A TRAVEL TIME FORECAST IN CASE OF INCIDENT CONGESTION USING TRAFFIC SIMULATOR

~ A VALIDATION AND NEXT CHALLENGE ~

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ABSTRACT

It is still very difficult to reliably predict travel time, particularly under situations such as during congestions caused by traffic incidents on the road network, and the existing travel information system is prone to provide travellers with the information with large deviation between the forecasted and the actual travel time. We have been receiving a considerable number of users' voices expressing their desire to obtain more accurate traffic information. This study was conducted with the objective to sophisticate the travel time forecast information service by improving its accuracy under congested situation due to incident when, as noted, the traffic condition rapidly worsens. We will improve the Hanshin Expressway Real-time Observation-based & INtegrated Evaluator (HEROINE), the mesoscopic type of network flow simulator for the Expressway, to account for the condition of incident congestions.

Keywords: travel time forecast, incident management, online traffic simulator

INTRODUCTION

The Purpose of the Study

Hanshin Expressway traffic control system has been continually modified 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). Particularly, the service to provide travel time information has been extended to various media including road-side information boards, information terminals and to mobile devices. It has been recognized that the service is useful for route choices and departure time decisions of drivers.

The current travel time information provided on the Hanshin Expressway is so-called ‘present travel time information’ and the information is created just by summing up the travel time of each section estimated from the velocities observed by traffic detectors. This method is based on a rather naive assumption that the traffic conditions across all expressway sections will continue, and has been criticized for generating extremely large estimation errors in the case of "incident congestions (congestions due to incidents on the expressway)", which are known for their rapidly worsening traffic conditions.

There has been a dire need for addressing this issue: a considerable number of users' voices called for improving the accuracy of the forecasts, while the operation of information provision had to be temporarily suspended when the system generated unrealistic inaccurate travel time forecasts.

In this context, the objective of this study is to sophisticate the travel time forecast information service by improving its accuracy under conditions of incident congestions when, as noted, the traffic condition rapidly worsens. We will improve the Hanshin Expressway Real-time Observation-based & INtegrated Evaluator (HEROINE), the traffic flow simulator of the Expressway, to estimate the condition of incident congestions. The accuracy of the travel time forecasts is tested, to be the foundation for future improvement of the travel time information service and perceived challenges for potential implementation.

The Process of the Study

HEROINE simulates traffic on all routes of the Hanshin Expressway as well as the surface arterials that competes or supports the Expressway, employing the Block Density method for the Expressway routes and the I-O method for the arterials to simulate the vehicles' movement. While the traffic flows are treated as vehicle groups, each vehicle is treated to have respective characteristic, thus the simulation system can be categorized as a meso-scopic traffic simulator. In order to account for impacts of incident congestions upon traffic condition on network, a temporal change in the capacity of road affected by the incident has been modeled considering its both beginning and ending points in time and the incident duration time. Then, a series of simulations are conducted to provide travel time

forecasts of major expressway sections to test their accuracy by comparing with the actual travel time data. Also there is a discussion on the potential for implementation of the simulator for travel time forecast information service and propose the future plan.

AN APPROACH FOR IMPROVEMENT OF TRAVEL TIME FORECAST ACCURACY

Overview of HEROINE

HEROINE is a network traffic flow simulator of Hanshin Expressway network[(2)]. The program simulates traffic on all routes of the Hanshin Expressway as well as the surface arterials that competes or supports the Expressway, employing the Block Density method for the Expressway routes and the I-O method for the arterials to simulate the vehicles' movement. While the traffic flows are treated as vehicle groups, each vehicle is treated to have respective characteristic, thus the program can be categorized as a meso-scopic traffic simulator. The HEROINE simulates the travel demand of the Expressway, and the arterials are included where they support the Expressway as alternative routes or detours for the traffic.

The simulation model treats the route choice as endogenous, and it allows for the application of various models of control measures, including inflow control at on-ramps, outflow control at off-ramps, and a few route choice models that responds to road traffic information and tolling measures.

Input data for the simulation includes On-Off traffic volume data (dynamic On-Off probability matrix) for specified time intervals and 5-minute interval on-ramp inflow traffic volume, and the simulator output includes section traffic volume, traffic speed, occupancy, traffic conditions such as congestion, and travel time.

