Mechanical Methods of Traffic Assignment

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Two general kinds of digital computation problems are very amenable to machine computations. The first kind is the performing of highly repetitive calculations for a mass of data. An example of this is the application of the traffic diversion curves to the assignment of traffic using O & D trip information. The second kind of computation is the performance of a great number of sequential calculations starting from a single set of data. An example of this is the distribution of individually forecasted zone trip frequencies by successive approximation.

Some of the advantages of punched card machine computations are greater speed, greater accuracy, freeing of technical personnel from routine calculations and the solution of problems that would otherwise be impossible or so time consuming as to never be attempted.

The amount of computation involved in the assignment of traffic to a selected line can be very great. The number of theoretically possible movements is the combination of zones and stations taken two at a time or $\frac{N}{(N-2)!}$; in which "N" is the number of zones or stations.

Machine computations on an IBM-602A enable the work to be done in $\frac{1}{2}$ to $\frac{1}{3}$ the time required using desk calculators. More advanced type calculators such as the Remington Rand "File Computor" or an "IBM-650" would permit a much greater time saving. The advanced computors have an added feature of internal automatic checking.

Alternate route possibilities are measured using map meters. This information for each zone-to-zone movement is key punched and verified. The time ratios are then computed by machine using assumed arterial street speeds and assumed expressway speeds. The cards are then collated with a rate deck and diversion percentages reproduced. The cards are then run through the calculator again to find the estimated expressway usage. The final step is to make an "on-off" tabulation from which the assigned traffic is entered on the expressway line. A specific application is cited and a number of additional machine applications are mentioned.

• TWO types of computational problems lend themselves readily to punched card machine solutions.

The first kind is the performing of highly repetitive calculations for a mass of data. This would include problems such as $\frac{(a + b - c)}{e}^{d}$ in which sets of values for (a, b, c, d, e) occur in very great numbers. An example of this is application of the traffic diversion curve to the assignment of traffic using O & D trip information.

The second kind of computation is the performance of a great number of sequential calculations starting from a single set or a restricted number of sets of values. An example of this is the distribution by successive approximation of individually fore-casted zone-to-zone O &D trip frequencies. One solution of this problem is the use of an inverted matrix.

There are some obvious advantages to the use of machines for computations. They are faster. They make fewer errors and make possible the tackling of problems whose magnitude or complexity are either very burdensome or insurmountable by ordinary desk machines. One of the most important advantages is the freeing of trained personnel for "thinking" work rather than wasting them on routine calculations.

The use of machine methods in the assignment of traffic could only be developed after predictable relationships could be established for driver route selection. The development of the empirical traffic diversion curves provided one of the most sought after and needed tools for the traffic engineer. Only someone who querulously and

CONTROL	ZONE TO ZONE		TIME TA	EXPRESSWAY TIME					FREQUENCY
	ORIGIN	DESTINATION	STREET TRIF	TIME TO Txi	INTERCHANGE ON	TIME ON Tx2	INTERCHANGE OFF	TIME FROM Tx3	FORECASTED
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Figure 1. Work Sheet.

prayerfully guessed his way through a traffic assignment in those days prior to the diversion curve development can fully appreciate the changes they have wrought. While it is recognized that relationships exist between diverted traffic and measurable factors other than "time saved", the time factor only is used in this paper for the sake of simplicity.

The number of movements to be considered when using O & D data to make a traffic assignment to a selected expressway line in a large metropolitan area can become very large indeed. For example: The City of Miami was broken up into 104 zones and external stations. The number of theoretically possible movements is equal to the number of combinations of internal zones and external stations taken two at a time. The number of movements is as follows:

Where:

 $\frac{N !}{(N-2) ! 2!} = \text{total possible movements}$

N ! = total number of zones and stations factorially

In the case of Miami there were 5,356 total possible origin to destination movements. Many of the theoretically possible movements never took place, were inconsequential in volume or "obviously" would not use the projected facility. Nevertheless, the number of calculations involved would be very large if only half that number of movements were deemed within the domain of possible usage yield.

