A COMPUTER-AIDED TRAINING TOOL FOR TRAFFIC ENGINEERS

Ricardo G. Sigua
Associate Professor
Department of Civil Engineering
College of Engineering
National Center for Transportation Studies
University of the Philippines
Diliman, Quezon City
E-mail Address: rsigua@up-ncts.org.ph

Abstract: A computer program using Pascal language and applying the concept of Knowledge-Based Expert System(KBES) was developed with the novice traffic engineer in mind. It is assumed that the user has some basic knowledge of intersection geometry and how traffic signals are used for controlling traffic. The program follows a logical way of designing the parameters of traffic signal settings. A major feature of the program includes the development of alternative phase patterns commensurate to the traffic volume and geometry of the intersection. The best phase pattern based on Y-value is selected to estimate important signal parameters such as optimum cycle, green time allocation of each movement, intersection degree of congestion, etc.

1. Introduction

Knowledge-Based Expert Systems(KBES) have been widely used in various disciplines. A KBES normally consists of a knowledge-base, an inference engine, and an interface with the user **(Figure 1)**. Strictly speaking, KBES does not depend on algorithms except when computations are required.

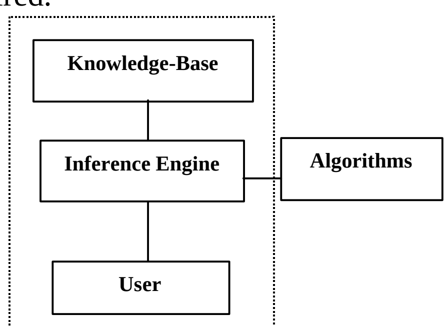

Figure 1. Structure of a KBES

1.1 Knowledge-Base

The knowledge-base is developed by sourcing out inputs based on experience of an expert or a number of experts in a particular field. A knowledge-base consists of rules normally written in **IF – THEN** format. New rules may be added anytime and old ones may be deleted or replaced within the knowledge-base.

1.2 Inference Engine

The inference engine serves as the control level of an expert system. It searches for facts through the knowledge-base and identifies new facts for subsequent inferencing. Inference engines are usually developed to perform either forward or backward chaining, or both

(Figure 2). Forward chaining simply makes use of initial data to arrive at a conclusion while backward chaining moves in the opposite direction. A forward chaining mechanism is considered more appropriate for this KBES.

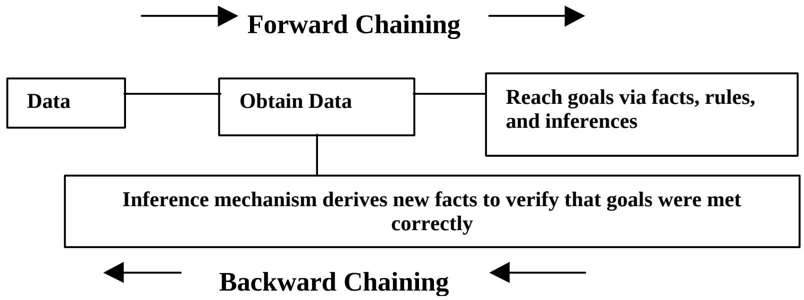

Figure 2. Inference Engine Mechanism

2. Major Components

2.1 Development of Phase Patterns

The minimization of vehicular and pedestrian conflicts is the primary basis of designing phase patterns for traffic signals. A simplified procedure for signal timing design is shown in Figure 3. In designing phase patterns, a trial and error procedure depending on vehicular directional volumes and types of conflicts is usually followed.

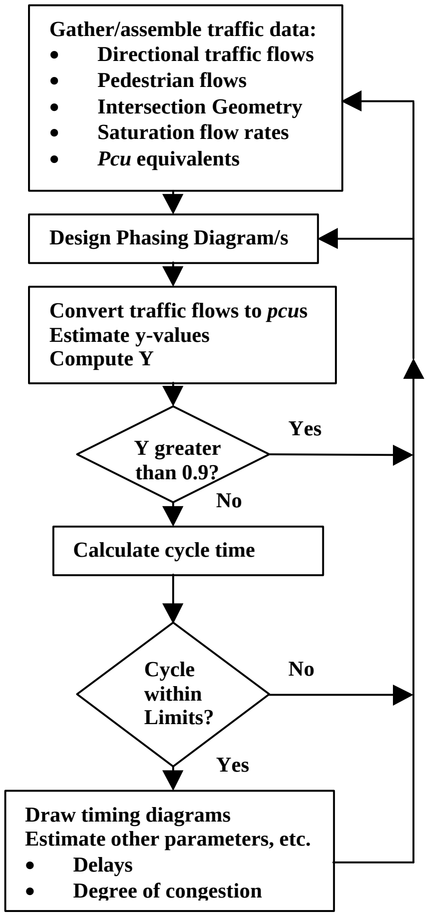

Figure 3. Procedure for Basic Signal Timing Design

The number of conflicts increases exponentially as a function of the number of legs of intersection. It is therefore imperative to design new intersections with legs no more than four. At signalized intersections, control of traffic is done by separation in time, i.e., a number of movements are given right of way in terms of time allocated to them. Three types of conflict are present in an intersection, namely: diverging, converging, and crossing. As to severity, crossing is the most problematic type dictating almost the number of phases. Simple rules can be developed to state what type of conflict arises between two movements ***i*** and ***j***:

> **IF** $\text{origin}_i = \text{origin}_j$ **AND** exit_i $\quad$ exit_j **THEN** conflict is diverging.
> **IF** origin_i $\quad$ origin_j **AND** $\text{exit}_i = \text{exit}_j$ **THEN** conflict is converging.

A rule to determine whether two movements cross its other's path can be set by evaluating the three angles shown in **Figure 4**.

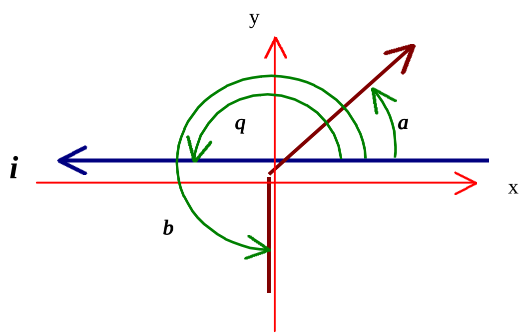

Figure 4. Crossing Conflict Determination

All angles(a,b,q) are reckoned from tail of ***i*** and are measured counterclockwise.

> **IF** $(b>q)$ **AND** $(q>a)$ **THEN** conflict is crossing.

The test may have to be performed twice by swapping movements ***i*** and ***j***. The conflict type is not crossing if either test does not satisfy the above condition.

2.2 Critical Movement Analysis

The determination of cycle time and green times needed by the different movements follows the critical movement analysis method. This is the same method used by Akcelik in his SIDRA program and by the US Highway Capacity Manual for the design and analysis of signalized intersections.

The illustrations below show the three typical 'stages' for vehicles at a T-intersection **(Figure 5a)** and the corresponding critical movement diagram **(Figure 5b)**. The term 'phases' is not used because of the overlapping movements (defined as movements present in more than one stage), namely: 1, 4, and 5. The cycle time and green times may be dictated by the time requirements of any of the following sets: [1, 6], [3, 5], [2, 3, 6], or [2, 4]. Each set consists of movements that form a complete cycle. The set that gives the highest Y-value forms the critical movements. In other words:

$Y_{cr} = \max (Y_1, \ldots, Y_n)$ where n is total number of possible sets.

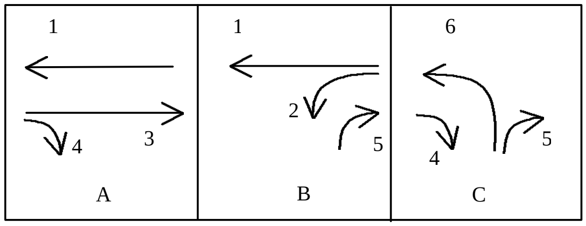

Figure 5a. Three Stages for a T- Intersection

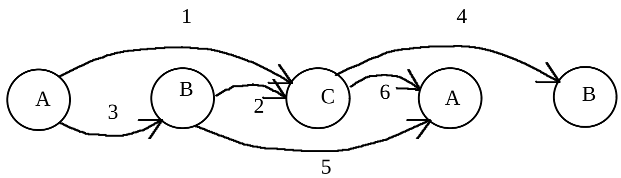

Figure 5b. Critical Movement Diagram

2.3 Cycle Time

The cycle time is determined by using Webster's formula, $C = (1.5L + 5)/(1-Y_{cr})$. It was obtained by considering vehicular delay as the objective function or measure of performance. A number of cycle formulas have been introduced but they follow the basic form of the equation by Webster.

3. Sample Run

The features and/or performance of the program will be demonstrated by an example using a T-intersection. The characteristics of the intersection may be gleaned from the data inputs that follow:

M A I N M E N U

1. Input Data
2. Get Test Data
3. Modify Flow Data
4. Modify Intersection Data
5. Modify Phasing
6. Run Program
7. Exit Program

Enter Choice [1-7]: 1

TRAFFIC AND INTERSECTION DATA:
No. of Movements? 6

Movement No. 1
Approach Leg [N, E, S, W, NE, NW, SE, SW]: E
Exit Leg [N, E, S, W, NE, NW, SE, SW]: W
Volume: 750
Movement No. 2
Approach Leg [N, E, S, W, NE, NW, SE, SW]: E
Exit Leg [N, E, S, W, NE, NW, SE, SW]: S
Volume: 200
Movement No. 3
Approach Leg [N, E, S, W, NE, NW, SE, SW]: W
Exit Leg [N, E, S, W, NE, NW, SE, SW]: E
Volume: 450

(cont'd.)

