travel Characteristics		
Type	Local*	Regional**	Local	Regional	Kilo-meters	Trips per Person	PKmT
1	High	High	1.52	1.99	6.17	0.86	5.27
2	Low	High	n.a.	n.a.	n.a.	n.a.	n.a.
3	High	Medium	1.26	0.98	6.34	0.85	5.41
4	Low	Medium	0.76	1.07	7.19	0.82	5.84
5	High	Low	1.11	0.24	8.32	0.78	6.46
6	Low	Low	0.66	0.25	8.59	0.86	7.33

* High is greater than 1.0; Low is less than 1.0.

** High is greater than 1.5; Medium is 0.75 to 1.5; Low is less than 0.75.

in regional accessibility are varied. In comparing Type 1 and Type 3, which both have high levels of local accessibility, but high or medium levels of regional accessibility, respectively, it seems that regional accessibility does not significantly affect the total amount of travel. But Types 1 and 3 have a much lower PKmT than Type 5, which also has high (although not as high) local but low regional accessibility. In other words, a very large (seven times) decrease in regional accessibility (with a 37 percent decrease in local accessibility) has a substantial impact on PKmT—a 23 percent increase in this case. Note that the impact of regional accessibility was greater for communities with low local accessibility: for Types 3 and 5, which have high local accessibility but medium and low regional accessibility, respectively, the PKmT difference was 19 percent, whereas for Types 4 and 6, which have low local accessibility, the difference was 26 percent.

Second, regional accessibility is held constant whereas local accessibility is varied. A comparison of Types 5 and 6, both with low regional accessibility but with high and low local accessibility, respectively, shows that when regional accessibility is low, higher levels of local accessibility are associated with 13 percent less PKmT. Another interesting comparison is between Types 3 and 4, both with medium regional accessibility, but with high and low local accessibility, respectively. In this case, high local accessibility means only 8 percent less PKmT. The effect is in the same direction, but not of the same degree. This finding helps to confirm the hypothesized push-pull relationship between regional and local accessibility.

CONCLUSIONS

Despite the simplicity of the accessibility measures used and the limitations of the existing data, significant relationships between accessibility levels and patterns of shopping travel were found. High levels of either local or regional accessibility were associated with shorter average shopping distances, but not with trip frequency. Apparently, residents in areas with poor accessibility do not compensate by taking fewer trips, whereas residents in areas with good accessibility do not take advantage of this fact by taking more trips, suggesting that there is an average or standard number of trips that residents make, regardless of the distance they must travel. As a result, communities with high levels of both local and regional accessibility were shown to have as much as 40 percent less shopping travel than communities with low levels of both, a significant finding.

But the relationships with shopping travel are not entirely independent. The effect of each type of accessibility was most significant in those communities in which the other type of accessibility was low. On one hand, high levels of local accessibility were most important when levels of regional accessibility were low; the better the access to regional centers, the less the impact of local activity. On the other hand, high levels of regional accessibility were most important when levels of local accessibility were low; the greater the amount of local activity, the less the impact of good access to regional centers.

Thus, policies directed toward providing high levels of local accessibility in new developments or increasing levels of local accessibility in existing developments may result in less automobile travel than it would otherwise. But regional accessibility is also important. The fact that higher levels of regional accessibility decrease the distance but not the number of trips suggests that people will travel a certain amount no matter what the distance (at least within the range analyzed here), since certain needs simply cannot be provided for at the local level. In other words, proposals to enhance both local and regional accessibility may be right on the mark.

It is important to recognize that as levels of accessibility increase, the impact of accessibility-enhancing policies will tend to decrease and may cancel each other out to some degree. Neotraditional developments with high levels of local accessibility, for example, will have a greater effect on nonwork travel when located at the edges of the region than when they are located within the region surrounded by highly developed areas. Attention must be directed toward the provision of commercial activity within a community, but the effect of surrounding development must also be considered.

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Comparative Assessment of Travel Characteristics for Neotraditional Designs

MICHAEL G. MCNALLY AND SHERRY RYAN

The claim that transportation benefits can be derived from neotraditional neighborhood design is explored. Conventional transportation planning models are used as tools to evaluate the performance differences of two hypothetical street networks designed to replicate a neotraditional and a conventional suburban community. Relative transportation benefits are measured in terms of vehicle kilometers traveled, average trip lengths, and congestion on links and at intersections. This comparison provides an assessment of how well the two networks in question deal with trips generated by the activities that they serve. All aspects of the modeled communities are held constant except for the actual configuration of the networks. The results of this evaluation indicate that equivalent levels of activity (defined by the land uses within the community) can produce greater congestion with conventional network structures and that corresponding average trip lengths are generally longer. The ultimate goal is to determine if one network type, because of the nature of its design, can result in a more efficient transportation system. The results indicate that neotraditional designs can improve system performance.

The neotraditional design movement was largely originated by two urban designers, Peter Calthorpe and Andres Duany. Although their approaches are often described differently, that is, transit-oriented development and neotraditional neighborhood design, respectively, the content of the underlying concepts is very similar. This concept can be generalized as an attempt to reorient subdivision development toward patterns reminiscent of U.S. pre-World War II traditional communities. These patterns are based on mixed land uses, a highly interconnected street network (often in the form of a gridiron), and street design that accommodates the pedestrian and bicyclist equally as well as the automobile. Neotraditionalists are generally concerned with issues such as the degraded quality of life in the suburbs, a lack of conveniently assembled land uses, and the domination of automobile travel.

The term "conventional" is used in this paper to describe a fairly broad range of design practices whose beginnings can be traced back to the Garden City movement of the late 1920s. Current planning movements that fall under the category of conventional suburban design would be planned unit development (PUD) and cluster development, which became popular in the early 1960s. The original goal of these design practices was to provide a safe, peaceful environment removed from the overcrowding and automobile congestion of inner cities. Techniques used to achieve this goal include segregated land uses, hierarchical street networks, and extensive use of cul-de-sacs. One of the major purposes of conventional suburban design is to create an attractive living environment that is sustained by the convenience of automobile travel. The use of hierarchical traffic networks and cul-de-sacs is crucial in conventional design practices as a means of both providing accessibility to sometimes isolated developments and also removing potentially dangerous and unpleasant automobile traffic from the living environment.

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Neotraditional planners generally claim that their design practices will result in reduced transportation impacts. The basic arguments are that neotraditional neighborhood design will reduce automobile dependence, increase public transit accessibility, and reduce travel distances and times (*1–3*). The arguments examined in this paper are the latter, namely, that this design concept will result in reduced vehicle kilometers and vehicle hours traveled.

Other more specific claims have been made in a paper presented by Kulash (*4*). He concludes that neotraditional street networks function more efficiently than conventional networks because (a) the large streets of a typically sparse conventional network operate under deficiency of scale, (b) turning movements are more efficient on the smaller streets associated with neotraditional networks, (c) the increased route choices offered by the typically dense neotraditional network make real-time route choice possible (drivers are not always forced onto a few large arterials), and (d) uninterrupted flow is more likely to occur in a dense network because smaller streets make it possible to have more unsignalized intersections.

In the following comparative assessment of alternative suburban designs, the neotraditional network will be referred to as the traditional neighborhood design (TND) network; the conventional network will be referred to as the PUD network.

HYPOTHETICAL NETWORKS

Description of Networks

The modeling exercise is based on two hypothetical networks developed to replicate a neotraditional and a conventional subdivision. The networks were developed with the guidance of several sources to ensure realistic networks and land uses (*5–10*). The hypothetical subdivisions are both approximately 1.3 km^2 (0.5 mi^2), and have approximately the same level of activity. Certain aspects of the two site designs, however, are not modeled here. For example, mixed land uses that would typically be found in neotraditional developments are not accounted for in this exercise. Also, the effect of certain design characteristics of the street environment such as street width, lane width, or landscaping cannot be directly modeled.

The characteristic of prime concern, therefore, is the shape of the networks.

Both networks are situated on intersecting collectors that break the developments into four equal quadrants. Each network is enclosed by arterials on the northern and eastern sides and by collectors on the southern and western sides (see Figures 1 and 2: unlabeled links are local streets). Both networks have approximately the same amount of land devoted to rights-of-way and housing. As seen in Table 1, approximately 30 percent of each network is devoted to rights-of-way, approximately 3 percent of the total land is made up of commercial areas, and approximately 60 percent of each network is devoted to housing.

Residential densities are also similar in both developments. Table 2 gives densities by quadrant in each network. Each development alternative has an identical number of residential units per quadrant. The amount of land devoted to rights-of-way varies slightly by quadrant; this contributes to the differences in the amount of land per dwelling unit. Most proposals for neotraditional development have been characterized by narrower rights-of-way, but with a denser grid. For this analysis, an equal trade-off is assumed. Further work is required to formally assess this trade-off and its potential impact on residential densities and trip rates. The networks were divided into 17 conventional traffic analysis zones. Table 3 summarizes zonal land use for each alternative network design. Figures 3 and 4 show the zoning system, including the location of external stations. The transportation facility types used in each network were identical in terms of right-of-way widths, lane miles, peak-hour capacities (*11*), and posted speeds. Table 4 illustrates the values assumed for creating the hypothetical networks.

Limitations of Networks

Efforts were made to create networks that would offer sufficiently general examples of both types of subdivision design. The intent here was to use generalized networks so that broad conclusions could be drawn rather than conclusions limited to specific networks. The fact that these networks are hypothetical, however, presents a certain randomness in the exercise. The street networks and arrangement of land uses could have assumed numerous different forms while still being described as neotraditional and conventional. To a certain extent, therefore, the results are restricted to these specific networks. It was not within the scope of this paper to compare a large number of networks from which truly generalized conclusions could be drawn. Rather, an attempt was made to begin with networks that would provide some reasonable basis

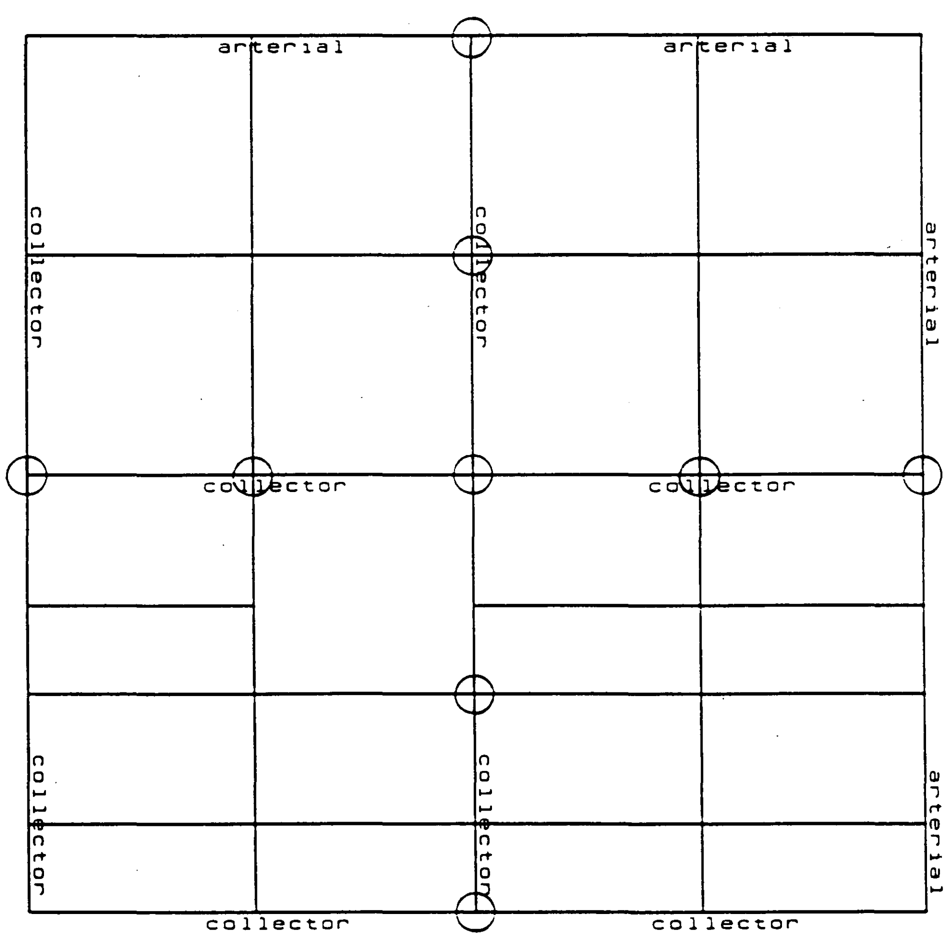

FIGURE 1 Neotraditional network design.

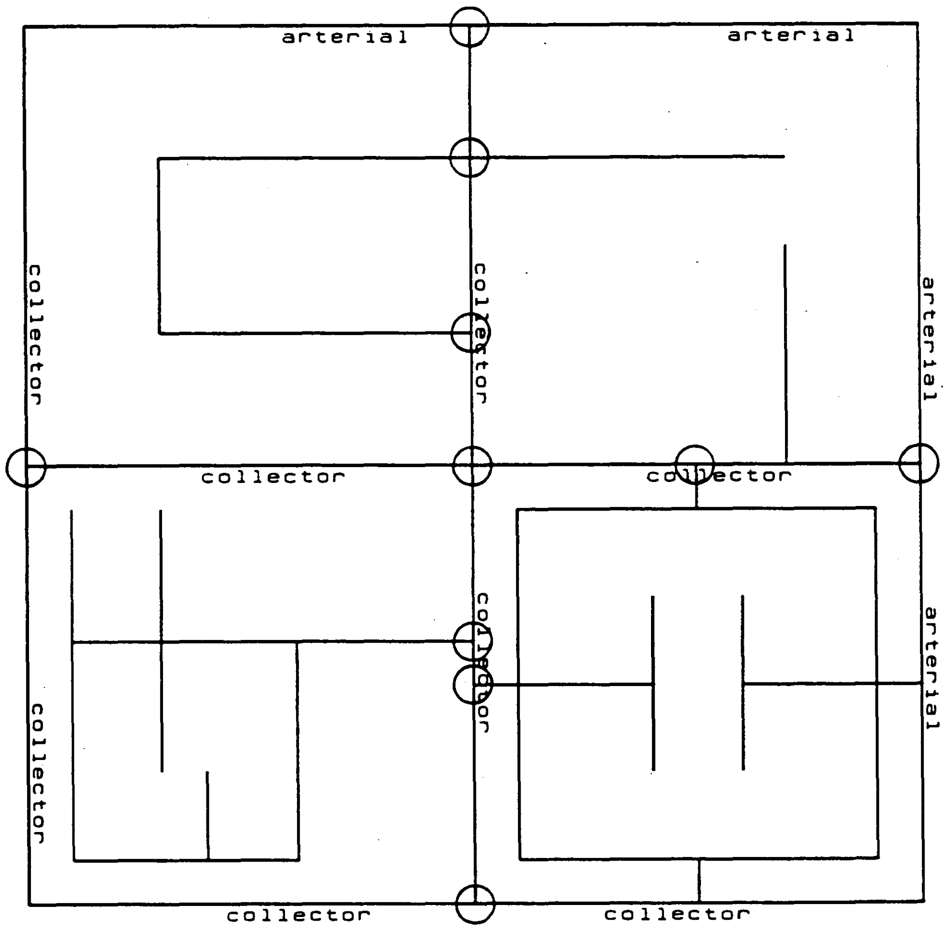

FIGURE 2 Conventional (PUD) network design.

for drawing general conclusions about the two design concepts in question.

COMPARATIVE ANALYSIS

Trip Generation

Trip generation for the study area was estimated on the basis of conventional land use trip rates, adapting rates developed by the city of Irvine, California (see Table 5). Other travel parameters assumed in this study were also based on those estimated for Irvine (*12*). Trip rates were applied to the land uses in the study area to produce estimates of total productions and attractions for the internal zones (1 through 17). These productions and attractions were categorized by the spatial orientation of the trip as (a) internal to internal (II), (b) internal to external (IE), and (c) external to internal (EI). To realistically simulate the distribution of trips in the study areas, it was assumed that a proportion of the trips would occur entirely within the area (II), and the remainder would have the production or the attraction outside the area (IE and EI). Eight external zones were created (see Figures 3 and 4). Because the external zone productions and attractions

TABLE 1 Summary of Land Use Percentages

LAND USE	TND[1]	PUDs[1]
Total Area of Development	439,649 m^2	439,649 m^2
Total Area devoted to R-O-W	131,784 m^2	128,439 m^2
Total Area devoted to Housing	261,152 m^2	264,498 m^2
Total Area devoted to R-O-W (%)	29.9	29.2
Total Area devoted to Housing (%)	59.4	60.2
Total Area devoted to Commercial(%)	3.4	3.4

1) 1 square meter = 10.76 square feet

TABLE 2 Land Areas and Residential Densities by Quadrant

QUADRANT	LAND USES	AREA (m²)	DWELLINGS	DENSITY (m²/DU)
Hypothetical Neotraditional Development Plan (TND)				
Southwest	School Park Housing R-O-W	11,617 11,617 50,185 19,516	118 units	425
Southeast	Housing R-O-W	70,631 22,304	144 units	490
Northwest	Housing R-O-W	81,784 11,152	480 units	170
Northeast	Commercial Housing R-O-W	23,234 58,550 11,152	360 units	162
Hypothetical Conventional Development Plan (PUD)				
Southwest	School Park Housing R-O-W	11,617 11,617 50,185 19,516	118 units	425
Southeast	Housing R-O-W	68,401 24,535	144 units	475
Northwest	Housing R-O-W	82,899 11,288	480 units	172
Northeast	Commercial Housing R-O-W	23,234 71,375 6,691	360 units	198

1 square meter = 10.76 square feet

TABLE 3 Land Uses by Zone

	TND		PUD	
Zone	Land Use	Quantity	Land Use	Quantity
1	Single family	36 SF units	Single family	34 SF units
2	Single family	38 SF units	Single family	28 SF units
3	Single family	36 SF units	Neigh. Park	1.2 km²
4	Single family	36 SF units	Single family	36 SF units
5	Single family	44 SF units	Single family	36 SF units
6	Elem. School	600 students	Single family	56 SF units
7	Neigh. Park	1.2 km²	Elem. School	600 students
8	Single family	36 SF units	Single family	36 SF units
9	Single family	36 SF units	Single family	36 SF units
10	Multi-family	120 MF units	Multi-family	90 MF units
11	Multi-family	120 MF units	Commercial	14,870 m²
12	Commercial	14,870 m²	Multi-family	90 MF units
13	Multi-family	120 MF units	Multi-family	180 MF units
14	Multi-family	120 MF units	Multi-family	60 MF units
15	Multi-family	120 MF units	Multi-family	120 MF units
16	Multi-family	120 MF units	Multi-family	120 MF units
17	Multi-family	120 MF units	Multi-family	120 MF units

1 square meter = 10.76 square feet

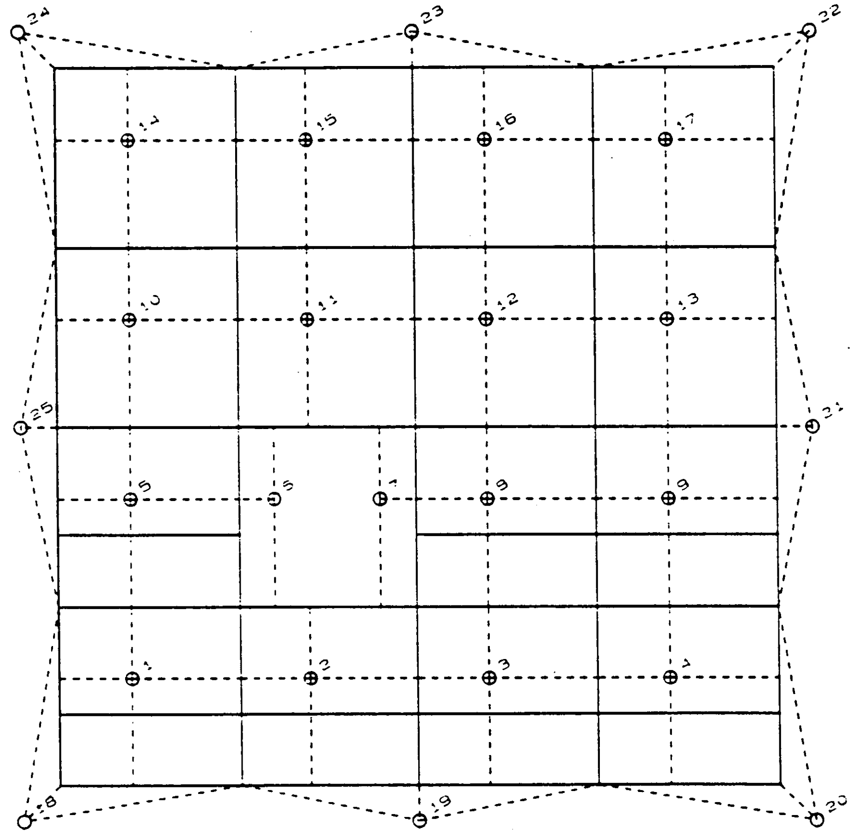

FIGURE 3 Neotraditional zone system.

