GENERALIZED LEVEL OF SERVICE (LOS) FOR WEAVING SECTION OF CONVENTIONAL ROUNDABOUT

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Abstract - This paper presents a development of weaving section flow model in weaving area of conventional roundabout. The outcomes were very satisfactory, indicating that the parameters considered were very crucial and relevant. Integration of weaving section capacities (QWSF and QP) enable LOS chart be developed that suit Malaysia conventional roundabout (design and operational). This being specified because of the constraint/limitation of using Arahan Teknik (Jalan) model and operational characteristics of the developed model (TISG). The main limitation of Arahan Teknik (Jalan) model in estimation capacity analysis is because it applies geometric design parameters without considering the traffic parameters such as flow and gap, and this may be considered an optimistic or ideal scenario. However, before a roundabout to be constructed, its maximum flow needs to be anticipated in order to reduce the probable traffic congestion. It can be anticipated that the Arahan Teknik (Jalan) model only can determined its capacity of weaving section based on its length of weaving section L, width of weaving section W and average entry width e. The resolution of congestion problem at weaving section is to get better estimation of flow and anticipated LOS at weaving section area under different range of traffic condition regimes such as 'weaving section flow' and 'ideal safe gap'. It will produce different sensitivity of the input parameter of the calibrated models in estimating the respond parameter QWSF which is used as the measures of effectiveness in weaving area of conventional roundabout. With adequate knowledge anticipated flow and using the developed LOS the appropriate design parameters are deduced to suit the target LOS. Thus, this section has developed a 'tool' for practicing traffic engineer and the procedure of using it had been deliberated through stepwise example.

Keywords - Weaving Section Flow; Weaving Section Capacity; Conventional Roundabout

I. INTRODUCTION

The process of deducing LOS using weaving section flow (QWSF) model is based on the sensitivity analysis of non-conflicting flow (QNCF), conflicting flow (QCF) and ideal safe gap (TISG). Generally, these variables are needed as an input parameter to determine QWSF as shown in Eq. (1). Several graphs were created based on the equation given in Eq. (1) for estimation of the weaving section flow at weaving section of conventional roundabout.

$$QWSF = 2700 + 0.000028\,(QNCF^{3/2}.\,QCF) - 1.22\,(TISG.\,QCF) \quad (1)$$

II. RELATED WORK

In the following section, weaving section flow model developed from this study and model from [1] which adopted and simplified from those of Wardrop's formula were examined, analyzed and integrated. As had been noted earlier that [1] capacity model solely consider geometrical parameters; The relationship between QWSF and Qp in predicting the weaving section flow (parameter of non-conflicting flow, conflicting flow and ideal safe gap) and weaving section capacity (parameter of weaving section length L, width of weaving section W and average entry width e), the integration can be made to both models in order to get more information of the traffic volume conditions at the weaving section of conventional roundabout in relating to geometric design and traffic performance. The following sections and paragraphs would explain the development of LOS chart, as a result of the combination of models QWSF and QP. Subsequent to the development of the LOS chart, the following paragraphs would provide application examples of the models and the weaving section flow level of service chart.

Type of Models	Equation Models for predicting at weaving section, Q(pcu/hr)
Model developed from this study Eq. (1)	$Q_{wsf} = 2700 + 0.000028\,(Q_{ncf}^{3/2}.\,Q_{cf}) - 1.22\,(T_{isg}.\,Q_{cf})$
Arahan Teknik (Jalan) 11/87 (1987)which was adapted from Wardrop (1957) model.	$Q_p = \dfrac{160W\left(1+\dfrac{e}{W}\right)}{1+\left(\dfrac{W}{L}\right)}$

