Swedish Capacity Manual

Part 1. Objectives, Scope, and Arrangement of the Manual

Bo E. Peterson, National Swedish Road Administration

Different methods for calculating the capacity of a traffic facility have given different solutions to the same problem. At the same time, it has been clearly shown that the actual capacity is higher than that indicated by calculation methods. The Swedish Road Administration has therefore completed a research and development project that produced a new capacity manual, which should improve old methods, produce new ones for types of facilities and efficiency factors not previously treated, and achieve uniform application of the methods in Sweden. The new manual treats three categories of traffic: motor vehicle traffic, bicycle traffic, and pedestrians. The main efficiency factors are capacity, queue length, delay, and proportion of stopped vehicles. Explanatory models based on the queue theory of motorist behavior have been chosen to limit the empirical evidence to parameters such as critical time headway. The main new types of facilities are unsignalized intersections and bicycle and pedestrian facilities. For signal-controlled intersections, new developments have been made for left-turning traffic with opposing conflict, right-turning traffic with pedestrian conflict, various lane divisions, and calculation of cycle length. Another objective was to systematize the calculation of different measures of efficiency. The methods are reported as a series of steps in a computation.

The purpose of this and the following two papers is to present the new Swedish capacity manual, a comprehensive study undertaken by the National Swedish Road Administration and published early in 1977. This first part of the paper gives an overview of the objectives, scope, and arrangement of the manual. The second part by Arne Hansson presents the theoretical developments, field studies, and recommended methods for unsignalized intersections, and the third part by Karl-L. Bång deals with the same aspects for signalized intersections.

BACKGROUND

There was no Swedish traffic manual until the Swedish Transport Research Commission published the Academy of Engineering Sciences Bulletin 39 on the capacity of streets and roads in 1958. This report contained an analysis by Stig Nordqvist of the capacity problem and was based on available foreign literature—especially the 1950 Highway Capacity Manual (HCM)—and a number of Swedish studies. The manual adapted calculation methods and recommended capacity values for sections and different types of intersection. However, it was intersections with signal controls that were dealt with in most detail.

The publication of the 1965 HCM has meant, at least in Sweden, that a number of methods for the calculation of the capacity of a traffic facility have been in existence for the last few years. In certain cases, however, different methods have given different solutions to the same problem. At the same time measurements in several countries have clearly shown that actual capacity is higher than that indicated by the methods.

During the last 10 years there has been considerable research in this field in the United States and Europe as well as in Australia. Recently gained knowledge, however, has only been applied to formulating new calculation methods to a limited extent. Some proposals for improving the old methods have been made, but there has been no coherent overview or critical analysis.

In light of the above, the National Swedish Road Administration at the end of 1971 initiated a study aimed at developing methods to calculate the discharge capacity of road facilities. The purpose was to produce methods for types of facilities and efficiency factors not previously treated and also to achieve a uniform application of the methods throughout Sweden.

The first stage of the investigation was a study of the literature. The report itself (1) includes a review and analysis of about 900 references from numerous countries and is to my knowledge the most thorough overview now in existence.

The second stage involved working out the actual calculation methods on the basis of requirement specifications. At this stage Bång and Hansson developed a number of methods for calculating capacity, queue length, delay, and proportion of stopped vehicles for different road facilities. This work required that the geometry and traffic dependence of certain variables under Swedish conditions be explained, which demanded rather extensive measurement (2, 3).

Some of the results from these field surveys on critical time headway, for instance, have received international attention. Great interest in the survey's actual technique and equipment has also been shown.

As a final result of the second stage, proposals for calculation methods for each type of facility were received in the form of internal memoranda, which were then distributed to various selected Swedish traffic engineers in order to canvas opinion on the choice of method. The methods were tested in a number of case studies, and several different examples were checked.

