A New Methodological Approach for Estimating Commuter-Adjusted Population In a Metropolitan Area: The Case of Metropolitan Manila

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Introduction

Estimates of daytime population, also known as commuter-adjusted population, are essential for planning in metropolitan areas. While new technologies such as mobile phones, GPS devices, and location-based services have become available to offer insights into population movements and concentrations during the day, census and surveys that collect detailed data on where people live and work to estimate the daytime population remain important data sources for governments.

Objective

The proposed new approach for estimating commuter-adjusted population uses multi-exponential logit models on data from the census and a special household survey on commuting. The survey data shall provide information on the socio-demographic characteristics of all household members, commuting day, expected time of departure from origin and expected arrival in destination, reason/s for commuting, city/municipality passed through within the metropolitan region, time segment, for all commuting household members, and reason for commuting.

Data, and Methods

Data from the most recent census and a household commuting survey covering the metropolitan area and provinces adjacent to it that are considered within commuting distance will be needed for this proposed estimation method for the commuter-adjusted population. Census data to be used are socio-demographic characteristics (e.g., age, sex, in school/place of school, working/place of work) of all household members. The metropolitan area and cities/municipalities within the metropolitan area should be considered sampling domains for the Household Commuting Survey (HCS). The minimum data to be collected from each sample household are socio-demographic characteristics (e.g., age, sex, in school/place of school, working/place of work) of all household members, commuting day, expected time of departure from origin and expected arrival in destination, reason/s for commuting, city/municipality passed through, time segment, for all commuting household members.

The following formula will be used in the estimation procedure:

Commuter-adjusted population = *Stayers+ Intracity/municipality commuters + Incommuters – Outcommuters + commuters passing through the metropolitan area*

Figure 1. Simple Origin-Destination (OD) matrix for each time segment and TYPICAL day of the week

		Destination	
		National Capital Region	Bulacan, Cavite, Laguna, Rizal
Origin	National Capital Region	Stayers and intra-city/municipality commuters (ICMC)	Outcommuters
	Bulacan, Cavite, Laguna, Rizal	Incommuters	Stayers and Commuters passing through MM (CPTM)

TIME SEGMENTS:
1=4:00AM-10:00AM
2=10:00AM-4:00PM
3=4:00PM-10:00PM
4=10:00PM-4:00AM

TYPICAL DAY OF THE WEEK
1=Weekday
0=Weekend

Illustration of Method for Metropolitan Manila (MM)

Metropolitan Manila will be used to illustrate how this approach can be applied. There are four adjacent provinces to Metro Manila from where the population can commute within a reasonable number of hours. These are Bulacan, Cavite, Laguna, Rizal,. The predicted number of commuters from origin to destination can be illustrated using a simple Origin-Destination (OD) matrix for each time segment and TYPICAL day of the week (see Figure 1).

First, the probability of being a commuter or stayer will be estimated using the following binomial logistic regression model using survey data for all household members in MM and nearly provinces:

$$log_e\left[\frac{\pi^{Commuter}}{\pi^{Stayer}}\right] = \beta_0 + \beta_1 Age_i + \beta_2 Age_i{}_i^2 + \beta_3 Sex_i + \beta_4 (Age*Sex)_i + \beta_5 (Age^2*Sex)_i$$

where: Age_i = age of respondent i
Sex_i= 1 if Male, 0 if Female
Day_i=1 if weekday, 0 if weekend
$Time_{ij}$=dummy variables for time segment, j=1 to 3
$Reason_{ik}$=dummy variables for reason for commuting, k=1 to 2

Figure 2. Expanded OD Matrix

	DESTINATION									
ORIGIN	**Manila**	**Pasay**	**...**	**Muntinlupa**	**Bulacan**	**Cavite**	**Laguna**	**Rizal**	**Batangas**	**Pampanga**
Manila	Stayer				Outcommuters					
Pasay		Stayer		ICMC						
...			Stayer							
Muntinlupa	ICMC			Stayer						
Bulacan	Incommuters				Stayer			CPTM		
Cavite						Stayer				
Laguna							Stayer			
Rizal					CPTM			Stayer		
Batangas									Stayer	
Pampanga										Stayer

$$P(Commuter) = \frac{1}{1+e^{-(b_0+b_1\text{Age}_i+b_2\text{Age}_i^2+b_3\text{Sex}_i i+b_4(\text{Age*Sex})_i+b_5(\text{Age}^2\text{*Sex})_i)}}$$

$$P(Stayer) = 1 - P(Commuter)$$

Using the age-sex distribution of the population based on census data for each MM city/municipality and neighboring provinces, multiply with pertinent values in the age-sex probability structure of being a Stayer.

The next model will be estimated among MM commuters only:

$$log_e\left[\frac{\pi^{outcommuter}}{\pi^{ICMC}}\right] = \beta_0 + \beta_1\text{Age}_i + \beta_2\text{Age}_i{}_i^2 + \beta_3\text{Sex}_i + \beta_4(\text{Age*Sex})_i + \beta_5(\text{Age}^2\text{*Sex})_I$$
$$+ \beta_6\text{Day}_i + \beta_7\text{Time}_{i1} + \beta_8\text{Time}_{i2} + \beta_9\text{Time}_{i3} + \beta_{10}\text{Reason}_{i1} + \beta_{11}\text{Reason}_{i2}$$
$$+ \beta_{12}\text{Dest}_{i1} + \ldots + \beta_{31}\text{ Dest}_{i20}$$

where Dest_{ik} is the city/municipality or province of destination, k=1 to 20

$$P(Outcommuter) = \frac{1}{1+e^{-(b_0+b_1\text{Age}_i+b_2\text{Age}_i^2+b_3\text{Sex}_i i+b_4(\text{Age*Sex})_i+b_5(\text{Age}^2\text{*Sex})_i+\ldots+b_{31}\text{Dest}_{i20})}}$$

$$P(ICMC) = 1 - P(Outcommuter)$$

Again, using the age-sex distribution of the commuting population from census data for each MM city/municipality, multiply each entry with pertinent values in the age-sex probability structure of being an ICMC.

The last model is estimated for all commuters in the nearby provinces of MM:

$$log_e\left[\frac{\pi^{Incommuter}}{\pi^{CPTN}}\right] = \beta_0 + \beta_1 Age_i + \beta_2 Age_{i\,i}^{2} + \beta_3 Sex_i + \beta_4 (Age*Sex)_i + \beta_5 (Age^2*Sex)_I + \beta_6 Day_i + \beta_7 Time_{i1} + \beta_8 Time_{i2} + \beta_9 Time_{i3} + \beta_{10} Reason_{i1} + \beta_{11} Reason_{i2} + \beta_{12} Dest_{i1} + \ldots + \beta_{31} Dest_{i20}$$

$$P(Incommuter) = \frac{1}{1+e^{-(b_0 + b_1 Age_i + b_2 Age_i^2 + b_3 Sex_i i + b_4 (Age*Sex)_i + b_5 (Age^2*Sex)_i + \ldots + b_{31} Dest_{i20})}}$$

$$P(CPTM) = 1 - P(Incommuter)$$

Using the age-sex distribution of the commuting population from census data for each province, multiply each entry with the age-sex probability structure of being an Incommuter.

Interaction terms for day and time and cubic terms may be later added to the models, if needed, after the initial viewing of graphs.

Concluding remarks

This approach is quite flexible to provide estimates on the commuter-adjusted population by city/municipality, day of the week, time segment of a day, and reason for commuting which are generally useful for urban planning and infrastructure, commercial planning, transportation planning, public health, and emergency services, among others.