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CONTROL OF CONGESTION IN HIGHLY SATURATED NETWORKS

SURVEY DESIGN AND DATA COLLECTION

D J Quinn

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Control of Congestion in Highly Saturated Networks

Survey Design and Data Collection

1. Introduction

1.1 Context

This working paper describes the initial stages of a "follow-up" study of the control of highly saturated signalised junctions in Bangkok. The previous study has been reported in WP 220, WP 221 and WP 222.

This paper describes why particular junctions were chosen for this second study and reports on the results of a survey designed to produce the data input requirements for TRRL's TRANSYT program. TRANSYT is a method of finding the "best" fixed-time plans with which to co-ordinate the traffic signals in any network of roads for which the average traffic flows are known. While this paper deals with the data input requirements, such as average flows, the results of an experiment comparing TRANSYT recommended signal timings with Traffic Police control will be described in a subsequent paper (WP 251).

1.2 Background

The TRANSYT program has been generally accepted as the most successful method for optimising the fixed-time control of signalised road networks. TRANSYT version 8 was used in the previous study to predict the timings for a series of four co-ordinated signalled junctions on a major east-west two way arterial road in Bangkok (namely, Rama IV Road). Before conducting the previous experiment it was, however, recognised that standard UK signal calculation methods were inappropriate because of high turning movement proportions, different p.c.u. values and high saturation flows maintained over long periods. The revised method of dealing with Bangkok traffic conditions has been described in WP 220 and WP 222. Despite these revisions an experiment in automatic co-ordinated signal control produced an average reduction in vehicle delay (veh-hours/hr) of 6% compared with manual police control. Although an improvement of 21% was recorded on one incident-free day, one would still have expected a greater overall reduction in delay through benefits of co-ordination. A likely explanation is that TRANSYT attempts to facilitate the "progression" of vehicles along a link, but when junctions are saturated then uninterrupted progression along a link is not possible since each vehicle will be delayed for at least one cycle at each junction. Instead, the key requirements are to avoid queues disrupting upstream junctions and to reduce the number of standing waves in a queue. Observations from the RAMA IV experiment indicated that problems did not occur in a junction provided that the tail of the queue was moving by the time the stage for its main feed had ended.

If stationary vehicles remained in the junction, then drivers from the main feed (ie Rama IV Road) entered the junction illegally and subsequent movements were disrupted.

The blocking of an upstream junction was most noticeable during the previous experiment on the east-bound link between Suriwong (SUR) and Silom (SIL) junctions along Rama IV Road. TRANSYT/8 recommended timings were employed on the first experimental day (2 July 1985) but these resulted in blocking of the upstream (SUR) junction and the offset between junctions SUR and SIL had to be altered. The "successful" offset between SUR and SIL junctions was based on the time taken for a starting wave to move backwards from SIL to SUR along a queue on Rama IV Road. Under the original TRANSYT/8 recommended timings the main feed at the upstream junction (SUR) finished before the starting wave had arrived from the downstream junction (SIL); whereas the adjusted offset allowed approximately 25 seconds in which traffic was free to flow across the SUR junction before the green for Rama IV Road terminated, hence the junction did not become blocked and cross-moving traffic was unhindered. (Technical Note 224 describes in more detail how video film for this critical link has been analysed).

As a result of the above work and after discussions at TRRL it was recommended that the TRANSYT/8 program should be amended. A new card (type 39) has now been introduced in order that a range of offsets can be specified which will avoid blocking of upstream oversaturated conditions, will avoid blocking of critical links yet still optimise within the constraints imposed by card type 39. Testing the usefulness of this modified TRANSYT program was one of the several aims of this follow-up study.

1.3 Objectives

i) To conduct an experiment in automatic signal control on a two dimensional road network.

At an isolated intersection with degrees of saturation approaching 100%, a policeman can respond immediately to variations in input flow or saturation flow (often caused by incidents) and therefore reduce the random element of delay. In a network of junctions, however, coordinated fixed-time control is usually better than manual or isolated responses because of the benefits of progressing platoons through successive junctions. However, the smooth progression of vehicles through a network breaks down in highly saturated conditions.

Another objective therefore, was to apply the specifically amended TRANSYT/8 program (with card type 39) to a network of roads in which blocking of several junctions was a common occurence and where the manual calculation of offsets would be more difficult.

ii) To calculate automatic timings which are effective in variable flow conditions.

The variablility of flows in Bangkok is one reason why the traffic police choose to manually control junctions during the peak periods. Hence, a further objective of this project was to implement signal timings which were sufficiently robust to accomodate variable demands. In particular, it was considered essential to calculate offsets between junctions which would ensure that stopping and starting waves arrived at upstream junctions at a desired point (or range of points) in each cycle, despite the expected variablility in demand and hence the variablilty in the speed of stopping waves.

iii) To provide Bangkok Traffic Police with guidance on how to best approach incident management.

If automatic signal timings were successfully implemented then the traffic police could be released to perform "incident management" duties which should further reduce delay and minimise the disruptive influence of incidents on the effectiveness of the automatic timings.

The most important of these three objectives was to organise and conduct an experiment in automatic signal control on a two-dimensional road network. Once the police were satisfied that the automatic timings were working adequately, they could be encouraged to leave the vicinity of the control-box and patrol the streets in order to promptly deal with incidents. Instructions were to be given on the most effective way of dealing with incidents without reverting to manual signal control.

2. Network Choice

2.1 Background

Three areas were considered in the search for a suitable network of highly saturated junctions:

i) Extension from the previous study of Rama IV Road southwards into the area of Silom and Sathorn Roads;

ii) The area north of Rama IV Road with similar sized junctions along Petchburi and Rama I Roads;

iii) An area of tightly-knit streets close to Chinatown along Bamrungmuang and Luang Roads and within the ATC area.

One disadvantage of the first option was that the streets south of Rama IV Road which cross Silom and Sathorn Roads are relatively minor roads and not through-routes. Also, major road construction was expected before the experiment if plans were to go ahead to build an "over-pass" at the junction of Rama IV and Sathorn Roads. A further difficulty would have been encountered when co-ordinating signals because of the age and variety of signal controllers in this "non-ATC" area. The advantage of this first option was that data for Rama IV Road junctions had already been collected and signal offsets had been successfully implemented.

For the second option there were two main drawbacks. Firstly, an experimental part-time two-way operation had been recently introduced along Phya Thai Road and the same was planned for Petchburi Road. Secondly, over-passes along Petchburi Road complicated the nature of "blocking" of junctions. The advantages, however, were that junctions are of similar size to Rama IV Road and all have Ericsson controllers with cabless linking units.

The main disadvantage of the third option was that the network contained none of the high capacity junctions tackled on Rama IV Road. Another problem was that the police operated a unique method of control at the junction of Bamrungmuang and Krungkasem Roads (junction 5) where drivers are encouraged to use the wrong side of the carriageway in an attempt to increase saturation flow. The main advantage of choosing this option was that it provided a true network of closely-knit junctions and that all junctions are within the control of the ATC system using the GEC highwayman. It would therefore be relatively easy to implement a new automatic signal plan with the possibility of extending automatic control to adjacent roads within the ATC area.

The third option was chosen because of the above advantages and because of uncertainty about future construction and traffic management changes in the other two area under consideration.

2.2 Choice of Junctions

Once the study area had been selected it was necessary to decide upon the exact junctions for investigation. The network of junctions had to:

a) be seriously congested;

b) be beyond the influence of junctions outside the network;

c) be close enough together for linking to be possible;

d) include several cases where blocking of junctions was a frequent occurrence;

e) be recognised by police as a serious problem and hence under their control;

f) be within the control of the ATC Centre;

g) have suitable vantage points for video-filming

h) have no sois* with major flows, or at least only a few sois which could be easily counted and used to adjust the flows on links between signalised junctions;

i) have parking restrictions during the evening peak in order to minimise the effect of side-friction.

* a soi is a minor street in Bangkok, often used to avoid major junctions.

Figure 1 shows a map of the area around Bamrungmuang and Luang Roads. A network of 10 junctions can be identified between Maha Chai Road eastwards to Krungkasem Road. The junctions experience severe congestion and all but two junctions in Luang Road (Maha Chai and Krungkasem) are under police control during peak periods. Blocking was observed to be almost continuous at two junctions along Bamrungmuang road (Yokhol 2 and Plupplachai) and intermittent at Worachark, Yokhol 2 and Plupplachai junctions on Luang Road.

Bamrungmuang road was chosen because it is severely congested during the evening peak and because the junction at Krungkasem (junction 5) is one of the most critical in the whole ATC area. Here two major one-way roads intersect and upstream junctions (ie 3 and 4) are always blocked during the evening peak because demand from Bamrungmuang and the side-roads to the south exceeds the capacity of junction 5. Consequently this provided an excellent area for testing the revised TRANSYT/8 timings because at least two junctions were guaranteed to be blocked. Bamurngmuang Road has two T-junctions with links from the south, therefore it was sensible to include the parallel road to the south (ie Luang Road) rather than the road to the north in order that a two dimensional road network could be studied.

A total of 10 junctions were selected between Maha Chai Road and Krungkasem Road because they seemed to form a relatively isolated network. However, it would have been prefered to cover more junctions to the north and south in order to minimise the influence of external junctions but ten junctions was considered to be the maximum within the constraints of the survey budget.

2.3 Physical description of network

Figure 1 shows the location of each junction and table 1 lists each junction and indicates the serial number used at the ATC Centre and the survey number used in this project for each junction.

Figure 1

The Study Area

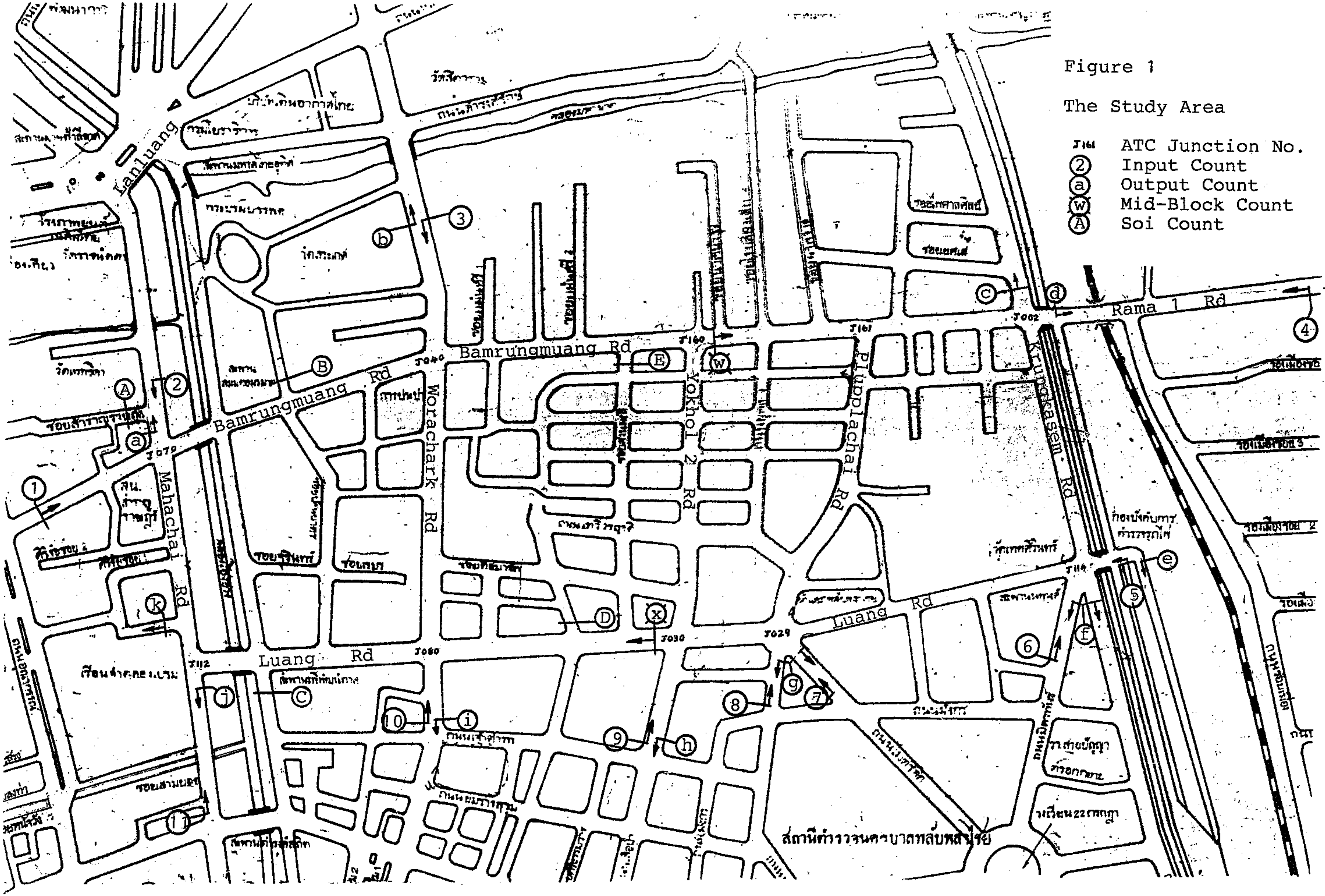


Table 1. Numbering of Junctions

Survey Number	Name	Number of arms	ATC number
1	Bamrungmuang/Maha Chai	4	70
2	Bamrungmuang/Worachark	4	44
3	Bamrungmuang/Yokhorn 2	3	160
4	Bamrungmuang/Plupplachai	3	161
5	Bamrungmuang/Krungkasem	4	2
6	Luang/Maha Chai	3	112
7	Luang/Worachark	4	80
8	Luang/Yorkhorn 2	4	30
9	Luang/Plupplachai	5	29
10	Luang/Krungkasem	5	114

Figure 2 shows the layout and stages at each of the 10 junctions while Figure 3 shows the dimensions of the network. The approach to junction 5 is oversaturated from the west and both the approaches from the west and south are oversaturated at junction 4. Consequently the link to the west of junction 5 blocks junction 4 which in turn means that the link west of junction 4 frequently blocks back to junction 3. The link south of junction 4 (ie Plupplachai Road) has a storage capacity sufficiently large that a queue on this link rarely extends to junction 9. The other link which regularly causes a problem of junction blocking is the relatively short 180 meters between nodes 7 and 8, on Luang Road.

