Framework for Transportation System Management Performance Evaluation

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ABSTRACT

A methodology is developed in this paper for the evaluation of transportation system management (TSM) actions. The evaluation is performed quantitatively in terms of goals achievement. A goal achievement function (F) is defined as the ratio of the amount of deviation of the observed or actual operational condition a, of a transportation management program from the before reference condition b, to the deviation of the assumed or expected goals e, from the same reference condition for each and every set of specified goals. In other words, the effectiveness of a transportation system management action is judged by the discrepancy between the before, after, and expected conditions of the program action. By this method, a third dimension (program goal) is considered in the post-implementation evaluation exercise of a TSM action. The validity of the evaluation model was investigated by examining its sensitivity to the number of observations in the before and after conditions. Through analysis it can be shown that the goals achievement function is applicable where the sample size is large and measurement errors are small. It is, however, sensitive to situations where both the sample size and errors in measurement are small. The technique can be applied to both small- and large-scale transportation management actions.

Evaluation of transportation plans has evolved in the past 20 years from a straightforward benefit-cost approach to a more complex cost-effectiveness analysis. The effectiveness framework expands the traditional analysis to include social and environmental factors, in addition to user costs-benefits. All are keyed to making decisions about the preferred plan to be implemented with regard to costs and implementation priorities.

After a project has been implemented, it is important to know how the project has performed, and whether forecast goals have been achieved. A generally accepted method of evaluating traffic management actions does not exist at present, especially after implementation. This is in part because of the difficulty of systematically assessing impacts for a wide range of actions--many with small-scale changes; and reflects the emphasis on implementation rather than evaluation. However, when it is done, post-implementation evaluation primarily consists of before and after comparisons.

NEED

Because the literature contains few post-implementation evaluation methodologies, especially for transportation management programs, there is a need to develop a systematic post-program evaluation procedure that is flexible enough to suit the wide range of traffic management actions and that can be efficient in evaluating traffic management program performance.

Prepared in this paper is a goals achievement function (F) methodology that considers post-implementation evaluation in a three-dimensional context: the before reference condition (status quo or what it was without the program), the after reference condition (observed performance), and the forecast condition, or expected goal. The method considers all three to be valid because to neglect one would give an incomplete picture of the evaluation procedure. Besides, because forecasts or policy goals provide a logical base for goal and objective fulfillment analysis, it is essential that the forecast condition be considered in post-implementation evaluations.

THE GOAL ACHIEVEMENT FUNCTION METHODOLOGY (1)

The goal achievement function technique conceptualizes that a traffic management scheme improves the existing transportation system. The improvement, in turn, increases the productivity or the production capabilities of the material inputs; that is, a traffic management program would allow the production of a larger level of output with the same level of input usage. This transportation productivity may be considered increased safety for both pedestrians and motorists, improved traffic flow and system throughput, decreased environmental pollution, and less delay because of congestion, to mention a few.

Figure 1 shows the basic concept of the goal achievement function approach, namely:

1. System variables that are deductively affected by proposed actions and that inductively affect implemented policy (before and after conditions);
2. The changes brought about by implementation of the program (discrepancy); and
3. The behavior of the variables identified in item 1 in relation to the expected or forecast change, making appropriate allowances for the effects of nonprogram factors (achievement level).

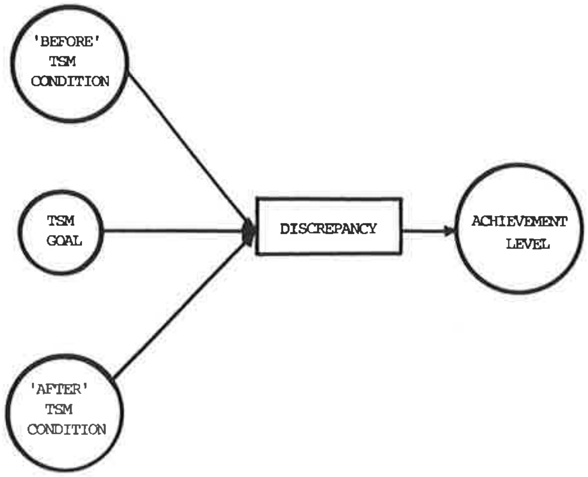

FIGURE 1 Basic concept of the goal achievement function technique.

