6) Select the project manager using the guidelines/decision rules provided in this paper. In doing so, the project's circumstances need to be considered.

Indeed, we need to stress that the significance of the methodology for managing projects in complex organizations lies in providing an objective basis for selecting a project manager—a person on whom the success of a project lies. However, the major defect of the model is that it is only applicable to large organizations. Another objection to the analysis presented in the paper, however, may probably be that it does not provide numerous examples of the application of the model. In fact, the nonuse of several case examples to illustrate the application of the model to companies (perhaps of varying complexity) does no harm to the analysis and the model's prescriptions, since throughout the analysis emphasis was placed on those features common to all complex organizations: shared and overlapping responsibilities (virtual positions) and the associated power struggles. In other words, despite the fact that numerous cases were not cited, the model is of general applicability to complex organizations.

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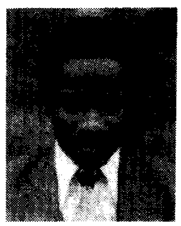

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Multiobjective Decision Making for Traffic Assignment

Gwo-Hshiung Tzeng and Chien-Ho Chen

Abstract—**In traditional traffic-assignment problems, only a single objective is considered. Although people's living quality improves and transportation needs increase, the environmental quality is destroyed with rapid economic and traffic growth. The concept of traffic assignment, an important procedure for transportation planning, should take all needs into consideration. Based on the viewpoints of all constituencies, this paper attempts to determine optimal flow patterns using three objectives—total travel time for road users, air pollution for nonusers (such as community residents), and travel distance for government—to formulate an effective multiobjective model for traffic assignment. By using multiobjective decision making and nonlinear programming tech-**

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niques, a series of noninferior solutions is generated. By combining an eigenvector weighting method with pairwise comparison, we obtain a compromise solution for the flow pattern. An application case for the Taipei network system is also presented and discussed. The results show that if other nontraffic related factors are taken into account, the multiobjective traffic-assignment approach is more reasonable and suitable than conventional approaches.

Keywords—**Compromise solution, descriptive and normative approach, MCDM-multiobjective decision making, noninferior solution, pairwise comparison, preference, traffic assignment.**

I. Introduction

Managers of urban traffic engineering systems must address the needs of three constituencies: road users who seek minimal travel time, nonusers such as the surrounding community who are affected by pollution, and government officials who are concerned with travel distance considerations.

It is generally recognized that traffic assignment, an important procedure of transportation-demand analysis, is critical for long-term transportation planning. Conventional traffic assignment is a demand-oriented approach according to road-users' behaviors. It is typically used to predict link-flows distribution between origins and destinations based on the behaviors of road users [8]. A single objective such as travel time or travel cost is used [21].

Transportation systems are complex and involve a large number of variables that can be fuzzy. They also involve a set of conflicting objectives and should consider different points of view. In addition, because the cost of a transportation system is a sunk cost, such a system cannot easily be altered. Because of these reasons, it is critical to consider the impact of different needs in designing transportation systems. This paper presents a normative traffic assignment model using the multiobjective decision making method to deal with multiple incommensurable objectives.

To simplify the problem, we assume that:

1) Only a single decision maker and deterministic data are considered.
2) Only three objectives—travel time, travel distance, and air pollution—are taken into account.
3) All traffic-flow units are transferred into passenger-car units (P.C.U.).
4) The internal-flow trips of a single traffic zone are not considered.

II. Basic Concepts of Conventional Traffic-Assignment Methods

The purpose of the conventional traffic-assignment model is to simulate or predict the trip-flow pattern between all origins and destinations. Most traffic-assignment methods employ descriptive approaches that assign trips with consideration only to the needs of road users [8], [20].

The criterion used in most approaches is the travel time of road users. This does not include the consideration of the impact of traffic-related nuisances, such as air pollution and noise pollution, or other people's benefit, such as nonroad users' living standards.

With the increased importance of environmental protection and rights of people, traffic assignments must take into account the wider impact of these transportation activities. Multiobjective planning should be considered in the process of traffic assignment since most objectives are incommensurable [3].

