passengers' commitment to and enthusiasm for vanpooling by providing articles on the benefits of ridesharing, its status in other cities and states, activities and innovations of the program, and so on.

Pooler's Packet

Supplying new carpoolers and vanpoolers with materials that promote ridesharing is an effective method for encouraging them to continue to rideshare and reinforces the message that pooling is a rewarding experience. Materials might include premiums (bumper sticker, litter bag, notepad), a letter congratulating them for joining a pool and reiterating the benefits of sharing the ride, a copy of the rideshare newsletter, a pooling pointers brochure, a general program brochure to give to a friend, a map of park-and-ride lot locations, and the business card of a program staff member for future reference and assistance.

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A Level-of-Service Framework for Evaluating Transportation System Management Alternatives

ABISHAI POLUS and ANDREJ B. TOMECKI

ABSTRACT

The complexity involved in evaluating a transportation system, as reflected in the large number of, and often conflicting, goals and objectives postulated by various groups affected by the system, is discussed. Desired improvements can encompass, for example, a reduction in person hours of travel, vehicle delay, traffic volume, or energy consumption as well as an increase in the number of transit passengers. Alternative strategies may result in different changes in each of the variables. Existing evaluation procedures, like goal-achievement analysis or cost-effectiveness analysis, are shown to have various disadvantages, the main one being an inability to compare the different magnitudes of improvement caused by different variables. A benefit-cost analysis can address this problem only if the variables evaluated can all be reduced to monetary terms, which is seldom possible. An evaluation procedure is proposed in which a panel of decision makers representing the various interests affected by the transportation system allocates weighting factors to the selected variables. The utility analysis can be used, thus allowing conflicting views to be presented in an open discussion and a consensus to be reached. The weighted worth of all variables is then summed to give the level of service of the transportation system (LTS), which allows the comparison of one strategy with another, enabling decision makers to select the most suitable alternative.

The elements of any typical transportation system, though rather complex, are interrelated. Private vehicles, public vehicles (e.g., buses, taxis, rapid transit trains), streets and parking facilities, pedestrians, and installations for pedestrian use should all be considered elements of a single urban transportation system. In recent years, there has been a shift in engineering philosophy toward better, more efficient use of existing transport systems. Whereas the standard solution to growing demand in the past was the provision of additional capacity, planners and engineers now seek the best possible use of existing systems with, perhaps, minimal cost adjustment.

In the present economic climate, characterized by the shortage of funds for transportation facilities and services, it is natural to expect the capital used for transportation purposes to be scrutinized carefully in respect to the efficiency and produc-

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tivity of the investment. The former emphasis on a high-cost urban transportation infrastructure and subsidized public transport operations has given way to the efficient management of existing facilities and services. Once it has been recognized that a transportation system encompasses a loose cluster of elements--public transport, arterial streets, paratransit, traffic signals, and so on--the need arises to manage them as a system. Tools must be developed for defining the objectives of the system, measuring its effectiveness, and evaluating its performance. Hence, the concept of transportation system management (TSM) was developed.

In the original FHWA definition of TSM [40 Federal Register 42976-42984 (1975)], the stated objective was to coordinate the individual elements through operating, regulatory, and service policies in order to achieve maximum efficiency and productivity for the system. This definition is dependent on an understanding of the concept of a system. Mackey (1) suggested a broad understanding and used the following definitions:

- A system is a set of elements with relationships between the elements and between their attributes.
- Efficiency is determined by comparing the consumption of the resources of a system with an agreed standard for a unit of output.
- Productivity is determined by comparing the actualities (demand) of the system and its capabilities (supply).

On the basis of these definitions, four observations emerged:

1. Pricing policies are essential for managing a transportation system.
2. In order to maximize the efficiency and productivity of a system, alternatives based on capital investment must not be excluded from consideration.
3. The elements of a transportation system can be broadly defined as transportation modes, transportation infrastructure, and land and its use (the FHWA document lists only transportation modes as elements of a system).
4. A change in any of the system's elements affects the attributes of the other elements. These effects may be beneficial or detrimental. Constant monitoring of the performance of the system is essential to assess the influence of changes on the system as a whole.