STRUCTURE OF THE GAF TECHNIQUE

Figure 2 represents an overview of the goal achievement function (GAF) approach. Simply stated, the goal achievement function framework provides a means whereby program evaluation focuses on goal-objective achievement rather than on a whole range of effects whose quantification and measurement are often difficult. It identifies the relationships among the evaluation components and planning policies and shows that

1. Traffic management planning studies are carried out in response to certain needs and deficiencies of the existing system;
2. Transportation management actions are then taken to solve perceived problems and to achieve desired goals and objectives;
3. Based on criteria that were established to measure program effectiveness such as reduction in travel time, minimization of accident occurrence, maximization of mobility needs of the population, or minimization of the environmental impacts of transportation, an evaluation of the traffic management program can be carried out;
4. The performance level of the TSM action is then determined by using the goal achievement function F > n, where n is the criterion of measurement arbitrarily chosen by the evaluator to represent an acceptable GAF for the action being evaluated; and
5. On the basis of the resulting evaluation, valuable lessons are drawn from the program's operation, and decisions about its continued operation, modification, or cancellation can be made.

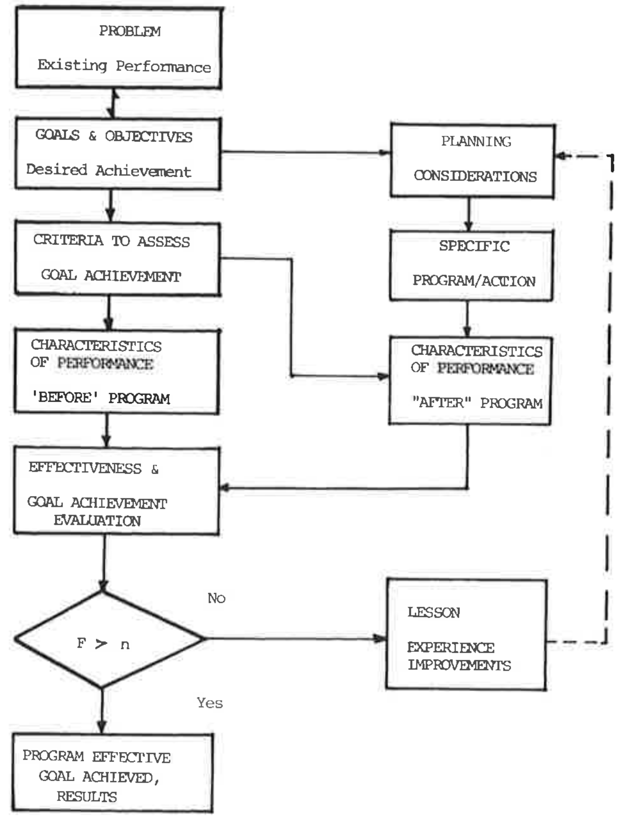

FIGURE 2 Structure of the goal achievement technique.

Figure 3 shows the three major components of the goals achievement model, which follow.

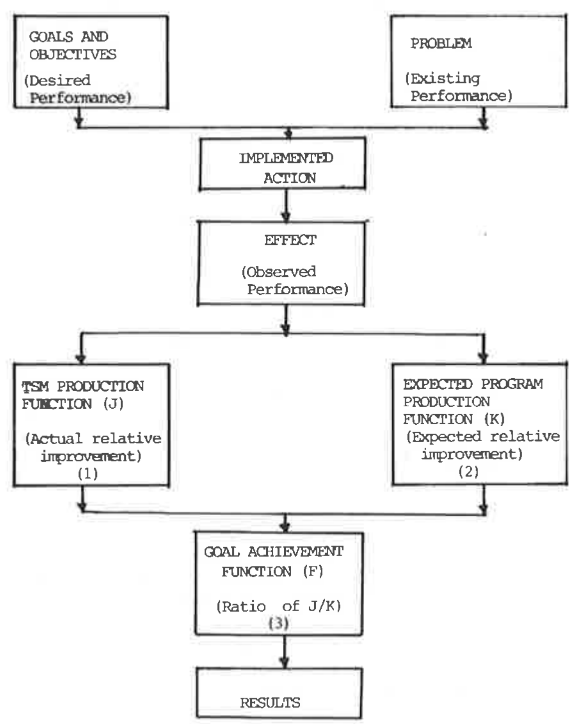

FIGURE 3 Components of the GAF evaluation model for transportation management actions.

1. A TSM production function (J) permits the identification of the underlying trend over a period of time that includes before and after implementation. It assumes a relationship between input and output from the travel production process and determines the discrepancy that has occurred between the before and after measurements in terms of the system variable, that is, the transportation production change as a result of the transportation management action.
2. An expected program production function (K) permits the comparison between the expected operational capacity or forecast levels and the before reference condition.
3. A goals achievement function (F) permits the

estimation of program effectiveness on the basis of the net results from items 1 and 2 above. The GAF results from dividing J by K.