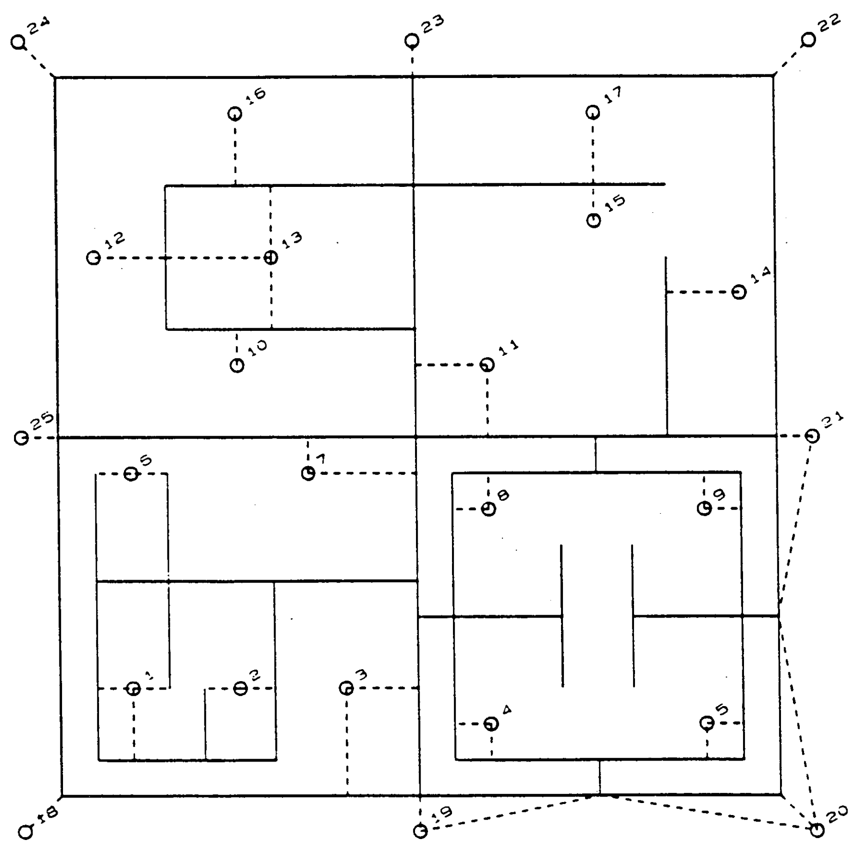

FIGURE 4 Conventional (PUD) zone system.

TABLE 4 Facility Characteristics (TND and PUD Networks)

Facility Type	1 Hour AM Peak Cap. (vph/lane)	R-O-W Width (m)	Number of Lanes	Speed (kph)
Arterial	800	33.5	2	64.4
Collector	600	24.39	2	48.3
Local	400	18.29	1	32.2

1 mile = 1.61 kilometers; 1 meter = 3.28 feet

could not be estimated as a function of nonspecified land uses (a shortcoming of modeling an isolated hypothetical subarea), they were estimated in proportion to the land uses within the study area. Specifically, an assumed percentage of the internal productions and attractions were generated outside the study area on the basis of assumptions of travel behavior and average travel times for each trip purpose. Trip length frequencies were adopted for each trip purpose (*12*) and used to determine the percentage of generated trips longer than 5 min that were assumed to cross the study area boundary (see Figure 5).

Because the study area is just less than 1.3 km^2 (0.5 mi^2), it was assumed that trips longer than 5 min would have to either begin or end outside the study area. A vehicle traveling at a constant 40.25 km/hr (25 mph) would traverse the study area in approximately 1 min; 5 min was used to account for delays or indirect routes. The area under the trip length frequency curve and to the left of the point on the x-axis depicting 5-min-long trips was assumed to represent the percentage of trips that would begin and end within the study area, corresponding to II trips. The remaining percentage was assumed to represent trips with one trip ending outside the study area or trips greater than 5 min, corresponding to IE and EI trips. Once these percentages were established for each trip purpose (see Table 6), they were applied to the original set of total productions (P's) and attractions (A's) by purpose. Zones 1 through 17 are internal zones; Zones 18 through 25 are external. Applying these splits to the total P's and A's resulted in estimates of P's and A's by trip type for each network.

Through trips were estimated with the intent of modeling realistic traffic volumes along the arterials and collectors found in the study area. Through trips were not distributed using the gravity model; rather, they were assigned to specific origin/destination (O/D) pairs and added directly to the origin/destination matrix. The method used to determine through trips was similar to that used for splitting P's and A's into II, IE, and EI trips. The trip length frequency curves seen in Figure 5 were used to determine that approximately 60 percent of home-based-work (HBW), home-based-other (HBO), and non-home-based (NHB) trips were longer than 20 min. By assuming that the study area is surrounded by similar types of areas, it could be assumed that 60 percent of the trips from each surrounding area would be longer than 20 min, a certain percentage of which would pass through the study area. It further was assumed that for each of the eight surrounding areas, one-fourth of the trips longer than 20 min would pass through the study area. The through trips added to the a.m. peak O/D matrixes were obtained by reducing the total through trips by a factor of 0.39 (*12*).

Because the neotraditional network provides greater accessibility than the conventional network (a 60 percent increase in connectivity measured in terms of the number of entrance and exit links), it was assumed that a greater number of through trips would be present with the TND design. At the site-specific level of analysis (as opposed to regional-level analysis), it is difficult to estimate the number of these trips. An increase in through trips for the TND design of 5 percent was assumed.

Trip Distribution and Assignment

Trip distribution was completed using a standard singly constrained gravity model routine. P's and A's for nine trip types were used:

1. Internal to internal (HBW, HBO, and NHB),
2. Internal to external (HBW, HBO, and NHB), and
3. External to internal (HBW, HBO, and NHB).

Friction factors from the city of Irvine were adopted for this study (see Figures 6–8). Using these factors could have introduced some error because they were developed for a study

TABLE 5 Trip Generation Rates (*12*)

LU Code	Land Use	Units[1]	Rate
12	Residential - Low Density	DU	10.00
15	Residential - High Density	DU	6.30
21	Community Commercial	1000 ft^2	70.00
72	Neighborhood Park	Acre	5.00
93	Elementary School	Student	0.75

1) 1000 ft^2 = 92.9 m^2; 1 acre = 3872.3 m^2

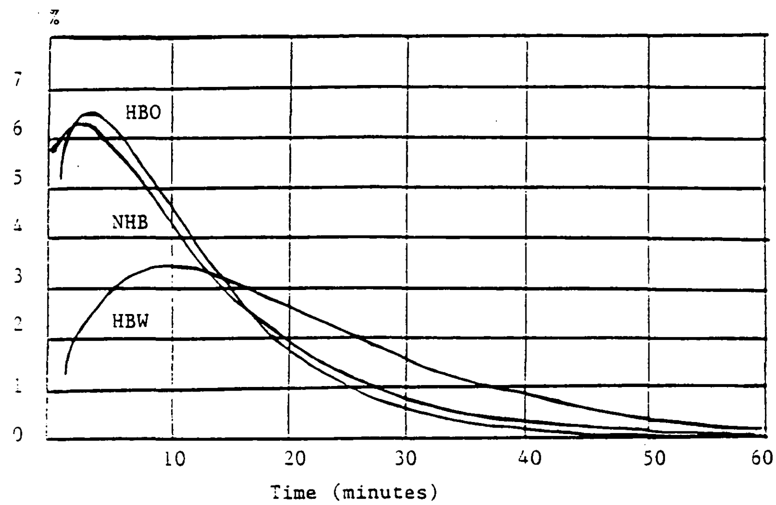

FIGURE 5 Trip frequency distributions (HBW, HBO, NHB).

TABLE 6 Percentage Splits for Total Productions and Attractions

	Internal-Internal			Internal-External			External-Internal		
	HBW	HBO	NHB	HBW	HBO	NHB	HBW	HBO	NHB
Internal Zones (1-17)									
P's	15	35	40	85	65	60	85	65	60
A's	15	35	40	85	65	60	85	65	60
External Zones (18-25)									
P's	0	0	0	0	0	0	85	65	60
A's	0	0	0	85	65	60	0	0	0

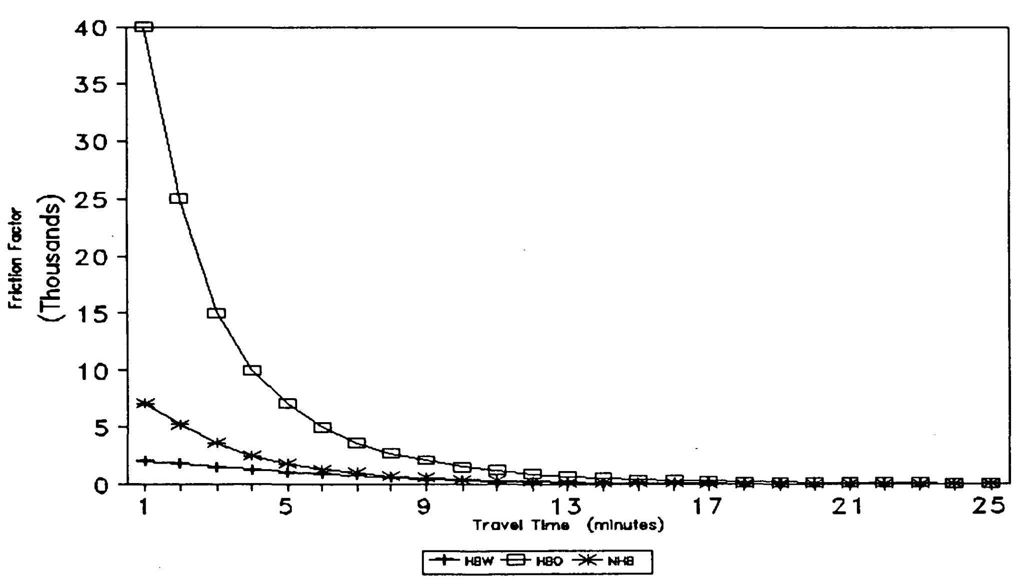

FIGURE 6 Friction factor distribution: internal-internal.

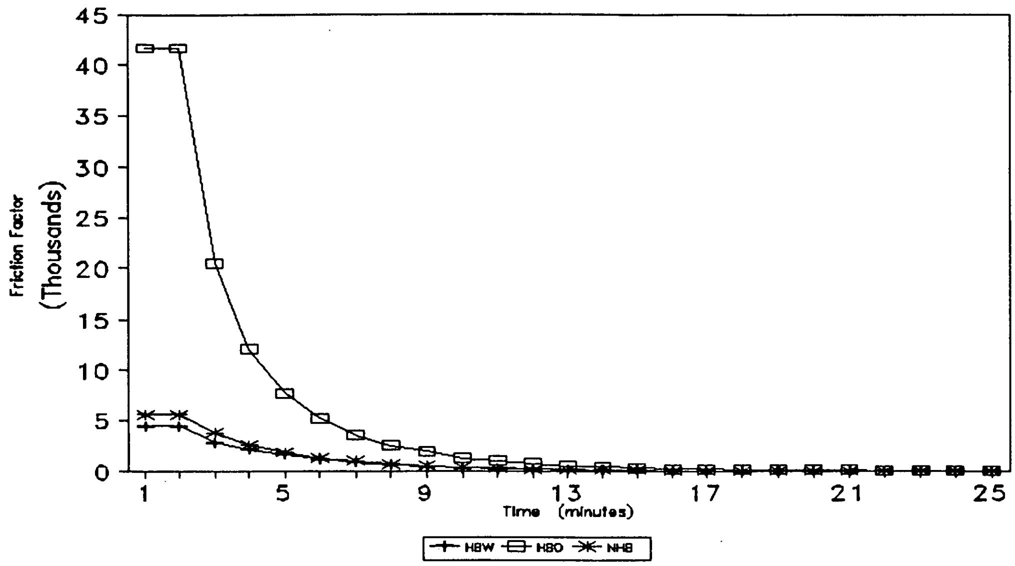

FIGURE 7 Friction factor distribution: internal-external.

area larger than that used in this exercise. Network loading was completed using a full user equilibrium assignment.

INTERSECTION ANALYSIS

Intersection analysis was conducted using a basic intersection capacity utilization (ICU) approach (*13*). This technique effectively compares volume-to-capacity ratios for each movement of an intersection. Input to the analysis program consists of the number of lanes per movement, the volume per movement, and the capacity per movement. Analysis is performed by identifying the highest conflicting volume-to-capacity (*V/C*) ratios for each direction and totaling these values into an ICU value that represents the percentage of the intersection capacity utilized by traffic demand. The ICU value is then used to reflect intersection level of service.

To compare the two networks in this exercise, nine intersections from the neotraditional network and ten intersections from the conventional network were chosen for ICU evaluation. These sample intersections included crossings of collectors with arterials, collectors with collectors, and collectors with local streets. The results of the intersection analysis are summarized in Table 7. These results indicate that there is not a great difference in the level of service provided by the intersections in the two networks. This is not fully consistent

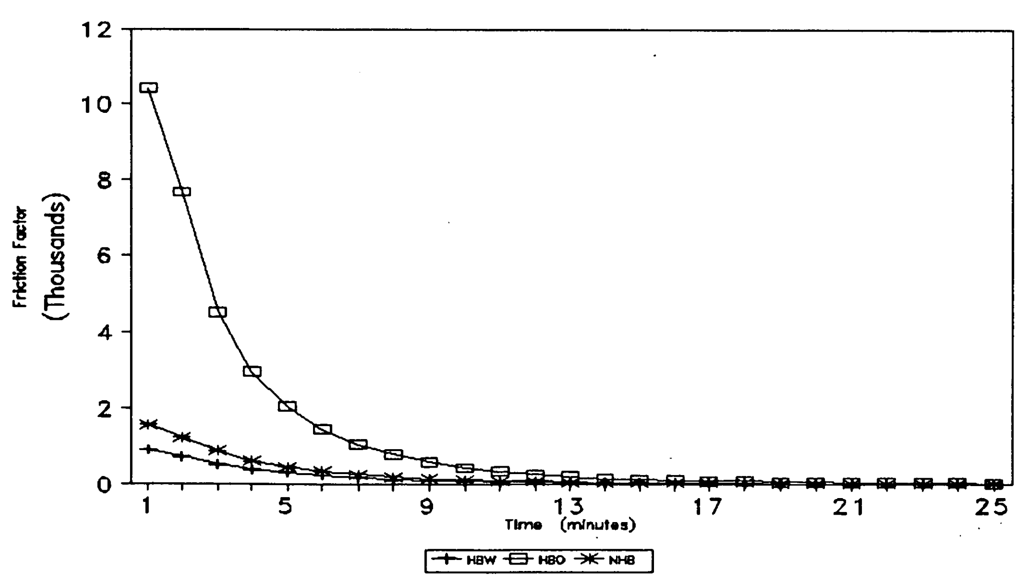

FIGURE 8 Friction factor distribution: external-internal.

TABLE 7 Summary of Measures of Effectiveness

Measure-of-Effectiveness	PUD	TND	Diff(%)[1]
1. Total Trips	14,019	14,733	+4.8
2. Vehicle-kilometers[2] (1000s)	290.13	259.36	-10.6
3. Total Vehicle-hours (1000s)	5.39	3.94	-26.8
4. Mean Speed (kph)[2]	53.85	65.75	+18.1
5. Mean Trip Length (km[2])	20.69	17.60	-15.5
6. Mean Trip Time (minutes)			
(a) Internal	1.74	1.50	-13.8
(b) Internal-External	14.79	9.87	-33.3
(c) External (thru)	14.64	10.76	-26.5
7. Intersection LOS			
(a) Arterial/Collector	0.78	0.79	1.9
(b) Collector/Collector	0.77	0.78	1.3
(c) Local/Collector	0.44	0.43	-2.7

1) Percent difference relative to PUD
2) 1 mile = 1.61 kilometers

with claims typically made by proponents of neotraditional design who suggest that a significant increase in intersection level of service (versus conventional networks) is achievable because of the dispersion of trips over the neotraditional grid. Examination of the selected intersections and the geometry of the alternative networks offers some explanation.

Figures 1 and 2 also present the selected intersections (unlabeled links are local streets). Five of the intersections are identical in each network; four of these are located on the periphery of the network and funnel external trips across the cordon. Although there are more entry/exit stations in the TND grid, there was also a higher proportion of through trips assumed. A systematic study of the tradeoff of network accessibility and increased travel, and the resultant congestion impacts, is necessary. It is also necessary to fully analyze resultant impacts of changes in intersection geometry that conventionally characterize TND plans.

Finally, intersections common to each network were compared to assess changes in level of service (LOS). For the central intersection (common to each network), the neotraditional network operates at an LOS that is 8 percent worse than that for the conventional network.

MEASURES OF EFFECTIVENESS

A variety of statistics were generated for postassignment evaluation. The following measures of effectiveness (MOEs) are based on a 1-hr a.m. peak trip assignment:

1. Vehicle kilometers traveled (VKT),
2. Average trip length,
3. Average trip length by trip type, and
4. *V/C* ratios.

Vehicle Kilometers Traveled

The VKT results show that the neotraditional network generates approximately 10.5 percent fewer kilometers of travel during the a.m. peak than does the conventional network. Total hours spent traveling during the a.m. peak in the neotraditional network is approximately 27 percent less than the hours spent traveling in the conventional network (see Table 7). Because the number of trips generated by each network is approximately the same, the difference in miles and hours traveled is very significant. The results imply that the neotraditional network operates more efficiently than the conventional network, most probably because of more direct routes and greater route choice. In addition, there is almost an identical amount of land devoted to right-of-way in each network, so that the increased efficiency cannot be discounted because of a greater supply of roadways. This factor is sometimes used as an argument to offset the apparent benefits of neotraditional design.

Mean Trip Length

The mean trip length in the neotraditional network is approximately 15.5 percent shorter than the trip length in the conventional network (see Table 7). These average trip length figures include trips that begin or end in the external zones. The length of each external zone connector varied, but in each network, the total length of the external connectors averaged 12.9 km. The neotraditional network has a definite advantage over the conventional network in that it has much greater accessibility from the external zones in terms of entrances to the study area. This factor could significantly affect route choice availability and, likewise, the resulting trip length.

TABLE 8 Vehicle Kilometers Traveled by *V/C* Ratio and Facility Type

VOLUME-CAPACITY RATIO	LOCAL		COLLECTOR		ARTERIAL	
	PUD	TND	PUD	TND	PUD	TND
0.2	128.8	20.9	0	0	0	6.4
0.4	22.5	0	1320.2	0	4033.0	2650.0
0.6	0	0	2509.9	6053.0	0	0
0.8	0	0	48.3	0	0	368.0
1.0	0	0	0	0	0	0
1.2	0	0	0	0	0	0
1.4	0	0	502.3	0	0	0

Note: V/C ratios for external connectors not included
1 mile = 1.61 kilometers

Average Trip Length by Trip Type

Results from average trip length by trip type show that, in effect, there is a greater difference between the trip lengths associated with external zones and the trip lengths strictly associated with internal zones. The II trip lengths in the neotraditional network are approximately 13.8 percent shorter than those for the conventional network, whereas the IE and the EI are approximately 33.3 and 26.5 percent shorter than those for the conventional network (see Table 7). As suggested in the previous section, the trip length by trip type results show that perhaps much of the trip length difference between the networks is caused by the increased accessibility of the neotraditional network to its external zones. Trip lengths associated with II trips are still significantly lower for the neotraditional network, a factor that directly reflects how the shape of the network itself is responsible for greater travel efficiency.

Volume-to-Capacity Ratios

The conventional network has 64 percent of its links operating at a *V/C* ratio of from 0.0 to 0.4, whereas the neotraditional network has 29 percent of its links operating at this level. About 30 percent of the conventional links operate at a *V/C* ratio between 0.6 and 1.0, whereas over 70 percent of the links in the neotraditional network operate at this level. All of these figures represent situations in which the networks are functioning within capacity. The conventional network, however, has 6 percent of its links operating above a *V/C* ratio of 1.0, which represents unacceptable levels of congestion. The neotraditional network has no links operating above a *V/C* ratio of 1.0 (see Table 8). These results suggest that the neotraditional design is better able to distribute trips throughout the network so that links do not become congested.

SUMMARY OF RESULTS

The performance measures obtained in this exercise indicate that in some senses the neotraditional network operates more effectively. The figures for kilometers traveled and average trip lengths point to the fact that less travel is required in the neotraditional network. In other words, drivers are able to choose more direct routes. Because no attempt was made to model the other elements of neotraditional neighborhoods that could have affected trip-making behavior (such as street design or mixed land uses), it must be assumed that the increased efficiency is entirely a result of more direct route choices. These results are consistent with earlier findings by Gordon and Peers (*3*), Kulash (*4*), and Stone and Johnson (*2*).

The congestion results obtained are less clear. Although the *V/C* link analysis indicates that the neotraditional network operates more efficiently, with no links showing volumes greater than capacity, the intersection analysis shows that the neotraditional network operates at approximately the same level as the conventional network. This result seems to contradict the neotraditionalists' claims that intersections should be less congested because there are more dispersed travel patterns.

The major limitation of the current results is the application to an isolated development. The transportation benefits of neotraditional design will most probably accrue on a regional basis. A comparative assessment of design benefits that reflects a regional mix of neotraditional and conventional developments is necessary. Such a development also will allow for the introduction of regional transit systems and a more accurate depiction of regional travel patterns.