Table.1. Model for Predicting Weaving Section Flow

The output from model developed in this study QWSF and the model from [1] QP is showed in Table 1. The variables from Weaving Section Flow (QWSF) model are QNCF, QCF and TISG and from [1] QP are W (width of weaving section), e (average

entry width) and L (length of weaving section).These geometrical values were site measurements (study area). Although both models do not use same parameters, but the findings or outputs are based at weaving section of conventional roundabout. In Figure 1, basically it shows that the weaving section flow (QWSF) is almost in the range of capacity of weaving section from [1] (adapted from [9] model) and other studies of [4], [3], [8] and [2] which depends on the value of non-conflicting flow (QNCF), conflicting flow (QCF) and ideal safe gap (TISG). Based on studies from [6], the studies and the results show that increasing of weaving section flow (QWSF) had effect the decreasing of the ideal safe gap (TISG). Figure 2 describes the geometric parameters of conventional roundabout from previous researchers where the minimum, mean and maximum values are evaluated from the studies of [4], [1] which adapted from [9], [3], [8] and [2].

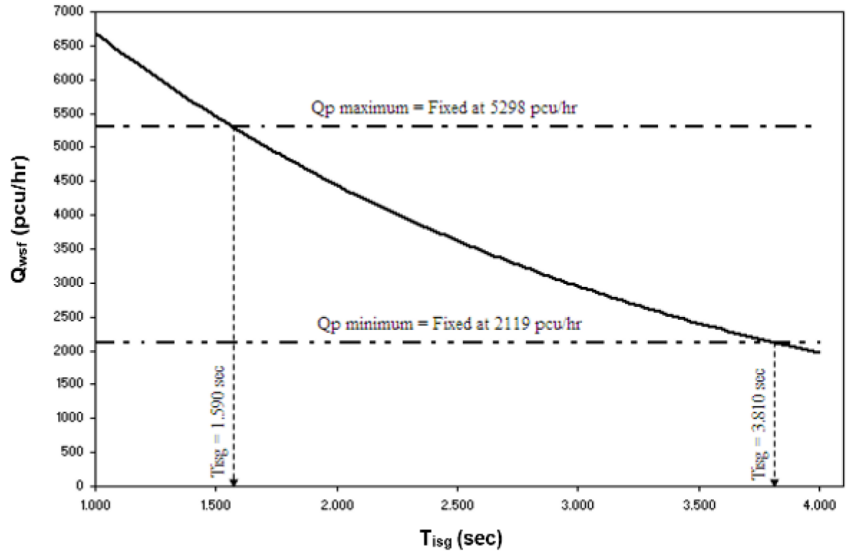


Figure 1: Output of integration from Trial values

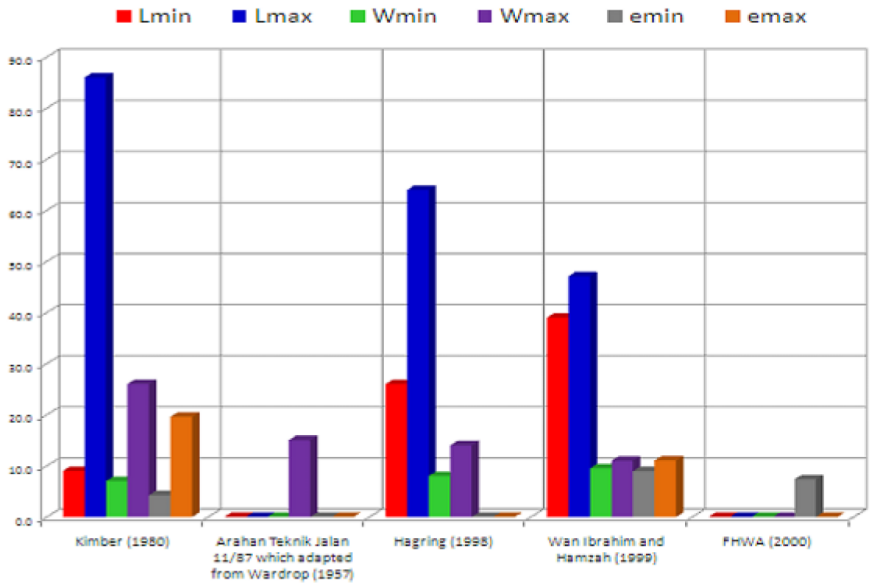


Figure 2: The Geometric Parameters of Roundabout from Previous Researchers

III. RESEARCH METHODOLOGY

Table 2 shows the identifying LOS that is based on QWSF versus TISG where the justification is made through sensitivity analysis output [5]. From the sensitivity analysis, there are direct relationship of QCF and the TISG. This is because when the QCF occurs, the TISG is also occurs. Consequently, the TISG can be used as MOE for the QWSF which does really measure the level service of the weaving section of conventional roundabout. In other hand, it also has direct relationship with driver's expectation especially when the QCF occurs is actually the TISG exist. The calculations in determining the types of LOS with respect to TISG such as A, B, C, D, E and F, were based on the application of Table 3 from [7].

