Adaptive Offset Control in Traffic Signal System

Y. Hibiya[a], M. Kudo[b], T. Fujikura[c], T. Nakanishi[d]

[a] *Kyosan Electric MFG. Co. Ltd. (y-hibiya@kyosan.co.jp)*
[b] *Kyosan Electric MFG. Co. Ltd. (m-kudou@kyosan.co.jp)*
[c] *Kyosan Electric MFG. Co. Ltd. (t-fuji@kyosan.co.jp)*
[d] *Tokushima Bunri University (tosio@blue.ocn.ne.jp)*

Abstract: Recently, we have had many traffic problems, such as traffic congestion, air pollution caused by exhaust gas and frequent traffic accidents. In order to cope with these problems, a special traffic signal control system corresponding to the traffic condition of each intersection is needed. At present, so many advanced research activities are seen on signal control method, which is called as ITS (Intelligent Transport Systems). The functions of signal control are to control optimally the situations and to deal with rapidly changing traffic flow with prediction, in other words, in feed-forward way. Now we have two main methods for systematic traffic control (offset control). This paper compares two methods and asserts the adaptive offset control method of our original proposal is superior to the automatic pattern selection control method.

Keywords: ITS; Offset control; Pattern selection control; Adaptive control

1. INTRODUCTION

The automatic offset pattern selection control is not flexible and unable to adapt itself immediately to the sudden change of traffic flow. On the contrary, the adaptive control can smoothly correspond to the rapid traffic change and is regarded as a better method in the changeable traffic conditions of intersection. For the actual application of automatic adaptive offset control, it is indispensable to simulate various situations and evaluate them under various traffic conditions [Japan Traffic Management Technology Association,1999].

This paper discusses the adaptive offset control system of our original proposal [Miyazaki,1999]. We show the simulation results on actual model along one road based on the adaptive control system. The model is built by our offset setting simulator. We compare the result of pattern selection control with those of adaptive system and evaluate the adaptive control method.

As an actual model, the authors have selected the national route 8 at Takaoka City, in Toyama Prefecture. We set up a road section in our model which includes up bound and down bound lanes ranging over a distance of about 2 km. The average travel time [Japan Society of Traffic Engineering, 1999] was compared between automatic offset pattern selection control mode and adaptive offset control mode.

2. OFFSET CONTROL

2.1 Description of Offset

An offset is the time difference between two green signal phases of adjacent intersections. Offset values are expressed in seconds or as a percentage of a cycle time. The adequate setting up of offset and vehicle running speeds can assume the least vehicle stops at the consecutive signals[Japan Society of Traffic Engineering,1996].

However, the efficiency of offset control is deteriorated by the traffic congestion and even if an offset control system is applied to an over-saturated road [Japan Society of Traffic Engineering, 1999], no satisfactory control effect may be obtained.

2.2 Offset Simulator

An offset is a unique signal control parameter [Japan Society of Traffic Engineering, 1999] for controlling a traffic system and greatly affects the efficiency of coordinated control [Japan Society of Traffic Engineering, 1999] performance. On a time-distance chart, the time in which vehicles can pass all related