Land-use in the study area typically comprises of small retail outlets except for hospitals on Luang Road and Bamrunmuang Road and the Bangkok Bank situated on Yokhol 2 Road. The eastern perimeter is bounded by a klong (canal) running parallel to Krungkasem Road, and part of the western perimeter is bounded by a prison.

Parking is not allowed on the two east-west roads except for the link between junctions 6 and 7 on Luang Road. Separate right turn lanes are provided wherever such a movement is permissible. Uncontrolled turns are found at junction 5 (west to north and south) Junction 10 (north to west) junction 1 and 2 (both north to east) and junction 9 (east to north).

3. Data collection

3.1 Requirements

One of the main input data requirements for the TRANSYT program is the average peak hour flows on each link of the network in terms of pcu per hour. Other major requirements are saturation

FIGURE 2 - LAYOUT OF JUNCTIONS AND SIGNAL STAGES

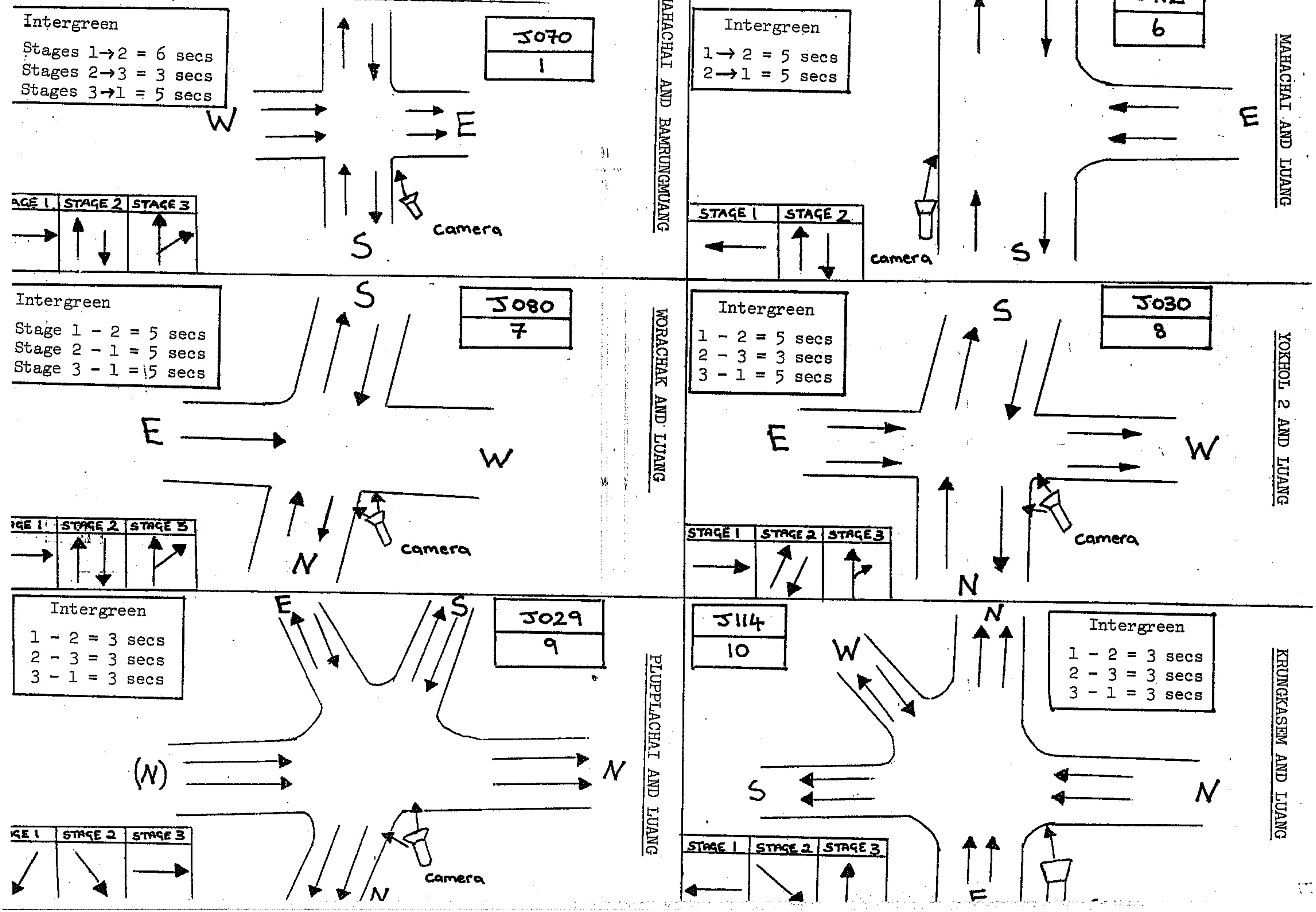


FIGURE 2 - CONTINUED

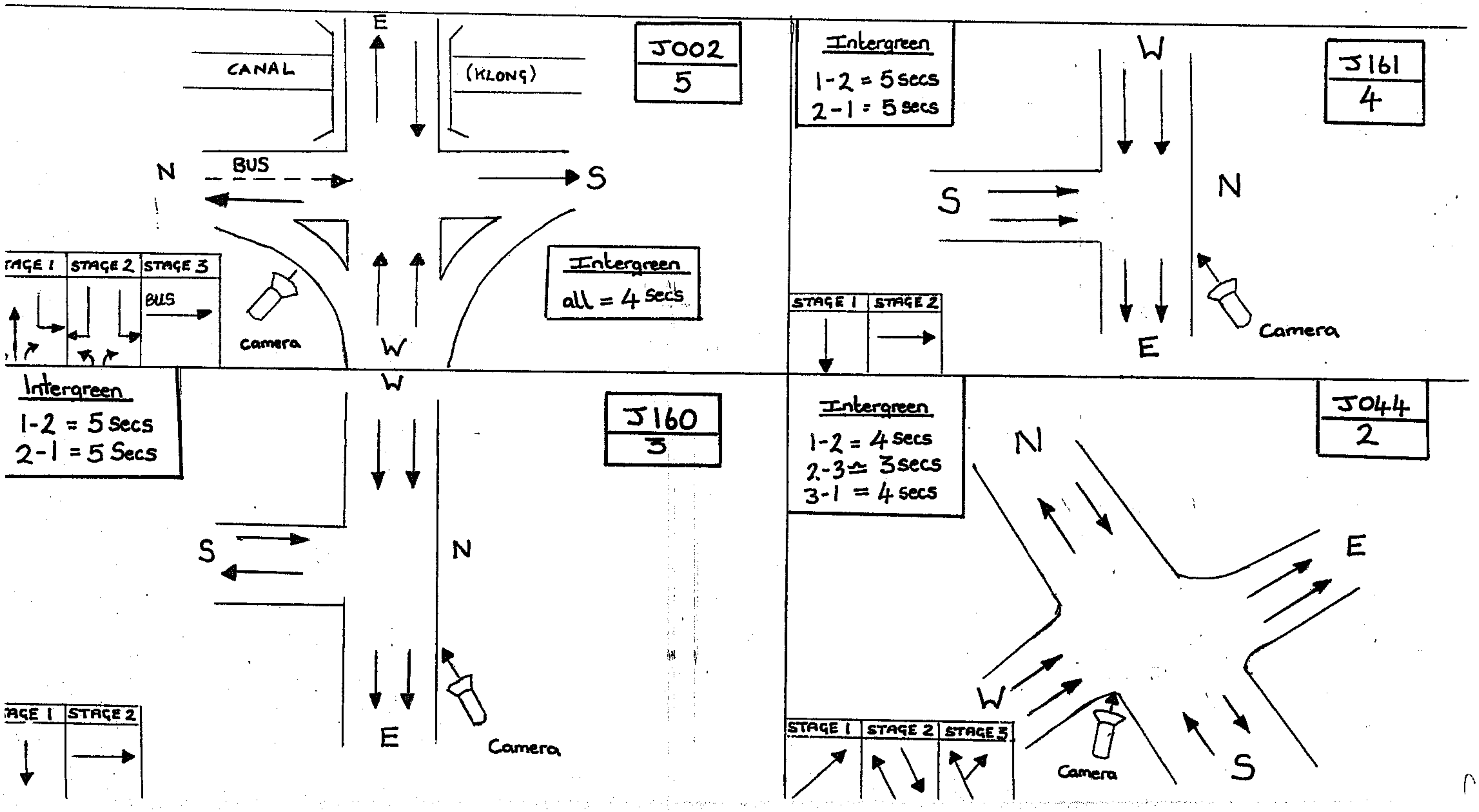
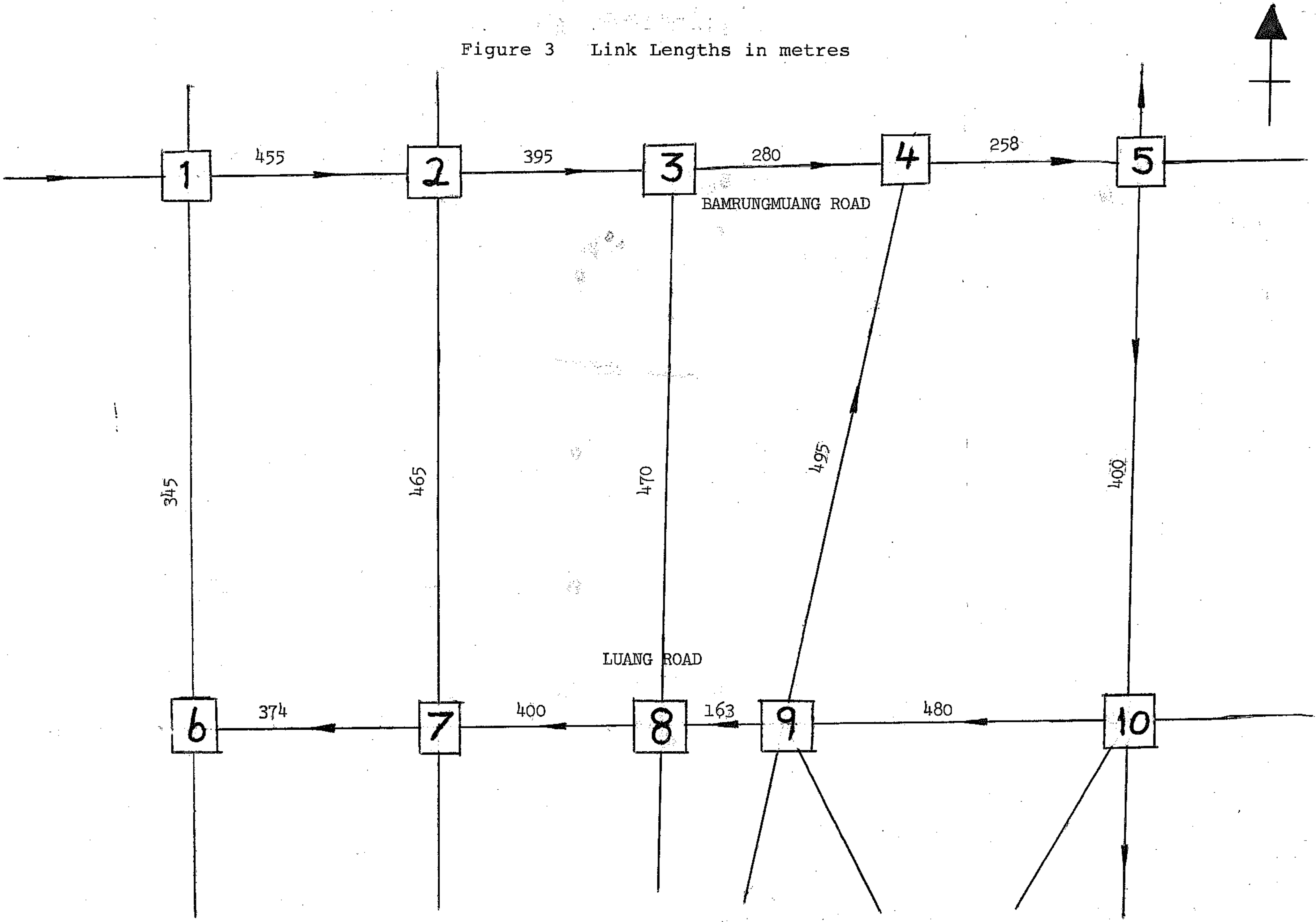


Figure 3   Link Lengths in metres



flows, start lags, and the signal stage order.