ACKNOWLEDGMENT

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Improved Sampling Techniques To Determine Trip Characteristics for Traffic Impact Analyses

BRUCE W. LANDIS

The development of sampling and surveying methodologies for statistically reliable trip characteristic surveys of land developments was researched. The two goals of the sampling methodology research were to (a) determine the effect of a monetary incentive on questionnaire response rates and (b) estimate the coefficients of variation of primary and diverted trip types and hence suggest a statistically based sample size guideline for a particular type of land development—a community-scale shopping center. The final part of the survey methodology research was to examine bias potential in land development surveys. On the basis of the finding that current sampling and surveying methods were inadequate to determine statistically reliable trip characteristics for some land developments, a hybrid prototype survey technique was designed and tested. Reduction and analysis of the test survey data revealed important findings. First, the monetary inducement of $1.00 increased the survey questionnaire response rate nearly threefold, from 11 percent to nearly 30 percent. Thus, sampling error at a given confidence level can be reduced. Second, the coefficients of variation of trip lengths varied substantially on an hourly basis, with the total day averages estimated at 0.8 and 1.6 for primary and diverted trip types, respectively. With minor verification these can be used as transferrable parameters for conducting statistically reliable surveys at other locations. And third, a test was conducted for potential intrasite sampling location bias. The test was designed to detect bias potential without affecting the data; the potential for bias was detected. The research underscores the need for establishing appropriate sampling techniques as developed in this research.

Frequently, trip characteristics are estimated or inferred from survey data that are biased because of an inappropriate surveying methodology. More often, the data were not collected using statistically reliable sampling methods. Often the traffic analyst is removed from the data collection method (*1*) and thus the subsequent traffic impact analysis, mitigation determination, and corresponding regulatory exactions are inaccurate. Transferable and statistically sound sampling and surveying methodologies are needed so that reasonably accurate traffic impact assessment, mitigation, and exactions can occur.

Three major groups of trip characteristic parameters are used in impact modeling and regulatory exactions of land development: trip generation rates, trip types, and trip lengths. Trip generation rates are well studied for the majority of land development types, and data coverage is throughout the day (*2*). Although trip type research is not complete, it is increasing substantially. However, little transferable research or guidance exists in the area of trip length determination, and this parameter will be increasingly significant in both traffic impact fee assessments and concurrency evaluations (*3*).

In most site traffic impact analysis references, the trip length parameter is not addressed in detail. Although there were some earlier studies of land use specific trip lengths (*4,5*), compared with the trip type parameter, little research has been done on this important parameter. Commonly, trip length is considered during the trip distribution and consequently the assignment steps of the modeling sequence. One recent and comprehensive publication, *Traffic Access and Impact Studies for Site Development: A Recommended Practice*, identifies three commonly used methods of trip distribution: analogy, gravity model, and surrogate data (*6*). In the last two methods, the trip length frequency distribution (or average) is a major parameter and requires careful selection on the basis of accurate sampling and surveying of land development.

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CURRENT METHODS OF TRIP CHARACTERISTICS SURVEYS

The three common survey methods used to ascertain trip-making characteristics of land development are roadside interview surveys, patronage (sidewalk) interviews, and driver postcard surveys. Each was examined to determine its applicability to the task of data collection for determining trip characteristics of land development. The factors of applicability considered were accuracy, response rate, and survey bias potential.

Roadside interview surveys typically are employed along public roadways (*7*) and are commonly used at driveways of land developments. For land development types with limited access, the roadside interview survey may provide reasonable accuracy and a standard response, and the bias potential would be similar to that of the patronage (sidewalk) interview. However, complete and proportioned sampling of all driveways would have to be implemented to prevent intrasite sampling location bias.

The most common method of obtaining data (at shopping centers) is the patronage (sidewalk) interview (*8,9*). The drawback of this method is its potential for interview location-induced bias. This bias could be severe at neighborhood and community-scaled retail centers with multiple tenants and large variations in pedestrian traffic, unless extensive interview locations and rate planning (to ensure random sampling) are employed.

The third survey type is the driver postcard method. Although response rates are poor—a recent source (*10*) reports response rates in the range of 5 to 15 percent—some advantages of this type of "self-administered" survey are that (a) more candid results are possible because the response is done in private and generally at an unhurried pace, (b) the response is elicited without the pressures of a personal interview, and (c) it is generally the least expensive survey method (*11*).

TEST SURVEY SITE SELECTION

The trip characteristics of retail shopping centers were chosen for the research for two reasons. First, shopping center trip characteristics are perhaps the most complex of all prevalent single land development types. Second, the sample and survey design methodology for shopping centers must consider a host of factors (e.g., multiple driveways; multiple tenants/or pedestrian access points, or both; and hourly variation) not often present together in other land development types. An existing shopping center in Brooksville, Florida, was selected for low to moderate area growth, the tenant stability of the survey site, a tenant mix typical of community-scaled shopping centers, and multiple driveway and access points. The shopping center serves a primary trade area of approximately 26,400 persons. It encompasses 17 acres of land, consists of 162,000 ft^2 of gross retail space, and has as major tenants a discount department store and a grocery store.

PLANNING, DESIGN, AND EXECUTION

Sample Size

The total sample size equation used in this research was based on one that is frequently used in regional household surveys. The form is

$$N = CV^2 \times Z^2/E^2 \quad (1)$$

where

N = number of required samples,
CV = coefficient of variation,
Z = normal variate, and
E = accuracy level expressed as a proportion.

A target confidence level of 95 percent ($Z = 1.96$) and a 10 percent acceptable error were selected. For the coefficient of variation, the value selected initially was unity ($CV = 1.0$), based largely on the research and recommendation by Smith (*12*). The required (unstratified, unclassified) sample size based on Equation 1 is $N = 384$.

Questionnaire Distribution Method

After considering the available survey methods, it was determined that a hybrid interview-postcard survey method would need to be developed to provide relatively unbiased sampling. This method would allow testing for bias potentials, particularly intrasite sampling location bias. It would in addition provide the vehicle for testing a response incentive. It was hypothesized that by offering a monetary ($1.00) incentive to the potential respondents, the response rate would be increased substantially. Accordingly, the following are the specific aspects of the final hybrid sampling design:

1. Questionnaires are distributed randomly throughout the parking lot of the shopping center.
2. Questionnaires are not given to individuals; rather they are left on the parked vehicle.
3. A monetary inducement to complete the questionnaire is stated in the instructions.
4. As respondents exit the parking lot, they return the completed questionnaire to a survey team member and receive $1.00. Recorded on the returned survey are the time and driveway location number at which the questionnaire was received.

Questionnaire Format

The primary data sought from the respondents were the origin of their (incoming) trip and their destination after leaving the center. By obtaining the origin-destination (O-D) information, the type of trip and the trip length could be determined through geocoding. In addition to allowing identification of the exact location (i.e., street address) of the respondent's origin or destination, a response area for "nearest intersection" was provided. In effect, the modified questionnaire accommodated both a "preferred" and an "unpreferred" procedure of determining trip O-D information, thereby minimizing a portion of procedural bias. Because of the need to test specific bias theories (and hence minimize nonresponse bias), the response form was kept brief.

Temporal Sampling Considerations

On the basis of information in a report to a technical committee of the Florida ITE Section (FSITE) (A. S. Byrne, unpublished data, 1975), Wednesday was the day selected for both the test and control surveys because it represented the smallest daily variation in the traffic of a community-scaled shopping center. Likewise, the questionnaire distribution rate throughout the day was based on hourly traffic variation information within the FSITE report, and continual adjustment of the distribution rate was made so that temporal bias was minimized.

REDUCTION AND ANALYSIS

The usable responses (82 percent) were geocoded and classified into the three trip types—primary, diverted, and captured—pursuant to work by Oliver (*13*). The data attributes of each response were then input into a spreadsheet program and further reduction and evaluation were performed. The survey summary totals were 31, 41, and 28 percent for primary, diverted, and captured trips, respectively. The average trip lengths were 4.7 and 1.0 mi (7.6 and 0.6 km) for primary and diverted trips, respectively. The weighted average trip length was 1.9 mi (3.2 km).

Trip Type Composition and Implications

One important trend evident from the test survey data is the difference between the percentage of trip types in the p.m. peak hour versus that of the entire day. The data revealed a p.m. peak hour (4:30 p.m. to 5:30 p.m., adjacent street traffic) profile of 22, 44, and 34 percent for primary, diverted, and captured, respectively. These percentages are significantly different (in chi-square tests with confidence levels of both 90 and 95 percent) from the totals for the entire day. These differences can result in considerable error and controversy, particularly if the p.m. peak trip type percentages (and trip lengths) are used for traffic modeling, mitigation exactions, and impact fee calculations, as is frequently the practice.

Trip Length

The lengths of both primary and diverted trips varied substantially throughout the day. Primary trip lengths tended to be greater than the daily average during the early morning, midafternoon, and early evening hours. They tended to be less than the average during the periods of high adjacent street traffic volumes. Diverted trip length correlated directly with the development's relative traffic volume. It tended to be greater than the day's average of 1.0 mi (0.6 km) during the noon and afternoon rush hours and considerably lower during the early and midafternoon.

A more important result of the data reduction is seen in the hourly variation and total day average coefficient of variation (trip length). Although the average coefficient of variation (CV) for the primary and diverted trips is 0.8 and 1.6, respectively, both CVs vary substantially throughout the day (Figure 1). The diverted trip experiences the widest range with a low of 0.8 in the midmorning hours to a high of 2.0 in the evening. The primary trips vary at a different pattern with trip uniformity (i.e., low CV) in the p.m. peak rush hour. The weighted composite CV is also shown in Figure 1; its

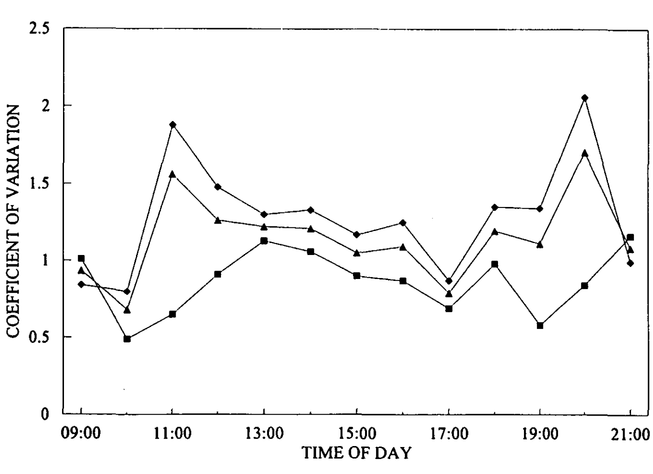

FIGURE 1 Coefficient of variation: hourly variation. (Note: These values are not statistically reliable for inference for some early a.m. and late p.m. hours because of small sample returns.)

weighting method is based on the relative proportions of primary and diverted trips for the respective period.

Response Rate

A control survey was conducted at the same site exactly 1 year after the first survey to evaluate the response incentive. Whereas in the test survey the average response rate was nearly 30 percent, in the control survey it was 11 percent. This rate was similar to that of a pretest (10 percent) conducted at another site before the original test survey. Although the control survey's percent shares of primary, diverted, and captured trips varied noticeably from those during the same survey period of the first test survey (44, 25, and 31 percent versus 30, 40, and 30 percent, respectively), the weighted average trip length was not significantly different (the T-statistic was -0.9) from that of the 1990 test survey during the same period studied (1:00 p.m. to 7:00 p.m.). Thus, it may be concluded that the same population was sampled both years.

EVALUATION AND APPLICATIONS

Coefficient of Variation

Perhaps one of the significant findings of this research is that the CV for trip length, an important variable in the sample size equation, is different for primary and diverted trip types and varies throughout the shopping hours. The research identifies, for both the total day as well as the various hours of the day, the estimate of the weighted CV. The average CVs estimated for the test site are 0.8 and 1.6 for primary and diverted trips, respectively. The findings may be used to initially determine sample size for both total day surveys or surveys whose goal is to obtain an estimate of trip characteristics for a specific time period (provided both the confidence limits and error range are not constrained within the shortened survey period).

Bias Control

The test survey was specifically structured to evaluate the commonly used roadside (or driveway/exit) sampling technique for its appropriateness in site surveys. Because the driveway exit selection of each survey respondent was recorded during data collection, reduction of the data permitted the identification of trip types and lengths as a function of driveway exit. Table 1 summarizes the day's totals for each. The most revealing result of the data reduction is that the observed percentages of trip types at the driveways are different from that of the parking lot (i.e., the total population). A contingency table (chi-squared) statistical test of the expected and observed returns confirms that there is a significant difference (at a 90 percent confidence level) between the sampling locations. This confirms the potential for intrasite sampling location bias.

As proportioned sampling is not feasible because of the high probability of differing access point selection rates of the

TABLE 1 Trip Type Percentages per Entrance

Sample Location	Primary	Diverted	Captured
Parking Lot	31%	41%	28%
Entrance #1	23%	43%	34%
Entrance #2	23%	49%	28%
Entrance #3	38%	37%	25%

trip types and because prestratification of trip types is virtually impossible, at land development survey sites (especially retail centers that have multiple access points), the roadside interview survey method should not be used except under one (limited) condition, wherein a single access point exists or can be temporarily created for the duration of the survey period.

Second, although the graphs are not shown here, trip type percentages were uniform at one of the site's entrances, but there was considerable temporal variation in the percentages utilizing the other entrances. Because each entrance has a different access geometry and serves different approaches to the site, the temporal variations and the differences in the trip type percentage totals among the entrances suggest that access configuration and traffic congestion may influence route choice, furthering the argument that roadside surveying at driveways of land developments with multiple access points should be avoided. To ensure representative population sampling, questionnaire distribution should be in the parking areas and should be metered hourly on the basis of patronage volumes.

Finally, although the test surveys reveal no data from which the sidewalk (patron) interview method can be proven to have relatively higher inherent biases, a case can be made for the high potential for interview (store tenant) location bias. Theoretically, unless the sidewalk interviews are proportioned among the pedestrian traffic (i.e., stratification of the pedestrian population according to store patronage), significant bias could be introduced into the survey. Although additional research and testing of this hypothesis are necessary for conclusive proof, it stands to reason that highly divergent tenant types will draw patrons of potentially different trip types and lengths, resulting in potentially substantial bias.

Response Incentive

The monetary inducement of $1.00 substantially increased questionnaire response rates from 11 to nearly 30 percent, thus reducing sampling error at a given confidence level. The effective cost reduction of the monetary incentive in the data collection phase was nearly 40 percent per response. The increased response rate makes this method vastly superior to the standard mailback postcard technique.

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Transit-Based Housing and Residential Satisfaction: Review of the Literature and Methodological Approach

JOHN SHAW

Given increasing problems with automobile dependence, many planners, policymakers, and others are examining the potential for alternative land use patterns in urban areas, specifically developing increased densities around existing or planned transit stations or developing new communities that would be served by rail transit. However, rail transit systems require certain minimum densities at both origins and destinations to be successful. Given a choice of residential locations within a metropolitan area, it is an open question whether residents will choose to live at densities necessary to support various types of transit service. Past research that has dealt directly or indirectly with this question is examined. Residential satisfaction studies have the most to offer; these are reviewed in some detail, and key findings are summarized. Hedonic pricing studies are reviewed and contrasted with studies of residential satisfaction. The strengths and weaknesses of both approaches are discussed, and modifications are suggested where appropriate. Finally, current research on satisfaction with high-density, transit-based housing is described.

Long accepted as given features of the American physical and cultural landscape, the automobile and the extensive network of roadways in American cities are currently under attack from many directions. Environmentalists point to the contribution of the internal combustion engine to dangerous levels of air pollutants in many cities. Economists note the drain on regional economies caused by the inefficiencies inherent in traffic congestion. Planners and policymakers worry about reliance on an energy source (oil) that is imported from other countries in large quantities, which decreases national energy independence. And everyone who experiences regular, extended traffic congestion complains about the associated stress and unpleasantness.

In light of these problematic aspects of continuing automobile dependence, an increasing number of planners, policymakers, architects, and developers are examining the potential for alternative land use patterns in urban areas to decrease the reliance on automobiles. A common starting point has been to support or develop increased densities around existing or planned transit stations or to develop neotraditional communities that would be served by rail transit. Theoretically, the higher residential densities would increase the potential ridership of transit lines and would also provide the consumer base necessary to support local commercial establishments within walking distance of many of the residents. In both of these ways, higher residential densities would contribute to decreased automobile dependence while maintaining or increasing accessibility to jobs, services, and other urban functions.

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NEW DEVELOPMENT ALTERNATIVES

Newly designed communities suitable for rail transit have been given considerable attention in recent years (*1,2*). Few if any such developments are actually in place, but plans have been proposed for several sites in northern California, including a potential city of 80,000 in Placer County east of Sacramento (*3*). The proposal would connect 10 "village neighborhoods" with walkways and mass transit. In the county of Sacramento itself, transit-oriented developments are explicitly identified as an objective in the county's draft general plan land use element (*4*). The objective, supported by a number of specific policies, states: "Locate higher residential densities and non-residential intensities that are designed to accommodate non-automobile modes of travel within walking distance of transit stops and along key transit corridors" (*4*,p. 96).

Transit and land use planners in many cities that currently have light or heavy rail lines have urged development of high-density residential, commercial, and office buildings near transit stations. In the San Francisco Bay Area, such development has occurred in fits and starts around Bay Area Rapid Transit (BART) stations since the late 1960s. Local opposition to zoning variances, periods of economic sluggishness, and the multiplicity of jurisdictions through which BART passes have all restricted opportunities for such development, although recent development proposals and state, regional, and local plans have begun to shift slightly toward transit-based development. A 1991 study released by the Transit/Residential Access Center of the University of California's Institute of Urban and Regional Development identified 16 major projects under construction or recently completed in the Bay Area near BART, CalTrain, or the Guadalupe rail system in Santa Clara County (*5*). Each development exceeded 30 units in size and 15 units/acre in density, and each had been built to capitalize on access to rail transit stations.

Transportation and land use planners have generally supported the idea that increased residential or employment densities around the stations would reduce traffic congestion and increase transit ridership. A sensitivity test of the 1991 Regional Transportation Plan for the San Francisco Bay Area assumed denser residential development around various Bay Area transit stations in the year 2010 (*6,7*). Although improvements to traffic conditions were fairly modest, this collaborative effort between the Metropolitan Transportation Commission and the Association of Bay Area Governments indicates the willingness of land use and transportation planners and policymakers to explore land use options for mitigating transportation problems.

Pushkarev and Zupan (*8*) examined existing residential and employment densities in the New York City metropolitan area in terms of the level of transit service each subcenter (such as Newark, Hartford, and midtown Manhattan) was able to support. They arranged transit systems in a rough hierarchy, depending on the densities required for each system to operate successfully (i.e., within the generally accepted levels of operating subsidies provided to transit systems at that time). Taxicabs and dial-a-bus services operated successfully at the lowest densities, followed by local fixed-route bus service, express buses, light rail, heavy rail ("standard rapid transit"), and commuter rail. Although any specific application of these technologies to a particular place and time would produce variations in the theoretical minimum densities required, the examples cited by Pushkarev and Zupan of transit services in the various New York subcenters tend to support their overall conclusions. A particular type of transit would work well in a city that met or exceeded the theoretical minimum density (expressed in residences per acre and million square feet of nonresidential floor space in the downtown area) but would usually struggle in a city that did not meet this minimum.

These findings, based on empirical analyses of existing systems, provide a benchmark against which minimum residential densities can be measured for their suitability for various types of transit service. For instance, in a later work, the authors noted North American cities that might be appropriate sites for rapid and light-rail systems on the basis of residential density patterns and the size of their central business districts (*9*). Such studies, although useful for determining what types of transit systems might not work in a given setting, are flawed in their assumption that residential densities of the type needed to support a particular transit system would in fact be achievable. In other words, they paint an idealized portrait of the best possible transit system an area could support; if actual residential densities are lower than anticipated, the expectations for transit service would need to be scaled down appropriately.

STATEMENT OF PROBLEM

Given a choice of residential locations within a metropolitan area, will enough people choose to live at densities supportive of various types of rail transit service for these services to be viable? The TRAC study mentioned above offers a tentative answer in the affirmative, but the large amount of rental housing in the projects under study (85 percent of total units) raises doubts about the extent of choice actually available to the projects' residents. This question would seem to be key to anticipating the success of various transit systems (particularly capital-intensive systems, such as light and heavy rail lines, which often are sold on their ability to focus development around transit stations). In addition, answering this question would provide an indication of the potential success of the new transit-oriented developments mentioned earlier.

The study on which this paper is based addressed the broad question of the viability of transit-based high-density residences by focusing on two more specific questions:

- What elements or attributes of transit-based, high-density housing are most attractive and least attractive to potential residents?
- Do potential submarkets exist that respond more or less favorably to transit-based, high-density housing?

A better understanding of the desirable and undesirable attributes of transit-based, high-density housing can aid planners in developing specifications and modifying zoning around transit stations to support attractive and discourage unattractive attributes. In addition, such information should prove useful to developers, designers, and architects interested in constructing or modifying such housing. An identification of existing or potential submarkets will also enable the construction of appropriate housing and neighborhood conditions. To the extent that such submarkets can be identified, they can also provide insights for transit planners that can anticipate particular sets of travel behaviors, travel frequencies, and mode choices, depending on the likely residents near the transit stations.