Multiobjective decision making (MODM) techniques [1], [2], [6] deal with conflicting objectives. They solve the problem by translating it into a mathematical programming problem and by using decision theory to evaluate the implied strategy. The most common techniques are:

1) Techniques of noninferior solution:
   a) Weighting Method [24];
   b) ϵ–Constraint Method [24];
   c) Noninferior Set Estimation Method [12].
2) Techniques of determining preference:
   a) AHP Method [22], [23];
   b) ELECTRE Method [4], [17];
   c) Utility Function Method [14];
   d) Weighting Average Method [24];
   e) Compromise Solution Method [25], [16];
   f) Goal Programming Method [6].

III. Modeling the Traffic Assignment Problem with Multiobjective Decision Making

The sets and symbols used are defined with a simple example network (Fig. 1).

- R The origin node set, $\{r\}$.
- S The destination node set, $\{s\}$.
- A The link set, $\{a_1, a_2, \cdots, a_n\}$.
- K_{rs} The path set from origin r to destination s $\{a_1, a_2, a_3\}, \cdots, \{a_7, a_8, a_9\}$.
- f^{rs}_k The flow of the kth path from origin r to destination s.

$$\delta^{rs}_{ak} = \begin{cases} 1 & \text{when } f \text{ passes through link } a \\ 0 & \text{otherwise.} \end{cases}$$

- x_a Flow of link a.
- q^{rs} OD flow from origin r to destination s.

$$x_a = \sum_{rsk} f^{rs}_k \cdot \delta^{rs}_{ak}, \qquad \forall a \in A.$$

The basic model consists of three objectives that raise the most concern; they are travel time, travel distance, and air pollution "carbon monoxide" (CO), which reflect, respectively, the needs of road users, the desire of government, and the impact on nonroad users. The model can be expressed in a mathematical form

$$\min \qquad Z(f_1, f_2, f_3) \tag{1}$$

subject to

$$\sum_k f^{rs}_k = q^{rs}, \quad \forall r \in R, \forall s \in S \tag{2}$$

$$f^{rs}_k \geq 0, \qquad \forall r \in R, \forall s \in S, \forall k \in K_{rs} \tag{3}$$

$$f_1 = \sum_a X_a \cdot d_a$$

$$f_2 = \sum_a X_a \cdot t_a(X_a)$$

$$f_3 = \sum_a X_a \cdot p_a(X_a)$$

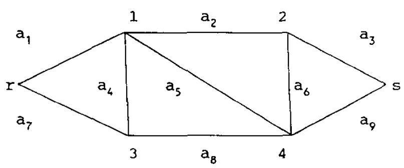

Fig. 1. Example of network.

where

f_1	total travel distance,
f_2	total travel time,
f_3	total air pollution of CO,
d_a	distance of link a,
$t_a(X_a)$	travel time on link a with flow x_a, and
$p_a(X_a)$	air pollution of CO on link a with flow x_a.

According to Pareto preference, the solutions of this model are indefinite continuous sets of noninferior solutions. The objective functions are nonlinear equations, but the constraint sets are linear. The result is that the feasible set is also convex. The model could be transferred into a single-objective optimization problem and solved effectively by using the weighting method (Program 1) and the solution is unique.

Program 1

$$\min \left\{ W_1 \cdot \sum_a x_a \cdot d_a + W_2 \cdot \sum_a x_a \cdot t_a(x_a) + W_3 \cdot \sum_a x_a \cdot p_a(x_a) \right\} \quad (4)$$

subject to

$$\sum_k f^{r\,s}_{k} = q^{rs}, \qquad \forall r \in R, \forall s \in S \quad (5)$$

$$f^{r\,s}_{k} \geq 0, \qquad \forall r \in R, \forall s \in S, \forall k \in K_{rs} \quad (6)$$

$$W_1 + W_2 + W_3 = 1 \quad (7)$$

$$W_1, W_2, W_3 \geq 0 \quad (8)$$

where

W_1	weight of the first objective,
W_2	weight of the second objective, and
W_3	weight of the third objective.

