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# Constructing a Benchmark Data Set for Validity Evaluation of Road Network Simulation Models

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## 1. INTRODUCTION

This research aims to construct a precise data set for validity evaluations of road network simulation models. To increase the reliability of the data set, the data was collected through the precise survey to read number plates of all vehicles at every input/output roadside of major intersections, and carefully processed. Such data set will be used for benchmark of simulation models.

Needs to estimate the effects of planning and/or improvements on traffic management has encouraged activities of developing traffic simulation models. Especially, the simulation models to deal with the traffic on road networks are strongly required for ATIS/DRGS applications and/or traffic management evaluation. In fact, dozens of simulation models have been developed and used for the last two decade.

However, they often have a problem in the model validation stage using real world data to evaluate their ability to reproduce traffic conditions, nevertheless the most of developers and users consider that the validity check is important (e.g. see SMARTEST, 1997).

The major difficulty to prevent developers from model validations is that such simulation models generally require the data which is hard to directly observe. For example, most of them require time-varying origin-to-destination (O-D) traffic demand as the input data. If the network size become larger, it is easily conceived how we have to pay a big effort to observe the origin and destination of each vehicle.

Even though several simulation models are validated, the developers use their own data set which may be in different conditions. Thus, it is difficult to directly compare their abilities of reproduction. This may be another difficulty for the users to select an appropriate simulation model to serve their purposes.

For the last five years, we have been developing and validating a traffic simulator 'AVENUE' which deals with urban road networks (Horiguchi *et al.*, 1996). Through the experience of the development, we have spent substantial effort to collect precise data set including time-varying O-D demand and individual vehicle trajectories besed on number plate survey.

The target area is Kichijoji-Mitaka area, the western part of central Tokyo, which spreads about 2 km from east to west and 1 km from north to south. This area contains 70 roadside points where the observers read the number plates of all passing vehicles. The survey was carried out during morning peak period from 7:00 a.m. to 10:00 a.m. by more than 200 observers.

The collected data was processed by the heuristic matching technique presented in this paper to extract vehicle trajectories. The vehicle trajectories have been aggregated into time-varying O-D traffic demand. Link flows and link/path travel times to be compared with the simulation results are figured out as well.

In the following chapters, the contents of benchmark data set required for the validation of road network simulation models are indicated at first. Secondly, the outline of the number plate survey are described. Then, the extraction of individual vehicle trajectories from the survey data is explained. The extraction process interpolates misreading data by observers with heuristics rules. The extracted vehicle trajectories are subsequently aggregated to time-varying O-D demand. Finally, further analysis currently on-going and future topics around benchmark data set is presented.

## 2. REQUIRED ITEMS OF BENCHMARK DATA SET

According to the purpose of traffic simulation, there must be several types of benchmark data set which have different contents. For example, the benchmark data set for the simulations of weaving sections has different contents from that of network simulations. This chapter discusses the required items of the benchmark data set for network simulation models regarding simulation inputs and traffic conditions to be compared with simulation results.

### 2.1. Simulation inputs

Simulation inputs consist of four categories, i.e. 1) network geometry, 2) time-dependent O-D traffic demand, 3) traffic control and management schemes and 4) notable events which may affect traffic flow conditions.

*Network geometry* -- such as node positions, link lengths, link-node adjacency, etc., is necessary for all simulation models. Link connectivity considering prohibited turn must be included. The curvature and the lane configuration of each link is optional but preferable especially in the case of microscopic simulation models. In this study, not only the lane configuration but also the turning movement at each lane are collected.

*O-D traffic demand* -- is the most important input, since it substantially affects the simulation result. Therefore, it should be accurately observed. O-D traffic demand should be time-depending and layered by vehicle types and any drivers' attributes.

*Traffic control and management schemes* -- are mainly the history of signal control plans, ramp metering, traffic regulations, i.e. one-way treatment, turning prohibition, route guidance, travel information provided, etc. They may be incorporated into simulation models. Related facilities, e.g. signals, detectors, beacons, variable message signboards, should be listed.

