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Automatic control system of temporary traffic signals at pipeline laying work site

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Abstract
Where pipe laying is carried out in urban areas, the disturbance to traffic flow can be substantial. However, by suitable sensing provisions coupled to an intelligent traffic light manage system, this can be greatly eased.

1. INTRODUCTION

Generally in Japan, pipeline laying works for gas supply in urban areas have been carried out mainly on non-arterial roads with less than three lanes. In this circumstance, one side of such roads is occupied during construction work as shown in Figure 1. Therefore two way traffic flow, which must pass alternatively, is greatly affected by execution of construction work. When we think about the fact that road traffic condition changes momentarily in two directions, traffic control by constant cycle time all through the day is not always adequate and some kind of dynamic traffic control should be introduced to this problem.

In this study, therefore, a system is proposed that signal cycle time should be adjusted dynamically as to cope with traffic volume for every time zone.

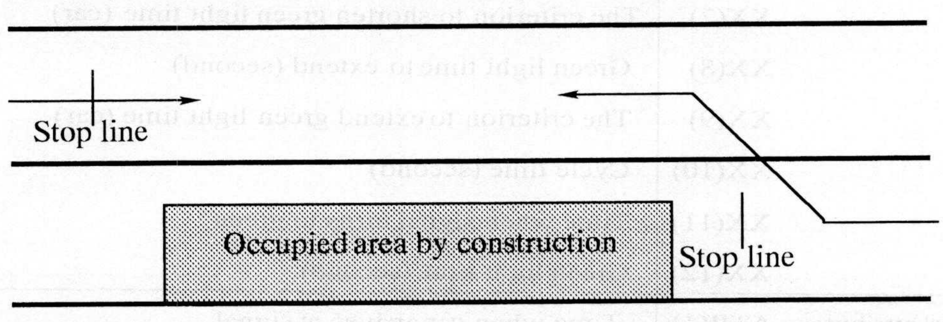

Figure 1 An outline of construction site

2. DYNAMIC TRAFFIC CONTROL BY TEMPORARY TRAFFIC SIGNALS

The length of waiting cars is timely and automatically measured by car sensors and/or video cameras installed at roadsides. When it reaches the maximum permissible length assumed in advance, traffic jam can be relieved by changing red light into green one. However, if road traffic is controlled only based on the length of waiting cars at signals, green light time at one side becomes either too long or too short. Traffic capacity decreases in latter case, and waiting time increases in former case. Green light time, anyhow, should have the maximum length and the minimum one.

This paper proposes an effective way to adjust green light time within this time range by using information from car sensors and/or video cameras.

3. DEVELOPMENT OF SIMULATION MODEL FOR ROAD TRAFFIC CONTROL

3.1. Introduction of simulation model

Road traffic of two directions controlled dynamically by waiting time and queuing length at temporary signals becomes complicated queuing phenomena, and then simulation technique is introduced.

This is developed using process oriented discrete simulation modeling function provided by SLAMII/PC, one of the excellent simulation languages just for personal computer. Three different controls are proposed here; traffic flow control for north direction, that for south direction and cycle control of traffic signals. These are modeled as sub-network in SLAMII/PC respectively. The variables used in the model are shown in Table 1.

Table 1 The variables used in this system

System variablbes	XX(1)	Road occupied length (m)
	XX(2)	The maximum green light time for north-bound(second)
	XX(3)	The maximum green light time for south-bound (second)
	XX(4)	Clearance time (second) (Time when both signals keep red at same time)
	XX(5)	The minimum green light time (second)
	XX(6)	Green light time to extend (second)
	XX(7)	The criterion to shorten green light time (car)
	XX(8)	Green light time to extend (second)
	XX(9)	The criterion to extend green light time (car)
	XX(10)	Cycle time (second)
	XX(11)	Time when signal turns to green
	XX(12)	Green light time (second)
Entities' attributes	ATR(1)	Time when car arrives at signal
	ATR(2)	North-bound car = 1 , South-bound car = 2
	ATR(3)	North-bound car = 3 , South-bound car = 4
	ATR(4)	Random numbers (from 0 to 1)
	ATR(5)	Mixing rate of large-sized cars
	NNQ(1)	The number of queuing cars for north-bound (car)
	NNQ(2)	The number of queuing cars for south-bound (car)
	TNOW	Present time in simulation

