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Auteurs: Authors:	Amir Reza Mamdoohi, Seyedehsan Seyedabrishami, & Amirhossein Baghestani
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Final Analytical Comparison of Aggregate and Disaggregate Mode Choice Models Transferability

Amir Reza Mamdoohi[1], Seyedehsan Seyedabrishami[2], Amirhosein Baghestani[3]

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Abstract:

Transportation models as tools for transportation planning are critical to such related decisions. Considering the high cost of calibrating and validating such models, effective alternatives are highly sought for; one such alternative being the use of models calibrated for other cities. This calls for transferability analysis which has not been the subject of many researches. Due to criticality of aggregate and disaggregate data in transportation models, this paper tries to compare transferability of models calibrated with data of both groups. Mode choice models for daily work trips in two real-sized cities of Qazvin and Shiraz are analyzed. Models are calibrated employing multinomial logit structure with four modes of private car, taxi, bus, and 2-wheelers. In order to increase reliability of results, the top five best models are selected for each city-data category to be transferred. Based on transferability test statistics, transfer index, and goodness-of-fit of transfer models, aggregate models are not transferable and their results are deceptive. Transferability measures of these models are not in acceptable range; whereas transferability of disaggregate models have relative proper response. According to transfer index and goodness-of-fit of origin models operate similar to destination models. However transferability test statistics rejects the assumption of equality coefficients in both cities models. Using personal variables helps to effectively transfer origin models in addition to improve them.

Keywords: Transferability, mode choice models, aggregate, disaggregate.

Corresponding author Email:armamdoohi@modares.ac.ir

1-Assistant Professor, Department of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran

2-Department of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran

3-Msc. Grad., Department of Civil and Environmental Engineering, Tarbiat Modares University, Tehran, Iran

1. Introduction

Since transportation planning studies are very costly, particularly due to high cost of data collection for modeling calibration and validation, model transferability could be a potential alternative [Ortuzar & Willumsen, 2002]. The ability to transfer models from one city to another can help in significant cost and time savings for cities that cannot afford to invest in extensive data-collection procedures. Oftentimes, the cost of collecting data through these surveys is so high that it could easily exceed the annual budget of a planning organization responsible for this task [Wilmot and Stopher, 2001]. Also, observing transferability of a model could provide a direct indication of model validity.

Transferability as a tool for predicting travel demand for a certain city using a model developed for another city; is a complex issue since some models are not transferable and some are poorly transferable. For instance, models that are dependent on the regional properties or geographical features (like aggregate models) are such models [Ou & Yu, 1982]. On the other hand, since behavioral models structure is based on causal relationships; the results may not be so different in regions of similar economical and social conditions.

According to literature review, model transferability is studied in four different levels. The firs level discusses the transferability of broad behavioral postulates. The second level is for mathematical model class transferability. In the third level, specific model form transferability is studied. In the fourth level and the most precise one, which is also the focus of this paper, the model is transferred keeping all coefficients [Sikder et.al, 2011].

Watson and Westin studied spatial transferability of binary logit intercity mode choice models among different subareas in the Edinburgh-Glasgow area of Scotland. Models estimated in the six travel corridors were then compared for similarity in model coefficients, and each was also transferred to the other five corridors to evaluate modal split predictions. Their findings indicate that there is a high level of model transferability between the three models estimated in the corridors with a trip-end in the central city. However, this is not the case for the models estimated in the remaining three corridors that did not have a trip-end in the central city [NCHRP, 2012].

Galbraith and Hensher emphasized the need to consider both level-of-service variables as well as a reasonably extensive set of socioeconomic characteristic in mode choice models before evaluating transferability. They also identified the need to use consistent data (sampling procedures and variable definitions) in the estimation and application contexts.

Their empirical analysis of the spatial transferability of disaggregate mode choice models involved examining the intra-urban transferability of commute binary mode choice coefficients from two suburban areas in Sydney. Results indicated that the model with lowest goodness of fit values in origin performed best in term of transferability measures which are transferability test statistic and goodness-of-fit of transferred model [Galbraith and Hensher, 1982].

Karasmaa explored the spatial transferability of work trip mode choice models in the Helsinki and Turku regions of Finland.

