Time-Area Concept: Development, Meaning, and Applications

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The concept of time-area occupancy by vehicles captures in the same unit not only the quantity of ground area (or space) that is required for safe vehicle movement or for storage but the period of time for which the area is occupied as well. Another advantage of time-area measure is that it links the two usually different concepts of static and dynamic transport units (either vehicles or persons) under a common variable, the time-area that they consume. Moreover, it allows efficiency to be evaluated in terms of consumed versus available time-area. This is particularly useful in comparing different transportation modes. The history of development of this concept is reviewed; previous use had been confined to cursory analyses of modes, except for pedestrian facility operational analysis and design. Further research of this concept and its applications is presented. Some basic concepts essential to time-area calculation are explained and simple formulas for several different cases are introduced. Based on these formulas, a graphical example of the time-area consumed for a hypothetical commuter round-trip using three different modes demonstrates some of the quantitative measures and insights regarding transportation and urban land use to be gained through this approach.

The ever-increasing ground-area consumption for transportation purposes is an issue of growing importance to the economy, the ecology, and the quality of life; in densely built cities, the remaining room for facility expansion and new rights-of-way is limited, while suburbs are increasingly consuming land that has a large value in remaining undeveloped.

Conventional analytical methods of area or space consumption by various transportation modes usually deal with properties measured at a point—such as speed, volume, or density for moving vehicles and persons—from which the instantaneous space requirements can be computed. Vehicles and persons that are not moving are analyzed by measuring separately the static storage area or space required, as well as the duration of area occupancy.

Time-area is the product of the time and the area consumed by a vehicle within a chosen time frame and location. Thus, the concept of time-area captures in the same unit not only the quantity of ground area (or space) that is required for safe movement or for storage but the period of time for which the area is occupied as well. This is a logical measure in that both time and area can be equally important determinants in facility sizing and in capacity computations. For example, an automobile commuter to the central city occupies a large amount of area while driving, but only for a short period of time. The driver then parks and consumes a lesser area, but for a longer duration. The total time-area expresses the entire resource demand as one unit, typically in m^2-s. By comparison, conventional methods analyze driving and parking separately.

The concept of time-space would be similar, except that space now refers to a three-dimensional volume instead of only the projected ground area. Unfortunately, the existing literature tends to use the term time-space for the two-dimensional case as well. The term *time-space* is also found in connection with the so-called time-space diagram, which is used for plotting the synchronization of traffic signals along streets. Although this is an erroneous name (time-distance diagram being the correct one), it is in common usage and thus is reason to avoid using the term time-space.

The time-area concept has several advantages:

- It represents a common measure for evaluation of area and time consumption by any transportation unit (pedestrian, vehicle, train), rather than for each mode separately.
- It allows joint measurement of consumption by moving and stationary transport units (either vehicles or persons), that is, it unifies the two usually different concepts of static and dynamic components of a transportation system. For example, a car consumes area not only when driving but when parked, and both are important, particularly in urban settings.
- It can provide a common variable for the comparison of different transportation modes. As will be seen, it is possible to do an informative analysis of relative land use and congestion effects of the various modal combinations urban travelers can select by calculating time-area consumptions for these various options.

The time-area concept has several applications, only a few of which have been fully developed. This paper shows one involving land consumption by commuters using different modes of travel. The particular application was chosen not only because it is of interest for its own sake, but because it can be presented with few equations and should be a relatively easy introduction for explaining the concept. Before this application can be presented, a brief historical review of the time-area concept will be presented, followed by a description of elementary quantitative methods of measuring and evaluating time-area.

HISTORY OF TIME-AREA CONCEPT

Previous Literature and Applications

The time-area concept has been discussed since at least 1959, when the Union Internationale des Transports Publics (UITP) published a brochure showing the concept (*1*). The next discussion of the time-area concept was in Leibbrand's 1964 book, *Transportation and Town Planning* (*2*). He used typical urban speeds of pedestrians and other transportation modes, each with typical occupancies, to calculate the number of square meters occupied to maintain their motion. The next discussion was in a 1965 publication by the Town Traffic Section of the International Exhibition of Transport and

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Communications (3). A comparison was made of streetcars, buses, and private automobiles all traveling at the same speed of 30 km/hr, to demonstrate the large difference in space requirements per passenger between the three modes, particularly the enormous space requirement for automobile passengers. In both of these discussions, the actual reference was to instantaneous area requirements, a closely related concept to time-area that will be explained later in more detail.

Pushkarev and Zupan, in *Urban Spaces for Pedestrians* (4), made a tabular comparison of many modes, ranging from a bicycle to an airplane landing, with the point of showing the space consumption required per person at one assumed speed and occupancy rate reasonable for the particular mode. They did not attempt to generalize the results for a wider range of potential speeds and occupancies by making a general time-area formulation. This was, however, an early effort to portray not only differences in travel times, but also the widely disparate area consumption implied by the use of different modes.

Louis Marchand, who later became chief engineer for the Regie Autonome des Transports Parisiens, made explicit reference to the time-area concept in an interview in the French journal *Metropolis* (5) regarding important aspects of urban mobility. Marchand gave typical time-area values for residential storage of an automobile and a bicycle and for travel by public bus, as well as per-kilometer area consumptions by a pedestrian, bicyclist, motorist, and bus passenger. However, no formulas used for calculating these values were supplied.

In the same issue of *Metropolis* in which Marchand was interviewed, Schmider (6) provided a table of time-area consumptions, reproduced here as Table 1. Consumptions were evaluated for a speed considered typical for each mode, assuming a travel distance of 4 km, but for three different storage times: 2, 4, and 6 hours. Thus, this was one of the early explicit calculations of time-area consumption along a path. It showed that the automobile rider consumes far more total time-area than the bicycle rider, who consumes, interestingly, far more than the bus rider.

