CHAPTER IV

RESULTS AND DISCUSSION

It has been classified the cases to be studied of the model into 9 cases. All cases studied are concerning with the queue that related to many different paramenters. The following explanation and discussion will clarify the studies.

In APPENDIX F, shows the sample of a complete result obtained from the computer programming. The first part of the result starting from NO. OF PHASES - 2, to the TABLE FOR 5 MINS. is resulted from the input data listed in Table 4-1A.

These data are used in TRAF1 Program. For TRAF2 there is only one data for denoting the number of run, for example:

DATA SET 1, QUEUE FROM A TO B.

Note that these data are used for generating the queues and services for intersection A only and it is fixed at this given phase ratio, but the phase ratio at intersection B is varied. Notice that the probability ratio of L-F-R for every bounds using here are all the same, actually it can be any ratio.

The second set of result is for intersection B. The data using here are almost the same as intersection A's, except the following data:

IX = 3; K4 = 2; IPHAS(1) = 55; IPHAS(2) = 65;

and QNOTE is DATA SET 1, QUEUE FROM B TO A.

The last set of result comes from TRAF3 Program. It is the result occurs in the link AB. It is observed that the most effective values of NVEHC is in the range of NVEHC = 2 up to NVEHC = 5 (maximum limit). If NVEHC is too big the internal generation of the distribution will be casued an error. From this part of result the solution for maximum queue; and volumes from intersection A to intersection B and from intersection B to intersection A, as well as the total input-output vehicles and clock time indicated the maximum queues and volumes occur are obtained. Each value of NVEHC gives one solution as shown in the APPENDIX.

Since the simulation method gives only the necessary and brief result, sometime the internal behavior of the simulated model cannot be expressed as a form of result for it is not the objective. To clarify this internal behavior of the model, every step of computation for queues and services at clock time equal to 1 up to 360th second for S-N-E bound has been tabuled in APPENDIX G. The data used in APPENDIX G is almost the same as Table 4-1A, except the phase ratio is 60/60 and IX is 59. In APPENDIX H shows the steps of computation for the 4-PHASE signal, it can be compared to the distinction from both APPENDIX G and H. The data used for this 4-phase signal are the same as the data of 2-phase except the number of phases using here is 4 and IPHAS(1) to IPHAS(4) are 30, 30, 30, 30.

The variables' name in the APPENDIX G and H are described as follow:

CLOCK	is the number of clock time
TRQE	is the turn-right queues for Eastbound
RSEV	is the number of turn-right vehicles that can be served, which having the same bound as the left-hand-side column.
FWQE	is the number of straightforward queues for Eastbound.

FSEV	is the number of vehicles that can be served which having the same bound as the left-hand-side column.
TLQE	is the turn-left queue for Eastbound.
LSEV	is the number of vehicles that can be served which having same bound as the left hand side column.
TRQN	is the number of turn-right queues for Northbound.
FWQN	is the number of straightforward queues for Northbound.
TLQN	is the number of turn-left queues for Northbound.
TRQS	is the number of turn-right queues for Southbound.
FWQS	is the number of straightforward queues for Southbound.
TLQS	is the number of turn-left queues for Southbound.

From these Tables at every clock time, seeing that the change of queue 5, the arrivals coming into the intersection, the services of vehicles crossing the intersection and the number of vehicles waiting in queues can be observed clearly. Even-though the clock time is only up to 360th second not 7200th second, it is sufficient for understanding the function.