The Helsinki region was used as the estimation context, and the Turku as the transfer context. Variant measure like transfer index, transferability test statistic, relative sample enumeration error were used to study transferability Also different methods were evaluated for updating the transferred model for making more accordance of results with destination city. The transfer procedures examined were the Bayesian updating, combined transfer estimation, transfer scaling, and joint context estimation. The results showed that the joint context estimation was generally the best method [Karasmaa, 2003].

Santoso and Tsunokawa examined spatial transferability in a developing country. Travel survey data from Ho Chi Minh City in Vietnam is used as the case study. A work trip disaggregate mode choice model with three modes (walking, bicycling, and motorcycles) was estimated for the urban area of the city, and its transferability to the suburban area was assessed. They studied the different dimensions of issue by analyzing the economic perspective of transferability of models [Santoso & Tsunokawa, 2005&2009]. Reviewing the literature, it was observed that the results of models` transferability are varied in different studies. In addition, previous researches have emphasized to update origin city model using destination city data to achieve better results than naïve transfer.

Various researches have been done on model transferability for different model types (aggregate & disaggregate) and models of different stages of transportation planning. Results show that still no consistent and robust effect of model type on transferability has been detected, which makes this field worth of research.
This paper makes a comparison between aggregate and disaggregate mode choice models' transferability of urban work trips, keeping all coefficients. While a few studies have been done in Iran, limited to trip generation step, this paper tries to compare transferability of aggregate and disaggregate models to approach the issue from a different point of view. Criteria of studying transferability are introduced in second part. The case study methodology is described in the third section. The last part includes conclusions and suggestions.

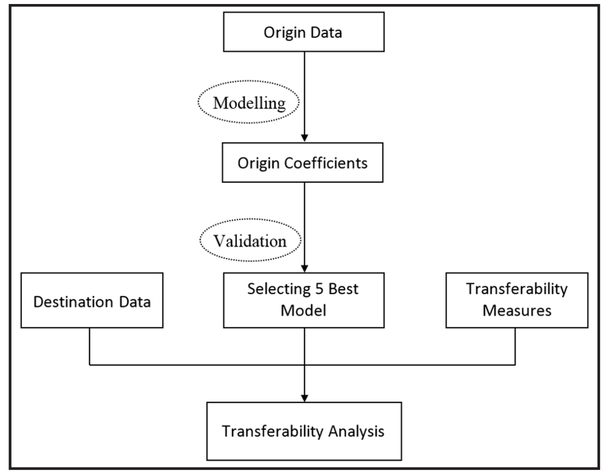

Figure 1. Transferability analysis flow chart of this paper

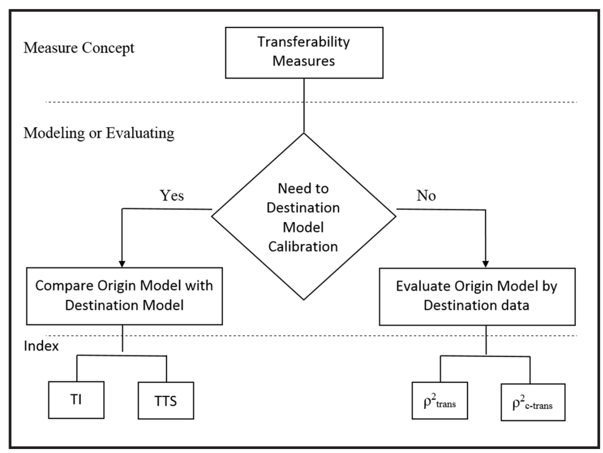

Figure 2. A classification of transferability measures at different levels

2. Methodology

Mode choice transferability procedure conducted in this paper follows that shown in figure 1. In order to increase reliability of results and be able to analyze more detailed results, a set of five different best models are selected for each category to be transferred. The five best models calibrated for the origin city are selected based on different indices such as goodness of fit index and variable significance to be applied for the destination city. Models of each city are used for another city and the results are compared to latter city's own model results. Various indices are defined for evaluating model transferability that are classified in 2 groups in the case of operation mode.
Transferability measures are classified by their need to destination model calibration which is time and effort consuming. However their application provides a much better perspective of transferability analysis as shown in figure 2. Factors of the first group compare the transferred model to the destination city model. For this purpose, first a similar structure of origin model should be developed in destination; so two models which are similar in structure and different in coefficients are compared and the main goal is measuring error of using each model for another city. Factors of the second group asses the transferred model based on its predictions of the destination city's data; so destination model calibration is not required.

