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The development of microscopic traffic analysis software "Road Canal"

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Abstract

KAJI is a traffic analysis software based on Indonesian Highway Capacity Manual, IHCM (1997). KAJI has some weaknesss. It has a quite basic graphical presentation and some incompatibility with recent operating system. Variables e.g. adjustment factors were fixed. The output of KAJI is presented in tables instead of diagrams. This research will develop new software (Road Canal) to analyze microscopic traffic condition and only concentrate on signalized intersection in this phase. IHCM (1997) adjustment factors were stored, but entering other values is possible. It was developed using Visual Basic with tool bar and icon style. The data is inputted through text boxes.

*Keywords:*signalized intersection, software, Indonesian Highway Capacity Manual, KAJI, macroscopic traffic condition

1. Introduction

Intersection analysis is the most important analysis on microscopic study. Today intersection analysis in Indonesia is based on Indonesian Highway Capacity Manual (IHCM) 1997. The available traffic analysis software based on IHCM (1997) is called KAJI. However, KAJI was developed using DOS as the operating system and has some weakness. The graphical presentation of KAJI is quite basic, i.e. picture using ASCII code. There are also some problems if KAJI is running on Windows operating system (Windows 2000 or newer). All variables and constants such as capacity adjustment factors were fixed, based on IHCM (1997). This is a bit inconvenient since many parts of IHCM 1997 have already required changes based on present traffic conditions in Indonesia. The output of KAJI is presented in tables and therefore a bit difficult to be understood instantly. Therefore, the objective of this research is to develop a new software to analyze microscopic traffic condition that will be able to overcome the weakness of KAJI but still based on IHCM (1997) with flexibility to enter other values of variables and constants if necessary. This software is called "Road Canal" as an abbreviation of road capacity analysis. In the first phase of its development, only signalized intersection module was developed. For comparison, other similar software was reviewed, i.e. SIDRA 4, SIDRA Intersection 4 and an IHCM (1997) spreadsheet based intersection

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analysis developed by Ahmad Munawar. Road Canal was developed using Visual Basic and using tool bar and icon style to present parts of the software. The data is inputted through text boxes with the use of combo boxes for input with limited range of values. There are also facilities to speed up the analysis of multiple intersections. Values from IHCM (1997) were stored as the defaults but in some cases can be changed with more appropriate values based on the user judgment. The performance of the signalized intersection in terms of degree of saturation, queue length, delay and number of stopping vehicles are presented graphically to enhance the understanding of the signalized intersection performance.

2. Signalized intersection analysis based on IHCM (1997)

According to IHCM (1997), the capacity of a signalized intersection approach can be formulated as follow:

$$C = S\frac{g}{c} \tag{1}$$

with

$$S = S_0 F_{CS} F_{SF} F_G F_P F_{RT} F_{LT} \tag{2}$$

Table 1 shows in brief the description of variables affecting the capacity and factors affecting each variable. In Indonesian context , effective green time is assumed to be the same with displayed green. Cycle time is affected by number of phases. The principle of operation of a signalized intersection is to avoid crossing conflicts between movements. However a conflict between a through movement and the opposing right turn movement is allowed. This is called opposed phase arrangement. If a conflict between a through movement and the opposing right turn movement is avoided, the phase arrangement is called protected.

Table 1 Variables affecting signalized intersection approach capacity

Variable	Description	As Function of:
C	Intersection approach capacity (pcu/hour)	
g	Effective green time (seconds)	
c	Cycle time (seconds)	
S	Intersection approach saturation flow (pcu/hour)	
S_0	Basic saturation flow (pcu/hour)	*P & O:* W_e; *O:* Q_{rt}, Q_{rto}
F_{CS}	City size adjustment factor	Number of population
F_{SF}	Side friction adjustment factor	Environment type, side friction class, *UV/MV*
F_G	Gradient adjustment factor	gradient
F_P	Parking distance adjustment factor	L_p, W_A, g
F_{RT}	Right turn flow proportion adjustment factor; only valid for protected flow, undivided, 2/2 UD	Right turn flow proportion ($1 + 0.26\rho_{RT}$)
F_{LT}	Left turn flow proportion adjustment factor; Only valid for protected flow without left turn on red	Left turn flow proportion ($1 - 0.16\rho_{LT}$)

Basic saturation flow is affected by effective approach width. Effective approach width is affected by lay out of the intersection, e.g. the existence of exclusive left-turn lane, entry width (W_{ENTRY}), exit width, etc. For opposed phase arrangement (*O*), basic free flow speed is affected by the right turn flow and the opposing right turn flow. For protected phase arrangement (*P*), if W_e is effective intersection width then the basic saturation flow is:

$$S_0 = 600W_e \quad (3)$$

In order to get basic saturation flow for opposed condition, one should refer to the graphs in IHCM (1997) page 2-51 (for intersection approach without exclusive right turn lane) and page 2-52 (for intersection approach with exclusive right turn lane).