The key research literature for this study is the work on residential satisfaction although neither density nor transit proximity has been a key variable in most residential satisfaction research. The paper also reviews relevant hedonic pricing studies, which, although using a very different method, attempt to answer some of the same questions as residential satisfaction researchers: in particular, what are the key attributes that contribute to value in housing?

RESIDENTIAL SATISFACTION

Residential satisfaction research provides the strongest basis for an investigation into attitudes toward transit-based, high-density residences. No in-depth studies have focused specifically on this set of characteristics, although density has been a common topic of investigation and transit accessibility an occasional one. To some extent, this reflects the relative newness of much of the transit-based residential work.

Research Overview

Foote et al. (*10*) provide an overview of early research in residential satisfaction and identify several themes that have continued to be a focus of research:

- Home ownership is an extremely strong social value.

> It seems safe to say that owning a home, even more than suburban living per se, is a basic part of the American dream of the good life. The fact that economists regard it as a questionable course of action on the part of the marginal buyer is more or less beside the point. Home ownership is not a purely rational utilitarian choice. It is overcrusted with sentiment, symbolic value, and considerations of status and prestige. (*10*,p. 190)

- Residents generally are satisfied with both the location and the quality of their dwellings.

- The social characteristics of the neighborhood are a potentially significant source of dissatisfaction with the residential location [see also work by Keller (*11*) and Moriarty (*12*)].
- Men are generally more satisfied with suburban living than are women, and adults in their 20s through 40s are more satisfied with the suburbs than teenagers and adults over 50.
- Suburban developments are valued highly for amenities for young children, especially safety, room to play, and good schools.

For the questions posed here, however, this summary lacks two key elements: residents' reactions to higher-density dwellings per se, and attitudes toward various transportation modes. These elements are introduced in research by Lansing et al. (*13,14*). In their latter work, the authors studied several planned communities in the United States (including Reston, Virginia; Columbia, Maryland; and Radburn, New Jersey), matching them with studies of "less-planned" communities. The effort to determine the extent to which the planned nature of the community affects the attitudes and behaviors of the residents is intriguing, although the study is hampered by the relative newness of Reston and Columbia (most residents had moved to these communities within the previous 2 years). Residents expressed greatest satisfaction with low neighborhood densities (under 2.5 dwelling units/acre), although only the highest density (above 12.5 dwelling units/acre) substantially decreased residents' satisfaction. Townhouses (predominating in higher-density areas) showed similar levels of satisfaction to single-family houses, except at extremes of density. Apartment dwellers were not studied. The authors note that "the preference for low density seems to arise out of needs for privacy, quiet, and outdoor space, needs which are met in varying degrees by different site arrangements" (*14*,p. 122).

The study also examined transportation behavior. Of the newer suburbs, both planned and less planned, only Reston showed a substantial number of transit commuters because of commuter bus service to Washington, D.C. Radburn and its "matched" community in the New York suburban ring both had substantial commuter use of transit, with bus, rapid transit, and commuter railroads all used. Although Columbia apparently had more bus service than a typical suburban or exurban community, only 5 percent of respondents said that they used the bus at least once a week, although 39 percent stated that it was "very important" to have a bus stop near their home. Because transportation facilities were not an integral part of the development of any of the planned communities studied here (including those in the central city areas of Detroit and Washington, D.C.), this research can only act as a general guide to the question of the attractiveness of transit-based, high-density residential developments.

A nationwide survey of metropolitan area residents (*15*) provided a richly detailed examination of residents' satisfaction with their environments. The research framework focused on attributes of various life domains, including housing, neighborhood, and community. The model included both individual perceptions of objective attributes and standards against which attributes are judged to relate attributes to expressed levels of satisfaction.

> Thus the model . . . makes a critical distinction between objective indicators (the reality) and subjective indicators (perceptions, assessments, and satisfactions) of the quality of the residential environment. This distinction is based on the assumption that characteristics of the individual intervene so as to influence the subjective indicators. Specifically, the manner in which an objective environmental attribute is perceived and assessed by individuals is modified by their present situation, their attitudes, and their past experiences. (*15*,p. 264–265)

Unfortunately, the study provided little information about residential density at either a community or neighborhood level. Type of residence was used as an independent variable, with significant correlations on ratings of satisfaction. However, this relationship largely disappeared when factors such as type of tenure (owner or renter) and unit size were taken into account. No questions were asked of travel behavior or proximity to transit service. Nevertheless, the study provides a cogent framework for understanding any relationship between satisfaction and environmental attributes [see also work by Marans and Rogers (*16*) and Marans (*17*)].

Another national survey conducted in the early 1970s is described by Baldassare (*18*). Following Hawley (*19*), he notes the potential benefits of high-density neighborhoods: a higher opportunity for diversity and stimulation, more conveniences, and a qualitative improvement in transportation and communication (*20*). But high-density neighborhoods can also produce conflicts over scarce resources and increased congestion. Baldassare observes that some individuals choose to live in high-density neighborhoods and speculates that "people with greater economic resources may be able to manipulate high-density settings to drastically reduce their costs and increase their benefits (e.g., using doormen and soundproofing to reduce interference)" (*18*,p. 161).

Baldassare identified moderate negative correlations between neighborhood density and overall neighborhood satisfaction (controlling for age, education, home ownership, years in the neighborhood, and census tract median income). However, these correlations did not translate into an increased desire to move. A possible explanation for this somewhat counterintuitive finding is provided by Michelson (*21*), who reports on one of the few longitudinal studies of residential satisfaction. Apartment dwellers, although expressing less satisfaction than residents of single-family houses, are no more likely to move because of their general expectation that their living conditions are temporary; that is, they plan to eventually move into lower-density housing in a suburban environment.

All the studies described found at least a moderate level of satisfaction with the residential environment. This general satisfaction is found among residents of single-family houses, townhouses, mobile homes (*22,23*), and even high-rise apartment buildings (*21,24*). However, most respondents aspire to a single-family detached house (*25,26*). This undoubtedly reflects the strong North American value placed on home ownership, as mentioned above by Foote et al. (*10*). However, it also is a reflection of objective features of a single-family house. One of the most salient of these may be private outside space (*27–29*), particularly for families with children. The ability of an owned, as opposed to rented, residence to be altered at the owners' wishes is also important (*21,30*).

Several studies have supported the findings of Foote et al. (*10*) that men are generally more satisfied with lower-density living than are women, particularly if women are not employed outside the house (*31,32*). Shlay and DiGregorio recommend that women would be more satisfied in residential settings with higher densities, levels of public service, and transportation, but "retain(ing) much of their residential ambience" (*32*,p. 66). Spain (*33*), however, noted that marital status appears to be more significant than sex as a predictor of neighborhood satisfaction; households consisting of a single person, whether male or female, express lower levels of neighborhood satisfaction than do those with married couples. Because persons in single-person households may be younger than those in married households, additional research is needed to determine if this finding is an artifact of age. Increasing age is generally associated with increasing satisfaction (*15*).

These findings support Galster's (*34*) critique of residential satisfaction studies, that such studies should be disaggregated by household type. In addition, he identifies nonlinearities between residential settings and their associated levels of satisfaction. These stem from the possibility that an upper bound of satisfaction is reached on various attributes (such as number of rooms within a house) and the diminishing marginal utility of increases in the levels of these attributes. These operate together to produce a curvilinear function that describes the relationship between satisfaction and various features of the residential environment. However, the shape of these functions is likely to vary substantially across different households that have their own sets of aspirations or perceived needs and that respond uniquely to gaps in such aspirations or needs and reality.

This disaggregation by households suggests differences in "life-styles," a topic explored on a parallel path by Kitamura (*35*) in his examination of life-style factors and travel demand. He identifies two major components of life-style: activity and time-use patterns, and values and behavioral orientation. Both components are useful in conceptualizing individual variations of residential satisfaction: values motivate individuals (or households) to achieve certain types of residential settings, and the settings in turn constrain or assist particular activity and time-use patterns.

This overview of residential satisfaction assessments suggests several themes that are of importance in evaluating the potential for transit-based, high-density residential developments:

- Most residents have a strong preference for ownership of a detached, single-family house.
- Certain groups of residents may be less inclined to favor single-family houses, particularly in suburban locations; these include the elderly, teenagers, and housewives working in the home. In addition, single householders of either type may be less likely to favor low-density living.
- Regardless of their current living conditions, most residents report general satisfaction with their home and neighborhood. Statements of dissatisfaction in and of themselves are not indications that an individual or household is planning or expecting to move.
- Income is likely to be a significant intervening variable affecting attitudes toward various residential locations.

Measures of Density and Proximity to Transit

Most residential satisfaction studies have not included valid measures of residential density in their model specifications. Many studies have not attempted to include such a measure, although some include characteristics that are clearly correlated with density. Sanoff and Sawhney (*27*) measured privacy from neighbors, ability to park in front of home, presence of front or back yard, and proximity to friends and services; all of these are likely to be correlated with various levels of density. Campbell et al. (*15*) measured size of community and evaluation of "convenience" of neighborhood, which are also likely to be correlated with residential density.

Other studies have explicitly included density measures but have not adequately specified such measures. The respondent's housing type has been used as a surrogate for residential density (*21,36*), as has size of community (*15,25*) and general location of residence in a metropolitan area (*37*). Density also has been subjectively presented to respondents as neighborhoods that are "densely populated" or "sparsely populated" (*32*). Some of these researchers have noted the inadequacy of their specifications but have been constrained by resources to use only easily available information or have simply not focused on density as an important variable.

Baldassare (*18*) represented neighborhood density as number of persons per residential acre. Similarly, Galster and Hesser (*38*) defined density as number of households per residential acre, identical to Baldassare's specification if a factor for number of persons per household is applied. These definitions of density as a continuous variable not identical to (although certainly correlated with) dwelling type or community size produce a much more flexible independent variable. This conceptualization is also much more closely related to density measurements used by planners and urban designers (*39*).

As noted above, proximity to transit has rarely been considered as a potential determinant of residential satisfaction; Lansing et al. (*14*) have conducted the only study that explicitly included transit service, and their study considered only rarely used bus transit. Other studies that included "accessibility" as a causal variable (*27,38*) may be measuring some amount of transit service, but such service is not explicitly identified. Such neglect of a potentially important feature of the urban landscape may be symptomatic of the declining role of transit in America over the past quarter century, or it may reflect a general neglect by residential satisfaction researchers of the various dimensions of accessibility; where accessibility is included as a variable, it is generally defined simply as travel distance, with no consideration of travel time, mode, or other potential components of a valid accessibility measure.

HEDONIC PRICING

Research Overview

Hedonic pricing refers to economists' efforts to understand the relative importance of various attributes of a particular commodity and to associate those attributes with the market price of the commodity. This technique has been widely applied to the analysis of housing markets. As described by Follain and Malpezzi (*40*), the process partitions the value of a commodity into components that can be individually measured; prices are then estimated for each component using multiple regression. "These prices can then be used to compute a standardized measure of housing quality. The measure, for any housing unit, is simply a weighted average of the components embodied in the unit, where the weights are the estimated prices of the components" (*40*,p. ix). Williams (*41*) traces the development of hedonic pricing theory from goods-attribute theory (*42*) and residential location theory (*43,44*). Kain and Quigley (*45*) were among the first researchers to focus on individual dwellings and give serious attention to the proper measure of the quality of residential services. Quigley and Rubinfeld (*46*) note that "the use of hedonic methods to evaluate the attributes of housing has become widespread, especially after the publication of Rosen" (*47*), who provided a synthesis of earlier material (p. 2).

McLeod (*48*) and Williams (*41*) observed that the bulk of empirical work (on housing as well as other topics, such as air quality) has focused solely on the individual value estimates of attributes (the hedonic price function). McLeod states that "very few studies have utilised the marginal valuations of characteristics implied by the estimated hedonic price function to develop estimates of willingness to pay for changes in the level of provision" (*48*,p. 389). Thus, much of the focus of this work has been on the identification and weighting (through multiple regression) of key attributes of housing and neighborhoods. This has provided the housing researcher with a rich data base of identified variables, along with some indication of their relative importance with respect to marginal housing prices.

Hedonic pricing (especially this first stage of relative attribute pricing or weighting) has much in common with measures of residential satisfaction. Both attempt to ascertain the value of housing (although value is not generally defined the same way in the two different approaches), usually through determining the impacts of housing components or attributes on the overall housing valuation.

Hedonic pricing equates the "value" of a particular dwelling unit with its cost, and the contribution of any feature of that unit (number of bedrooms, location next to a park, etc.) is expressed in terms of the amount of monetary value that such a feature adds or subtracts from the cost of the dwelling unit. In residential satisfaction studies, "value" is usually represented by expressed levels of satisfaction with housing, neighborhood, community, or some combination of all three. Occasionally, willingness to move is used as an expression of dissatisfaction, and thus (lack of) value, but such willingness is not generally correlated with measures of satisfaction (*21,49*). Of the two techniques, hedonic pricing has greater face validity; dollar amounts are culturally accepted as at least a rough indication of an object's (or attribute's) value, which may not be true of satisfaction ratings; certainly, such a rating represents a less common indicator of value. This also reflects the likely greater reliability of hedonic pricing measures: a $200,000 house with a certain set of attributes is likely to be more clearly understood by most people than the same house with the same set of attributes and a certain satisfaction score. Even hedonic pricing results, however, must be viewed in context; the value of, say, a $200,000 house can be very different depending on the locational and temporal context of the valuation. The validity and reliability of hedonic pricing measures, just as the validity and reliability of residential satisfaction surveys, must be viewed within a particular context.

Measures of Density and Proximity to Transit

As with residential satisfaction studies, dwelling type often stands as a surrogate for residential density in hedonic pricing studies (*45,50,51*). Follain and Malpezzi (*40*) calculate a measure of internal density (persons per room) but do not measure external density. Williams (*41*) included "residential density" as a housing attribute, but simply estimated "above average, average, and below average" house sizes from an exterior vantage point. Lot size was measured in square meters. From this description of the density variables, it is difficult to determine how a general breakdown of houses into large, medium, and small, even if it is somehow linked to lot size—a link that is not explicitly made—says anything about residential density, whether interior (e.g., persons per room) or exterior (e.g., dwelling units per block or per acre).

To the author's knowledge, no hedonic pricing studies have explicitly examined the effects of external residential density on price. Although it may be argued that hedonic pricing studies have determined the impacts of variables that might serve as surrogates for density, such as dwelling type, building size, and lot size, these variables can exhibit such a variety of specifications (*39*) that they effectively say very little about actual site or neighborhood densities.

Two hedonic pricing studies have examined the impacts of accessibility to rail transit stations on housing prices. Diamond (*52*) notes that accessibility to commuter rail stations is an important amenity to many residents.

> However, there is a clear division between those for whom it matters (commuters to the CBD) and those for whom it is irrelevant. It seems that the former group dominates the formation of land prices since there is a relatively strong effect on them. But those who have no use for the rail lines can avoid paying those prices by moving further away from the stations. The two groups may nullify each other in the general pattern, with the result of a negligible correlation with income and, relatedly, relatively large variance on the estimate of the income elasticity

for the rail station accessibility variable (*52*,p. 11). Such interpretation of the results clearly suggests the need for a market segmentation into CBD workers and other residents. In general, the residents did not live near the rail stations; the mean distance to a rail station was 3.0 mi with a standard deviation of 1.3 mi.

Dewees (*53*) describes a more relevant hedonic pricing study, examining the impacts on housing sale prices of construction of a subway line in Toronto. The subway replaced a streetcar line; unfortunately, the report does not indicate if headways changed along with the change in mode, although the subway did operate at speeds about double those of the streetcars (22 mph versus 10 to 12 mph). Housing prices were significantly related ($p < .05$) to accessibility to the transit system both before and after construction of the subway system. Dewees tested several specifications of the transportation variable in the regression model, including walking distance, travel time, and travel cost. In general, travel time proved to be a better measure of access than distance or travel cost, and access to the transit facility was more important than access to the CBD. In addition, using a threshold cut-off distance of ⅓ mi, the author demonstrated that construction of the subway had no impact on housing prices beyond this point. Within ⅓ mi of the subway station, rent slopes increased almost 50 percent in constant dollars, suggesting a definite impact of increased transit service on area property values.

The primary weakness of hedonic pricing for the purpose of the current study is its inability to ascertain the value of new housing characteristics or new combinations of existing characteristics (*54*). Since relatively few transit-based, high-density developments have yet been constructed [and many of those currently in place are rental units (*5*)], a method that relies on sales of existing dwelling units for its data set will not be able to provide an adequate data base. Hedonic pricing seems most appropriate when minor changes are being made or proposed to existing systems, services, or structures, and preferences can be fairly clearly identified. Where qualitatively new situations are being considered—such as "pedestrian pockets" and residential densification around existing rail lines—residential satisfaction surveys are more appropriate.

To some extent, the dichotomy between hedonic pricing and residential satisfaction studies parallels that of revealed preference–stated preference survey techniques. The former relies on directly observed (or reported) behaviors to draw conclusions about the desirability or undesirability of certain actions under specific conditions. Revealed preference models suffer from some of the same shortcomings as hedonic pricing models: variables of potentially limited range and a lack of some choice alternatives (*55*).

Stated preference surveys can manipulate the dependent variables based on a controlled experimental design procedure (*56*). However, some researchers note the possibility that such surveys can be prone to response bias (*57,58*). These concerns also have been raised regarding attitudinal surveys and statements of intended behavior. Recent techniques to evaluate public goods, such as the contingent valuation method (*59*), may reduce such threats to validity.

COMPARISON OF RESIDENTIAL SATISFACTION AND HEDONIC PRICING METHODOLOGIES

Despite their differences, residential satisfaction and hedonic pricing methods often have been used to answer questions that are basically identical: what are the important attributes of housing, and what do they contribute to the overall value of housing? As indicated above, these procedures use divergent means (generally those of stated preference versus those of revealed preference, respectively) and are based on various conceptions of "value." However, they share several methodological strengths and weaknesses:

1. Both lend themselves to disaggregate data analysis. Because both methods are based on actions or statements by individuals or households, the data have been collected at a disaggregated level and thus provide analysts with a flexible data base to test a wide variety of behavioral hypotheses, and (with a large enough sample) to control for a variety of socioeconomic or demographic variables. However, neither method has been widely used in this manner, and analysis often has neglected potentially useful submarket divisions (*34,60*). Residential satisfaction techniques would seem to be more capable of exploring such divisions, because information about a large number of household or individual characteristics can be collected in the process of interviewing. Hedonic pricing studies, on the other hand, are usually [although not always—see a previous study (*45*)] limited to information available from records of home sales. Additional information may be available from other sources (*53*) but often only at an aggregate level. Efforts to provide proxy measurements of socioeconomic characteristics of individual households, for example by assigning median census tract values for income, age, and family size (*48*), say more about neighborhood characteristics than about individual household characteristics and may produce spurious results.

2. Both produce models that should generally take account of nonlinearities but infrequently do so (*34,48,60*). In general, hedonic pricing analysis more often develops nonlinear specifications for the relationships between the housing valuations and the housing attributes (generally semi-log and log-linear models). Both methods, however, too frequently assume simple linear relationships.

3. As noted above, neither method has developed an adequate standard representation for residential density. Such a representation should relate a unit of population to a unit of area; depending on the needs of the researchers, the numerator might be persons or households, and the denominator might be square footage, acres, or blocks of a standard size. In addition, residential density measurements should specify the extent to which nonresidential land uses found in proximity to residences are being included; such land uses include streets, shops, and various business and commercial services (*39*). Such specifications would link estimates of housing value with more detailed representations of the residential environment, which in turn are linked to estimates of transit patronage through trip generation rates and mode choice estimates. Thus, use of an appropriate measure of density may provide a linkage among residential housing value (whether measured through residential satisfaction studies, hedonic pricing, or some other method), residential density, and projected transit service demand.

NEXT STEPS

Based on the findings described above, as well as the rationale for high-density, transit-based housing discussed previously, research is currently under way to investigate the following questions:

- Given a choice of dwelling units, would residents select those at such densities as to allow the successful operation of various forms of urban transit?
- What attributes of the residence are most closely associated with positive or negative attitudes toward density?
- What variables distinguish groups of people (i.e., markets) with various reactions to high-density, transit-based housing?

Questions of residential satisfaction and attitudes toward various residential attributes are being asked of a sample of the general public and a sample of current residents of high-density, transit-based housing. Both focus groups and face-to-face interviews are being used. By inquiring about particular attributes of housing and neighborhoods, this study will provide information about desirable and undesirable housing/neighborhood features. In addition, attitudes toward specific attributes will be broken down by various market segments, permitting detailed analysis of residential satisfaction across various groups of respondents. The answers to these questions should help to determine the potential success of current high-density, transit-based residential developments; they also should be useful to planners and developers considering future high-density, transit-based housing projects and transportation planners estimating future transit demand from such projects.

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Light-Rail Transit Stations and Property Values: A Hedonic Price Approach

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What are the effects of proximity to light-rail transit (LRT) stations on the value of single-family homes? Two forces are at work. Proximity to LRT stations may improve the accessibility of residents to the central business district and the rest of the urban area. Further, proximity to rail stations may result in transportation cost savings for nearby residents. These effects should be positively capitalized in property values. Alternatively, without attention to design, LRT stations may impose negative externalities on nearby properties, with a resulting decline in house values. Which of these effects predominates in the housing market with respect to station proximity? A study was undertaken to analyze sale prices of homes in metropolitan Portland, Oregon. Two distance models to LRT stations were compared. The first showed a positive capitalization of proximity to LRT stations for homes within 500 m (1600 ft or ¼ mi) of actual walking distance. This effect was equally felt for all homes within that distance zone. The second model found a statistically weak negative price gradient for homes within the 500-m zone. This implies a positive influence of proximity the closer the home is to an LRT station.

