Research Towards Practical Environment Protection Management Systems

Tadashi Kebukawa(Universal Traffic Management Society of Japan)*1
Airman's Building,7th Floor,2-6 Ichigaya-Tamaachi, Shinjuku-ku, Tokyo 162-0842
JAPAN
Tel: +81-3-3235-6520,Fax:+81-3-3235-6522,E-mail:tadashi_kebukawa@koito-ind.co.jp

Teruyuki Tajima(Universal Traffic Management Society of Japan)
Airman's Building,7th Floor,2-6 Ichigaya-Tamaachi, Shinjuku-ku, Tokyo 162-0842
JAPAN
Tel: +81-3-3235-6520,Fax:+81-3-3235-6522

*1 Koito Industries, LTD

SUMMURY

The Environment Protection Management Systems (EPMS) is part of the "UTMS" advanced traffic control system formulated by the Japanese National Police Agency. The purpose of the EPMS is to reduce roadside pollution caused by automobile traffic, with optimizing the deployment of signal controls, providing appropriate traffic information, guiding motorists to alternative routes, and using other effective tools. We began our research in 1994 and in 1996 demonstrate in general field experiments a system for measurement and control that reduced emissions of NOx. Based on these results, we investigated signal control techniques and utility of simulations to calculate emission volume. This paper describes the results of these verifications.

INTRODUCTION

The purpose of the EPMS is two-fold: to reduce roadside pollution caused by automobile traffic, thereby providing a broad spectrum of residents and pedestrians with healthier road traffic environments, and also to contribute to the protection of the global environment by reducing emissions of greenhouse gases. It does this by optimizing the deployment of signal controls, providing appropriate traffic information, guiding motorists to alternative roots, and using other effective tools. This paper discusses the system's innovations in optimized deployment of signal controls.

RESEARCH FINDINGS THROUGH 1997

From the beginning of the project until 1997, research focused on the relationship between road traffic and exhaust gas. The findings from these studies have already been published, and while the research is not yet complete, the insights gained so far have enabled work to begin on the construction of a system. Below are the major insights gained in research through 1997.

* There is a correlation between NOx and CO_2 as measured at roadside.
* However, this correlation breaks down when wind speed exceeds 2.5 meters per second.
* There is a range of travelling speed in which it is possible to reduce emissions of NOx.
* There is also a range of travelling speed in which it is possible to reduce emissions of CO_2.
* The travelling-speed ranges that reduce emissions of NOx and CO_2 are different.

These findings formed the basis of our research into traffic control techniques.

RESEARCH TOWARDS PRACTICAL APPLICATION

The Configuration of the EPMS

The EPMS comprises three main subsystems: the Traffic Environment Subsystem, Air Pollution Reduction Control Subsystem, and Vehicle Regulation and Warning Subsystem.

Traffic Environment Subsystem

Gathers information on traffic volumes and pollution volumes (NOx, CO_2) in real time, builds a statistical database and analyzes and monitors pollution levels.

Air Pollution Reduction Control Subsystem

Processes signal controls so as to suppress exhaust gas emissions. Uses controls to maintain vehicle movement on specific roads and at specific locations in a state that minimizes emissions.

Vehicle Regulation and Warning Subsystem

Provides and processes information about the automobile itself and about the driving environment. Reduces automobile emissions by providing information that will mitigate excessive concentrations of traffic.

To use these controls to provide effective administration, the system must be able to forecast emission volumes and deterioration in traffic environments so that is able to modify signal controls to counteract this. We therefore utilized simulations to investigate concepts for signal controls and to calculate emission volumes.

Signal Control Techniques

We began in 1996 to conduct studies of the correlation between changes in vehicle behavior and changes in traffic pollution. To do this, we varied signal control parameters in order to verify the effect that they have on traffic pollution from vehicular traffic.

These studies demonstrated clear correlations between changes in traffic volume and traffic pollution volumes between start/stop controls and non-stop travel.

In this section, we summarize the basic concepts for the traffic pollution response control algorithm that was developed from these findings.

Study of control parameters

The following section describes the control parameters that were used to implement pollution response controls. Three control parameters were defined: pollution, weather, and traffic flow. Below is an explanation of each.

