Mode Choice Models Transferability: A Bayesian Update for Two Cities in Iran

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***Abstract*—Bayesian updating is introduced as a method to improve results of model transferability intended for decreasing cost of related studies. The main goal of this paper is to study the effects of Bayesian updating on transferability of aggregate and disaggregate mode choice models. These models are calibrated for a city in Iran and transferred to another city. Results of employing transferability measures such as Transfer Index (TI) and goodness of fit of transfer model are evaluated in two forms of naïve and Bayesian updating. Results show that Bayesian updating can noticeably enhance transferability of disaggregate models, but not as much in aggregate models. It is concluded that applying Bayesian update approach is reliable only when transferability of naïve model is not rejected.**

***Index Terms*—transferability, Bayesian update, mode choice model**

I. Introduction

Transportation models as tools for transportation planning are critical to such related decisions. Considering the high cost data collection for calibrating and validating such models, effective alternatives are highly sought for. On the other hand, quick response of travel behavior in some cases is needed, and economizing procedures to minimize time costs are still preferred. One such alternative being the use of models calibrated for other cities [1]. This calls for transferability analysis which is a complex issue requiring more detailed attention. Although one cannot expect perfect fit to the observations in the new city, model transferability analysis can provide a broad insight [2].

Many researchers have suggested that updating approaches need to be applied to improve the performance of the model to be transfer (transfer model). Naïvely transferring a model is not a preferable option because no model is ever sufficiently specified, which also means no model can perfectly reflect the travel behavior of commuters. As a result, evaluating model transferability only on the basis of the set of model coefficients being equal in the two areas is unlikely to be met [3], [4].

Updating approaches are used to modify coefficients of the transfer model by incorporating available information about the new application context. One of these procedures is Bayesian updating which combines information in the base and application context, by computing the update coefficient on any one variable as the weighted average of the coefficient of that variable as estimated in the base model, and the coefficients as estimated with the sample from the new area [4].

Atherton and Ben-Akiva examined the spatial transferability of a home-to-work trip mode choice model. They further examined the benefit of updating approaches that use a Bayesian update method. The results indicate that the Bayesian update approach works best, especially when the disaggregate sample available from the application context is small in size and the original estimation context choice model is well specified. However, there is little difference in the extent of transferability between the model with no updating and that with even the Bayesian update [5].

Wilmot also emphasized the need to have quality data in the application context to evaluate transferability. In his study, he found a substantial improvement in transferability when the constant in the linear regression model is updated based on application context data [6], [7].

Galbraith and Hensher used Bayesian update method in their study on Transferability of work trips mode choice models. They stated that if the results based on statistical criteria are considered, the Bayesian updating approach performs quite well. The benefits resulting from a Bayesian update are likely to be less pronounced unless the estimated coefficients of the small disaggregate sample have small standard errors [4].

Santoso and Tsunokawa examined spatial transferability in a developing country. Naive transfer and four updating methods associated with small sized samples were used in the transfer process and were evaluated. The results show that updating ASCs, updating both ASCs and scale parameter, and use of combined transfer estimators all produce significant improvement, both statistically and in predictability, in updating the model. They also concluded that naively transferring a model is not recommended, and Bayesian updating should be avoided when transfer bias exists [8], [9].

This paper aims to analyze the spatial transferability of mode choice models on the specific level of transferring model coefficients improved by Bayesian updating procedure. As the evaluation of Bayesian updating on

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aggregate and disaggregate models has not been the subject of many research projects, this paper has tried to compare the effectiveness of this technique on both aggregate and disaggregate models. Criteria of studying transferability are introduced in the next part. The case study methodology is described in the third section. The last part includes conclusions and suggestions.

II. METHODOLGY

According to this paper purpose which is studying the effectiveness of Bayesian updating method on transferability of aggregate and disaggregate models, firstly calibrating of estimated model for both kinds is necessary. After calibrating two models of aggregate and disaggregate, they are used for predicting of mode choice results in the application context. Since the most accurate level of transferability is considered in this paper, estimated models are used for application context data with all variables and coefficients. At first step, coefficients are transferred in naive form.