*Notable events* -- which may affect traffic flow conditions should be recorded. Incidents, blocking by roadside parked cars, interaction with pedestrians, queue spill back from the outside of the area, etc. may be useful to define network configuration as well as model parameters.

### 2.2. Traffic conditions

Observed traffic conditions should be compared with the simulation result. As most of the simulation models provide indicators to measure flow condition and travel efficiency, following values should be observed.

*Flow condition* -- is represented by link flow and queue length. Saturation flow rates at bottleneck intersections should be precisely measured, because it is dominant in flow reproduction and useful in model calibration.

*Travel efficiencies* -- are mainly referred to speed and travel time. These are measured along links and, if possible, routes. Other indicators of efficiency may be delay and number of stops at each signalized intersection.

*Other indicators* -- are sometimes used for model validation. For example, when the model objective includes the evaluation of adaptive signal control, detector data should be recorded during the survey. Other indicators may be those about public transport regularity, safety, environment, etc., depending on model objectives.

## 3. PRECISE SURVEY IN KICHIJOJI-MITAKA AREA

In this chapter, the outline of the survey that we have carried out in Kichijoji-Mitaka area on 30th Oct. 1996 is presented.

### 3.1. Target area

The target area is Kichijoji-Mitaka area, the western part of central Tokyo, which spreads about 2 km from east to west and 1 km from north to south (Fig. 1). We selected this area based on two reasons; there were several alternative routes for major O-D pairs and changes in traffic condition were seen during morning peak period.

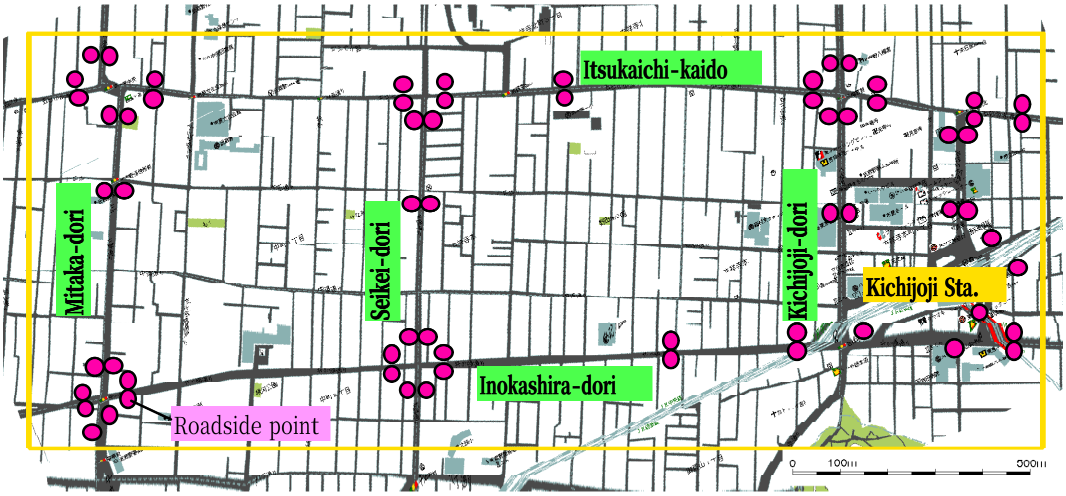



Fig. 1: Kichijoji-Mitaka area and roadside points where observers were located.

The network in the target area consists of four major north-south streets and two major east-west streets. Most of the links are two-lane roads and partially four-lane roads. Mitaka-dori Avenue has a reversible center lane.

Traffic congestion during morning peak period is constantly found on Itsukaichi-kaido Street, on Inokashira-dori Street, both are caused by the traffic from west to east, and on Mitaka-dori Avenue from north to south.

### 3.2. Number plate survey

Seventy roadside points where observers read the number plates of passing vehicles were arranged in the target area. Each input and output link of major intersections has a roadside point near the intersection (Fig. 2).

