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dense road network,
capacity of intersection

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COMPUTER AIDED EVALUATION OF INTERSECTION CAPACITY IN DENSE ROAD NETWORK

From increasing number of vehicles comes the need to quantify congestion in dense road network. The paper presents useful computer aided tools for evaluating priority-type and signalized intersection capacity parameters. The applications have been designed on the basis of popular and verified methods. Along with related database they are essential components of system that enables optimization of road closures placing in dense road network.

KOMPUTEROWO WSPOMAGANA OCENA PRZEPUSTOWOŚCI SKRZYŻOWAŃ W GĘSTEJ SIECI DRÓG

Wzrost liczby pojazdów w sieciach drogowych zmusza projektantów do opracowania odpowiednich narzędzi służących do oszacowania przepustowości poszczególnych składników sieci oraz usprawniania ruchu. Wybór metody powinien zależeć zarówno od indywidualnych potrzeb, jak i możliwości zastosowania w określonych warunkach ruchu.

Ruch na skrzyżowaniu może być regulowany odpowiednim oznakowaniem (znaki A7 i B20) lub sygnalizacją świetlną. W Zakładzie Inżynierii Ruchu Politechniki Śląskiej w oparciu o znane i sprawdzone w warunkach polskich metody opracowano aplikacje komputerowe służące do obliczania przepustowości obu typów skrzyżowań. Programy te zapewniają łatwy dostęp do bazy danych, która została zaprojektowana i uzupełniona wartościami parametrów geometrycznych, ruchowych i sygnalizacyjnych centrum Katowic. Obliczone parametry przepustowościowe są przesyłane z powrotem do bazy danych. W ten sposób jest ona stale uaktualniana w zależności od rzeczywistych wartości natężenia ruchu. Proces ten jest niezbędny przy optymalizacji zamknięć drogowych w sieci transportowej.

Aplikacje są stale rozbudowywane i weryfikowane. Jako składniki systemu optymalizacyjnego zapewniają możliwość dołączania nowych elementów.

1. INTRODUCTION

Estimation of an intersection capacity is one of the most important traffic engineering problems. It enables rational planning and traffic improvement in network. The capacity evaluations result in a view of transportation abilities expressed as relationship between traffic volume and conditions for individual junction of network. Traffic conditions are characterized by travel speed and time, level of service, convenience and safety [1,6,8].

The assumption that intersection capacity is limitation of road network capacity has frequently been made. A significant number of theoretical and experimental works have

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focused on the issues connected with evaluating the intersection capacity under various geometric and traffic conditions. They resulted in various capacity calculation methods. For that reason designers should analyse very critically possibilities for adaptation of individual method in concrete situation.

The proper calibration of model is an essential component influencing the results. The parameters of capacity model should be verified in such a way that adaptation to traffic conditions, vehicles type and driver behaviour would be optimal.

2. RELATED DATABASE

It is necessary to design mathematical model of road network in such a way that it should enable component identification, structure description and assignment of certain characteristics to individual components. Hence application of graph theory to road network issues is a natural tendency [2,7]. The network structure is defined as a graph, where transportation points (intersections) are nodes, and joints between them are links. The permissible traffic movements are taken into consideration.

The related database has been designed and developed in Dept. of Traffic Engineering, The Silesian Technical University as a part of road closure optimization system [12]. The present version allows inserting and storing data that are necessary for network components specification, analysis and evaluation of required capacity parameters. It has been designed in Dbase IV format, where data are stored in table structure files. The base has been filled with geometric and traffic parameters of Katowice centre. The application consists of three basic forms: "Odcinki", "Wezly". Screens of them are presented in Fig.1.