Previous studies have introduced various measures for transferability analysis [1]. Transferability measures employed in this paper include Transfer Index (TI) and goodness of fit of transferred model. Transfer index which operates based on the estimated model's ability in describing application context observations and likelihood function [10]. The main comparison is the difference between log-likelihood function of models which one is developed in estimated context i and used in application context j ($L_j(\beta_i)$) and another is developed and used in application context j ($L_j(\beta_j)$).

TABLE I. TRANSFERABILITY MEASURES OF THIS STUDY

Measure	Equation	Description	Acceptable Range
Transfer index	$\frac{L_j(\beta_i) - L_j(C_j)}{L_j(\beta_j) - L_j(C_j)}$	Ratio of estimated model to the application context model.	0≤ ≤1
ρ^2_{trans}	$1 - (\frac{L_j(\beta_i)}{L_j(0)})$	Goodness of fit of estimated model for application context (equal share).	0≤ ≤1
$\rho^2_{c\text{-}trans}$	$1 - (\frac{L_j(\beta_i)}{L_j(C_j)})$	Goodness of fit of estimated model for application context (market share).	0≤ ≤1

The maximum value of transfer index is one, which means estimated and application context models operate similarly. There is no minimum value for this index. Negative value of TI means the estimated model is weaker than a base model and results will be deceptive. Measures and their equations used to assess model transferability are introduced in Table I.

After transferring models naively and calculating transferability measures, the next step is updating models with Bayesian method. Equation 1 explains the Bayesian method.

$$\beta_{upd} = \left[\left(\beta_{EC}/\sigma_{EC}^2\right)+\left(\beta_{AC}/\sigma_{AC}^2\right)\right] \Big/ \left[\left(1/\sigma_{EC}^2\right)+\left(1/\sigma_{AC}^2\right)\right] \quad (1)$$

where β_{EC} and β_{AC} are the estimated and application context coefficients, σ_{EC} and σ_{AC} are standard deviations of the estimated and application coefficients, and β_{upd} is the new updated coefficient for the variable [4].

After applying this method on coefficients, transferability measures are calculated again for new coefficients and results are compared with first step results.

III. CASE STUDY AND RESULTS

Transferability analysis needs two spatial data sets in order to calibrate model in an estimation context and then transfer it to an application one. Hence, data for two real-sized cities of Qazvin and Shiraz are selected to study the effectiveness of Bayesian update method on transferability of mode choice models (Qazvin (Q) as estimation context and Shiraz (SH) as application context) [11]. General characteristics of the case studies are presented in Table II.

TABLE II. 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

Mode choice models for daily work trips are calibrated employing multinomial logit structure with four modes of private car, taxi, bus, and 2-wheelers. Due to criticality of aggregate and disaggregate data in transportation models, both are addressed in this paper. 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. Variables used in models are explained in Table III.

TABLE III. RESEARCH MODE CHOICE VARIABLES DESCRIPTION

Characteristic	Variable Symbol	Variable Description	Unit
-	ASC	Alternative Specific Constant	
Trip	TT	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 bus boarding for each OD	-
	Ndst	Shortest distance between internal origin-destination pairs on road network	meter
	Ddst	Shortest aerial distance between internal origin-destination pairs	meter
Socio-economic	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	-
	Age	Age (over 18=1, else=0)	-
	Dl	Driving license (owns=1, else=0)	-
	Job1	Occupation (seller=1, else=0)	-
	Job2	Occupation (seller or officer=1, else=0)	-

In order to study transferability in the most precise level, first we need to develop models with similar structures in Shiraz. After determining model coefficients using Qazvin data, the model is developed using Shiraz data to determine new coefficients. Results of calibrated models with similar structure in Qazvin and Shiraz would be shown in following. In order to figuring transferability measures, Qazvin model is applied to Shiraz data keeping all coefficients and variables.