The HEROINE has been incorporated into the traffic control system of the Expressway, and operates on-line and real time, based on the data from the vehicle detectors that are input every five minutes to renew as well as information of events such as accidents, which are input immediately (Figure 1). This study pertains to the HEROINE's travel time forecast that is operational as a part of the traffic control system.

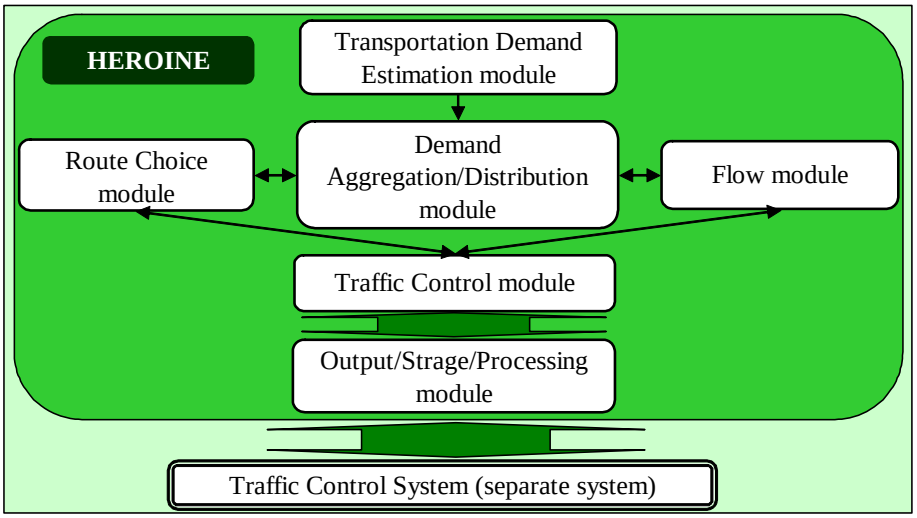

Figure – 1 System Configuration of HEROINE

Predictive Procedure for Improvement of Travel Time Forecast Accuracy

Ever since the construction of the HEROINE, Hanshin Expressway has invested on improvement of the accuracy of travel time estimated during congestions due to incidents (e.g. accidents). These improvements include: adjusting parameters of the KV (traffic density-velocity) model; automatic update of traffic merging rate during congestions; updating the dynamic OD probability matrix [(3)]; traffic capacity when incidents are present; and improvements on the methods to set the duration of incident presence on the network. In terms of the system-wide simulation accuracy, the effect of constructing the method to estimate the time-interval ramp OD matrix based on the ETC statistics has been notable[(4)]. In this context, this study emphasizes the simulation performance when incidents are present on the network and address the methods to determine the traffic capacity and the trip durations under congested traffic due to these circumstances.

Analyzing the daily incidents report from the traffic control system, we have determined the method to set the traffic capacity when the incidents are present as follows:

1): "Occurrence:" when an incident happens, the vehicle detectors' real time data has yet to be obtained to reflect the incident. As such, the data for the interval of the occurrence of the incident will be set as a product of the traffic capacity of the normal condition and the rate of decline for the route, cause and the degree of the particular incident, constructed based on the previous records.

2): "Continuing Congestion:" during the continuing incident congestion periods, the traffic capacity is set as the smoothened squared traffic volumes.

3): "Pre-dissolve" : during the three time intervals (15min) prior to the dissolve of the incident congestion, the rate of traffic volume recovery is linearly modeled, as regaining traffic volume is apparent.

As shown on the Figure 3, the determination of the incident congestion duration is

modeled and set to have the following characteristics:

- The variables that influence object congestion durations are assumed to be the cause, severity, the nature of the incident, expected recovery, and the day/night time classification,
- Particularly when the incident cause is "accident & stopped vehicle," accounting for details could more accurately explain the congestion duration,
- As the expected recovery variable changes to "momentarily," the congestion duration can be set without regard to any other variables, and
- It should be kept in mind that the incident congestion duration data is subject to a substantial deviation.

