Spatial Interaction Modelling by Transport Mode: A glimpse into the impacts of a Motorbike Ban in Hanoi

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Summary

The city of Hanoi, Vietnam, like many rapidly expanding cities, is experiencing problems such as congestion, and the emergence of informal transport infrastructures. This paper presents preliminary results of a Spatial Interaction Model (SIM) which aims at predicting the impact of a potential motorbike ban, by simulating the number of journeys made from an origin to a destination using a particular transport mode. This analysis lays the foundation of how SIMs will be used to derive new insights and answer policy development questions such as where motorbikes should be banned and the impacts on existing modes of transport.

KEYWORDS: urban expansion, informal transport infrastructures; Spatial Interaction Model; policy development; Hanoi

1. Introduction

In Hanoi, over 90% of the vehicles driven are motorbikes (Van, 2009). The effects of such a large number and high density of motorbikes has led to severe problems such as traffic congestion, and noise and air pollution. Analysis of travel survey data has been widely used by policy makers to make informed decisions to meet future transport needs (Charleux, 2018). As a result, this paper presents preliminary modeling results of a travel survey, which was undertaken to capture the dynamics and trends of people's regular travel in and around Hanoi. This paper preliminarily investigates the impact of a potential motorbike ban on transport flows, by using a Spatial Interaction Model to simulate the number of journeys made from an origin to a destination using a particular transport mode. Early results begin to unravel how the journey costs for each mode could affect its corresponding trips, how flows by transport mode would shift if a ban were introduced, and the effects on the destination areas. It is hoped that this will elucidate new insights and answer policy development questions such as how, where, and when motorbikes should be banned (if at all) and the impacts on existing modes of transport.

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2. Research context

An overwhelming majority of inhabitants in Hanoi city use motorbikes as their primary means of transport. To put this into context, as of 2015 Hanoi had 4.9 million motorbikes and there are two and a half motorbikes per person (Van, 2009). The implications of such a massive number of fossil fuel vehicles include traffic congestion as well as serious air and noise pollution which regularly exceeds WHO guidelines. The "motor biking" culture, which allows Hanoians to enjoy greater flexibility and personal control, could be one of the obstacles to the usage of the public transport system (Ng and Phuong, 2015). As a result, policy makers have considered implementing a ban of all non-electric motorbikes in parts of the city, particularly in the central business district but this has been met with strong public opposition (Malleson *et al.*, 2021). As such, it becomes imperative to not only investigate the factors influencing individuals' attitudes towards planned policies but also the impact of the policies on future transport flows. For example, if a policy results to a vast majority of people using cars, then this could potentially worsen the traffic congestion.

3. Methodology

3.1. Travel Survey

The analysis presented in this paper is based on a transport survey that is being undertaken to capture the dynamics and trends of people's regular travel in and around the city, including the attitudes towards different transport modes and a proposed motorbike ban. The travel survey collects data such as general information (e.g. age, location), travel behaviour (e.g. origin-destination trips, means of transport) and attitudes towards the ban (e.g. opinion on the ban, alternative vehicle if ban is implemented). This paper then links the survey to a Spatial Interaction Model to predict the impact of a potential motorbike ban on transport flows. At the time of writing, there are approximately 1500 responses out of a target of 10,000; largely due to interruptions by COVID restrictions. Due to the limited number of responses, this paper aims at presenting preliminary findings that will support future analysis once we have more data.

3.2. Modelling transport flows using spatial interaction models

Spatial interaction models are a class of models that parameterise flows between geographical units as a function of one or more variables, always including some measure of the separation between geographical units (Andrew P Smith and Nik, 2019). In principle, spatial interaction models were developed based on the analogy of the Newtonian law of gravity and were popularised by researchers such as (Wilson, 1971). Only a brief summary of the mathematical underpinnings of these models are presented for brevity of this paper. More detailed mathematical theory can be found in (Dennett, 2018).

The basic premise of spatial interaction models is that the flows between two geographical units are governed by three factors: the emissivity of the origin, the attractiveness of the destination, and some measure of the cost or resistance of making the journey. This can be modelled as:

$$F_{ij} = k\, V_i^{\mu} W_j^{\alpha} c_{ij}^{-\beta} \tag{1}$$

where F_{ij} represents the estimated number of trips between origin i and destination j, V_i is a measure of the emissivity of an origin i, W_j is a measure of the attractiveness of a destination j, and c_{ij} represents the cost or resistance of making a trip from i to j. k, μ, α and β are all model parameters to be estimated.