The basis of using Table 3 in deducing LOS is because the Eq. (2) (delay equation) that uses the parameter flow and time period which almost similar with the Eq. (1). The assumption made is that the delay incur is related to the available time gap to merge /cross traffic stream. Thus, the range of delay (unit in second) at entry (Table 3) is adapted to be applicable for possible TISG (unit in second) at the weaving section of roundabout. The TISG is based on Figure1 in the range of 1.590 sec to 3.810 sec. These minimum and maximum TISG values were extracted or obtained through integration of graphs plot of weaving section flow (QWSF) of the developed model and weaving section capacity (QP) of [1] that adapted from [9]. As an example, to determine LOS A, B, C, D, E and F with respect to TISG at the weaving section of conventional roundabout, the basic mathematic calculation are:

$$\text{For LOS A} = \left[\frac{10}{50}\, x\, (3.810 - 1.590)\right] + 1.590 = 2.034$$

$$\text{For LOS B} = \left[\frac{15}{50}\, x\, (3.810 - 1.590)\right] + 1.590 = 2.256$$

$$\text{For LOS C} = \left[\frac{25}{50}\, x\, (3.810 - 1.590)\right] + 1.590 = 2.700$$

$$\text{For LOS D} = \left[\frac{35}{50}\, x\, (3.810 - 1.590)\right] + 1.590 = 3.144$$

$$\text{For LOS E} = \left[\frac{50}{50}\, x\, (3.810 - 1.590)\right] + 1.590 = 3.810$$

$$\text{For LOS F} = \left[\frac{50}{50}\, x\, (3.810 - 1.590)\right] + 1.590 = 3.810$$

Thus, the indicator of LOS A, B, C, D, E and F which based on TISG is used as MOE for the weaving section which does give a measure of level of service of the section (see Table 2). Comparing with previous LOS studies from [7], LOS is measured using density, delay, or travel time, etc. Although all of those MOE has direct relationship with driver's expectation, TISG seemed to be also contributing an effect on the driver's movement either through QNCF or QCF (ideal safe gap occur) which translated into LOS in the field using video capture technique. Furthermore, nowadays the technology of using real time application software using video capture is easy to be apply as when compare with last five to ten years before.

LOS	Calculation	T_{isg} (second)
A	2.034	0 – 2.034
B	2.256	> 2.034 - 2.256
C	2.700	> 2.256 - 2.700
D	3.144	> 2.700 - 3.144
E	3.810	> 3.144 - 3.810
F	3.810	> 3.810

Table 2 New LOS of TISG at Weaving Section of Conventional Roundabout

IV. RESULT AND ANALYSIS

Table 3 shows the different ratio of conflicting flow to non-conflicting flow demand. These ratios are not fixed but those values were determined based on the minimum, mean and maximum of QCF and QNCF. For example, to determine the minimum ratio of conflicting flow to non-conflicting flow demand:-

QCF minimum = 90 pcu/hr
QNCF minimum = 1500 pcu/hr
Therefore:
Ratio of QCF: QNCF = 90 : 1500
= 0.06