In an article comparing the efficiency and impact of different urban transportation modes, the French economist Jean-Marie Beauvais presented a formula for computing the time-area consumed within the city traveling 2 km and then working for 8 hours (7). The three mode choices compared were private motorist, bus rider, and pedestrian. Beauvais summed the time-area used in motion along city streets, as well as in storage in the case of the automobile.

Marchand wrote an unpublished paper that also provided a formula for computing time-area consumption along a path and applied it to a short fixed-distance trip of 5 km. For auto travel, parking for three different time durations was included. In addition to the three modes evaluated by Beauvais—auto driver, bus passenger, and pedestrian—Marchand included the bicycle and the Metro

TABLE 1 Time-Area Calculations by André Schmider (6, p. 57)

1a. Example of consumption of time-area for a 4 km round trip with variable time on-site

Speed	Mode	Time on site					
		2 hours		*4 hours*		*8 hours*	
kmph		time	m^2-h	time	m^2-h	time	m^2-h
	Bicycle:						
12	moving	1/3	6	1/3	6	1/3	6
	parked	2	3	4	6	8	12
	total	2+1/3	9	4+1/3	12	8+1/3	18
	Private auto:						
40	moving	1/10	9.6	1/10	9.6	1/10	9.6
	parked	2	16	4	32	8	64
	total	2+1/10	25.6	4+1/10	41.6	8+1/10	73.6
	Bus:						
15	moving	4/15	1.2	4/15	1.2	4/15	1.2
	parked	1/10	0.1	1/10	0.1	1/10	0.1
	total	11/30	1.3	11/30	1.3	11/30	1.3

1b. Consumption of area on a per unit basis

	Area occupied per vehicle	No. of persons per vehicle	Area occupied per person	Area consumed per vehicle	Area consumed per person
	[m^2]	-	[m^2]	[m^2•h/veh-km]	[m^2•h/prs-km]
Mode					
On foot	0	1	0.3	-	0.4
Bicycle	1.5	1	1.5	1.5	1.5
Auto	10	1.25	8	3	2.4
Bus	30	30	1	9	0.3

Note: Translated from the French, with terminology corrected for consistency.

(*8*). A paper similar to Marchand's 1985 paper was presented by his superior but attributed largely to him at the 1989 Congress of the UITP in Singapore (*9*).

The French analysts used the time-area concept to gain some macroeconomic policy insights regarding the future development and functionality of cities. Meanwhile, during the same years, a parallel effort was under way in the United States to develop a design and operational analysis tool for pedestrian facilities. Fruin and Benz (*10*) published the first comparison of using a time-area approach versus the conventional approach as outlined in *Transportation Research Circular 212*: *Interim Materials on Highway Capacity* (*11*). The basis for comparison was going to be a level of service standard for pedestrians created by Fruin in his landmark book *Pedestrian Planning and Design* (*12*). These standards are analogous to those used in the *Highway Capacity Manual* (*13*) for motor vehicle facilities.

Using aggregated average values for storage densities and times and averaged walking speeds, Fruin and Benz have shown it is possible to get very similar results regarding offered level of service to those found by using the much more complicated procedure outlined in *Circular 212*. In addition, it was easy to estimate the service offered under surge conditions, that is, when two heavy pedestrian platoon flows must bypass each other in the middle of the crossing, a design situation not accounted for in *Circular 212*. Benz (*14–16*) as well as Grigoriadou and Braaksma (*17*) have successfully enhanced and used this approach in the operational analysis of rapid transit stations.

Recent Work and Further Applications

The work reviewed can be categorized into two different types of analysis based on their goals. One goal is to use the relative time-area consumption of various modes as an indicator helpful for macroeconomic and area (space) allocation decisions where area (space) is scarce and opportunity costs are high. Yet, analyses to date had been too cursory to be able to draw many policy conclusions.

The other goal has been to develop a new method to analyze the performance of existing pedestrian facilities by an easier method than those currently in common usage and to use this method for preliminary sizing of new facilities. While providing useful results for many applications, the analysis was still coarse in the use of bulk or averaged pedestrian movement speeds and aggregate storage properties.

Significantly, the time-area approach had not been extended to other realms, such as roadway or intersection design, facility performance evaluation for vehicles running on fixed rights-of-way, a resource consumption indicator for costing and pricing, and so forth. Thus, general formulas needed to be created for computing time-area for a variety of modes under different conditions and for different analysis purposes. Furthermore, these relations would need to be evaluated under a range of conditions and presented in comparative graphical formats. Such work was done by one of the authors in his doctoral dissertation (*18*). The formulas and example applications in the remainder of this paper are distilled from this work.

BASIC DEFINITIONS AND FORMULAS

The Shadow, Braking Regime, and Module

As a vehicle moves along its right-of-way, it may be visualized as traveling with an open area attached to the front of it, an area referred to as its "shadow." The purpose of the shadow is to maintain adequate reaction and braking distance from the preceding vehicle. The shadow is regulated using one of four systems of vehicle driving and control:

- Manual, with visual control;
- Manual, with advisory signals;
- Manual, with fail-safe signals (automatic override); and
- Automated.

With manually driven vehicles, the driver must use judgment and visual control to maintain at least the minimum shadow. An example of manual driving with advisory assistance is the use of track-side signals, but the system takes no action if a signal is disregarded. With automatic override, the driver maintains the shadow, but the control system triggers automatic braking if the minimum shadow is violated. On fully automated vehicles, a computer regulates the shadow at all times.

The minimum shadow depends on the "safety regime," that is, the vehicle-following rules that determine the degree of safety offered under various circumstances. Under a manual system, the rule can be as simple as the "2-second separation" rule taught in driver education, or the obsolete "one vehicle length for every 10 mph" rule used by previous generations. Higher safety regimes consider not only speed but also the relative braking rates of the leading and following vehicles, vehicle subsystem reliability, gradients, and other factors.