Table 2 shows city size adjustment factor for signalized intersection approach saturation flow.

Table 2. City size adjustment factor for signalized intersection approach saturation flow

City Size	No. of Population (Million)	City Size Adjustment Factor, F_{CS}
Very Small	< 0.1	0.82
Small	0.1 – 0.5	0.88
Medium	0.5 – 1.0	0.94
Large	1.0 – 3.0	1.00
Very Large	> 3.0	1.05

Side friction adjustment factor for intersection approach saturation flow is presented in Table 3. The more restricted the access the lesser the reduction to the saturation flow of the intersection approach. The more the ratio of the number of unmotorized vehicle to the motorized vehicle, the more the reduction to the intersection approach. The higher the side friction class the higher the reduction to the intersection approach.

Table 3. Side friction adjustment factor for intersection approach saturation flow

Road Environment	Side Friction Class	Phase Type	Ratio of Unmotorized Vehicles to Motorized Vehicles					
			0.00	0.05	0.10	0.15	0.20	0.25
Commercial Area	High	Opposed	0.93	0.88	0.84	0.79	0.74	0.70
		Protected	0.93	0.91	0.88	0.87	0.85	0.81
	Medium	Opposed	0.94	0.89	0.85	0.80	0.75	0.71
		Protected	0.94	0.92	0.89	0.88	0.86	0.82
	Low	Opposed	0.95	0.90	0.86	0.81	0.76	0.72
		Protected	0.95	0.93	0.90	0.89	0.87	0.83
Residential Area	High	Opposed	0.96	0.91	0.91	0.81	0.78	0.72
		Protected	0.96	0.94	0.94	0.89	0.86	0.84
	Medium	Opposed	0.97	0.92	0.92	0.82	0.79	0.73
		Protected	0.97	0.95	0.95	0.90	0.87	0.85
	Low	Opposed	0.98	0.93	0.93	0.83	0.80	0.74
		Protected	0.98	0.96	0.96	0.91	0.88	0.86
Restricted Access	High/ Medium/ Low	Opposed	1.00	0.95	0.90	0.85	0.80	0.75
	High/ Medium/ Low	Protected	1.00	0.98	0.95	0.93	0.90	0.88

On Figure 1 the gradient adjustment factor on approach intersection saturation flow is shown. If the intersection approach is flat the factor become 1 and there will be no effect on the saturation flow. The effect of uphill gradient to the reduction of saturation flow is greater than the effect of downhill gradient on the increase of saturation flow.

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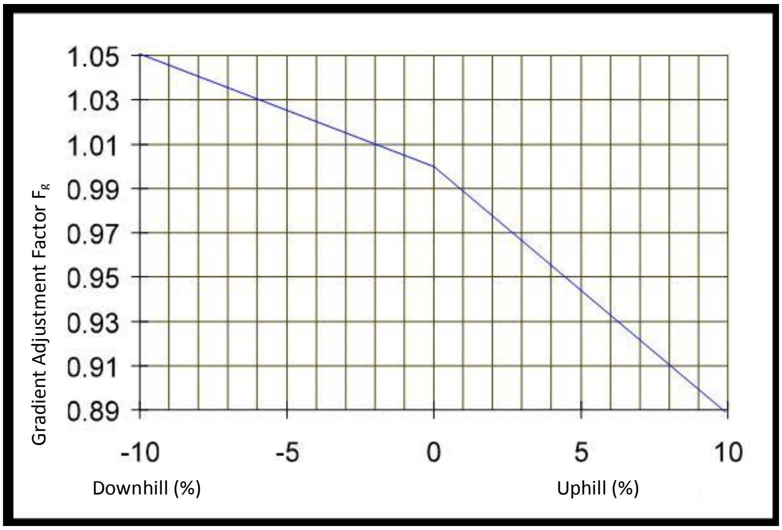


Figure 1. Gradient adjustment factor on approach intersection saturation flow

Figure 2 shows the parking distance adjustment factor on approach intersection saturation flow. The further the parked vehicle distance from the intersection stop line and the wider the intersection approach, the smaller the reduction to the intersection approach saturation flow. If the parked vehicle is more than 80 m from the stopping line, parked vehicle effect is ignored.