Types	Q_{cf}	Q_{ncf}	Ratio of $Q_{cf} : Q_{ncf}$	Remarks
low of weaving section flow	90	1500	0.06	Low
	180	3000	0.06	Low
	270	4500	0.06	Low
medium of weaving section flow	135	1500	0.09	Moderate
	270	3000	0.09	Moderate
	405	4500	0.09	Moderate
high weaving section flow	180	1500	0.12	High
	360	3000	0.12	High
	540	4500	0.12	High

Table 3 The ratio of conflicting flow to non-conflicting flow demand

As the results, from Table 3, the ratio of conflicting flow to non-conflicting flow demand is determined from 0.06 until 0.12 based on minimum, mean and maximum of QCF and QNCF. Table 3 signifies the type of low, medium and high weaving section is mentioned in order to classify the differences of ratio QCF and QNCF accordingly. Graphically, Figure 3 illustrates the situation in low weaving section flow where the ratio of conflicting flow to non-conflicting flow demand is 0.06, Figure 4 illustrates medium weaving section flow where the ratio of conflicting flow to non-conflicting flow demand is 0.09, and Figure 5 illustrates high weaving section flow where the ratio of conflicting flow to non-conflicting flow is 0.12. The overall chart for level of service based on Eq. (1) is showed in Figure 6. Details explanation on the individual figures are as follows; as to Figure 4 and Figure 5 show the weaving section flow QWSF for medium and high weaving section flow are reached QP minimum when the ideal safe gap TISG are 3.790 sec and 3.600 sec respectively. The weaving section flow QWSF for medium and high weaving section flow also reached QP maximum when the ideal safe gap TISG is 1.300 sec and 1.650 sec respectively. Thus, this indicate that the situation where ratio of conflicting flow to non-conflicting flow was medium and high, the ideal safe gap increases for QP(max) and decreases for QP(min) and this contribute to the limitation of weaving section flow of the weaving area. In line plot of Figure 6

shows that there are intersect line at ideal safe gap of 3.090 sec when the ratios of conflicting flow to non-conflicting flow are varying at 0.06, 0.09 and 0.12 according to minimum, mean and maximum descriptive statistic value. Thus, the findings indicate that the certain amount of ratio QCF to QNCF can define same values of ideal safe gap TISG. Regarding with weaving section flow and ideal safe gap, there have a relation between QCF, QNCF and TISG where if the conflicting flow occurs, the non-conflicting flow and ideal safe gap are also occurs. In this situation, the movement of flow is under stable flow until it reached the maximum ratio of QNCF and QCF. As the result, the ideals safe gap also needs to take a long time to accept the results of QCF and QNCF at their maximum ratio. Furthermore, this can be separated into two types of weaving section flow which are stable flow for ideal safe gap less than 3.090 sec and approaching to unstable flow for the ideal safe gap greater than 3.090 sec. As for the determination of LOS and use Figure 3 as example; if a person wants to determine the LOS at weaving section flow (let say QWSF is equal to 3200 pcu/hr that obtained from the fieldwork results) of conventional roundabout using the ratio of conflicting flow to non-conflicting flow equal to 0.06 (i.e. where conflicting flow is 181 pcu/hr and non-conflicting flow is 3019 pcu/hr). Consequently, the ideal safe gap is found to be 2.500 sec that result in LOS C. From this example, the steps on how to determine the value from the ratio of conflicting flow to non-conflicting flow demand which equal to 0.06 of 3200 pcu/hr, the calculation is:

QWSF = QCF + QNCF … (A)
QCF: QNCF = 0.06
QCF = 0.06 QNCF … (B)
Put (B) in (A):
QWSF = 0.06 QNCF + QNCF
If QWSF = 3200 pcu/hr under ratio of 0.06,
Therefore:
3200 = 0.06 QNCF + QNCF
3200 = 1.06 QNCF
QNCF = 3019 pcu/hr
QCF = 3200 – 3019 = 181 pcu/hr