The length of the shadow is a function of the vehicle-following rule being used, and, therefore, it changes continuously with the speed profile. The shadow can vary randomly among individuals and situations in the case of a manually driven mode. Figure 1 presents the important coordinates used to measure the location of a vehicle and its shadow. The key reference, x_i, marks the front of a vehicle i. x_{1i}, marks the rear of the vehicle, which is located simply at x_i minus the length of the vehicle, δ. x_{2i} marks the location of the front of the shadow. The shadow length $x_{2i} - x_i$ is a function of speed, and is therefore designated as $f(v_i)$. As the vehicle changes speed while proceeding along the path denoted by x, the shadow length changes. It is directly, but not usually linearly, proportional to speed. Therefore, when the speed is constant, the length of the shadow stays constant. When the speed drops to zero, the shadow disappears.

One more term must be defined before proceeding to equations that calculate time-area consumption. $L_i(V_i)$, defined as the sum of the vehicle length plus its shadow length, is referred to as the "module length." The area of the right-of-way occupied by the vehicle and its shadow will, in turn, be referred to as the "module," the term used by Fruin (*12*). The module may be visualized as the instantaneous area associated with or required by a vehicle for operation at a given time. Note that as the speed goes to zero, the module—or instantaneous area—decreases to the length of the vehicle times the right-of-way width, δW.

As an example, the module length of an automobile in congested flow can often be approximated fairly well using the "one vehicle length per 10 mph" car-following rule:

$$L_i(v_i) = \delta + f(v_i) = \delta + B_1 \frac{\delta}{10} v_i \qquad \text{(feet)} \qquad (1)$$

where B_1 is just a conversion factor for unit consistency. But as a more general relation, one could use any speed increment, D:

$$L_i(v_i) = \delta + B_2 \frac{\delta}{D} v_i \qquad \text{(meters)} \qquad (2)$$

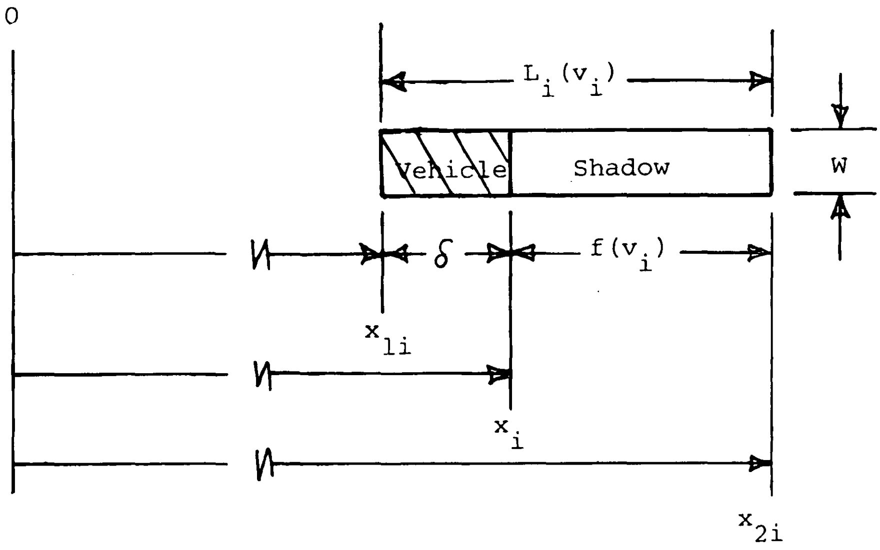

FIGURE 1 Coordinates used to locate the instantaneous area or module of a vehicle.

In the SI system, the value of D for the "10-mph increment" car-following rule would be 16.1 km/hr.

As another example, the module length for a signal-controlled rail vehicle uses a safe vehicle-following rule, that is, a distance at least equal to the stopping distance under all conditions, because it is based on physical considerations and not merely on a rule of thumb:

$$L_i(v_i) = n\delta + t_r v_i + \frac{v_i^2}{2b_2} - \frac{v_i^2}{2b_1} \quad \text{(meters)} \tag{3}$$

where $n\delta$ is the length of an n-car train; t_r is the operator reaction time; and b_1 and b_2 are the braking rates assumed for the leading and following trains, respectively. The module, M, then follows as the product of the right-of-way width and the module length:

$$M = WL_i(v_i) \tag{4}$$

The braking rates selected depend on the stringency of the safety regime. The highest regime, designated "A," provides that the following vehicle can stop safely even if the leading vehicle hits a brick wall. Regimes B and C provide somewhat less protection, and therefore can have shorter shadow lengths. [See the text by Vuchic (*19*) for further elaboration.] Figure 2 illustrates module versus speed for three different sizes of rolling stock using typical values for operator reaction time and for braking rates. As train length gets longer, the module can be visualized to shift upward, and the train itself becomes an increasingly large fraction of the module. The effect of the more stringent operating regime is to make the module rise more steeply as speed increases.

Since vehicles do not generally run at the precise module required by the safety regime at which they try to operate, a stream of vehicles can be represented by an average value, analogous to conventional flow-based models.

Time-Area Consumption for a Continuous Stream of Vehicles Moving at Constant Speed

The derivations of precise formulas for time-area consumption under general conditions are lengthy and complex and cannot be presented here. Complexities include treatment of vehicles as either discrete or continuous flows depending upon traffic conditions, physical characteristics of vehicles, rights-of-way involving curves, intersections, and boundary conditions where vehicles pass into or out of the area being analyzed. However, under conditions of uninterrupted moderate to heavy flow of vehicles that is maintaining a constant speed, calculation is straightforward. T is the duration of the analysis period, while A is the analysis area, in most cases a length of right-of-way S with width W. Q is the flow of vehicles into (and out of) the analysis area during the analysis period. The average time-area consumed by each vehicle i is then

$$\overline{TA_i} = \frac{TA}{Q} = \frac{TWS}{Q} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{5}$$

In words, it is the total available time-area divided by the flow. Under the current assumption of uninterrupted constant rate flow, T can be eliminated by using the relation

$$Q = qT \quad \text{(vehicles)} \tag{6}$$

where q is the flow rate expressed in vehicles per hour. Thus,

$$\overline{TA_i} = \frac{TWS}{Q} = \frac{TWS}{qT} = \frac{WS}{q} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{7}$$