Simply counting throughput flows would under-estimate the demand when a junction is over-saturated. Therefore it was necessary, as with the previous study, to take input counts on external links leading into the studied network upstream of the longest queue; combined with a classified turning movement count for each junction it was therefore possible to estimate accurately the demand flow on each link. A further advantage was that another unclassified input count taken at a later date would be sufficient (using turning movement proportions and a pcu/veh ratio for each link) for quickly calculating revised flows for the network. Classified turning movement proportions were obtained using the VISTA system which is described later.

3.2 Input counts

Unclassified manual counts of all vehicles except motorcycles were conducted at the locations indicated in figure 1. Motorcycles were omitted in order to make the enumerators' task easier; the total flow including motorcycles could be estimated later from the classified turning movement counts at each stopline. Each enumerator was equipped with tally counter, clipboard, prepared survey forms and a digital watch. The cumulative total was recorded at five minute internals. Counts were taken between 3.30 and 6.00 pm on each weekday over a 2 week period from 9th September until 23rd September 1986.

Input count locations were upstream of the longest queue at all stations except on the short links leading into the survey area at counts 5, 6, 7, and 8. However this was not considered to be a problem because the queue completely cleared during each green, hence the 5 minute totals would not under-represent the demand.

Apart from being upstream of the longest queue there should also not be any significant entry or exit points between the count point and junction stopline. This was not possible at two locations (count locations 2 and 3) and it was therefore necessary to make a count on one day of these entry and exit points in order to adjust the input counts.

3.3 Soi counts

Between signalled junctions within the network there are numerous minor intersections between the main arterial roads and minor roads (sois). Many sois are merely culs-de-sac but 6 intersections were found to have significant turning proportions, hence counts were taken on one day between 3.30 and 6.00 pm at each of the identified locations. These counts were used to adjust the flows on internal links in the network. The six soi counts (A to F) are indicated on Figure 1.

3.4 Turning movement proportions

In order to conduct an on-site classified turning movement count of the very high flows in Bangkok it would have required as many as 12 enumerators at certain junctions. For reasons of data accuracy it was decided to video record each of the 10 junctions. The location of the camera for video-recording each junction had to provide a clear view of all movements on every stage during each cycle. Permission for access was obtained from owners/managers of various buildings and in some cases a letter of authority from the Ministry of Interior was required. The position of the camera at each junction is shown in Figure 2. Recordings were taken on each of the 10 days for the input counts. The method employed to analyse the video film was the VISTA system developed by Wootton Jeffreys. VISTA was used successfully in the previous study and the method has been described in WP 220. A few modifications to key-movement configurations were necessary for this current study, otherwise the procedure was the same as for the Rama IV Road data analysis.

3.5 Saturation flows

The saturation flows for each movement were calculated using the cumulative discharge graph method. In the previous study a computer program was specially written in order to calculate the vehicular flow by movement by vehicle type by 6 second interval for each green period. Another program was used to factor the flow in each period by the appropriate pcu value and turning movement penalty in order to obtain a t.c.u. value (through car unit). For purposes of this study one comprehensive computer program was developed so that the user need only input the datafiles for the movement flows and signal stage time changes as well as the appropriate tcu values for each movement. Cumulative tcu values for 6 second periods produced by the program output could then be used to plot cumulative discharge graphs. The straight segments of the graphs provided the average saturation flows.

3.5 Start and end lags

The Start lag is the time fron the start of actual green to the start of effective green, and the end lag is the time from the start of red (end of amber) to the end of effective green. In WP 220 these two values were found to be 3.3 and 1.3 seconds respectively. The same values have been used in this study.

4. Survey results

4.1 Input flows

Table 2 shows the average flows (all vehicles excluding motorcycles) at each counting station over the total 10 days survey period for various time periods. The peak 30 minutes for the total of all counts was found to be 16.15 to 16.45. Note that counts at stations 2 and 3 needed to be adjusted because of a significant outflow of vehicles between the count point and the junction stopline. This outflow was measured on one day during the survey period for each location and the percentage reduction

Table 2 Input Counts: Average Flows Between 9/9/86 and 23/9/86 All Vehicles Excluding Motorcycles

Counting Station (see fig.1)	1	2	3	4	5	6	7	8	9	10	11
1530-1600	723	719	929	1197	351	231	377	218	416	214	485
1600-1630	706	718	894	1159	402	218	374	194	414	234	564
1630-1700	714	737	968	1128	453	210	387	191	425	234	495
1700-1730	641	722	1053	1084	386	213	419	195	475	221	470
1730-1800	592	778	936	1079	354	210	425	214	464	230	493
1530-1630	1429	1435	1823	2356	759	448	751	412	830	448	1049
1600-1700	1419	1455	1862	2287	856	428	761	385	839	468	1059
1630-1730	1355	1509	2020	2293	839	423	805	386	900	455	966
1700-1800	1233	1550	1988	2163	740	418	843	409	939	450	963
1615-1645	743	716	937	1155	468	214	369	190	425	238	549
(x2)	1486	1432	1874	2310	936	428	738	380	850	476	1098

was obtained using the input flow for the same day.

4.2 Classified turning movements

4.2.1

The VISTA method was used to obtain classified turning movements at each of the 10 junctions from video film taken one day at each of the junctions throughout the input count survey period (9th to 23rd September, 1986).

4.2.1 Vehicle types

Vehicle types in Bangkok are similar to those in the United Kingdom except for the three-wheeled samlors, small minibuses and that there are practically no articulated lorries or pedal cycles. Lorries are banned from Central Bangkok during the evening peak period, therefore it was decided to classify vehicle types for the purposes of this study as follows:

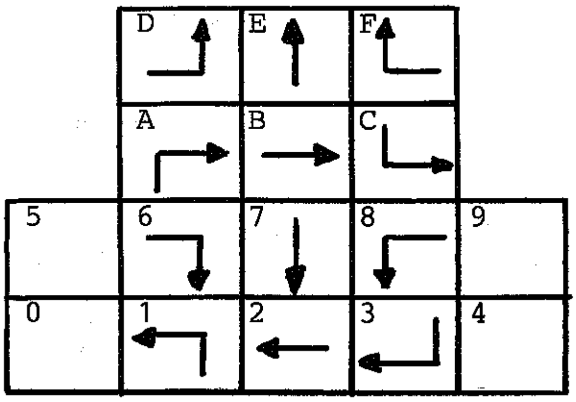
1. Cars
2. Motorcycles
3. Samlors
4. Buses and lorries

In the previous study (see WP 220, page 20) a total of 6 classifications were used. However the number of pedal cycles was considered to be insignificant and as lorries were supposed to be banned it was considered reasonable to combine lorries and buses into one category. An adjustment was however made later in the PCU factor for this combined classification based upon the observed average number of lorries which violate the restricion.

4.2.3 VISTA key configurations

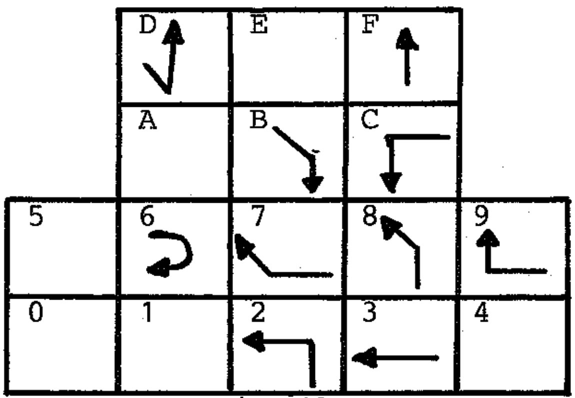
The keys on each terminal represented the 16 possible turning movements as shown on page 15. Note that the terminals had always to be orientated to line up with North as shown on the video picture.

NORTH



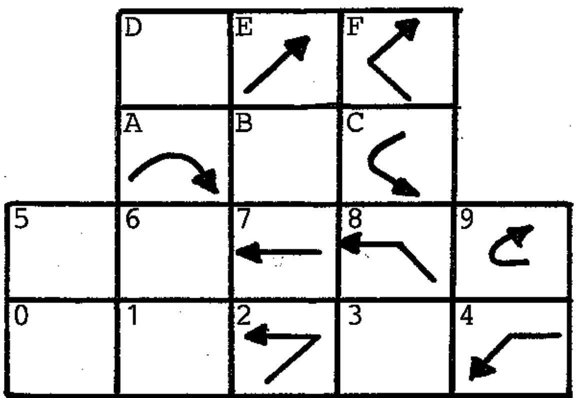
However this standard key configuration had to be amended for the two 5-arm junctions (juntions 9 and 10). The key configuration for movements specific to each of the 5-arm junctions are illustrated below.

NORTH



Junction 10

NORTH



Junction 9

Each film was analysed in 15 minute segments and each segment was processed three times in order to obtain the flow data by vehicle type/turning movement as follows:

Run	Terminal 1	Terminal 2
1	Cars to N and E	Cars to S and W
2	M/C to N and E	M/C to S and W
3	Samlors (All directions)	Buses and Lorries (All directions)

The above arrangement was devised in order to reduce the chances of missing vehicles, yet minimise the required number of "runs" through each film. Vehicles were recorded, not at the stopline but when they left the junction to avoid any confusion regarding destinations. For the five arm junctions it was necessary to use VISTA's Data Review facility in order to minimise mistakes when dealing with samlors in all directions.

The data files from each separate 15 minute segment were linked into one large file for each vehicle type and movement group. These files were then treated by the VISTA "Count Analysis" program to obtain classified turning movements and by the specially written saturation flow program.

4.2.4 Count Analysis

For each possible turning movement a total of all vehicles was obtained using the VISTA "Count Analysis" program and turning movement proportions were subsequently calculated. Figures 4, 5, 6 and 7 show the turning movement proportions for different time periods. As expected there was not a large variation in the turning movement proportions.

4.3 Link flows

In order to calculate the flows on the internal links of the network it was necessary to use a matrix method to solve 16 simultaneous equations. This computer program was developed still further in order to remove several tedious stages in obtaining link flows in tcu per hour from the initial input flows, turning movement proportions and pcu values. Figure 8 shows the average hourly flows on all links in terms of all vehicles excluding motorcycles for the peak period (16.15 to 16.45).

4.4 Average t.c.u. Values

4.4.1 General

The method of dealing with p.c.u. values and turning movement penalties was developed in the previous study and reported in WP 220. The VISTA 'Count Analysis' produced a fully classified turning count from which it was possible to calculate a total t.c.u. (combined p.c.u. and turning movement penalty) value for