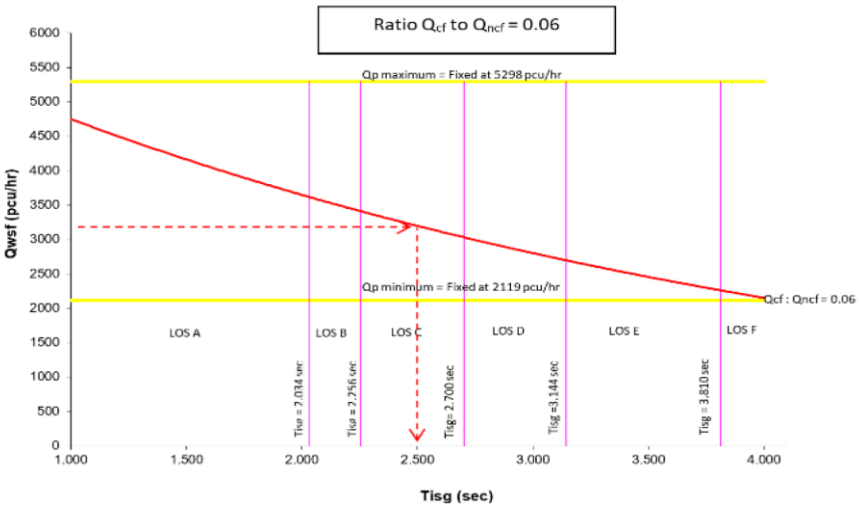


Figure 3: LOS Chart for Weaving Section with Ratio QCF to QNCF Equal to 0.06

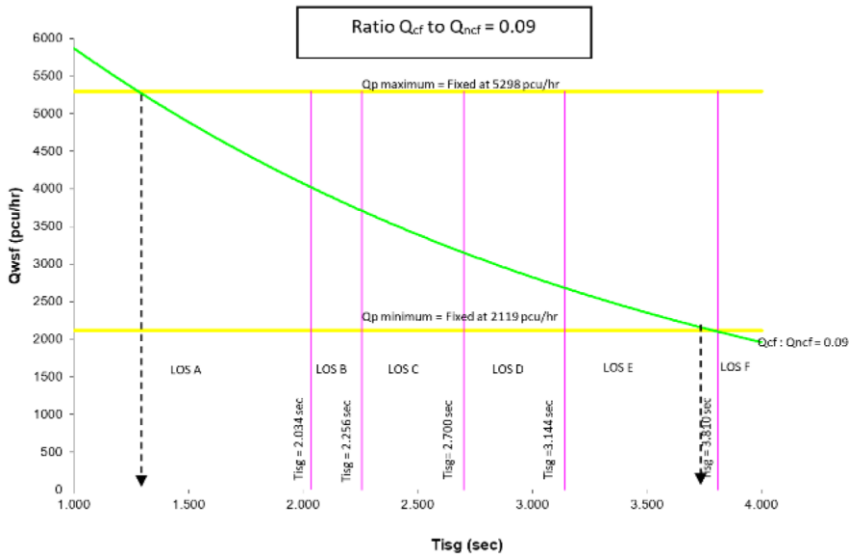


Figure 4: LOS Chart for weaving section with ratio QCF to QNCF equal to 0.09

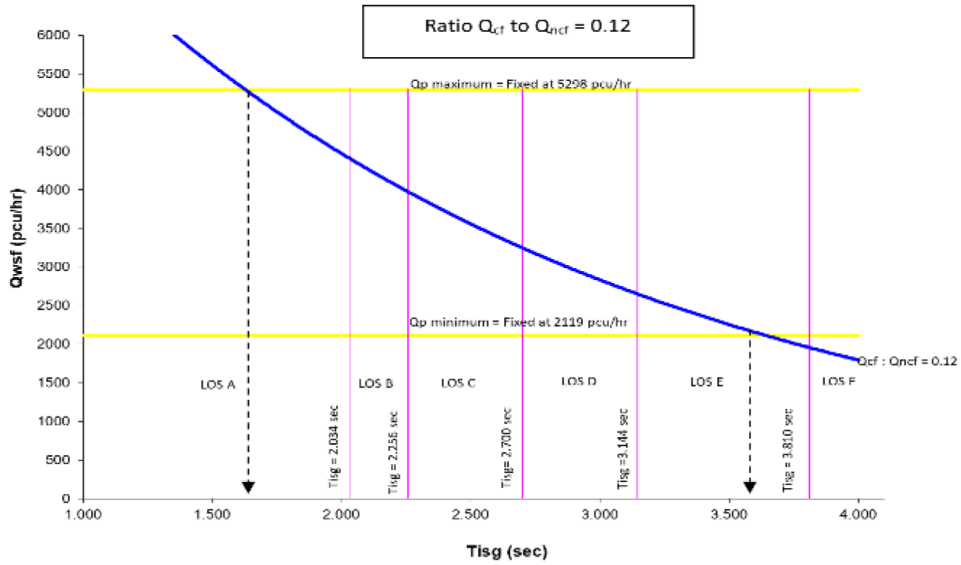


Figure 5: LOS Chart for weaving section with ratio QCF to QNCF equal to 0.12

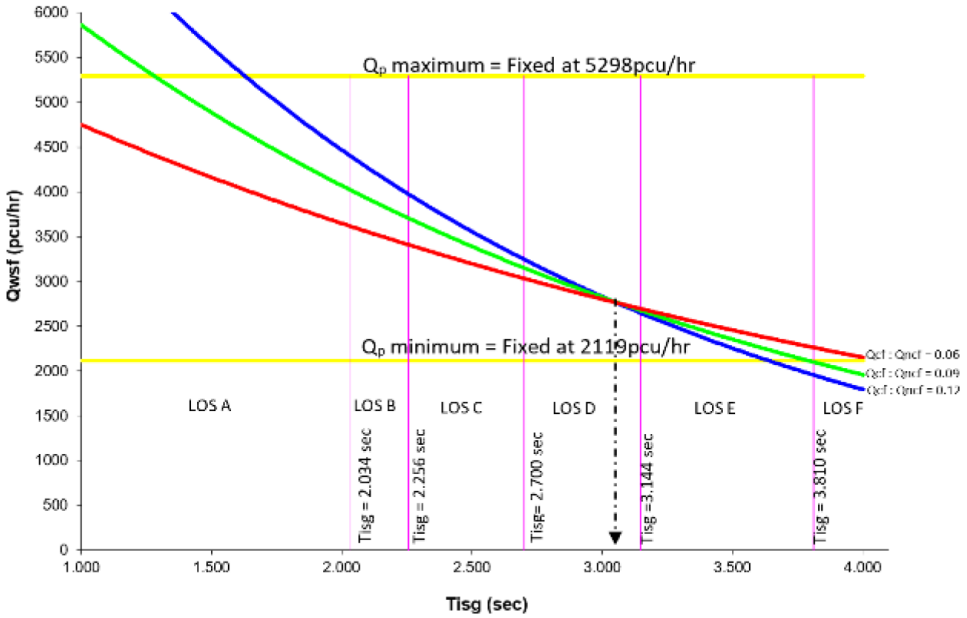


Figure 6: LOS Chart for weaving section flow QWSF

The effect of ideal safe gaps to weaving section flow variations that were obtained from fieldwork can generate different LOS with three different ratios of conflicting flow and non-conflicting flow. Back to the previous example, after the value of weaving section flow (let say QWSF is equal to 3200 pcu/hr that was obtained from the fieldwork), the ratio of conflicting flow QCF and non-conflicting flow QNCF (where QCF : QNCF = 0.06) was defined, then the length (L), width (W) and average entry width (e) of weaving section can be deduced from charts as 50 m, 12 m and 11.5 m respectively (see example for determining length (L) in Figure 7). Thus, the weaving section flow that was obtained from the fieldwork enable prediction be made in terms of the ratio of QCF and QNCF, the ideal safe gap (TISG), the LOS and also the associated geometrical design parameters dimensions of the weaving section. The LOS chart together with geometrical section that shown in Figure 8 can be used to deduce roundabout design that suit targeted weaving section capacity.