Pollution parameter

Defined as the pollution level as expressed by pollution data from either observations or simulations. Table 1 gives an example of the breakdowns used for raw data on NOx pollution.

Table 1. Breakdown of Levels for Pollution Data (NOx)

Pollution level	0	1	2	3
Observed pollution value (ppb)	0-399	400-799	800-1199	1200-

Weather parameter

For the weather parameter we used a coefficient with threshold values as a means of correcting for the influence of wind direction and speed, which will have an impact on the dispersion of pollution volumes. The weather parameter is not directly reflected in pollution response controls. Rather, it is used in simulations to estimate and forecast total emission volumes and observed values.

Traffic flow parameter

Vehicle detector information (traffic volume, occupancy rate, speed) is used as data to express vehicle behavior, one of the causes of traffic pollution. The traffic flow parameter should also take account of the length of traffic jams and the degree of saturation, but detailed study of these areas is a task for the future.

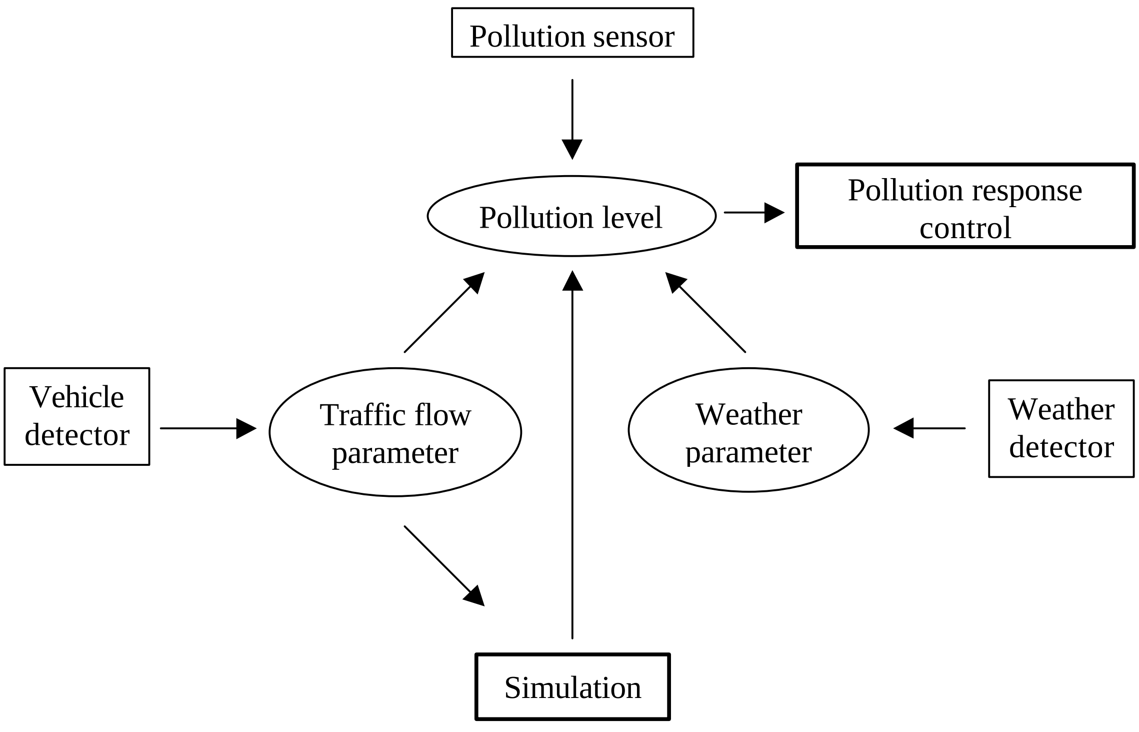

Figure 1. Relationship between pollution controls and parameters

Relationship between traffic parameters and pollution response signal controls

Figure 1 illustrates the relationship between the control parameters and pollution response signal controls and pollution simulations.

It is possible the relationship of parameters and pollution response control use three methods.

Method 1 reflects in controls the results of simulations based on traffic parameters. These are reflected as pollution parameters. This is the recommended method for controlling the total amount of emissions.