The cases to be studied for accomplishing the research are resulted as follow:

Since the first case of study depends on the effective value of NVEHC which stated in the second case, so the value of NVEHC which makes the input arrivals generated by DISCR subprogram having the value close to the total number of vehicles detected by the detector at W-bound is to be considered. The Table 4-1 shows the result of total input vehicles generated by subprogram DISCR with the various values of NVEHC and compare the results with the actual total input from the detector by means of varying the phase ratio of timing singal at intersection B and the phase ratio at intersection A is fixed. There are two ways as shown in Fig. 3-2, for vehicles to flow in the link AB, then the total input vehicles of both directions are to be considered simulatenously so that the most effective value of NVEHC for each phase ratio can be found. The data used in Table 4-1 are the same as the data lisked in Table 4-1A, and IPHAS can be varied. The method of finding the optimal value of NVEHC will be shown as follow:

From Table 4-1, for phase ratio = 45/75 the generated input from A to B is to be considered. Determine the deviation of the generated input from the actual input by substracting them for each value of NVEHC and changing the result to its' asolute value, for example:

for NVEHC = 2 ; the actual input = 2688 vehicles/ 2 hr. and the generated input = 2640 vehicles / 2 hr.

Then, the deviation of the generated input from the actual input is

$|2688 - 2640| = 48$ vehicles / 2 hr.

Similarly, for NVEHC = 3

The deviation = $|2688 - 2643| = 45$ veh. / 2 hr.

for NVEHC = 4

The deviation = $|2688 - 2684| = 4$ veh. / 2 hr.

for NVEHC = 5

The deviation = $|2688 - 2670| = 18$ veh. / 2 hr.

and for the generated input from B to A the deviations are obtained as following tables:

NVEHC	DEVIATION
2	110
3	81
4	16
5	57

Because, at one phase ratio, one NVEHC should give the optimal solution for both directions, so that deviations from A to B must have the relation with the deviations from B to A. Notice that if the deviation of the corresponding value of NVEHC are added which is to be called as effective deviation, it will give the optimal solution. The example is shown below:

NVEHC	DEVIATION FROM (A TO B)	DEVIATION FROM (B TO A)	EFFECTIVE DEVIATIONS
2	48	110	158
3	45	81	126
4	4	16	20
5	18	57	75

From the Table it can be seen that optimal solution for generated input from A to B and from B to A should be at NVEHC = 4, because it gives the minimum effective deviation. Table 4-2 shows all deviations with the various phase ratio from 45/75 to 75/45. The effective deviations for every value of NVEHC are plotted as the relation with phase ratio and NVEHC. It is shown in Fig. 4-1. The optimal value of NVEHC for each phase ratio can be noticed easily from the histogram and it is tabulated as the Table below:

TABLE 4-3

PHASE RATIO	OPTIMAL VALUE OF NVEHC
45/75	4
50/70	4
55/65	3
60/60	4
65/55	4
70/50	4
75/45	4

By using these optimal value of NVEHC, the optimal queue and volume can be found.

Techniques of finding the optimal queue and volume

The results to be considered are tabulated in the following tables: Table 4-4 shows the number of vehicles for maximum turn-left queues from intersection A to B and the maximum turn-left queuês from intersection B to A, with the various phase ratios and various values of NVEHC. 2-phase signal is used for analysis and the data used are the same as previous section which is shown in Table 4-1A. With the same data, the maximum straightforward queues from intersection A to B and from intersection B to A are tabulated in Table 4-5, and the maximum turn-right queues from intersection A to B and from intersection B to A are tabulated in Table 4-6. From the previous section the effective value of NVEHC has already been obtained, therefore the effective maximum queue for each lane can be found by the use of specific NVEHC. For example, from Table 4-4 at phase ratio = 45/75 the maximum turn-left queue from A to B and the maximum turn-left queue from B to A are in the column NVEHC = 4. Then the maximum turn-left queue from A to B is 7 vehicles, and the maximum turn-left queue from B to A is also 7 vehicles. Similarly, other maximum queue can also be found by the same method. From Table 4-3, notice that only the phase ratio = 55 / 65 has the optimal value at NVEHC = 3 for this set of data, the less are at NVEHC = 4. Observing that, even the phase ratio has been changed, the maximum queue in this turn-left lane still has about the constant number of vehicles. It may be assumed that the turn-left queue has no effect with variations of timing. If the probability of vehicles to distribute into the specific lane is higher, the characteristics of the queue may be changed.