Equation (1) is typically referred to as the 'unconstrained' / 'total constrained' spatial interaction model (Dennett, 2018). By and large, the literature on measuring spatial interaction is structured around the notion of constrained origin–destination (O-D) or trip distribution tables that are 'constrained' on the marginal totals over either the rows, or columns, or both. Production constrained models estimate the share of a fixed number of trip emanating from an origin to a given set of destinations and so replaces the terms k and V_i^{μ} to produce the following model:

$$F_{ij} = A_i O_i W_j^{\alpha} c_{ij}^{-\beta} \tag{2}$$

where

$$O_i = \sum_j F_{ij} \tag{3}$$

and

$$A_i = \frac{1}{\sum_j W_j^{\alpha} c_{ij}^{-\beta}} \tag{4}$$

A_i is a vector of values referred to as a *balancing factor* which ensures that the model reproduces the observed origin trip totals O_i. (Wilson, 1971) proposed considering a combined form of trip distribution and transport modal choice. Since the aim of this paper is to explore how trips will change with the introduction of a motorbike ban, Equation (2) was modified to Equation (5), to simulate the number of journeys made from origin *i* to a destination *j* using a transport mode *m* as shown:

$$F_{ij}^{m} = A_i O_i W_j^{\alpha} c_{ij}^{m^{-\beta}} \tag{5}$$

where F_{ij}^{m} represents the number of trips using a transport mode *m* and c_{ij}^{m} the cost for each mode *m*.

Equation (5) was then modelled as a multivariate Poisson regression as:

$$\lambda_{ij}^{m} = \exp(\mu_i + \alpha ln W_j - \beta ln c_{ij}^{m}) \tag{6}$$

where μ_i is the equivalent of the balancing factors A_i and is subsequently modelled as a spatial fixed-effects, which in this case was the name of the origin area of a given trip.

In this study, OSM (OpenStreetMap) was used to estimate destination attractiveness by the number of universities, colleges, hospitals and retail amenities in a given geographical unit. Currently all features are weighted equally but future work will revise and improve the attractiveness estimate. The distance between the origin and destination of a trip was used as the basic measure of cost for making the corresponding trip.

A Poisson regression model was subsequently fitted to produce estimates of μ, α and β using the Tidymodels framework in R with *glm* package as the underlying engine. One of the advantages of singly constrained models is that once initial parameters have been calibrated on existing data, then changes can be made to the model variables and the impact on flow estimates explored. For instance, to simulate a potential motorbike ban, the cost of making a trip using a motorcycle was increased by a factor and the flows recomputed resulting in a new O-D matrix.

4. Preliminary results and discussions

This section presents preliminary results that lay the groundwork for more robust analysis which will be undertaken in the availability of sufficient and better quality data. The production-constrained model achieved a Root Mean Score Error of approximately 1.592725 and an R^2 of approximately 0.409816. Equation (6) also allowed this study to investigate the negative influence of trip cost associated with each mode of transport. We need to transform β as shown in Equation (6) through an exponential in order to get a sense of the effect of distance on the number of trips for a given mode as shown below:

Table 1 Influence of trip cost to flows for each transport mode

Vehicle	β	$\exp(\beta)$
Bike	0.0415044	1.0423778
E-bike	-0.1582326	0.8536512
Car	-0.1869758	0.8294638
Motorbike	-0.2014786	0.8175210
Bus	-0.2043177	0.8152033
Taxi	-0.2286827	0.7955810
Walk	-1.0941846	0.3348125

This presents policy makers with insights on how trips could potentially vary given the journey cost matrices for each mode and in turn, a greater flexibility when estimating various scenarios. For instance, policy makers can expect a 67% decrease in the number of trips made by walking for an increase of one standard deviation of cost associated with walking. This can be compared with 0.817520 for the motorbikes, or a reduction of about 18% in the number of trips for every increase of a standard deviation of motorbike cost.

