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# Generating and Calibrating a Microscopic Traffic Flow Simulation Network of Kyoto

## First Insights from Simulating Private and Public Transport

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**Abstract.** Microscopic traffic flow simulations as tools for enabling detailed insights on traffic efficiency and safety gained numerous popularity among transportation researchers, planners and engineers in the first to decades of the 21st century. By implementing a test bed for simulation scenarios of complex urban transportation infrastructure it is possible to inspect specific effects of introducing small infrastructural changes related to the built environment and to the introduction of advanced traffic control strategies. The possibility of reproducing present problems or the transportation services, such as the ones of public bus services is a key motivation of this work. In this research, we reproduce the road network of the city of Kyoto for observing specific travel patterns of public buses such as the bus bunching phenomena. Therefore, a selection of currently available data sets is used for calibrating a cutout of the Kyoto road network of a relatively large extent. After introducing a method for geodata extraction and conversion, we approach the calibration by introducing virtual detectors representing present inductive loops and make use of historical traffic count records. Additionally, we introduce bus routes partially contributed by volunteer mappers (OSM project). First simulation outcomes show numerous familiar (local knowledge) flow patterns.

**Keywords:** Simulation and Modeling, Network Modeling, Public Transportation Management, Calibration

## 1. Introduction

In this research, we aim to design data conversion procedures to create a digital twin (of at least the transportation-related aspects) of the city of Kyoto, Japan. Starting with gathering various data sources – static and dynamic information on infrastructural design elements, movement representations of tracked road users and sensors for providing traffic counts – we define suitable options for modeling and simulating private and public transport. The basic idea is to make use of the available traffic count information gathered in 5-minute-intervals from more than 1000 sensor location across the whole city for calibration purposes. By extracting OpenData on public transport services, we are able to model and simulate most of the present bus services and routes (and partially rail-based public transport).

We aim to first validate our microscopic traffic flow simulation with real bus trajectories and understand specific patterns of delays and congestions at selected time windows. Furthermore, our idea is to introduce method improvement procedures to not only design a data-driven conversion pipeline, but also to define a prototypical testbed for testing various traffic control strategies for different travel modes.

# 2. Methodological Approach – An Overview

## 2.1 Open Geodata Extraction and Conversion into Simulation Networks

One first complex task is the generation of a directed and routable road network, which should allow route generation by means of estimating OD-Matrices based on traffic count information coming from static sensors such as induction loops. The conversion of this network can be started with Volunteered Geographical Information (VGI) coming for example from the OpenStreetMap project [1]. Other, more detailed information might come from video data acquisitions and field observations. Our approach makes use of the netconvert tool [2] of the microscopic traffic flow simulation environment SUMO [3]. Similar to the approach of Keler, Grigoropoulos, and Mussack (2019) [4], we start with an extraction of raw OSM data by selecting a rectangle investigation area. After the conversion step into a PlainXML format, we are able to improve manually the quality of the road network representation by adjusting elements and specific details of the transportation infrastructure via the tool netedit (of SUMO). We refer to this by the blue box on the lower left side of Figure 1 by "Improving Conversion Quality".

