# ONLINE TRAFFIC SIMULATOR (HEROINE) INTRODUCED AT THE HANSHIN EXPRESSWAY TRAFFIC CONTROL CENTER


**ISHII, Yasuhiro**
Second Chief Engineer
Hanshin Expressway Public Corporation, Dep. of Management, Traffic Control Div.
Osaka Center Bldg. 1-3, 4-chome, Kyutaro-machi, Chuoh-ku, Osaka 541-0056, JAPAN
Phone: +81-6-6252-8121, Fax: +81-6-6252-7410, E-mail: yasuhiro-ishii@hepc.go.jp
**YAMAGUCHI, Hirotsugu**
Assistant Manager
Hanshin Expressway Management Technology Center
4-5-7, Minami-hommachi, Chuoh-ku, Osaka 552-0006, JAPAN
Phone: +81-6-6244-6058, Fax: +81-6-6244-9612, E-mail: yamaguti@tech-center.or.jp
**FUJII, Masaru**
Supervisor, OMRON Corporation
1-6-20, Dojima, Kita-ku, Osaka 530-0003, JAPAN
Pnone: +81-6-6347-5865, Fax: +81-6-6347-5961, E-mail: mfujii@trf.osaka.omron.co.jp
**DAITO, Takehiko**
CEO, Transportation System Studies Laboratory Co., Ltd.
1-20, Nishinakajima 7-chome, Yodogawa-ku, Osaka 532-0011, JAPAN
Pnone: +81-6-6101-7001, Fax: +81-6-6101-7002, E-mail: daito@tss-lab.com


## ABSTRACT


In November 2002, the Hanshin Expressway Public Corporation started the operation of a traffic simulation program called HEROINE. This report outlines the functions of HEROINE and its actual operation. The program was evaluated by comparing the estimation results against actual traffic volume data for two months from the start date of the operation. Discussion extends to possible system improvements in the near future. It also contains proposals for future development direction based on the user survey. The program evaluation verified adequate accuracy of HEROINE.


## THE PURPOSE OF THE STUDY

The Hanshin Expressway traffic control system has been continually adjusted and expanded since its first introduction in 1969. Until today the system has been operated successfully and is highly regarded as a unique and distinguished traffic control system worldwide(1). In 1999, studies on innovative functions started for a new generation of the system. Those efforts resulted in a wide-range renovation in May 2003(2). Another highlight of the new system is a traffic flow simulator, named HEROINE (Hanshin Expressway Real-time Observation-based & INtegrated Evaluator). Its operation started in November 2002.

HEROINE is designed to enable real-time traffic simulation for the purpose of supporting routine traffic control operation, examination of restriction plans required for construction, and decision-making on operational measures. In the near future, it will also be used for traffic forecast information services(3).

This study evaluates the traffic forecasts generated by the traffic flow simulator immediately after its introduction. It also explains the current use of the simulator and, based on the evaluation, proposes a discussion on possible improvements and actions to resolve presently found problems. This is an effort to utilize the simulator more effectively as an integral function of the traffic control system.

# HEROINE OVERVIEW

## SYSTEM CONFIGURATION

HEROINE consists of six modules: Transportation Demand Estimation estimates the five-minute on-ramp inflow traffic based on traffic data received from the traffic control system; Flow simulates the traffic flow on the road network; Route Choice Behavior simulates each vehicle's choice at every point where more than one route can be taken; Data Aggregation/Distribution manages each simulation of the vehicles; Traffic Control implements on-ramp controls; and Output/Storage/Processing stores and updates the data (Fig. 1).

The outline of the modules is as follows:

- Flow module type: meso-simulation
- Road network for simulation: Hanshin Expressway network (234 km), and its complementary surface roads
- Vehicle movement: block density method on the Hanshin Expressway, and I/O (Input/Output) method on the surface roads
- Vehicles: Individual vehicles are identified and simulated independently.
- Transportation demand: The OD traffic volumes between ramps are estimated from the five-minute on-ramp traffic volume estimation.