The Lagrangian of the equivalent minimization problem with respect to the equality constraints can be formulated as follows:

$$L(X(f), u) = W_1 \cdot \sum_a x_a \cdot d_a + W_2 \cdot \sum_a x_a \cdot t_a(x_a) + W_3 \cdot \sum_a x_a \cdot p_a(x_a) + u^{rs} \cdot \left(q^{rs} - \sum_k f^{r\,s}_{k} \right) \quad (9)$$

where

$$x = \{x_a\}$$

$$f = \{f^{r\,s}_{k}\}$$

$$u = \{u^{rs}\}.$$

By applying the Kuhn–Tucker optimality condition, the following conditions are held:

$$f^{r\,s*}_{k} \cdot \left(W_1 \cdot \tilde{D}^{r\,s}_{k} + W_2 \cdot \tilde{T}^{r\,s}_{k} + W_3 \cdot \tilde{P}^{r\,s}_{k} - u^{rs} \right) = 0, \qquad \forall r, s \quad (10)$$

$$W_1 \cdot \tilde{D}^{r\,s}_{k} + W_2 \cdot \tilde{T}^{r\,s}_{k} + W_3 \cdot \tilde{P}^{r\,s}_{k} - u^{rs} \geq 0, \qquad \forall r, s, k \quad (11)$$

$$\sum_k f^{r\,s}_{k} = q^{rs}, \qquad \forall r, s \quad (12)$$

$$f^{r\,s}_{k} \geq 0, \qquad \forall r, s, k \quad (13)$$

where

$$\tilde{T}^{r\,s}_{k} = \left[t_a(x_a) + x_a \cdot \frac{dt_a(x_a)}{dx_a} \right] \cdot \delta^{r\,s}_{a\,k} \quad (14)$$

$$\tilde{P}^{r\,s}_{k} = \left[p_a(x_a) + x_a \cdot \frac{dp_a(x)}{dx_a} \right] \cdot \delta^{r\,s}_{a\,k} \quad (15)$$

$$\tilde{D}^{r\,s}_{k} = d_a \cdot \delta^{r\,s}_{a\,k}. \quad (16)$$

u^{rs}	The cost from origin r to destination s, obtained at optimum for each driver.
$f^{r\,s*}_{k}$	Path flow obtained at optimum.

Equations (10)–(13) can be interpreted as follows: At the optimum, the total weighting marginal cost of OD pair r–s is equal. In this case, the marginal cost of unused paths (path flow equals zero) must be greater than or equal to used paths. It means that while a path is used, the cost of using this path and other related paths should be considered. The total marginal cost for each used path is equal when we take into consideration the effects of all people.

From the viewpoint of mathematical programming, this model is a nonlinear program and the constraint set is in linear form. By applying the Frank–Wolfe algorithm, we could simplify the model into an "all or nothing assignment" with every set of fixed weights. The algorithm can be described as follows (Fig. 2):

1) Taking the gradient of the objective function with respect to link flows, we obtain the auxiliary link variable $\{y_a\}$.
2) Taking the gradient of objective function with respect to path flows, we have

Program 2

$$\min Z(g^n) = \nabla_f Z(x(f^n)) \cdot g^t = \sum_{rsk} \left[\left(W_1 \cdot \tilde{D}^{r\,s}_{k} + W_2 \cdot \tilde{T}^{r\,s}_{k} + W_3 \cdot \tilde{p}^{r\,s}_{k} \right) \cdot g^{r\,s}_{k} \right] \quad (17)$$

subject to

$$\sum_k g^{r\,s}_{k} = q^{rs}, \qquad \forall r \in R, \forall s \in S \quad (18)$$

$$g^{r\,s}_{k} \geq 0, \qquad \forall r \in R, \forall s \in S, \quad \forall k \in K_{rs} \quad (19)$$

where G is the auxiliary path variable $\{g^{r\,s}_{k}\}$.

Obviously, this linear program calls for minimizing the total marginal cost over a network with fixed travel costs of iteration n and each OD pair. The total marginal cost would be minimized by transferring a portion of path flow to other paths. All the processes are transferred into an