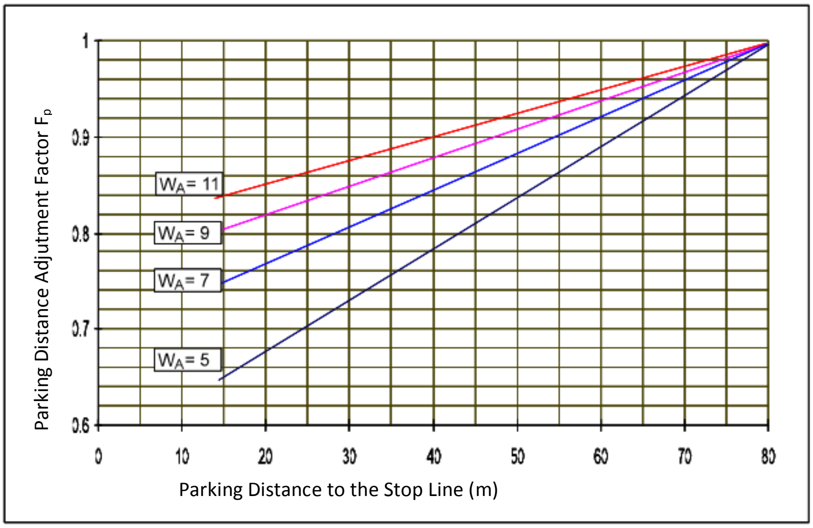


Figure 2. Parking distance adjustment factor on approach intersection saturation flow

If ρ_{RT} a ratio of right turn flow to the total flow of an intersection approach then the adjustment factor of ratio of right turn flow on intersection approach saturation flow (F_{RT}) can be formulated as follows:

$$F_{RT} = 1 + 0.26\rho_{RT} \tag{4}$$

If ρ_{LT} a ratio of left turn flow to the total flow of an intersection approach then the adjustment factor of ratio of left turn flow on intersection approach saturation flow (F_{LT}) can be formulated as follows:

$$F_{LT} = 1 - 0.16\rho_{LT} \tag{5}$$

If a left turn on red is possible (during red signal) then the left turn flow is beyond the control of the signal and therefore ignored in the calculation.

The passenger car unit (pcu) is based on vehicle type and phase arrangement of signalized intersection. Light vehicle pcu is 1.0 both in protected and opposed conditions, Heavy vehicle pcu is 1.3 both in protected and opposed conditions. The pcu of motorcycle in protected condition is 0.2 whilst in opposed condition is 0.4.

Q/S is called a flow ratio. *FR*. Critical flow ratio, FR_{crit} is one of the factors determined optimum cycle time, *c* optimum as indicated in equation (6). FR_{crit} is the highest *FR* of the approaches moving in the same phase. In equation (6), all FR_{crit} should be summed up and after deducted with 1 become denominator and therefore FR_{crit} should be less than 1.

$$c = \frac{1.5LTI + 5}{1 - \sum_i FR_{crit_i}} \tag{6}$$

Lost time intersection. *LTI* is the total of amber time and all red time (if any) in all phases. Amber time is about 2-3 seconds. All red time is also about 2-3 second. If $FR_{crit} \geq 1$ IHCM 1997 suggest 40-80 seconds cycle time for 2 phases signal, 50-100 second for 3 phases signal and 80-130 seconds for 4 phases signal. Green time (g_i) for each phase can be allocated based on equation (7).

$$g_i = (c - LTI)\frac{FR_{crit_i}}{\sum_i FR_{crit_i}} \tag{7}$$

After the calculation of capacity (*C*) is completed the degree of saturation. *DS* (*Q/C*) can then be calculated. Further analysis on signalized intersection performance is mainly affected by degree of saturation. If *NQ* is number of vehicles waiting behind the stopping line then:

$$NQ = NQ_1 + NQ_2 \tag{8}$$

NQ_1 is the number of remaining vehicles from the previous green (please refer to IHCM 1997 page 2-64) whilst NQ_2 is number of vehicles arriving during the red that can be estimated using equation (9).

$$NQ_2 = c\frac{1 - \frac{g}{c}}{1 - \frac{g}{c}DS}\frac{Q}{3600} \tag{9}$$

Afterward NQ_{max} can be calculated as a function of NQ and P_{OL}, probability of overloading using a chart in IHCM (1997) page 2-66. Queue length (QL) in meters can be calculated using equation (10).

$$QL = \frac{20NQ_{\max}}{W_{ENTRY}} \tag{10}$$

Number of stops per PCU can be calculated using equation (11) and number of stops per hour (N_{SV}) can be calculated using equation (12). In intersection level, number of stops per PCU (NS_{TOT}) can be calculated using equation (13).