3.2. Modeling of road traffic flow control

The cars both for north-bound and for south-bound are created at each CREATE node as entities and necessary attributes are given to each entity at ASSIGN node. In case of cars for north direction, for example, the second attribute is set to 1. Traffic signals for north-bound and south-bound are represented by GATE block called LIGHT1 and LIGHT2. When traffic signal is green, GATE keeps open. Otherwise, GATE closes. The point where north-bound car just passing signal is named as START1 and the opposite point as START2 corresponding to LIGHT1 and LIGHT2. Because cars pass through each traffic signal one by one, RESOURCE blocks are used, which is seized while car passes the signal. When car seizes RESOURCE, the signal is checked whether green or red. If it is green, RESOURCE is released immediately and statistical data on waiting time are compiled at COLCT node. Otherwise, car must wait at designated file. If related RESOURCE for each car is seized, car must wait at file designated by AWAIT node until RESOURCE is released by the former car.

As the mechanism of GATE and RESOURCE for each traffic flow is just as same, traffic flows of both directions can be expressed as one sub-network model just by designating different entities' attributes to GATE and RESOURCE. Network model to control traffic flow is shown as in Figure 2.

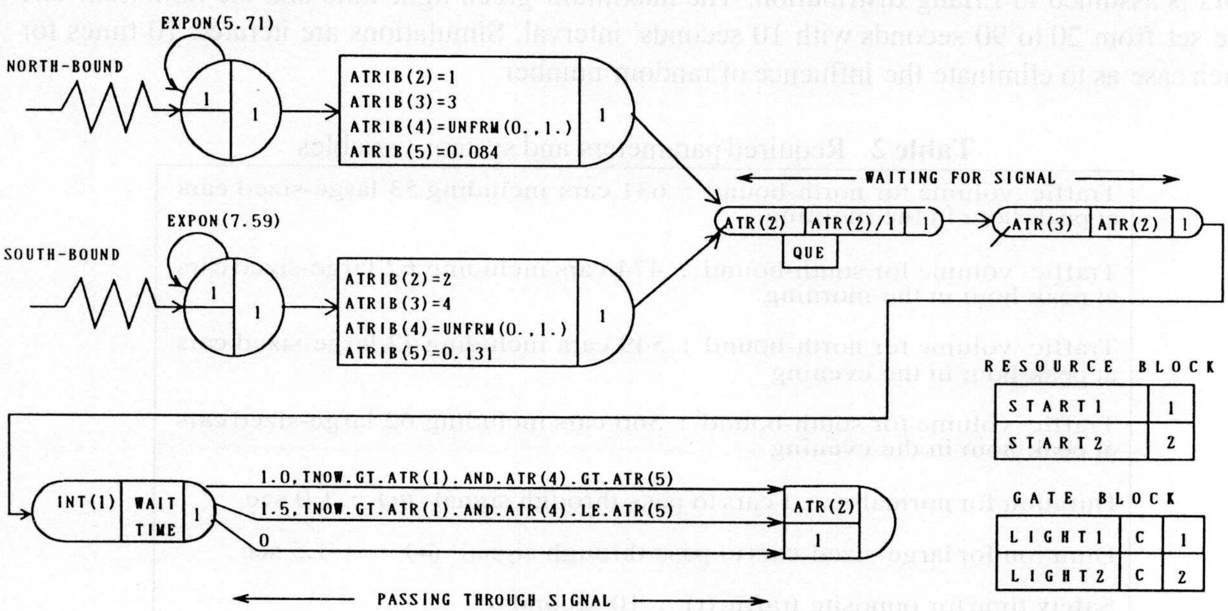

Figure 2 Network model to control traffic flow

3.3. Modeling of signal control

First, clearance time XX(4) is set using road occupied length XX(1) as follows, where the coefficient 0.12 sec/m comes from the velocity of passing car 30 km/h.

$$XX(4) = 0.12 \times XX(1) + 10 \qquad (1)$$

The signal for north-bound turns to green after clearance time {XX(4) seconds} passes. Suppose the minimum green light time passes and if queuing car length for south-bound {NNQ(2)} reaches the criterion to shorten green light time {XX(7) cars}, the signal turns to red and clearance time passes. After that, the signal for south-bound turns to green. If not so, queuing car length for south-bound is checked again after green light time extends to XX(6) seconds. Here, if NNQ(2) reaches XX(7), the signal turns to red and clearance time passes. Then the south-bound signal turns to green. If not so, above-mentioned operation is repeated. Finally, suppose green light time for north-bound passes XX(2) seconds. If queuing car length for south-bound does not reach XX(9), the signal turns to red after green light time extends up to XX(8) seconds and clearance time passes. Then the signal for south-bound turns to green. If not so, the signal turns to red without extending green light time for north-bound and clearance time passes. Then the signal for south-bound turns to green.