Proximity to light-rail transit (LRT) stations may positively or negatively affect the value of single-family homes in nearby residential neighborhoods. Having easy access to a station may improve the accessibility of residents to commercial centers and result in increased home values. Similarly, proximity to LRT stations may reduce commuting costs, which would be positively capitalized in housing values. Alternatively, a consequence of living near an LRT station may be increased noise, traffic, and other nuisances, with a resulting decline in home values.

This paper addresses the following questions:

- Does proximity to LRT stations affect the value of nearby homes?
- Is there a positive or negative effect?
- Is there a price gradient with respect to distance from an LRT station?

The study analyzes single-family home sales in areas of Portland, Gresham, and Multnomah County, Oregon, that are within a reasonable walking distance to an LRT station. The paper also reviews the development of LRT in metropolitan Portland and planning and design considerations of neighborhood LRT stations.

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BACKGROUND

In September 1986, an LRT line called MAX initiated service to Portland's Eastside. The 24-km (15.1-mi) line comprises 27 stations, 5 park-and-ride facilities, and 5 transit centers. The line was developed as part of the Banfield Transitway project, a package of 140 transit and highway improvements, which included freeway improvements to 6.9 km (4.3 mi) of the Banfield Freeway (I-84). Local planning for the LRT project began in the mid-1970s following rejection of an early 1960s proposal to build the Mt. Hood Freeway, a connection of I-5 and I-205 along the Powell Boulevard corridor (Figure 1).

The LRT line includes three different segments of stations. The segment along the downtown corridor has simple sheltered stations. The depressed Banfield Freeway segment has split-level stations. Passengers board at the freeway level, and transit access to commercial or residential areas is provided by buses arriving at overpasses or adjacent streets. In the third segment, surface stations along East Burnside Street are directly accessible by walking from nearby residential areas (Figure 2).

The stations can also be classified functionally in the following ways:

1. Transit stations that serve older commercial centers and connecting bus lines (e.g., Hollywood and Gresham Central);
2. Developed area stations that serve shopping centers with connecting and feeder bus services (e.g., Lloyd Center and Gateway);
3. Park-and-ride stations that serve commuters from low-density residential areas (e.g., Gresham City Hall); and
4. Neighborhood stations located in established low- and medium-density residential areas. These types of stations are the subject of this study.

PLANNING AND DESIGN OF NEIGHBORHOOD TRANSIT STATIONS

The Banfield Light-Rail Transit Station Area Planning Program was initiated in 1982 as a 2-year cooperative project that included the participation of Portland, Gresham, Multnomah County, Tri-Met, the Oregon Department of Transportation, and Metro. The objectives were to prepare detailed land use plans, evaluate potential, and adopt development strategies

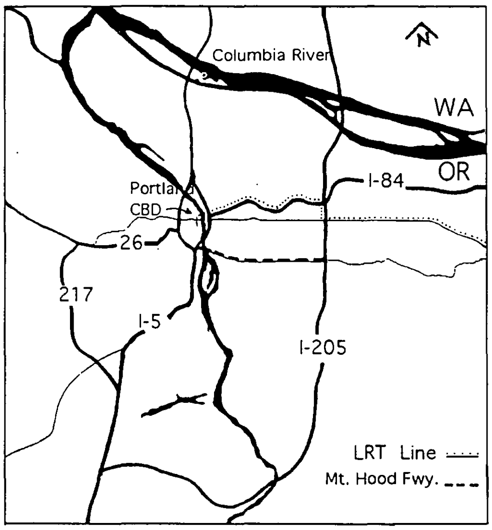

FIGURE 1 Portland metropolitan region.

for each of the 26 LRT stations between downtown Portland and Gresham.

In conjunction, the communities along the LRT line initiated changes to their zoning regulations. In 1984, Multnomah County designated LRT station area zones. The city of Portland adopted changes in its zoning code and comprehensive plan in the vicinity of the stations. Further, the cities of Portland and Gresham annexed large areas of mid-Multnomah County. As part of the annexation program, Portland adopted a new T-zone (transit overlay) to provide comparable regulations to Multnomah County transit zones and their accompanying regulations. The new T-zone serves a number of purposes that include encouraging transit-oriented development by promoting development mix and minimizing potential conflicts between vehicles and pedestrians near transit stations.

Higher densities, both residential and commercial, have been zoned within a half kilometer of LRT stations, especially along the Burnside arterial corridor. Transit supportive land use planning was done to generate relatively higher levels of transit trips while minimizing vehicular trips and parking demand.

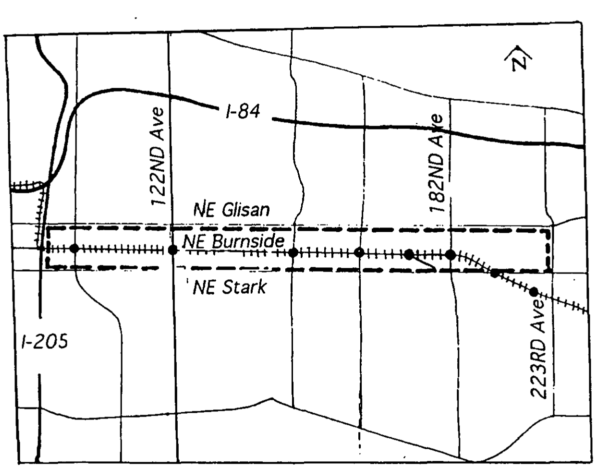

FIGURE 2 The study area.

However, potential LRT impacts on land development may not be achieved in the short run. Such influence would require, in addition to a transit-oriented zoning, a strong regional economy, availability of developable land, and a long-term market adjustment to accommodate new transportation improvements (*1,2*). In Portland, LRT has influenced land development only in selected areas around its corridor. Downtown Portland, downtown Gresham at the other end of the line, and the area around Lloyd Center were the major beneficiaries (*3*). Modest changes in land development have been identified in other areas along the MAX corridor, including the study area (*3*).

IMPACTS OF LRT STATIONS ON PROPERTY VALUES

Proximity to LRT stations improves the accessibility of residents to the central business district (CBD) and to other parts of the urban area served by transit. This benefit should be positively capitalized in property values (*4–7*). Further, proximity to rail stations may result in transportation cost savings for nearby residents (*8*). These travel savings would be reflected in home price capitalization for nearby properties. The Philadelphia-Lindenwold rapid transit is a prime example of these positive impacts (*9,10*). These impacts are more apparent in lower- and middle-class areas than in higher-income areas (*10,11*). Similar conclusions were reached by Nelson (*6*) concerning elevated rail line impacts on housing prices in Atlanta. On the other hand, Gatzlaff and Smith (*12*) concluded that proximity to Miami Metrorail yielded slightly increased property values in highly priced, growing neighborhoods relative to declining neighborhoods. They also found weak, inconclusive impacts for proximity after the announcement of the project and the system operation (*12*). Other potential benefits of proximity include a speculation value for nearby homes (*8*). This may result from the potential for future conversion to other uses, such as multifamily or commercial development.

Whether improvements in accessibility will positively affect land values is influenced by other planning and design measures for transit stations. Strong housing market demand and careful planning and zoning considerations may produce positive impacts. For instance, Toronto rail transit has had a major impact on residential land values. Property values near the Spadina subway line were $2,237 higher than they were elsewhere (*13*). Strong development controls were important in stimulating these positive effects. Similarly, Lee and others (*5*) concluded that the Bay Area Rapid Transit (BART) had a noticeable effect on residential property values in only some areas. Other studies showed inconclusive results in terms of detecting an overall increase in residential property values as a function of proximity to rail stations (*4,6,14*). In fact, land use impacts in terms of development patterns and land values would require the presence of other favorable factors in addition to rail transit proximity (*15,16*).

Without attention to design, LRT stations may impose negative externalities on nearby properties. These externalities may include noise, increased pedestrian and automobile traffic near the station, attraction of undesirable groups to neighborhoods, and the disruption and noise associated with the construction of such stations (*4,6,12*). Further, transit stations may create an incentive for higher-density development, in conflict with the characteristics of nearby stable neighborhoods.

In summary, net positive impacts could be observed if the market viewed improved accessibility more as a benefit than a nuisance. Conversely, net negative impacts could exist if the market viewed externalities as more important than accessibility to transit.

Study Area

The study area along the E. Burnside corridor MAX segment contains neighborhood-type LRT stations. The area extends from Interstate 205 (west) to N.E. 192nd Street (east), between N.E. Glisan Street (north) and S.E. Stark Street (south) (Figure 2). N.E. Glisan and S.E. Stark are each 500 m (¼ mi) from the light-rail tracks. The actual distance between some homes and a station is longer because of a cul-de-sac and other circuitous street configurations. Any residence that had an actual walking distance of more than 1.6 km from a MAX station was excluded. The study area is dominated by developments of single-family homes, with a few pockets of multifamily apartments. Sale prices of homes within the study area during 1988, 2 years after LRT operation began, were used for this study. During the study period, the average sale price for all homes was $47,912. For homes that are close to stations, less than 500 m (¼ mi) of actual walking distance, the average sale price was $40,554.

Model Specification

Hedonic analysis is used to isolate the effects of proximity to LRT stations on property values. The first model uses sales of homes that are located within the 1,000-m band width along the LRT line but distinguishes those that are within 500 m of actual walking distance to a station. A 500-m distance was chosen as a reasonable walking distance between homes and an LRT station. A second model was constructed using sales data for homes that are within a 500-m zone of actual walking distance.

The first model contains 235 home sales. It can be generally expressed as follows:

$$P_i = b_0 + b_1 \, DDST_i + \Sigma_j \, b_{ij} \, X_{ij} + e_i \qquad (1)$$

where

P_i = sale price of each transacted home (i), $i = 1, \ldots, n$;
$DDST_i$ = dummy variable equaling 1 for all homes that are within a 500-m walking distance from a station and 0 otherwise;
X_{ij} = characteristic attribute (j) defining residence i, $j = 1, \ldots, k$; and
e_i = error term.

The second model includes 90 sales located within a 500-m (¼ mi) actual walking distance from an LRT station. It can be expressed as follows:

$$P_i = b_0 + b_1 \, DST_i + \Sigma_j \, b_{ij} \, X_{ij} + e_i \qquad (2)$$

where

P_i = sale price;
DST_i = distance (m) of each home (i) from the station;
X_{ij} = characteristic attribute (j) defining residence i, $j = 1, \ldots, k$; and
e_i = error term.

A bundle of characteristic variables of each home were incorporated into the model to control for their effect on housing prices. These variables include the following:

1. Structural characteristics (area in square meters of both lot and house, the presence of a basement, the number of bedrooms, and age in years),
2. Jurisdictional identifier (whether the house is located in Portland, Multnomah County, or Gresham), and
3. Other important variables such as zoning type (whether the lot is zoned for single-family residential or multifamily residential use) and the school district. Because the school and the city variables are highly correlated with distance to the CBD, only the city dummy variables were included in the model.

RESULTS

Regression results for the first model are presented in Table 1. All characteristic attributes of the houses were significant at the 0.05 level and have the expected signs. For instance, a marginal increase in lot size and house area increase the house price significantly, whereas the age of the house negatively affects its price. Further, single-family residential zoning has a significant positive effect on sale prices. This could reflect the buying up of lower-quality single-family homes in multifamily zones for subsequent development or a depressing effect of multifamily zoning on single-family housing. Positive effects were also estimated for homes located in the city of Portland and Multnomah County as compared with the city of Gresham, which is interpreted as reflecting the effect of distance from the Portland CBD.

The interpretation of the positive coefficient of the dummy variable implies that LRT stations had a positive impact on home values within 500 m. There, property values were $4,324 higher than properties located within the study area but with walking distances greater than 500 m. The total contribution of proximity to stations in home prices, on average, is nearly 10.6 percent.

The second model uses a distance measure to detect price gradient of homes within 500-m actual walking distance. The results in Table 2 show that property values are estimated to decline with distance from an LRT station at a rate of $21.75/m ($6.60/ft). The significance of this estimate is weak, however. Thus, for properties within 500 m of actual walking distance, the accessibility and the speculative effects are apparently higher the closer the home is to the station. There is a detectable distance decay, but the results of the second model are not strong enough to imply a significant price gradient of distance to LRT stations. Nuisance effects may have played a role in reducing the potential benefits of proximity

TABLE 1 Results of Linear Regression of All Homes

Variable	Coefficient	T-score
Distance from nearest station (1=within 500 m.[1], 0=further)	4324	2.49*
Lot size in sq. meters[2]	3.98	4.19**
House size in sq. meters	210.35	6.67**
Presence of Basement (1=Yes, 0=No)	6330	3.75**
Number of bedrooms	3398	2.24*
Age of house in years	-384	-6.32**
Single family zoning (1=Yes, 0=No)	6661	3.46**
Located in Portland (1=Yes, 0=No)	4476	2.40*
Located in Multnomah County (1=Yes, 0=No)	6583	3.62**
Constant	16919	
Number of cases	235	
Coefficient of Determination (R^2)	.631	
Standard error of estimate	11018	
F-Ratio	42.66**	

[1] 1 meter = 3.28 feet.
[2] 1 sq. meter = 10.76 sq. feet.
* Significant at the 0.05 level (two-tailed test).
** Significant at the .005 level (two-tailed test).

to nearby homes. Short- and long-term nuisance effects caused by construction and operation of stations are two examples. The housing market may take a longer time to recover from such impacts.

CONCLUSION AND IMPLICATIONS

The results indicate that the housing market views proximity to an LRT station as a benefit with a distance decay effect. This effect is felt only for houses within 500 m of actual walking distance.

However, the benefits of accessibility to a transit station may not be as great as some expect. In an automobile-dominated city such as Portland, transit's role in people's travel behavior is minor. Such a role is exemplified in low ridership rates for LRT and other transit modes. In 1988, on an average weekday, MAX ridership was nearly 19,300 passengers. Only 2,317 passengers per day depart from the study area stations, on average. Therefore, the housing market may not be noticeably influenced by transit users' locational decisions. Nevertheless, the proximity to an LRT station may have produced modest benefits to nearby properties. These benefits are reflected by a price differential of nearly 10.6 percent for houses within walking distance. In addition, a statistically weak, negative gradient of $21.75/m ($6.60/ft) from the station was detected. This translates to $6,939 at the mean distance of 319 m (1,046 ft).

The finding of a net benefit indicates that the positive effects of accessibility are stronger than the nuisance effects. These effects may partially have to do with the design of LRT stations. Design treatment should be sensitive to potential impacts on nearby neighborhoods. Failure to do so may lead to an adverse price effect on homes (*17*).

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TABLE 2 Results of Linear Regression of Homes Within 500 m Actual Walking Distance of an LRT Station

Variable	Coefficient	T-score
Distance from nearest station (in meter units)	-21.75	-1.50
Lot size in sq. meters[1]	3.23	2.21*
House size in sq. meters[2]	270	3.68**
Presence of Basement (1=Yes, 0=No)	5073.35	1.49
Number of bedrooms	479.35	0.16
Age of house in years	-395.22	-3.83**
Single family zoning (1=Yes, 0=No)	11280.74	3.80**
Located in Portland (1=Yes, 0=No)	2157.35	0.69
Located in Multnomah County 2(1=Yes, 0=No)	9755.52	2.61*
Constant	20050	
Number of cases	90	
Coefficient of Determination (R^2)	.620	
Standard error of estimate	12602	
F-Ratio	14.476**	

[1] 1 meter = 3.28 feet.
[2] 1 sq. meter = 10.76 sq. feet.
* Significant at the 0.05 level (two-tailed test).
** Significant at the .005 level (two-tailed test).

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Automating Construction Data Acquisition for the Florida Department of Transportation By Using Pen-Based Computers

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The management and administration of construction contracts require the collection and analysis of a great deal of information as the project progresses. Much of this information is recorded and collected at the project site. Although the microcomputer is now used extensively as a construction management tool, the collection of field data remains essentially a paperwork process. The results are presented of a trial program undertaken by the Florida Department of Transportation that involved the use of pen-based computers for job-site data acquisition. Data entry with the pen-based computer is accomplished by writing on the screen with a tethered pen. Capabilities of this new technology are discussed. Results of the field trials are presented with recommendations for future implementation.

Effective management of construction requires a continuous collection of project information. Most of this information must be observed and recorded at the project site. For example, progress updates, pay estimates, inspection, and testing all require extensive field data collection. A state transportation agency's construction management success depends largely on the quality of the information obtained from the project site. Accurate and timely information is essential for sound management decisions.

Although the microcomputer is now widely used as a construction management tool, the recording of information at the job site remains essentially a handwritten paperwork function. Both owners and contractors make extensive use of preprinted forms to record daily project information. Field personnel may be required to commit much of their time to this paperwork. The field reports are normally submitted back to the office at intervals. At the office, the handwritten information might be retyped or keyed into a computer. Often the information remains in handwritten form and is simply stored in a project file. Obviously, the retrieval of this handwritten information at some future date can require a great deal of time.

Various direct data entry devices have emerged and have been tried with varying degrees of success in the construction industry. One of the most successful has been the bar code readers (*1*). Bar coding has proven to be particularly useful in material management applications (*2,3*). Other, still evolving systems such as the voice recognition systems have had limited application (*4*). These devices can recognize and respond to a limited preset vocabulary. However, direct data acquisition remains a goal that industry has not yet been able to achieve. Data collection procedures for the majority of today's construction projects are the same paperwork-intensive methods used for years.

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The Florida Department of Transportation (FDOT) has one of the nation's largest construction programs. In the past few years, the construction budget has doubled. This year the dollar volume is expected to approach one billion. Managing this expanding construction program is extremely challenging.

In an effort to improve the efficiency of its construction management system, the FDOT continually examines emerging technology. The recently developed pen-based computer appeared to be ideally suited for job-site data collection. Consequently, the FDOT employed the University of Florida to develop and field test a pen-based computer data acquisition system for use on FDOT construction projects. This study has now been completed and the results are presented in this paper.

PEN-BASED COMPUTER TECHNOLOGY

Hardware

Pen-based computers utilize recent technological advances in computer screens, microchips, and software. The primary difference between the pen-based computer and a conventional notepad computer is the absence of a keyboard. The user interface is a tethered pen.

When the pen is touched to the screen, an electrical voltage is passed between the pen and the screen. The screen has a special coating that facilitates the electrical connection. Microprocessor hardware within the computer records the exact position of the pen point on the screen. Using advanced handwriting recognition software, the computer is able to interpret handwritten print. The character recognition algorithm functions by analyzing both the sequence and the location of the pen strokes. When the writer pauses, the pen strokes are instantly converted to digitized characters and the handwritten print is replaced on the screen with a standard text.

These computers are about the size of a clipboard and weigh about 4 lb. Internally, the pen-based computer is comparable with a conventional microcomputer. Pen-based computers are available with the latest microprocessor chips. Configuration typically includes 1 to 4 megabytes of main memory. Memory storage is provided by removable random-access memory (RAM) storage disks. Access time for the RAM storage disk is much faster than that for even the fastest hard drive. In addition to the RAM storage devices, the latest models can now be obtained with a conventional hard disk drive. As with conventional laptop computers, power is supplied by an internal rechargeable battery pack or by direct connection to a power source.

Using an MS-DOS operating system allows the pen-based machines to run practically all IBM XT–compatible software. Spreadsheets, scheduling, estimating, and other traditional application programs can be performed. A graphic image of a standard keyboard can be called up on the lower portion of the screen. Touching the pen to the keyboard image acts exactly as a keystroke on a keyboard. However, the true power of the pen-based computer is realized by using specifically developed application software.

Software

Pen-based computers are a new technology; consequently, national software vendors have not yet emerged. Some application software is being custom developed for individual users by software consultants. Other organizations have elected to do the programming with in-house resources.

Programming is generally accomplished through a pen-based interface programming language. This interface software provides the handwriting recognition capabilities that translate printing into ASCII characters. The interface software also contains a specialized function library that facilitates the development of the input screens. The interface language requires a general programming language platform such as C or Clipper.

Programming design focuses on objects and events. In the pen-based environment, objects are the figures on the screen. For example, a check box is an object. An event is some occurrence caused directly or indirectly by the user. Examples of events include touching the pen to the screen or writing in a field. Essentially, the software is designed to look for an event and then make an appropriate response.

The basic product of the application software is the form or input screen template. A particular application may use a single form or may use multiple input screens linked interactively. The form serves as the input interface. Data are acquired from the user by means of several different types of input objects shown on the screen. These input mechanisms are

- Lists,
- Buttons,
- Radio buttons,
- Check boxes,
- Text fields, and
- Graphic fields.

The list provides the user with a group of choices. Selection is made by touching the screen. The list can contain many more choices than are shown on the screen. The user can scroll through an extensive data base of items and select the appropriate one. The list feature is perhaps the most useful of the data input devices.

Buttons, radio buttons, and check boxes are simply either on or off. They may be used to record a user choice or to activate a dynamic list. The buttons may also be used as a menu of choices for selecting different forms or applications.