Some of the first group indices are transferability test statistic (TTS) and transfer index (TI) which operate based on the origin model's ability in describing destination city's observations and likelihood function. The main comparison of these indices is the difference between log-likelihood function of models which one is developped in origin city i and used in destination city j ($L_j(\beta_i)$) and another is developped and used in destination city j ($L_j(\beta_j)$). Transferability test's statstical equation that is defined by Atherton and Ben-Akiva is shown in Table 1[Ortuzar & Willumsen, 2002]. The critical value of chi square is used in order to check to models' parameters matching.
Koppelman and Wilmot defined transfer index by

evaluating likelihood logarithm's acuurance based on a reference model (such as market share model). $L_j(C_j)$ is observations' likelihood logarithm in the destination city of j which is defined based on market shares model (Table 1) [Koppelman & Wilmot, 1982].

It is expected that $L_j(\beta_j)$ is more than $L_j(\beta_i)$ and $L_j(\beta_i)$ will be more than $L_j(C_j)$. The maximum value of transfer index is one, which means origin and destination models operate similarly. There is no minimum value for this index. Negative value of TI means the origin model is weaker than a base model and results will be deceptive and worse than model-less situation.

The second group of transferability indices indicates the origin model's ability to explain the destination's trip behavior. Some of these parameters are ρ^2_{trans} and $\rho^2_{c\text{-}trans}$ [Galbraith and Hensher, 1982]. $L_j(0)$ in their equations is observation likelihood logarithm in the destination city of j while all model parameters are zero.

3. Modeling and Transferability Analysis

Transferability analysis requires data for both origin and destination cities, and calibration of at least origin city models (for calculation ρ^2_{trans} and $\rho^2_{c\text{-}trans,}$ destination city model in else required). Due to criticality of aggregate and disaggregate data in transportation models, both are addressed in this paper.

One purpose of this paper is to analytically implement the theoretical methodology (explained in Section 2) in an empirical context to examine the corresponding challenges for real-sized cities in Iran. Since the required detailed data (for the implementation of the methodology for two real-sized cities) is not very readily available, two (rather different) cities were selected to study model transferability challenges. The case study includes daily urban work trips of Shiraz and Qazvin cities, whose general characteristics are presented in Table 2.

Table 1. Measures used to assess model transferability

Measure	Equation	Description	Acceptable Range
Transferability test statistic	$-2\,[L_j(\beta_i) - L_j(\beta_j)]$	Tests equality of parameters in origin & destination models.	Less than critical $\chi 2$
Transfer index	$\frac{L_j(\beta_i) - L_j(C_j)}{L_j(\beta_j) - L_j(C_j)}$	Ratio of origin model to the destination model.	0≤ ≤1
ρ^2_{trans}	$1 - (\frac{L_j(\beta_i)}{L_j(0)})$	Goodness of fit of origin model for destination city (equal share).	0≤ ≤1
$\rho^2_{c\text{-}trans}$	$1 - (\frac{L_j(\beta_i)}{L_j(C_j)})$	Goodness of fit of origin model for destination city (market share).	0≤ ≤1

Table 2. Some characteristics of the case cities of Shiraz and Qazvin

variable \ city	Shiraz	Qazvin
Population	1549453	464323
Area (square kilometer)	225	40
Average Travel time for private car (minute)	13.54	9.31
Average Total travel time of bus (minute)	47	24.85
Average Number of boarding for bus	1.69	2.07
Average Shortest aerial distance between internal origin-destination pairs (meter)	5740.57	2921.45

All models (aggregate and disaggregate) are developed as multinomial logit models with four modes of taxi, private car, bus, and 2-wheelers. Since the main goal is using a city's model for another one, required data for all variables must be available in both cities. Aggregate models' variables are mostly network properties such as different modes' travel time, and ground and aerial distance between origin-destination. The only socioeconomic variable is vehicle ownership (private cars and 2-wheelers). Beside these variables, age, gender, job, and driving license owning are also used in disaggregate models. Table 3 illustrates description of model's variables.