As to south-bound signal, which is controlled based on queuing car length for north-bound, the procedure of which is just as same with north-bound signal described above.

4. ANALYSIS OF TRAFFIC SIGNAL CONTROL AT PIPELINE LAYING WORK SITE

4.1. Execution of simulation

Taking into consideration that the greatest effect on traffic control appears at peak hours both in the morning and in the evening, simulation experiments are executed for these peak hours. The required parameters and system variables are shown in Table 2. Arrival interval of cars is assumed to Erlang distribution. The maximum green light time and the minimum one are set from 20 to 90 seconds with 10 seconds' interval. Simulations are iterated 10 times for each case as to eliminate the influence of random number.

Table 2 Required parameters and system variables

Traffic volume for north-bound at peak hour in the morning	: 631 cars including 53 large-sized cars
Traffic volume for south-bound at peak hour in the morning	: 474 cars including 62 large-sized cars
Traffic volume for north-bound at peak hour in the evening	: 549 cars including 42 large-sized cars
Traffic volume for south-bound at peak hour in the evening	: 566 cars including 62 large-sized cars
Duration for normal-sized cars to pass through signal (μ)	: 1.0 sec
Duration for large-sized cars to pass through signal (μ)	: 1.5 sec
Safety time for opposite traffic (t)	: 10 seconds
Average car speed (v)	: 30 km/h = 8.3 m/sec
XX(1) : 200 m	XX(6) = 1 second
XX(2) , XX(3) : 20 ~ 90 seconds	XX(7) = 10 cars
XX(4) : 0.12 x XX(1) + 10 = 34 seconds	XX(8) = 10 seconds
XX(5) : 20 ~ 60 seconds	XX(9) = 4 cars

4.2. Analysis of simulation results

4.2.1. Analysis of waiting time at the signals

The average waiting times for both bounds at peak hour in the morning are shown in Figure 3. In case when the minimum green light time is set rather shorter, the traffic flow for north-bound, which is larger than that for south-bound, has priority. This is because queuing car length for north-bound has already reached the criterion to turn signal color when the minimum green light time for south-bound passes. As to peak hour in the evening, in every case there is no difference between waiting time for north-bound and that for south-bound. This is because traffic volumes for both bounds are not very different at peak hour in the evening in this example. Waiting time are decided by the minimum green light time, namely, it is not affected by the maximum one.