The number of calculations involved in making the assignment for one movement is dependent upon the number of facilities to be utilized during the trip and the kind of data available. We shall consider only the problem of assignment to a single line which would only be traveled once during a trip.

There are two possible situations involving the availability of time data. The first situation is that in which time runs have been made along all the arterial streets. The second is that in which time field data are not available. The first case is not necessarily the more accurate. In most instances in which a comprehensive analysis is done, part of the program will be the improvement of a high type arterial street network along with an expressway. It may be that synthetic times derived from assumed arterial speeds may be preferable. In the second case, where time information is not available, synthetic times have to be used.

Either case is amenable to machine calculation with the main difference being some additional calculations done by machine.

The number of calculations to be performed is the same whether the work is done by hand on desk machines, slide rules or on punched card machines. An examination of the calculations involved in making one assignment will make it possible to clearly show the punched card approach.

First, consider the case where time data are available. The following relationships exist and the calculations must be performed;

1.
$$R = \frac{T_x}{T_a} = \frac{T_{x_1} + T_{x_2} + T_{x_3}}{T_a}$$

2. From calculated R, one determines D from the curve

3. D x F = Volume of traffic diverted to expressway

R=time ratio

 T_X = total time for trip from origin to destination via expressway

 T_a = total time for trip from origin to destination via arterial streets

 $T_{x_3} = time \text{ from origin to expressway}$ $T_{x_2}^{x_1} = time \text{ from interchange "on" to interchange "off"}$ $T_{x_3}^{x_2} = time \text{ from expressway to destination}$

D = decimal equivalent traffic usage from diversion curve

F = total forecasted trip frequency

There are a total of four calculations plus one curve reading to be performed. Now consider the case where the time field data are not available. Working from a map, the following calculations are made:

$$R = \begin{pmatrix} K \frac{d_{a_2}}{v_a} + \frac{d_x}{v_x} + \frac{d_{a_3}}{v_a} \\ \frac{K \frac{d_{a_1}}{v_a}}{v_a} \end{pmatrix} = \frac{T_x}{T_a}$$

From calculated R, one determines D from the curve. $D \times F$ = volume of traffic diverted to expressway Where: R=time ratio d_{a_1} = distance via arterial streets in inches $d_{a_1}^{a_1}$ = distance via arterial streets in inches = distance via arterial streets in inches to expressway $d_{a^2}^2$ = distance via arterial streets in inches from expressway a_3 = distance via expressway in inches v_a = arterial velocity in feet per minute v_x = expressway velocity in feet per minute

 \mathbf{K} = map scale in feet per inch

D = decimal equivalent traffic usage from diversion curve

It can be seen that this would entail a minimum of nine separate calculations plus one curve reading.

In a city the size of Miami with 104 zones and stations and 5,356 theoretically possible movements, the number of calculations becomes quite large if a single assignment is made to only one line. If only half the theoretical movements (2, 678) were considered there would be a total of 10,712 calculations in the first case or 24,102 calculations in the second case.

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Where:

FREQUENCY X DIVERSION % FREQUENCY ZONE PERCENTAGE ⊿ EXPRESSWAY TIME EXPRESSWAY TIME Tx EXPRESSWA FREQUENCY TO TIME RATIO ZONE CONTROL TRIP EXPRESSWAY ARTERIAL F <u>بد</u> INTERCHANGE ON INTERCHANGE OFF FROM DIVERSION DESTINATION FORECASTED LIME e S **FOTAL** ORIGIN STREET TOTAL Ш. Тхі TIME Tx3 TIME T_{xe} 'OTAL

Figure 2. Layout form for punched cards.

In order to estimate doing the calculations by hand, assume that a rate of two calculations per minute could be maintained including recording and curve reading. In the first case a little over eleven man days would be necessary and in the second case about 25 man days would be necessary.

The use of punched card methods and an IBM 602-A calculating punch would enable the job to be done in less than half the time. It should be pointed out again that technical personnel are not involved in the machine calculating time.