The text field allows the input of printed text. Information printed in by the user is converted to ASCII text and recorded. A numeric keypad or a typing keyboard may be called up on the screen from a text field. The information can be entered as key strokes rather than as printing.

Graphic fields are used to record graphical information input by the user. The graphic image is digitized and recorded. One important use of this feature is for a signature block. Signatures can be recorded and stored as graphic images.

DEVELOPMENT OF PEN-BASED REPORTING SYSTEM

FDOT's Daily Report of Construction

Although many different forms are used in FDOT's construction management system, it was initially decided that only a single form would be converted to the pen-based system. The form selected was the Daily Report of Construction. This is a two-page form (single sheet, front and back) used by FDOT to record general information about construction project status. The contents of this report include the following general categories:

1. Project number, contractor, subcontractor identification, date;
2. Listing of the work activities performed on the report date;
3. Listing of the numbers and trade classification contractor personnel on the project;
4. Listing of the numbers and type of contractor equipment on the project;
5. Listing of the work quantity increases by contract pay item number;
6. Weather information including any delaying effects;
7. General comments; and
8. Signatures of the technician and the project engineer.

A daily report of construction is completed each day on every FDOT construction project. A separate report is done for the prime contractor and each subcontractor.

The daily reports are handwritten in the field by FDOT personnel. Normally, the reports are submitted to the resident construction office once a week where a weekly summary report is prepared. Each month a monthly pay estimate summary is prepared. The monthly pay estimate lists the work quantity performed on the project by pay item number. The original copies of the daily report of construction are held in the project construction file. Other than the work quantities for pay estimates, no daily report information is extracted, retyped, or keyed into a computerized data base.

Retrieval of specific information requires physically reviewing the paper copies of the daily report of construction, which can be a time-consuming task. For example, gathering information relating to a contract claim may involve many person-hours of management time.

To facilitate the field personnel's use of the pen-based computer, the daily report of construction replicated on the pen-based computer was almost an exact copy of the original preprinted form. However, the length of the form required that it be divided into seven sequential computer screens.

Computer Hardware

The pen-based computer selected for this study was the GRIDPAD model 1900 by GRID Systems Corporation. When this study began in 1991, GRID had been manufacturing pen-based computers for several years. In fact, GRID was the only viable source for the required hardware. Since that time, several computer manufacturers have now developed pen-based computers.

The GRIDPAD is approximately the same size and weight as a conventional notebook computer. Power is provided by a rechargeable battery pack. Input to the computer is by writing on the screen with a tethered pen. Data storage is provided by two removable RAM cords available in 512-kilobyte or 1-megabyte capacity.

The computers appeared to be quite durable and suitable for field use. However, the screen, which is glass, can be broken if struck by a hard object. Figure 1 shows a GRIDPAD pen-based computer.

Software

Software development was performed using the Clipper data base language and Pad Base pen-based development tools by R2Z, Inc.

Building the on-screen forms with the Pad Base tool kit is fairly straightforward. However, writing the underlying Clipper code involved considerably more work. The daily report of construction actually consisted of 278 data fields, which required more than 3,000 lines of Clipper code to support the application.

Software development for the daily report of construction application required approximately 500 programming hours. Much of this time can be attributed to learning a new development language. Subsequent applications are expected to require far less programming effort.

An office resident data base management utility was also developed in Dbase IV. This application was designed to receive the report information from the pen-based computers and to provide reporting and file storage functions.

Pen-Based Reporting System

The FDOT's daily report of construction form was converted to a pen-based computer application requiring seven screens. When the computer is turned on, the initial pen-based reporting system (PRS) screen appears. Menu selections include

1. Work on a new report;
2. View/edit a previous report; and
3. Quit.

A pop-up scrollable list gives all projects currently in the computer memory. The user selects the appropriate job by touching the pen to the project number on the list. Standard project information is then pasted to the header portion of the daily report form on the screen. Menu selections are made by touching the pen to the appropriate on-screen button. Figure 2 illustrates the PRS opening screen.

Data are entered on the form either by touching the pen to a check box or by printing the information in a text field. Because of space constraints, not all the PRS screens have been included here. However, Figures 3 and 4 show the general layout and are representative of the complete application.

One of the more convenient features of the PRS is a memory resident listing of all contract pay items for each project. When updating pay item quantities, the inspector can pop up a scrollable listing of all pay items. By touching the pen to an item, that item can be pasted to the form. Because the signature blocks are programmed as graphic fields, the inspector's signature is saved exactly as signed in a graphic file.

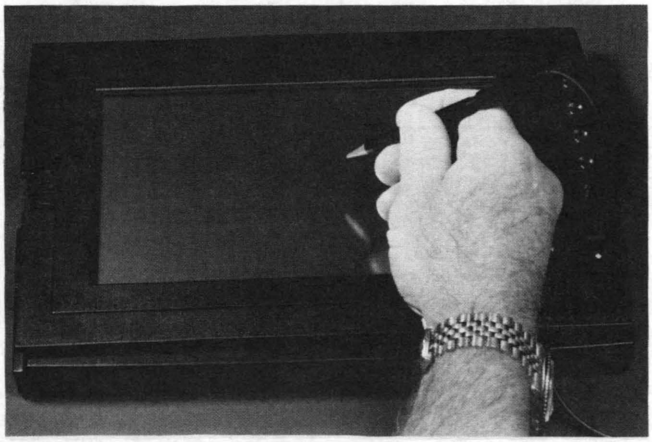


FIGURE 1 GRIDPAD pen-based computer.

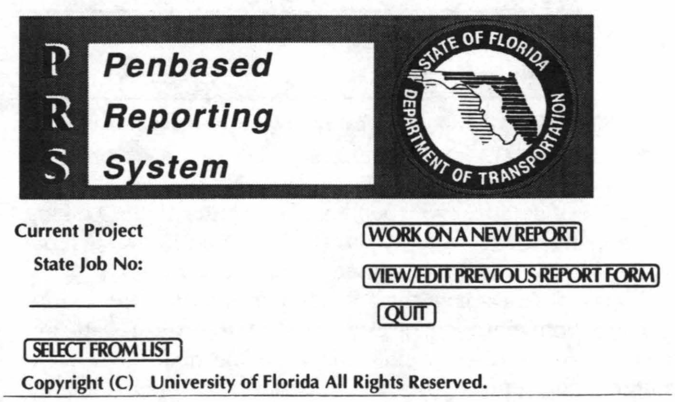
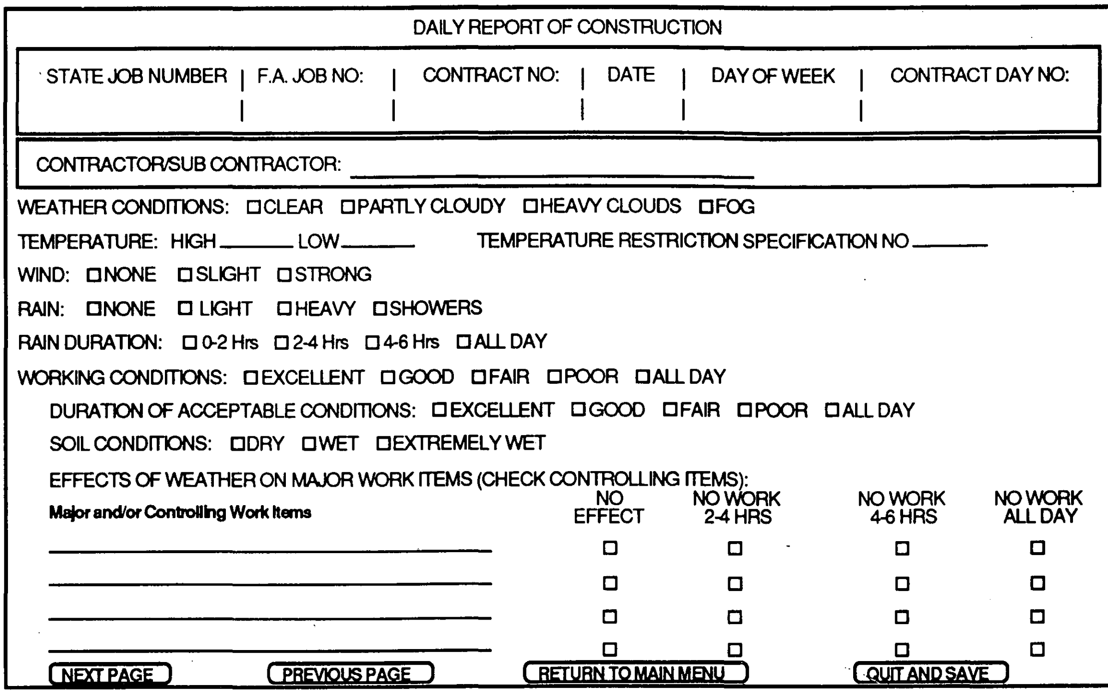


FIGURE 2 Opening screen of the pen-based reporting system.


DAILY REPORT OF CONSTRUCTION

STATE JOB NUMBER | F.A. JOB NO: | CONTRACT NO: | DATE | DAY OF WEEK | CONTRACT DAY NO:

CONTRACTOR/SUB CONTRACTOR: ____

WEATHER CONDITIONS: ☐CLEAR ☐PARTLY CLOUDY ☐HEAVY CLOUDS ☐FOG

TEMPERATURE: HIGH ____ LOW ____ TEMPERATURE RESTRICTION SPECIFICATION NO ____

WIND: ☐NONE ☐SLIGHT ☐STRONG

RAIN: ☐NONE ☐LIGHT ☐HEAVY ☐SHOWERS

RAIN DURATION: ☐0-2 Hrs ☐2-4 Hrs ☐4-6 Hrs ☐ALL DAY

WORKING CONDITIONS: ☐EXCELLENT ☐GOOD ☐FAIR ☐POOR ☐ALL DAY

DURATION OF ACCEPTABLE CONDITIONS: ☐EXCELLENT ☐GOOD ☐FAIR ☐POOR ☐ALL DAY

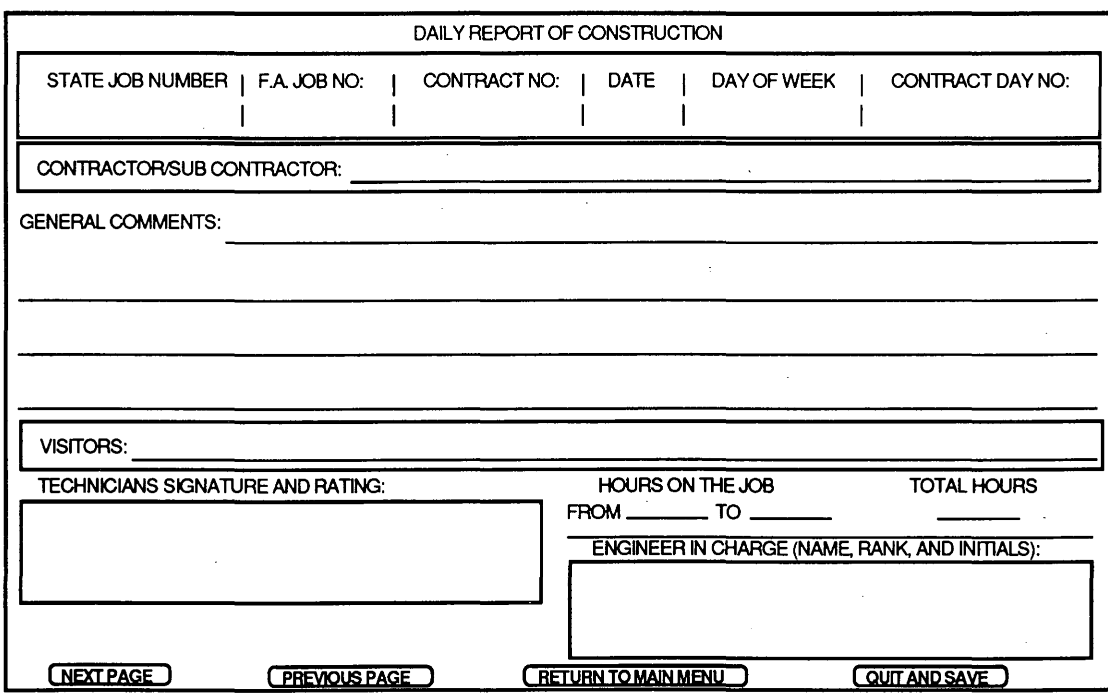
SOIL CONDITIONS: ☐DRY ☐WET ☐EXTREMELY WET

EFFECTS OF WEATHER ON MAJOR WORK ITEMS (CHECK CONTROLLING ITEMS):

Major and/or Controlling Work Items	NO EFFECT	NO WORK 2-4 HRS	NO WORK 4-6 HRS	NO WORK ALL DAY
____	☐	☐	☐	☐
____	☐	☐	☐	☐
____	☐	☐	☐	☐
____	☐	☐	☐	☐

NEXT PAGE | PREVIOUS PAGE | RETURN TO MAIN MENU | QUIT AND SAVE

FIGURE 3 Weather information screen.


DAILY REPORT OF CONSTRUCTION

STATE JOB NUMBER | F.A. JOB NO: | CONTRACT NO: | DATE | DAY OF WEEK | CONTRACT DAY NO:

CONTRACTOR/SUB CONTRACTOR: ____

GENERAL COMMENTS: ____

VISITORS: ____

TECHNICIANS SIGNATURE AND RATING:

HOURS ON THE JOB FROM ____ TO ____

TOTAL HOURS ____

ENGINEER IN CHARGE (NAME, RANK, AND INITIALS):

NEXT PAGE | PREVIOUS PAGE | RETURN TO MAIN MENU | QUIT AND SAVE

FIGURE 4 General comments and signature screen.

Transfer of data from the pen-based computer to the desktop microcomputer is made by direct connection between serial parts. LapLink software is used to transfer data.

Figure 5 shows how the PRS functions within the FDOT construction management system. Initial project data are transferred by direct connection from the mainframe computer at the central office to the desktop personal computer (PC) in the resident's office. This initial project information is then transferred to the pen-based computer from the office PC. At weekly intervals the daily report data are uploaded from the pen-based computer to the office PC. Printed copies of the daily reports as well as weekly and monthly summaries can be produced from the Dbase utility in the office PC. The monthly pay estimate is generated and transferred to the central office by the office PC. Keyword or conditional queries to the data files can be made using the Dbase utility.

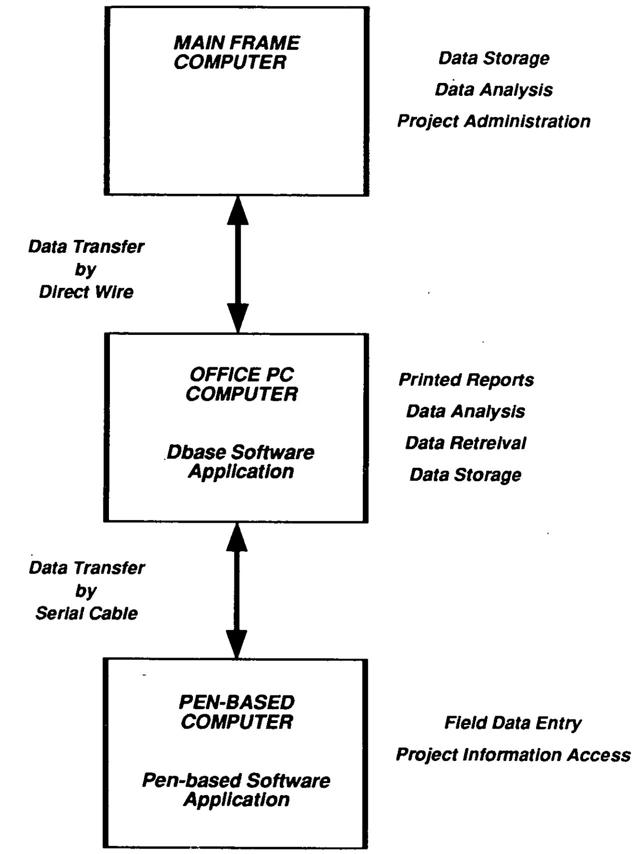


FIGURE 5 FDOT automated project site data acquisition system.

FIELD TESTING

After bench testing and initial debugging, the application was field tested concurrently on six projects for 2 months. The projects selected were typical of the FDOT construction program. One bridge construction project was included. The others were roadway projects.

The PRS was used in parallel with the traditional preprinted daily report of construction. The paper forms were filled out first and then the data were entered on the pen-based computer. This arrangement ensured that the project information would not be at risk. Field users of the system were given a half-day orientation seminar on the pen-based computers and the PRS software.

Computers were assigned to the field users after the orientation seminar. Users were asked to practice with the pen-based machines for 1 week before actually beginning work on the daily reports. Also, a handwriting tutorial by GRID Systems, Inc., was installed on each of the computers. Each user was encouraged to work through the tutorial.

Throughout the field testing, debugging and enhancement of the software continued. Problems were eliminated when reported to the researchers by the field users. At the conclusion of the testing, users were interviewed to obtain their opinions and input into the study.

RESULTS OF THE STUDY

PRS functioned successfully. Field inspectors were able to use the pen-based computers to record FDOT's daily report of construction. Reports were transferred to the office PC. Printed copies of the daily reports and weekly and monthly summaries were produced by the Dbase utility. No hardware failures occurred.

Most new systems are met with a certain amount of organizational resistance. However, FDOT field users were committed to giving the pen-based computer a fair trial. Some problems were discovered during the field testing. These lessons learned should prove valuable when developing organization implementation plans.

Aside from software debugging, the following were the most significant problems:

1. The handwriting recognition feature of the computers requires that some letters be formed in a certain way. Some of the field users experienced difficulty in having the computer correctly interpret their writing. As might be imagined, the frustration level of the user at the job site can rise considerably.
2. More space needed to be allocated to the text fields.
3. Users were required to complete the report on the printed form and then enter the data on the computer. Therefore, they were burdened with twice the work.
4. Primarily because of problems with the handwriting recognition, most of the users believed that the pen-based computer required more time than manual completion of the form.
5. The pen-based computers used did not have back-lit screens. Therefore, night use was not possible.

The following are some of the direct benefits of the pen-based system:

1. The need to key in or retype handwritten reports is eliminated.
2. Field data are managed by a computerized information management system.
3. The field user is given direct access to project information stored in the pen-based computer.
4. With enhanced pen-based forms, the field user's recording time can be reduced.

CONCLUSIONS AND RECOMMENDATIONS

Automating the recording and analysis of construction site data will improve project management efficiency. Pen-based computer technology provides a tool for eliminating job site paperwork. The walking user at the job site can now directly access the microcomputer. Pen-based technology is evolving very quickly. Hardware capabilities are expanding rapidly. Software development will undoubtedly follow.

This study has resulted in the following specific recommendations:

1. Pen-based forms should be designed so as to minimize the need for the user to input data by writing. The use of check boxes and scrollable lists can eliminate much of the

printing. The daily report of construction was replicated as is. An enhanced pen-based version would be preferable.

2. Users should be given adequate practice time with the pen-based computer before trying an actual application. Field testing in this study indicated that handwriting recognition success improved significantly after 1 to 2 weeks of practice.

3. The specific categories of information included on job-site forms should be reviewed before conversion to a pen-based system. Basic information management concepts should be applied when evaluating the report designs and content.

4. The full potential of a pen-based reporting system is only possible when integrated with an organizational computerized management information system.

5. Enhanced or "smart" forms can be developed that not only collect data but also provide information and analysis to the field user.

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Technology Transfer Using Electronic Bulletin Board Systems

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One technology transfer mechanism used by some Local Technical Assistance Program (LTAP) technology transfer (T^2) centers is the electronic bulletin board. Through the use of a transportation-related electronic bulletin board system (EBBS), one can obtain public domain software, send and receive messages and announcements, learn about publication listings, and access other resources of transportation and traffic engineering knowledge. The success of an EBBS as a mechanism for technology transfer depends on the computer fluency of potential users, system maintenance and reliability, the cost of access, and the quality of products and marketing. The results of a research project that evaluated the performance of five transportation-related electronic bulletin board systems operated by LTAP T^2 centers are described. Information was collected from T^2 centers through interviews and raw bulletin board system log files. Utilization models that quantify the T^2 center EBBS experience are presented. This experience base can be used to establish guidelines for similar EBBSs in other public works sectors.

To speed the process of transferring transportation technology developed at federal laboratories to state and local governments and the private sectors, Congress passed the Stevenson-Wydler Innovation Act of 1980 followed by the Technology Transfer Act of 1986. These acts mandate that all federal agencies such as FHWA develop active programs for transferring technology. The Rural Technical Assistance Program (RTAP) was developed by FHWA to achieve the economical improvement of rural roads and bridges through a program of training and technical assistance for local government officials and technical staff (*1,2*). The goal of RTAP is to transfer highway technology to over 38,000 local highway agencies across the United States.

In 1991, RTAP was expanded to include urban areas and renamed Local Technical Assistance Program (LTAP). The largest and most prominent of the technical projects carried out under LTAP is the Technology Transfer Program for local transportation agencies. This project has created a national system of 51 LTAP centers that are referred to as technology transfer centers or "T^2 centers." The objectives (*2*) of T^2 centers are to

- Establish mechanisms for transferring highway technology to rural officials;
- Improve the flow of technical information among FHWA, state departments of transportation, universities, and rural officials;
- Encourage the use of new, cost-effective technology by rural officials; and
- Test innovative technology transfer methods.