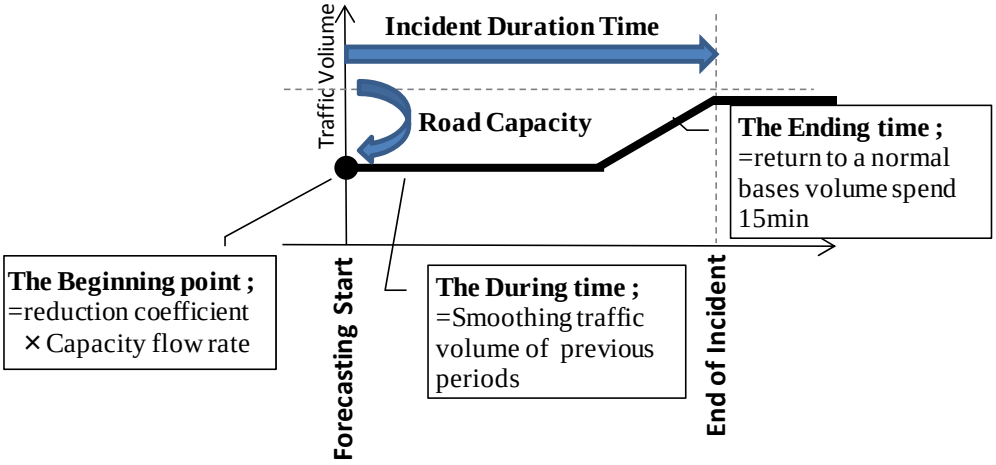

Figure – 2 Incident Duration Time and Capacity

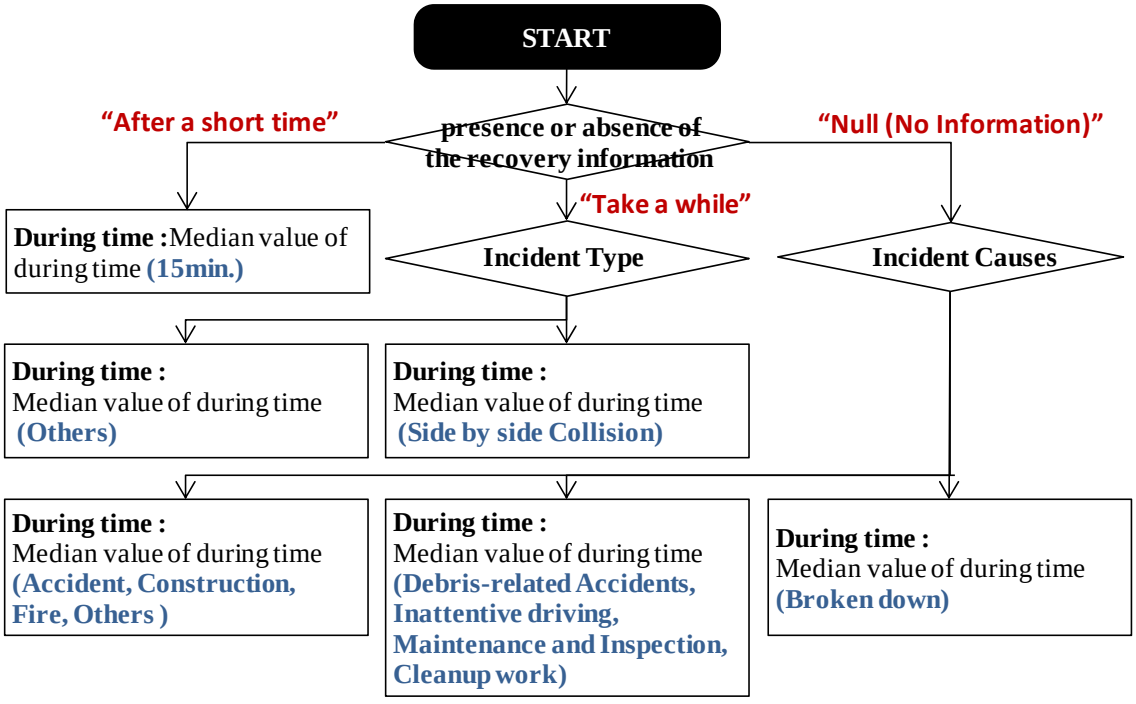

Figure – 3 An Algorithm : Incident During time Configuration

A VALIDATION METHODOLOGY USING HEROINE

Framework of the Validation

We employed the following analytical framework in testing the accuracy of travel time forecast under congestions due to incidents.