Developing aggregate models requires that all trips with the same origin and destination zones be aggregated and mode choice shares of origin-destination be calculated. Dependent (response) variables in such models are shares on a continuous interval from zero to one [0, 1]. In the disaggregate models, however the dependent (response) variables are each person's decision to make their trip by respective modes (or not); hence zero or one discrete values {0, 1} for each observation. Goodness of fit is approximately equivalent in all selected models for each city (5 models) and the difference depends on utilized variables and their significance. Table 4 shows the set variables of selected model in details of mode and city.

Comparing model results in 2 levels indicates that disaggregate models are better than aggregate ones (The average ρ^2_c for aggregate models of Qazvin and Shiraz are 0.03 and 0.04 whereas for dissaggregate models are 0.29 and 0.33). Using personal information is the most important reason of this. In order to studying transferability in the most precise level, first we need to develop models with similar structures in destination (developing origin model with destination data).

After determining model coefficients using origin data, the model is developed using destination data to determine new coefficients. In order to figuring transferability indices, destination city's likelihood logarithm should be calculated based on origin's model. Therefore, origin model is applied to destination city's data keeping all coefficients and variables. Destination model's properties (under origin structure), transferred model's logarithm for destination's data, and finally transferability indices for aggregate and disaggregate models are shown in table 5 and table 6 respectively.

Table 3 . Research mode choice variables description by category

Variable category	Variable name	Description	Application in aggregate models	Application in disaggregate models
Network	Tc	Travel time for private car (minute)	✓	✓
	Tin	In-vehicle travel time for bus (minute)		
	Tout	Out-of-vehicle travel time for bus (minute)		
	BTT	Total travel time of bus (minute)		
	Nbrd	Number of boarding for bus		
	Ndst	Shortest distance between internal origin-destination pairs on road network (meter)		
	Ddst	Shortest aerial distance between internal origin-destination pairs (meter)		
Seicoeconomic	ACO	Average Car ownership of origin zone (number of private car per zone)	✓	-
	AMO	Average 2-wheelers ownership of origin zone (number of 2-wheelers per zone)		
	HHCO	Number of private car per household	-	✓
	HHMO	Number of 2-wheelers per household		
User	Gender	Gender (man=1, woman=0)	-	✓
	Age	Age (over 18=1, else=0)		
	Dl	Driving license (owns=1, else=0)		
	Seller	Occupation (seller=1, else=0)		
	Officer	Occupation (officer=1, else=0)		

As shown in table 5, log-likelihood of transferred models from Qazvin to Shiraz is even lower than Shiraz's base models which indicates the transferred model's weakness. Negative goodness of fit values show the fact that Qazvin's models do not fit to Shiraz's data. Moreover, transfer index is negative too which means the transferred model's results are deceptive. Greater transferability test statistic than critical chi square at level of 95%, rejects the primary assumption of equal coefficients in both models. The total results show that Qazvin's models are not transferable to Shiraz.

Table 5 indicates that aggregate models' transferability from Shiraz to Qazvin is not possible either. Negative transfer index indicates weaker transferred model compared with market share model; so, Shiraz's model's results for Qazvin are deceptive and using this model is worse than no-model situation. ρ^2_{trans} is calculated as %3 and ρ^2_{trans} is negative (as expected) that shows low fitness of Shiraz's model for Qazvin's data. Therefore, Shiraz's model is not suitable for mode choice behavior in Qazvin. Greater transferability test statistic comparing to critical value of chi square ignores primary assumption of equal coefficients in both models. Generally, based on investigation of this study, aggregate models are not transferable and their results are deceptive.

Transferability analysis and calculations of Qazvin's disaggregate model to Shiraz for chosen models are shown in Table 6. $\rho^2_{c\text{-}trans}$ range from 0.18 to 0.22 with an average of 0.20 for transferring Qazvin's 5 models to Shiraz that are acceptable. Transfer index with a mean of 0.65 suggests a rather acceptable transferable model. However, transferability test statistic rejects the primary assumption of equal coefficients in both cities' models. According to table 6, transferring Shiraz's disaggregate models to Qazvin is acceptable too. Shiraz's transferred models with average values of 0.35 and 0.22 for ρ^2_{trans} and $\rho^2_{c\text{-}trans}$ respectively, not as well as Qazvin's own models, could be a proper alternative for describing Qazvin's travelling behavior. The average value of TI for Shiraz's models is 0.68 that is more than previous case (transferring Qazvin's model to Shiraz). Moreover, TTS is greater than chi square.