(This is the problem that can be studied forward, but for this research, it is sufficient for the work since there are a lot of problem to be studied more). When it is compared with the variations forward lane, shown in Table 4-5, this variation has no any effect to the system. Coming to the Table 4-5, it can be seen that the maximum queues for straightforward lane are varied in a wide range of scale. By using the specific value of NVEHC which has been found from the first section, the maximum value of the maximum queue from A to B is 570 vehicles at phase ratio equal to 45/75, but the minimum calue of maximum queue for this direction is only 40 at phase ratio equal to 70/50. The queue increase nearly 15 times from the minimum values. It means that the variation of the phase ratio has much effect to the maximum queue-length for the straightforward lane. But for the maximum queue from B to A, the range of maximum value to the minimum value is not so wide, only 30 to 69 vehicles in deviation. Note that the maximum queue from A to B has started from the big value of queue to the minimum value of queue, at the same time the queue from B to A has the value from the minimum value to the maximum value, because of this reason it should have one optimal value at the specific phase ratio. From this idea, the relation of all phase ratio with the maximum queue for both directions has been ploted, and it is shown in Fig. 4-2. Seeing that curve a, the maximum queue from A to B is varied in a large scale for different values of phase ratio, but curve b, the maximum queue from B to A is the straight line by approximation. For the optimal condition, the solution for the maximum queue should have the queues in both directions about the same value or in the other word the queues in both directions are balanced. It is observed that, the both directions of queues are intersected at one unique point between phase ratio 65/55 and phase ratio 70/50. That means the optimal timing should exist between these phase ratio. If it is needed to find the exact solution of timing, the phase ratio between 65/55 and 70/50 would be tried.

From Table 4-7 the maximum volumes waiting inqueue between the intersections have also been used, in plotting as shown in Fig. 4-3, their curves have the same characteristic as the curve plotted in Fig. 4-2. It is proved that the straightforward lane is the most effective lane to be controlled by the timing signal. And the optimal volume for this result occurs at the phase ratio about 65/55, it is close to the maximum queues.

From the graph in Fig. 4-2, the balanced queue for the optimal timing is about 60 vehicles. Finally this optimal queue is converted to the unit length of the street, if there are the space left in both directions of the link AB, it means that the capacity of the street is bigger than the tested model, then the cycle of timing signal is increased by trying some more value of timing cycle with the constant phase ratio as the optimal one. By this way the suitable optimal timing cycle for the model can be obtained. For the case that the optimal queues obtained are bigger than the capacity of the street, the cycle of timing signal should be decreased by trying the lower value of cycle until the most suitable value of timing cycle is obtained. The Table 4-8 shows the various value of timing cycle with the constant phase ratio of the optimal queue-length obtained before. Seeing that when the timing cycle is in creased, the maximum queues and maximum volumes as well as the input vehicles at the detector also increase. This proves that all asumptions defined before are reasonable.

From Table 4-9, it is the result of the output or the number of vehicles that can be served through the given 2 hours period between intersection A and B. The results are selected for tabulating only the values which correspond to the optimal value of NVEHC determined previously. It is observed that the more output will be served in both directions when the phase ratio id increased. Seeing that the input at the direction from A to B is constant but the input from B to A is increased when the phase ratio is increased. The result has been plotted in Fig. 4-4.

The clock times indicating the maximum queue occurred for each lane between the intersections have been shown in Table 4-10, notice that for the turn-left lane and turn-right lane, the maximum queue may occur in any time, but for the straightforward lane the maximum queue would oftenly occur nearly the end of the period, this because the queue will be accumulated all the time until coming to the end of the period. Denote that, the clock time shown in Table 4-10 are not the exect time for the maximum queue occur, since the delay time of vehicles moving from A to B or from B to A is not taken into account yet. The delay time is the unknown unless the length of the street and the speed of vehicles, which is assumed constant, are given. Table 4-11 is also the result for clock time, but this is shown the maximum volume occurs.