$$NS = 0{,}9\frac{NQ}{Qc}3600 \tag{11}$$

$$N_{SV} = QNS \tag{12}$$

$$NS_{TOT} = \sum \frac{N_{SV}}{Q_{TOT}} \tag{13}$$

Delay is a very important performance indicator of a signalized intersection because it is exposed directly to the road users. Delay, D in seconds per PCU is a summation of traffic delay (D_T) as indicated in a chart in page 2-68 of IHCM (1997) and geometric delay (D_G) calculated from equation (14).

$$DG = 6\rho_T(1-\rho_{SV}) + 4\rho_{SV} \tag{14}$$

The intersection delay (D_I) in seconds per PCU can be calculated using equation (15).

$$D_I = \frac{\sum QD}{Q_{TOT}} \tag{15}$$

3. Comparison between available signalized intersection analysis software

In this paper the features of several signalized intersection analysis software (KAJI, SIDRA 4, SIDRA Intersection 4 and an IHCM 1997 spreadsheet based intersection analysis developed by Ahmad Munawar) are briefly discussed. The purpose of the discussion is to identify any weakness that might be overcome by Road Canal.

3.1. KAJI

KAJI stands for “Kapasitas Jalan Indonesia” (Indonesian Highway Capacity) and was developed based on IHCM (1997). The appearance of each module of the software is similar with forms used for manual calculation. This was intended to help the users who were familiar with the manual calculation of IHCM (1997). There are 7 modules available in KAJI, i.e. signalized intersection, unsignalized intersection, weaving section, roundabout, urban road, interurban road and freeway. The module and the level of analysis (planning, design or operation) can be selected after clicking enter in the opening screen (Figure 3). Signalized intersection module consists of 5 forms (SIG-1 to SIG-5).

SIG-1 was designed to enter approach definition, signal timing and intersection geometry. In the planning and design level of analysis, no signal timing data need to be entered (except cycle time as optimum cycle time is not calculated by KAJI), as this will be calculated by KAJI. In the operation level of analysis, detailed signal timing should be entered, starting with number of phases, movements within each phase, green time and red time within each phase and indication of left turn on red (LTOR) if any. All LTOR flows entered in SIG-2 will be ignored in the calculation of flow ratio (*Q/S*). In the intersection geometry, detailed intersection geometry as well as road side environment data should be entered, e.g. land use, side friction class, approach gradient, distance between stopping line and nearest parked vehicle, approach width, entry width, exit width, LTOR lane width, the existence of median, the existence of special right turn lane and whether the approach is one way road or not etc.

SIG-2 was designed to enter the classified flow (by vehicle type). Appropriate passenger car unit (pcu) would then be assigned to the original flow data entered in vehicle. In planning level of analysis the classified flow is not available and therefore SIG-2S should be used by entering Average Annual Daily Traffic (AADT) and appropriate K factor to get the design hourly volume (DHV). The DHV would then be derived into classified flow by KAJI using user's entry or default vehicle composition of IHCM (1997). The default value of vehicle composition might be misleading, since there is a radical increase of motorcycle proportion in the general traffic in the last 5 years.

SIG-3 was designed to enter inter-green information, i.e. amber time and all red time (if any). If later in SIG-4 sub-phases (either by late start or by early cut-off) are defined, any inter-green time entered in the particular phases will be ignored.

SIG-4 needs minimum entry. However this form is a bit complex and very important (as it summarized all values that will be calculated to get the results in SIG-5). In the design and planning level of analysis, the phasing arrangement is entered here, whilst in operation level of analysis the phasing arrangement will be according SIG-1 and the related cells will not be editable. Although in the newest version opposed or protected right turn movement was automatically, but in the older version, the user should indicate this matter in SIG-4. Late start sub-phases or early cut-off sub-phases should be indicated in this form.

SIG-5 is a results form. All performance indicators of the signalized intersections will be shown (degree of saturation, queue length, delay, etc). Although IHCM (1997) had no level of service concept, but US HCM was used to indicate the relationship between the delay and level of service.

Figure 3. Opening screen of KAJI

Figure 4. Main screen of SIDRA 4

3.2. SIDRA 4 and SIDRA Intersection

SIDRA is originally stands for Signalized Intersection Design and Research Aid. In the first development US HCM and Australian/ New Zealand capacity manual were used by Akcelik since 1975. SIDRA 4 (further called as SIDRA) was the embryo of SIDRA Intersection. SIDRA runs on DOS (disk operating system) and consists of three main moduls, i.e. RIDES, SIDRA and GOSID (Figure 4).

RIDES is an input modul for signal timing and phasing, intersection geometry and traffic volume. Default values were available in the software. SIDRA is calculation module using input from RIDES. A message will be appeared to indicate whether a calculation was successfull or not. A guidance to correct the possible incorrect input will accompany an error message. GOSID (Graphical Output System for Intersection Design) is a results module. Results can be viewed by approach or by overall intersection.