FIGURE 4 - TURNING MOVEMENT PROPORTIONS - ALL VEHICLES EXCL. MOTORCYCLE

TIME PERIOD = 16.15 to 16.45

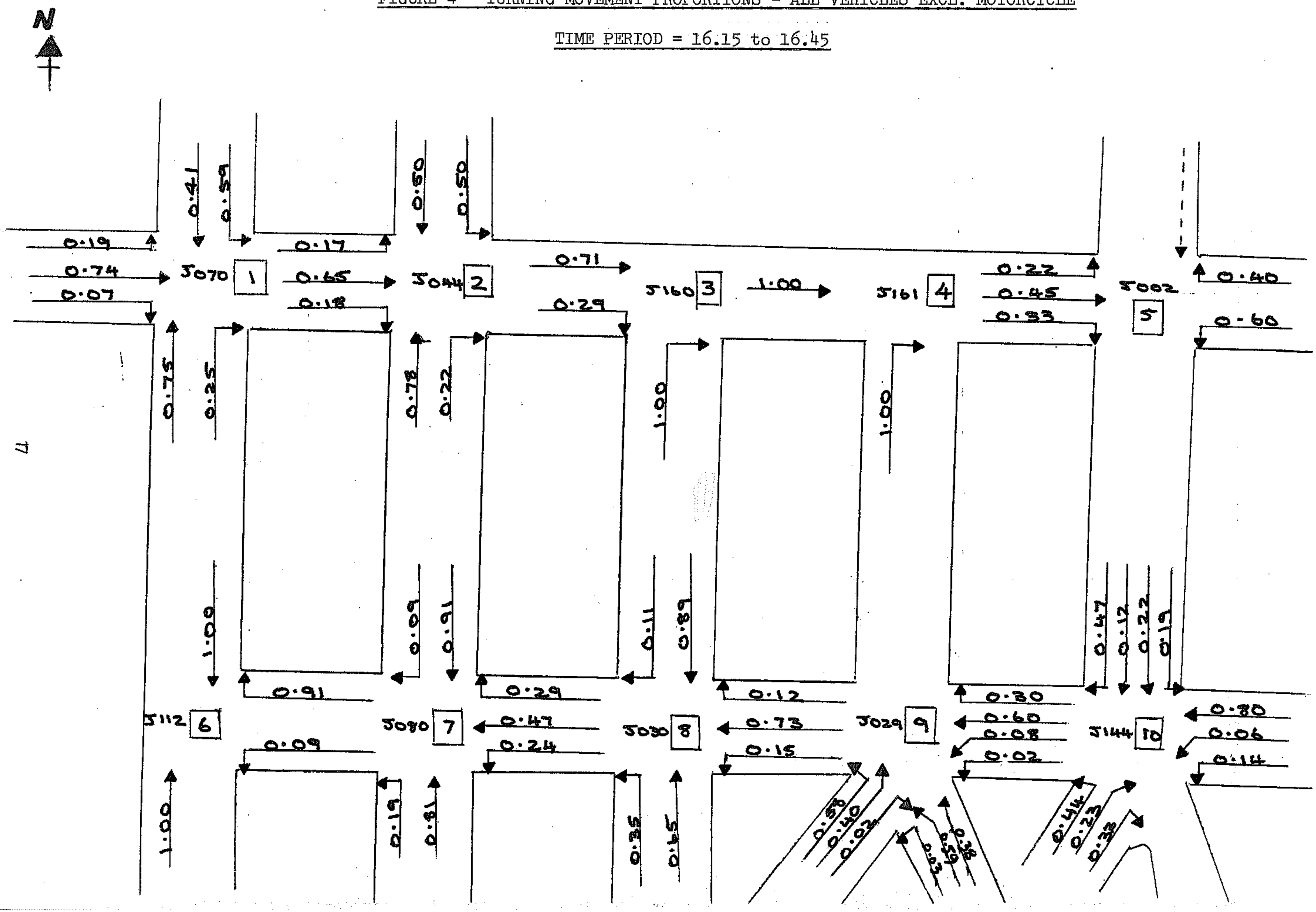


FIGURE 5 - TURNING MOVEMENT PROPORTIONS - ALL VEHICLES EXCL . MOTORCYLE
TIME PERIOD = 15:30 - 16:30

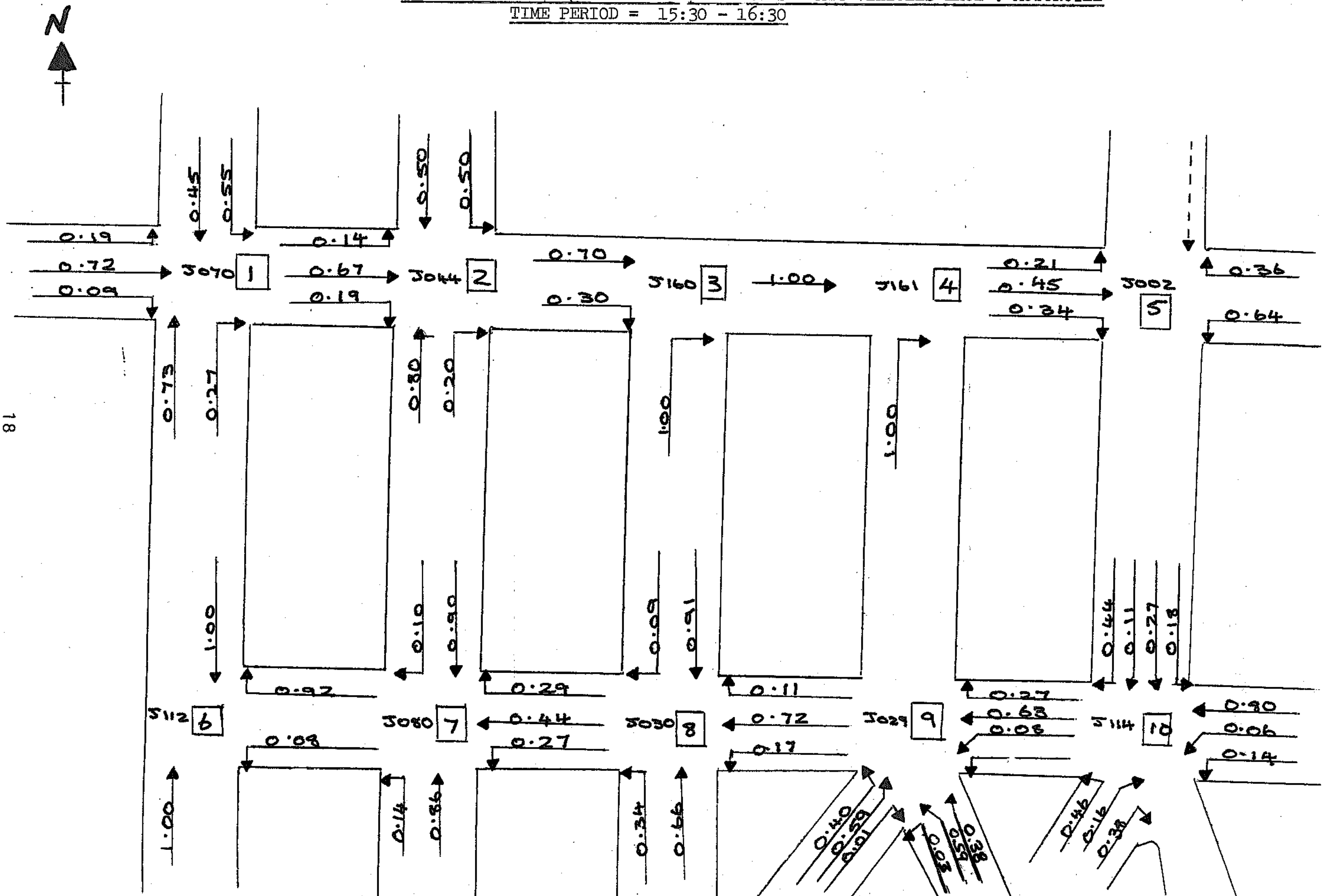


FIGURE 6 - TURNING MOVEMENT PROPORTIONS - ALL VEHICLES EXCL.MOTORCYCLE

TIME PERIOD = 16:00 - 17:00

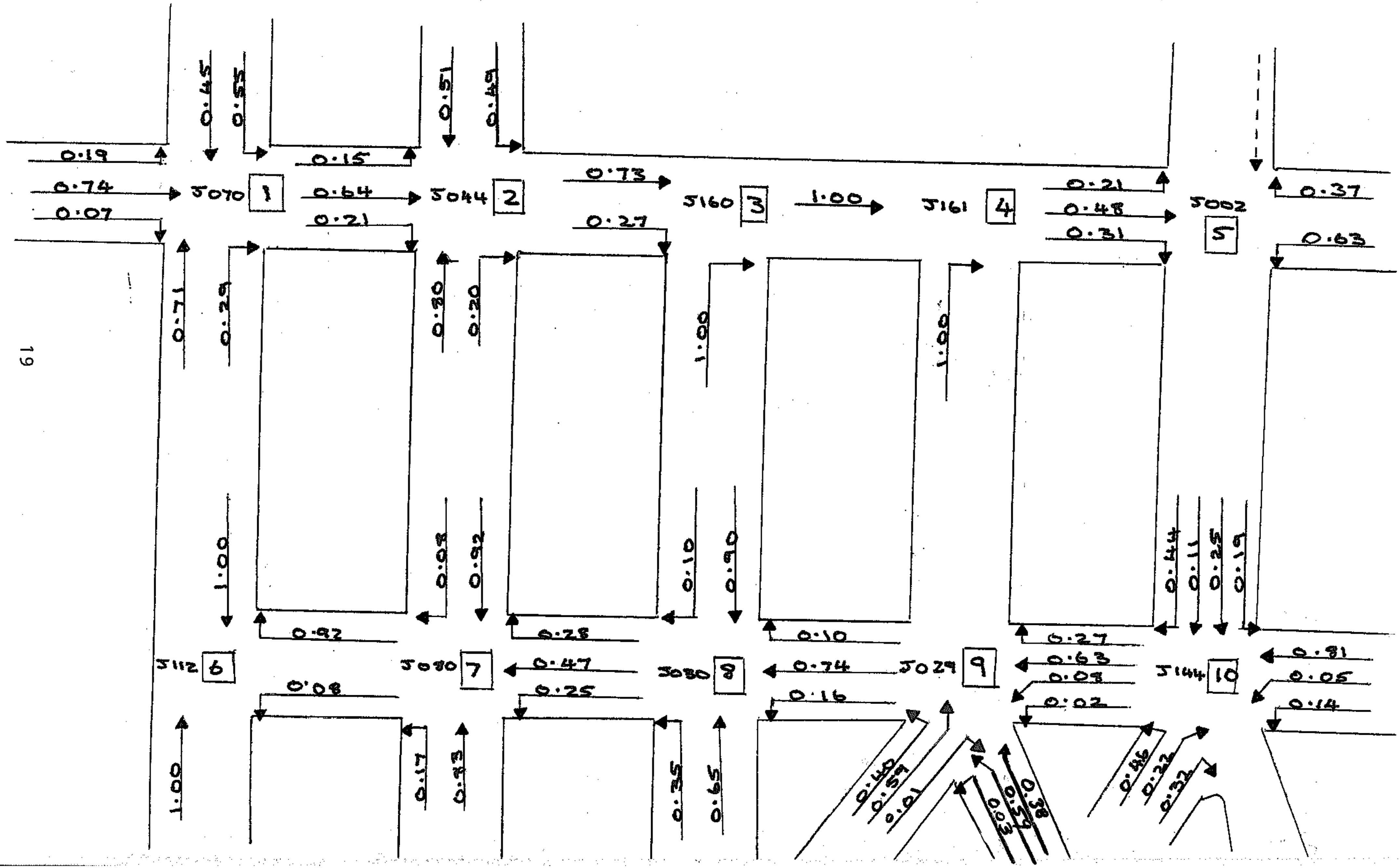


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FIGURE 7 - TURNING MOVEMENT PROPORTIONS - ALL VEHICLES EXCL. MOTORCYCLISTS
TIME PERIOD = 16.30 - 17.30