Results of various naïve transferability measures (transfer index, and goodness-of-fit) are indicated in Table IV. It shows 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 which indicates inappropriacy of transferred models. Transferability of disaggregate models (as compared with aggregate ones) could be attributed to personal variables improving base models in the former models.

TABLE IV. RESULTS OF NAÏVE TRANSFERABILITY MEASURES OF MODE CHOICE MODEL

Model	TI	ρ^2_{trans}	$\rho^2_{c\text{-}trans}$
Aggregate	-2.70	-0.08	-0.11
Disaggregate	0.60	0.20	0.18

At next step, Bayesian update procedure is adopted for modifying the transferred coefficients as explained in the methodology. Then transferability measures are calculated again with updated coefficients. For both kinds of models, the Bayesian updating procedure performed better than naïve transfer (Table V). Applying the Bayesian method makes the transfer coefficients values closer to the value of application context model coefficients. As a result, transfer model could fit better on application context data.

TABLE V. RESULTS OF TRANSFERABILITY MEASURES OF MODE CHOICE MODEL UPDATED BY BAYESIAN APPROACH

Model	TI	ρ^2_{trans}	$\rho^2_{c\text{-}trans}$
Aggregate	-0.73	-0.01	-0.03
Disaggregate	0.93	0.30	0.28

Results show that the values of transfer index and goodness-of-fit for updated aggregate models increase although still not in acceptable range. Increasing the values of transfer index in disaggregate models are noticeable. Bayesian updating method could enhance the value of transfer index from 0.6 to 0.93.

It could be concluded that the effectiveness of Bayesian updating method on transferability of mode choice models in this paper are generally positive. Based on results of transferability measures, applying Bayesian update approach could be reliable only when the transferability of naïve model is not rejected.

Results of calibrating aggregate and disaggregate mode choice models and transferring coefficients in two forms of naïve and Bayesian update are illustrated in Table VI. For each variable, three sets of coefficients are showed which $\beta_{SH,}$ β_Q and β_{update} are calibrated coefficients using Shiraz date (application context), Qazvin data (estimation context) and Bayesian update method, respectively. It is obvious that the values of β_{update} are always between the values of β_{SH} and $\beta_{Q.}$ Indeed, applying the Bayesian approach approximates the value of β_Q to β_{SH}.

TABLE VI. RESULTS OF BAYESIAN UPDATE FOR TRANSFERABILITY OF MODE CHOICE MODELS OF QAZVIN (Q) TO SHIRAZ (SH)

Model	Mode	Taxi			Private Car			Bus			2-Wheelers		
	Variable	β_{SH}	β_Q	β_{update}	β_{SH}	β_Q	β_{update}	β_{SH}	β_Q	β_{update}	β_{SH}	β_Q	β_{update}
Aggregate	ASC	0.61	-6.71	-3.11	-2.70	-4.87	-3.89	-1.85	-5.4	-3.82			
	LnTT	0.07	-0.67	-0.32	-0.06	-0.41	-0.25						
	Tin							0.01	-0.02	0.00			
	Nbrd							-0.22	-0.08	-0.14			
	LnNdst										-0.34	-0.84	-0.6
	LnDdst	-0.33	0.4	0.07									
	ACO	2.56	3.09	2.91	13.59	9.20	10.75						
	AMO										15.71	6.44	6.82
		TI^{naive}= -2.70		$\rho^2_{trans}{}^{naive}$ = -0.08		$\rho^2_{c-trans}{}^{naive}$ = -0.11		$TI^{Bayesian}$= -0.73		$\rho^2_{trans}{}^{Bayesian}$ = -0.01		$\rho^2_{c-trans}{}^{Bayesian}$= -0.03	
Disaggregate	ASC	-0.50	-0.36	-0.48	-0.02	1.37	0.85				2.44	5.82	4.43
	TT	-0.04	-0.05	-0.04									
	BTT							-0.01	-0.04	-0.01			
	Tout							-0.03	0.03	-0.02			
	HHCO	0.48	0.67	0.60	3.77	3.14	3.38						
	HHMO										1.33	1.33	1.33
	Age							-0.26	-1.15	-0.37			
	LnNdst				-0.54	-0.57	-0.55				-0.58	-1.06	-0.89
	Dl				2.20	1.07	1.27						
	Job1							-0.71	-0.38	-0.57			
	Job2							-0.05	-0.56	-0.26			
		TI^{naive}= 0.60		$\rho^2_{trans}{}^{naive}$ = 0.20		$\rho^2_{c-trans}{}^{naive}$ =0.18		$TI^{Bayesian}$= 0.93		$\rho^2_{trans}{}^{Bayesian}$ = 0.30		$\rho^2_{c-trans}{}^{Bayesian}$= 0.28	