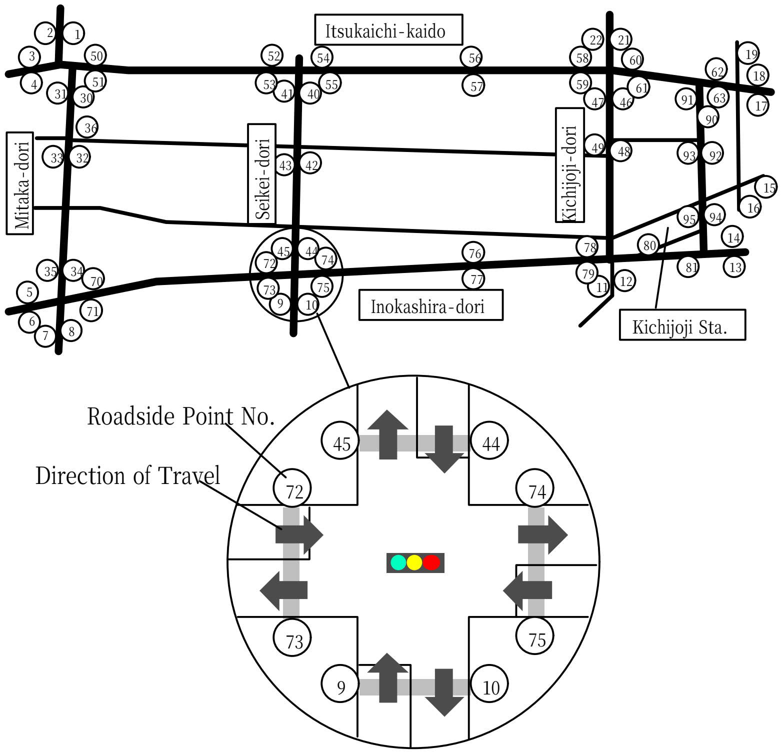



Fig. 2: Roadside points and the detail of major intersections.

Observers recorded vehicle type and the four large digits in the number plate of all passing vehicles. Vehicles were divided into tree types, i.e. buses, taxies and other miscellaneous vehicles. If the observer could not catch the number plate of a vehicle, 'unknown' statement was recorded. Passing time of vehicles were simulteniously recorded in minutes. In order to increase the reliability of the data, two observers for one lane were assigned to each roadside point. One recorded type and numbers with a cassette tape recorder and another wrote down them. These double data source were used to detect contradictions like mistypes in the digitized data.

The survey was carried out during morning peak period from 7:00 a.m. to 10:00 a.m. Totally 71,837 data were collected during the valid time period, 7:50 - 10:00.

### 3.3. Other observed data

Signal control parameters, i.e. cycle, split and offset, of each signalized intersection were recorded every fifteen minutes. Video recorders were placed in two roadside points to measure the percentage of large vehicles. Furthermore, the saturation flow rates at distinguished bottleneck intersections were observed.

## 4. EXTRACTION OF VEHICLE TRAJECTORIES

Vehicle trajectories can be extracted from the result of the survey by matching number plates and vehicle types between two neighboring roadside point (Hanabusa *et al.*, 1997). Travel times are also calculated by subtraction of the passing times. The extraction process has six steps; 1) resolving inconsistencies in the data, 2) number plate matching between two roadside points, 3) pruning irregular matches, 4) disentangling twisted vehicle trajectories, 5) retouching irregular trajectories and 6) reuse of unused data elements. The extracted trajectories are aggregated to time dependent O-D traffic demand.

**4.1. Resolving inconsistencies**

Inconsistencies in the observed data are divided into two types. One is coming from clock synchronization error. If an observer's clock is faster than the other synchronized clocks, each vehicle's travel time from where the observer stands to the next roadside point is shortened, and sometimes may be minus. This inconsistencies can be detected by preliminary matching between two neighboring roadside points and checking too many minus travel times.

Another is duplicated number plates at the roadside points on multi-lane links. As the observers are assigned to each lane, they sometimes read same vehicle at the same time when the vehicle shows untidy movement over two lanes (Fig.3). Thus, one of the data which have the same number plate, the same vehicle type and the same time stamp at the same roadside point should be eliminated. In this step, 838 double counting were detected and the total number of the data became 70,999.