The following sub-modules are used for estimation, if necessary in combination, depending on the type of the operation.

- Transportation Demand Estimation module: Generates movement schedule data for each vehicle using the Hanshin Expressway. It estimates the inflow traffic volume for up to two hours (Short-term Forecast) and for up to 24 hours (Long-term Forecast) based on the time line estimation module.
- Demand Aggregation/Distribution module: Manages the simulation of each vehicle.
- Flow module: Calculates and manages the traffic condition of each section of the Hanshin Expressway. It simulates the movements of vehicles by moving the vehicles downstream based on the block density method. The I/O method is used for the vehicles on surface roads.
- Route Choice module: Simulates route choices of each vehicle at every point where more than one route or more than one on-ramp can be taken. It applies the "on-ramp choice module", "off-ramp choice module" and "transit choice module for toll-free transit sections," based on available traffic information on the main routes to the desired exits.
- Traffic Control module: Proposes and implements control measures based on available traffic information every five minutes, using the built-in On-Ramp Closure and Booth Restriction Control Method.

Refer to references (2), (3) and (4) for more detailed explanation of these modules.

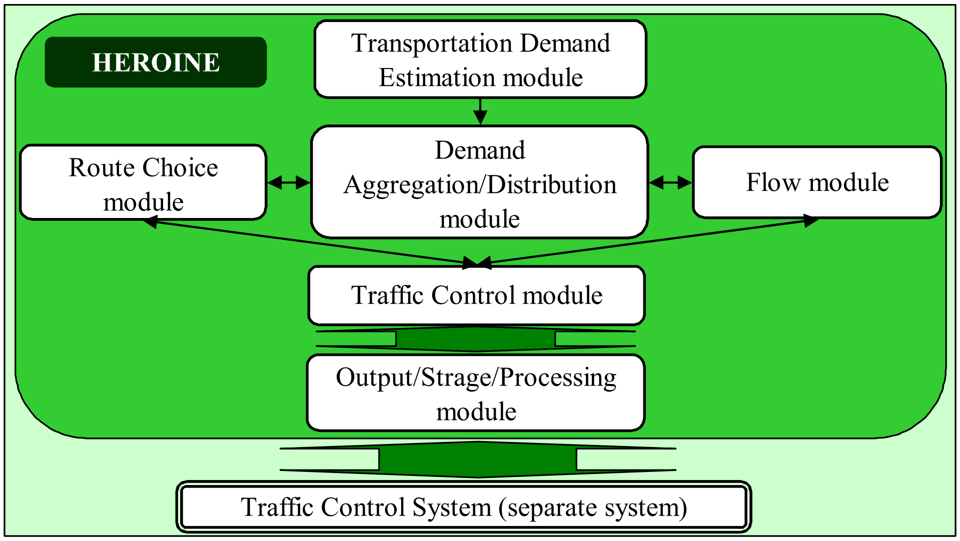


**Fig. 1 System Configuration**

## SYSTEM STRUCTURE

HEROINE keeps the Traffic Simulation Processing Device and the Simulation Web Server on the basic local area network (LAN). This allows the network to obtain inputs from the vehicle detectors and other real-time information including objects on the road and on-ramp controls. Upon request, traffic control and other data stored in the Data Warehouse as well as construction plan data held in the Management System of Traffic Control on Construction and Maintenance are also available. There are 25 online terminals installed at related offices of the Hanshin Expressway Public Corporation (HEPC).

## REQUIREMENTS AND CURRENT USES OF HEROINE

Functions required of HEROINE are the Short-term Forecast, the Intervention Forecast for evaluating immediate operations, the Long-term Forecast, and the Preliminary Forecast for evaluating measures under consideration.

