# TRAFFIC CONTROL AIMING FOR $CO_2$ REDUCTION UTRIZING PROBE INFORMATION

**Hiroshi Morimoto*[1], Toshihiko Oda*[2]**
**Katsuyuki Suzuki*[3], Kunihiro Kamata*[4]**
**Universal Traffic Management Society of Japan**
**2-6, Ichigayatamachi, Shinjuku-ku, Tokyo 162-0843, Japan**
**TEL: +81-3-3235-6520, FAX: +81-3-3235-6522**
**Email:teng0262@teng.utms.or.jp*[1], teng0181@teng.utms.or.jp*[2]**
**teng0613@teng.utms.or.jp*[3], kamata@utms.or.jp*[4]**

## ABSTRACT

This paper represents the role which the traffic control center plays in $CO_2$ emissions reduction. Today, the signal control system aiming at direct $CO_2$ emissions reduction is desired. For this, it is necessary to estimate $CO_2$ emissions and possible to utilize probe information. We have conducted an experimental run using vehicles which transmit probe information and estimated $CO_2$ emissions. On the other hands, distribution traders are required to reduce $CO_2$ emissions and this can be attained by providing traders with $CO_2$ emissions information obtained from probe information. To realize this, the vehicle operation management system for commercial vehicles is examined.

## KEYWORDS
$CO_2$ emissions reduction, Traffic control system, Probe vehicle, signal control system

## BACKGROUD

Today, global warming is a global environmental problem and is increasing its seriousness every year. $CO_2$ is mentioned as a key factor substance which has brought about global warming. The Kyoto Protocol was adopted among advanced major powers in 1997. Ignited by this, the measure turned to the $CO_2$ emissions reduction is also promoted in Japan. However, the $CO_2$ emissions reduction is not still progressing. The percentage which originates in automobile traffic among $CO_2$ emissions of the whole country is about 20% and there is no big change in the past ten years[1].

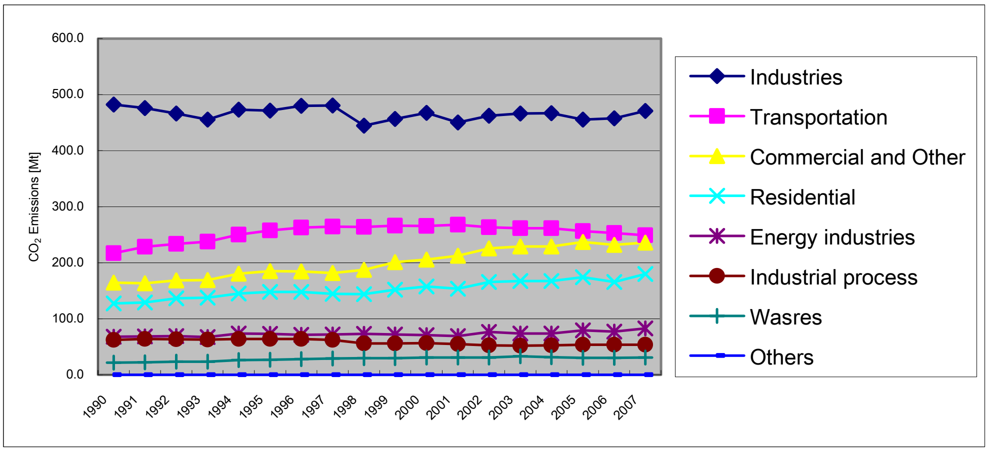


**Figure 1 - Trends in $CO_2$ emmissions in each sector**

The traffic control center which manages urban traffic has been working aiming for safe and smooth traffic flow and environmental measures. In this situation, it is necessary to perform traffic management aiming at the $CO_2$ emissions reduction.

## SUBJECT OF THE TRAFFIC CONTROL SYSTEM IN $CO_2$ EMISSIONS REDUCTION

Currently, traffic control centers reduce $CO_2$ emissions by smoothing traffic flow. In a word, the amount of $CO_2$ emissions reduction is calculated by converting the amount of reduction of travel time. However, the accuracy of the $CO_2$ emissions estimated is low because estimation is not based on changes of vehicle speed as, the conventional traffic control systems use spot type detectors installed on the roads. Spot type detectors detect the presence of vehicles within the specific narrow area but can't measure the changes of vehicle speed which inferences $CO_2$ emission. Besides that, conventional detectors are installed on major roads and traffic condition on minor roads where detects are not installed can't be obtained. Therefore, the target zone for calculation of $CO_2$ emissions is limited within the target zone for traffic control system.