Considering the latest information technology development, SIDRA is a bit inconvenient to be used by the recent generation of traffic engineers due to unfamiliarity with DOS (especially the “non-mouse based” computer operation) and incompatibility with recent operation system (Windows 2000 and newer).

SIDRA Intersection 4.0 was developed to overcome the weakness of SIDRA 4.0 and appear in MS Office 2007 format (Figure 5). It is compatible with Windows operating system and its graphical appearance is improved. There is also additional features such as pollution analysis and sensitivity analysis.

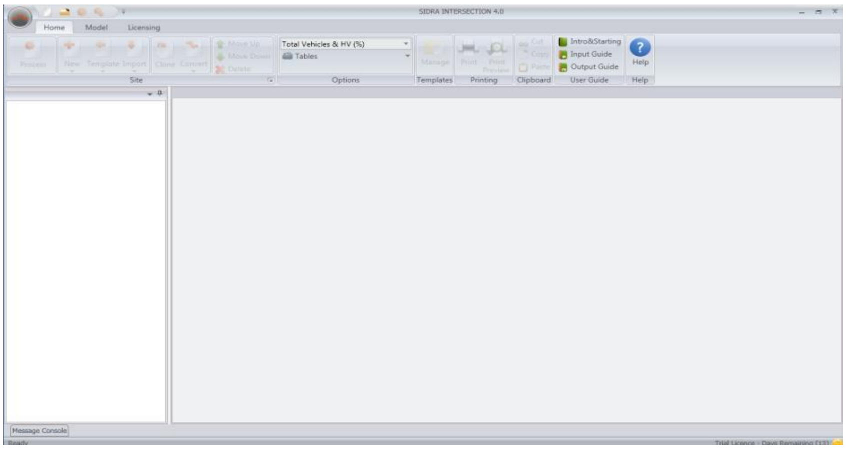


Figure 5. Main screen of SIDRA Intersection 4.0

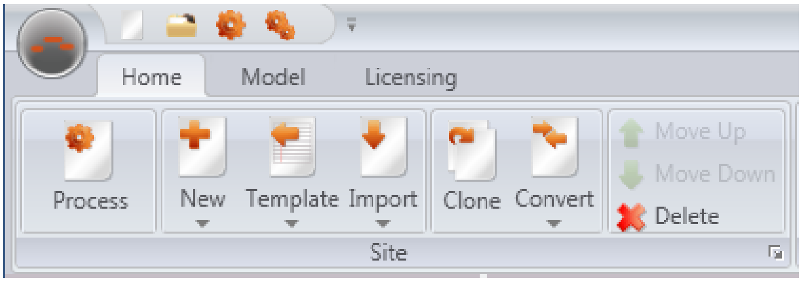


Figure 6. Quick entry features in SIDRA Intersection 4.0

This software also has a quick entry feature by using *template, import, clone,* and *convert* menu. By using this feature, a set of data can be used for different scenarios of analysis (Figure 6).

By using Windows operating system as the basis of software development, in SIDRA Intersection, drop down menu bar in DOS can be change into tree system. Improvement shown by SIDRA Intersection 4.0 was not leaving the advantages of the previous system (SIDRA 4.0). Therefore SIDRA Intersection 4.0 was relatively ideal model for the development of Road Canal.

3.3. Spreadsheet of IHCM (1997)

This spreadsheet based IHCM (1997) was developed by Achmad Munawar from Gajah Mada State University, Yogyakarta, Indonesia. In brief, it is only a spreadsheet version of forms in IHCM (1997). In general, users should enter the required values of adjustment factors, especially factors from a chart.

4. The Development Principles of Road Canal

Seven traffic modelers ranging from 1 year to 25 years experienced were interviewed. There were several expectation of an ideal software for signalized intersection, i.e.:

- The software should be easily used by novice users who have already understood the principles of signalized intersection analysis.
- The software should have graphical presentation to support users' orientation.
- Number of input parameters should be minimized to let the users focus on the most important aspects of the analysis.
- The software should facilitate the need for using a set of data for several scenarios of analysis.
- Although IHCM values might be stored as default values, flexibility for adjustment should be available for users.

Based on the review of previously available signalized intersection analysis software and the result of interview to the modelers, Road Canal was developed. On the opening screen, users should choose either four legs or three legs intersection. The users also need to choose the level of analysis (planning, design or operation). City size in terms of number of population also should be entered here.

Once all the required parameters were entered in the opening screen the next input screen will be appeared, i.e. general data input screen. The general data input screen consists of four sub-screens, i.e. environment, intersection general geometry, lane properties and lane widths (Figure 7). In any of the sub-screens, if the choice is limited, Road Canal will list the choices and the user can click the appropriate choice. In any part of the sub-screen in which the user need to enter a value, the default value from IHCM (1997) was stored and might be changed by the user.