The Short-term Forecast automatically estimates traffic conditions up to 90 minutes ahead to provide traffic information. The Intervention Forecast evaluates possible traffic measures (traffic restrictions and/or on-ramp controls) when an accident occurs or construction is being performed. The Long-term Forecast generates traffic forecast information up to 24 hours ahead to provide basic data for the HEPC operators and road users who are planning their travels. The Preliminary Forecast evaluates future traffic measures under consideration, estimating the results of on-ramp and other controls under a given traffic condition, based on the abundant traffic data collected through the traffic control system.

## HEROINE OPERATION

The operation procedure of HEROINE is shown in Table 1.

**Table 1. Operation Procedure of HEROINE**

| Type/Purpose | Operation Procedure | Calculation Timing | Forecast Period |
|---|---|---|---|
| Short-term Forecast | Automatic calculation | Every five minutes, at each event input | Up to 90 minutes |
| Intervention Forecast | Calculation based on the operator inputs | As specified by the operator | Up to 90 minutes |
| Long-term Forecast | Automatic calculation | Every hour | Up to 24 hours |
| Preliminary Forecast | Calculation based on the operator inputs | As specified by the operator | As specified by the operator (within 24 hours) |

# VALIDATION OUTLINE

## PERSPECTIVE OF THE VALIDATION

Validation of HEROINE was carried out based on the following perspectives in order to promote a more effective use of the simulator.

- Reproducibility. Compare the simulation results against the actual traffic volume values to evaluate the performance.
- Usability. Analyze the user evaluation.

## VALIDATION FRAMEWORK

### Data for the Validation

The sectional traffic volume, inflow traffic volume, congested traffic volume, required travel time and other indexes were used for the comparative evaluation. This validation was regarded as an analysis available immediately after the introduction of the system. Therefore, short-term forecasts by the simulation for the period from December 1, 2003 to January 31, 2004 were evaluated, using the actual data from the traffic control system for the same period.

### User Survey

The use of the program was determined, and users' requests were surveyed with 58 operators belonging to a traffic control center or maintenance office of the HEPC that may use HEROINE.

# REPRODUCIBILITY

## REPRODUCIBILITY VALIDATION

### Initial setting of the traffic density

For the initial setting, an identical number of vehicles currently traveling on the Hanshin Expressway is being placed on a virtual network. Since it is impossible to determine the current number of vehicles at any given time, the estimation accuracy was evaluated by comparing the estimated values against the actual value for the sectional traffic volume immediately after the start of estimation process.

Estimation was performed for a typical section of each route of the Hanshin Expressway, every five minutes for 30 minutes after the start. The estimation results were classified into three traffic condition types for analysis: congestion due to heavy inflow traffic; congestion due to incident; and congestion-free traffic flow.

The findings from the comparative analysis are summarized below.

- In general, it was reasonable to conclude that the estimation accuracy was sufficiently high when the average values of error and the proportion of the standard deviation to the actual traffic volume were taken into account (Fig. 2).
- Error values were greater immediately after the start of estimation and tended to decline with time.
- The initial sectional traffic values were estimated slightly lower than the actual values for the busy time slots, and slightly higher for the time slots with fewer vehicles.

### Inflow traffic volume

The 30-minute traffic volume was adopted for the comparison since five-minute values were known to vary significantly.

Table 2 shows the correlation coefficients of the estimated 30-minute traffic volumes to the actual values for all on-ramps on the Hanshin Expressway. The estimated and actual values were classified into three traffic condition types. The estimation accuracy was considered to be sufficient when the average values of error and the proportion of the standard deviation to the actual values