As a result of these definitions and observations, a modified TSM concept emerged: Urban transportation system management is a process of coordinating the individual elements of a system through operating, regulatory, pricing, service, and investment policies so as to achieve maximum efficiency and productivity for the system as a whole. Monitoring is an essential part of the process and is discussed at length by Meyer (2).

Two terms emphasize the essence of the TSM philosophy: coordination of the elements of the system (rather than changing individual elements) and maximization of the efficiency and productivity of the system. The idea of quality of service has not been included in the definition, but in this paper it will be treated as an inherent part of the TSM process.

The TSM process consists of the following components:

- Definition of the problem,
- Generation of alternative feasible solutions,
- Evaluation of these solutions,
- Selection of the most appropriate solution,
- Implementation of this solution, and
- Monitoring of the system.

The adoption of TSM as a short-term planning and implementation approach has a considerable effect on the planning process as a whole. For example, traditional long-range urban transportation planning processes, which involve massive data collection and development of long-range prediction models, do not always apply. Furthermore, although one can expect tangible benefits from TSM to be achieved relatively soon after its introduction, it is important to understand that TSM should be looked at as a continuous process, composed of interrelated marginal modifications, not a one-time improvement.

There is ample literature on some of the TSM process components. Prominent publications include Transportation Research Board Special Reports 172 and 190 (3,4) and a management overview on alternatives for improving urban transportation by Rowan et al. (5). Some studies concentrate on a more specific problem, such as the FHWA handbook on freeway management (6), NCHRP Report 241 (7), or a study by May (8) on models used to predict impacts resulting from traffic management strategies applied to freeway corridors, arterial networks, or rural highways.

The emphasis in this paper will be on the selection and evaluation of the solution to be implemented, because it is believed that these are the most vulnerable components of the process and the least covered aspects in the literature.

GOALS AND MEASURES OF EFFECTIVENESS

In the TSM process, the definition of the problem consists of the formulation of objectives, the selection of strategies and tactics leading to the achievement of the objectives, and the selection of the relevant measures of effectiveness (MOEs). The traditional approach, based on a single objective and a small number of strategies and MOEs, is no longer workable. The objectives must satisfy many, often conflicting, requirements--authorities demand economic efficiency, public transport users want quality of service, automobile users are concerned about the availability of road space and parking, and nonusers of transport request the protection of their environment. In order to illustrate the complexity of the problem, the work of Abrams and Direnzo (9) and Abrams et al. (10) can be cited. They postulate five TSM goals:

- To maintain or improve the quality of transportation services,
- To increase the efficiency of the existing system,
- To minimize the cost of the improvements,
- To minimize undesirable environmental impacts, and
- To promote desirable and reduce undesirable social and economic impacts.

These goals lead to 20 objectives as diverse as "minimize travel time," "maximize public transport use," "maximize capacity," "maximize automobile use," "maximize equity," and so on. The objectives, in turn, are assessed in terms of 70 different MOEs. In such a situation, no project can be unequivocally evaluated. Therefore, the foregoing studies finally recommend what are termed the 12 most essential MOEs for TSM planning:

- Person hours of travel
- Point-to-point travel time
- Vehicle delay
- Vehicle hours of travel
- Number of vehicles by occupancy

- Person miles of travel
- Traffic volumes
- Vehicle miles of travel
- Transit passenger miles of travel
- Number of transit passengers
- Energy consumption
- Emissions

Even with this reduced number of MOEs, a comparison of alternative solutions remains difficult.

The issue of the overall evaluation of various TSM strategies attains its full significance when some strategies are composed of contradictory impacts and the available knowledge about the relative effectiveness of the various actions is limited. For example, improvement in priority treatment for public transit may be adversely related to network supply of parking for passenger vehicles. The simultaneous judgment and evaluation of impacts, consequently, are of prime importance for a TSM project before its implementation. As a starting point, one has to hypothesize tentatively how a given strategy may affect the range of MOEs of a system. For this analysis, it may be necessary to use both historical and existing field data and, perhaps, some simulation techniques. The most promising strategy, or combination of strategies, may thus be identified by evaluating its expected effectiveness and impact.