The experience gained from seminars and the tests mentioned above were taken into consideration before the final manual was edited early in 1977 (4). Some computerization of the methods was carried out by Arne Hansson, who helped work out a dialogue computer program—CAPCAL—that calculates capacity and delay in an intersection for which the design and traffic load are known. Four different types of control—yield sign, stop sign, traffic signal, and traffic circle—can be studied.

OBJECTIVES

A main objective was to create a handbook, rather than a textbook of the discursive and explanatory type, that dealt with descriptions of consequences, known design, degree of accuracy, computational steps, and samples. One aim was to produce methods for describing consequences rather than for dimensioning alone. This also means that no recommendations for design standards, such as the 1965 HCM service levels, are given.

Highway and traffic engineering measures aim, among other things, at improving road facilities' discharge capacity, which is measured in such efficiency factors as capacity, queue length, delays, and proportion of stopped vehicles. Decisions on measures to be taken on a road network or parts of it should be based on a judgment of the consequences of these measures for society. This judgment should be the result of wide-ranging inquiry into not only discharge capacity but also factors such as road safety, cost, and environ-

ment. Existing calculation methods only provide knowledge of the effects of different measures on the discharge capacity and thus do not provide the complete basis required for decisions on dimensioning road facilities or on dealing with a road network.

Because methods for dimensioning were not developed, the design of a facility must be known or assumed. Traffic flow must also be known or assumed. If a facility is required to meet some specific demands expressed in one of the efficiency factors, an iterative calculation has to be made. When the design of the facility has been assumed, the efficiency factor can then be calculated for this design. Thereafter the design has to be altered and new efficiency factors recalculated until the design meets the requirements.

Resources in the road and street sector are today very limited. Each decision made must therefore be preceded by careful calculation to arrive at the amount of detail to be included in the calculation method. In the process, methods of a more schematic nature give results that are too approximate. Thus, considering the economic consequences of incorrectly dimensioned roads and streets, the amount of work needed for calculations according to the new methods is fully justified. This can also be expressed as choosing the degree of accuracy that is right both socially and economically.

Another objective was systematizing the calculation of different measures of efficiency—capacity, queue length, delay, and proportion of stopped vehicles. This is in line with the aim of producing methods for analyzing social and other consequences rather than for dimensioning alone. This systematization also makes it possible to add different delays together for the total delay of an intersection or street section. The methods are thereby reported as a series of computational steps for each efficiency factor.

Calculations for vehicle traffic facilities are made on special forms. For each type of facility, a complete sample calculation for a standard case is given, by which it is possible to ensure that one has completely understood the methods.

SCOPE

Three categories of traffic lie within the scope of the manual: motor vehicle, bicycle, and pedestrian. The types of facilities included and their efficiency factors that can be calculated are listed below. All common traffic facilities, such as streets, ramps, weaving sections, and different types of intersection, are covered, as are pedestrian sidewalks and bicycle paths. The primary efficiency factors treated are capacity, queue length, proportion of stopped vehicles, and delay. In some cases speed, travel time, and number of stops can also be calculated.

Type of Traffic	Type of Facility	Efficiency Factor
Motor vehicle	Road sections	Capacity
	Street sections	Travel time
	Ramps	Capacity
	Long weaving sections	Capacity
	Traffic circles and short weaving sections	Capacity, queue length, proportion of stopped vehicles, delay
	Unsignalized intersections	Capacity, queue length, proportion of stopped vehicles, delay
	Signalized intersections	Timing, capacity, queue length, proportion of stopped vehicles, delay
	Street network without signal synchronization	Capacity, number of stops, travel time
	Street network with signal synchronization	Effect on capacity, queue length, number of stops, travel time
Pedestrian	Sidewalks	Capacity, speed
	Steps	Capacity, speed
	Unsignalized crossings	Queue space, delay
	Signalized crossings	Timing capacity, queue space, delay
Bicycle	Streets with mixed traffic	Capacity
	Bicycle paths	Capacity, speed
	Unsignalized crossings with bicycle paths	Capacity, queue length, proportion of stopped bicycles, delay
	Signalized crossings with bicycle paths	Timing, capacity, queue length, proportion of stopped bicycles, delay

INNOVATIONS

One of the most important innovations in the calculation methods is that these are based not only on the results of regression analyses from a number of field surveys but also on the queue theory of motorist behavior.