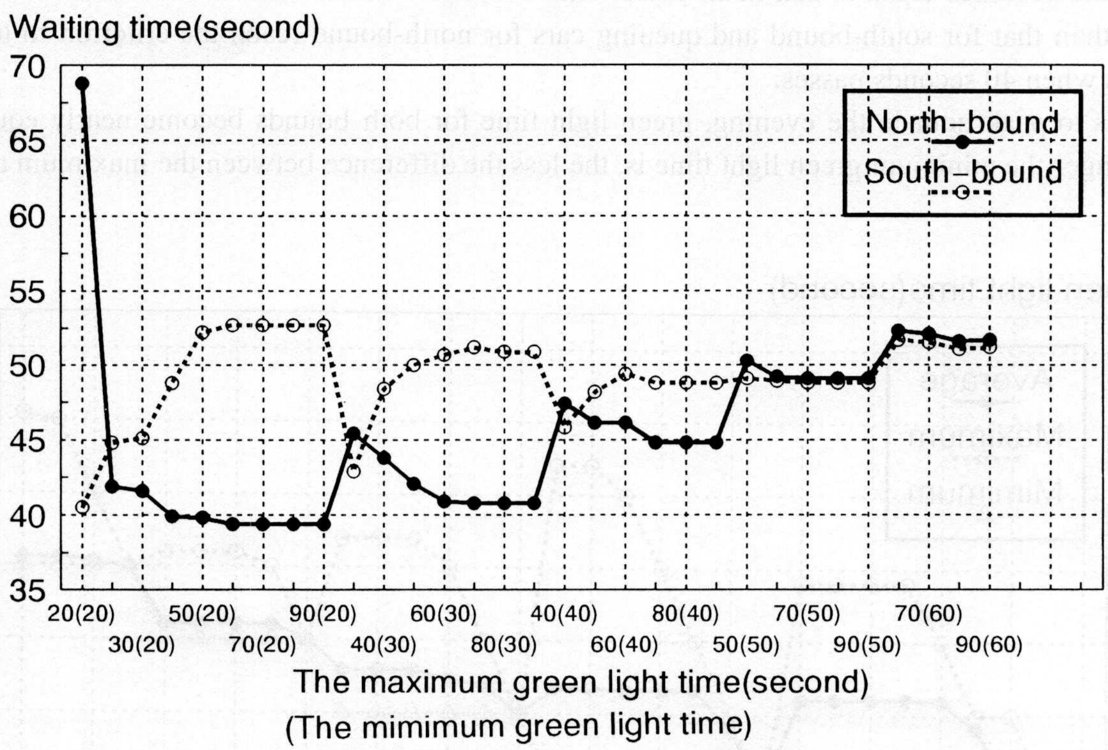

Figure 3 The average waiting time at peak hour in the morning

4.2.2. Analysis of waiting car length at each signal and the number of passing cars without waiting

Queuing cars are decided by the minimum green light time except in case when both the maximum green light time and the minimum one are set to 20 seconds. Average queuing cars keep almost the same level in all cases except when both the maximum green light time and the minimum one are set to 20 seconds. Average queuing cars are not different between both bounds and they are almost the same level in all cases, because traffic volumes are not different between both bounds.

As to the number of passing cars without waiting, if the minimum green light time is set rather shorter, there is great difference between both bounds and north-bound has priority. As the minimum green light time is set longer, the difference becomes small between both bounds, though the number of passing cars without waiting increases. In case of peak hour in the evening, when the minimum green light time is set to more than 30 seconds, there is no difference between both bounds.

4.2.3. Analysis of green light time

Figure 4 shows green light time of signal for north-bound at peak hour in the morning. As the minimum green light time is longer, green light time becomes almost equal to that. In case of south-bound when the minimum green light time is set to more than 40 seconds, green light time becomes equal to that in all cases. This is because traffic volume for north-bound is larger than that for south-bound and queuing cars for north-bound reach the criterion to turn signals when 40 seconds passes.

As to peak hour in the evening, green light time for both bounds become nearly equal. The longer the minimum green light time is, the less the difference between the maximum and