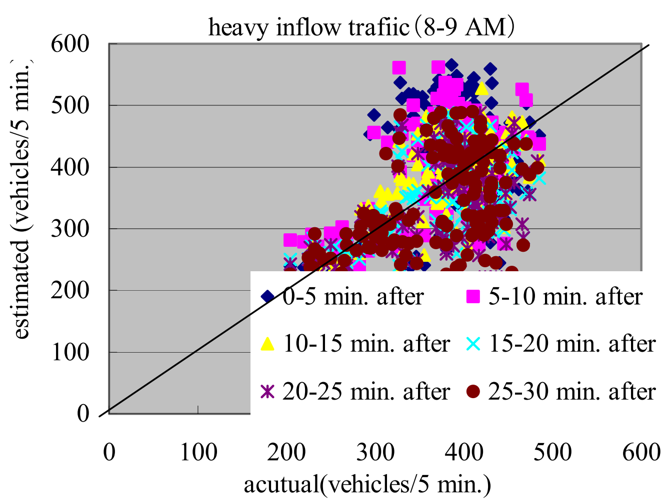


**Fig. 2. Estimation vs. Actual Sectional Traffic Value by Traffic Condition Type (Shinanobashi-Tosabori Section on The Loop)**

were taken into account. However, the reproducibility was substandard for the time slots with abrupt changes in the traffic volume, especially during the morning rush. The accuracy was also lower for later time periods from the start of the estimation. The presence or absence of obstacles on the road or the days of the week did not seem to make a difference.

**Table 2. Correlation Coefficient of The Estimation to The Actual Traffic Volumes**

| congestion | days of the week | 0-30 min. after | 30-60 min. after | 60-90 min. after | n |
|---|---|---|---|---|---|
| due to heavy inflow traffic | weekdays | 0.919 | 0.898 | 0.881 | 1,469,778 |
| | holydays | 0.916 | 0.891 | 0.847 | 136,482 |
| | weekends | 0.917 | 0.897 | 0.880 | 52,200 |
| due to incident | weekdays | 0.907 | 0.867 | 0.847 | 296,094 |
| | holydays | 0.946 | 0.934 | 0.918 | 53,148 |
| | weekends | 0.880 | 0.853 | 0.836 | 96,906 |

## Congested traffic volume

Table 3 shows a comparison of the actual and estimated congestion values on each route of the Hanshin Expressway. The congestion starting points, the starting time and the entire congested traffic volume were successfully reproduced in general. When closely examined, however, some cases were over- or underestimated on some specific routes (Table 3). Deviations from the actual values were apparently larger for the later time periods from the start of the estimation. Reproduction of the rapidly extending congestion cases during morning rushes was unsuccessful. Although the direct cause of the low reproducibility was the improper adjustment of QK and KV module parameters which determined a flow model, this problem was also attributable to the initial setting as well as the estimation accuracy of the inflow traffic volume.

**Table 3. Comparison of The Congested Traffic Volume for Each Route of The Hanshin Expressway (due to Heavy Inflow Traffic)**

| Route | 0-30min.after (km・h) | | | 30-60min.after (km・h) | | | 60-90min.after (km・h) | | |
|---|---|---|---|---|---|---|---|---|---|
| | actual | estimated | difference | actual | estimated | difference | actual | estimated | difference |
| Loop | 11.4 | 11.9 | 0.5 | 10.5 | 10.1 | -0.4 | 9.6 | 10.8 | 1.2 |
| Ikeda (in) | 33.7 | 51.1 | 17.4 | 30.8 | 42.7 | 12.0 | 27.3 | 37.5 | 10.2 |
| Moriguchi (in) | 26.6 | 23.1 | -3.4 | 24.9 | 18.3 | -6.6 | 23.0 | 15.5 | -7.4 |
| Higashi-Osaka (in) | 27.8 | 18.6 | -9.2 | 25.6 | 22.2 | -3.4 | 23.6 | 27.1 | 3.5 |
| Higashi-Osaka (out) | 13.8 | 6.8 | -6.9 | 11.8 | 3.2 | -8.6 | 10.9 | 5.4 | -5.5 |
| Matsubara (in) | 24.7 | 18.6 | -6.1 | 22.7 | 8.4 | -14.3 | 20.1 | 4.0 | -16.2 |
| Sakai (in) | 19.9 | 10.5 | -9.4 | 17.9 | 3.4 | -14.5 | 15.5 | 2.3 | -13.3 |
| Sakai (out) | 2.3 | 1.1 | -1.2 | 2.1 | 0.9 | -1.2 | 2.0 | 0.7 | -1.3 |
| Osakako (in) | 15.7 | 6.5 | -9.2 | 15.2 | 4.3 | -10.9 | 14.6 | 9.8 | -4.9 |
| Kobe (Osaka, in) | 13.5 | 7.2 | -6.3 | 12.9 | 0.6 | -12.3 | 11.9 | 0.5 | -11.5 |
| Kobe (Hyogo, in) | 17.5 | 12.9 | -4.6 | 16.8 | 15.2 | -1.7 | 16.2 | 18.1 | 1.9 |
| Kobe (Hyogo, out) | 18.4 | 9.1 | -9.3 | 18.7 | 3.9 | -14.8 | 18.5 | 4.4 | -14.1 |
| Wangan (in) | 3.6 | 5.5 | 1.9 | 3.5 | 2.5 | -1.0 | 3.4 | 1.3 | -2.0 |