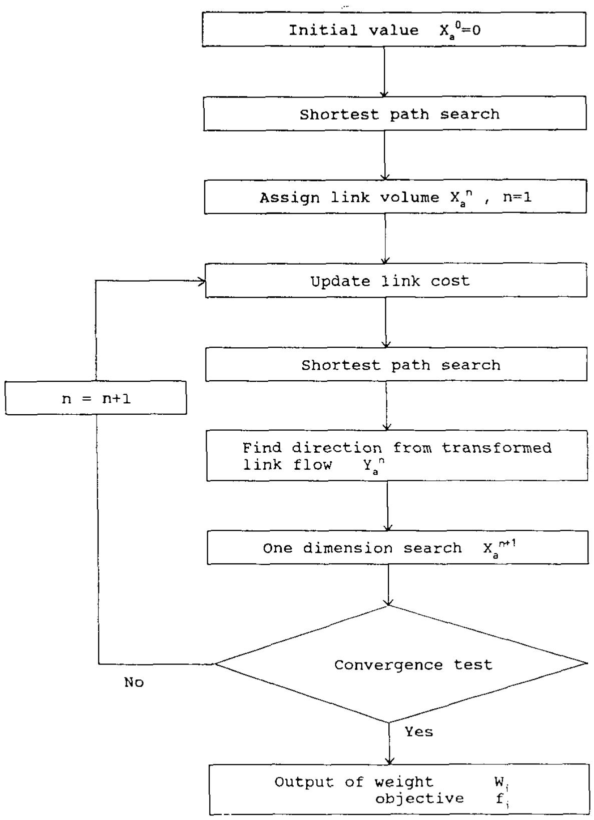

Fig. 2. Flow chart of an algorithm of traffic assignment with MODM.

"all or nothing assignment" because the travel cost is now flow-independent.

3) Determine a descent direction $d^n = y^n - x^n$.
4) Find the step size.

Program 3

Let

$$V^n = X^n + \alpha \cdot (Y^n - X^n)$$

$$\min \left[W_1 \cdot V_a \cdot \tilde{d}_a + W_2 \cdot V_a \cdot \tilde{t}_a(V_a) + W_3 \cdot V_a \cdot \tilde{p}_a(V_a) \right] \quad (20)$$

subject to

$$0 \leq \alpha \leq 1 \quad (21)$$

where

$$\tilde{d}_a = d_a$$

$$\tilde{t}_a(x_a) = \left[t_a(x_a) + x_a \cdot \frac{dt_a(x_a)}{dx_a} \right]$$

$$\tilde{p}_a(x_a) = \left[p_a(x_a) + x_a \cdot \frac{dp_a(x_a)}{dx_a} \right].$$

5) Stop criterion $X^{n+1} = X^n$: Stop while there is little change in link flow between the nth iteration and the $(n + 1)$th iteration.

The solution of the previous procedure would be unique if all the objective functions are strictly convex.

IV. Method of Decision Making

In the previous model, the noninferior solutions obtained by applying the weighting method are uniformly distributed on the noninferior curve. The decision maker (DM) may highlight the importance of some specific objectives by increasing the values of the corresponding weights. In the meantime, the cost of this highlighted objective would be a large portion of the total cost. The result of the assignment will show that the improvement toward this objective is obvious.

The following process will use the solutions of the previous method and the eigenvector weighting method to decide the set of weight of the optimal flow pattern. The ideal point can be found with this characteristic and pairwise comparison of the eigenvector weighting method. Using a compromised solution, the set of weight (with respect to each objective function) of the optimal solution closest to the ideal point could be determined. The optimal solution is obtained by using Frank–Wolfe algorithm with this set of weight.

1) Generate representative noninferior solutions f with several different sets of weights W.
2) Get the comparison matrix $\boldsymbol{C} = [c_{ij}]$ by the eigenvector weighting method. The elements of this matrix will represent the DM's feeling toward improving one objective at the cost of another. The same scale is used here as in the analytic hierarchy process. That is,
   - $c_{ij} = 1$ implies that the DM is indifferent with the values of objectives i and j;
   - $c_{ij} > 1$ means that the DM prefers to improve objective i while degrading objective j; and
   - $c_{ij} < 1$ means that the DM prefers to improve objective j while degrading objective i.
3) Generate comparison index $\Phi = \{\phi_i\}$, $i = 1,\cdots,n$ [22]

$$\phi_i = \frac{1}{\lambda_{\max}} \sum_{j=1}^{n} c_{ij} \phi_j$$

where $\lambda_{\max}$ is the maximum eigenvalue of $\boldsymbol{C}$ (comparison matrix) and n is the number of objectives.