The Results For Basic Intersection

For the case of basic intersection, the characteristics to be studied are the variations of queue-length for each bound, and its' distribution intersection B is used for studying pattern at detector W-bound. From Table 4-12, it is observed that for the various values of phase ratio, the turn-left queue and turn-right queue have no effect from the variations, only the straightforward queue that has an effect. Clarifying that the main effect which cause the variations of phase ratio has much effect to the straightforward queue is because of the probability of lane-distribution into the straightforward lane given is very high compared to the other lanes. The relation between the phase ratio and the maximum queue for this lane has been plotted in Fig. 4-5, seeing that the phase ratio which make the queue balancing is about 60/60 or the ratio of 1:1. The case for balanced queue in every bound may taken into account as the optimal case if it is desired. The amout of queues and volumes for the basic intersection are nearly the same, by comparing the result from Table 4-12 and Table 4-13.

In Table 4-14, the total input and output vehicles for every bound of intersection B are tabulated with the variation of phase ratio. The result has been plotted, as shown in Fig. 4-6, seeing that the input are nearly constant, but the output are varied during the phase ratio is changed. From the curve shown in Fig. 4-6, it can be seen that the total output for Southbound and Northbound decrease when the phase ratio is increasdd but for Eastbound the output increases during the phase ratio is increased. Notice that the curve for the total vehicles input in Westbound has the similar characteristics as Eastbound's.

In Fig. 4-7a, Fig. 4-7b and Fig. 4-7c, show the frequency pattern of the input vehicles at the detector placed in Westbound, with the various values of phase ratio of intersection A and B which have the same input data as the former section. Fig. 4-8 shows the sample result of frequency distribution pattern and the accumulative probability of 1-min, 5-mins and 15 mins. interval of counts from the result of intersection A. According to the real world data shown in chapter III, the 5-mins count is used for generating the arrivals between intersections.

Though the input IX of the random generation of RANDU subroutine can be any odd positive integer, according to the probability distribution theory any input of IX should give about the same distribution form, maximum queues, volumes and total vehicles input and total vehicles output at a constant phase ratio. The results of this case are tabulated in Table 4-15, Table 4-16 and Table 4-17. It is observed that the maximum queues, volumes and total input-output vehicles are not exectly the same, but their values are around that. In the practical work, if the specific phase ratio is to be used, it must be tested for suffifient values of IX first, then using the statistical method solves for the mean values and the standard deviations of them. The frequency pattern for various values of IX are shown in Fig. 4-9. Table 4-18 shows the maximum queues and vaticles input at W-bound for different probability ratio of the vehicles distribution into a specific lane, seeing that the values of maximum queues for each lane are corresponding to the probability ratio of L-F-R but the input into W-bound can be varied to any higher or lower values.

4-phase application

The results discussed in former section are all about 2-phase signal control, because the 4-phase signal can also be applied to the model. Then, the 4-phase signal data are used for testing. The data used in 2-phase signal in Table 4-1A, except the number of phases and phase period, are used in this section. If is not necessary to discuss about the variation of the queues and volumes again, since the former section contain a lot of this result and discussion. Only the case of the variation of number of lanes has not been discussed yet, therefore it is considered for studying. The maximum queues for each lane of S-N-E bounds with the variation of lanes have been tabulated as shown in Table 4-19. Seeing that if the maximum queue of 3-lane street is used as the reference, the result from the straifhtforward queue for S-bound shows that when the number of lanes is increased to 4 lanes the number of queue decreases its' value about 88.70 % with respect to the reference queue. When the number of lanes is 5 the percentage of decreasing is up to 99.0 %. Notice that it is very high for the decreasing of queues when the number of lanes is increased. The result of N and E bounds are also the same. But for the turn-left queues and turn-right queues still have about constant values, no changing even the number of lanes is changed. The maximum volumes in queue are also have the high percentage of decreasing when the number of lane is increased, which is shown in Table 4-20. In Table 4-21 shows the results of the total input-output vehicles for each bound with the change of lanes, seeing that the input values are nearly constant, but the output values are varied, the percentage of decreasing is shown in Table 4-22. The flow patterns of this case are shown in Fig. 4-10. It can be concluded that the number of lanes is the most effective and sensitive variable for the traffic system.