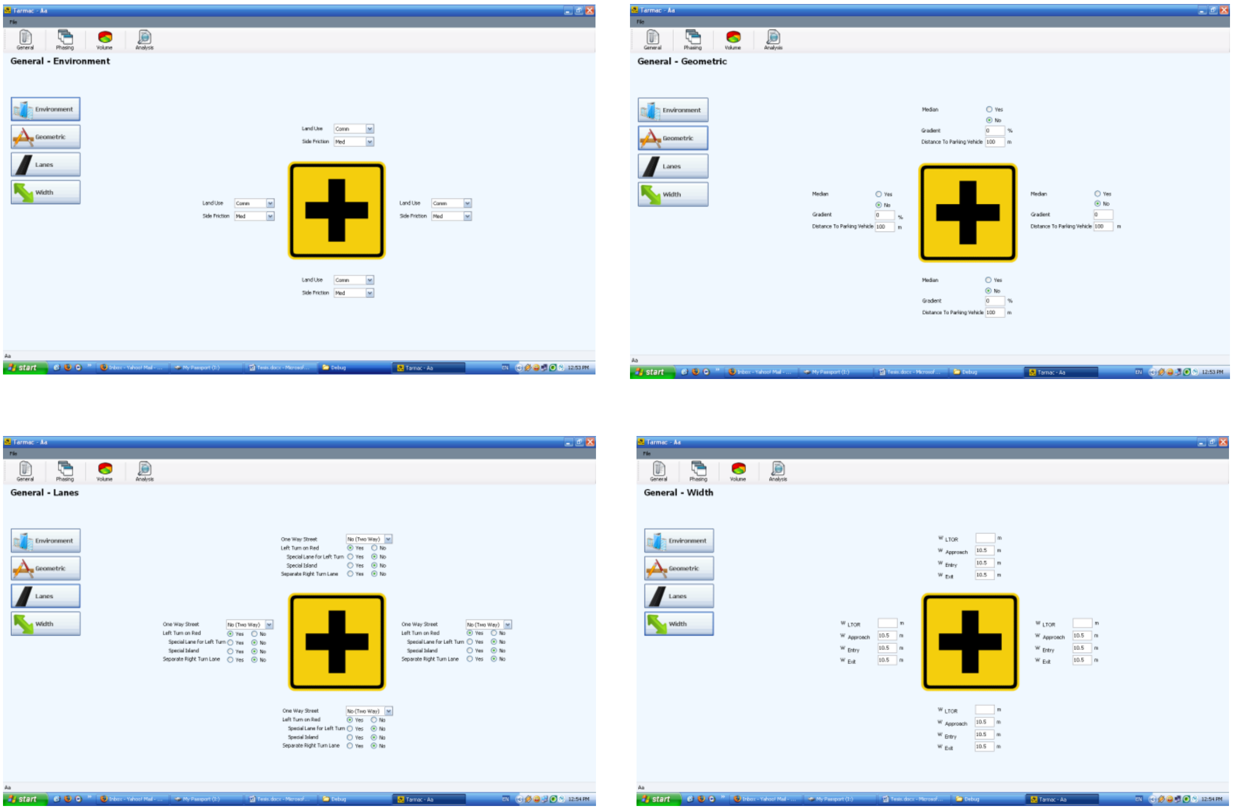


Figure 7. Four sub-screens of general data input screen

In the environment sub-screen, land use and side friction parameters of each approach should be entered. The choice of input for road environment consists of “Com” representing commercial area, “Res” representing residential area and RA representing restricted access. In the geometric sub-screen, the user is required to enter the availability of median, approach gradient and the distance between parked vehicle and the stop line. In the lane sub-screen, number of direction of flow at each approach, the possibility of left turn on red (LTOR), the availability of special lane for LTOR, the availability of traffic islands for LTOR and the availibility of special right turn lane should be entered. In the lane width sub-screen, the required entries i.e. LTOR lane (if any) width, approach width, entry width and exit width of each approach.

After entering the general parameters, the next step is signal timing. Road Canal willl ask for number of phases. Afterward the users should enter green time, amber time and all red time (if any) at each phase. Red time is not required, since it will be calculated automatically by Road Canal. For each phase, the user should indicate which movements are included by clicking directional arrow in the screen. The click operation will change the color of the arrow from red (stop) to green (move) vice versa (Figure 8). If in the previous screen LTOR was indicated, the left turn arrow will always green. As a helping tool, phasing analysis menu can be clicked to determine whether the movement is protected or opposed. Road Canal can also show signal timing diagram after all required cells have been entered by clicking phasing diagram.