MOEs must be formulated to be applicable to analyses of different scales; for example, a corridor of one arterial and several local streets is to be examined differently from an area of several satellite towns adjacent to a large city. In the first instance, one may want to look at measures that describe in detail local traffic flow characteristics on the highway concerned and on the adjacent streets to which traffic may be diverted. In the second case, it may be more appropriate to look at overall MOEs, such as general measures of the amount of travel or modal-choice characteristics. Lockwood and Wagner (11) suggested that, as a general rule, the larger the area of application of a TSM strategy, the less detailed the MOEs should be.

Several potential MOEs are presented in Table 1. These suggested measures are categorized according to area of TSM application and subdivided into preliminary and final measures. They are presented as an example only; one could, of course, change or replace several of them, both among groups and in general, depending on the strategy adopted and the type of study. However, it should be recognized that MOEs must be responsive to the most complete range possible of relevant impacts. Preferably, they should also be quantifiable and measurable either directly by conventional traffic, safety, and environmental variables or indirectly by being represented by common monetary worth.

In evaluating a TSM project, further consideration must be given to the data collection and analysis capabilities of the local implementing agency. Therefore, practicality, directness, and ease of data collection are relevant criteria for selecting appropriate measures. For example, travel time, speed, number of stops, and delays are more simple, direct measures than are overall parking demand, energy consumption, and central business district (CBD) vitality. This is the reason that at certain times, such as when evaluation resources are limited, it is desirable to apply small-area measures to a regionwide or citywide evaluation scheme. Finally, one should also try to avoid using redundant MOEs, thereby measuring and evaluating similar impacts; for example, because average speed and travel time may measure the same effect, they should preferably not be used together in the same evaluation scheme.

TABLE 1 Potential MOEs by Area of TSM Application

	Area of TSM Application	
Type of MOE	Small Area or Longitudinal Transportation Corridor	Regionwide or Citywide
Preliminary and readily available	Change in average speed or travel time	Impact on delay at preselected priority and signalized intersections
	Change in peak and off-peak vehicle volumes	Impact on modal choice
	Change in vehicle occupancy	Impact on environmental variables, such as air-pollution or noise levels
	Change in bus ridership or seat availability	Impact on overall energy consumption
	Change in traffic composition, particularly heavy-vehicle percentages	Impact on parking demand
Final general and extended	Change in link reliability	Impact on system reliability
	Change in link and adjacent street level of service	Change in vehicle travel
	Change in accident risk and accident rates	Change in system modal choice
	Change in public transport level of service	Impact on overall operating costs
	Change in sidewalk pedestrian flow level of service	Impact on CBD vitality through office space availability, rental rate change, residential floor area variability, or retail tax paid, or all of these
	Change in pedestrian risk exposure	Impact on residential neighborhood, such as change in through-traffic percentage, change in truck use of local streets, or change in noise levels
		Impact on overall pedestrian and vehicle safety

EXISTING EVALUATION METHODS

The evaluation methods currently used cannot give more than a general indication of the worth of a solution. A short discussion of the three most common evaluation methods follows.

Goal-Achievement Analysis

This method is used for a subjective assessment of the extent to which the goals of a TSM project are attained. Its main disadvantages are

- Limited number of MOEs,
- Difficulty in comparing the worth of the different magnitudes of improvement of different MOEs, and
- Lack of consideration of project costs.

The advantage of this kind of analysis is that it enables the magnitude and incidence of individual impacts to be predicted. A decision is taken according to a weighted array of results based on predicted changes in the MOEs as shown in the following simplified example:

	Percent Change	
MOE	Alternative A	Alternative B
Vehicle delay	-5	-10
Traffic volume	-3	+1
Energy consumption	-1	0

Cost-Effectiveness Analysis

The basic process of cost-effectiveness analysis compares the costs of gaining an objective with the degree to which each alternative in a series of schemes approaches the goal or objective. The individual results are divided by the costs required to achieve them. Different factors cannot be combined; separate comparisons must be made for each MOE individually assessed. An advantage of the method is that it takes economic efficiency into account; however, a single comparison taking all important measures into account cannot be made. A decision is made on the basis of the individual results, as shown in the following example:

	Percent Change/Cost of Project	
MOE	Alternative A	Alternative B
Vehicle delay	-5/50 = -0.10	-10/40 = -0.25
Traffic volume	-3/50 = -0.06	+1/40 = +0.03
Energy consumption	-1/50 = -0.02	+0/40 = 0

Benefit-Cost Analysis

All benefits resulting from a project are reduced to monetary terms and then compared with the costs of the project. The outcome is a single ratio of benefits to costs. The serious weakness of this method, however, is that many MOEs cannot be expressed in economic terms; therefore, they must either be excluded from the analysis or have an arbitrary value ascribed to them.