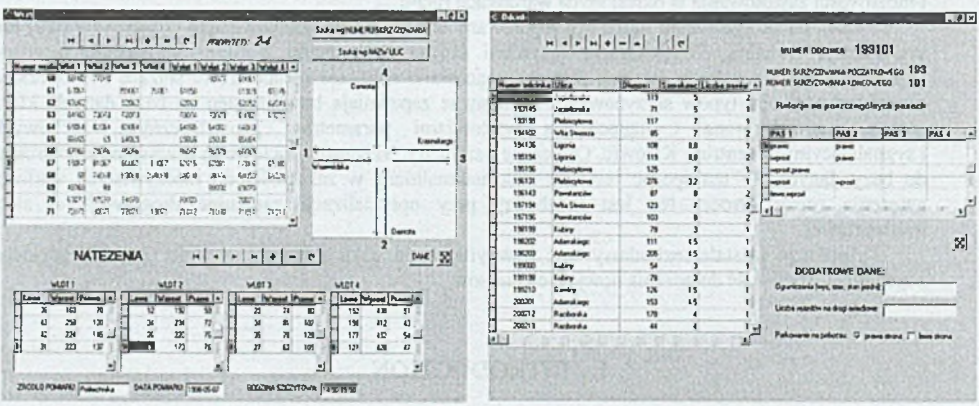

Fig.1. Screens of basic forms of database

Every section is represented by number of 6 digits. First three figures correspond to initial intersection number and next ones specify final intersection number. Information on sections has been displayed on the form that enables inserting, deleting, saving and moving data to proper record.

The junctions have been described as proper joints of sections. A scheme of the simple intersection has been also placed on the form. Additional data are accessible in next form including information that concerns priority road specification, traffic organization at the intersection and volume of pedestrian on the crossing.

The network connections have been demonstrated in schematic way on the form "Mapa". The table corresponding to this form covers graphic components designed for displaying the vector map on the screen.

Detailed pieces of information on road database have been included in the article: [11].

3. CAPACITY OF PRIORITY-TYPE INTERSECTIONS

The priority-type intersections with minor street approaches controlled by traffic signs: A7 (YIELD) or B20 (STOP) are considered to be majority of road network junctions. At unsignalized intersections all permissible movements of traffic may be divided into three separate groups: major (vehicles are not minor with the others), choked minor (vehicles are major with some vehicles and minor with the others) and minor (vehicles do not have priority over the others). Only capacity of major movement is completely independent on traffic volume at the intersection. Capacity of minor and choked minor movement is closely connected with traffic volume of priority movements.

The application PRZEPUST has been designed to calculate capacity of unsignalized intersections [5]. A simplified scheme of the method used in the program has been mentioned in fig.2. This method has been developed at The Cracow Technical University and is one of the most popular methods adapted to Polish conditions [3]. The geometric and traffic characteristics include traffic volume at approach, priority approach specification, lane width, volume of pedestrian, traffic signs at minor street approach, number of lanes at approach, permissible traffic movements at individual lanes, lane use description, visibility and slope of approach. These parameters should be defined for every intersection in the network.

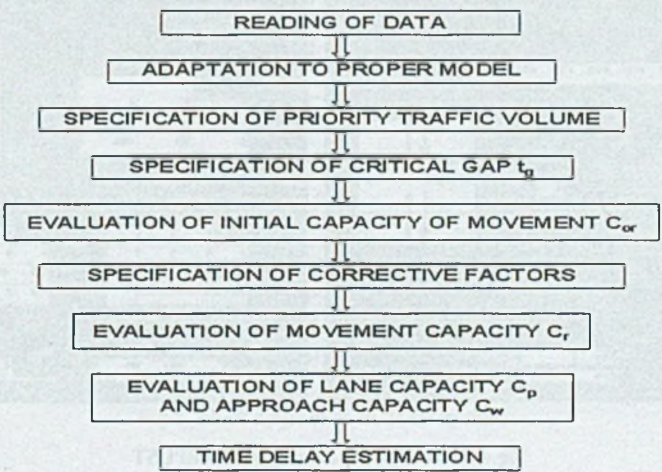

Fig.2. Block diagram of PRZEPUST application

Two models of intersections with various priority traffic flows have been taken into account by designing the application. Both of them are presented in fig.3. For each of the models the principle of priority traffic volume specification is different.

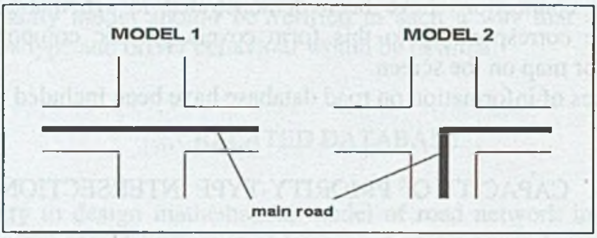

Fig.3. Two models of intersections

Analysing models of priority-type intersections one should assume that the driver of minor road stops, estimates every gap between vehicles of main road and takes decision on crossing. The driver accepts a gap (a headway or a portion thereof) if the gap is greater than the driver's critical gap that is a parameter of considerable importance [1]. Its value is dependent on traffic organization, type of manoeuvre, main road permissible speed and intersection model.