4) Check to see if the DM is consistent and that a consistency ratio (C.R.) of less than 0.1 would be satisfied [22] where

$$\text{C.R.} = \frac{\text{C.I.}}{\text{E(R.I.)}}$$

C.R. consistency ratio,
C.I. consistency index,
R.I. random index,
E(·) expected value,
and

$$\text{C.I.} = \frac{(\lambda_{\max} - n)}{(n - 1)}.$$

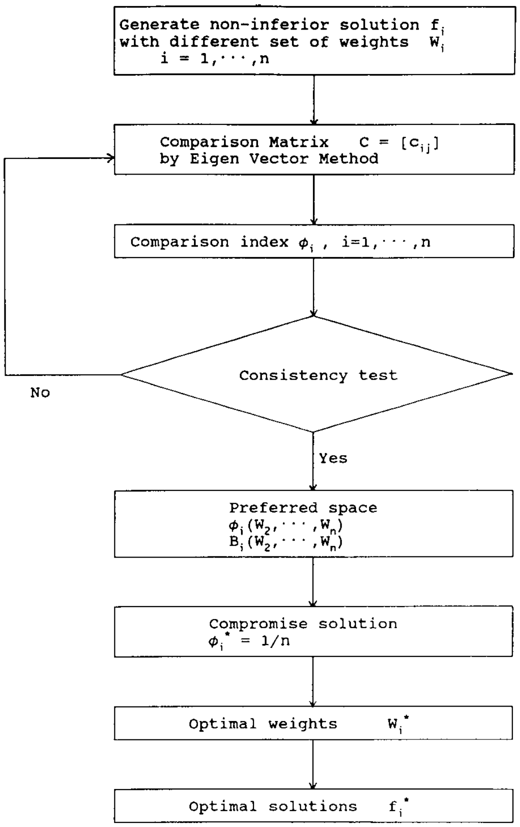

Fig. 3. The process of decision making.

5) Generate the ideal point: As Step 2 indicates, while $c_{ij} = 1$ means that the DM is the most satisfied, the comparison index will be $1/n$, n being the number of objectives. Then, the ideal point for each objective will be the value of the comparison index, which is $1/n$.
6) Set preferred space by applying multiregression analysis and the boundary of preferred space $B(W_2,\cdots,W_n)$ and $\Phi(W_2,\cdots,W_n)$ is obtained.
7) Find the best compromise solution by solving

$$\min \sum_{i=1}^{n} [(1/n) - \phi_i(W_2,\cdots,W_n)]^2 \qquad (22)$$

subject to

$$\phi_i \in B, \qquad i = 1,\cdots,n \qquad (23)$$

where

$$B = \{B_i\}, \quad i = 1,\cdots,n.$$

8) Obtain the optimal solution by setting the weight of the source model to be the optimal weight set and solving it with Frank–Wolfe algorithm.

The resulting solution is one of the Pareto optimal solutions guaranteed by the Kuhn–Tucker conditions. Fig. 3 summarizes this. This model and approach have been used to analyze the traffic flow in Taipei.

V. Case Study of Metropolitan Taipei

With the rapid growth and concentration of traffic flow, metropolitan Taipei faces a serious problem involving traffic and air pollution. This affects the residents and the road users alike. The government also has to build more routes to alleviate the situation. The study in this paper is applied to metropolitan Taipei for a roadway network of 38 traffic zones, 268 nodes, and 688 links (Fig. 4).

The travel time function we adopt from a field study of Taipei city is

$$t_a = t_0[1 + 2.5 \cdot (x_a/c_a)]^2$$

where

- t_a travel time on link a,
- t_0 free flow travel time on link a,
- x_a traffic volume of link a, and
- c_a capacity of link a.

The air pollution function of carbon monoxide (CO) is obtained with the result of a survey in arterial links (for the link of width over 20 m).

$$p_a = p_0 + p_1 \cdot x_a$$

where

- p_a air pollution value on link a,
- p_0 air pollution constant, and
- p_1 sensitivity of traffic volume effect toward air pollution value.

Using the pricked procedures, several noninferior solutions with different sets of weights were obtained as shown in Table I.

Because of the lack of proper preference information of the people, the flow patterns are classified into five types as in Table II. The characteristics of each pattern are described as follows (Table III).