Study subject: congestions due to accidents

Study Period: April 26, 2011 (Thursday) - May 9, 2011 (Monday)

Unit of Analysis: travel time of the "unit route section" (sections used for travel time information service to drivers)

Data for the Analysis: relatively significant accident congestions (maximum congestion length over 2km and congestion duration over 30min) among all accident congestions during the study period

Validation Methodology

We analyzed the accuracy of the simulation forecasts by comparing the "actual travel time" values with the present travel time information as well as the HEROINE "simulated travel time forecasts". The actual travel time values are assumed to have been represented by the aggregated section travel times by tracking the vehicles through the particular Expressway unit route section. The "traditional" forecast is the scheme that the current travel time information service operation employs. The traffic speed of a particular Expressway section is estimated using the speed measured by the corresponding section's vehicle detector. The travel time required to add at the same time aggregates the section travel time of the same unit time interval across all Expressway sections within the unit "route section," which is the format by which travel time is provided to the Expressway users. In short, the travel time required to add at the same time is present travel time information. The "simulated" travel time forecast is the travel time estimated by the short term traffic forecast function of simulator, HEROINE, with the adjusted algorism discussed below.

We employed the following two perspectives in testing the simulation:

1): A minimally desired level of travel time forecast accuracy will be set prior to the simulation as the target error accomplishment rate. The "desired" target error level will be less than 5min, and the "required" error level, at which point the travel time forecast information to the drivers should stop if exceeded, will be 10min. These were based on the consideration on the acceptable degree of forecast errors for general Expressway users, and that the major sections for the travel time information provision is for the unit route section that is approximately 10km.

2): The authors will evaluate the statistical measures of errors such as the mean forecast error, the mean absolute error, the absolute error ratio, and the measures of the relationship between the forecasts and the real travel time data such as the correlation efficient and the RMS errors.

VERIFYING THE ACCURACY OF TRAVEL TIME FORECAST ON INCIDENT CONGESTION

Comparison of Travel Time during Incident Congestion

We made a comparison between the present travel time information, the simulated travel time forecast (by HEROINE) and the actual values in terms of accuracy of forecast. As a representative case, Figure 4 shows the case of the accident congestion that took place on April 28, 2011 (Thursday) 9:50AM-10:47AM at the 4.5Kp of the Loop Route and extended to the Up-bound of the Moriguchi Route and the Up-bound of the Ikeda Route. The figure compares the present travel time information, the HEROINE simulation forecast, and the actual travel time values from the Moriguchi Route Up-bound to the Loop Route.

During the "Occurrence" period, the actual travel time values show a dramatic increase, while the present travel time information and the simulation forecasts show some delay before starting to increase. Another explanation could be that the accident might have taken place prior to the recorded time of 9:50AM.

During the time intervals after the rapid increase to reach the longest forecasted travel time, the present travel time information is apparently large in excess of other measures. This has been pointed as the problem with the current travel time information. The excess forecasted travel time continues into the time intervals in which the accident scene activities complete and the traffic condition starts improving. As it is evident in the case of the Figure 4, present travel time information are incapable of following the rapid increase of travel times soon after the accident occurrence, and hence demonstrate extremely long travel time forecasts even during the time intervals after the actual travel time hits the peak, and the problem persists during the time intervals in which the congestion in mitigated. This propensity is observed not only in this instance but also in other cases of accident congestions.

In comparison, the HEROINE simulation forecasts appears to reasonably follow the changes of the actual travel times, although it shows some delay in responding to the initial occurrence of the congestion. The result indicates that the HEROINE simulation forecasts are closer to the actual travel time values, at least in the relative term compared with the travel time required to add at the same times.