A scenario of a ban that resulted in a 5% decrease in the use of motorbikes was estimated and the change in flows by mode are compared as shown below:

Table 2 Results of a 5% decrease in the use of motorbikes

Vehicle	Observed flows	Estimated flows	Change in flows
Walk	511	561	50
Bus	417	451	34
E-bike	142	159	17
Bike	60	66	6
Taxi	51	56	5
Car	79	83	4
Motorbike	1503	1422	-81

Consequently, the map in Figure 1 illustrates the impact of the scenario to the flows at various destinations of the trips. Although these are preliminary results and it is too soon to draw firm conclusions, such a scenario results in an increase in the flows associated with the other means of transport and it appears that the majority of the flows will shift to walking, buses and e-bikes respectively. It is also interesting to see that most of the destinations affected by the scenario are towards the west of the city centre, a variation worth exploring further. It is also worth noting that these results are reflective of the underlying data and hence amplifies the need for more comprehensive and wider distributed data.

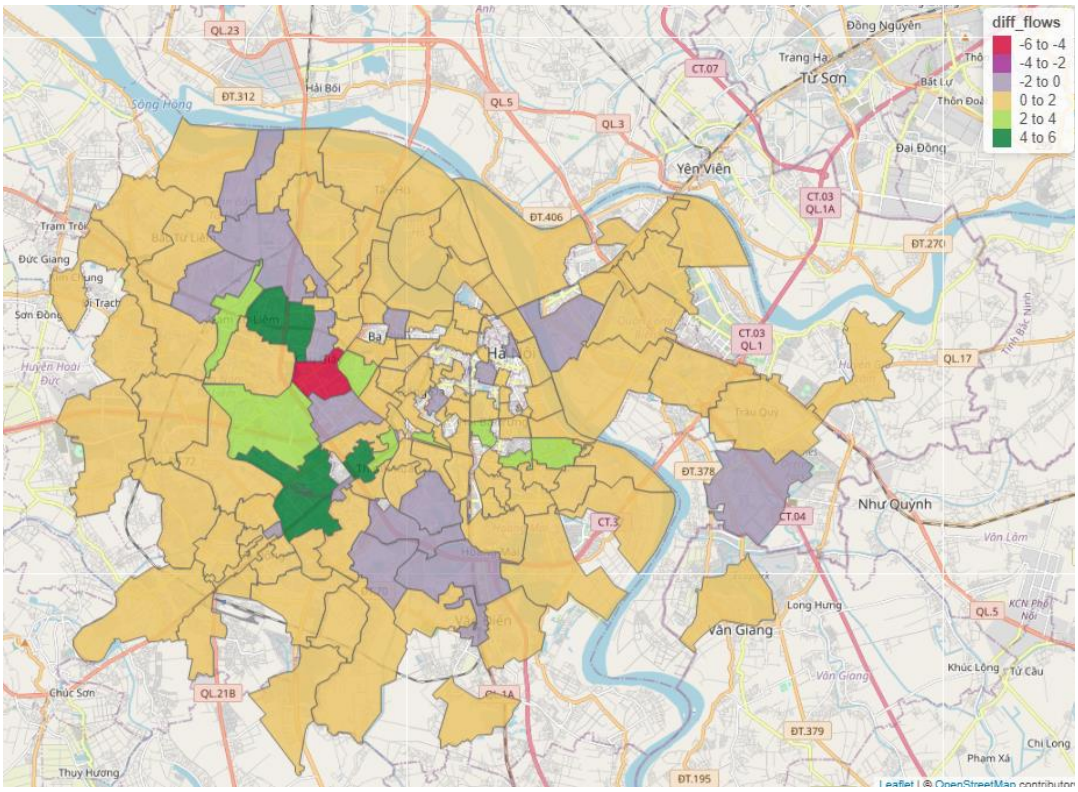

Figure 1 Change in incoming flows at various destinations in response to a 5% decrease in motorbikes

5. Conclusion

This study presents some early modelling results from the *Urban Transport Modelling for Sustainable Well-Being in Hanoi* project. Specifically, a spatial interaction model is linked to the survey in an attempt to predict the impact of a potential motorbike ban on the existing modes of transport and the corresponding variation in flows arriving at various destinations. Ongoing work is focusing on getting better measures of a destination's attractiveness, exploring different quantities and combinations for the cost function and formulating more realistic scenarios.

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Biographies

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Kristina Bratkova is an *Early Career Researcher* with an academic background in mathematics and music, but she recently transitioned to the world of data science and is currently working as a Data Scientist Intern at the Leeds Institute for Data Analytics. Kristina's research interests are urban analytics, GIS and everything R-related.