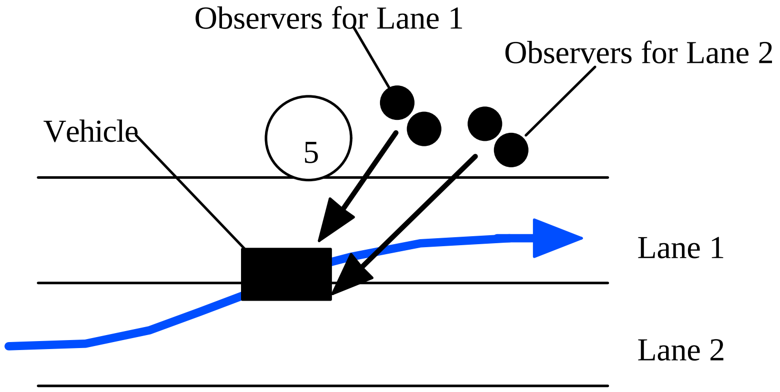



Fig. 3: Double count of a vehicle with untidy movement.

**4.2. Number plate matching**

In this step, matching between two adjacent roadside points are checked at first. Fig. 4 illustrates an example of adjacent matching. Matching pairs of which time difference are too longer than the ordinary link travel time are out of consideration. In this case, the link travel time is limited within five minutes.

However, if the number plate of a vehicle was misread at one roadside point, the actual vehicle trajectory would extract as two divided trajectories. Therefore, a data element which have no matching pairs in the adjacent roadside point skips them and may be matched with the data at one more farther adjacent roadside point. Fig. 5 shows an example of skip matching.

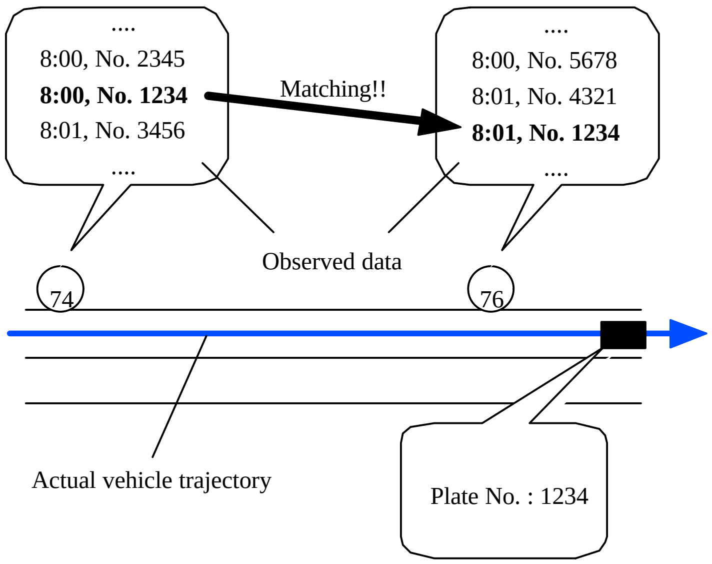



Fig. 4: Number plate matching between two neighboring roadside points.