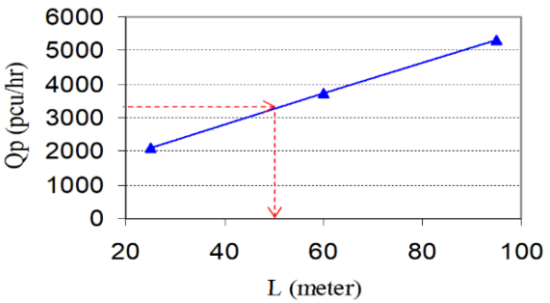


Figure 7: Example for determining length (L) at weaving section

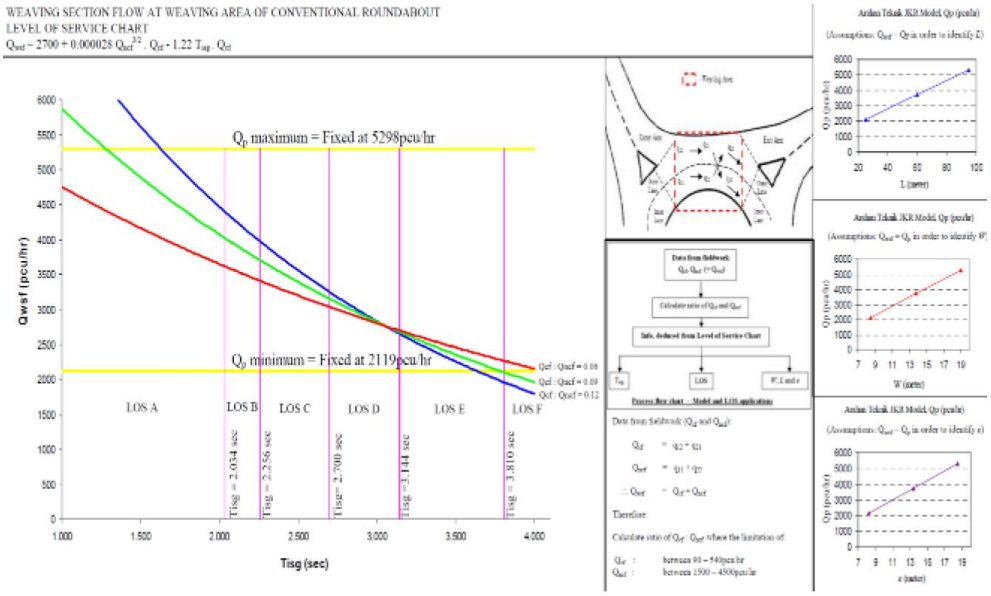


Figure 8: The LOS chart together with geometrical section

V. APPLICATIONS OF THE DEVELOP MODEL AND LOS CHART

Roundabout is where three or more roadways meet and change of directions made through circulatory clockwise movement. This form of intersection is effective when approaches flow is about the same and below capacity. Vehicles do not have to stop and reasonable travel speed is expected, thus reduce delay.