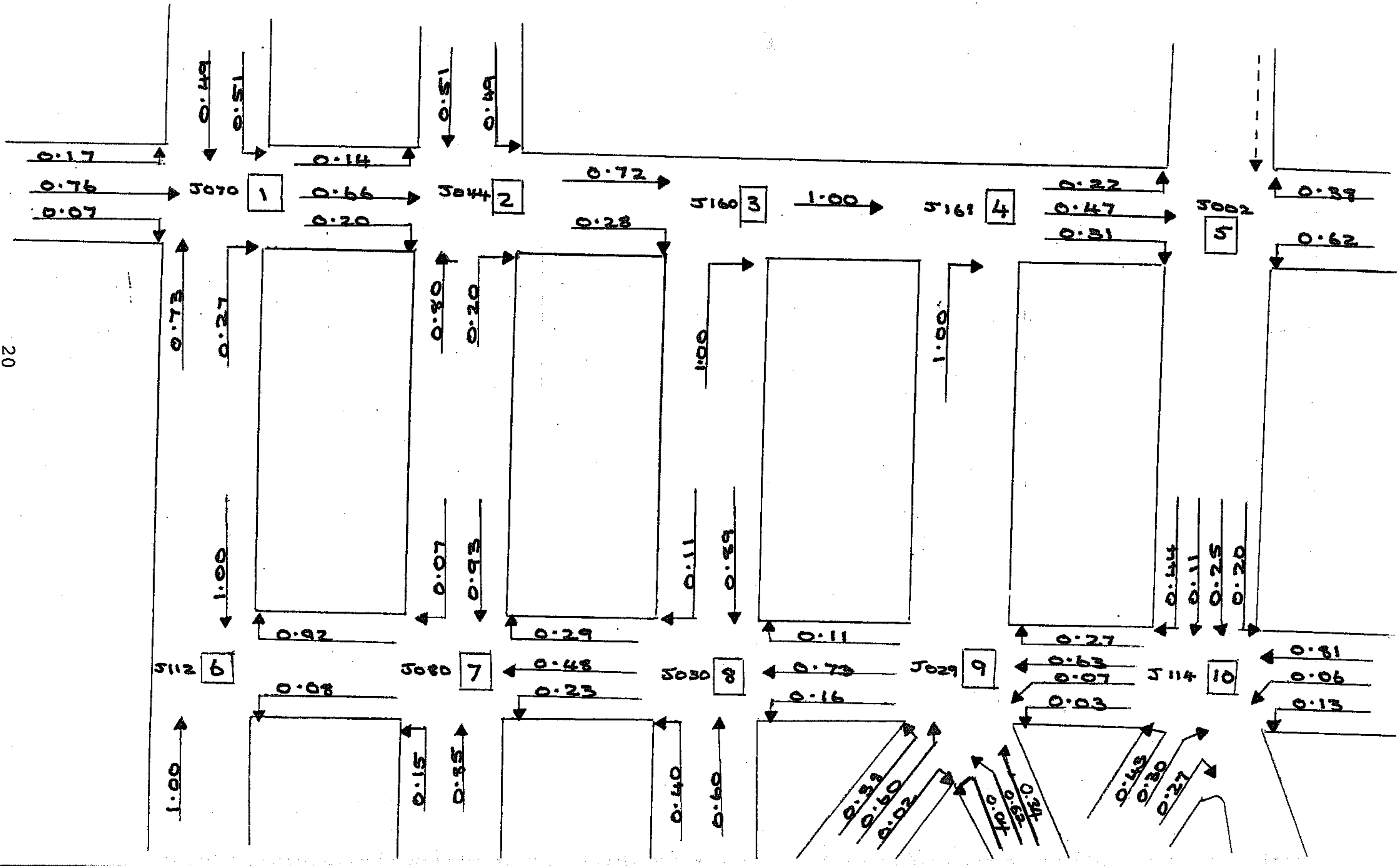
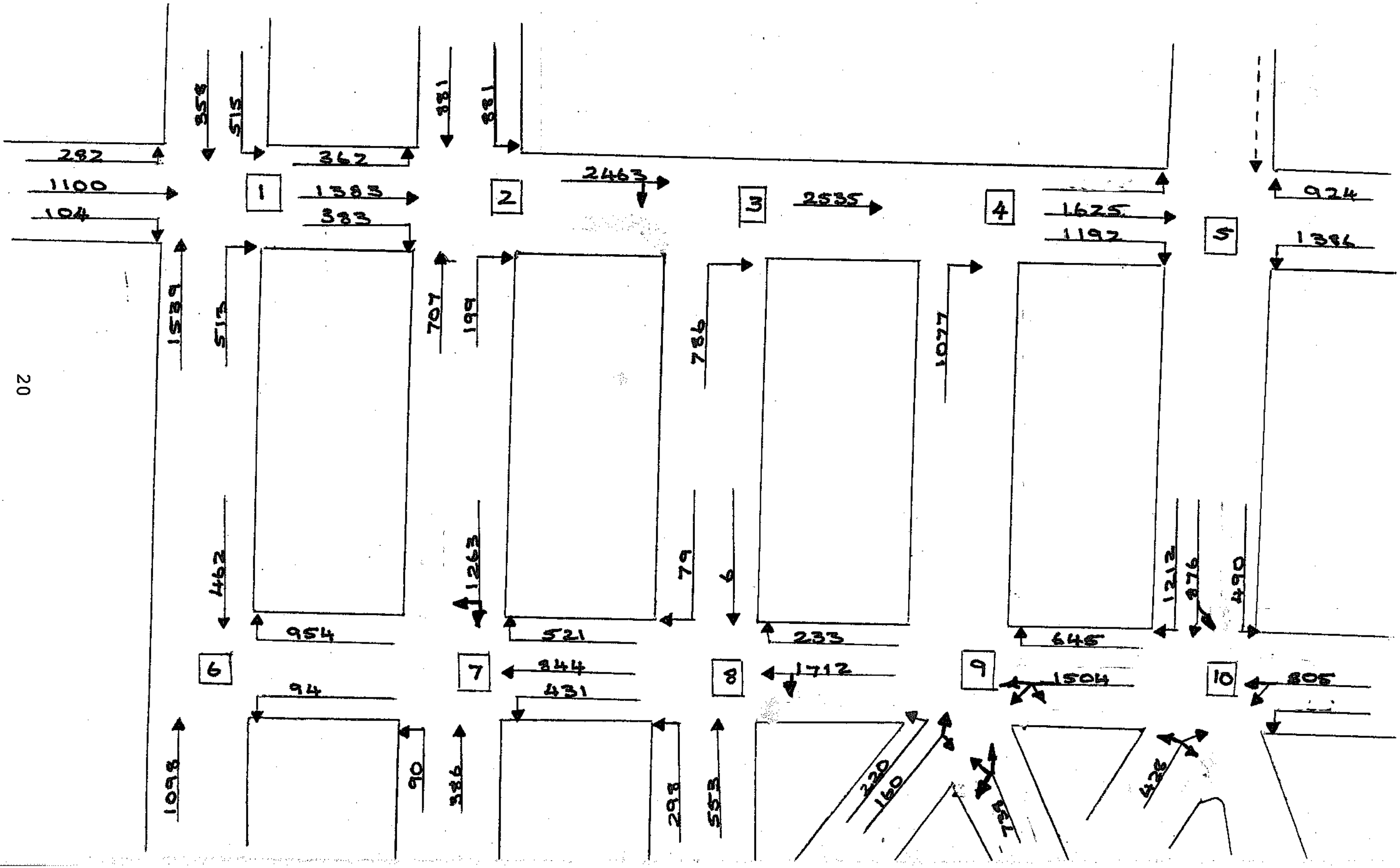


FIGURE 8 - LINK FLOWS
(ALL VEHICLES EXCLUDING MOTORCYCLES 16.15 - 16.45)



each movement. Some turning movements were combined in order to be compatible with the movements which considered to constitute a single saturation flow). The ratio facilitates the computation of link flows in terms of t.c.u. values which is necessary for TRANSYT data input.

4.4.2 Motorcycles

It was argued in WP 220 and WP 222 that motorcycles in the first six seconds of each 'green' period have a p.c.u. value of zero. A preliminary investigation suggested that the R/g ratio for each movement reflects the flow of motorcycles in the first 6 seconds, because a longer red period allows more time for motorcycles to percolate to the front of the queue. Lee (1986) reports on this investigation and a formula has been suggested. However from the data collected for this study it was possible to directly compute the flow of motorcycles in the first 6 seconds of each green for each movement and these were given a p.c.u. value of zero.

Figures 9, 10, 11 and 12 illustrate the t.c.u./all veh. exc. m/c ratios for various time periods. These figures are relatively high compared with the ratios calculated for links on Rama IV Road. An explanation for this difference is that there are more sharp left turns along Bamrungmuang and Luang Roads, hence the t.c.u. value is increased by the relatively high turning movement penalties for left turns. Also, these junctions are smaller than on Rama IV with shorter cycle times, hence, there is less red time during which motorcycles percolate to the front of the queue. This means that fewer motorcycles will have a p.c.u. value of zero and therefore the t.c.u./vehicle ratio will be higher.

4.5 Saturation flows

In addition to the three runs through the video film for classified turning movement data a fourth run was also made to record the end of each stage as seen in the video. The data from all four runs was input into a specially written program (developed further from the earlier project) which output the cumulative total t.c.u. value for each movement by six second intervals of each green period. Cumulative discharge graphs were plotted and critically examined in order to obtain saturation flows. The plots generally had an elongated S-shape form, the top curve representing the drop in flow at the end of green. The slope of the straight section in the middle of the plot gives the saturation flow although in some cases there would be a break in the curve caused by a drop in demand or blockage. There were also some plots which suggested that the saturation flow decreased towards the end of long greens.

In the analysis the tops and tails of the curves were excluded, as were breaks and jumps, unusually shaped curves, and the later parts of exceptionally long greens where throughput was seen to be falling. The saturation flow was calculated as the average flow during the remaining periods. Figure 13 shows the

FIGURE 9 16.15 - 16.45
T.C.U / ALL VEH exl. M / C.

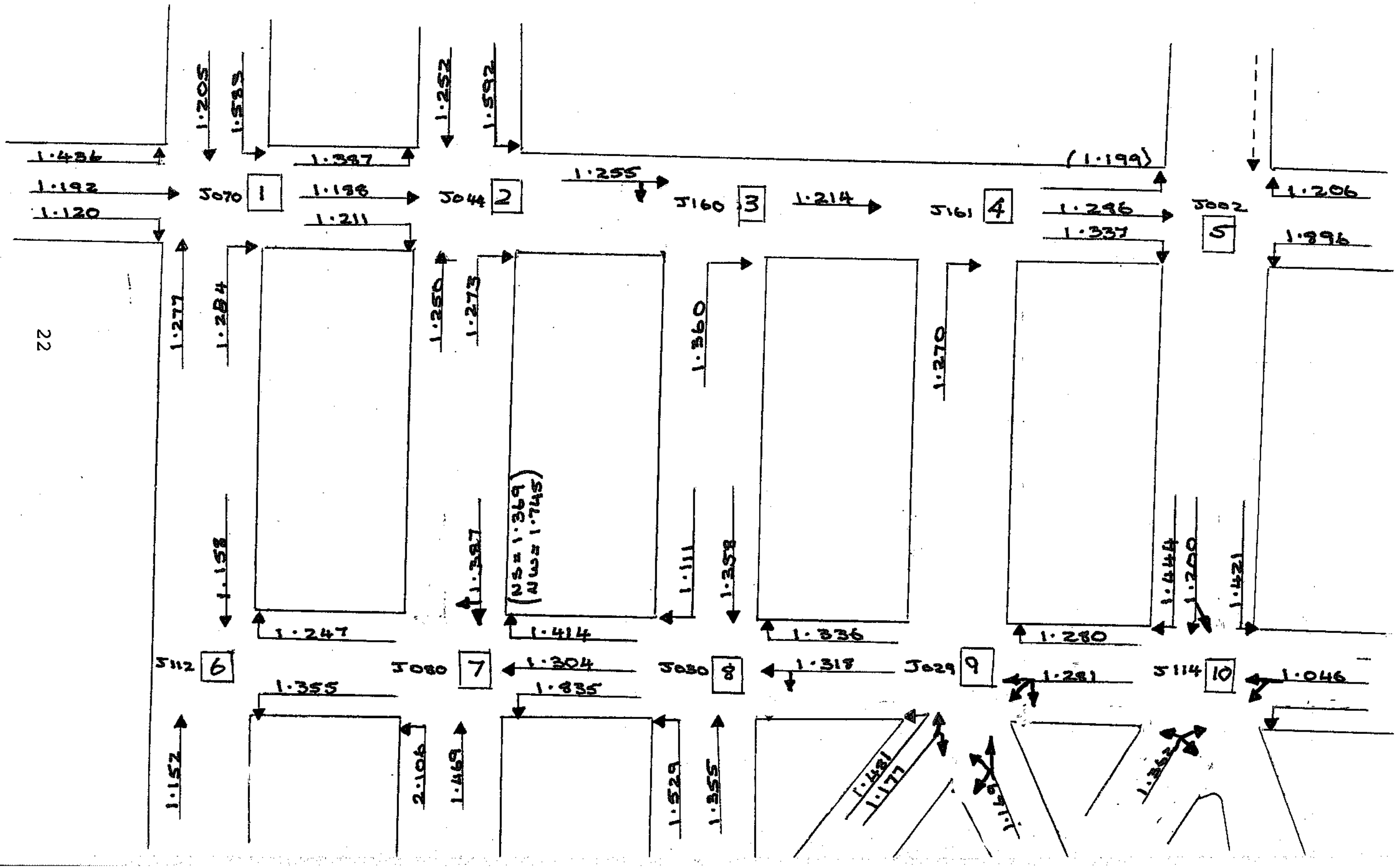


FIGURE 10 15.30 - 16.30

T.C.U / ALL VEH. excel. M/C.

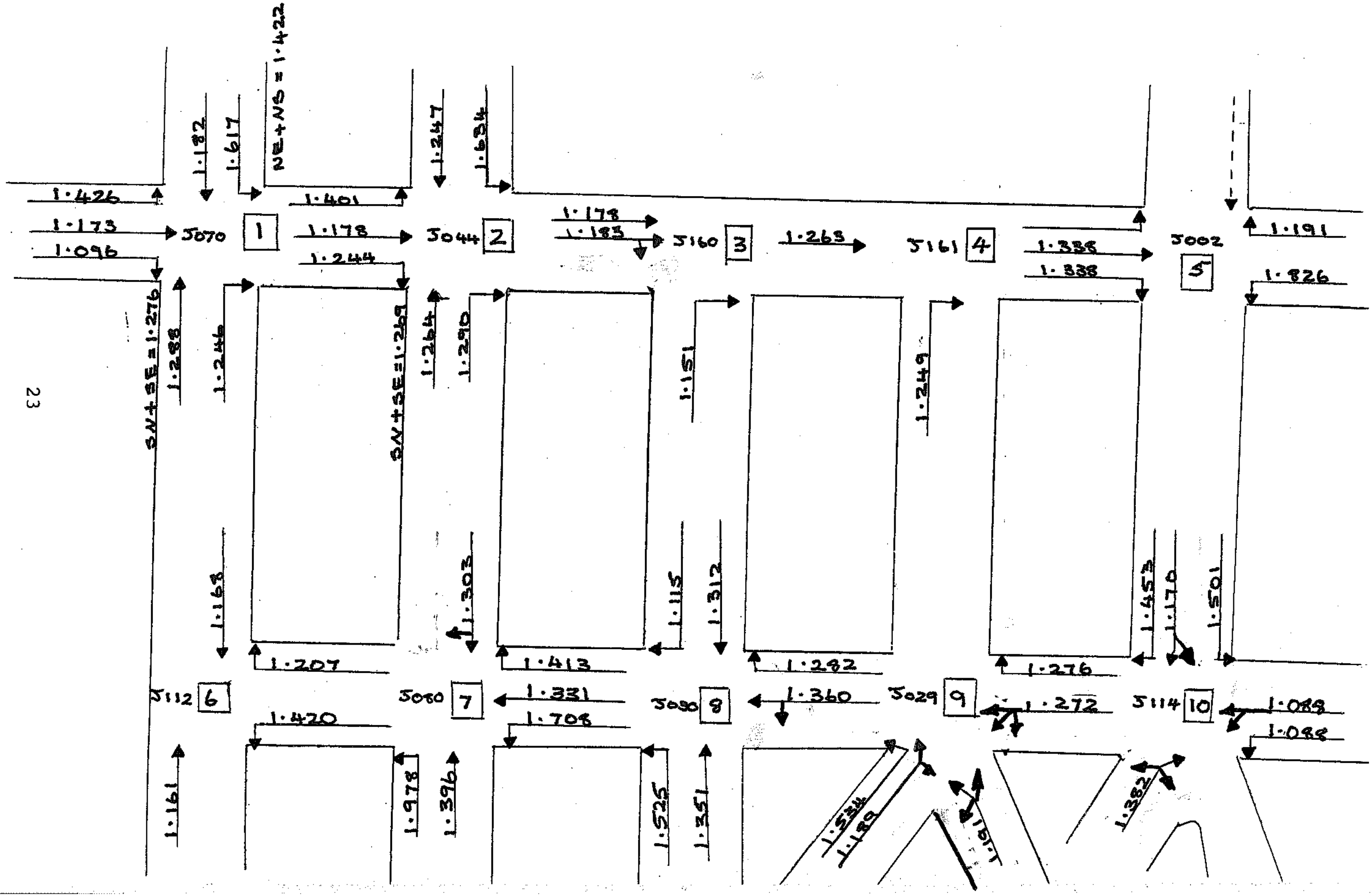


FIGURE 11 16.00 - 17.00
T.C.U./ ALL VEH. exel. M/C.