## ESTIMATION OF $CO_2$ EMMISIONS USING PROBE INFORMATION

Recent years, the Universal Traffic Management Society has been considering collection of probe information through infrared beacons[2]. As probe information includes the record of time changes of vehicle position, the changes of vehicle speed or the frequency of acceleration is attained. Therefore, by utilizing probe information, the estimation of $CO_2$ emissions of a road section unit is attained in accuracy higher than the present. Further, probe vehicle also provides information of minor roads where detectors are not installed.

In this study, $CO_2$ emission is calculated by multiplying conversion coefficient by the estimated value of the fuel consumption. In order to estimate the fuel consumption, the following model equation proposed by Oguchi *et al* [3] is used.

$$E = K_C(0.3T + 0.28D + 0.056\sum_k \delta_k(v^2{}_k - v^2{}_{k-1})) \tag{1}$$

where,

$E$ : $CO_2$ emissions [cc]

$K_C$ : coefficient to convert the gasoline fuel consumption to $CO_2$ emissions

$T$ : travel time of the road section unit [sec]

$D$ : distance of the road section unit[m]

$\delta_k$ : $\delta_k = 1$ if $v_k > v_{k-1}$, otherwise $\delta_k = 0$

$v_k$ : velocity at time $k$ [m/s]

This model equation is derived by analyzing data recoded by the unit of 100ms. Data is obtained by the test run of 2000cc vehicle with a measuring instrument.

### Measurement of the amount of fuel consumption

The experiment is conducted using test vehicles in the Kanagawa Prefecture Yokohama city to compare the amount of real fuel consumption and estimated value of fuel consumption based on the model formula. In this experiment, vehicles listed on the Table 1 run in urban area within three time zones, morning (9:00-10:00), daytime (12:00-15:00) and evening (17:00-20:00).

**Table 1 - Characteristics of test vehicles**

| Vehicle No. | Vehicle type | Engine displacement | Load of freight |
|---|---|---|---|
| 1 | Passenger car | 2000cc | - |
| 2 | Passenger car | 2000cc | - |
| 3 | Passenger car | 1300cc | - |
| 4 | Van | 2000cc | 0 kg |
| | | | 500 kg |
| | | | 750 kg |
| | | | 1000 kg |

The amount of fuel consumption and average travel time for 20km's run at each time zone are shown in Figure 2 and Figure 3. This result shows no major difference of the amount of fuel consumption when vehicles belong to the same vehicle type and have the same engine displacement. On the other hands, a major difference is observed when the engine displacement of test vehicles differs.