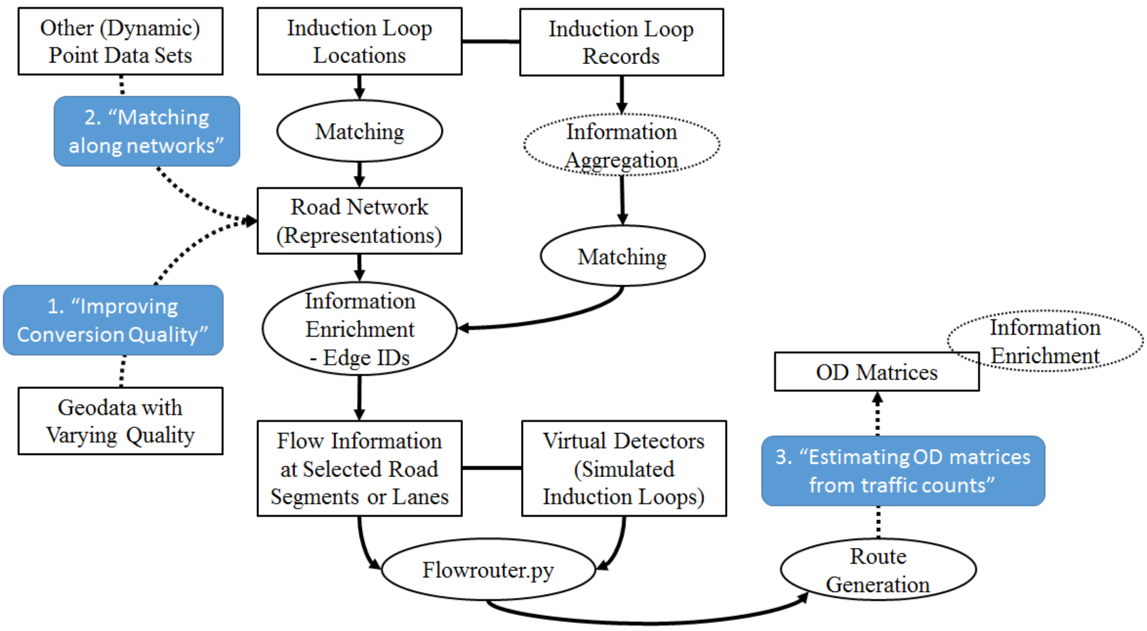


**Figure 1**. Workflow of the approach and components of improvement in blue boxes numbered from 1 to 3.

With the aim of creating a case study covering the most urban area of Kyoto and focusing on the most complex intersections in the City – we extracted a study area around the public bus route 205, as it is pictured in Figure 2.

## 2.2 Matching Sensor or Event Locations along Simulation Networks

After this road network representation generation, we are facing the problem of matching exact sensor locations onto lanes of the road network with respect to the allowed driving direction. Matching in the present approach for the Kyoto investigation area is conducted as Nearest-Neighbor-Search with a matching relation of 1:1, which means one point record (respective induction loop location) is matching exactly one road edge or one road lane (in this case with a specific driving direction).

Related research, which might improve the current data matching outcomes for the case of induction loop locations, includes the idea of an exact statistical method for analyzing co-location on a street network with a Japanese case study by Morioka, Okabe, Kwan, and McLafferty (2021) [5]. This fact is visualized in Figure 1 by the blue box on the upper-right side, indicating that this may highly influence the quality of the subsequent calibration and simulation results.

This problem of matching point data along a network is also partially intensively investigated by Okabe and Sugihara (2012) [6] in a practitioner book and an accompanying GIS tool named SANET (Spatial Analysis along NETworks).

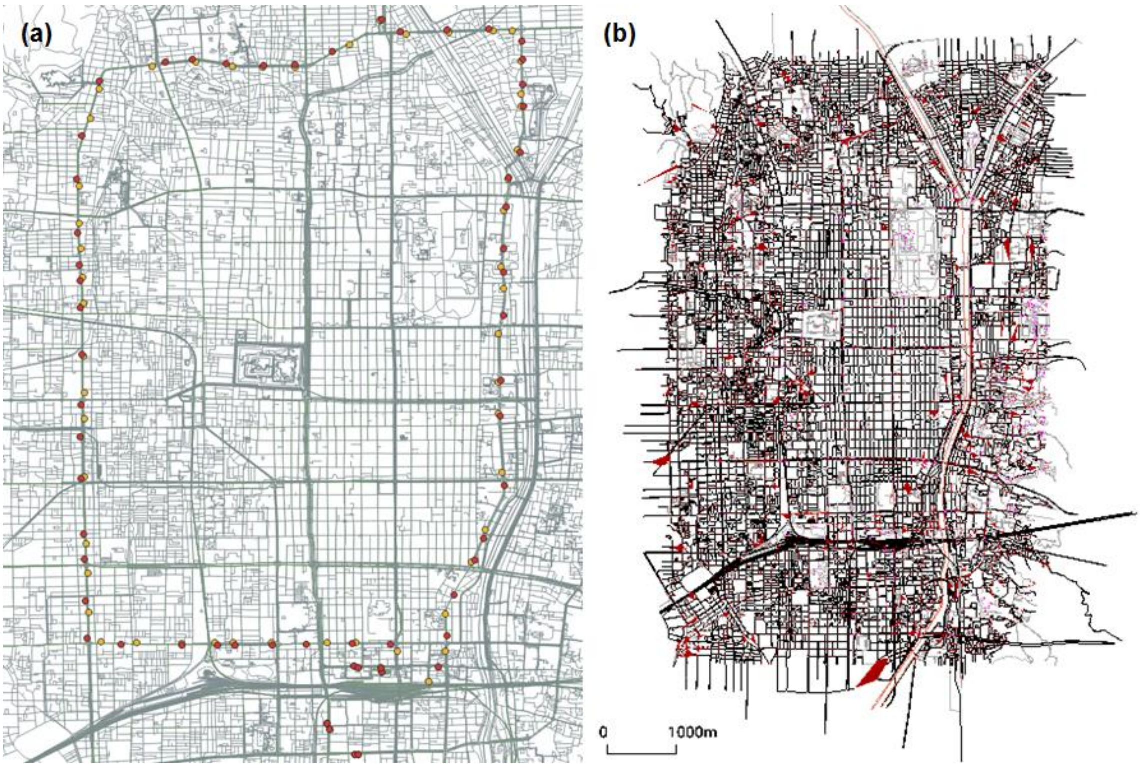


**Figure 2**. Locations of the bus stops of bus route 205 in Kyoto (a) and extracted and converted sumo traffic flow simulation network (b).