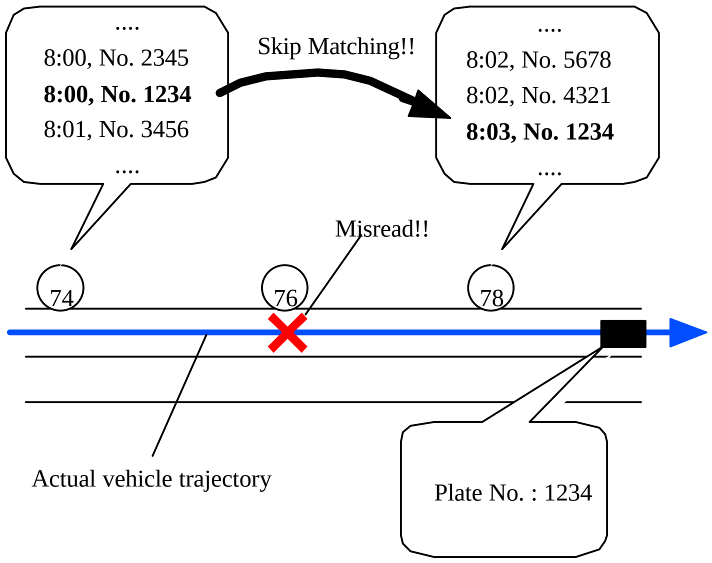
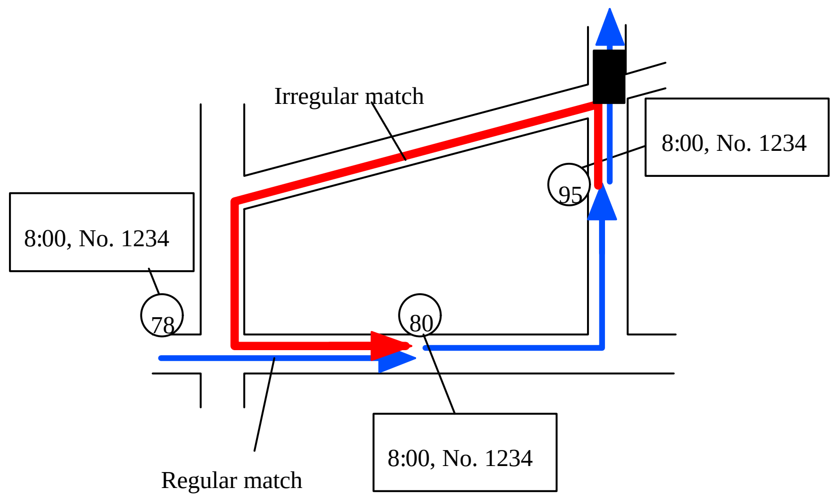



Fig. 5: Skip matching

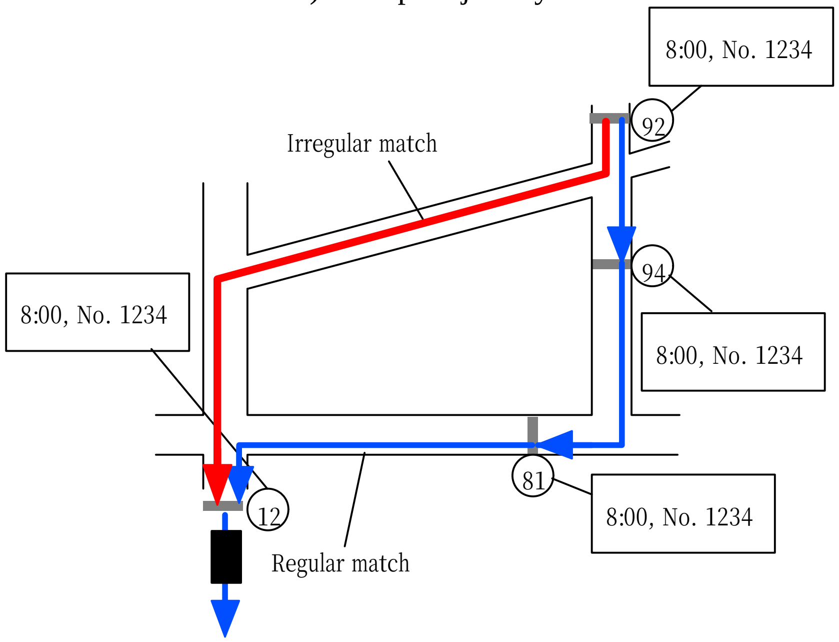
### 4.3. Pruning irregular matches

A vehicle trajectory must be extracted as a direct road without merging and diverging. There are, however, irregular matches which form merged or diverged trajectories. Those matches are should be eliminated.