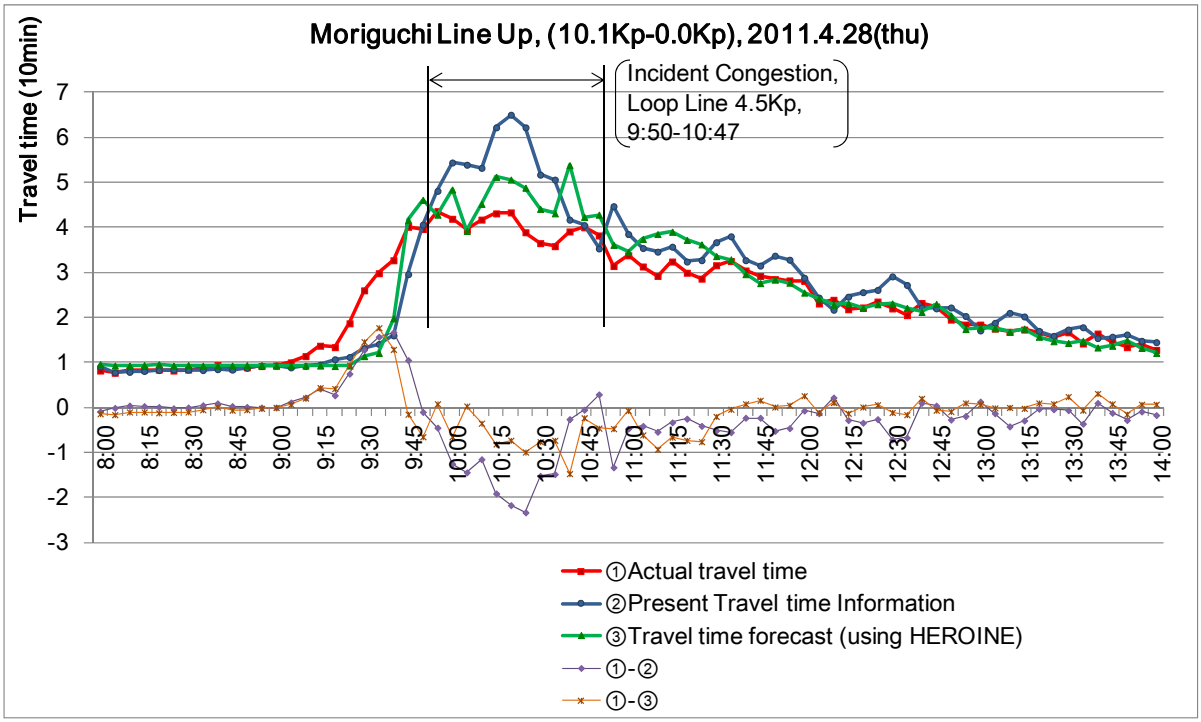

Figure – 4 Comparison of travel time during incident congestion

Verification of the Accuracy of Travel time Forecast on Incident Congestion

In this section, we tested the error terms of the present travel time information and the HEROINE simulation against the actual travel time values. First, we calculated the ratio of accomplishing the target levels of the simulation errors. Regarding the "desired" target error level of travel time forecast accuracy (5min), the HEROINE simulation forecast was 66%, while the present travel time information was 58% (a difference of 8%). Regarding the "required" error level (10min), the HEROINE simulation forecast was 88%, while the present travel time information was 78% (a difference of 10%) the results are summarized on the Table 1.

We also analyzed the correlations between the actual travel time values and the present travel time information as well as the simulation forecast. Evidently, the HEROINE simulation forecast shows the higher correlation with the actual travel times, as shown on Figure 5. Other measures (i.e. correlation coefficients and RMS error statistics) also suggest the higher accuracy of the simulation forecasts. Furthermore, it should be noted from Table 1 that the mean absolute errors of present travel time information was 7.6 minutes while that of the HEROINE simulation forecasts was 4.7 minutes, which satisfies the "desired" target error level. From a different perspective, the HEROINE simulates travel time forecasts achieved approximately 70% of its forecasts satisfying the "desired" target error level, and 90% of its forecasts satisfying the "required" target error level. The bottom line of the finding of this analysis is that the simulation would be more desirable with its smaller errors compared with the present travel time information.