In accordance with the method the intersection capacity under ideal conditions is defined. It depends on priority traffic volume and critical gap. To evaluate the capacity under real conditions some factors should be applied. The values of these factors are dependent on traffic lane width, approach type, volume of pedestrian and choke of traffic.

Screens of the forms with input data and capacity parameters have been presented in fig.4. The application has been described in detail in the article: [10].

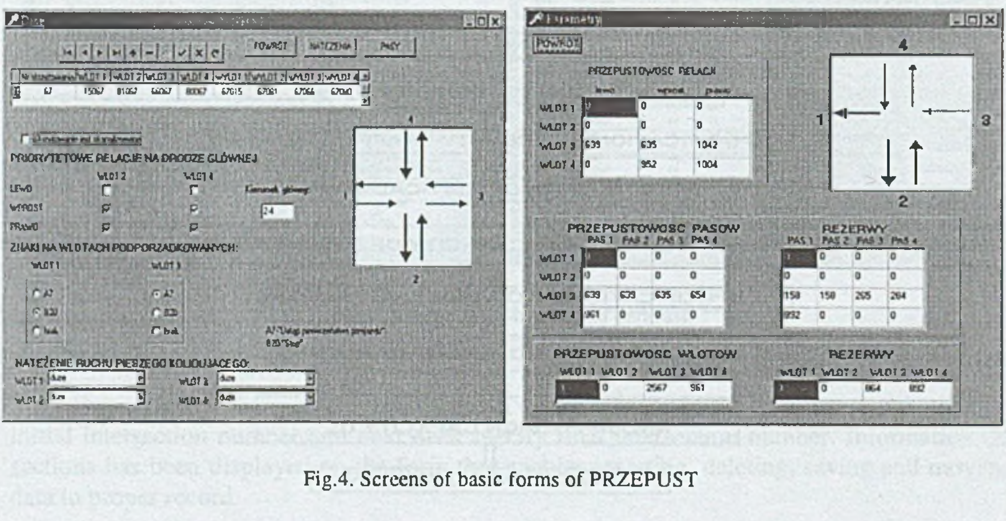

Fig.4. Screens of basic forms of PRZEPUST

4. CAPACITY OF SIGNALIZED INTERSECTIONS

The use of traffic lights at an intersection provides for the orderly movement of traffic by assigning right-of-way to conflicting movements. Signals also may increase the traffic-handling capacity of an intersection by permitting conflicting streams to share the same intersection. In database of Katowice centre [11] the rate of signalized intersections amounts to 13 percent. In this connection the necessity to design efficient tool for evaluating capacity parameters of such intersections occurs. The application should also be interactive with database worked out earlier.

One of the most frequently used and the best applied to Polish conditions methods is HCM-94 that is collection of procedures and methodologies for calculating the highway capacity and quality of service [4]. Possible capacity is defined as maximum number of vehicles that can be handled by a particular roadway component under prevailing conditions. The Highway Capacity Committee of the Highway Research Board has proposed six levels of service recommended for application in describing the conditions existing under the various speed and volume conditions that may occur on any facility. The 1994 manual provides great flexibility in adapting procedures to actual conditions. The HCM is updated continuously on the basis of the latest researches [9].

The auxiliary application "SSS" has been designed in Dept. of Traffic Engineering. It calculates signalized intersection capacity as well as it enables to insert and change data. A simplified scheme of method used in the application has been demonstrated in fig. 5 [1].