T^2 centers maintain mailing lists of rural officials in the area, publish quarterly newsletters, provide local officials with information on new technology, provide technical assistance, conduct seminars, and perform self-evaluations. Some technology transfer mechanisms used by the centers include traveling "roadshows" that offer training and technology to local officials, "how-to" manuals, technical bulletins, videotape libraries, hotlines, and satellite training classes.

One technology transfer mechanism used by some T^2 centers is the electronic bulletin board system (EBBS). An EBBS is a computer hardware and software system that allows computers to communicate over a standard telephone line (*3*). There are thousands of microcomputer-based EBBSs around the country and many that deal in part or primarily with transportation-related topics (*4*). Through the use of a transportation-related EBBS, one can obtain public domain software, send and receive messages and announcements, learn about publication listings, and access other resources of transportation and traffic engineering knowledge. The six EBBSs given in Table 1 were established for technology transfer as special projects of LTAP T^2 centers (*4*). INFOTAP, PC-TRANSport, UTEC/T2, MTU T3C, and Transporter are operated by the California, Kansas, Northwest, Michigan, and Texas T^2 centers, respectively. McLink is operated by McTrans. Although none of the EBBSs have a toll-free telephone access to users, most of the systems are otherwise free.

EBBSs can make a difference in achieving the objectives and goals of technology transfer by saving money and time through increased productivity. This paper describes the results of a research project that evaluated the effectiveness and usefulness of transportation-related electronic bulletin board systems in T^2 centers. Information was collected on the use of T^2 centers EBBSs as well as on the evolution of the systems and plans for future operation. This paper attempts to quantify the experience base and suggest guidelines that can be used in similar EBBSs for other public works facilities. Specific objectives of this research are to

- Measure the size and operation of current EBBS aplications in T^2 centers;
- Evaluate the effectiveness of transportation-related EBBSs for information exchange among transportation professionals and other public officials; and
- Draw conclusions regarding the usefulness and applicability of the various EBBS services that are provided.

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TABLE 1 Transportation-Related Bulletin Board Systems at T^2 Centers

Organization	EBBS	Startup Date
Institute of Transportation Studies (ITS) System Unit University of California, Berkeley	INFOTAP	Sept. 84
McTrans Center for Microcomputer in Transportation University of Florida	McLink	Mar. 90
Kansas University Transportation Center T^2 Program	PC-TRANSport	1986
Northwest T^2 Center Washington State Department of Transportation	UTEC/T2	1986
Michigan Transportation T^2 Center Michigan Technological University	MTU T3C	1988
Texas Department of Transportation Texas A & M University	Transporter	1984

This paper suggests that success of an EBBS as a mechanism for technology transfer will depend on four factors:

1. Overall computer fluency of potential EBBS users and access to training,
2. System maintenance and reliability,
3. Cost of access, and
4. Quality of services and products that are available and marketing directed toward potential new users.

These factors can be viewed as barriers to be overcome if an EBBS is to generate enough use to justify continued operation. Although computer fluency is not essential for users of EBBS, individuals who use computers regularly as part of their daily responsibilities are more likely to learn how to use the required communications software and want to acquire other software obtainable from an EBBS. A computer-fluent staff is more likely to be found in urban rather than rural areas and in large rather than small organizations. Because most T^2 centers have had a small urban and rural focus, limited use of EBBSs by T^2 centers to date is not surprising. Three of the five EBBSs evaluated herein are either in very urban states or have a mission that extends beyond their state boundaries. Some centers provide brief EBBS connection instructions and operating tips to potential users in newsletter articles (*5–11*). Utilization of EBBSs could be encouraged by providing communications software training and access demonstrations.

Little information is available on the frequency of EBBS file updates, system crashes, and off-line time. Backup systems are essential in ensuring continuous availability to users.

EBBS access costs include long distance telephone connect time cost and staff cost. These costs are a minimum of $12.00/hr for long distance connection and $20.00/hr for staff (assuming an engineer). Thus, the minimum cost to a user for a 15-min call is approximately $8.00. This cost is justified if the information has a significant time value. Alternatively, newsletters, technical reports or program/data diskettes may provide a more cost-effective means of accessing information. Although the use of 800 access numbers would encourage some additional users of EBBS services, the often significant staff time cost will remain a barrier.

Existing EBBSs provide a variety of services and products (*12*). In general, the functions of T^2 center electronic bulletin boards include the following:

- Uploading and downloading shareware and public domain computer programs for transportation engineering and public works management;
- Sending and receiving electronic mail and messages;
- Notification of upcoming conferences, seminars, workshops, training courses, and meetings;
- Lists of publications, research abstracts, and available videotapes;
- Announcements of job vacancies;
- Tips on using computer programs and the bulletin board; and
- Data base searches.

All centers reported downloading software as the primary EBBS activity. Although most systems provide electronic message services, centers recognize that messages are used infrequently. Some EBBSs have evolved to provide services that differ from the original purposes. For example, the original purpose of the Northwest T^2 center EBBS was to distribute microcomputer application programs written by city and county traffic engineers. In addition to distributing software, this system now provides on-line information regarding revisions and amendments (general special provisions) to standard specifications and other official state department of transportation documents (G. Crommes, Northwest T^2 Center, unpublished data). Recently, the MTU T3C system installed the Michigan Accident Location Index (MALI) data base that comprises 100 MB of statewide traffic accident data accumulated during the past 2 decades (*13*). Callers can retrieve data in a standard report format for use in analysis. Because MALI was installed in October 1992 (subsequent to this analysis), its impact on MTU T3C system usage was not measured.

Five T^2 center EBBSs will be evaluated empirically using four categories of performance measures:

1. Number of users. Measures include total number and percentage of target audience reached. Also important are changes over time and duration of active use.
2. Level of use. Measures include number of calls and number of activities performed by callers.
3. System cost. Measures include both start-up and operating cost.
4. Cost-effectiveness. Measures include system cost per user and system cost per call.

AVAILABLE DATA

Available data for measuring the performance of transportation-related bulletin board systems includes user attributes, call attributes, call activities and estimates of system start-up and operating costs. The quantity and quality of EBBS data vary from center to center. Differences in the available data result from differences in the capabilities of EBBS software used as well as each center's policies on the level of data needed to monitor system performance. Raw data were obtained for INFOTAP, McLink, PC-TRANS, UTEC, and MTU. For this project, data attributes are divided into three types:

1. *User Attributes.* User attributes characterize each EBBS user during a particular month and during the period covered by the available data. In general, user attributes obtained from each EBBS include first name, last name, city, state, country, first call date, and time of first call. Other user attributes from particular systems include
   a. Phone number, zip code, and agency (for McLink only),
   b. Number of calls, number of downloaded files, number of uploaded files, and computer type (for PC-TRANS, McLink, and MTU only); and
   c. Birthday, number of messages put on the system, and transportation engineering interest area (in MTU only).
2. *Call Attributes.* Call attributes characterize each incoming call. Call attributes data were obtained from INFOTAP, McLink, PC-TRANS, and UTEC. Call attributes include caller identification, call date, and time. The frequency of calls from each user, number of calls with activities from each user, distribution of in-state and out-of-state calls, and number of calls per month can be derived from call attributes data.
3. *Call Activities.* Call activities characterize the activities or actions during each call. Call activities data were derived from INFOTAP, McLink, PC-TRANS, and UTEC EBBSs and tabulated for each month. Call activities data include activity type, file names associated with relevant activity types, and action time. Activity types include downloaded file, uploaded file, aborted file, operator paged, read mail, read message, read newsletter, read bulletin, search file, and displayed file. The level of detail of call activities varies among the EBBSs because of differences in system administration policies and bulletin board software. The frequency of each activity type and primary usage of EBBSs can be derived from call activities data.

Estimates of start-up and operating costs were also obtained from T^2 centers. Start-up costs associated with an EBBS include acquisition of appropriate computer hardware and software, phone line installation and staff training time. Software costs range from \$20 to \$1,500. The median cost for a single line personal computer (PC) system is \$200. Hardware requirements for running an EBBS are minimal. A 286-level PC with a 20-MB hard drive is sufficient (*3*). If a maximum hardware and software cost of \$1,500 is assumed with a 5-year amortization period at 7 percent interest, the monthly cost is approximately \$30.

After hardware and software installation, primary costs for operating an EBBS include a dedicated phone line and system operator staff time. Operators of existing T^2 center electronic bulletin boards spend 2 to 5 hr/week maintaining the system. Assuming 12 hr/month of operator time (3 hr/week times 4 weeks/month) at \$15/hr results in staff costs of \$180/month. Adding a phone line at \$20/month to staff, hardware, and software costs yields a total cost of \$230/month. Other management and staff time costs required to provide technical assistance are viewed as part of the overall T^2 mission. That is, an EBBS from a cost allocation viewpoint is just one of several ways centers provide technical assistance to agencies and individuals.

T^2 centers that support extensive data bases require hardware systems that can store large amounts of information and process complex queries with reasonable retrieval rates. These data bases will also require more operator maintenance. For example, the MALI data base currently requires 100 MB of storage and will be expanded to 200 MB in the near future (D. Calomeni, Michigan Transportation T^2 Center, unpublished data). Thus the reader should note that hardware and software costs for an EBBS that supports access to large data bases, such as MALI, are higher than those estimations given above.

User Attributes

The total number of different individuals who used each EBBS ("users") during the period for which data were available is shown in Table 2. The wide range in the number of users is, in part, explained by the differences in the number of months represented by the data. A wide range also exists in the number of users for which activities were recorded. Records indicate that only 16 percent of PC-TRANS users, in contrast to 93 percent of McLink and UTEC users, engaged in some form of activity. The problem here is that only two of the five systems recorded more than three basic activities: file download, file upload, and abort. Other activities, such as read bulletin and search files, were not recorded. Consequently, subsequent analysis of activity levels must be carefully qualified because of the level of detail provided by the raw data.

The location of EBBS users (in state versus out of state) is of interest to identify the market being served. As shown in Table 2, two EBBSs are serving an in-state market almost exclusively, whereas McLink and PC-TRANS are serving a national market. Table 2 also shows the extent to which EBBSs are serving users that do not have direct service from an in-state EBBS. Over one-half of McLink and PC-TRANS users live in a state without an EBBS. International use exists but

TABLE 2 User Attributes, Call Frequency, and Duration of EBBS Use

User Category (Months)[a]	INFOTAP (46)	McLink (11)	PC-TRANS (15)	UTEC (5)	MTU (13)
	Cumulative User Attributes				
Total Users[b]	538	278	88	116	168
w/activities	43%	93%	16%	93%	-
w/o activities	57%	7%	84%	7%	-
In-state	58%	27%	20%	87%	88%
Out-of-state	40%	69%	76%	5%	12%
States w/ EBBS	65%	43%	44%	87%	90%
States w/o EBBS	33%	53%	51%	5%	10%
International	1.3%	2.8%	1.2%	0.9%	-
	Call Frequency				
Called Once (% of Total)	252 (47%)	120 (43%)	48 (55%)	58 (50%)	54 (32%)
Multiple Calls					
Single Day (% of Total)	47 (9%)	36 (13%)	4 (5%)	10 (9%)	-
Multiple Days (% of Total)	239 (44%)	122 (44%)	36 (41%)	48 (41%)	-
	Duration of System Use (Months)[c]				
Multiple Days Users					
Mean	10.9	2.7	2.7	1.1	-
Std. Deviation	12.3	2.7	2.8	1.0	-
Maximum	45.2	9.8	9.2	3.5	-
All Users					
Mean	4.9	1.2	1.1	0.5	-

[a] Number of months of EBBS data
[b] Total number of users during the period with data
[c] (Date of Last Call - Date of First Call + 1 day) / 30 days/mo.
- Indicates data unavailable

is very limited, with McLink having the highest level at nearly 3 percent.

The number of active EBBS users varies substantially from month to month. Figure 1 shows the change in the number of users per month for each EBBS over a 4-year period from October 1987 to October 1991 during which data were collected. Our initial expectation was that the graph of monthly users would follow an *s*-shaped growth curve, with slow initial growth followed by rapid growth leading to a plateau of slow growth. However, Figure 1 indicates that none of the EBBSs for which monthly data could be developed showed this expected growth curve. Instead, two EBBSs show declining trends. One shows an increasing trend and the fourth has too few data to determine a trend. One problem here is that only McLink data represent the startup pattern. Although other EBBSs have been in operation for several years, data for their initial operation were not available.

The change in users per month depend on new users attracted to the EBBS and retention of prior users. The extent to which users make multiple calls is shown in Figure 2. Table 2 contains a summary of frequency and duration of EBBS use. The percentage of one-time callers ranges from a high of 55 for PC-TRANS to a low of 32 for MTU (not plotted in Figure 2). Longer tails on the curves in Figure 2 suggest, but do not guarantee, a longer time period as a regular user. Users who have made more than 20 calls are not shown in Figure 2. Such users account for 4 percent of INFOTAP users and less than 1 percent of other system users.

The time spent as an "active user" can be computed as the difference in time between the first and last calls. For users who have made multiple calls, the average time spent as active users is presented in Table 2.

Call Attributes

Three EBBSs—McLink, UTEC, and MTU—with the greatest level of use averaged 83 to 95 calls per month (four to five calls per weekday). Thus, even with long calls of 15 to 20 min, access to these single-line systems should not be a problem. The least-used EBBS averaged less than one call per weekday (15.4 calls per month).

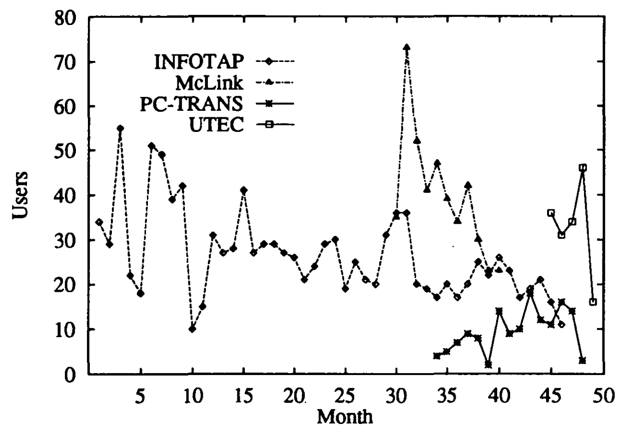

FIGURE 1 Number of users per month for each EBBS.

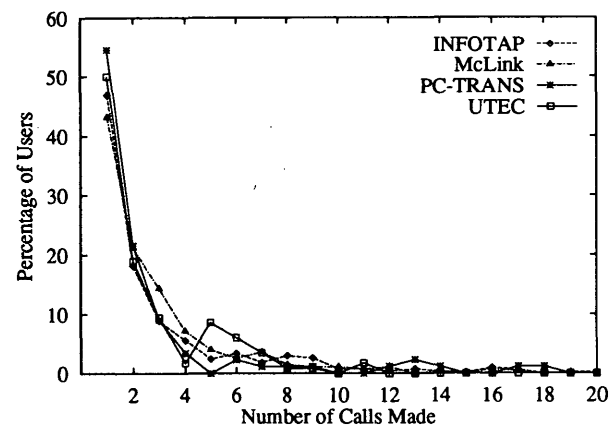

FIGURE 2 Frequency distribution (percent) of total users by number of calls made.

Information about "activities" that are associated with each call varies widely. The percentage of calls with activities ranged from a low of 16 for PC-TRANS to 80 for McLink calls. Information about activities during calls is more limited than is information about activities of users. Thus, comparisons between systems with respect to the purpose of calls must be made with care.

The proportion of in-state calls to each EBBS varies from 28 to 93 percent. In general, the proportion of in-state calls is higher than the proportion of in-state users. The difference is particularly great for McLink, which has 48 percent in-state calls but only 27 percent in-state users. Although differences in long distance phone rates may make an EBBS more accessible to local in-state users and thus generate more frequent use, a more important factor is probably more direct communication and marketing that can be provided to in-state users.

EBBS calls tend to originate from in-state and other states that have an EBBS. This percentage of total calls ranges from 48 to 95 with up to 21 percent being attributed to calls from other states with an EBBS. Thus, an in-state EBBS clearly does not satisfy the entire demand for EBBS services in a state.

Call Activities

Call activity analysis is based on data recorded by EBBS operating systems. Substantial differences exist in the level of activity recordkeeping between EBBSs. As shown in Table 3, all EBBSs record file downloads, uploads, and aborted activities, but only McLink and UTEC systems record details of other activities such as reading mail, listing files, or viewing systems of file statistics. A separate survey of EBBSs revealed that although each system has the capability of viewing messages, bulletins, and other information, only two of the five systems record such activities.

To the extent that call activities can be compared, Table 3 shows that except for McLink, file downloads are by far the most common activity. Primary McLink activities involve reading and listing, whereas file downloading accounts for only a small percentage of recorded activities.

EBBS UTILIZATION MODELS

Performance evaluation of EBBSs requires an understanding of relationships among users, calls made by users, and activities generated by calls. Ideally, the number of users and other attributes could be modeled as a function of EBBS target groups and the extent of marketing and promotion. Such detailed models are beyond the scope of this effort; however, we will make a simple comparison between EBBS client group size and the actual number of EBBS users. Next, we will estimate the number of calls, given the number of users. One might expect a direct relationship between the number of calls and the number of users, but whether the relationship is similar across different EBBSs and whether it is stable over time is unknown. Similarly, one might expect a direct relationship between activities and calls. However, given the varying levels of activity details that are recorded in each EBBS system log file and differences in the utility of EBBS information available to users (files versus messages versus newsletter, etc.), the relationship between activities and calls is likely to be unique for each EBBS.

The primary target audience for EBBS services is likely to be recipients of quarterly newsletters that all T^2 centers are required to publish. Table 4 presents data on newsletter circulation volume and the estimated number of EBBS users as obtained from T^2 center staff. Table 4 also gives the actual number of EBBS users as determined from system log files. The primary reason for the discrepancy between numbers of estimated and measured users is that occasionally EBBS operators will purge the user base of longtime inactive users. INFOTAP has the largest total "measured users" because operational data for nearly 4 years were available. For INFOTAP, the value of "estimated users" reflects an estimate of the number of active users. For McLink, PC-TRANS, UTEC, and MTU, the value of estimated users is the cumulative number of users over the EBBS's life rather than the number of currently active users. For all systems, average measured users, "average users/month" is based on actual users each month over the period for which data were available. EBBS staff-based estimated users is roughly 10 percent of regional newsletter circulation volume, excluding McLink's national newsletter and PC-TRANS's national magazine. Average

TABLE 3 Frequency Distribution of Call Activities

Activities Transactions	INFOTAP	McLink	PC-TRANS	UTEC	MTU
DOWNLOADED	75.99%	12.88%	69.86%	45.38%	82.33%
UPLOADED	3.01%	0.80%	1.37%	0.50%	17.67%
ABORTED	18.20%	4.54%	26.03%	6.25%	-
OPERATOR (SYSOP) PAGED	0.96%	0.00%	-	0.75%	-
NOT ENOUGH TIME	1.84%	-	2.74%	-	-
READ BULLETIN/MAIL	-	25.3%	-	11.38%	-
READ MESSAGE/FILE	-	7.0 %	-	5.6%	-
READ NEWSLETTER	-	3.15%	-	7.88%	-
SEARCH NEWFILES/FILE	-	4.8%	-	3.50%	-
AREA MESSAGE/LIST AREA	-	34.9%	-	7.25%	-
LISTED AREA	-	31.74%	-	-	-
DISPLAYED INFORMATION	-	1.12%	-	4.88%	-
COMPLETED FILE	-	1.33%	-	-	-
VIEW SYSTEM/FILE STATISTICS	-	4.1%	-	6.6%	-
Total Activities	2495	3393	73	800	283

- Indicates data unavailable

measured users per month, in turn, are about 10 percent of estimated users at least for McLink and UTEC systems. Clearly, EBBS usage rates as a percentage of newsletter circulation are small for any 1 month. However, California data on total users over several years demonstrate a much higher level of market penetration on the order of 20 percent. On the basis of "estimated total users," market penetration for UTEC and MTU systems are on the order of 10 percent.

EBBS performance can be evaluated by relating calls to users. Table 5 presents aggregate data on calls per user for two temporal levels: the cumulative level, over all the months for which data were available, and the monthly level. At the cumulative level, calls per user are remarkably similar considering the wide range of periods examined. Three of the five systems are within the range of 3.6 to 4.5, with one system substantially lower and one substantially higher. Clearly, the "average" user makes multiple calls to the system over a period of several months. However, as shown in Figure 2, the general pattern for distribution of users by call frequency decreases in the number of users as the number of calls made increases. At the monthly level, the ratio of average number of calls to average number of users falls in the range of 1.6 to 2.6. Thus, although the average number of users per month varies considerably among systems, the level of use per user (calls per user) is quite similar.

An estimation of the number of calls per month based on a single ratio of calls per users for each EBBS will not be valid if the ratio changes over time or if the relationship between calls and users is nonlinear. A plot of calls per user versus month revealed no consistent upward or downward trend over time for any of the EBBSs. Separate plots of calls versus users for each EBBS showed highly linear relationships.