In sum, existing evaluation schemes are inadequate for TSM projects because (a) they assess alternatives in terms of a limited number of MOEs that are readily convertible to monetary terms and (b) they lack sensitivity to the magnitude of the capital involved.

These weaknesses explain in part why the concept of TSM is widely accepted but seldom implemented to its full significance. Because the evaluation results are open to criticism, it is difficult to convince a broad spectrum of interested parties that their objectives are being met satisfactorily. Clear, explicit evaluation methods would greatly encourage practical interest in a TSM project.

EVALUATION AND WORTH TO SOCIETY

The evaluation method proposed in this paper attempts to eliminate some of the drawbacks of the existing methods. It is based on several assumptions:

1. The size of the system is immaterial: TSM may be applied, at one extreme, to a single operational environment (e.g., an outlying commercial center or residential suburb) or, at the other extreme, to a large conurbation containing many operational environments. It is assumed that the system, large or small, contains three elements: modes, infrastructure, and land use; that these elements have different characteristics and that different influences act on them; and that linkages between the elements exist and are variable. If the system is small, the interface with the outside must be considered an integral part of the study.
2. There is a group of involved but objective individuals, transport specialists, and others able to define the problem and assess the relative importance of the objectives.

TSM strategies should receive the full attention of local and state authorities, as well as of the public, because these strategies may have significant effects on traffic, the environment, and the economy. It is important, therefore, to assess the full range of impacts, both short-term and long-term, and to find out whether they may counteract one another. In a survey of parking management strategies by Ellis (12), for example, reducing parking-space supply and increasing parking costs in the CBD area were considered. Although this strategy may initially create a mode-choice shift toward further use of public transport, it may eventually lead to a deterioration in the residential and economic vitality and prosperity of the CBD by stimulating a change in land use.

Another problem associated with the evaluation of TSM strategies is that low capital improvements may at times have the highest payoff in improved efficiency. Among these, one may count such tactics as the restriction of parking near intersections to allow for turning lanes, the installation of parapets to separate pedestrians from heavy traffic flows, and stricter enforcement of traffic regulations. Nevertheless, any policy considered must evaluate the full range of potential improvements, regardless of their initial capital costs.

An alternative approach that is proposed in this paper for the evaluation of TSM projects consists of comparing the costs of a series of alternatives with system efficiency as measured by its level of service.

The hypothetical relationship between capital investment and a change in vertical level of service may assume the general shape shown in Figure 1. At Point I, low-cost projects are introduced, such as pedestrian barriers, road-lane marking, or improved signing, and some slight change in vehicle level of service may be expected. At Point II, more capital investment is made, perhaps for improving road lighting, resurfacing deteriorated roads, or improving drainage at certain locations, as well as for implementing parking-control strategies, and a further upgrading of the level of service is achieved. TSM projects represented at Point III, such as the improvement of the signal system (by coordination or vehicle actuation techniques) or the diversion of truck traffic to special truck routes, may reduce delay and the number of stops and increase average speed.

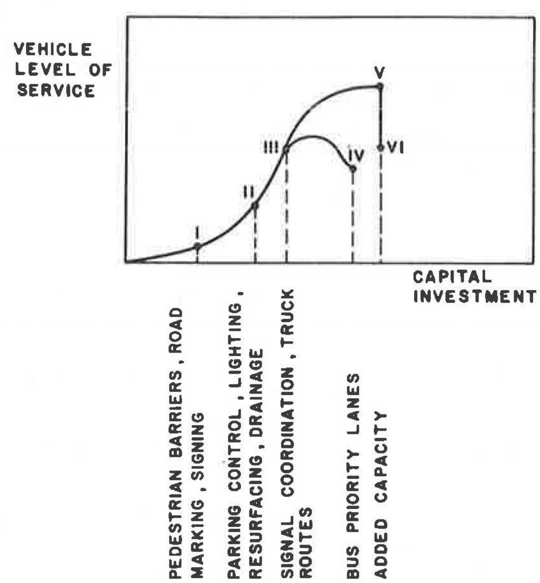

FIGURE 1 Potential change in level of service as related to capital investment.