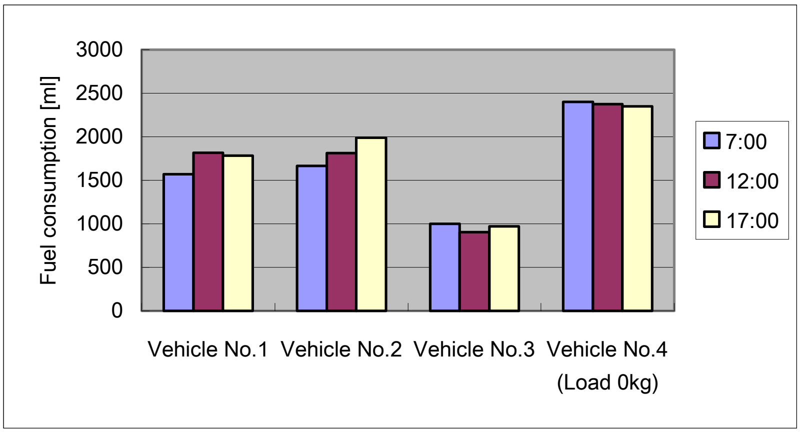


**Figure 2 - Amount of fuel consumption according to vehicle No.**

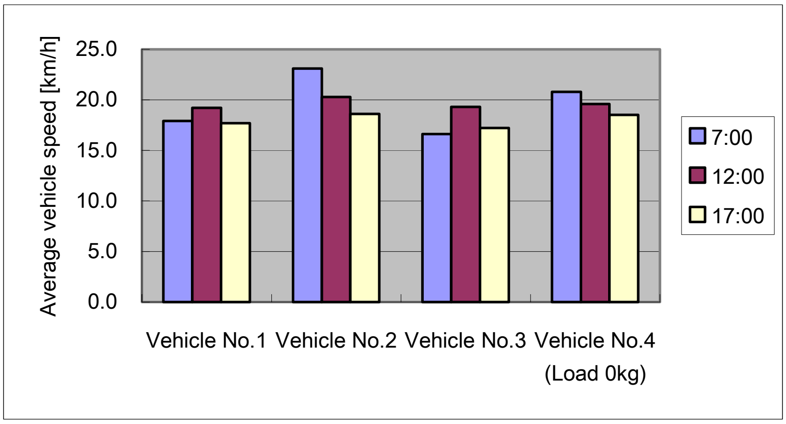


**Figure 3 - Average vehicle speed according to vehicle No.**

Figure 4 shows the amount of fuel consumption and Figure 5 shows average vehicles speed when the load of freight assumed is changed. This result shows the amount of fuel consumption increases in accordance with the increase of the load of freight.

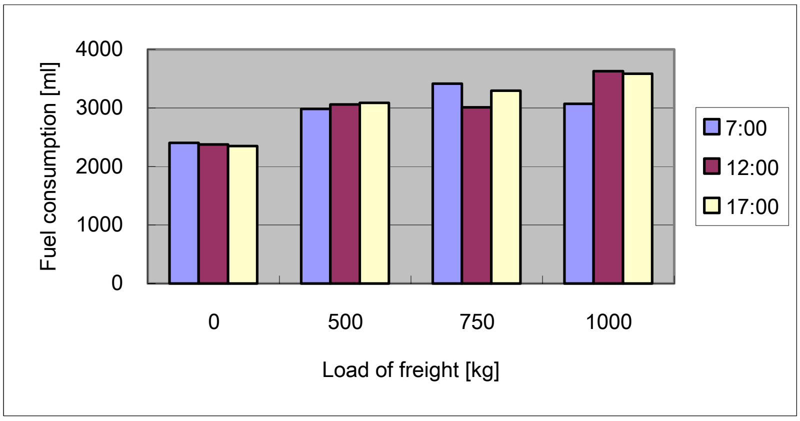


**Figure 4 - Amount of fuel consumption according to load.**

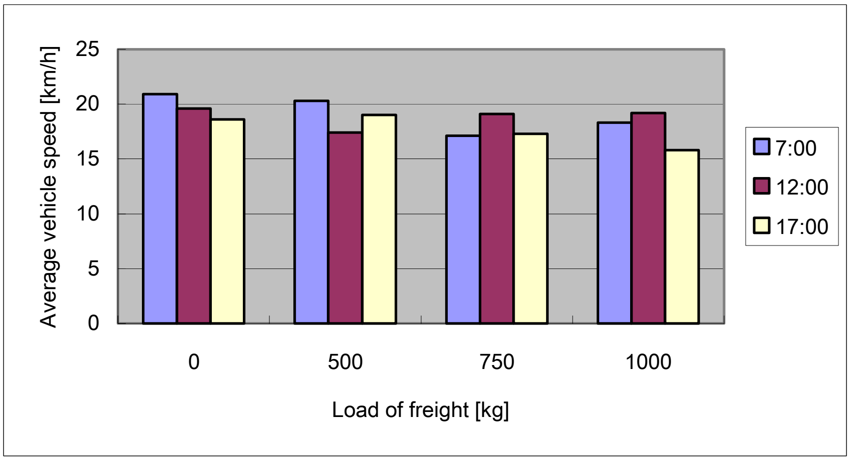


**Figure 5 - Average vehicle speed according to load.**

These results above show that the amount of fuel consumption is remarkably affected by the engine displacement and the load of freight. Especially, it is confirmed that engine displacement is an important factor when estimating the amount of fuel consumption.