Method 2 reflects pollution levels directly in controls. This method provides controls based on the concentration of emission gases measured on the spot, but needs to be corrected for weather data (wind direction and speed).

Method 3 reflects traffic parameters indirectly in controls. This method is the least precise control.

Pollution response control objectives

Experimental findings to this point indicate that offset controls that provide for random starting and stopping will cause NOx values to increase, while non-stop (priority) travel offsets cause NOx values to decrease. We studied the objectives of pollution response controls based on these findings.

Pollution response offset control

This section describes offset controls that correspond to different pollution levels. The implementation of pollution response controls requires that several patterns of priority offsets be established ahead of time.

We studied a matrix corresponding to pollution levels in order to select priority offset control patterns for both the upstream and downstream traffic flows. The results are found in Table 2. Offset controls are effective when the pollution level is low or when there is an imbalance between upstream and downstream pollution levels, but when pollution levels are high or when both upstream and downstream are at medium levels, offset controls are of limited efficacy. In these cases, therefore, split controls and cycle length controls must also be considered in conjunction with offset controls.

Table 2. Pollution Response Offset Controls for Different Pollution Levels

		Upstream pollution level			
		0	1	2	3
Downstream pollution level	0	Normal offset	Upstream priority	Upstream highest priority	Upstream highest priority
	1	Downstream priority	Normal offset	Upstream priority	Upstream priority
	2	Downstream highest priority	Downstream priority	Normal offset	Normal offset
	3	Downstream highest priority	Downstream priority	Normal offset	Normal offset

Pollution response split controls

Splits at controlled intersections require a signal control method that tries to reduce starting and stopping (traffic jamming). This is because fewer starts and stops will reduce traffic pollution.

Pollution response split controls require that a pollution level matrix be drawn up ahead of time for the trunk road and the intersecting road. Table 3 shows an example. If the pollution level in one direction is 2 or above, then pollution control split controls are invoked. “Priority” in this case refers to giving that direction more splits. If pollution is at low levels, then normal split controls are used to reduce congestion, with offset controls providing the bulk of the pollution response controls. However, as pollution levels move higher, pollution response split controls and offset controls must be linked together. There must also be policies on priority controls for cases in which pollution levels are the same on the trunk and intersecting roads (for example, a decision to give priority to the trunk road).

Table 3. Pollution Response Split Controls for Different Pollution levels

		Trunk road pollution level			
		0	1	2	3
Intersecting road pollution level	0	Normal control	Normal control	Trunk road priority	Trunk road highest priority
	1	Normal control	Normal control	Trunk road priority	Trunk road highest priority
	2	Intersecting road priority	Intersecting road priority	Normal control	Trunk road priority
	3	Intersection road highest priority	Intersection road highest priority	Intersecting road priority	Policy priority

Table 4 contains a summary of the objectives of pollution response controls based on the findings discussed above.

Table 4. Signal Control Methods Used for Different Pollution Levels

Pollution Level	Signal Control	Control Objective
Small	Offset	Optimized offset that minimizes starts and stops (total delay)
Medium	Split Offset	Split that controls emission volumes above all else
Large	Cycle Split	Signal control that give stock-holding longest green time to the direction with the highest pollution volume

Functions of the Pollution Forecasting Simulator

The air pollution simulator was created because the EPMS, if it is to counteract traffic pollution, must be able to simulate the emission gas pollution that is generated by specific forms of road traffic behavior.

Purpose of simulator

The simulator estimates and forecasts the total volume of exhaust gas emitted by vehicles travelling along a certain section of road (the total emissions volume) based on data input on road conditions, traffic information, weather information, and signal control information. Its purpose is to make it possible to support the formulation of traffic policies designed to reduce total emissions volumes and to assist in the assessment of the effectiveness of these policies in reducing total emissions volumes.

Basic concepts

Minimize data input

Even if the functions are superb, a system with too many items to input will not be feasible. However, even when there are large numbers of items to be input, it may be possible to use preset values for most of them, so that standard functions are achieved with few actual input items.

Able to update (improve) individual function modules

The simulator should start with a focused group of input items and functions, and then be gradually upgradable.

Usable without need of special operating environments

Should be able to be used on generally available hardware and software.