But q can also be expressed as the product of constant traffic density, k, and speed, v:

$$\overline{TA_i} = \frac{WS}{kv} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{8}$$

This is a convenient substitution because the inverse of density is spacing, which is also the module length under the present assumptions, so that the previous equation can be rewritten:

$$\overline{TA_i} = WS\frac{L_i(v_i)}{v} = \frac{MS}{v} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{9}$$

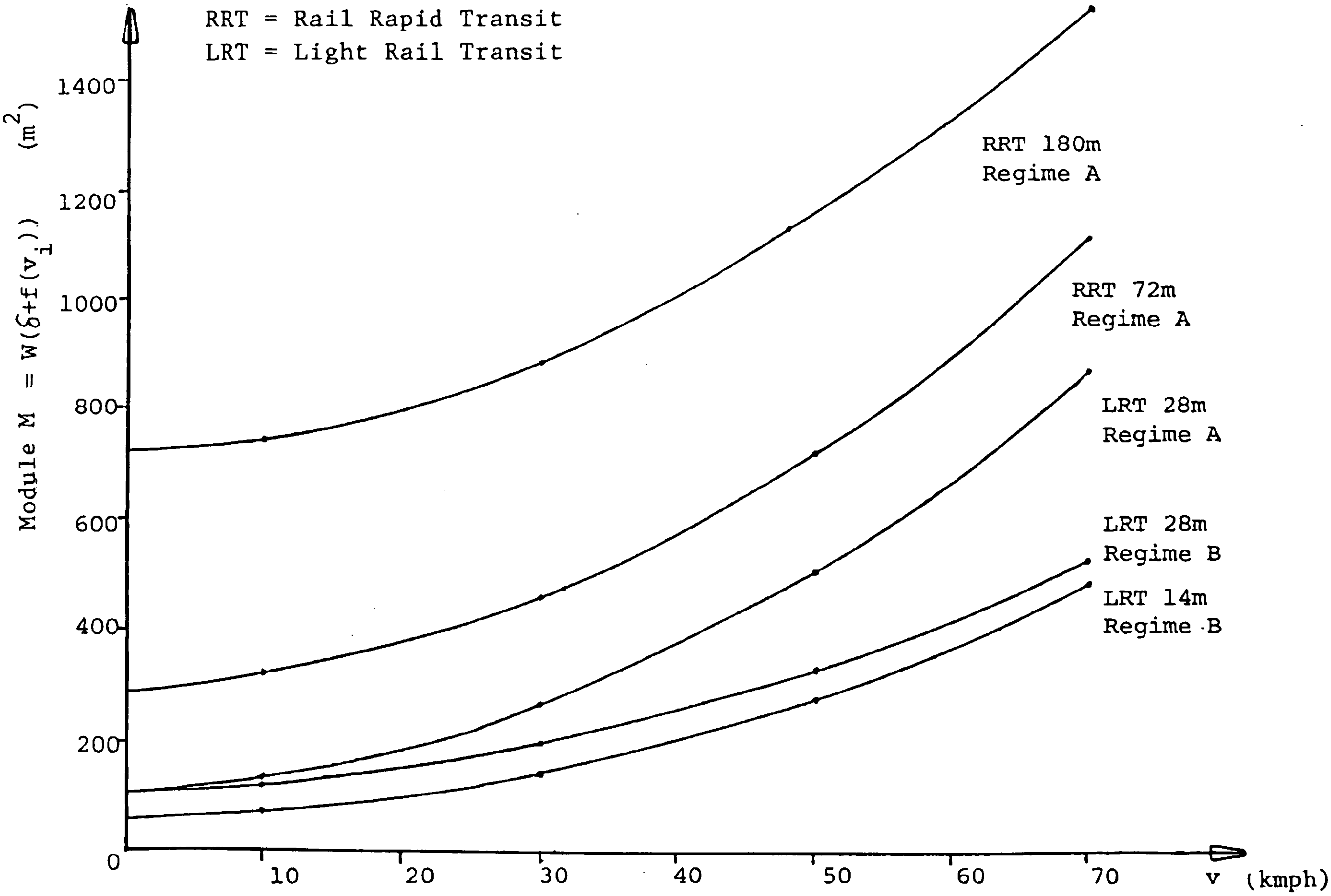

FIGURE 2 Time-area modules of rail transit vehicles.

Equation 9 gives the time-area consumption per vehicle in the course of occupying and traversing the analysis area of size *WS*.

For many purposes, it is not necessary to be specific about the length of analysis area. In such cases, one can look at the consumption per unit length of right-of-way by dividing both sides of Equation 9 by *S*:

$$\frac{\overline{TA_i}}{S} = W\frac{L_i(v_i)}{v} = \frac{M}{v} \qquad \left(\frac{\text{m}^2\text{-s/m}}{\text{vehicle}}\right) \tag{10}$$

So far the formulas for time-area have all centered on consumption simply on a per-vehicle basis. Another very useful comparison is on a per-unit-of-transportation-work-performed basis, that is, the time-area consumed per passenger-kilometers performed. This is found by dividing the previous equation by the average number of passengers, or average occupancy, in the type of vehicle in question:

$$\frac{\overline{TA_i}}{(\alpha C_i)S} = \frac{W}{(\alpha C_i)}\frac{L_i(v_i)}{v} \qquad \left(\frac{\text{m}^2\text{-s}}{\text{pass-m}}\right) \tag{11}$$

where C_i is the capacity of vehicle type i and α is the average load factor for this type of vehicle while operating within the analysis area.