There are two types of irregular matches, loops and shortcuts. Byroads which have no roadside point at either end cause irregular matches. Fig. 6 shows the examples of a loop and a shortcut. In order to resolve this problem, loops can be detected by depth-first-search from the root of a vehicle trajectory, and shortcuts can be done by width-first-search.




a) a 'loop' trajectory




b) a 'shortcut' trajectory

Fig. 6: Irregular matches in 'loop' and 'shortcut' trajectories.

### 4.4. Disentangling twisted trajectories

When two vehicles of which the number plate and the vehicle type are same as each other closely travel in the area, their trajectories will be entangled with unnecessary matches. In order to disentangle those trajectories, we give preferences to ambiguous matches using following heuristic rules and take higher ones; i.e.

*Rule-1: To give higher preference to the matches that the disentanbled trajectories are as possoble as long when those matches are removed.* -- In the example in Fig. 7, matches {A, F} divides the trajectories into two long ones and should be removed..

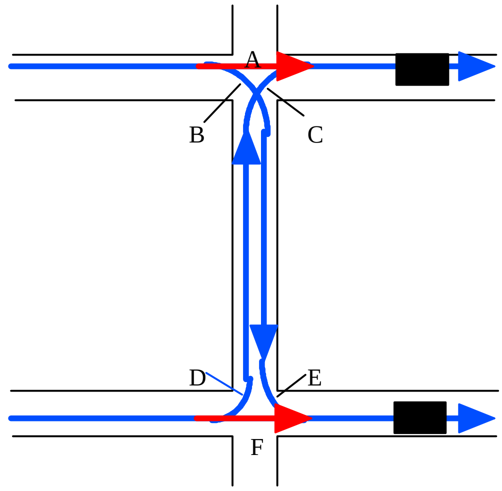



Fig. 7: Prefernce to longer trajectories.

*Rule-2: To give higher preference to the matches that the disentangled trajectories are as possible as straight when those matches are removed.* -- In the case in Fig. 8, A and B are to be removed to take two straightforward trajectories.

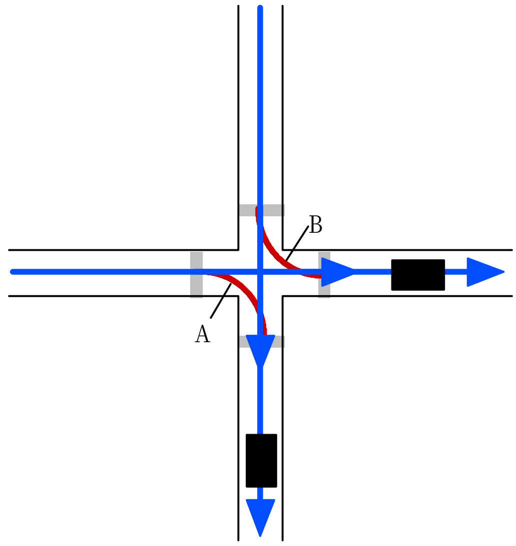



Fig. 8: Preference to straight movement.

*Rule-3: To give higher preference to the matches that the disentangled trajectorires keep first-in-first-out principal when those matches are removed.* -- The example in Fig. 9, A and B should be removed.

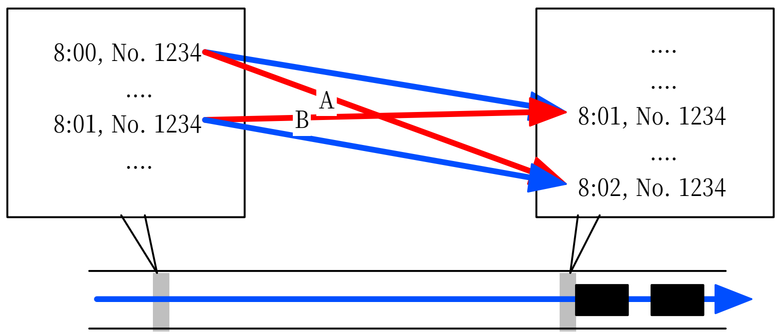



Fig. 9: Preference to FIFO trajectories.