in: inbound ; out: outbound

## Travel time

Travel time estimation exhibited a tendency similar to the congestion estimation (Table 4), because of its dependency on the traffic condition estimation results.

**Table 4. Comparison of The Travel Time to Pass Through The Main Sections (due to Heavy Inflow Traffic)**

| section | distance (km) | N | correlation coefficient | actual travel time (min.) | estimated travel time (min.) | estimate actual (min.) |
|---|---|---|---|---|---|---|
| Ikeda Route (Toyonaka - Fukushima) | 8.7 | 855 | 0.594 | 20.8 | 24.2 | 3 |
| Sakai Route (Sakai - Shiomibashi) | 8.9 | 1,885 | 0.894 | 10.6 | 10.5 | -0 |
| Higashi-Osaka (Nagata - Morinomiya) | 4 | 561 | 0.903 | 6.5 | 7.3 | 0 |
| Moriguchi Route (Moriguchi - Nagara) | 8.2 | 1,748 | 0.803 | 12.0 | 8.3 | -3 |
| Matsubara Route (Miyake - Fuminosato) | 6.8 | 1,457 | 0.911 | 10.2 | 9.4 | -0 |
| Osakako Route (Tempozan - Honden) | 5.4 | 1,114 | 0.059 | 9.8 | 4.0 | -5 |
| Wangan Route(Koshien - Hokko) | 8.6 | 894 | 0.466 | 6.6 | 9.2 | 2 |
| Sakai Route (Minatomachi - Sakai) | 10.5 | 1,015 | 0.447 | 7.4 | 8.0 | 0 |
| Kobe Route (Yanagihara - Ashiya) | 14.5 | 3,528 | 0.736 | 13.6 | 13.6 | 0 |
| Kobe Route (Tsukimiyama - Yanagihara) | 5.6 | 3,241 | 0.760 | 5.2 | 6.0 | 0 |
| Kobe Route (Nishinomiya - Kyobashi) | 14.2 | 1,421 | 0.765 | 16.3 | 14.7 | -1 |

## DEFINED PROBLEMS AND POSSIBLE SOLUTIONS

The problems found during the reproducibility validation indicated a need for further examination on the following points to improve accuracy.

- Initial setting: adjustment of the KV parameter (especially for the high density areas)
- Inflow traffic volume: adjustment of the neural network model
- Flow and travel time estimation: adjustment of the KV parameter (to include the characteristics of each route)

# USABILITY

## USER EVALUATION

The program was used 835 times during the two months immediately after the installation, with 1,171 screens accessed. This is equal to 16 times of use on daily basis, with 24 screens accessed. Although it could not be a full use yet, these figures could be justified under the current circumstance. Only 25 terminals in total were available to access the program, and no promotional announcement was made to the staff of the HEPC. Since the terminals installed at the traffic control rooms were constantly online, the accesses from there were not included in the counts.