The simplified formulations given are not valid at zero speed. Instead, the time-area consumed while standing for time t on the right-of-way is given by the simple relation:

$$TA_i = W\delta t \qquad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{12}$$

When a parking spot is used, the total parking lot size divided by the number of spaces is used to account for the maneuvering space inherent in the design of off-street parking lots. The area per vehicle is the total floor area divided by the number of spaces, or A_{eff}, the effective area per vehicle, so that

$$TA_i = A_{\text{eff}}t \qquad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{13}$$

In a related vein, the general issue of how much area to attribute to the right-of-way for a mode can be problematic. Sometimes, only the lane width may be appropriate; in others, the minimal right-of-way width (e.g., road plus shoulders) or, in yet other cases, the entire right-of-way width should be used (e.g., the large amount of time-area consumed by rail stations, freeway interchanges, embankments, etc.). Therefore, careful consideration must be given when computing static time-areas, perhaps by using an effective right-of-way width.

AN EXAMPLE IN URBAN LAND-USE ANALYSIS

A numerical example for evaluating consumption along a path using equations introduced in the previous section, with a few added details, is plotted in Figure 3 for a hypothetical commuting trip per-

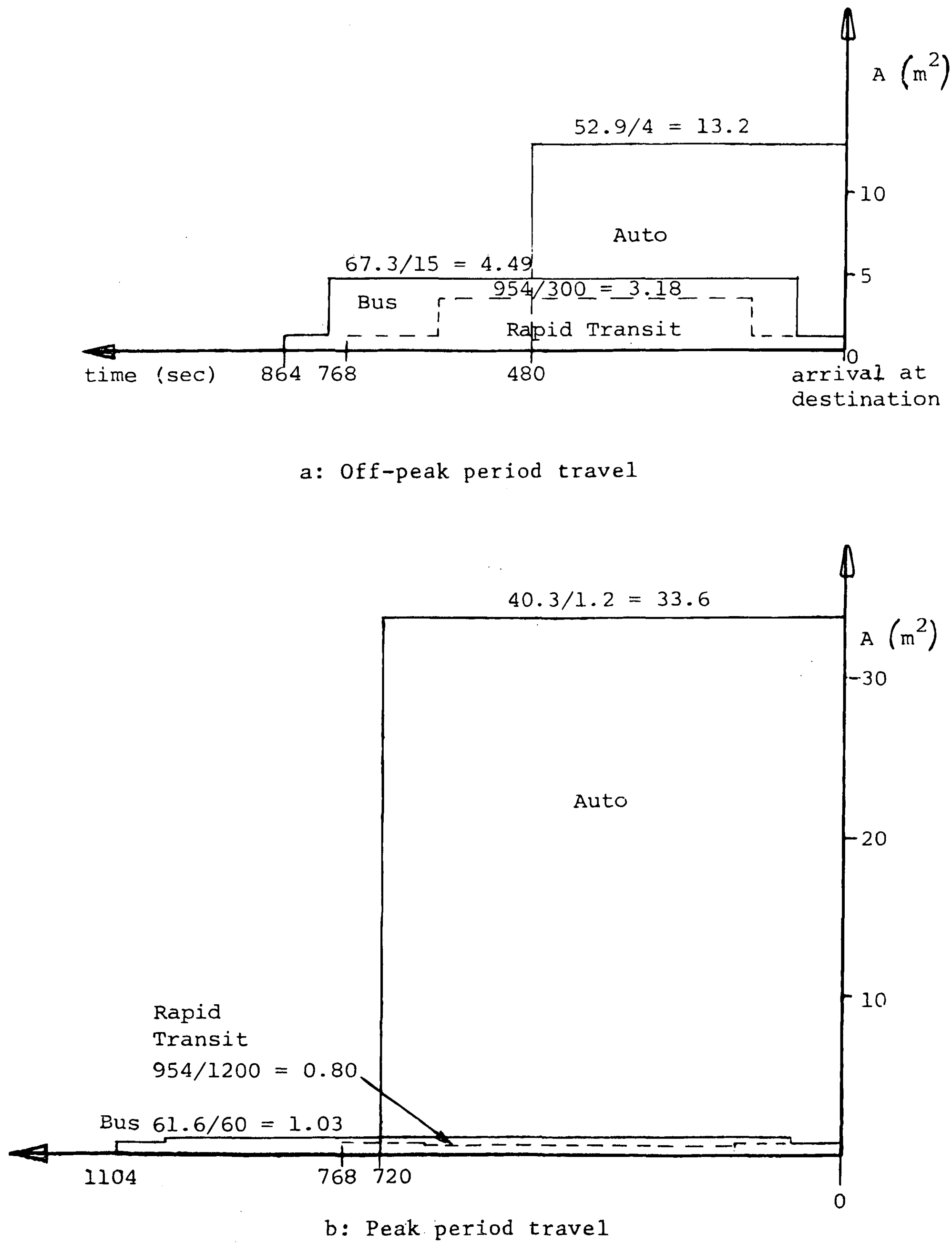

FIGURE 3 Time-area consumed per passenger on a 4-km-long trip using three different mode choices.

formed by three different mode combinations: (a) walking 100 m to a bus stop, followed by a 4-km bus ride, and again walking 100 m to the destination; (b) walking 200 m to a rapid-transit station, followed by a 4-km train ride on an at-grade right-of-way, again followed by walking 200 m; and (c) driving virtually door to door in a 5-m-long private automobile. The road right-of-way width is 3.7 m, the rapid-transit right-of-way width is 4 m, and an off-street parking module A_{eff} of 25 m^2 is assumed. The pedestrian module and speeds for a commuter are based on values developed by Fruin (*12*). The additional values assumed and some calculated results are summarized in Table 2.