## 2.3 Calibration of the Simulation Network based on Aggregated Induction Loop Information - Estimating OD Matrices from Traffic Counts

The problem of estimating O-D demand flows using traffic counts is already very present in the literature and might be solved via numerous different approaches [7].

In our approach, we use the tool “flowrouter.py” [8] with partially reasonable results for our case study in Kyoto.

The simulation outcomes are currently being validated. Out of the 1100 installed permanent inductive loops in Kyoto, there are 451 located at the road network selection of the investigation area pictured in Figure 2. Based on selected or aggregated time windows we generate routes that comply with the observed or temporally-aggregated number for every virtual detector in our simulation runs. This means that every direction and lane that matches every of the

451 detectors is being taken into account while generating the routes of the private transport vehicles.

On the other hand, the buses are being simulated by introducing time tables and known headways for every fully- or partially-available bus route of our investigation area.

## 3. First Results and Novel Insights

Our first traffic flow simulation outcomes deliver novel insights of how to model road users and their compositions. As there different driving behavior with differing thresholds for car following and overtaking (compared to European conditions), deadlock situations as in Figure 3a appear at selected simulated intersections of the Kyoto simulation network. These situations might be avoided by adjusting the behavior of all simulated road users.

Other appearances, when simulating all public bus services, are similar to the bus bunching phenomena as pictured in Figure 3c. This might be a pattern of the real world worth to be validated with real bus trajectories. As Sun, Schmöcker, and Nakamura (2020) [9] state in their research this is a typical pattern for the bus service in Kyoto, implying a problem for passengers and other road users due to its relation with operational delays and with bus dwell times. In Kyoto, there is a schedule-adhere mechanism (holding the bus at the stop until the timetable time) but only when the bus is ahead of schedule. Bunching can happen when both buses are behind schedule and the operator will not hold the following bus to retrieve the headway [9,10].

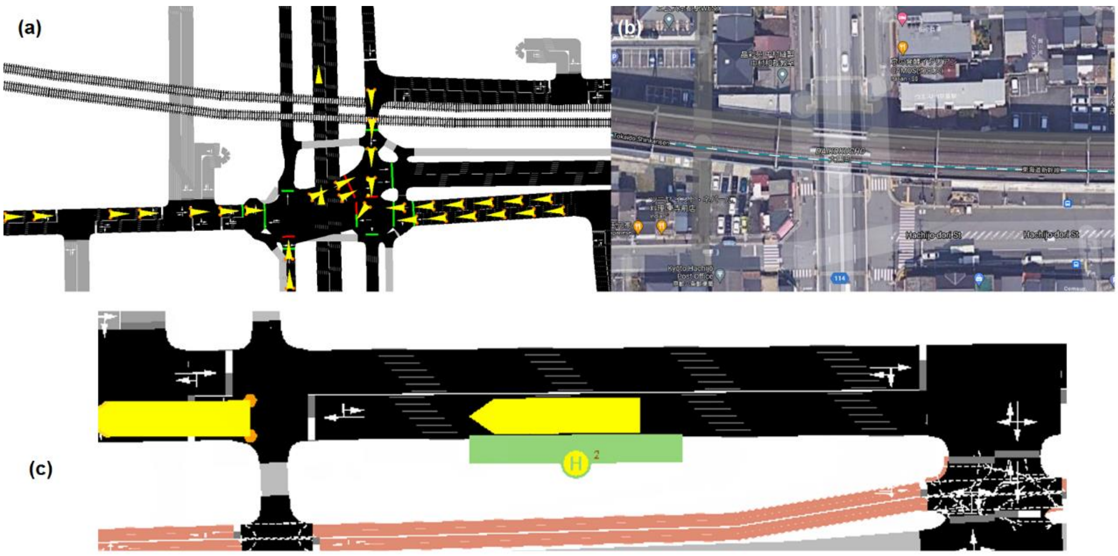


**Figure 3**. Selected results of the sumo simulation of Kyoto with (a) showing a deadlock situation at (b) a signalized intersection, and (c) bus bunching example.

## 4. Conclusion and Outlook

This work presents a framework for generating and calibrating a microscopic traffic flow simulation network of the larger scale investigation area in Kyoto as pictured in Figure 2. Several simulation outcomes comply with real world observations, mainly due to the availability of the detailed (records from 5-minute-intervals) historical traffic count data sets.