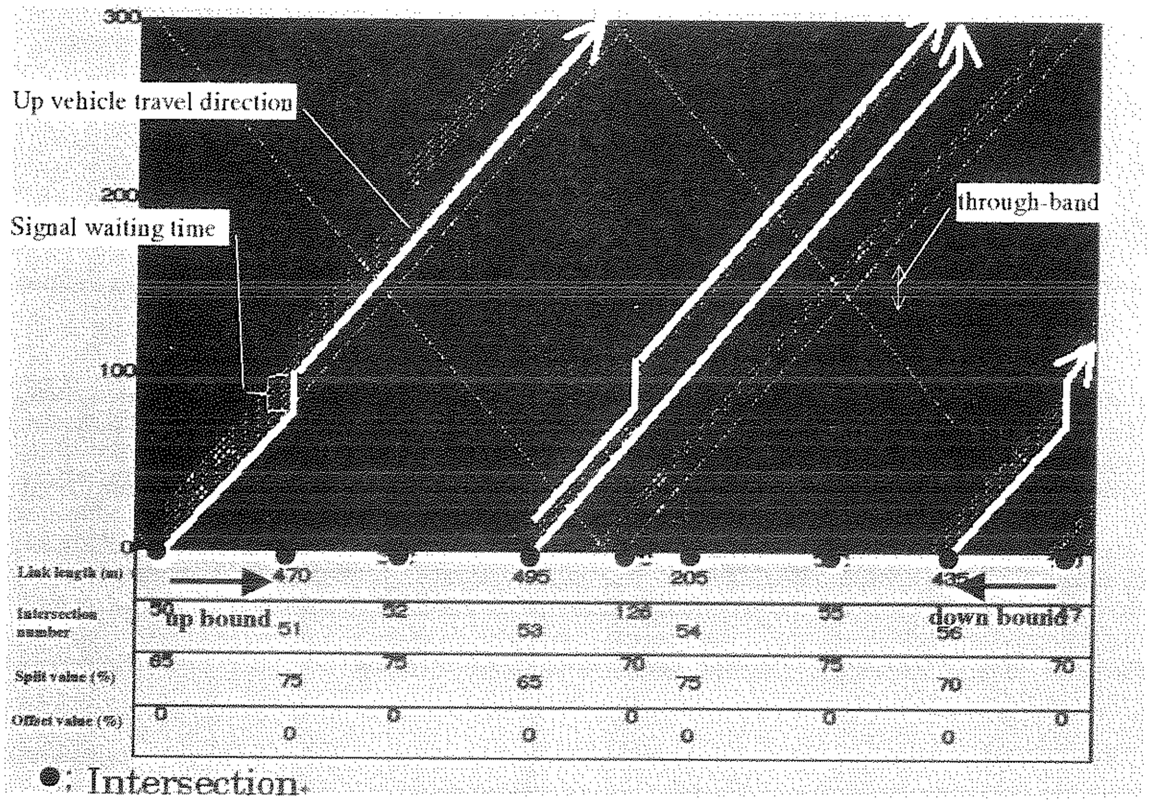

Figure 1. An example of offset simulator application.

intersections in green signal phases is called a through-band (Figure 1).

Conventionally, setting up an offset is based on the experience of control operators, so the effect of setting up an offset can be evaluated depending only on the results of actual operation. [Miyoshi,1995]

Owing to the above circumstances, the authors have developed an offset simulator which calculates an offset value with evaluation criteria clearly defined by a weighed summation of delay times and the number of stops [Japan Society of Traffic Engineering, 1999]. Using the offset simulator, each parameter has to be input; however, delay times [Japan Society of Traffic Engineering, 1999] and the number of stops for up bound and down bound lanes can be automatically calculated at each intersection. Using the offset simulator, an input offset value can be evaluated quickly for its adequacy.

2.3 Automatic Offset Creation Control System

2.3.1 Features of automatic offset creation control system

An automatic offset creation control system can cope smoothly even with rapid variations of traffic conditions. Even if trends in traffic volume on a road vary greatly because of an expansion of the road, for example, no human intervention is required, but an appropriate offset can be configured automatically. Figure 2 shows the flow chart of the automatic offset creation control system.

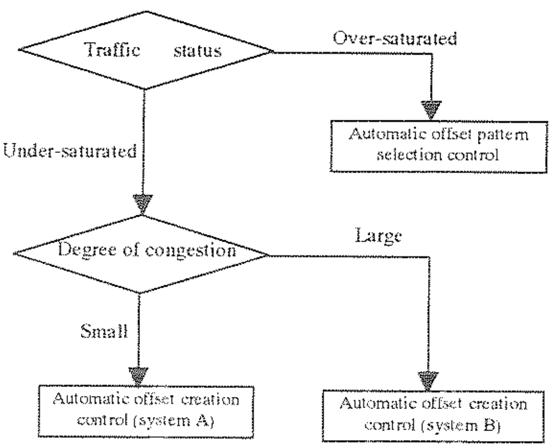

Figure 2. Offset control flow chart.