The advantages of a theoretical model are better consistency, fewer required observations, and facility of updating.

The empirical evidence was thus limited to certain parameter values, for example, critical time headway. It should be pointed out in this connection that it is precisely the measurement of critical time headways that has, in the opinion of many, become more accurate than was previously the case.

The main new types of facilities are unsignalized intersections and facilities for bicycle traffic and pedestrians. The studies of the literature and the development of the methods for unsignalized intersections are presented in part 2 of this article. A new method has been produced for weaving sections of up to 40-60 meters. The model is similar to that developed for unsignalized intersections. It has been found that traffic circles operate in much the same way as series of T-intersections. Longer sections are calculated according to the 1965 HCM.

The methods for pedestrian and bicycle facilities are mainly applicable to those facilities that are separated from motor vehicle facilities.

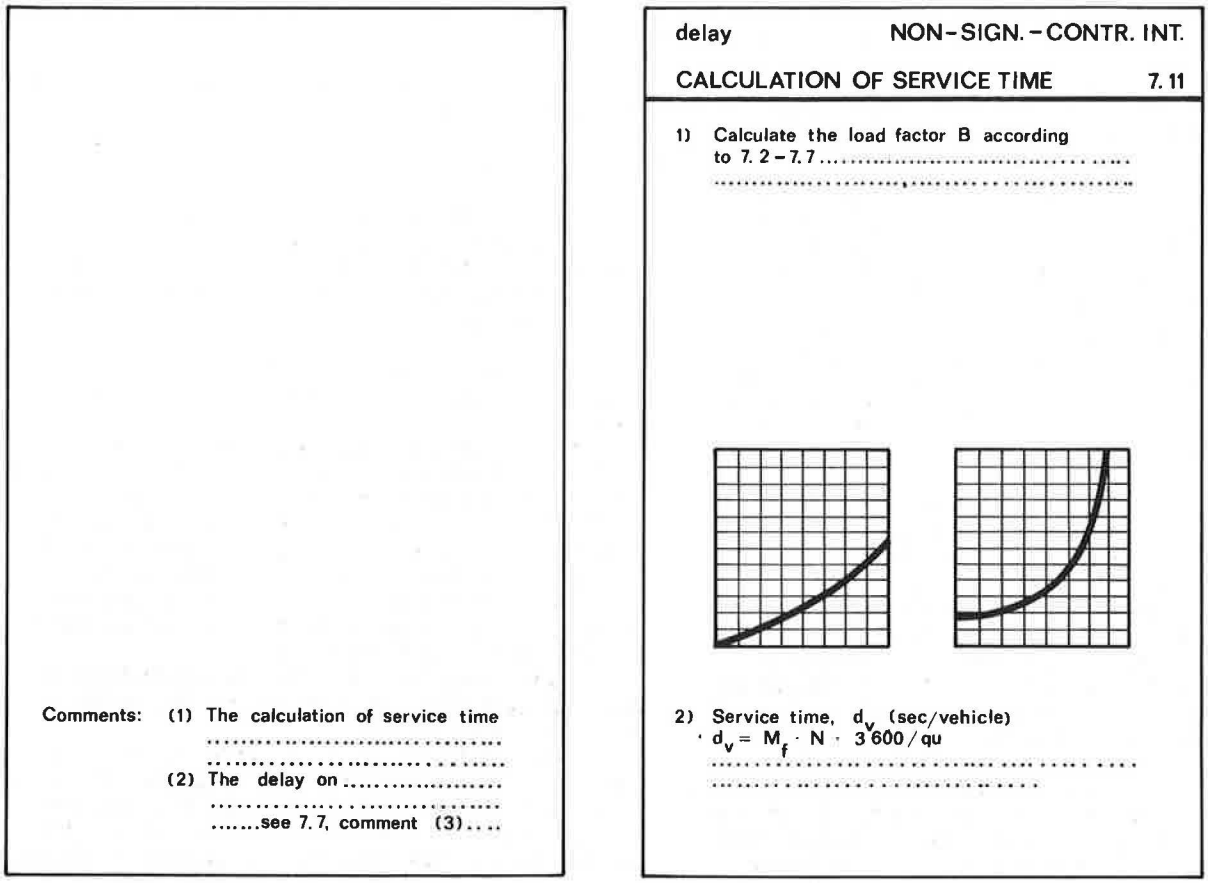
For pedestrian crossings, the methods are primarily developed for crossings between intersections. In some cases calculations can also be made for crossings at intersections, but no reliable method has been found for calculating the capacity of a pedestrian crossing when the pedestrian flow is in conflict with the vehicle flow.

