CHAPTER 2

CONCEPTS INHERENT TO TRAFFIC SIMULATION

2.1 INTRODUCTION

The major concepts inherent to traffic flow simulation and, consequently, needed by the MST, are described in this Chapter.

2.2 DEFINITION OF HEADWAY

Headway is the time interval in seconds separating two successive vehicles, measured from the front of one vehicle to the front of the following vehicle (Figure 2.1).

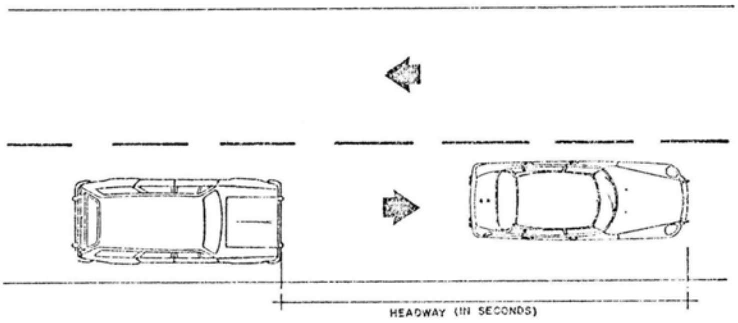

FIGURE 2.1 - REPRESENTATION OF THE HEADWAY CONCEPT.

There exist other more specific concepts of headway, such as minimum headway, average headway of constrained group, and free headway, correlated to this concept of headway.

- *Minimum headway* is the minimum time interval in seconds that is possible between two successive vehicles.
- *Constrained group* is the group of vehicles in a queue, each vehicle awaiting the opportunity to overtake the preceding vehicles.
- *Average headway of constrained group* is an average headway of all vehicles in one constrained group.
- *Free headway* is the average headway of a group of vehicles travelling at free speed, i.e., when not constrained.

By definition, the vehicles in the constrained group will be travelling at a speed lower than that desired, and their drivers will be awaiting the opportunity to overtake. On the other hand, the vehicles in the unconstrained group will be travelling either at the desired speed or at a lower speed, also in a platoon, but their drivers will not be trying to leave the platoon.

2.3 HEADWAY DISTRIBUTION

Adams (1936) was probably the first to observe the apparently random distribution of vehicle arrivals at a given point of a highway. He compared these observations of vehicle arrivals with values obtained from the Poisson distribution and obtained a good degree of adjustment at relatively low volumes of traffic. A number of authors have proposed modifications in the Poisson distribution, since this type of distribution accepts the hypothesis of zero headway, which is impossible. Schuhl (1955) showed that a traffic flow can be composed of a combination of vehicles in free flow and vehicles in constrained flow, and that both flows fit the Poissonian behavior.

On the basis of data gathered from a two-lane highway with traffic volumes per lane ranging between 50 and 950 vehicles/hour, Grecco and Sword (1968) developed predictions of parameters for Schuhl's headway distribution, and found that these parameters varied according to the traffic volume. The Schuhl's equation utilized by Grecco and Sword was the following:

$$P(h \geq t) = \sigma e^{-(t-MH)/t_1} + (1-\sigma) e^{-t/t_2}$$

where:

$P(h \geq t)$ = probability that the headway be equal to or greater than the time t;

σ = percentage (decimal) of the vehicles in the constrained group;

MH = minimum headway of the vehicles of the constrained group, in seconds;

t_1 = parameter based on the average headway of the constrained group, in seconds;

t_2 = parameter based on the average headway of the free-speed group, in seconds;

t = time, in seconds;

e = base of Napierian logarithms

Grecco and Sword affirmed that one second was a reasonable value for the minimum headway (MH). However, on at least two sections of highway BR-381, which joins São Paulo and Belo Horizonte, minimum headways as short as half second were observed. The equations developed by Grecco and Sword for t_1, t_2 are as follows:

t_1 = 2.5s (constant value for any volume, on any lane);
t_2 = 24-1.22 (lane volume/100);
σ = 0.115 (lane volume/100).