2.3.2 Selecting automatic creation control

In an offset control procedure, traffic status has to be judged over-saturated or under-saturated [Japan Society of Traffic Engineering, 1999], and if over-saturated, the automatic offset pattern selection control mode is adopted. If under-saturated, the automatic offset creation control mode is used.
The automatic offset creation control mode is classified into two types. In one type, only the relationship between adjacent intersections is taken into account, and offsets are calculated automatically to allow vehicles to pass only two adjacent intersections (system A). This system may give birth to a large discrepancy between a designed speed and an actual speed on a highly congested road, therefore, offsets are calculated and automatically applied to controlling traffic only between two adjacent intersections.

The other method is a system by which adjacent intersections should be controlled by a simultaneous offset [Japan Society of Traffic Engineering, 1999] (offset value: 0%) or an inverted offset [Japan Society of Traffic Engineering, 1999] (offset value: 50%), and a basic offset is created for the road, and an optimum offset value is searched from the basic offset (system B).

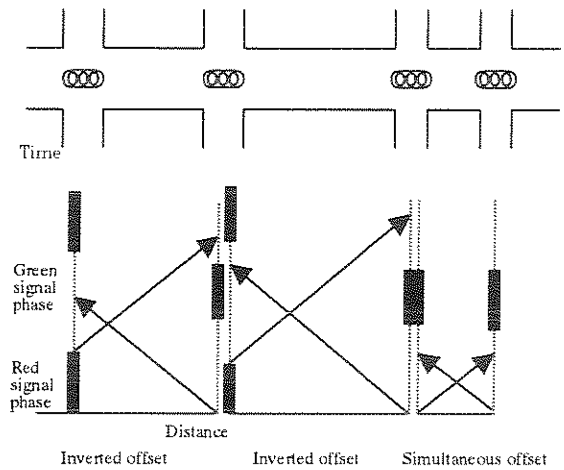

Figure 3. Diagram showing simultaneous and inverted offsets.

The basic offset at an intersection with a narrow split is shifted by ±5% for compensation, and a delay time with the compensation is calculated and compared with the delay time when the basic offset and the pattern selection control system are operated without compensation. Then, we adopt a combination that leads to the smallest PI (performance index: delay time and number of stops) as a result of calculations. System B is applied when traffic conditions are such that vehicles can travel at a design speed (when it is less congested).

2.3.3 Basic offset

The basic offset is either a simultaneous offset or an inverted offset for adjacent intersections, according to a judgement made from distance, split, and travel speed between the intersections. Physical distance is converted into a standard unit length, and the minimum delay time is searched according to period, speed, and distance in a mutually dependent relationship. The standard unit length of a road is the distance that a vehicle to be controlled travels in the cycle of a traffic control signal.

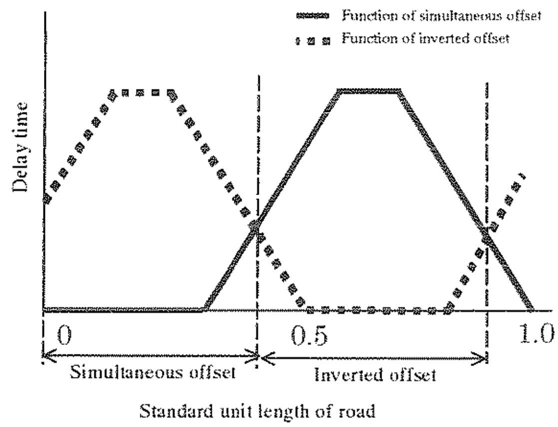

Figure 4. Relationship between offset and delay time.

2.3.4 PI VALUE (PERFORMANCE INDEX)

The PI value is a weighed sum of total delay time and number of stops, where one stop corresponds to a delay time. PI values for up and down routes are calculated by vehicle detectors in up and down lanes.

PI value = total delay time + (number of stops × coefficient of converting stop cycles)

Note that a coefficient whereby the number of stops is expressed as a delay time, determines how many seconds the delay time of a stop corresponds to.

3. EXPERIMENT WITH AUTOMATIC OFFSET CREATION CONTROL SYSTEM

Table 1. Comparison of travel times before and after the experiment.

	Travel direction	
	From Showa-cho to Takaoka IC	From Takaoka IC to Showa-cho
	1-hour average travel time	1-hour average travel time
Before the experiment	316	324
After the experiment	278	283
Time reduction ratio (%)	About 12% (38 sec)	About 13% (41 sec)

We measured average travel times on a road controlled by the automatic offset creation control system.