Outline of Simulation

Information input and output

Below is the information input to and output from the simulator.

* Road: Covers a straight zone with up to 10 intersections; input number of intersections, length of links, number of lanes, land priorities, land widths, and size of intersections.
* Traffic: In view of the degree of impact on emission volumes, input the model mix, on-street parking (yes or no), right and left turn rates, acceleration and deceleration speed, minimum distance between vehicles, and response delay.
* Weather: Input wind direction and wind speed, the items that have the largest impact.
* Traffic signals: Input seconds for each stop and offset for all traffic signals.
* Pollution (output: Estimated volume of CO_2 and NOx emissions.

Software functions and configuration

The simulator has the three functions listed below.

* Traffic micro-simulation: Generates vehicles of each type (uniform traffic flow), processes vehicle movement and vehicle elimination (because of right and left turns), taking account of speed, acceleration speed, and signal displays.

* Calculation of emission volumes: Calculates the emissions generated by each vehicle, and totals them to arrive at the total vehicular emissions volume for the simulation zone.

Network configuration

The simulation covers 10 intersections and 11 links. Vehicle generation uses a uniform flow distributed evenly over multiple lanes. At intersections, the elimination of vehicles from right and left turns is processed at the incoming stop line, with the generation of vehicles from influx from the intersecting road processed at the outgoing stop line.

Vehicle movement

Four types of vehicle movement are assumed at links.

* Following and travel behavior: follows the vehicle in front and travels at the minimum distance between vehicles.
* Individual movement: travels at the speed limit uninfluenced by other vehicles.
* Stopping movement: Stops at a stop target.
* Conversion movement: travels at a conversion speed in order to make a right or left turn.

Software configuration and flow of processing

Figure 2 contains the software configuration and flow of processing for the simulation.