It can be noted that σ is greater than 1 when the volume of traffic per hour and per lane is greater than 870.

Khasnabis and Heimbach (1977) tested three models of headway distribution: (1) negative exponential; (2) Schuhl; and (3) Pearson type III. The Schuhl model provided the highest degree of adjustment for the field data of North Carolina (USA).

In light of this result, it was decided to utilize the Schuhl model in the development of the MST, while analyzing the application of other headway distributions to data already gathered. With the exception of minimum headway - set at a half second in the MST on the basis of field observations carried out for this specific purpose - the parameters of Grecco and Sword were accepted.

2.4 *VEHICLE CLASSIFICATION*

In addition to determining the headway, each vehicle must be classified within one of the six classes used in the model: (1) automobiles; (2) utilities; (3) light gasoline-powered trucks; (4) medium trucks; (5) bus; or (6) heavy trucks. The MST user may adopt a different classification, provided that a free-speed model be constituted (to be used as input data), and that the functions of acceleration, deceleration, steady-state speed and the corresponding levels of fuel consumption of the vehicle classes adopted be introduced into the program.

The user specifies the percentage of vehicles in each class, for each traffic lane. The Model assembles an array for the accumulated distribution of the vehicle classes and designates a class for each vehicle, based on a random number generated according to the array of percentage distribution of the vehicle classes.

2.5 *ADDITIONAL LENGTH*

A basic concept in most traffic simulation models is the existence of a minimum headway that is independent of vehicle length. As previously stated, this minimum intervehicle time interval is approximately one half second. An intervehicle time interval equal to a half second, in the case of heavy trucks at low speed on steep positive grades would mean that the physical space corresponding to this headway between the fronts of consecutive vehicles would be less than the length of the vehicle. To resolve this problem and to test the effects of very long vehicles, such as the multitrailer rig (road train), on traffic flow, an additional-length table is included with the vehicle classification. This makes it possible for the user to specify an "additional length" in relation to vehicle class 1, for the vehicle classes from 2 to 6. At any point of the highway, therefore, the minimum headway is increased by the time spent in overtaking the "additional length" at the speed of the follower vehicle.

2.6 *VEHICLE PERFORMANCE*

In the MST, it is assumed that all drivers attempt to drive at the desired speed, defined here for a particular class of vehicles as the average of the free speeds, plus the variance of the speed of one vehicle. The average speed, however, varies along the highway due to such factors as type of surface, roughness, vertical and horizontal geometry and speed limits, all of which affect the speed of the vehicle in different degrees. The data gathered shows that the speed variance within each class of vehicles also differs from one point of the highway to another. In general, the higher the speed, the higher the variance.

Leong (1968) concluded that the normal distribution adjusted well (at a level of significance of 5%) to practically all speed distributions measured in 31 straight sections of New South Wales, Australia. In McLean's study (1976), only one of the 248 speed distributions obtained from speed measurements both on curves and straight sections showed a statistically significant deviation from normality ($p < 0.05$). Leong (1968) concluded that the standard deviation from the standardized distribution (coefficient of variation expressed in decimals) was practically the same for automobiles in all places, except in the case of grades of $>+7\%$ and $<-7\%$. Considering that the coefficient of variation is known for each vehicle class at all points of a highway section, the performance of each vehicle can be expressed as:

$$DV = 1 + VAR \times CV$$

where:

DV = vehicle performance;
VAR= deviation from the mean, in standard deviations;
CV = coefficient of variation.

To determine VAR, the scientific subroutine GAUSS, of IBM, is utilized. This subroutine generates random numbers normally distributed with zero mean and variance one. The desired speed (free speed) of the vehicle at any section of the highway is, therefore:

$$VL = VM \times DV$$

where:

VL = free speed of the vehicle;
VM = average of the free speeds of the vehicle class.

2.7 *MAXIMUM NUMBER OF VEHICLES OVERTAKEN AT A SINGLE TIME*

This is an input variable of the Model, for which a maximum value of six is accepted. Up to the present, the Model has spotted only a few events of six vehicles in a queue being overtaken at a single time. After a more complete analysis of field observations of overtaking operations this rule could be altered.