Movement No. 4
Approach Leg [N, E, S, W, NE, NW, SE, SW]: W
Exit Leg [N, E, S, W, NE, NW, SE, SW]: S
Volume: 120
Movement No. 5
Approach Leg [N, E, S, W, NE, NW, SE, SW]: S
Exit Leg [N, E, S, W, NE, NW, SE, SW]: W
Volume: 350
Movement No. 6
Approach Leg [N, E, S, W, NE, NW, SE, SW]: S
Exit Leg [N, E, S, W, NE, NW, SE, SW]: E
Volume: 200

(cont'd.)

Give me the max. no. of lanes for the east approach: 2
Give me the max. no. of lanes for the south approach: 2
Give me the max. no. of lanes for the west approach: 1

Data input completed.

Summary of flow data may be viewed by choosing item #3 in the main menu. Default values for Intergreen(IG), Saturation flow rates (Sat_Flow), and Practical degree of congestion (Xp) are added. These values can be easily modified using the procedure below.

Flow Data:

Move	IG	Volume	Sat_Flow	Xp
1	5	750	1800	0.90
2	5	200	1800	0.90
3	5	450	1800	0.90
4	5	120	1800	0.90
5	5	350	1800	0.90
6	5	200	1800	0.90

Give me the movement to be modified [1-6]: 1

Menu for Changing Data for Movement No. 1

Item	Current Value
1. Volume	750
2. Saturation flow rate	1800
3. Intergreen	5
4. Starting loss	2
5. End gain	3
6. Practical degree of saturation	0.90

7. Modify other movement
8. Go back to Main Menu

Enter choice [1-8]: ___

Sample Output(in text format):

Flow Table: (*Direction is identified automatically*)

Movement	Entry	Exit	Direction
1	E	W	through
2	E	S	left
3	W	E	through
4	W	S	right
5	S	W	left
6	S	E	right

Conflict Table:(*Summarizes the different conflicts between pair of movements*)

	1	2	3	4	5
1					
2	di				
3	no	cr			
4	no	co	di		
5	co	cr	cr	no	
6	no	no	co	no	di

Note: di - diverging co - converging cr - crossing no - no conflict

Generation of Phase/Stage Patterns:

(Different movements are assigned to phases; the number of phases is determined based on traffic volume and types of conflict)

Reduced no. of Phases/Stages: *(with initial movements)*

Phase 1: 2
Phase 2: 5
Phase 3: 1 3

Rearranged phases/stages: *(phases are arranged in logical manner)*

Phase 1: 1 3
Phase 2: 2
Phase 3: 5

Final phases/stages: *(other movements are added)*

Phase 1: 1 3 4
Phase 2: 1 2 6
Phase 3: 4 5 6

Flow Data:

Move	SP	TP	IG	Volume	Sat_Flow	L	Xp
1	1	3	5	750	1800	4	0.90
2	2	3	5	200	1800	4	0.90
3	1	2	5	570	1800	4	0.90
4	3	2	-	---	----	-	----
5	3	1	5	350	1800	4	0.90
6	2	1	5	200	1800	4	0.90

Calculations:

Move	y_value	u_value
1	0.42	0.46
2	0.11	0.12
3	0.32	0.35
4	----	----
5	0.19	0.22
6	0.11	0.12

The critical movements are: 2 3 5

Available Lanes per Approach:

App. No.	Approach	No. of lanes
1	E	2
2	S	2
3	W	1

Lane Allocation:

Approach	TL	RL	LL
1 (E)	1	0	1
2 (S)	0	1	1
3 (W)	1	0	0

TL – through lanes; RL – right turn lanes; LL – left turn lanes

Optimum cycle time: 60.88 sec.
Practical cycle time: 38.88 sec.

Chosen cycle time: 50.0 sec.
Ave. Delay: 20.48 sec./veh.
Degree of Saturation, X: 0.82

4. References

Akcelik, R., Traffic Signal Design, Australian Road Research Board Special Report/ SIDRA User's Manual.

Buchanan, B.G., Shortliffe, E.H., 'Rule-Based Expert Systems', Addison-Wesley , 1984.

Hayes-Roth, F., Waterman, D.A., Lenat, D.B., 'Building Expert Systems', Addison-Wesley, 1984.

Negoita, C.V., Expert Systems and Fuzzy Systems, Benjamin/Cummings, 1985.

Special Report 209:Highway Capacity Manual. TRB, National Research Council, Washington, D.C., 1985.

Webster, F.V., and Cobbe, B.M. Traffic Signals. Technical Paper 56. U.K. TRRL Report, Crowthorne, England, 1966.