The last data entry that should be made is traffic flow. There are three types of traffic flow allowed to be entered, i.e. annual avarage daily traffic (AADT), unclassified hourly volume and classified hourly volume.

If AADT is entered, *K* (peak hour factor) should also be entered. In IHCM (1997), *K* is between 7 and 12% dependes on city size in terms of number of population and land use. If unclassified hourly volume is entered, vehicle composition should be entered. In IHCM (1997) percentage of light vehicles is between 40 and 60, percentage of heavy vehicles is between 2.5 and 4.5 and percentage of motorcycle is between 34.5 and 57 depends on city size in terms of number of population. However, recent dramatic increase in motorcycle use in Indonesia is believed to change the default value of vehicle composition.

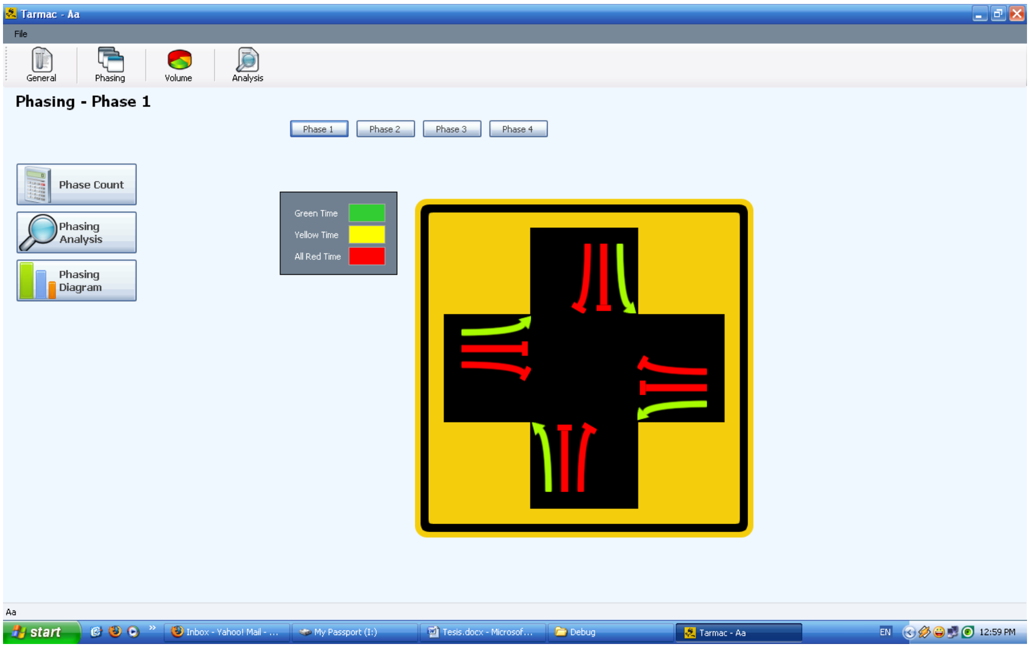


Figure 8. Phasing Sub-screen

If classified hourly volume is chosen, the user needs to obtain calssified traffic count data of that intersection. Afterward the obtained data should be entered to the Road Canal (Figgure 9) and the program will automatically calculate the design hourly volume of each approach in passenger car unit per hour.