1) The result of the first pattern neglects the effect of air pollution. The air-pollution level of CO will be over 50 000 (thousand PCU-ppm). The total travel time will be 3800 (thousand PCU-hr) below average. Total travel distance is 5500 (thousand PCU-km). This kind of flow pattern mainly uses the shortest travel-time and shortest travel-distance paths.
2) This type of flow pattern is similar to the first one, but the usefulness of the shortest path is not so obvious.
3) The third flow pattern is weighted more with air-pollution objectives; the total travel distance and time will be higher.
4) This flow pattern is heavily weighted with the air-pollution objective. In this case, the flow of CBD in real loading network will be reduced as much as possible.
5) This flow pattern will not consider the effect of total travel distance; it is used more often to assign flow with highways or expressways.

Analysis of these five flow patterns provides important reference information to the DM and the planner. Different sets of

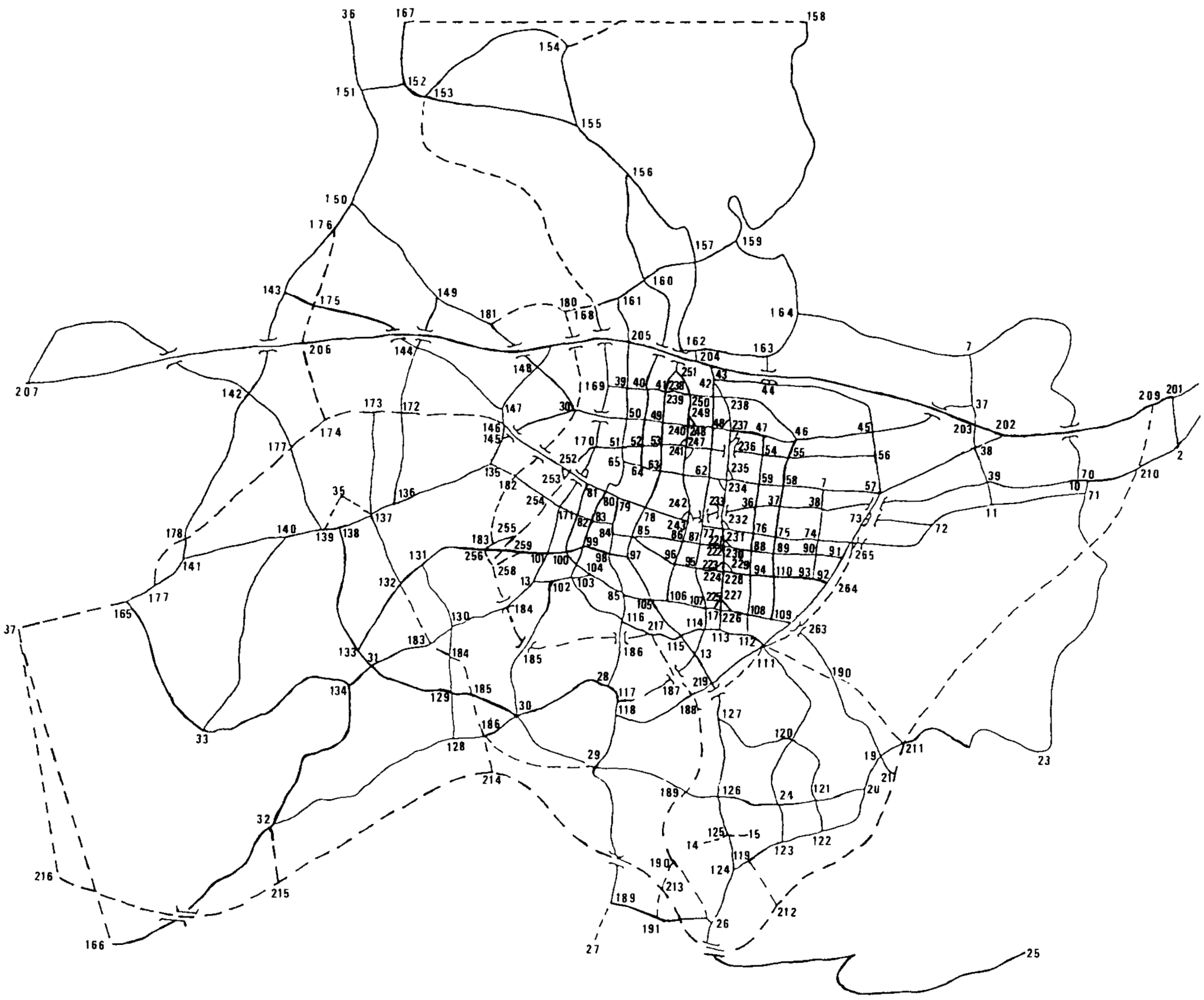

Fig. 4. The road network of metropolitan Taipei.

weights will get different results. Analytical variation of weights provides the DM with an idea of what scale the weight should be in order to get more reasonable and suitable outputs. The flow patterns except the second and third are obviously extreme patterns and such assignments should be avoided. The second and third flow patterns could consider the three objectives at the same time.