Nevertheless, several evaluation steps are required for inferring a valid simulation testbed, which can be seen as parts of the calibration procedure.

The inclusion of realistic behavior in the simulated traffic of Kyoto requires the adjustment of various model parameters. In case of the sumo applications this is related especially to the intersection model, but as well the car-following and lane-changing model. Introducing cyclists besides pedestrians would as well rely on for example adjusting the sub-lane model parameters in sumo.

Another bigger adjustment is related to the requirement to depict the signal programs at the signalized intersections in our investigation area. This would need an evaluation step for adjusting the previously estimated signal phases via applying the netconvert tool [2]. The availability of this information is currently being proven. Optionally, on-site observations would be required for a more detailed evaluation of the currently implemented programs at the respective intersections.

In an outlook to further linking additional information we can estimate selected possibilities due to the availability of additional Open Data, which might be important for estimating the demand of passenger flows. One example is pictured in Figure 4 by conducting a spatial analysis of GeoNames locations at the Kyoto investigation area.

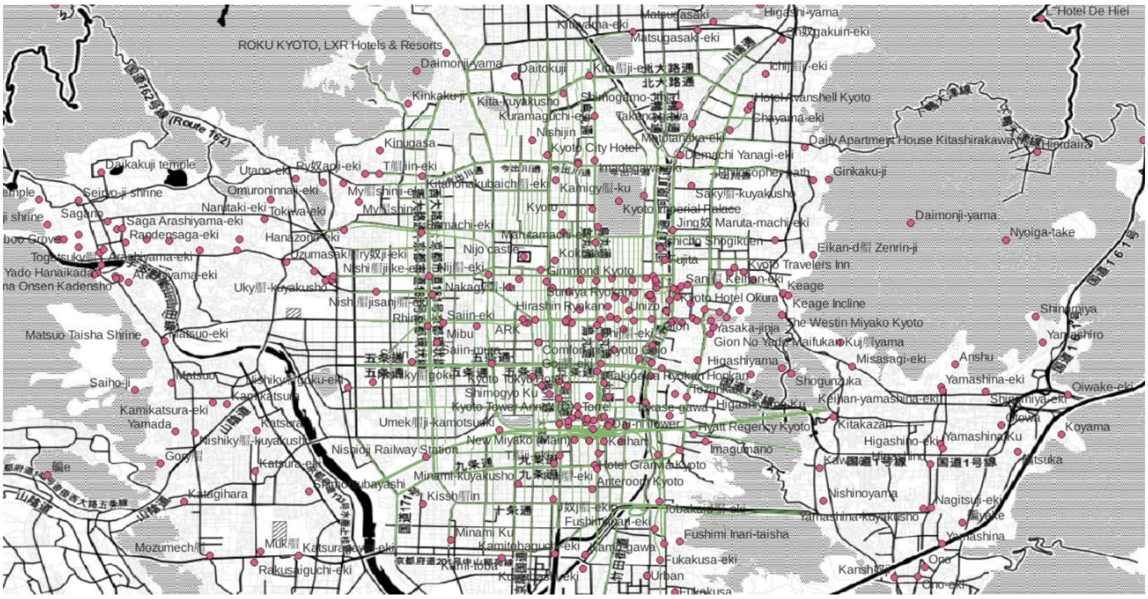


**Figure 4**. Spatial analysis example for estimating the amount of semantic and linked information in points of interest (POIs).

This takes also into account that intermodal trips should be defined for representing the most important times of the day of the inspected bus services – rush hours during week days with the presence of numerous tourists making use of selected bus routes for sightseeing purposes. This passenger demand is as well related to the distribution of populations in the city, which is itself related to distribution of selected building types and respective specifications. By including these insights into the present traffic flow simulation, we might estimate the numbers and spatial distributions of daily commuters and their daily travel patterns on a macroscopic level.

All in all, we can say that additional input data might highly benefit the already realistic simulation outcome of our present simulation testbed for the Kyoto case study. Additionally, the idea of a network-scale calibration for the entire City of Kyoto is an additional work in progress, which might benefit evaluating the findings discovered from our present study [10].

## Data availability statement

The underlying SUMO networks originate from freely accessible and usable OpenStreetMap data extracts. The induction loop record extracts and signal plans used in this study are currently (April 2023) not freely-accessible.

The authors additionally refer to the recent (April 2023) main SUMO reference, which includes applications with the recent version of this tool: Lopez et al. (2018) [11].

## Author contributions

All authors have contributed equally.

## Competing interests

The authors declare that they have no competing interests.

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