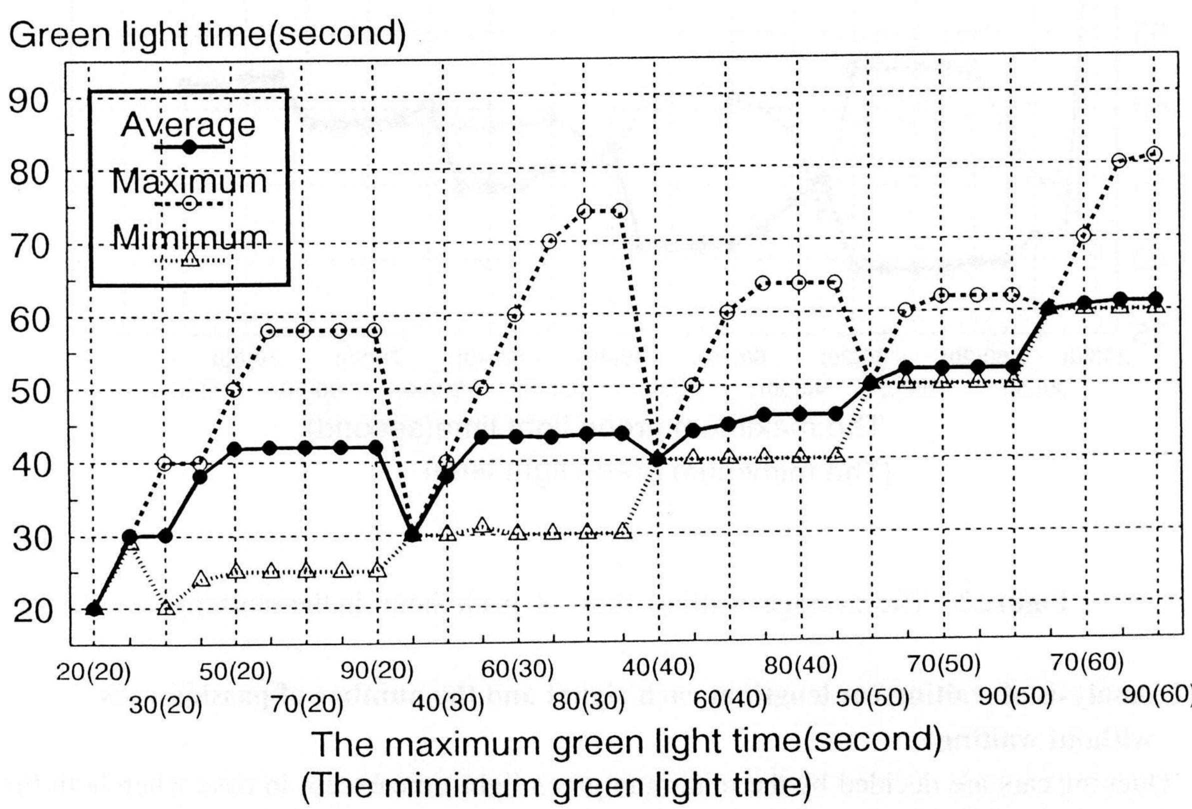

Figure 4 Green light time for north-bound at peak hour in the morning

the minimum of green light time becomes. When the minimum green light time is set to 60 seconds, green light time is constant as 60 seconds in all cases.

4.3. Findings from analysis

From above-mentioned results, as to peak hour in the morning if the minimum green light time is rather shorter, traffic flow for north-bound has priority and the capacity for south-bound becomes small because traffic volume for north-bound is larger than for south-bound. In case when the minimum green light time is too long, neither waiting time or queuing car length is not affected by the maximum green light time. However, the maximum green light time should be longer so as to correspond to any case when traffic volume increases.

As to peak hour in the evening, waiting time has little difference with the queuing car length among all cases. The minimum green light time should be set to 50 seconds or 60 seconds because the number of passing cars without waiting becomes longer in case when the minimum green light time is set longer than shorter. The maximum green light time should be longer so as to correspond to increase of traffic volume as peak hour in the morning.

5. CONSIDERATION OF APPLICATION TO REAL CONSTRUCTION SITE

From results in Section 4, we find that dynamic signal control system adapting to traffic volume is effective as the way to relieve traffic congestion on road occupied by construction work. This section examines how to apply the system to real construction site.

First of all, traffic volume on road, where construction work will be carried out, is surveyed not only at peak hours but also at off-peak hours. Occupied road length given by construction work and queuing car length permitted by conditions around the construction site are also surveyed. Then traffic flow control is analyzed by simulation model presented in this study to find the minimum green light time and maximum one for each time zone, by which traffic can be controlled most effectively. These two data become input information for dynamic signal control.

Though ultrasonic type detector and looped type one are typical as car sensors, the former is introduced in this study because of its low price and easy installation. Car sensors are installed not over occupied road but on roadside for facile use. The role of car sensors is to judge whether queuing car length reaches permissible length or not. Therefore 3 or 4 car sensors should be installed at 1 meter interval around this point. A self-timer, in which the minimum green light time, the maximum one and the green light time to be extended obtained previously by simulation are input, are set into temporary traffic signals. These signals extend green light time with a certain interval up to the maximum green light time after the minimum one passes by information from car sensors.

6. CONCLUSION

This study has proposed the way to improve traffic obstacles on occupied road with less than three lanes in pipeline laying work by dynamic and automatic control of temporary traffic signals. When road condition and traffic flow one are given, simulation model programmed by SLAMII/PC can analyze the ideal relation between the phase of traffic signals and queuing cars. Then temporary traffic signals can be controlled automatically using dynamic information on queuing cars from car sensors and/or video cameras installed on roadside.

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