IV. CONCLUSIONS AND SUGGESTIONS

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. In literature, it was common to improving the performance of the model by using updating approaches. One of the widely used approaches in literature is Bayesian updating approach. Due to the limited number of studies in transferability comparison of aggregate and disaggregate models, current paper has focused on evaluating effectiveness of Bayesian update on both types of models. By using the Bayesian update, this paper analyzed the spatial transferability of mode choice models on the specific level of transferring model coefficients. In this regard, mode choice models for daily work trips, by employing multinomial logit structure with four modes of private car, taxi, bus, and 2-wheelers, are calibrated and Transferability measures included Transfer Index (TI) and goodness of fit are used. Results show that the values of transfer index and goodness-of-fit of transfer models for updated aggregate models increase although still not in acceptable range. Increasing the values of transfer index in disaggregate models are noticeable. Bayesian updating method could enhance the value of transfer index for disaggregate models from 0.6 to 0.93. Fig. 1 and Fig. 2 indicate the comparison of na ïve and Bayesian update transferability of aggregate and disaggregate mode choice models of this study, respectively.

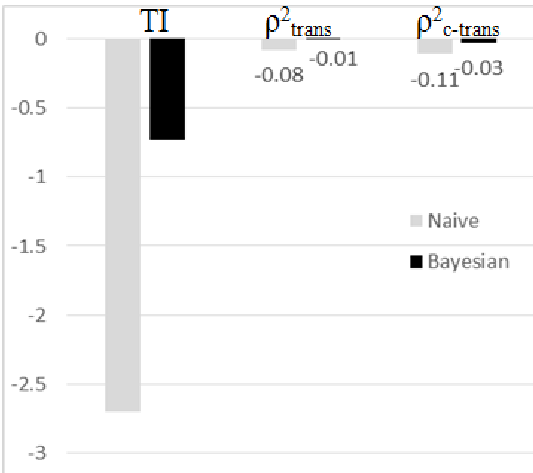

Figure 1. Comparison of na ïve and bayesian update transferability of aggregate mode choice models

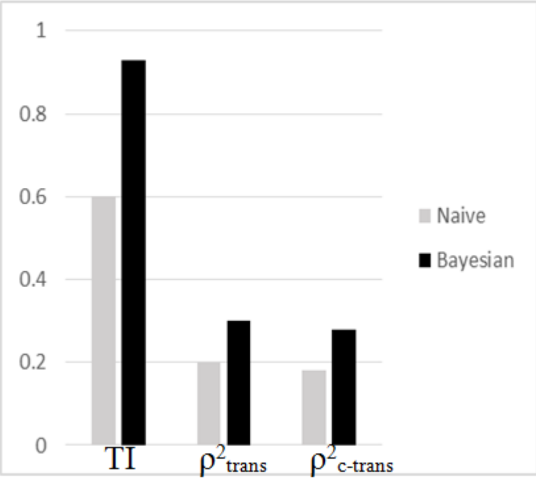

Figure 2. Comparison of naïve and bayesian update transferability of disaggregate mode choice models.

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