Linear regression models for calls per month as a function of users per month are presented in Table 6. All models have reasonable explanatory power (R^2 of 0.77 or larger). Regression coefficients for users are highly significant, but constant terms are not significantly different from 0 at the 0.05 level. Negative constant terms, although not statistically significant,

TABLE 4 Target Audiences Versus Actual Users

EBBS	Newsletter Circulation	Estimated Users[a]	Measured Users	Average Users/Month
INFOTAP	3,000	120-150	538	26.4
McLink	22,000	425	278	39.9
PC-TRANS	5,000 (N)[b] 24,000 (M)	320-510	88	9.5
UTEC	2,300	300	116	32.6
MTU	3,400	300	168	-

[a] EBBS staff estimates of users
[b] (N) Quarterly newsletter; (M) Bi-monthly magazine
- Indicates data unavailable

TABLE 5 Overall EBBS Utilization Levels and Cost-Effectiveness

Utilization Measure (Months)[a]	INFOTAP (46)	McLink (11)	PC-TRANS (15)	UTEC (5)	MTU (13)
			Cumulative Data		
Users	538	278	88	116	168
Calls	2397	1045	231	415	1162
Activities	2495	3393	73	800	283
			Cumulative Performance		
Calls/User	4.46	3.75	2.63	3.58	6.92
Activities/Call	1.04	3.25	0.32	1.93	0.24
			Monthly Performance		
Avg. Users	26.4	39.9	9.5	32.6	-
Avg. Calls	52.1	95.0	15.4	83.0	89.4
Calls/User	1.97	2.38	1.62	2.55	-
			Cost-effectiveness		
Cost/Call[b]	$3.80	$2.10	$13.00	$2.40	$2.20
Cost/User[b]	$7.60	$5.00	$21.10	$6.10	-

[a] Number of months of EBBS data
[b] Based on monthly operating cost of $200 per month
- Indicates data unavailable

TABLE 6 Regression Models for Relationships Between Monthly EBBS Calls and Users and Monthly EBBS Activities and Calls

EBBS	n	Monthly Calls Const Term	Monthly Calls Coeff for Users	Monthly Calls R^2	Monthly Activities Const Term	Monthly Activities Coeff for Calls	Monthly Activities R^2
INFOTAP	46	-2.4 (-0.51)	2.1 (12.5)	77.4%	6.4 (0.56)	0.92 (4.6)	31.3%
McLink	11	-14.3 (-1.3)	2.7 (10.2)	91.1%	-25.1 (-0.61)	3.5 (8.8)	88.5%
PC-TRANS	15	-3.8 (-1.2)	2.0 (6.9)	76.9%	-3.9 (-1.4)	0.57 (3.8)	48.4%
UTEC	5	-46.8 (-1.6)	4.0 (4.6)	83.6%	-31.6 (-0.9)	2.3 (6.1)	90.1%

Note: "t" values in parentheses

suggest that months with fewer users have lower rates of calls per user than months with many users. This results in regression coefficients for users being larger than overall ratios for calls per user shown in Table 5. The most extreme example is the UTEC model with a regression coefficient of 4.0 compared with the overall calls per user ratio of 2.55. The most important result here is the stability of calls per user ratio, both over time and for wide fluctuations in number of users.

The final relationship considered is between activities and calls. Ratios of activities to calls for cumulative data on EBBS utilization are presented in Table 5. Ratios for monthly performance data are the same as those for cumulative data and thus are not repeated in Table 5. As discussed earlier, ratios of activities to calls vary widely because of EBBS software recordkeeping capabilities. Nevertheless, analysis of monthly performance data reveals consistently linear relationships between activities and calls for all EBBSs. In addition, there are no apparent trends over time. The resulting regression models are presented in Table 6. INFOTAP and PC-TRANS models have relatively low explanatory power (R^2 of 31 percent and 45 percent, respectively), but regression coefficients for calls are highly significant. Although constant terms are not statistically significant, inclusion of constant terms does affect the call's coefficient value slightly. As for calls versus user regression models, the activity versus calls models exhibit a high degree of stability over time. The value of the regression coefficients, however, depends on the definition of activities and the extent to which activities are recorded by each EBBS operating system.

EVALUATION OF EBBS PERFORMANCE

Performance can be measured by number of users, level of use, and system cost. Cost-effectiveness measures can then be developed in terms of users per unit cost and utilization per unit cost. In theory, system performance should consider current operating costs and should be monitored monthly. If system performance goals are not being met, then corrective action can be taken in a timely manner. The problem is that the primary measures of system performance, calls per month, and users per month are quite variable. Over its 46 months of operation, calls per month for INFOTAP varied from 15 to 110 with an overall average of 52. Because operating costs should be quite stable, the cost-effectiveness measure, cost per call, for INFOTAP was also highly variable. Thus, major decisions about EBBS operation should be based on long-term trends rather than on month-to-month variations.

Cost-effectiveness of the five case study EBBSs is presented in Table 5. Cost-effectiveness measures are based on monthly performance and are computed using a common operating cost of $200/per month ($180 for staff time and $20 for phone as explained earlier). The cost per call generally ranges from $2.10 to $3.80 with one outlier at $13.00. The cost per user ranges from $5.00 to $7.60 with one outlier at $21.10.

EBBS cost-effectiveness for delivery of technical assistance is assessed by considering alternative modes for delivering comparable products. For example, an alternative mode for distribution of software is by diskette and U.S. mail. For comparison, consider a telephone hotline with distribution of requested technical publications by FAX. Assuming 6 min per call with staff time at $15.00/hr plus a $2.00 FAX cost, the total cost per call is $3.50. This cost per call for FAX is well within the range of EBBS case study costs per call.

SUMMARY AND CONCLUSIONS

Data on users, calls, and activities were available for five EBBSs. In general, the data were analyzed at two levels: first, as total cumulative values covering the time periods for which data were available and second, as monthly time series looking at both the monthly average and variation over time. In addition, the average time that users participate in each system was computed.

User attributes showed that two systems serve a national market, two are regional, and the fifth serves both a national and regional market. In general, the distribution of calls is more likely to be in state than is the distribution of users. Some users are attracted from other states that have an EBBS, suggesting that unique services are being provided by each EBBS.

The change in the number of EBBS users from month to month did not follow the expected growth curve. Instead, users per month followed a downward trend for two of the systems, an upward trend for one system, and no trend for the fourth. There is also considerable month-to-month variation within the trends.

Calls per month followed a pattern similar to that for users per month. Although there is considerable variation for all systems, the variation takes place within a relatively narrow band of one to three calls per user, and the trend over time is essentially flat. Thus, the needs and incentives to utilize EBBSs appear to be similar across the systems and stable over time.

Examination of the distribution of users by number of calls made shows that most users made only one or two calls during the periods studied. Normalized distributions based on percentage of users are very similar for the four systems that could be compared. The small proportion of repeat callers is consistent with the relatively short duration of system use on the part of callers. Mean duration of use is typically about 10 percent of the total months for which data are available.

The small proportion of repeat callers suggests a reason for decline in users and calls for two systems. Initial system marketing should generate use by the most computer-fluent individuals who are highly motivated to gain access. Once the initial demand is satisified, subsequent marketing must reach individuals who are less motivated and computer fluent; thus the number of users declines. Information on marketing and services offered over time is needed to test this hypothesis.

The level of call activity record keeping is a function of EBBS software capabilities and administrative policy decisions. File download and upload information was available for all five systems; however, details of other common activities such as reading mail or displaying information were available for only two systems. With the exception of McLink, file downloads were the dominant activity for all systems and, with the exception of MTU, file uploads were quite rare.

EBBS staff estimates of users and actual measured users should have some relationship to target audience size as measured by T[2] center newsletter circulation volume, but the relationship is not perfect. Nevertheless, for systems with a target audience composed of individuals who receive the regional newsletter, we roughly estimate an optimistic utilization rate of 10 to 20 percent over the extended life of the EBBS. Utilization models relating users to calls and calls to activities using linear regression, were much more successful. These regression models have reasonable explanatory power with highly statistically significant regression coefficients and, as expected, constant terms were not statistically significant. In addition, these models are not biased by any trends over time. Note however, that for these models, "users" is an independent variable; thus, the decline in users over time for two systems is not modeled.

Finally, system cost-effectiveness was estimated based on an assumed common operating cost of $200/month. With the exception of one system, the cost per call ranges from $2.20 to $3.80. This range is entirely consistent with the estimated cost of a telephone hotline and FAX method for delivering printed materials and is likely to be highly competitive with the cost of alternative modes for distributing software.

This research has demonstrated the ability to quantify the attributes and the operation of a diverse set of EBBSs for transportation-related technology transfer. Operation and performance data exhibit some remarkable similarities, particularly call frequency distributions and calls per user data. Performance measures provide an initial basis for assessing the effectiveness of an EBBS as a tool for technical assistance and information exchange. Clearly there are potentially large economies of scale because staff costs are essentially independent of level of use. If more technical assistance activities are tailored to the EBBS environment and marketed effectively, the cost of technical assistance might be substantially reduced. We suggest that activities with the greatest potential include timely information that can be packaged in a computer file for downloading by users in the field.

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Impact of Downsizing of Information Technology on Engineering Operations

SHYU-TU LEE

Computers have helped engineers and planners improve productivity and perform tasks that are impossible for manual operation. Development in computerized information technology will certainly affect engineering operations. One of the emerging issues in the information profession is the downsizing of information technology. The scope of the downsizing is defined, the status and the pros and cons of downsizing are reviewed and evaluated, and finally, the possible impact on engineering operations is pointed out. An attempt is made to bridge the gap between the engineering and the information technology professions.

What is downsizing of information technology (IT)? In many journal articles, downsizing is defined as converting large computer systems to smaller ones. Peri (*1*) of Computer Support of North America, Inc., defines downsizing by identifying six downsizing strategies: from mainframe to personal computer (PC) local area network (LAN), from a mainframe to a UNIX host, from a mainframe to a hybrid PC LAN with UNIX hosts, from a mainframe to a hybrid PC LAN with mainframe relational data base management system, from a mainframe to a cooperative PC LAN with AS/400, and from a mainframe to a less expensive mainframe.

Some consider downsizing to go beyond just using smaller equipment. Klein (*2*), the president and founder of the Boston Systems Group, a systems development firm, defines downsizing as "a gradual transition to the dispersed usage of computer based information systems by groups of multiple individuals to support unique and specific business responsibility" (*2*,pp.2–7). He suggests that downsizing has three dimensions: equipment, systems development, and decision making. The process of downsizing will change the centralized environment to a decentralized one. It converts the large centralized equipment to distributed smaller ones, and it changes centralized systems development activity and decision making to a decentralized activity that involves users.

In this paper, downsizing is defined as having three dimensions: equipment, systems development, and decision making, as suggested by Klein (*2*). Downsizing activity will generate more benefits if it is conducted with these three components. Considering the interdependency of hardware, software, and applications, it is necessary to include factors other than equipment. There are several synonyms for the downsizing of information technology. "Client/server computing" and "distributed computing" environment are frequently used to describe the same concept with a different emphasis. The term client/server computing is used when the hardware configuration and its functionality are emphasized, in contrast to the centralized mainframe computing. The term distributed computing is used when computing power, as it relates to users, is stressed (*3*).

To predict the possible impact of downsizing of information technology on engineering operations, the purpose for and the status of downsizing should be understood.

IMPORTANCE AND PURPOSE

Downsizing recently has become one of the most frequently discussed subjects in the information technology profession. In a survey conducted by the Society for Information Management in 1991, reported by Millers (*4*), the client/server issue topped the list of important technological advances; this indicates that more organizations are moving toward the client/server computing environment. At least three national conferences on downsizing were offered between March and September of 1992. Articles on this subject frequently appear in magazines such as *COMPUTERWORLD*, *INFORMATIONWEEK*, *PCWeek*, *CIO*, and *Business Week*. All these factors suggest that this activity deserves close attention.

Purposes for downsizing information technology vary. Peri (*1*) suggests several reasons for downsizing: cost efficiency, improved applications, avoidance of mainframe upgrading, shared data, increased reliability, and improved user and programmer productivity. Downsizing is the response of the management information systems (MIS) profession to pressures from users and management. MIS is pressed by end users to provide more services, and, on the other hand, MIS is pushed by chief executive officers to spend less. Arguments such as Peri's on cost saving for downsizing reflect the consideration of downsizing economy.

Some downsizing experts cite other factors as purposes for downsizing. Kiely states, "Ultimately, downsizing is a path to distributed computing, client/server architectures, the reengineering of outdated business process, new ways of managing information, new IS [information systems] skills, and a new job description for the CIO [chief information officer]" (*5*,p.42). Arguments such as this one consider downsizing as an effort for revitalizing an organization (*6*).

Considering its scope and purposes, a downsizing effort aims to produce the following benefits:

- Cost avoidance,
- Cost reduction,
- More flexibility in hardware configuration,

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- More flexibility and efficiency in systems development,
- More computing power and functionality for users,
- Higher productivity for users and MIS professionals, and
- Revitalization of an organization's business process.

STATUS OF DOWNSIZING IN THE INDUSTRY

Technology Readiness

The readiness of the technology for downsizing is questioned by many downsizing experts who caution us to act slowly. "The technology's a little raw and new" admitted Cheryl Currid, a downsizing consultant based in Houston in a report by Kiely (*7*). Kiely reported that, in a survey to 60 CIOs and 30 vendors conducted by Input, a market research firm, the respondents, in general, believe that

> the mainframe offers better reliability and security than do PC LANs, and that there is better vendor support for mainframe. . . . In many ways, the new technology must still prove itself—especially to IS executives in large, centralized organizations. CIOs worry about coherence, compatibility, integrity, and security. (*5*,p.38)

Downsizing with current technology is not for every organization. If an organization has a high degree of homogeneity in technology and a high degree of similarity across applications, then it should pass up the technology for now (*7,8*). Some "considered it totally unrealistic to get rid of the mainframe when certain financial and operating information will always need to be centralized (*9*,p.56).

However, some downsizing advocates push downsizing vigorously. In the same survey conducted by Input, the respondents listed a wide array of applications they intend to downsize in 1992. "People are definitely moving in this direction" (*5*).

Reviewing the arguments from both sides, it is reasonable to conclude that the present technology for downsizing is only partially ready. For small organizations that do not require complex hardware and software configurations, the technology is available. But for large organizations with sophisticated information systems, the technology is not quite mature. The efforts required to downsize in a large scale may be greater than the benefits it can derive.

Cost Consideration

Some experts argue that cost is a major consideration for downsizing; others suggest that downsizing may not be able to save cost.

In the survey conducted by Input, the respondents cited cost saving as the driving force behind downsizing, although they doubt that downsizing will yield big cost savings. Peri (*1*) cited a survey of 25 large companies by Forrester Research that revealed that 17 of the 25 companies had replaced their mainframe entirely with smaller computers and that each had an annual savings ranging from $200,000 to $4.5 million. There are numerous success stories in saving costs. For example, Home Mutual Life Insurance Co., in Baltimore, replaced an ancient Honeywell mainframe with five PC LANs. The company will recoup its $480,000 migration costs in just 2 years. JFK Medical Center in Atlantis, Florida, substituted a RISC-based network for its mainframe, reducing IS staff costs by 25 percent and saving thousands of dollars in hardware and service costs (*5*).

But there are companies that have found the cost issue complicated and are not as optimistic as expected. Harley-Davidson, headquartered in Milwaukee, had spent about 10 to 20 percent over budget when it was only halfway through a project to move from a mainframe environment to IBM AS/400s and LANs. McKesson Water Products Company, in Los Angeles, moved some business systems from a mainframe to AS/400s, which cost the company more than it had expected to pay (*5*).

Judging from reports from both sides, it is clear that there is no guarantee of saving costs by downsizing. The cost savings depends on a variety of factors. Gartner Group predicted that the cost savings through downsizing will be realized as system tools advance over the next 5 years (*10*).

Organizational Issues Involved

What are the problems encountered in relation to the organizational issues? Is downsizing well received by all elements in an organization? In fact, some push for downsizing, but still many resist it.

In the survey conducted by the Society of Information Management, "respondents indicated that the most important issue they faced was reshaping business processes. It has become so pervasive that many believe it is the key to managing change and improving the way companies do business" (*4*,p.24). Some people, however, would rather fight than follow the trend (*6*). The resistance is caused by the fear of change and protection from losing what they have acquired. Downsizing may make some people's knowledge obsolete and eliminate jobs.

Downsizing eventually will bring an organizational culture change, particularly if it is used as a tool for organizational transformation. It will change the business process, require new skills, change job descriptions, reallocate resources, and break power balances. We should not stop downsizing out of fear of change. We should manage the downsizing to make it benefit both the organization and the workers.

Evaluations and Predictions

According to Schay, "The migration to client/server computing is inevitable" (*11*). "Client/server will be the predominant technology architecture, and it will evolve into an important application architecture" for the next decade (*12*,p.9). To predict the impact of downsizing on engineering operations, it is necessary to understand the scope of the activity and the tool and process used. The key points from the above discussion can be summarized as follows:

- Downsizing is a complex process that migrates all information systems from mainframes to smaller computers and provides distributed computing power to end users while maintaining current applications to support business needs. It needs to be well planned.

- Downsizing is a major endeavor for an organization. It will change organizational culture, reengineer business processes, and require staff retraining. It needs all-out efforts and support from top management.
- Downsizing of information technology will be continued since it can provide distributed computing power to users, be used as a tool for organizational transformation, and save costs if it is conducted correctly.
- The technology is not quite ready. For small organizations and simple applications, there have been numerous success stories. But for large organizations and complex applications, the key word is caution.
- The technology will be continuously improved; therefore, organizations should be ready to take advantage of the developments.

EFFECTS ON ENGINEERING OPERATIONS

Encompass IT Knowledge and Skills in Engineering Operation

As the computing power is distributed to the end-user's areas, users have to assume more responsibilities in using the information technology. For example, staff engineers have to know how to use hardware and software and back-up files, handle systems security, and, in some cases, use programming languages (third or fourth generation) to develop programs or simple systems for localized applications. Managing engineers have the new responsibility of managing the information resources in their areas. They have to learn how to develop staff skills to use it, how to use IT to improve productivity, and how to fully utilize the technology (*13*). These all require new IT knowledge and skills to be incorporated into the engineering profession.

Plan a "Learning Organization" to Develop Human Resources

A massive education and retraining program will be required. Information technology is a very dynamic field. New technologies and new tools appear on the market almost every month. To take advantage of these new technologies and to improve productivity we need to retrain our staff. Without the commitment to develop human resources, the result will be an inefficient work force.

The idea of a "learning organization," as suggested by Senge (*14*), should be promoted so that new IT knowledge and skills can be quickly developed. The productivity of an engineering organization in the 1990s may well depend on the rate at which its engineers relearn how to apply information technology. To increase IT skills, not only do engineering organizations need to retrain their engineers, but universities should also better prepare new engineers.

Facilitate Integration of Management and Design of Engineering Systems

As powerful computers become available on the desktop, an engineer should be able to use other new technologies, such as geographic information systems and organization-wide data bases. With these capabilities, an engineer can review the interactions in an easily understandable graphic format of multiple subjects, such as the integration of land, transportation systems, water, sewer, utility, environmental conservation, project status, and even social and economic factors. These multiple subjects have to be treated as an integral system and designed and managed with information technology. This capability, although it is not immediately available, will become a reality as an organization creates its organization-wide data base.

It is difficult now to predict the impact of this capability on the management of engineering operations. However, it certainly will affect the way engineering components are viewed in a complex urban environment. It will facilitate the integration of the management and the design of these engineering components. This move of integration will also affect engineering education.

Be Prepared Mentally and Administratively

Because downsizing will alter the information technology infrastructure and the level of service to an operation, one should assess the readiness and give an opinion on the pace of the downsizing from the perspective of the operation, regardless of one's position in the organizational hierarchy. In other words, one should neither let past practice block one's thinking nor let political considerations blur one's vision (*15*). A position is taken on the basis of business need.

On the other hand, it is necessary to assess one's readiness. Engineers should develop an action plan to guide migration for downsizing. One needs to secure financial support (*16*) for the migration, as well as automation support for the operation in transition.

Conduct Organizational Transformation

As more computing power is distributed to user areas, it will change the job nature and work load for every employee. It will make people aware of the need to review the work flow, the engineering operation processes, and the new responsibility. A review of the business process, work load distribution, organizational structure, resource allocation, and even management style is almost inevitable. As a result, an organization could become smaller, flatter, and less structured; an individual may find himself or herself either doing the same function in different ways or performing a different assignment.

Davenport and Short (*17*) use "new industrial engineering" to describe the recursive relationship of information technology and business process redesign. They suggest that

> Thinking about information technology should be in terms of how it supports new or redesigned business processes, rather than business functions or other organizational entities. And business process and process improvements should be considered in terms of the capabilities information technology can provide. (*17*,p.12)

Information technology should be viewed as more than an automating tool; it can be used to reshape the way engineering operations are done and it should be used to improve organizational efficiency.

CONCLUSION

Downsizing of information technology can give end users more computing power, help organizations improve productivity, and revitalize business processes. Although the technology is not quite ready for large-scale downsizing, organizations should be ready to take advantage of it. Engineering organizations should realize the need to encompass IT knowledge and skills in engineering operations, to commit to a staff retraining program, to integrate the management and the design of engineering systems, to be prepared mentally and administratively, and to conduct organizational transformation by using information technology.

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