In this example, the calculation is performed and the results plotted for two different conditions; Figure 3a uses average occupancies and speeds appropriate for off-peak-period travel, while Figure

TABLE 2 Summary of Values Used in Example Time-Area Calculation for a 4-km Trip and 8-hr Stay Using Three Different Modes

Assumed Values

MODE VARIABLE	Automobile Peak / Off-peak	Bus Peak / Off-peak	Rapid Transit	Pedestrian
following rule	16 kmph increment	16 kmph increment	safe, regime A	N/A
speed [kmph]	20 / 30	15 / 20	30 (operating)	5
occupancy [prs/vehicle]	1.2 / 4.0	60 / 15	1200 (10 x 18m cars)	1

Calculated Values

MODE VARIABLE	Automobile Peak / Off-peak	Bus Peak / Off-peak	Rapid Transit	Pedestrian
travel time = d/v [s]	720 / 480	960 / 720	480	72 to Bus 144 to RT
Module per vehicle [m^2]	40.3 / 52.9	61.6 / 67.3	954	0.83
Module per person [m^2]	33.6 / 13.2	1.03 / 4.49	0.80	0.83

3b uses values appropriate for peak-period travel. The assumed occupancies can be read off the figures as the denominators to the shown module per vehicle values. Recall from the previous section that average occupancies are used to convert time-areas from a per-vehicle basis to a per-passenger basis.

The ordinate on the diagram is the instantaneous area or module, while the abscissa is the elapsed time. The horizontal reference point is the arrival time at the destination, marked as zero, so that the values are actually plotted from right to left. Every time there is a transfer between modes, there is a change in the module required, and hence a vertical jump in the plot. The resultant areas under the curve are the time-areas consumed on each link. If a constant speed is assumed, as in the current example, the resulting shape under the curve for each link is a rectangle. (For increased accuracy, the rapid-transit alternative is not assumed to have a constant speed, instead operating speed is used.)

Figure 3 indicates that in this case auto travel has the advantage of a shorter horizontal dimension, time, but it also has a disadvantage of much greater vertical dimension, area. The difference is already pronounced in off-peak travel (Figure 3a), but is more dramatic during the peak period (Figure 3b). This is the result of decreased occupancies in automobiles and increased occupancies in transit vehicles during peak periods. Thus, individual automobile users tend to put the highest claim on limited road resources (road area) at the very time that the maximum vehicles are on the road. Note also that during the peak under the assumed conditions (close to crush conditions), the rapid-transit train's time-area consumption per passenger is actually lower than for a pedestrian!

This type of diagram can be very revealing about the consumption of an urban district's available space resources assuming various splits between travel modes. If there is a contemplated change in modal split, the difference in total time-area consumption will be a good indicator of the impact. This difference is found by multiplying the consumption per person for each mode by the total number of persons affected, and then comparing it with the changes for each of the other modes.

Figure 4 extends the plot to include not only the links involved with the peak-period trip to work but also the 8 hours at work, followed by the trip home. Note that the module for parking is somewhat lower than the module for driving at low urban speeds, but parking is the dominant time-area consumption component because of its long duration. By comparison, the alternative modes do not require parking as it is generally possible to store public transportation vehicles at remote locations between the peak periods. (Even if a large aboveground terminal is used, as long as many passengers use it, the time-area consumed per passenger is still very low.)

This type of diagram gives additional information about the consumption of off-street space resources not shown on the previous figure. Again, differences in total time-area consumption among modes can be easily observed, and the impacts of a change in mode split can readily be computed. In this example, the much larger size of the time-area rectangle for parking than of the two rectangles for driving shows that the time-area dedicated during the day to parking facilities is greater than that required for driving on streets.

In addition to the module-versus-time format used in this example, another useful graphical display format is cumulative time-area versus time. In the previous figures the time-area was represented as the area under curves. Now the time-area is integrated and represented simply by the ordinate. Such a format indicates both the rate of consumption and the total time-area consumed by each type of user as the day proceeds. Figure 5 shows the same situation as portrayed in the previous figure but in the cumulative format. Not only does this type of diagram conveniently illustrate the total consumption up to any given time but the slope of the curve shows the rate of consumption; a horizontal line represents no consumption.

Again, one can see that the bus rider uses a very small fraction of the time-area of the automobile rider, and that the automobile rider continues to consume during the entire day as a result of parking requirements. Note that the module for off-street parking is 25 m^2 versus a modestly higher value of 40.3 m^2 while driving at 20 km/hr, which explains why the parking consumption component is so dominant; the long duration of parking is far more important than the difference in module size.

Finally, Figure 6 is another example of a cumulative consumption plot. It illustrates the effect of increasing auto occupancy from the peak-period average of 1.2 to 2.0, and then to 4.0 persons per auto. Note that while increases in auto occupancy reduce consumption considerably, the rate for a full car is still far higher than the consumption for even a quarter-full bus; the need to have parking nearby is an inevitable major cause of time-area consumption by automobile users.