A deterioration in vehicle level of service may be experienced at Point IV, where the capacity of the system is partly reduced by the construction of bus priority lanes; on the whole, however, the public will probably benefit because of the expected improvement in transit level of service. On the other hand, a major project, such as expanding the network capacity, may further improve the level of service (note Point V) if it can be assumed, of course, that travel demand will remain constant. Because this assumption is not valid in many instances, one may expect some shift in the travel function toward higher demand. Some future deterioration in the level of service is then to be expected (note Point VI) until equilibrium between network supply and travel demand is achieved.

The question arises of what level or range of capital investment a public agency involved in TSM may want to consider or, more specifically, the recommended limit of capital investment sought for a TSM strategy. It is now necessary to ascertain what acceptable range of strategies or capital-investment limits will still provide the best benefits to the community. For this, consider the two curves shown in Figure 2. The first is the capital-investment curve, which is of the same logistic type as the curve shown in Figure 1. The capital-investment curve shows that for high and low levels of service, the investment needed to create a constant amount of change is higher than that needed for an intermediate level of service. Similarly, if the monetary worth to society is considered, the opposite trend may be observed: an improvement in a higher level-of-service situation provides lower monetary benefits and that in a lower level-of-service situation may yield a higher monetary worth.

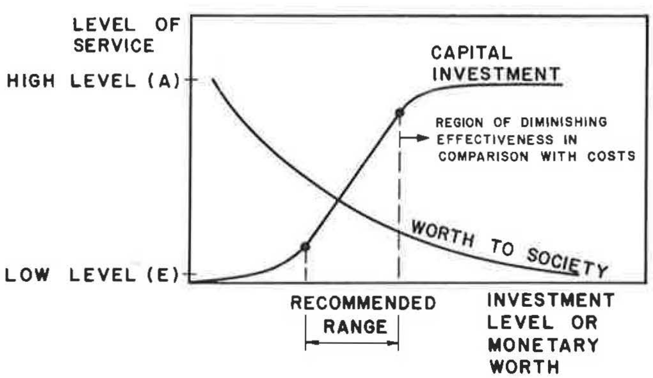

FIGURE 2 Recommended range of capital investment for TSM strategies as related to capital investment and monetary worth to society.

A similar approach was discussed recently by Brinkman and Smith (13) in their analysis of two-lane rural highway safety. They showed the diminishing returns for additional investments on present worth of benefits over a next-20-years curve. They also demonstrated the rapid reduction on safety and operational cost-benefit-ratio curves: the ratios are shown to be very high at a low-expenditure level and to decrease rapidly as the expenditure level increases.

Thomas and Schofer (14) suggested earlier that because of the nature of transportation decisions, some basic requirements have to be satisfied, such as knowledge of all feasible solutions and their consequences and a precise definition of optimality. These requirements, however, cannot always be met.

It is suggested, therefore, that the recommended range of capital investment for TSM projects be established at the middle level, as shown in Figure 2. The exact amount allocated for each project has to be determined on the basis of its individual merits and in accordance with decision policies determined by the authorities concerned. Expansion investments are not always recommended for TSM projects because of the diminishing returns for high level-of-service situations and also because of elasticities of demand, which in turn may further reduce the final level of service.

It should be noted that when the concepts of worth and capital investment are discussed in this paper, it is assumed that the investment capital is designated by society for TSM projects only.

LEVEL OF SERVICE OF THE TRANSPORTATION SYSTEM

The traditional measurement of the level of service, such as a load factor for isolated intersections or an operating speed for highways, cannot be applied to TSM projects, in which a large number of diverse variables have to be included. It is therefore proposed that the level of service of the transportation system (LTS) be introduced to represent the performance of the system. The LTS must be capable of incorporating both tangible and intangible MOEs. For different projects, the number of MOEs may vary, but for a single project the number of MOEs for various alternatives must remain constant. In each case, a single LTS value will result.

The LTS is constructed as a function of several MOEs:

$$LTS = f(x_1, x_2, x_3, \ldots, x_k) \qquad (1)$$

where x_i is the independent MOE and i is the index of MOE ($i = 1 \div k$).