It is obvious that studied disaggregate models transferability, unlike aggregate models, is not rejected; however, they perform relatively well. According to all indices, exept of transferability test statistic, transferred model operates similar to destination's model. Bearing in mind that it seems unlikely for transferability test statistic's primary assumption not to be rejected. Using personal variables helps to effectively transfer origin

Table 4. Set of variables used in the selected mode choice models

Data	City	Mode	Variables of selected models
Aggregate*	Qazvin	Taxi	Asc[1]/ ACO/ Tc/ LnTc/ LnNdst/ LnDdst
		Private Car	Asc,/ACO/ Tc/ LnTc/ LnNdst
		Bus	Asc/ Tin/ Nbrd/ BTT
		2-wheelers	AMO/ LnNdst
	Shiraz	Taxi	Asc/ LnNdst/ LnDdst
		Private Car	Asc/ ACO/ LnNdst
		Bus	Tout/ LnTout/ Ln(Nbrd/Ndst),
		2-wheelers	Asc / AMO/ LnNdst/ LnDdst
Disaggregate**	Qazvin	Taxi	Asc/ HHCO/ Tc/Ln(Tc/Ndst)/Gender/Seller/Officer
		Private Car	Asc/ HHCO, LnNdst/Dl/Gender/Seller/Officer
		Bus	Asc/ Tin/Tout/BTT/Ln(BTT/Ndst)/Age/Seller/Officer
		2-wheelers	Asc / HHMO/ LnNdst/ Gender
	Shiraz	Taxi	Asc/HHCO/Tc/LnNdst
		Private Car	Asc/HHCO/LnNdst/Dl/ Gender/Seller
		Bus	Tin/LnTout/Nbrd/Dl/Age/Seller
		2-wheelers	Asc/HHCO/HHMO/LnNdst/Dl/Gender/Seller

* dependent variables are four [0,1] continuous share

** dependent variables are four {0,1} discrete values models in addition to improvin them. It's due to using personal variables but regional data (which depends on geographical features) in behavioral modelling. Also, under 18 years olds are not able to choose private passenger car regardless of in which city they are. Results show that some user behavorial variables improves transferability. Another noteworthy point is that descriptive staticstics of these variables for Qazvin and Shiraz are closed. Similarity of driving lisence ownership, officers and sellers, and over 18 years olds' shraes are some of effective parameters on these city's models transferability.

4. Conclusions and Recommendations

Transportation model transferabilty as a simple and cheap alternative to traditional costly transportation planning studies has been a popular research subject. This paper tried to compare spatial transferability of mode choice models at two different data types, namely aggregate and disaggregate for real-sized cities. Transferability is studied in its (at least currently) most presice level of model structure and coefficients. Aggregate and disaggregate models (5 for each group) were developed using OD data of daily work trips for Qazvin and Shiraz cities as case studies. Table 7 indicates acceptability of mode choice models transferability for both types of aggregate and disaggregate models of the case cities of this reseach. The tick sign (√) shows that transferability is acceptable based on the corresponding measures. Results of various transferabilty indices

Table 5. Transferability measures for aggregate mode choice models

Origin	Destination	Destination base models		Model No.	Destination model properties			Transferred model's logarithm for destination	Transferability indices			
		$-L_j(0)$	$-L_j(c)$		$-L_j(\beta_j)$	$\rho^2_0(j)$	$\rho^2_c(j)$	$-L_j(\beta_i)$	ρ^2_{trans}	$\rho^2_{c\text{-}trans}$	TI	TTS
Qazvin	Shiraz	3561.39	3461.83	1	3324.772	0.066	0.040	3831.938	-0.076	-0.107	-2.70	1014.33
				2	3326.163	0.066	0.039	3875.593	-0.088	-0.199	-3.03	1100.86
				3	3326.382	0.066	0.039	3732.812	-0.048	-0.079	-2.00	812.86
				4	3327.282	0.066	0.039	3785.692	-0.063	-0.094	-2.41	916.82
				5	3328.15	0.066	0.039	3806.078	-0.069	-0.1	-2.57	955.86
Shiraz	Qazvin	5643.60	4640.315	1	4504.011	0.202	0.029	6793.759	-0.204	-0.464	-15.80	4579.50
				2	4503.967	0.202	0.029	6810.004	-0.207	-0.468	-15.91	4612.07
				3	4503.971	0.202	0.029	6819.864	-0.208	-0.470	-15.99	4631.79
				4	4503.381	0.202	0.029	6794.079	-0.204	-0.464	-15.73	4581.40
				5	4506.050	0.202	0.029	6768.690	-0.199	-0.459	-15.85	4525.28