2.8 OVERTAKING-SPEED DIFFERENTIAL

For overtaking to be possible, there must be a minimum speed differential between vehicles. Boal (1974) used the Critical Overtaking Speed (COS), a value that is higher than the free speed of the vehicle by a fixed percentage. According to that author, one vehicle will not overtake another if its COS is not higher than the free speed of the preceding vehicle. However, the author does not mention the value of the COS utilized. No data seems to be available suggesting the values that should be used for all cases. However, field surveys (Miller and Pretty, 1968) suggest that some vehicles will never overtake a preceding vehicle if acceleration is required. It would therefore seem that some type of speed-differential relation should be incorporated into the Model. It is known that the number of overtakings increases as the overtaking-speed differential declines. The sensitivity of the Model output is being tested as to changes in this parameter, so as to determine the most realistic values of the speed differential.

2.9 SAFETY MARGIN

Safety Margin is a concept applicable principally to overtaking operations on two-lane roads. For safe overtakings, the vehicle should complete the overtaking operation, that is, should return to its lane several seconds before a vehicle coming in the opposite direction reaches the point at which the overtaking operation was completed (See Figure 2.2). It should be emphasized that such a safety margin depends on the interaction of the vehicles, and does not take visibility into account. However, the MST will not simulate an overtaking operation if visibility is not adequate.

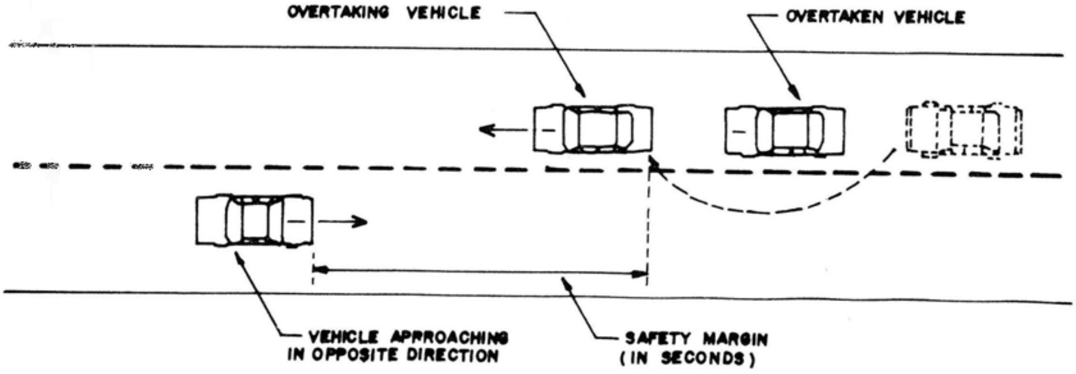

FIGURE 2.2 - PICTORIAL REPRESENTATION OF THE SAFETY MARGIN.

In future studies, a simple adaptation of the technique used to determine headway will make it possible to determine safety margins, particularly on positive grades, in the following manner: photographs are taken at a point from where perfect sight of the entire grade is possible. The camera is synchronized to a chronometer and activated at approximately equal time intervals. Along the entire course of the grade, equally spaced and numbered posts are set out (the smaller the space, the greater the precision of measurement). By examining the resulting photographs, one is able to obtain not only the beginning and end of overtaking operations, but also the safety margins. These observations would make it possible to elaborate a distribution of safety margins.

2.10 TIME INCREMENT

The time increment (time interval established by the MST user) is the time interval in which the vehicles in the primary lane and in the opposite lane are alternatively processed. In other words, after all of the vehicles in one lane have been processed within a given time increment, the MST program moves to the other lane and repeats the process. The MST user can establish a time increment of one up to nine seconds.

2.11 SUMMARY

This chapter defined and explained the basic concepts used in traffic simulations. The following chapter will describe how the free-speed profile is generated for the simulation model.