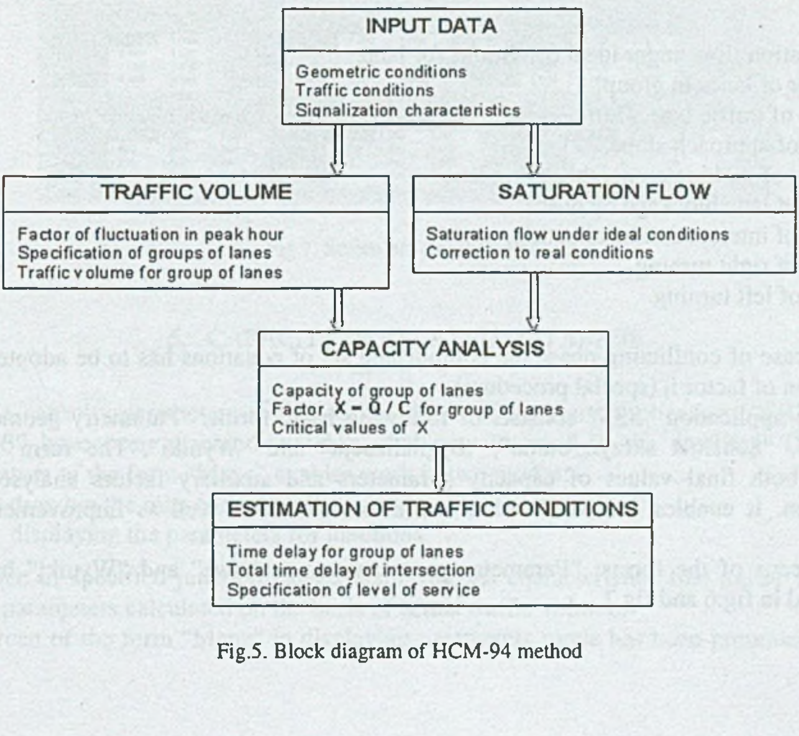

Fig.5. Block diagram of HCM-94 method

The number of vehicles that can discharge during the green phase is related to the saturation flow. Hence in HCM-94 capacity is defined for group of lanes and calculated according to the equation [4]:

$$C_i = S_i \cdot (G_e/T)_i$$

where:
G_e/T - rate of the effective green G_e in cycle T for group of lanes i,
S_i - saturation flow rate.

The group of lanes may consist of one or several lanes. Each group is assigned to specific type defined following:

- group 1 – straight lanes or shared through and left or right turn lanes,
- group 2 – separate left turn lanes,
- group 3 – separate right turn lanes.

The saturation flow for group of lanes is defined as maximum number of vehicles that cross the group of lanes during the efficient green hour under specific traffic conditions. The saturation flow for lane S_0 under ideal conditions is assumed to be 1900 E per efficient green hour per lane. To adapt this value to real conditions, some factors should be applied. The saturation flow for lane may be expressed as follows:

$$S = S_0 \cdot n \cdot f_w \cdot f_s \cdot f_{mp} \cdot f_a \cdot f_o \cdot f_p \cdot f_l$$

where:
S_0 - saturation flow under ideal conditions for lane,
n- number of lanes in group,
f_w- factor of traffic lane width,
f_s- factor of approach slope,
f_{mp}- factor of parking on neighbouring lane
f_a- factor of lane blockage by buses,
f_o- factor of intersection localization,
f_p- factor of right turning,
f_l- factor of left turning.

In case of conflicting phase the complicated set of equations has to be adopted for the calculation of factor f_l (special procedure).

The application "SSS" consists of following basic forms: "Parametry geometryczno-ruchowe", "Schemat skrzyżowania", "Sygnalizacja" and "Wyniki". The form "Wyniki" presents both final values of capacity parameters and auxiliary factors analysed during calculation. It enables fast verification and errors search as well as improvement of the project.

Screens of the forms: "Parametry geometryczno-ruchowe" and "Wyniki" have been mentioned in fig.6 and fig.7.

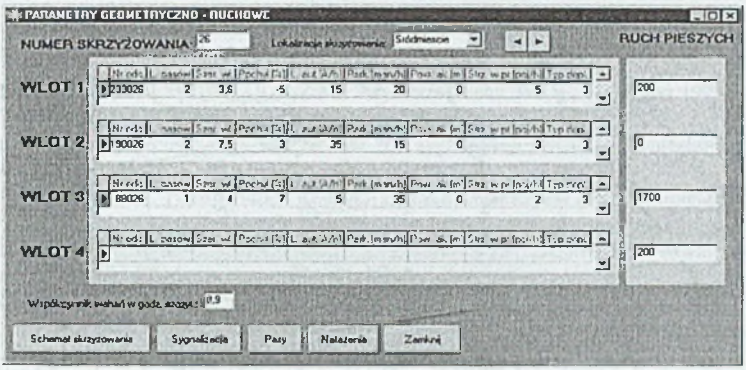

Fig.6. Screen of form "Parametry geometryczno-ruchowe"