### 4.5. Retouching irregular trajectories

There are irregular trajectories that have either end inside an intersection. Such trajectories should be retouched as to move their irregular ends to the outside of the intersections. For that purpose, those irregular ends are connected to 'similar' data elements at neighbor roadside points (Fig. 10) with the following rules.

*Rule-4*: If four digits are same but in different order, those two data elements are similar.
*Rule-5*: If three digits out of four are same, those two data elements are similar.
*Rule-6*: If one of two data elements has no information for number plate, those two are similar.

If there are no similar data elements, new data elements will be imposed within the data of the nearest roadside point.

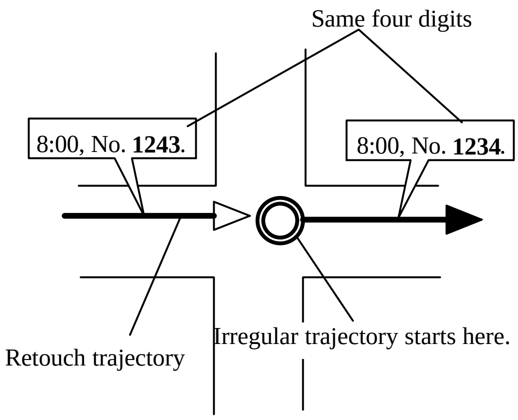



Fig. 10: Retouching a irregular trajectory.

### 4.6. Reuse of unused data elements

There are still remaining data elements which are 'unused' for extracted trajectories. According to the previous rules, detected similar pair of unused elements between two adjacent roadside points across an intersection are connected to be a trajectory. If there are no similar data elements to be connected, new data elements will be imposed within the data of the nearest roadside point and create a trajectory with them.

### 4.7. Aggregation to O-D demand

The number of extracted trajectories and the number of used data (percentage out of 70,999) at each step are listed below.

| **Step** | **# of trajectories** | **# of used data** | |
|---|---|---|---|
| 1) resolving inconsistencies | - | - | |
| 2) number plate matching | 13,936 | 62,713 | (88.3) |
| 3) pruning irregular matches | 14,208 | 64,038 | (90.2) |
| 4) disentangling twisted trajectories | 14,953 | 68,334 | (96.2) |
| 5) retouching irregular trajectories | 14,953 | 69,123 | (97.4) |
| 6) reuse of unused data elements | 16,043 | 71,265 | (100.4) |

As the step proceeds, the number of trajectories and the number of used data increases. The total number of the data finally increases up to 71265 because of the newly created data elements. The number of routes used by vehicles are 930.

Those trajectories are aggregated into time dependent O-D traffic demand sliced in every 10 minutes by their departure time. The number of O-D pairs are summed up to 747. Not only the nodes at the network end but also every links have flows and sinks of the demand, therefore links can be origins and/or destinations.

## 5. SUMMARY AND FUTURE TOPICS

In this paper, the required contents of benchmark data set for the validation of network simulation models have indicated. In order to build such data set, we coordinated precise survey and data processing based on number plate matching. We have obtained the extracted 16,043 vehicle trajectories and time dependent O-D traffic demand which are very close to real ones.

Further analysis is required to complete the benchmark data set. Path-based analysis are currently on-going to identify the drivers' route choice behavior. Traffic conditions to be compared with simulation results can be obtained from similar analysis. Traffic conditions includes not only link flows but also path flows.

Using this benchmark data set, the following items are recommended to be addressed in the model validation stage, i.e. 1) correlation of time-varying link flows as well as link travel times and 2) correlation of time-varying path flows as well as path travel times.

This benchmark data set will be distributed through World Wide Web site. Any developers and users of network simulation models can access the data. The data of the number plate survey and the result of the analysis will be included with documents describing the procedure of the analysis. Validation results of simulation models using this data will be appended if possible.

This benchmark data set is useful for the researches such as estimation of time-varying O-D matrix from observed vehicle counts on roadside. It is expected that this data set will be used not only for validation but for other applications.

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