The recommended methods for measuring the results of bicycle traffic in intersections are primarily intended to be used for intersections with special cycleways. All calculations for signalized intersections are based on the assumption that there are no conflicts with traffic (or pedestrians) during the green phase. For unsignalized intersections, however, instructions on how to calculate the effects of bicycle traffic mixing with vehicle traffic are given.

It may generally be stated that the empirical basis for the calculation method for pedestrian and bicycle facilities is less reliable than that for motor vehicle traffic. For instance, it has not been possible to provide any reliable calculation method for capacity at unsignalized pedestrian crossings. It should be stated that the results for bicycle traffic should be used with great caution where mixed traffic with many bicycles is concerned.

For signalized intersections, which are treated in part 3 of this article, four aspects of considerable importance have been distinguished: left-turning traffic with opposing conflict, right-turning traffic with pedestrian conflict, various lane divisions, and calculation of cycle length. Using a development of previous

Figure 1. Arrangement of the manual (right- and left-hand pages).



methods with these elements has meant that all the various designs of signalized intersections, from the very simple to the highly complex, can be dealt with.

Street networks are dealt with in two parts, those with and those without synchronized traffic signals. The efficiency factors in networks without such traffic signals are calculated by using the methods developed for other facilities. For networks with synchronized signals, a rough description of how coordination affects efficiency factors is given.

ARRANGEMENT

The methods are reported as series of computational steps, on the one hand for each efficiency factor (capacity, queue length, delay, proportion of stopped vehicles), and on the other within each efficiency factor (division into subapproaches for whole intersections; determination of critical time headway, service time, and part-capacity ratios for each vehicle stream in each subapproach; and determination of capacity ratio and capacity for each subapproach).

These steps are reported on the right-hand pages of the report, while notes, where necessary, are given on the facing left-hand pages (Figure 1). Thus a complete computational stage can be seen at a glance upon opening the report.

The purpose of this arrangement is for the right-hand pages to give the necessary instructions for carrying out the calculations, omitting deviations and explanatory arguments. The idea behind this is that the calculation process not be interrupted or the train of thought broken, but that easily accessible notes be provided. Insofar as possible, diagrams and tables have been provided as support material to the actual calculations.

Great importance has been attached to design, and great care has therefore been devoted to editing the methods. A secondary advantage may be that certain diagrams are of a size smaller than that demanded for ease of reading. This possible disadvantage is justified on the grounds that ease of understanding, on the other hand, has been achieved.

REFERENCES

1. Kapacitetsutredning: Literaturstudier och analys. Statens Vägverk, TV 118, 1973.
2. Trafikavlastning i usignalreglerade korsningar. Institute for Traffic Engineering, Univ. of Lund, 1975.
3. A. Hansson. Fältmätningar avseende fordons- och gångtrafikens framkomlighet i signalreglerade korsningar. Statens Vägverk, TV 127, Feb. 1977.
4. Beräkning av kapacitet, kölängd, fördröjning i vägtrafikanläggningar. Statens Vägverk, TV 131, 1977.