However, the issue of imbalance traffic flow does sometimes occur. It is interesting to say that, study at the weaving section of conventional roundabout is relevant and crucial in Malaysia context especially under two conditions; the practical capacity is being calculated solely based on geometric parameters and secondly, Malaysian traffic behavior (manoeuvrability at weaving area) are much to be desired. Thus, effectiveness of movement at the weaving section would have some influence on the effectiveness of the whole system especially on the issue of imbalance traffic flow on the weaving section that causes congestion on roundabout legs, hence affected the capacity of roundabout. Therefore, the developed model can be used by traffic engineers to evaluate the effectiveness of the operation at weaving section of conventional roundabout and assist the roundabout designers and planners to adjust the geometry of weaving section such as the length and width of weaving section lane in order to obtain and produce the desired level of service (LOS) at weaving section of conventional roundabout. As such, the congestion issue on the roundabout legs is also being taken into consideration in this research. Simplified procedure to determine LOS and relate to geometric design parameters can be explained and illustrated through example in the following paragraph below. A process flow chart shown in Figure 9, explained the procedure to use the developed model/formulation in actual traffic engineering application in term of the type of data that need to be collected such as QNCF and QCF (=QWSF) . Ratio of QCF and QNCF needs to be computed in order to select the appropriate line graph. Value obtained within speculated range needs to be interpolated. Interception between ratio of QCF and QNCF with QWSF, the value of TISG and LOS are obtained from the chart (see Figure 8). At the same time, from the fieldwork data of QWSF, the geometric design of weaving section of conventional roundabout such as W, L and e can be deduced from the chart (see Figure 8). With the assumptions: QWSF = QP it is possible to identify W, L and e. As for operational monitoring purposes, the results obtained (QCF and QNCF) would relate to the appropriate design parameters. These design parameters can be checked / compared to the existing geometric design values. Thus, the model and LOS chart that have been developed have practical applications and very useful tool (design and operational) to practicing traffic engineers and researchers (investigators).

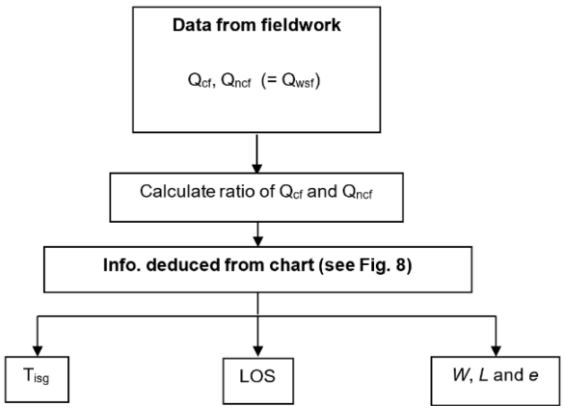


Figure 9: Process flow chart - Model and LOS applications

VI. SUMMARY AND CONCLUSION

The developed model for weaving section flow in weaving area of conventional roundabout had undergone a rigorous sensitivity analysis to evaluate and determine the sensitivity of the MOE with respect to a change in each predictor parameter. The outcomes were very satisfactory, indicating that the parameters considered were very crucial and relevant. Integration of weaving capacities (QWSF and QP) enable LOS chart be developed that suit Malaysia conventional roundabout (design and operational). This being specified because of the constraint/limitation of using[1] model and operational characteristics of the developed model (TISG). The main limitation of [1] model in estimation capacity analysis is because it applies geometric design parameters without considering the traffic parameters such as flow and gap, and this may be considered an optimistic or ideal scenario. However, before a roundabout to be constructed, its maximum flow needs to be anticipated in order to reduce the probable traffic congestion. It can be anticipated that the [1] model only can determined its capacity of weaving section based on its length of weaving section L, width of weaving section W and average entry width e. The resolution of congestion problem at weaving section is to get better estimation of flow and anticipated LOS at weaving section area under different range of traffic condition regimes such as 'weaving section flow' and 'ideal safe gap', it will produce different sensitivity of the input parameter of the calibrated models in estimating the respond parameter QWSF which is used as the measures of effectiveness in weaving area of conventional roundabout. With adequate knowledge anticipated flow and using the developed LOS the appropriate design parameters are deduced to suit the target LOS. Thus, this section has developed a 'tool' for practicing traffic engineer and the procedure of using it had been deliberated through stepwise example.

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