By definition a TSM action is expected to improve existing traffic conditions and thereby produce a benefit; and because the differences in the level of performance occur as a result of the action, the production can be related to the action directly.

The transportation system management production function (J) is given by:

$$J = (b - a)/b \quad (1)$$

where b is the activity condition or operational parameter at status quo; and a is the condition after the implementation of the program (TSM production or actual achievement).

By definition, the expected program policy function K, is the transportation production change that occurs between the set or expected goals of a program, e, and the before condition or status quo, b. Expressed mathematically

$$K = (b - e)/b \quad (2)$$

From Equations 1 and 2, a goal achievement function for a given state of a traffic management policy can be derived as follows:

$$F = J/K = (b - a)/(b - e) \quad (3)$$

where a, b, and e are as defined previously.

ASSUMPTIONS

The following assumptions underly the proposed GAF model:

1. The traffic condition repeats itself in a pattern that is susceptible to investigation and quantification;
2. The traffic patterns are predictable because on the basis of item 1, it is possible to reproduce the repetitions;
3. Goals are both rational and realistic. Because management actions are implemented to improve an existing condition, goals will not be set lower or exceedingly higher than is practically achievable;
4. Objectives are defined operationally rather than in abstract terms; that is, objectives can be measured and compared; and
5. The difference in level of performance occurs as a result of the change in the system's operational and physical characteristics (i.e., management action-implemented).

From the preceding, goal achievement has been expressed as the ability of a management action to produce what policy makers expect of it. The question arises as to whether a significant improvement has actually been made as indicated by the measurements and the forecast estimate, and what the magnitude of the total error is in the goal achievement function. In other words, an answer must be provided for the question of how sensitive the function is to its components, as compared with the before condition measurements, b, the after condition measurements, a, and the expected or forecast estimate, e. The sensitivity or validity would depend on

1. Magnitude of error as measured by $S_{\bar{a}}$, $S_{\bar{b}}$, $S_{\bar{e}}$.
2. Sample size used to obtain $S_{\bar{a}}$ and $S_{\bar{b}}$.
3. $S_F = S[(b - a)/(b - e)]$.

And the estimate of F will vary $\pm 1.96S_F$ with a 95 percent confidence level (assuming a normal distribution). [Note: The assumption of a normal distribution is vital here because sample means are used to obtain the standard error. Furthermore, to evaluate the significance in the difference in means, the normal distribution allows us to assume that they are, in fact, representative of the same population. The general specification for certification of the significance of an observed difference (i.e., the rejection of the assumption that they are the same) is that it must be no more than 5 percent probable and that the difference in means was a result of pure chance is z = 1.96.]

S_F can be obtained by using the "propagation of errors" technique. This method asserts that if a quantity Q is a function of n variables, such that

$$Q = f(x_1, x_2, x_3, \ldots, x_n)$$

and each variable of the function is estimated with an independent and random error, $S_{\bar{x}_i}$, such that

$$i = 1, 2, \ldots, n, \text{ where } S_{\bar{x}_i} = S/\sqrt{n-1}$$

then the total error (Eq) of the value of Q is given by partial differentiation whereby

$$Eq = \left[(\delta Q/\delta x) \cdot S_{\bar{x}_1}\right]^2 + \left[(\delta Q/\delta x) \cdot S_{\bar{x}_2}\right]^2 + \ldots + \left[(\delta Q/\delta x) \cdot S_{\bar{x}_n}\right]^2 \quad (4)$$

In our case,

$$F = (b - a)/(b - e)$$

If $S_{\bar{a}}$, $S_{\bar{b}}$, and $S_{\bar{e}}$ are the standard errors of the mean in a, b, and e, respectively, then

$$\left[(\delta F/\delta b) \cdot S_{\bar{b}}\right]^2 = \left[\{(b - e) - (b - a)/(b - e)^2\} \cdot S\right]^2 = \left[(a - e)/(b - e)^2 \cdot S\right]^2 \quad (5)$$

$$\left[(\delta F/\delta e) \cdot S_{\bar{e}}\right]^2 = \left[(b - a)/(b - e)^2 \cdot S\right]^2 \quad (6)$$

$$\left[(\delta F/\delta a) \cdot S_{\bar{a}}\right]^2 = \left[1/(b - e) \cdot S\right]^2 \quad (7)$$

And the total standard error S is

$$S_F = [1/(b - e)^2]\ [S_{\bar{b}}^2 (a - e)^2 + (b - e)^2 S_{\bar{a}}^2 + (b - a)^2 S_{\bar{e}}^2]^{1/2} \quad (8)$$

APPLICABILITY AND IMPLICATIONS

The model approach that has been proposed is basically heuristic in nature, a sketch planning-type technique that can be used to assess program performance especially in practically data-deficient environments. It also allows for flexibility on the part of the user to examine effects for a variety of measures. However, it should be applied carefully.