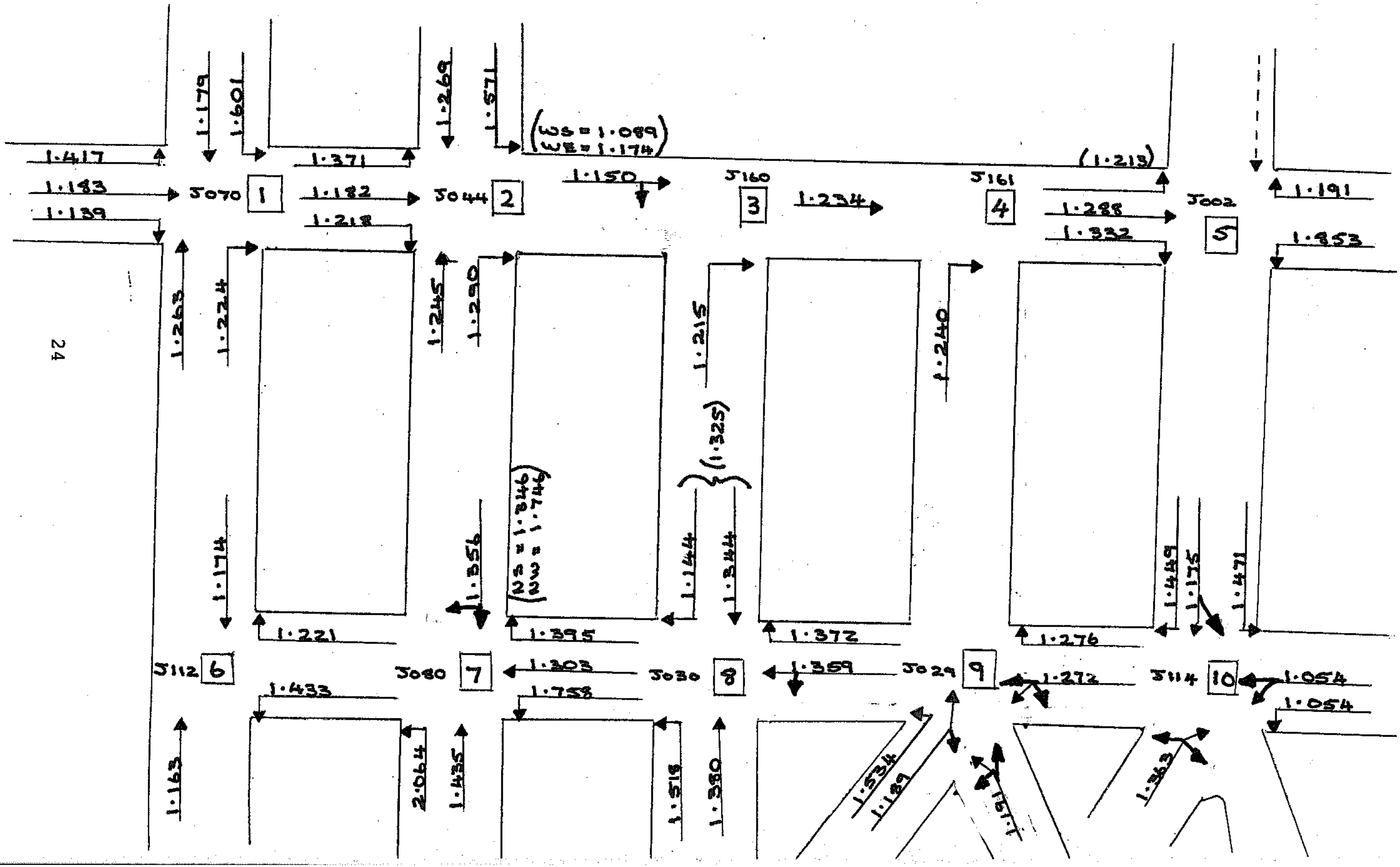


FIGURE 12 - 16.30 - 17.30
T.C.U / ALL VEH exl. M / C.

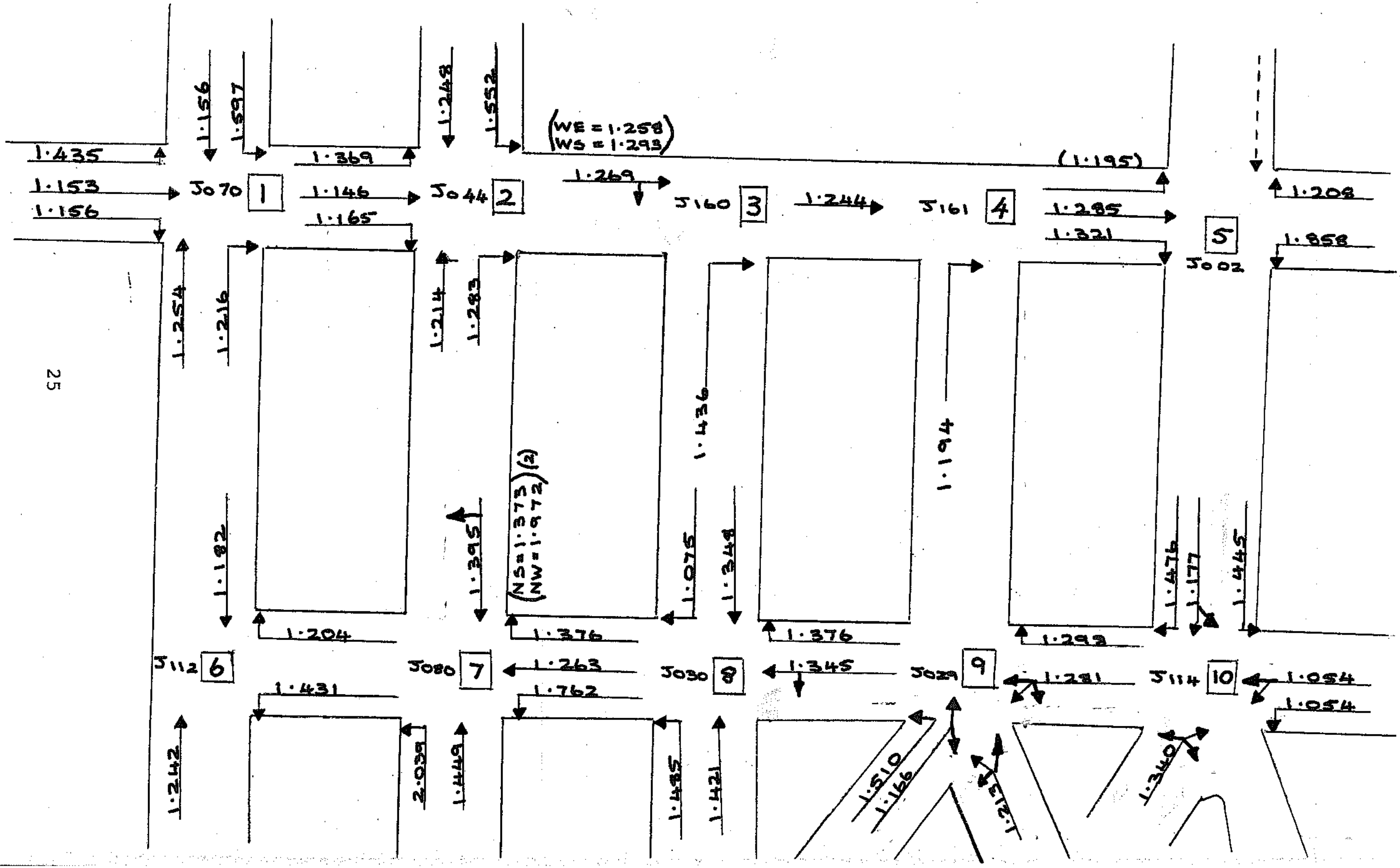
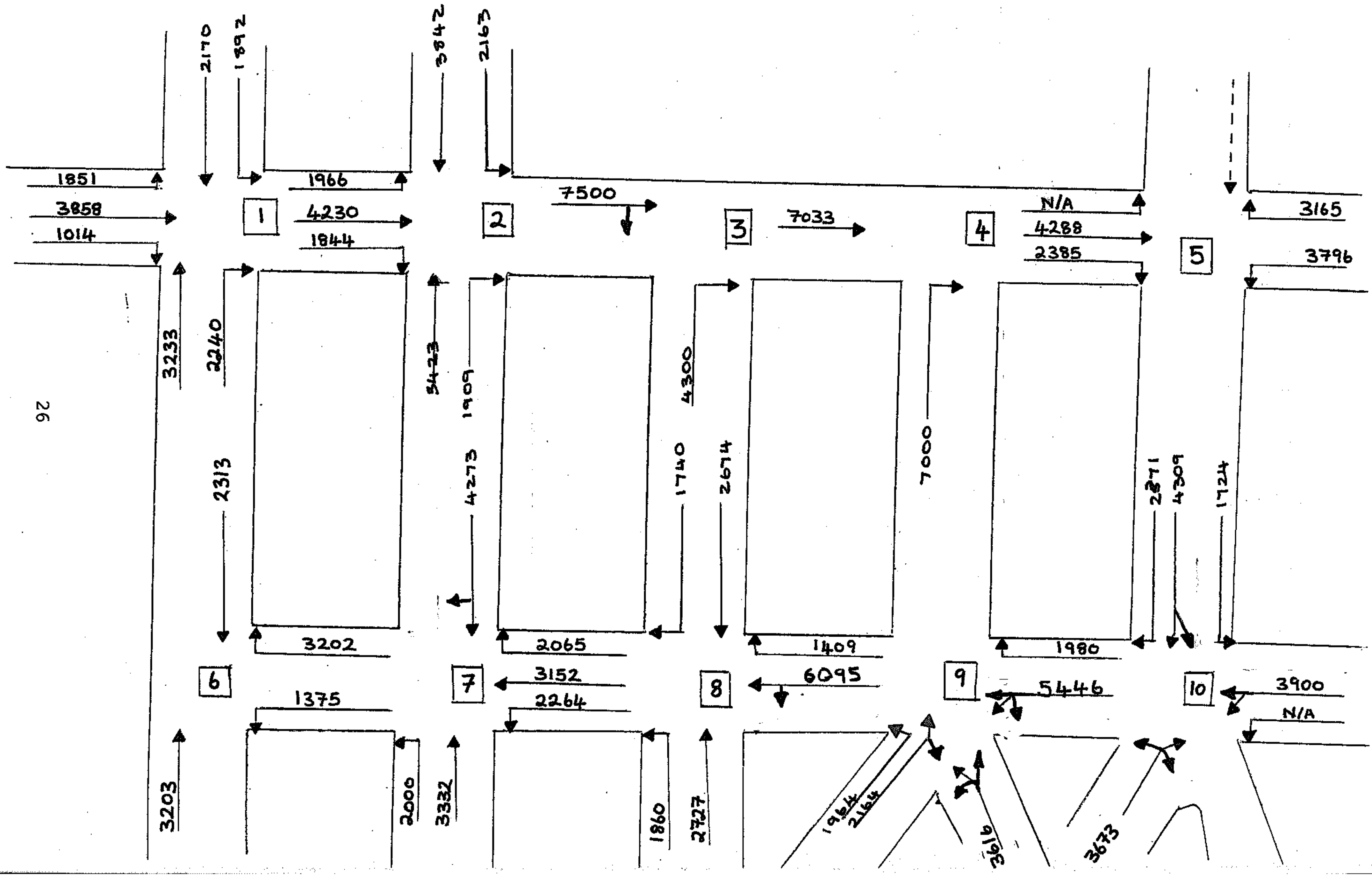


FIGURE 13 - SATURATION FLOWS

(T.C.U./HOUR)



saturation flows in t.c.u. per hour for each movement. Some turning movements were combined into one saturation flow depending on whether or not vehicles queued in separate lanes for each particular turning movement.