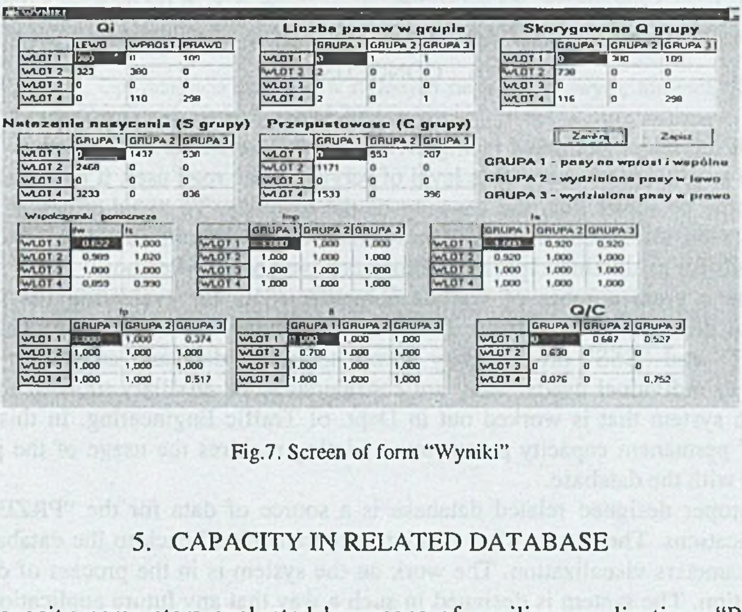

Fig.7. Screen of form "Wyniki"

5. CAPACITY IN RELATED DATABASE

The capacity parameters evaluated by means of auxiliary applications "PRZEPUST" and "SSS" have been recorded in tables that may be used in the database. The proper configuration of the form "Mapa" enables work in two modes:

- drawing the map components,
- displaying the parameters for junctions.

The choice of specified junction causes displaying its characteristics like traffic volume or capacity parameters calculated on the basis of actual traffic volume.

Screen of the form "Mapa" in displaying parameters mode has been presented in fig.8.

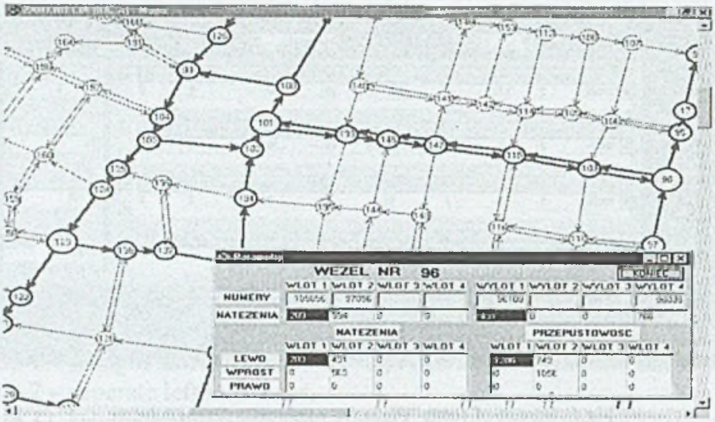

Fig.8. Screen of form "Mapa" in displaying the parameters mode

6. CONCLUSIONS

One of the major problems facing drivers in road networks is congestion. In order for the highway to provide an acceptable level of service to the road user, it is necessary that the service volume be lower than the capacity of the roadway. To avoid situation when many decision on road improvements would have been taken without adequate analytical tools, many methods for evaluating capacity parameters have been worked out.

Despite a great number of various computer tools for evaluating the intersections capacity, the decision on designing the new applications has been made. The programs: "PRZEPUST" and "SSS" provide easy access to traffic data and adaptation of capacity evaluations to individual needs. They are considered to be auxiliary tools in road closures optimization system that is worked out in Dept. of Traffic Engineering. In this system the necessity of permanent capacity parameters updating requires the usage of the proper tools that interact with the database.

The proper designed related database is a source of data for the "PRZEPUST" and "SSS" applications. The results of evaluations are transmitted back to the database enabling capacity parameters visualization. The work on the system is in the process of development and verification. The system is designed in such a way that any future application can easily be added to its environment.

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