AN EXAMPLE

A traffic management plan was expected to reduce traffic volume within the city center (CBD) from 40,000 vehicles to 20,000 vehicles. After the action, it was observed that the number of vehicles that entered the CBD was actually 30,000. On the basis of established traffic-counting practice, it was assumed that the before volume count had a standard error of the mean ($S_{\bar{b}}$) of ± 600, the after count had a standard error ($S_{\bar{a}}$) of ± 400, and the forecast was estimated to have a standard error ($S_{\bar{e}}$) of ± 300 (assumed); n_b, n_e, and n_a are the corresponding number of observations or counts.

The computation of the goal achievement function of the traffic is as follows:

Given

$b = 40{,}000$	$S_{\bar{b}} = 600$	$n_b = 45$
$e = 20{,}000$	$S_{\bar{e}} = 300$	$n_e = 1$
$a = 30{,}000$	$S_{\bar{a}} = 400$	$n_a = 45$

By definition

$$F = (40{,}000 - 30{,}000)/(40{,}000 - 20{,}000) = 0.5 \quad (9)$$

By using the general form for the error in F, the performance level of the TSM action can be computed as follows:

$$\begin{aligned} S_F &= (1/4 \cdot 10^8)(4 \cdot 10^8 \cdot 16 \cdot 10^4 + 10^8 \cdot 9 \cdot 10^4 + 10^8 \cdot 36 \cdot 10^4)^{1/2} \\ &= (1/4 \cdot 10^8)(64 \cdot 10^{12} + 9 \cdot 10^{12} + 36 \cdot 10^{12})^{1/2} \\ &= (1/4 \cdot 10^8)(109 \cdot 10^{12})^{1/2} \\ &= 10.44 \cdot 10^6/4 \cdot 10^8 = 0.026 \end{aligned} \quad (10)$$

But the GAF computation produced

$$F = 40{,}000 - 30{,}000/40{,}000 - 20{,}000 = 0.5$$

Therefore, the range of F for a 95 percent confidence level would be 0.45 to 0.55, based on $F = 0.5 \pm (1.96) \times 0.026$.

Now, suppose a, b, and e remain the same but the standard errors have values as shown in Table 1. The standard error (S = 4,000) for the expected condition in this case is a more realistic assumption because the goal is based on a single estimate.

$$\begin{aligned} S &= (1/4 \cdot 10^8)(4 \cdot 10^8 \cdot 64 \cdot 10^4 + 10^8 \cdot 16 \cdot 10^6 + 10^8 \cdot 144 \cdot 10^4)^{1/2} \\ &= (1/4 \cdot 10^8 (256 \cdot 10^{12} + 1600 \cdot 10^{12} + 144 \cdot 10^{12})^{1/2} \\ &= (1/4 \cdot 10^8)(2000 \cdot 10^{12})^{1/2} \\ &= 44.72 \cdot 10^6/4 \cdot 10^8 = 0.4472 \cdot 10^8/4 \cdot 10^8 = 0.112 \end{aligned} \quad (11)$$

$F = 0.5 \pm (1.96) \times 0.112$, which ranges between 0.28 and 0.72 for a 95 percent confidence level.

Further analysis shows that the goal achievement function is applicable where the sample size is large and errors are small. It is, however, sensitive to situations where both sample size and the standard error of measurements are small. Because of the sensitivity to measurement errors in the values of b, caution should be exercised in its use for actions where the values of b and a cannot be reliably measured (i.e., large standard error of the mean). In other words, if the variances in the values of b and a are large in relation to (b - e), this technique is not an appropriate tool. These observations reinforce the assumptions articulated earlier in modeling the goal achievement function; that measurements be reliable and goals be realistic. Under such conditions the goal achievement technique can be an efficient evaluation tool. Nonetheless, the technique can be applied to both small- and large-scale management actions.