Conditions of experiment:

- Object road: National route 8, Takaoka City, Toyama Prefecture
- Object intersections: Six intersections between Showa-cho - Takaoka IC
- Object section: About 2.1 km
- Period: 2001, 5, 27 - 2001, 6, 6

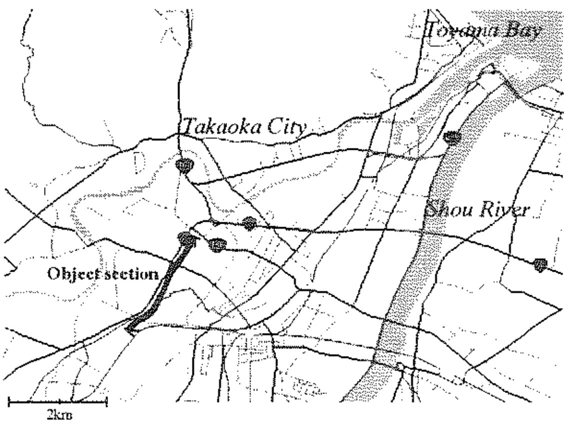

Figure 5. Map of object road in Takaoka City, Toyama Prefecture.

Average travel times were measured under the following conditions:

- Automatic offset pattern selection control. Measured on weekdays between 2001 5/28 - 6/5
- Automatic offset creation control. Operated during 2001 6/6 21:00 - 22:00

4. COMPARISON AND EVALUATION

Averages of travel times were calculated from the results of the experiment, and the results were compared before and after the experiment. Study results are shown in Table 1.

According to Table 1, average travel time from Showa-cho to Takaoka IC direction was reduced by about 12% in terms of one-hour average between 21:00 - 22:00. For the direction from Takaoka IC to Showa-cho, one-hour average time between 21:00 - 22:00 was reduced by about 13%.

Therefore, the authors could verify a large improvement of travel times using the automatic offset creation control system.

5. CONCLUSIONS

It was confirmed from the comparison of experimental results, the automatic offset creation control system can significantly improve average travel time. The length of the road subject to the experiment was 2 km, however, the authors plan to make another experiment on a longer stretch of road.

We also have the future task of applying the adaptive offset control system to an area range by improving the conventional system for a linear range. The present experiment related to a single, linear road to create an offset automatically. The authors' plan to apply the automatic offset creation control system in the future is related to an area where a number of roads intersect.

6. ACKNOLEDGEMENTS

The authors express their sincere thanks to General Manager, Toyama Prefectural Police Headquarters and all other people concerned for their advice and cooperation.

7. REFERENCES

Japan Traffic Management Technology Association ., ITS developed by Japanese police, 52-56, 1999.

Japan Society of Traffic Engineering ,Manual on Traffic Signal Control, 47-53,1996.

Japan Society of Traffic Engineering , Terminology of Traffic Engineering, 1999.

Miyoshi,I., T.Fujikura, M.Takahashi, T.Nakanishi, The State of the Art of Urban Traffic Control System and Its Prospect, International Congress on Modelling and Simulation Vol.4, 1995.

Miyazaki,I., T.Nakanishi, M.Takahashi, H.Kazama, Y.Hibiya, Response of Signal Control Systems to Traffic Variations, International Congress on Modelling and Simulation Vol.4, 1999.

8. APPENDIX

Terminology [Japan Society of Traffic Engineering, 1999].

- Travel time; time for a vehicle to travel a section, including stop time and delay time.

- Over-saturation; state in congestion.

- Signal control parameters; generally mean cycle length, split, and offset, which are time elements required for signal indications; also called signal control parameters or constants.

- Coordinated control; signals, installed over a continuous range, are operated cooperatively, so that vehicles can travel smoothly.

- Number of stops; number of times a vehicle is stopped by a traffic signal when it travels on a section.

- Delay time; the difference in travel times for a vehicle when it travels without being interrupted by a signal or a waiting queue (without acceleration or deceleration) or it actually travels.

- Under-saturation; uncongested state.

- Simultaneous offset; an offset along a system route, determined so that indications at all intersections are changed to green signal phase simultaneously.

- Inverted offset; an offset to make signals at adjacent intersections on a system route, to indicate green signal phase by shifting a half-cycle each.