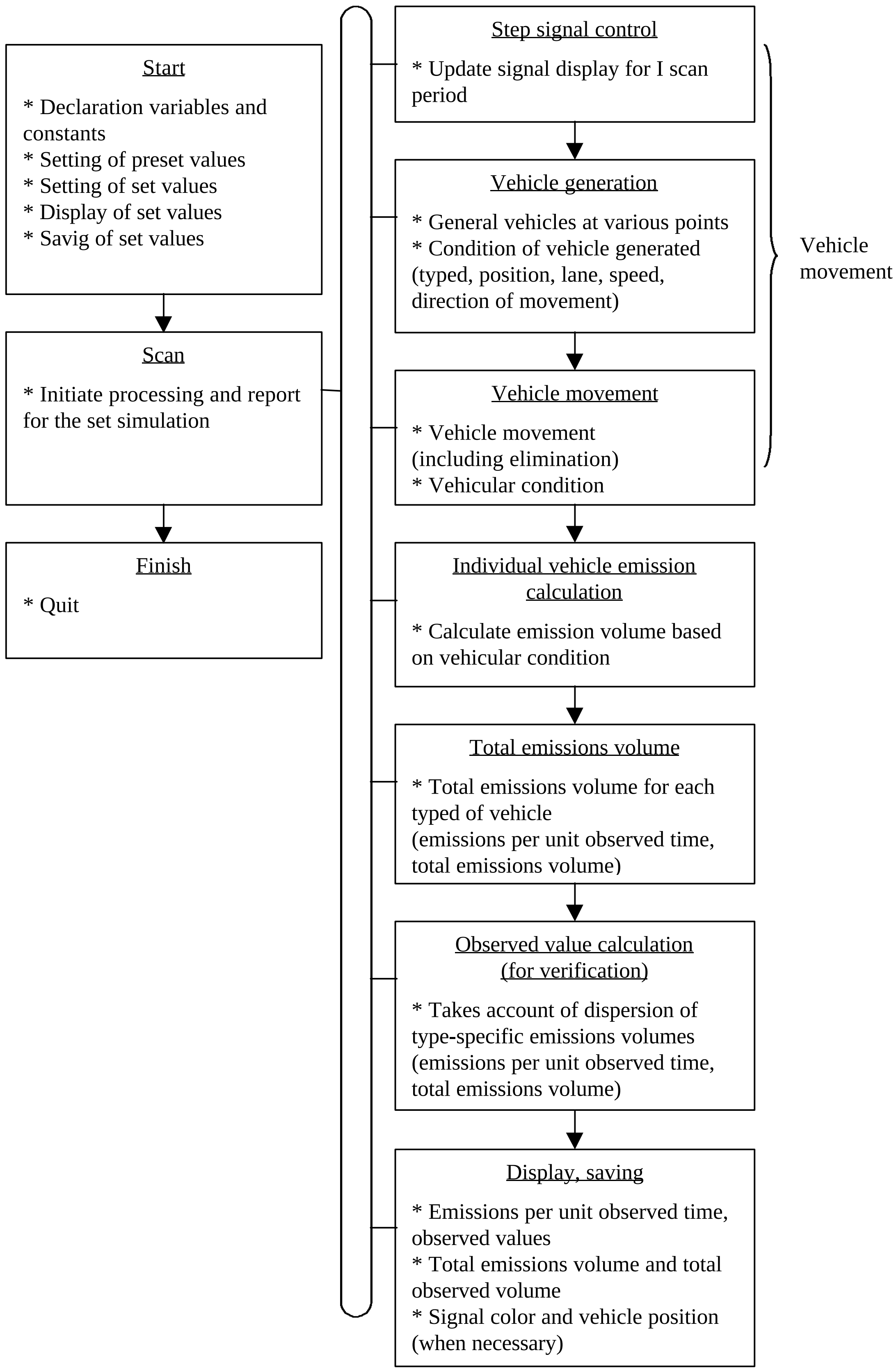

Figure 2. Software configuration and processing flow

Vehicle movement information

For each scan, the system process vehicles generated, vehicle movement, and vehicles eliminated, as warranted by signal displays. This is used to create vehicle movement information.

Type-specific emissions calculation

For each type of vehicle, the system calculates the amount of CO_2 and NOx emitted during the scan based on vehicle movement information during the scan and using a type-specific formula embedded in the software.

CO_2 emissions calculation

Based on vehicle movement information, the system calculates the CO_2 emitted during 1 scan period.
The following emissions formula is used.

* Bus : $y = A1 \times (413+59.4v-0.0320v^2+0.00332v^3)$
* Large-sized : $y = A2 \times (2190+180v-0.449v^2+0.000268v^3)$
* Others : $y = A3 \times (1970+203v-2.26v^2+0.0207v^3)$

A1, A2, A3: Constants (adjusted for observed values)
y: emissions volume (ml/100 ms)
v: Travel speed (km/hair)

NOx emissions calculation

Based on vehicle movement information, the system calculates the NOx emitted during 1 scan period.
The following emissions formula is used.

* Bus : $y = A1 \times (4.42+0.506v-0.00462v^2+0.0000266v^3)$
* Large-sized : $y = A2 \times (9.21+0.491v-0.00413v^2+0.0000399v^3)$
* Others : $y = A3 \times (1.68-0.0529v+0.00285v^2+0.0000252v^3)$

Total emissions volume calculation

The system totals the emissions volumes for all vehicles between the intersection farthest upstream (the outgoing stop line) and the intersection farther downstream (the incoming stop line). This is accumulated for set period of time to calculate a total emissions volume. The accumulation time is set to match a minimum time that changes for the signal control method employed.

Verification of calculation results

Simulation precision could be verified if there were a method available to observe to emissions volumes, but they cannot be measured directly. We therefore employ the following method to verify results.

* Extract vehicle behavior for a 10 meter range on either side of a point within the simulation zone, seeking emissions for this area only.
* Measure emission gas concentration from detectors at the same point.
* Compare the two values against each other.

Results verified by this method are generally good, and will be reported on at a later date after detailed verifications are performed.

FUTURE TASK

The required specification presented here are not complete; they represent the outcomes of studies and the experimental findings so far. We anticipate that they will be enhanced as the simulator is used.

(1) Online connection with traffic management system

An on-line connection is necessary so that information on traffic and weather conditions can be input to the simulator in real time and simulation results automatically reflected in signal controls.

(2)Expand coverage to entire road network

The current specifications are suitable to simulations for major roadways, but the system will need to be adapted for constant monitoring of the entire road network covered by the traffic control system.