Table – 1 the Accuracy of Travel time Forecast on Incident Congestion

Evaluation Index		Error of Present Travel Time Information	Error of Travel time forecast (using HEROINE)
Achievement Rate of Error Objective	Error Objective, Level 1 (±5min)	58%	66%
	Error Objective, Level 2 (±10min)	78%	88%
Statistical Evaluation	Average of Predictive Error (min)	-5.62	0.61
	Average of Absolute Error (min)	7.55	4.74
	Absolute Error Ratio	34%	21%
	R	0.832	0.855
	RMS	12.4	6.5

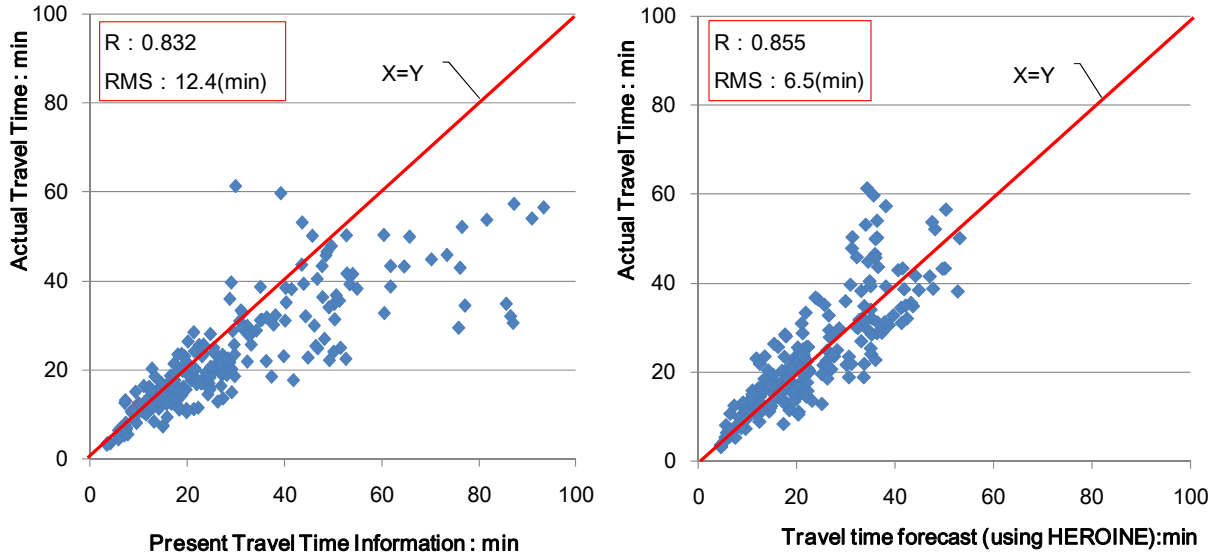

Figure – 5 The Correlation of the True Travel Time and the Estimated Travel Times

CONCLUSION

Conclusion

This study tested the accuracy of the travel time forecast of the HEROINE simulator of the Hanshin Expressway. The simulator demonstrated smaller errors of travel time forecasts compared with the present travel time information (i.e. simultaneous sum of section travel times estimated from vehicle detectors). It is reasonable to conclude that the simulator offers a more accurate alternative to travel time information provision service at least to an acceptable extent, suggesting an optimistic outlook for practical implementation.

However, it is desirable to continue the effort to further improve the simulation accuracy when considering the rate at which the travel time forecast was simulated within the "desired" level of accuracy. For this sake, the authors perceive the need to address the following further improvements that were identified through the analysis of the propensity of the current errors of the travel time forecasts.

1): Improve the forecast accuracy of accident congestion duration and the traffic capacity during the accident congestions. These two forecasts considerably influences the overall simulation forecast accuracy. Further improvements from the following perspectives are highly desired: decision of traffic capacity in cases of extremely declining traffic volume during the "Continuing Congestion" period (in the present program, this is determined by squared smoothening of the traffic volume in the immediately previous time duration); and incorporation of other detail variables such as the duration of congestion into the simulation model.

2): Improve the forecast accuracy of natural congestions. Continued adjustment of the KV (traffic density - velocity) model parameters for the Expressway routes where the simulation errors are relatively large under natural congestions.

Prospect in the Near Future

The analysis in this study to test the accuracy of the simulation program based on the system improvement discussed above suggested that the simulation forecast is desirable than the travel time required to add at the same time method in cases of accident congestions. Provided that the needed adjustment suggested in this study will be addressed, the next step will be to do a test implementation to gather users' feedback, aiming at the eventual application to the Expressway's travel time information service operation.

In the practical sense, the simulation forecast could first be provided internally of the Hanshin Expressway Company to build results of further analyses of users' feedback. Then, coordination with related agencies ad regulators should follow, and a travel time forecast information system can be developed to begin operation.

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