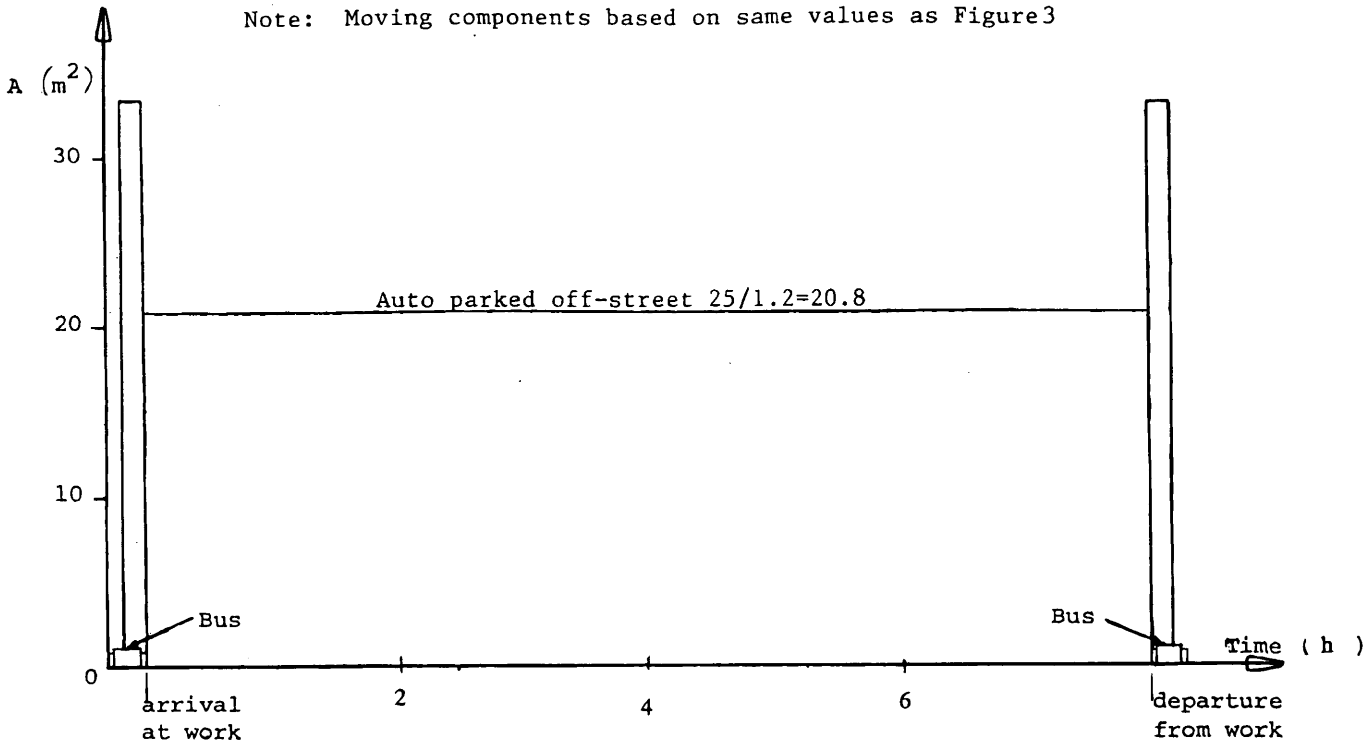

FIGURE 4 Time-area consumed per passenger on an 8-km round-trip commute using two different mode choices.

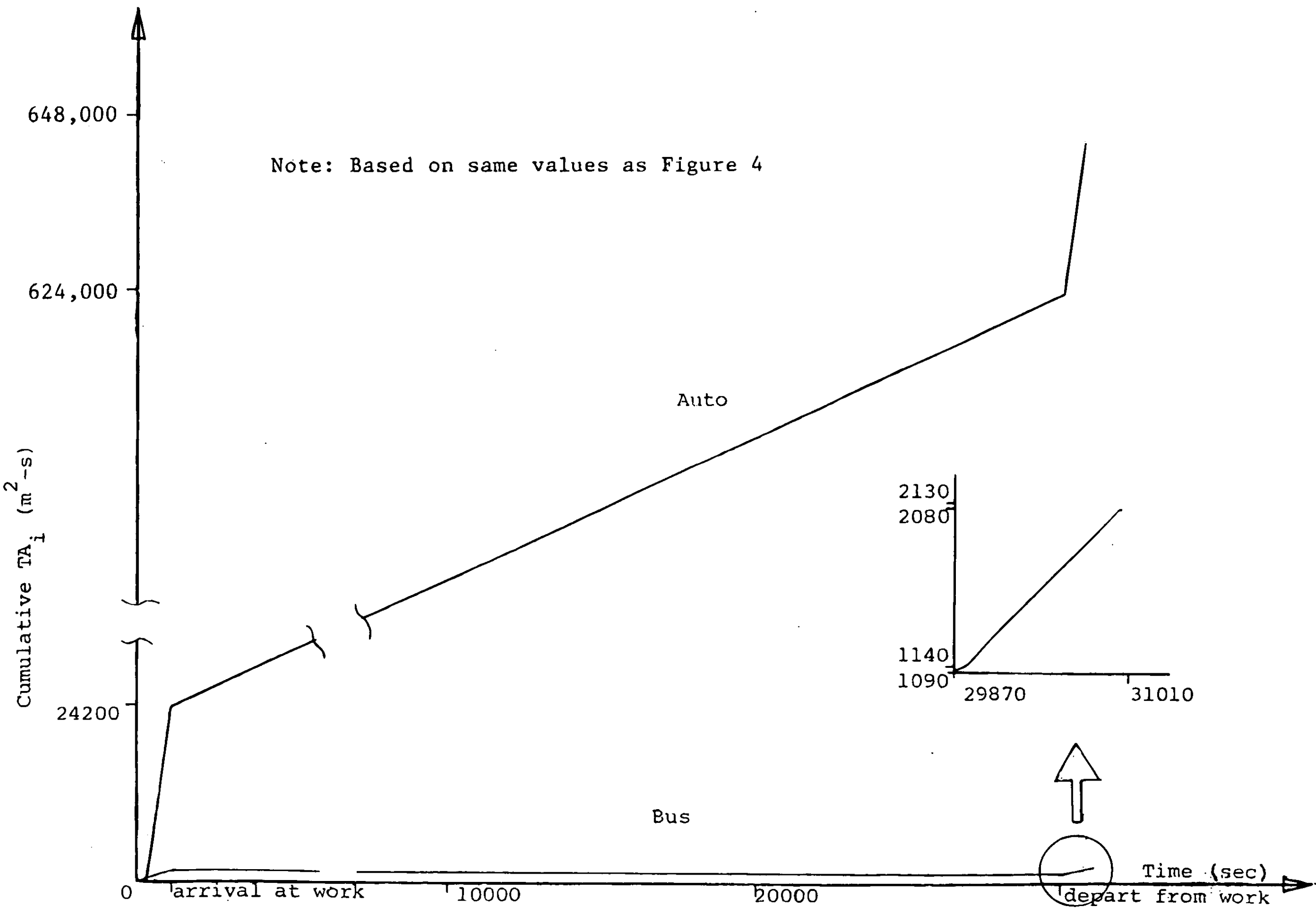

FIGURE 5 Cumulative time-area consumed per passenger on an 8-km round-trip using two different mode choices.