In considering a broad spectrum of independent variables, such as those presented in Table 1 or those in the discussion of existing methods of evaluation (e.g., vehicle speed, vehicle delay, traffic volume, or energy consumption), a common denominator has to be found. The independent variables are thus allocated relative values (a_i; $i = 1 \div k$) of weighting factors established by utility analysis, and the system level of service is expressed as

$$LTS = a_1x_1 + a_2x_2 + \ldots + a_kx_k \qquad (2)$$

Utility theory defines utility functions for different attributes of a system, such as aesthetic comfort, the amount of emissions, automobile travel time, bus waiting time, or traffic volumes. Although the MOEs produce tangible figures, allocating comparable values to such diverse variables as emissions, aesthetics of transportation facilities, or traffic volumes requires the assessment of intangibles. The utility analysis described by Roebuck (15) is therefore recommended for the determination of the LTS function. Utility analysis is a semiquantitative approach for "trading off" the possible effects of implementing any given scheme, and as such is a guide to decision making. The procedure calls for the establishment of a utility analysis panel of decision makers, in accordance with the spirit of TSM, which emphasizes coordination of elements. The members of the panel should represent the three elements of the system:

- Land use: town planners, residents, and local businessmen;
- Infrastructure: traffic or highway engineers and traffic police; and

• Transportation modes: public transport planners and operators.

The size of the panel and its composition will vary from project to project; in each case, however, it must reflect the more important or relevant elements of the system. The panel may undergo some changes during the lifetime of a project as additional elements, ignored initially, are introduced or, conversely, as the initially envisaged elements are dropped as matters progress. The role of the panel is to define the problem (guided by the experts initiating the project), set out the objectives, and determine the relative importance of these objectives, and thus to allocate weighting factors, based on utility curves, to the independent MOEs in their system level-of-service function.

The main advantages of utility analysis, then, are that

• A comprehensive range of effects can be considered;
• A multidimensional goal system can readily be handled;
• A minimum level of service or maximum tolerable disbenefit can be introduced;
• The views and values of interested or affected parties, rather than arbitrary values, are taken into account; and
• During the discussion, each individual on the panel is exposed to other points of view.

As a result of the panel discussion, every variable is unequivocally rated against others. It remains for the project management to calculate the values of the LTS for various proposed alternatives. The selection of the most suitable alternative is performed with the use of a graph of the kind shown in Figure 3. The vertical axis shows the LTS values associated with the proposed alternatives and the horizontal axis, the expenditure level. The four curves indicate the overall efficiency (or productivity, depending on the MOE selected) of each of the four assumed alternatives. The project selected would show the highest efficiency (highest LTS) within the financial constraints. If two alternatives give similar results, the utility analysis panel should be consulted again to approve a final decision.

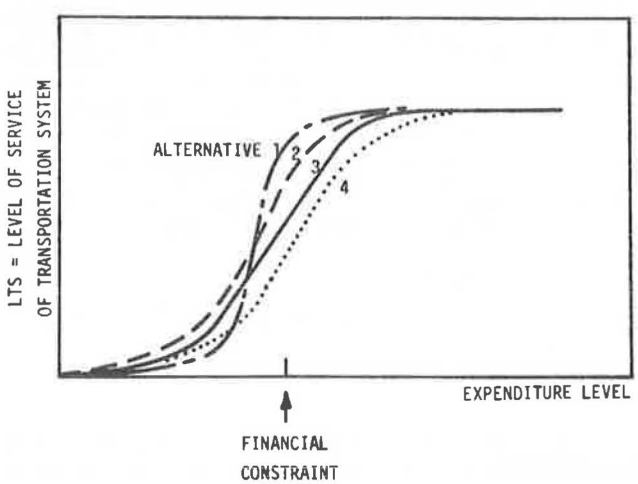

FIGURE 3 LTS of four alternatives as related to expenditure level.

APPLICATION OF THE LTS FUNCTION

A TSM study is being conducted for the city of Springs, South Africa. The study is run by a professional team representing the provincial, metropolitan, and local authorities and the Department of Transport. Public participation is secured by the involvement of elected and appointed representatives, local transport companies, and the general public, organized into three groups: decision makers, those involved in transportation, and those affected by transportation. The purpose of the groups is the identification of transportation problems in the area and the selection of the objectives, constraints, and MOEs of the study.