4.6 Start lags

The calculation of the start lags at each junction is complicated by the behaviour of motorcycles (i.e. the build-up of motorcycles at the front of a queue during the red period). In WP 222 page 11, a revised method of dealing with the behaviour of these motorcycles is outlined. The flow of all vehicles (except motorcycles) in the first 6 seconds was calculated and can be represented as an average flow (f6) over 6 seconds. Alternatively it can be represented by saturation flow (s) for a time T6 where 6 x f6 = T6 x S. Hence the start lag is 6-T6. Figure 14 shows the start lags calculated for each movement at each junction. (Note that f6 may be greater than s is there is a substantial flare or if the initial discharge flow falls off for any other reason. In this case some start lags could be negative.)

4.7 Routeing

4.7.1

For TRANSYT it is necessary to estimate for each link the proportion of traffic which is feeding it from the upstream links. O-D data was not available therefore the routeing was estimated by assuming that drivers will not turn right through two consecutive junctions if that movement can be achieved by another route. Also, the input flows to each link were obtained from the proportion of the out flow from an upstream link which is fed into each downstream link. For example in Figure 4 the inflow into link 23 (see Figure 15) from the south comes from link 17. The flow from link 17 feeds links 23 and 24 in the proportion of .17/(.17 + .65) and .65/(.17 + .65) respectively. The sum of the inflows to a link need not equal the total flow on the link. TRANSYT automatically increases or decreases by the same proportion all upstream flow curves so that the flow along each link is maintained in TRANSYT computations. The vehicle flows rather than t.c.u. flows have been used to calculate the inflows of turning movements because turning movement flows have already been 'weighted' by a turning movement penalty. Figure 15 shows all the links and feeding links.

4.7.1 Sois

The flows in and out of six sois within the surveyed network of 10 signalled junctions were counted on one day. The main purpose of these soi counts was to establish whether or not there were any significant flows in or out of a link between nodes. Clearly this could affect the platooning of vehicles. It was decided not to treat any of the sois as a "give-way" node (TRANSYT-card type 30) because any inflow from the soi was sporadic and furthermore

FIGURE 14 - START LAGS

(BRACKETED FIGURES ARE INTERGREEN TIME)

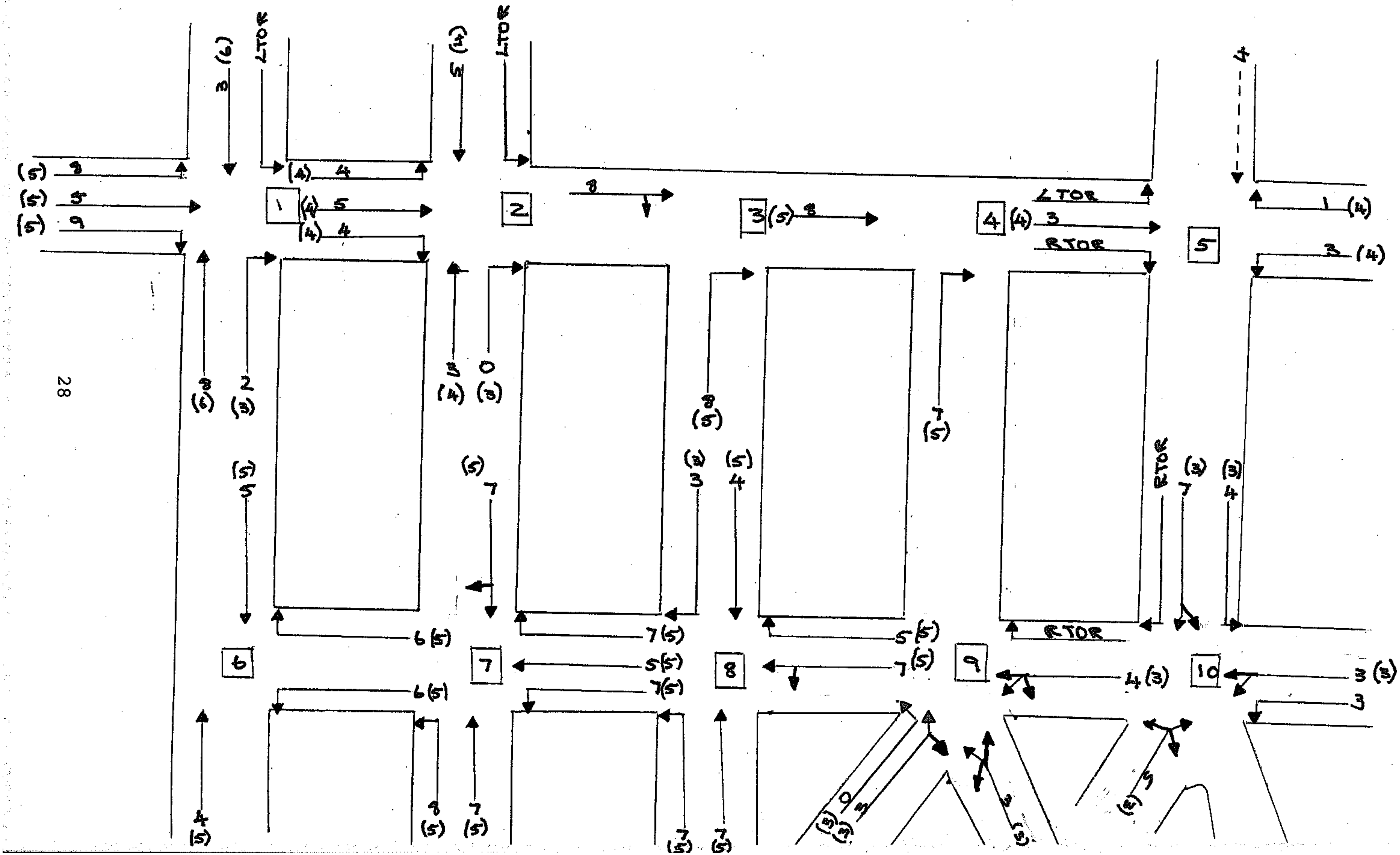
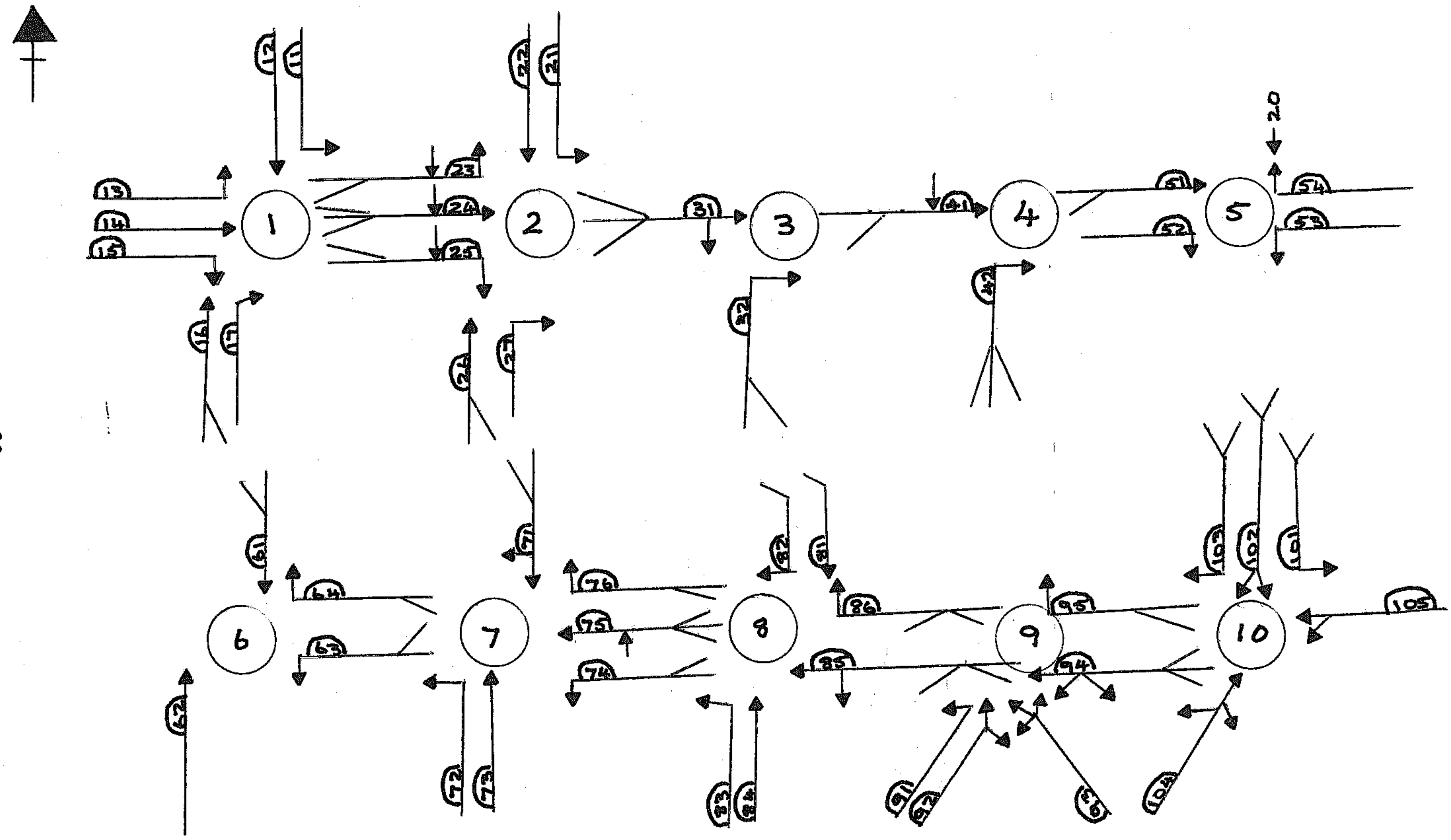


FIGURE 15 - LINK DIAGRAM



the "give-way" behaviour in Bangkok under highly-saturated conditions does not reflect UK "give-way" driving behaviour. Consequently, the most sensible method of dealing with Soi flows was to (a) reduce any internal link flow by the proportion of vehicles leaving the network via a soi and (b) to include the inflow from a soi as a "uniform input flow". (TRANSYT card type 32 column 20.)

(a) The outflow from a link to a Soi affected the following links with an average reduction factor as follows.

Link	Reduction Factor
16	0.78
17	0.78
23	0.72
25	0.95
64	0.83
74	0.73

(No significant outflow of vehicles was recorded at the Soi located on the north side of link 41.)

(b) The inflow from a soi was not considered to affect every "link" across the width of the road. For example the inflow from the soi between junction 7 and 8 was only likely to influence the straight ahead link (75) because a left or right turn would have been more easily accomodated by other adjacent sois. The inflow was calculated as the average between 1530 and 1730 for all vehicles. However the t.c.u. value of each flow depends upon the type of link into which vehicles feed. In other words a "uniform flow" into a left turning link has been multiplied by the t.c.u. value of a sharp left turn (i.e. 1.26) in order to be compatible with the internal link flow.

Link	Average Flow (All Vehicles)		t.c.u./hr	Type of Link
23		(99	103	left turn
24		(466	187	straight
25	706	(141	117	straight
41		(120	100	straight
75		(220	182	straight

5. Intergreens

The standard intergreen in Bangkok is 5 seconds comprising two seconds all-red after 3 seconds amber. However because of either particular stage sequences or faults in the hardware some differences in the lengths of intergreens were detected. Figure 2 shows the signal stage and length of intergreens at each junction.

6. g/c Ratio

Under police control cycle times vary over a given period but the ratio of effective green divided by cycle time remains relatively constant (±4%). The g/c ratio for the TRANSYT recommended signal timings should not differ very much from police control. Table 3 shows the average g/c ratio recorded between 1600 and 1730 at each junction. The average cycle time at junctions along Bamrungmuang Road (junctions 1 to 5) gradually increase in the direction of traffic flow (i.e. eastwards) towards junction 5 (i.e. the critical junction for the entire network), where police operate an average cycle time of 6 minutes. Junctions along Luang Road are relatively more consistent with a cycle time close to 2 minutes. (Note that junctions 6 to 10 are less frequently under police control.) A common cycle time of 120 seconds seemed to be the most appropriate for, at least, the initial TRANSYT runs, although a cycle time of 180 seconds with double-cycling at some junctions could also be suitable.

7. Traffic Composition and Junction Throughput

Table 4 shows the number of vehicles at each junction for each of the four classifications. The grand total for the network demonstrates that the proportion of motorcycles in this area of Bangkok is 38.3% which is very much higher than in British cities.