Table 6. Transferability measures for disaggregate mode choice models

Origin	Destination	Destination base models		Model No.	Destination model properties			Transferred model's logarithm for destination	Transferability indices			
		$-L_j(0)$	$-L_j(c)$		$-L_j(\beta_j)$	$\rho^2_0(j)$	$\rho^2_c(j)$	$-L_j(\beta_i)$	ρ^2_{trans}	$\rho^2_{c\text{-}trans}$	TI	TTS
Qazvin	Shiraz	3561.39	3461.83	1	2408.241	0.324	0.304	2831.51	0.205	0.182	0.60	846.54
				2	2390.418	0.329	0.309	2782.47	0.219	0.219	0.63	784.11
				3	2365.79	0.336	0.317	2789.91	0.217	0.194	0.61	848.25
				4	2357.318	0.338	0.319	2763.47	0.224	0.202	0.63	812.30
				5	2347.487	0.341	0.322	2672.45	0.250	0.228	0.71	647.92
Shiraz	Qazvin	5643.60	4640.315	1	3157.122	0.441	0.320	3723.876	0.340	0.197	0.62	1133.51
				2	3149.191	0.442	0.320	3574.538	0.367	0.230	0.72	850.69
				3	3179.401	0.437	0.315	3627.085	0.357	0.218	0.69	895.37
				4	3190.299	0.435	0.312	3594.710	0.363	0.225	0.72	808.82
				5	3179.364	0.437	0.315	3654.095	0.352	0.212	0.68	949.46

(transferability test statistics, transfer index, and goodness-of-fit) show that aggregate models are generally not transferable while it is possible to transfer disaggregate ones with relatively good performance.Goodness of fit values are negative for aggregate models in both cities which indicates inappropriacy of teransferred models. In addition, transfer index shows low fitness of transferred models because of negativity of values. Greater value of transferability test statistics compared with critical chi square also rejects the assumption of equal coefficients of two models (Table 8).
Based on the first two measures (goodness of fit and transfer index), Qazvin disaggregate models were transferable to Shiraz, and vice versa. However, this was not true based on the third (transferability test statistic) measure (Table 8). Transferability of disaggregate models (as compared with aggregate ones) could be attributed to personal variables improving origin models in the former models. Moreover, it could be attributed to similar descriptive statistics of these models.
Considering the fact that not many studies have been conducted in this field, particulaly in Iran, many suggestions could be made for fututre researches. For example, research on measures of similarity of cities for a better fit, or on other levels of details of model transferability.

5. Endnote

1- Alternative Specific Constant

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Table 7. Transferability* of mode choice models by model type (aggregate vs. disaggregate) **

Model \ Index	Goodness of fit values	Transfer index	Transferability test statistic
Aggregate	-	-	-
Disaggregate	✓	✓	-

*The tick sign (√) shows that transferability is acceptable based on the corresponding measure.

Table 8. Overall findings of transferability analysis and their interpretation*

Model	Finding	Interpretation
Aggregate	ρ^2_{trans}, $\rho^2_{c\text{-}trans}$ & TI are negative	Reject transferability
	TTS is greater than critical value of chi square	Reject equality of coefficients
Disaggregate	ρ^2_{trans}, $\rho^2_{c\text{-}trans}$ & TI are in acceptable range	Accept relative transferability
	TTS is greater than critical value of chi square	Reject equality of coefficients

** These results are only valid for case cities of this study and cannot necessarily be generalized to other cities.*
These results are only valid for case cities of this study and cannot necessarily be generalized to other cities.

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