The most frequently accessed screen was the Short-term/Congestion Forecast. It was followed by the Long-term/Congestion Forecast, Congestion Forecast and Travel Time Required Between Major Points. The Preliminary Forecast was executed 54 times.

## VALIDATION AND DEFINED PROBLEMS

Since only a limited number of personnel with access had a few experiences with the program during the initial two months from the start of evaluation, it was too early for a complete evaluation. Some users suggested the following applications they actually used or attempted to use in the trial.

- Aid for answering the inquires from road users, including a tendency of a specific congestion (increasing or decreasing) or expected time for it to dissolve, or an expected time for traveling between two specific locations.
- Reference for the staff planning a travel: Traffic forecasts can be used as reference information for the staff before departure to a construction site or other location.
- Reference for material preparations for a meeting with other organizations: The program should be useful when evaluating alternative traffic control plans for construction or when preparing materials for a meeting with the police department or other organizations.

The system has just started to work, but even with a limited experience in using it, some users presented generally favorable evaluation, further referring to some problems they faced during use. It is necessary to examine such issues, giving special priory to those related to the functions with higher priorities. Promotional activities will be also needed to encourage the staff of the HEPC to use it more frequently. Future efforts will include:

- improvement of accuracy;
- improvement of the Preliminary Forecast function and its screens;
- examination for traffic forecast service in future; and
- promotion for more frequent use.

## INCREASED USE OF HEROINE

HEROINE will be updated continually, introducing a higher degree of simulation modules, so that the system will be more useful for the traffic control operators and other staff of the HEPC. The forecast information currently held within the staff will be shared with road users at the earliest point possible. Some details of future efforts are described below.

**Continued validation and updating of the system:** The current validation was performed on the initial performance of the system immediately after the introduction. The estimation generated for the first two months were evaluated against the actual traffic values for the same time period, and some swift improvements were proposed from the findings. The system will be continuously validated and updated, since these, together with an accumulation of use, will determine future growth of the system. The current study was limited to a simple comparison of the actual and estimated values, but there can be more focus areas on validation as listed below.

- An index needs to be created to indicate the level of accuracy for each estimation.
- The forecast accuracy needs to be improved for construction, accident and other extraordinary cases, and a new system should be developed for future availability of the forecast information service to road users.
- For more effective use in traffic control operation, the on-ramp control proposal function needs to have practical applications that fit the actual environment.
- The screen design needs to be improved as suggested by the users.

**Efforts to promote more frequent use:** Evaluation and further feedback on the modules and the entire system relies primarily on a more frequent use. It is essential to the proper growth of the system in future. Immediate efforts are being made to promote the more frequent use of the system among the staff of the HEPC.

**Examination of future traffic forecast service:** There is a high demand for traffic forecast service among road users as well as at the traffic control towers. The staff of the HEPC is also expected to use the service when it is ready. A discussion is required as to how the traffic forecast can best be supplied. While meeting the optimal demand, a measure should be in place to clearly distinguish the traffic forecast from the current traffic information. This is to prevent confusion among the information users.

## REFERENCES


(1) "Technologies: Traffic control system" at http://www.hepc.go.jp/english/structures_f.html (as of June 2004)
(2) Research & Study Committee, *Report on the Hanshin Expressway Traffic Control System*, Osaka, 1999 to 2003 (in Japanese)
(3) Saita, K., Kurauchi, F., Okushima, M. and Daito, T., "Establishment of HEROINE (Hanshin Expressway Real-time Observation-based & Integrated Network Evaluator)", *9th ITS World Congress Proceedings* (CD-R), 2002.
(4) Uno, N. and Kurauchi, F., "Issues in Model Application: Some Experiences in Developing HEROINE", *Proceedings of the International Symposium on Transport Simulation*, pp. 135-147, August 2002.