The average throughput at each junction is 5,950 vehicles (including motorcycles) per hour. The throughput at junctions along Luang Road are consistently close to each other. Junction 5 on Bamrungmuang Road has the highest throughput of nearly 10,000 vehicles/hour, but all junctions along this road present more problems than Luang Road junctions because of the heavy eastbound movement in the evening peak and relatively few cross-movements (ie junctions 3 and 4 and T-junctions and therefore the entire inflow from the south feeds into the western approach to junction 5).

8. Cruise Times

Cruise times or link speeds are required for TRANSYT data input on each link. Either the undelayed cruise time or speed can be entered. Figure 16 shows the average speeds and times from two or three runs in a survey car through the network links during the off-peak.

9. Link Flows

The flows on every link in terms of t.c.u./hour can be computed from the turning movement proportions; input flows; link inflows; t.c.u./veh. ratio, and soi adjustment and then entered into the TRANSYT Data Input procedure. Figure 17 shows the hourly flow rate for the peak period 1615 to 1645.

Table 3 Effective Green and Cycle Time: 1600-1730

Junction	Average Cycle Time	No. of Cycles	g1	g2	g3	g1/c	g2/c	g3/c
1	153.0	35	67.9	38.7	38.4	0.44	0.25	0.25
2	129.8	42	56.5	50.7	17.5	0.44	0.39	0.13
3	169.8	32	111.5	52.3	-	0.66	0.31	-
4	262.3	20	192.8	63.5	-	0.74	0.24	-
5	361.1	15	198.5	128.8	26.2	0.55	0.36	0.07
6	118.7	46	60.2	52.5	-	0.51	0.44	-
7	181.4	29	91.6	83.8	-	0.51	0.46	-
8	105.0	52	47.0	37.4	13.6	0.45	0.36	0.13
9	105.2	52	30.9	27.2	44.0	0.29	0.26	0.42
10	120.0	44	49.9	31.0	36.1	0.42	0.26	0.30

Table 4 Traffic Mix - 1530-1730

JCT	TOTAL	CAR	%	MC	%	SA	%	LB	%	REMARKS
1 (070)	11350	5799	51.09	3875	34.14	1348	11.88	328	2.89	
2 (044)	15941	7642	47.94	5837	36.68	1941	12.18	521	3.29	
3 (160)	6626	3161	47.70	2378	35.89	905	13.66	182	2.95	
4 (161)	9226	4971	53.88	3150	34.14	907	9.83	198	2.15	
5 (002)	19156	9039	47.19	7402	38.64	2277	11.89	438	2.29	
6 (114)	12098	5927	48.99	4268	35.28	1511	12.50	392	3.24	
7 (029)	11337	5346	47.16	4397	38.78	1314	11.59	280	2.47	1600-1730
8 (030)	13049	5205	39.89	5950	45.60	1565	11.99	329	2.52	
9 (080)	12425	5256	42.30	5436	43.75	1284	10.33	449	3.61	
10 (112)	7621	3757	49.30	2812	36.90	874	11.47	178	8.33	
T O T A L	118829	56103	47.21	45505	38.29	13926	11.72	3295	2.77	

MC = Motorcycle

SA = Samlor

LB = Lorries and Buses

FIGURE 16 - LINK SPEEDS KMS/HOUR

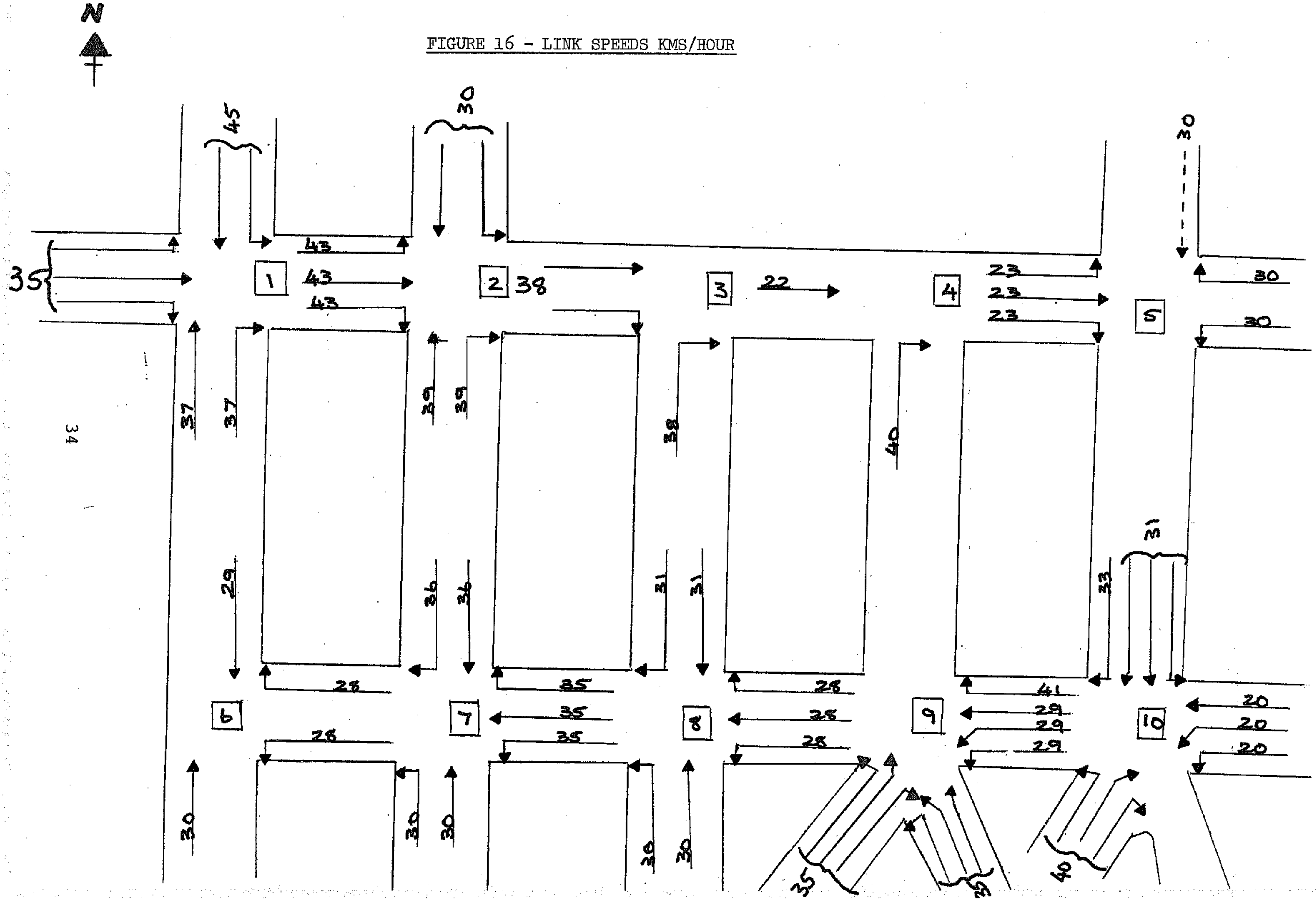
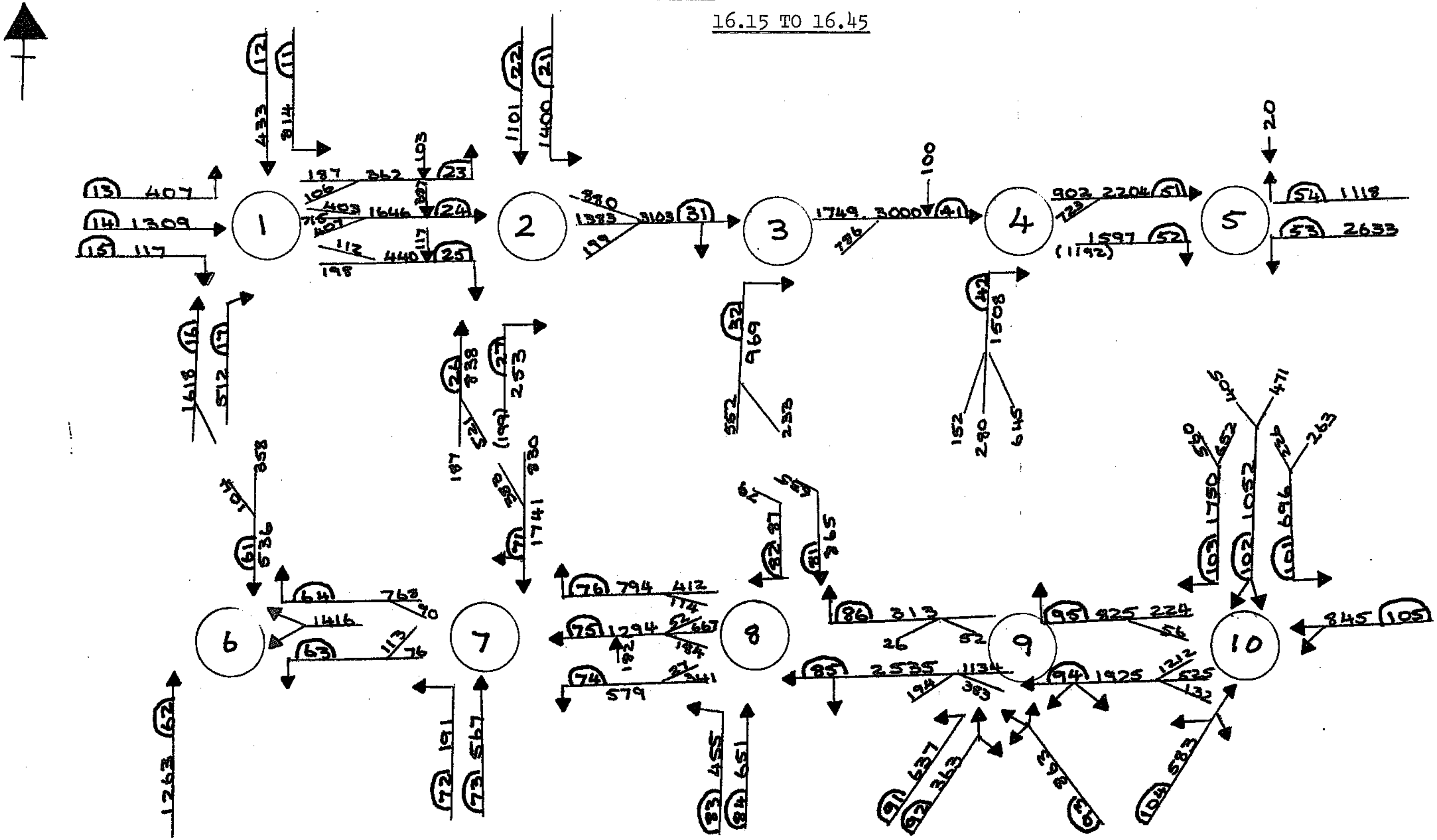


FIGURE 17 - LINK FLOWS TCU/HR

16.15 TO 16.45



These figures for the average input flows along with the saturation flows and start lags constitute the main data input requirements for the TRANSYT computer program. The signal timings recommended by TRANSYT and used in the main experiment will be reported in a later paper.

References

Lee, Man Ho (1986): The Treatment of Motorcycles in Signal Controlled Junctions. MSc Thesis. Institute for Transport Studies, Leeds.

May, A.D. and F.O. Montgomery (1986): Control of Congestion at Highly Saturated Signalised Intersections : Experiments on Rama 4 Road, Bangkok. WP 222. Institute for Transport Studies, Leeds.

Montgomery, F.O. (1986): Control of Congestion at Highly Saturated Signalised Intersections : Survey Methods. WP 220 Institute for Transport Studies, Leeds.

Montgomery, F.O. (1986): Control of Congestion at Highly Saturated Signalised Intersections : Experiments at an Isolated Junction. WP 221. Institute for Transport Studies, Leeds.

Quinn, D.J. (1986): Calculation of Offsets to avoid Junction Blocking in Oversaturated Conditions: A Case Study of Rama 4 Road, Bangkok. TN 224. Institute for Transport Studies, Leeds.

Quinn, D.J. (1986): The Effect of Incidents in Oversaturated Conditions on Rama 4 Road, Bangkok. TN 225. Institute for Transport Studies, Leeds.

Quinn, D.J. (1987): Control of Congestion in Highly Saturated Networks: Number Plate Matching, Pilot Survey. TN 226. Institute for Transport Studies, Leeds.

Quinn, D.J. (1987): Control of Congestion in Highly Saturated Networks: Survey Design and Data Collection. WP 248. Institute for Transport Studies, Leeds.

Quinn, D.J. (1987): Control of Congestion in Highly Saturated Networks: Development of Signal Timings. WP 249. Institute for Transport Studies, Leeds.

Quinn, D.J. (1987): Control of Congestion in Highly Saturated Networks: Incidents and Their Management. WP 250. Institute for Transport Studies, Leeds.

Quinn, D.J., F.O. Montgomery and A.D. May (1987): Control of Congestion in Highly Saturated Networks: Experimental Results and Conclusions. WP 251. Institute for Transport Studies, Leeds.

Vincent, R.A., A.I. Mitchell and D.I. Robertson (1980): User guide to TRANSYT version 8. LR 888, TRRL, Crowthorne.

Wootton Jeffreys (1985): VISTAFLOW User Guide. Wootton Jeffreys PLC 4/1985.