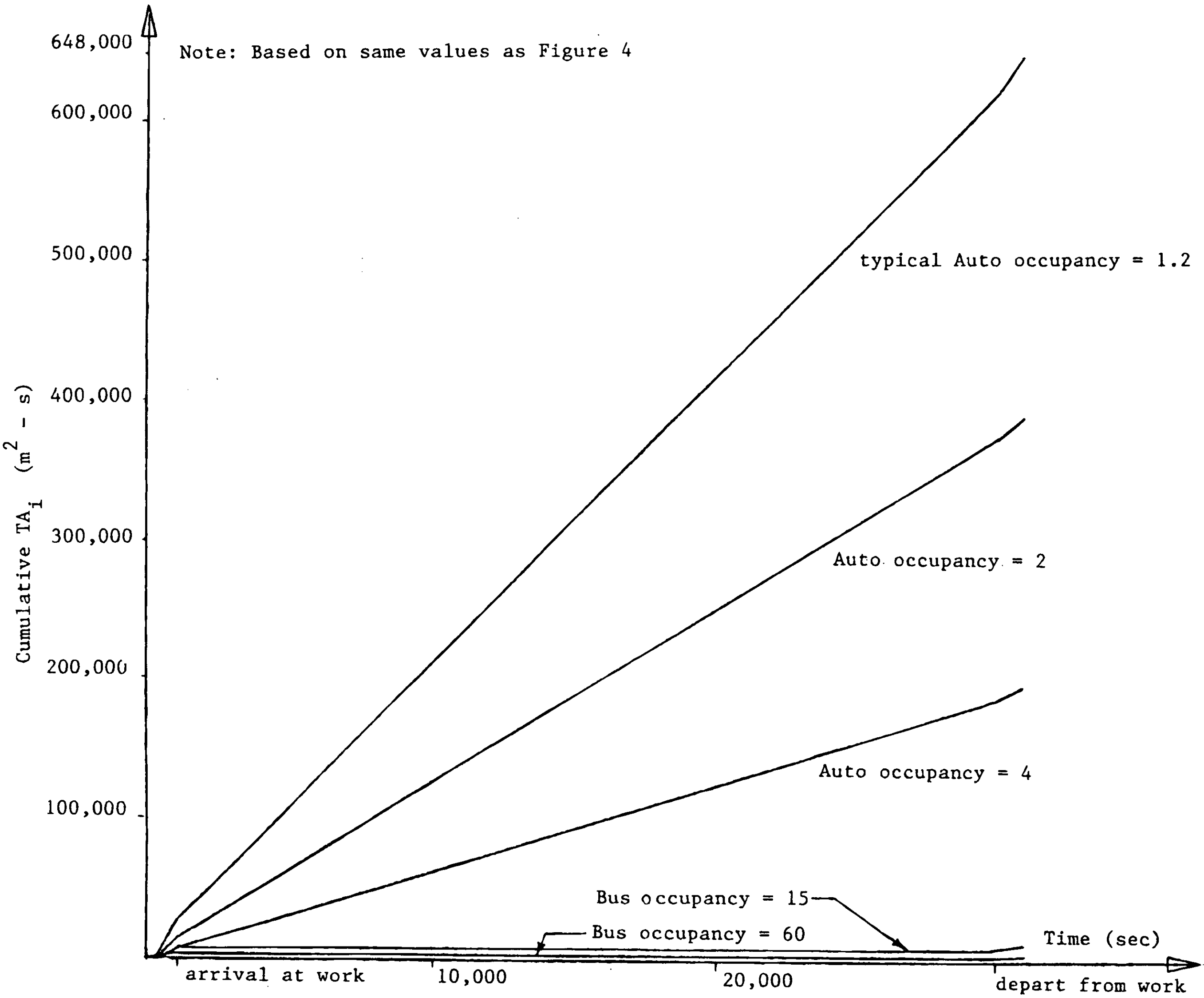

FIGURE 6 Cumulative time-area consumed on an 8-km round-trip comparing the automobile with a fully loaded bus.

SUMMARY AND CONCLUSIONS

The time-area concept—the product of the land area occupied by a vehicle and the time for which it is occupied—is a powerful one that had not been fully developed. Its history of development and limited applications were reviewed. It was found that practical applications have been confined to the design and operation of pedestrian facilities. The research presented here discusses other applications that have not been seen in practice. One of the authors developed this concept more fully as a doctoral dissertation; some of the resulting formulas for the important special case of moderate to heavy traffic moving at a constant speed have been presented here.

There are several types of analyses in which the time-area concept offers unique advantages, including:

- A joint analysis of land consumption by moving and standing pedestrians or vehicles;
- Relationships of consumed to available time-area, again for moving and standing vehicles;
- Comparison of total area consumption (static and dynamic) by different modes;
- Efficiency of land usage by different modes, assuming constant volumes of travel;
- Impacts of changes in modal split on land consumption; and
- Impacts from changes in vehicle occupancies.

An example case of a hypothetical commuter using three different mode combinations—including walking to and from a bus, walking to and from rapid transit, and traveling by private automobile—was analyzed and portrayed using time-area versus time diagrams and then cumulative time-area versus time diagrams. Some of the important characteristics of travel by the different modes that can be observed include the following:

- Auto offers time savings and convenience of not having to transfer, but these advantages are traded off against the much higher land area requirements needed for driving it.

- Parking all-day is the predominant component of time-area consumption of an auto commuter if travel speeds are slow because the somewhat smaller area requirement while parked than while driving is far offset by the long duration of parking.
- A passenger in even a fully loaded automobile consumes far more area than a person in a fully loaded bus, both while driving and while parked.

These findings are particularly important for transportation planning in urban areas with limited space.

In conclusion, the time-area unit can provide new ways to look at old problems in a number of analyses related to urban planning, and transportation systems analysis and design, like the example presented. It can also be used in specific applications such as design of multimodal transportation systems at major activity centers, determination of various land-use development taxes, or various schemes of road and congestion pricing.

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