Another important issue is the managerial problem. The previous procedures provide better references to the DM to make a decision, but the management of the traffic system to achieve the optimal flow pattern is more practical. The main issues are also listed as follows:

1) detection system (of current traffic condition);
2) information system (to/from drivers);
3) flexible traffic control system;
4) nontraffic control method;
5) integration of vehicles, drivers, and road network.

VI. Conclusions and Suggestions

This paper proposes the use of traffic-assignment methods with multiple-objective decision making to remedy the shortcomings of conventional traffic-assignment methods. We conclude by noting that:

1) Conventional single-objective traffic assignment is a special case of multiobjective traffic assignment. The multiobjective case provides a more realistic approach.
2) Transforming traffic assignments into a shortest path problem simplifies the formulation of roadway networks, especially in a large area.
3) The decision method used could apply the eigenvector weighting method (which is mostly used in discrete cases) to solve continuous cases by performing simple pairwise comparisons.
4) Analysis and classification of the flow pattern by comparing different weights would probably help DM's and planners better realize the planning processes.

Additional enhancements are suggested as follows:

1) The model uses three objectives. Other factors such as safety, economic benefit, etc., should be taken into consideration in order to make the model more useful.

TABLE I
NONINFERIOR SOLUTIONS OF DIFFERENT WEIGHTS

Weight of Distance (W_1)	Weight of Time (W_2)	Weight of Pollution (W_3)	Total Travel Distance (f_1^*)	Total Travel Time (f_2^*)	Total Air Pollution (f_3^*)
.333	.333	.333	565.2	379.0	4206.9
.500	.500	.000	541.6	385.7	5350.0
.500	.000	.500	529.4	566.5	4214.7
.000	.500	.500	607.6	377.2	4133.9
.000	1.000	.000	615.5	376.0	5073.6
.000	.800	.200	606.0	374.8	4149.3
.000	.600	.400	606.7	375.5	4146.1
.000	.400	.600	606.9	378.1	4087.6
.000	.200	.800	605.8	383.0	4030.2
.000	.000	1.000	600.0	426.9	3991.2
.200	.800	.000	578.1	373.2	5199.9
.200	.600	.200	579.6	374.3	4367.8
.200	.400	.400	579.8	376.4	4159.4
.200	.200	.600	579.0	381.8	4065.4
.200	.000	.800	565.7	467.9	4025.8
.400	.600	.000	550.6	380.9	5240.1
.400	.400	.200	555.0	379.7	4385.1
.400	.200	.400	556.9	388.6	4169.1
.400	.000	.600	540.1	524.2	4127.8
.600	.400	.000	531.6	393.6	5526.9
.600	.200	.200	523.4	402.8	4459.2
.600	.000	.400	518.4	642.4	4345.9
.800	.200	.000	504.8	454.5	6328.8
.800	.000	.200	499.3	800.8	4824.6
1.000	.000	.000	468.4	2329.6	11603.6

*unit of f_1 is thousand PCU-km; unit of f_2 is thousand PCU-min; unit of f_3 is thousand PCU-p/pm

TABLE II
CLASSIFICATION OF FLOW PATTERN

Flow Pattern		Weight						
1	W_1	0.0	0.2	0.4	0.5	0.6	0.8	1.0
	W_2	1.0	0.8	0.6	0.5	0.4	0.2	0.0
	W_3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	W_1	0.2	0.4	0.6	0.8	—	—	—
	W_2	0.6	0.4	0.2	0.0	—	—	—
	W_3	0.2	0.2	0.2	0.2	—	—	—
3	W_1	0.2	0.4	0.6	0.33	—	—	—
	W_2	0.4	0.2	0.0	0.33	—	—	—
	W_3	0.4	0.4	0.4	0.33	—	—	—
4	W_1	0.2	0.2	0.4	0.5	—	—	—
	W_2	0.2	0.0	0.0	0.0	—	—	—
	W_3	0.6	0.8	0.6	0.5	—	—	—
5	W_1	0.0	0.0	0.0	0.0	0.0	0.0	—
	W_2	0.8	0.6	0.5	0.4	0.2	0.0	—
	W_3	0.2	0.4	0.5	0.6	0.8	1.0	—