In the Springs study, the following were identified as the major problems:

• Delays to vehicular traffic at some intersections on main routes leading to the central business district (CBD),
• Delays to traffic caused by school buses, and
• Inadequate parking facilities at the railway station.

The main constraint appeared to be the availability of funds, which are not sufficient to attend to all the existing problems. Three alternative solutions were proposed by the professional team:

1. Geometric and signalization improvement of critical intersections;
2. Signalization improvement at critical intersections, relocation of the bus stop at one of three affected schools, and development of a parking area for 50 vehicles in the vicinity of the railroad station; and
3. Relocation of the bus stops at three schools.

The selected MOEs were vehicular delay, fuel consumption, commuters' delay while walking to the station, and students' delay. A panel consisting of the professionals and the group representatives allocated the following weighting factors to the selected MOEs:

MOE	Weighting
Vehicular delay (vehicle-minutes)	$a_1 = 2$
Fuel consumption (liters)	$a_2 = 10$
Pedestrian delay (person-minutes)	$a_3 = 4$
Students' delay (person-minutes)	$a_4 = 2$

The computer and manual analyses indicated that the following benefits can be achieved during a morning peak hour:

• Alternative 1--1,000 vehicles would save 60 sec and 100 mL each;
• Alternative 2--1,000 vehicles would save 30 sec and 50 mL each, 200 vehicles would save 15 sec and 20 mL each, 400 students would save 15 sec each, and 75 people would save 3 min each in walking time; and
• Alternative 3--600 vehicles would save 15 sec sec and 20 mL each, and 1,200 students would save 15 sec each. The LTS function was calculated as

$$LTS_j = \sum_{i=1}^{k} a_i x_{ij}$$

where $i = 1, \ldots 4$ is the index of MOE and $j = 1, 2, 3$ are the alternative solutions.

The calculation results are shown in Table 2. The decision was made to base the selection of the alternative for implementation on the maximum value of the LTS function. Alternative 1 yielded the highest

TABLE 2 Evaluation Process Using LTS Function

Improvement	MOE	x_{ij}	$x_{ij}a_i$	LTS
Alternative 1 (j = 1): geometric and signalization improvements at intersections	Vehicle delay	1,000 x 60/60	$1{,}000a_1$	3,000
	Fuel consumption	1,000 x 100/1,000	$100a_2$	
Alternative 2 (j = 2)				2,740
Signalization improvements	Vehicle delay	1,000 x 30/60	$500a_1$	
	Fuel consumption	1,000/50/1,000	$50a_2$	
Bus stop relocation	Vehicle delay	200 x 15/60	$50a_1$	
	Fuel consumption	200 x 20/1,000	$4a_2$	
	Students' delay	400 x 15/60	$100a_4$	
Parking facility	Pedestrians' delay	75 x 3	$225a_3$	
Alternative 3 (j = 3): bus stop relocation	Vehicle delay	600 x 15/60	$150a_1$	1,020
	Fuel consumption	600 x 20/1,000	$12a_2$	
	Students' delay	1,200 x 15/60	$300a_4$	

value of LTS and therefore was recommended for implementation.

CONCLUSIONS

Five major conclusions may be drawn from the foregoing discussion of evaluating TSM projects:

1. The essence of the TSM approach is the coordination of the elements of the system in order to maximize its efficiency and productivity.
2. Various transportation management strategies require a capital input that is not necessarily proportional to the resulting change in the level of service.
3. The assessment of a transportation system by the conventional level-of-service measure (i.e., based on one variable, such as speed) cannot be done because of the multiplicity of the system users' expectations. Therefore, the use of the LTS based on a combination of variables is proposed.
4. In order to include a broad spectrum of sometimes conflicting objectives in the evaluation procedure, a panel of decision makers should be consulted to allocate weighting factors to the relevant variables, such as speed, fuel consumption, or traffic volumes.
5. The LTS may be calculated for each alternative proposed on the basis of the magnitude of changes in each variable multiplied by the relevant weighting factors. The selection of the alternative to be implemented is based on its efficiency (or productivity) within the capital-investment constraints.

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