## Estimation of the amount of fuel consumption

As a next step of experiment, the estimation of the amount of fuel consumption based on equation (1) is performed using probe information. Vehicles listed on the table 1 are used as probe vehicles. The value of parameters of equation (1) is determined using probe information which includes the record of time changes of vehicle position. The estimated value of the amount of fuel consumption is compared with the real value of fuel consumption. Regarding vehicle No.1 and No.2 on the Table 1, the average square error margin becomes 15% or less and the correlation coefficient becomes 0.85 or more. This result shows that equation (1) is applicable when estimating the amount of fuel consumption of 2000cc passenger vehicle. Regarding vehicle No.3 and No.4, as the type vehicle and engine displacement differs, the difference between the estimated values and measured value is large. Therefore, when estimating the amount of fuel consumption of other than 2000cc passenger vehicle, we consider that the value of coefficients of equation (1) to be decided in accordance with categories, such as type of vehicle or engine displacement.

In this experiment, though conditions of experiment are limited, the validity of equation (1) is proven, resulting shortening of travel time, parameter $T$ of equation

(1) and decrease of number of acceleration, parameter $\delta_k$ of equation (1) leads to decrease of the amount of fuel consumption. Therefore, the signal control system is expected to directly control these parameters and contribute to the decrease of the amount of fuel consumption.

In the viewpoint of practical use of the estimation of $CO_2$ emissions of each road section with high accuracy, it needs an increase of the number of probe vehicle equipped with a unit which can generate and transmit probe information. Therefore, the problem here is how to spread probe vehicles. In order to spread probe vehicles, it is often pointed out that direct incentives to driver are necessary. As an example, by observing the generation of traffic congestion using probe information and notifying it to the signal control system in real time manner, the signal control system is expected to dissolve traffic congestion smoothly.

### Application of probe information for the signal control system

In Japan, phases of traffic signal are calculated using traffic demands. Traffic demands consist of not only traffic inflow into the intersection but also the length of traffic queue. Currently, the length of traffic queue is estimated using information obtained by spot type detectors which can not detect the change of traffic flow widely, resulting low the accuracy of estimation. On the other hands, probe vehicles can measure own stop position and this enables an accurate calculation of the queue length. By this, the signal control system is enhanced based on the appropriate traffic demands. Furthermore, probe vehicle can detect the emergence of bottlenecks of traffic flow such as a lane close at the outflow of an intersection, which conventional detectors can not detect. For this reasons, the signal control system using probe information is expected to respond to not only the generation of congestion but also the sudden emergence of traffic bottlenecks more quickly.

## THE VEHILCE OPERATION MANAGEMENT SYSTEM AIMING AT $CO_2$ EMISSIONS REDUCTION

In general, the running frequency of the commercial vehicle is higher than that of the private vehicle. Therefore, in the spread early stage of a probe vehicle, it becomes possible to secure the quantity of information with the small number of vehicles by utilizing commercial vehicles. However, in order to make the distribution traders who make it operate around a commercial vehicle introduce a probe vehicle, a certain incentive is required. From such a background, we are considering the construction of a vehicle operation management system which utilizes probe information. The vehicle operation management system estimates the $CO_2$ emissions of each vehicles using probe information sent from distribution trader's vehicles equipped with an probe units and provide the distribution trader the result of estimation. Then, the distribution trader can understand own $CO_2$ emissions by visualizing the result. Moreover, it is possible to add the function of estimation $CO_2$ emissions to the traffic simulator and estimate $CO_2$ emissions of each road section by inputting not only probe information but also the various kind of traffic information gathered by traffic control centers. By this, the optimized running root which minimized the $CO_2$ emissions is offered to the distribution traders and it enables them to tackle on the reduction of their $CO_2$ emissions.

## SUMMARY

In this paper, the role of which traffic control center plays in $CO_2$ emissions reduction is described. Through the experiment using probe vehicles, equation (1) which would be the basis of the signal control system aiming for $CO_2$ emissions reduction is validated and the possibility of equation's application is examined.

Based on the results of this study, the following activities are planned.

- Describe a traffic signal control method, which directly reduces $CO_2$ emissions.
- Base on the method above, conduct the simulation and filed validation test.
- Promote the construction plan for the vehicle operation management system aiming at $CO_2$ emissions reduction.

By realizing plans above, the traffic control center is expected to play a role for the prevention of global warming.

## REFERENCE

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