2) The addition of group decision making and uncertainty should be more realistic.
3) The process of transportation-demand analysis contains trip generation, trip distribution, mode choice, and traffic assignment. Every process is closely related, so the integration of the entire process and the variable demands could make a significant contribution to transportation planning.

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TABLE III
THE CHARACTERISTICS OF DIFFERENT FLOW PATTERN

Flow Pattern	1	2	3	4	5
Weight of travel distance (W_1)	0.0–0.8	0.2–0.6	0.2–0.6	0.2–0.5	0
Total travel distance (f_1)	500	560	580	550	600
Weight of travel time (W_2)	0.2–1.0	0.2–0.6	0.0–0.4	0.0–0.2	0.0–0.8
Total travel time (f_2)	˜380	˜400	˜420	˜520	˜380
Weight of air pollution (W_3)	0	0.2	0.3–0.4	0.5–0.8	0.2–1.0
Total air pollution (f_3)	5000˜	4400˜	˜4200	˜4100	˜4200

Notes: 1) Unit of f_1 is thousand PCU-km; unit of f_2 is thousand PCU-hr; unit of f_3 is thousand PCU-p/pm. 2) ˜A: over A; A˜ : below A.

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R & D Manpower Forecasting for Chemical Industries in India

Susy Philipose

***Abstract*—This paper is the result of a study conducted in India to determine the manpower requirements toward the end of the century in R & D for the country's chemical industries. For 1981–1987 data projection is made for short-term and long-term manpower requirements. To take care of the environmental changes, variable-parameter regression is used for ten years and exponential smoothing is used for subsequent years. The explanatory variables for the manpower requirements are established and are partitioned into time-dependent and time-independent variables.**

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I. Introduction

In view of the swift technological changes at the global level, developing countries such as India need to keep pace in this race so that they do not lag behind technologically. Over many centuries R & D has been the area contributing to rapid technological development, leading to changes in life-styles. India's recent five-year plans have focused on R & D. In spite of this, expenditures in the public and private sectors amount to only 0.83% of the GNP for 1983–1984. To encourage R & D the government has created tax incentives for investment in R & D.

The chemical industry is intimately connected with basic needs of the society such as food, clothing, shelter, and health. The recent advances and explorations by the Oil and Natural Gas Commission (ONGC) in India has given hope for a bright future for natural resources and progress for the chemical industries. In order for these industries to have a good foundation, stress needs to be placed on the area of R & D. This study was made to determine the discrepancy between the supply and demand of the manpower requirements for R & D.

India has a pool of skilled and competent workers comparable to many industrially developed countries. In contrast to their counterparts in developed countries, the salary structure of employees is low. The purpose of this study was to determine where to direct the skills and talents of the manpower.

II. Objectives of the Study

The study was aimed at the following aspects of the R & D manpower requirements for the chemical industries:

1) To forecast the manpower requirements for short-term (five years) and long-term (fifteen years) periods.
2) To determine future manpower requirements according to discipline breakdown.
3) To discover the interrelationship between R & D manpower and total manpower.

III. Methodology

Since India is a vast country the present study was focused on only one part of the country. Two states in the western region were selected, Maharashtra and Gujarat, where there is a concentration of chemical industries. Except for the coal industries, most other branches of the chemical industries are located in this area. Some companies in the chemical industries have more than one division, which are spread out in different parts of the country. So, to define the geographical location of each company it was decided that a company having its registered office in either of these two states was considered as located in this region, irrespective of its factories located elsewhere.

The classification of chemical industries was based on the Annual Survey of Industries (ASI) by the Central Statistical Organisation (CSO) published for 1974; this is the latest authorative publication available in India and the most often-used reference. In this publication major groups 30 and 31 were chosen for studys. Subgroups of these groups are shown in Table I.