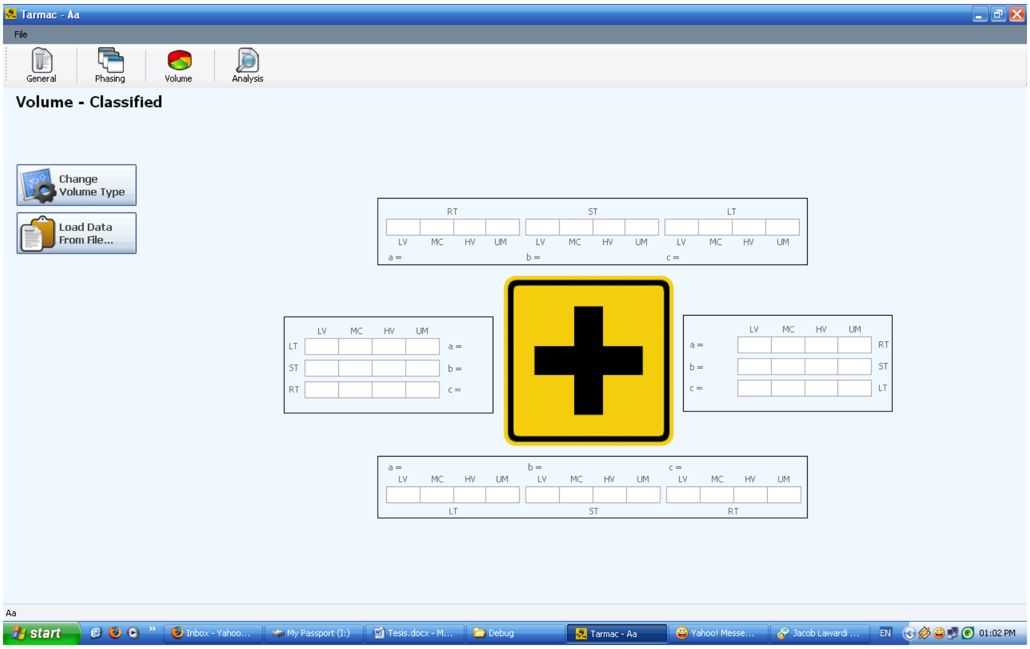
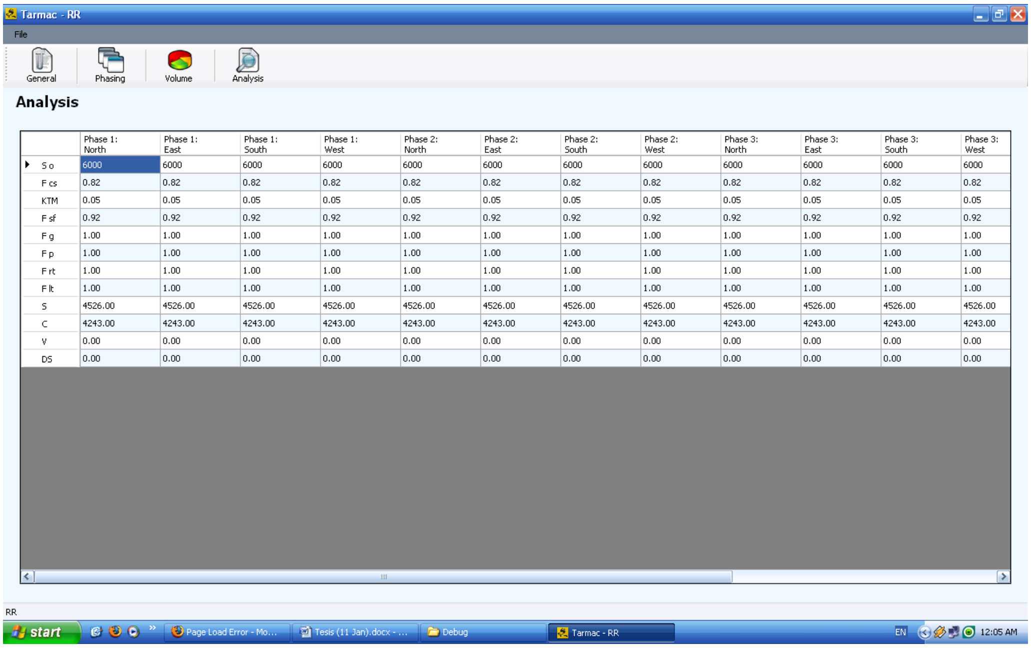


Figure 9. Classifed Hourly Volume Sub-screen



	Phase 1: North	Phase 1: East	Phase 1: South	Phase 1: West	Phase 2: North	Phase 2: East	Phase 2: South	Phase 2: West	Phase 3: North	Phase 3: East	Phase 3: South	Phase 3: West
S o	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
F cs	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
KTM	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
F sf	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
F g	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F p	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F rt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
F lt	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
S	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00	4526.00
C	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00	4243.00
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 10. Intersection Performance Report in Table Form

After all the required values are entered, if the analysis icon is clicked an itersection performance report will be appeared (Figure 10). If Road Canal is asked to print the result, it will produce three reports, i.e. input report, intersection performance report and signal adjustment report.The input report consists of the summary of all entered values including signal phasing and signal timing diagram. The intersection performance report will produce graphical presentation of the intersection performance, including degree of saturation, queue length and delay. Signal adjustment report will provide proporsed signal timing diagram based on optimum cycle time equation developed by Webster (1966).

5. Conclusion

There are several signalized intersection softwares available to be used. It is not convenient to use non-IHCM based software to analyze Indonesian signalized intersection. Such software might unable to represent Indonesian traffic characteristics. KAJI is the only available comprehensive software of capacity analysis based on IHCM 1997. However, it was developed originally to work on DOS based operating system and therefore not fully compatible with current widely used Windows based operating system. Furthermore in some part of KAJI, there is no flexibility to change the default values, although many values in IHCM 1997 have already reequired changes. Road Canal was developed to evercome the problems of using other signalized intersection software. It was developed to be used in Windows operationg system, has flexibility to change the IHCM 1997 default values and provide easily understood graphical presentation.

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