TABLE 1 Standard Error Values

Reference Condition	Volume	Estimated Coefficient of Variation (%)	Standard Error of Volume	Assumed No. of Days Counted	Standard Error of Mean $[S/(n-1)^{1/2}]$
Before	40,000	±10	4,000	11	1,200
Expected	20,000	±20	4,000	1	4,000
After	30,000	±10	3,000	11	800

The method has one additional limitation that underscores the need for careful and selective application. It does not sufficiently account for any systematic error or bias within the measured effects. For instance, it assumes that any discrepancy between the observed and before conditions or any deviation from the expected value can be completely attributable to the management action. This limitation is, however, not critical because historical data are used to establish both the before condition and anticipated effect, and so the effects of annual or seasonal variations are assumed to be marginally accounted for within the data.

PROGRAM COST: A DISCUSSION

Transportation System Management actions and programs are by definition noncapital intensive and relatively inexpensive. Most are, by design, operated and administered within an existing public functionary or body and so do not have direct operational costs charged to them. Second, although the costs of operation and enforcement are considered at the planning phase, design details and operational requirements on implementation have often dictated the development and implementation of low-cost, self-enforcing or partly police-enforcing strategies. Furthermore, a few TSM programs have been known to be included in long-range transportation programs, which presents the problem of when these short-term TSM elements and their corresponding costs must be isolated to provide an efficient performance evaluation.

However, this is not to say that costs are not incurred in one way or another. The exclusion of costs in the goal achievement function approach recognizes that (a) compared to capital intensive and long-range transportation measures, TSM program costs are insignificant; (b) methods already exist that can better evaluate TSM programs involving costs; and (c) the proposed methodology is not a planning tool that makes a choice between alternatives, but is, rather, a means by which actions that are already in place can be assessed.

CONCLUSION

An approach to traffic management evaluation has been proposed in this paper. The goals achievement function--a post-implementation evaluation method--is a comparative process that relates the performance of an implemented project to expected performance or as it would have been if the project were not implemented. It measures the performance or goal achievement of a traffic management strategy.

The technique provides a third dimension to post-implementation evaluation by introducing program goals into it. These goals are important in plan formulation but are left out of plan performance evaluation. By this method, therefore, actual performance is not only compared with the before condition but is also compared with the expected or forecast performance.

In addition, it does not require the transformation of all effects and impacts of the traffic management scheme into monetary terms. Thus, market and nonmarket values can be considered whether or not they are priceable or measureable. This quality is important for making technical and political decisions because it is not possible to transform all outputs and effects of transportation management actions into a single monetary scale. Also, the method allows for subjective analysis in situations where an explanation is required for the observed behavior.

RECOMMENDATIONS

The application of the goals achievement function methodology to actual cases of TSM implementation is recommended as this will further increase program experience, provide valuable insights into transportation decision making and official accountability, and overcome existing obstacles and biases that sometimes inhibit program evaluation.

Also, with the proliferation of transportation system management actions in many cities in recent years and improvements in recordkeeping and data collection methods, there currently exists the data base for more comprehensive modeling. In this regard, it will be necessary to expand the goals achievement function model to include not only program costs but also growth patterns in economic and business activities and trends in social and other behavioral areas within the program environment. Two outcomes: a TSM production predictive model that includes a cost function or a TSM production model, or both, that can be used to evaluate performance of an improved transportation system supply relative to a predetermined cost, and socioeconomic impacts can be appropriate additions to the literature.

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Managing Traffic in Residential Areas

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ABSTRACT

This report presents traffic management concepts that were developed as part of a traffic plan for the city of Greenwood Village, a suburb of Denver. Greenwood Village includes established neighborhoods in addition to extensive commercial development in the Interstate 25 corridor. The community wishes to preserve its environmental quality while accommodating the traffic demands of commercial development and residential growth. Through travel demand modeling, it was demonstrated that substantial roadway improvements would be necessary to resolve the area's traffic problems. The magnitude of these improvements was environmentally unacceptable. As the forecasted demand exceeded the system capacity, a primary concern was the spillover effect of arterial traffic onto residential streets. This led to the development of a traffic management strategy, which considered the legal aspects of traffic diversion. The recommended plan attempts to manage systemwide traffic by encouraging traffic on selected streets and discouraging it on others. These objectives were accomplished by controlling roadway capacity through allocations of green time at signalized intersections, roadway design features, and travel time penalties. The plan does not totally satisfy the travel demand, but does provide reasonable travel routes for through traffic while minimizing the traffic impact on residential areas.