At this point in the operation the hand calculation would have produced results in a form that would necessitate tabulating "ons" and "offs" by hand. In order to speed up the process, add accuracy and have the results in an easily usable form, it would be necessary to use punched card methods to obtain the final results. This would entail key-punching and key-verifying of the hand calculated results.

The machine calculated results, however, are already on cards at the end of the calculation cycle and are ready to be tabulated. In addition, the estimated time using machine methods in the example cited is based on slow performance rates for both people and machines. For example: the key punching and verifying time estimate was based on an average of 5,000 key strokes per hour. Rates of 6,000 to 10,000 strokes are common. The 602-A time was based on the simplest step by step programing; optimum programing might also save time in this step.

In any case, the 602-A calculating punch is a relatively slow machine with limited storage capacity. In comparison with an IBM 650 or a Remington Rand File Computer it is like finger counting compared to an automatic desk calculator.

The whole process of machine calculation is very flexible and expandable over the previous two cases mentioned. The arterial street network could be broken into sections of different speeds. Ramp travel could be handled separately and expressway speeds might be varied by location. In all such cases, the only difference would be to add extra terms to the numerator and the denominator of the time ratio fraction and add some extra machine steps.

The methods developed to date can be illustrated by reference to the forms, flow chart card layouts and machine procedures that could be used with O&D trip information and where time data are available. As pointed out previously, the methodology is easily expandable.

Figure 1 is a reproduction of the basic work sheet. The first step is to enter all the origins and destinations on the work sheet. In order to insure proper control of the operation, we found it best to enter all of the theoretically possible movements and let the diversion curve do the selecting as well as the assigning.

Next, the time for each trip using the arterial streets from origin to destination is entered. There are a number of ways of organizing the time data so as to make it readily accessible and usable.

Then the time segments must be entered for the same trip using the expressway. The time from the origin to the nearest interchange is entered and also the "ON" interchange number. We have been using a three digit code for the interchange numbers. The first two digits represent the interchange number and the third digit the direction of approach or leaving. This permits ramp assignments and ramp end turning movements to be created.

The next entry is the time on the expressway. This is the time from the interchange where the trip gets on the expressway line to the interchange where it gets off. Naturally this would be a calculated time from an assumed speed or speeds on the expressway. The "OFF" interchange is entered next followed by the forecasted zone to zone trip frequency.

From this point, the process becomes a normal punched card operation. Figure 2 is a layout for the punched card. The work sheets are first key punched and key verified and any punching errors corrected.

The cards are now ready for the calculation cycles. Our machine installation has an IBM 602-A calculating punch. The cards are run through the 602-A. During this run several steps take place. First the three pieces of expressway time are summed



Figure 3. Curve determining percentage of expressway use.



Figure 4. 24 hour assigned traffic volumes.

and the total punched in the proper columns. Secondly, the time ratio is calculated and the result punched.

Figure 3 is a representative diversion curve. We have broken the abscissa into 27 intervals with a five-hundreths range. The next step is to match the calculated time ratio to the proper diversion percentage. A master deck of cards was previously punched with time ratios and equivalent diversion percentages. The master deck is placed in front of the detail cards and sorted by time ratio. This groups the detail cards behind the proper master card. The combined deck is then run through a reproducing punch to gang punch the diversion curve decimal equivalents into the detail cards.

The final pass through the 602-A is then made. The diversion decimals are multiplied by the trip frequency and the volume assigned to the expressway is obtained. During the same pass, the expressway volume is subtracted from the total volume and the remainder or arterial volume is punched.

The detail cards are then ready to be sorted in the sequences necessary for the "ON-OFF" tabulations. Figure 4 is a sample flow map illustrating graphically the final results. The insert shows the manner of entering volumes on and off at an interchange. In actual use, the volumes themselves and not bands are utilized since the primary purpose is design data.

Initial success with the use of machines has led the authors to investigate their utilization in major facility location, sufficiency rating calculations, signs, signals and pavement marking inventory. It is quite obvious that only a beginning has been made in traffic engineering utilization of digital and analogue computers. Much more remains to be done.