Project Research on
"Transportation Survey and Travel Demand Forecast in Developing Countries"

Final Report
Digest

November 2018

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

ALMEC Corporation
Oriental Consultants Global Co., Ltd.

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List of Abbreviations

Abbreviation	Original Words
ABM	Activity-Based Modeling
ADS	Activity Diary Survey
BRT	Bus Rapid Transit
CCTV	Closed-Circuit Television
CDR	Call Detail Record
CoMTrans	Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs
CTS or CS	Commuter Trip Survey
DCC	Dar es Salaam City Council
DSM	Dar es Salaam Transport Policy and System Development Master Plan
DSM	Dar es Salaam
DTCA	Dhaka Transportation Coordination Authority
F/S	Feasibility Study
GNI	Gross National Income
GPS	Global Positioning System
GUI	Graphical User Interface
HTS	Household Travel Survey
ICT	Information and Communication Technologies
IMM	Istanbul Metropolitan Municipality
IUAP	The Study on Integrated Urban Transportation Master Plan for Istanbul Metropolitan Area
JICA	Japan International Cooperation Agency
JUTPI	JABODETABEK Urban Transport Policy Integration Project
LOS	Level of Service
M/P	Master Plan
MAC	Media Access Control
MCDCB	Metro Cebu Development and Coordinating Board
MDPI	Multidisciplinary Digital Publishing Institute
Metro Cebu	The Roadmap study for sustainable urban development in Metro Cebu
METROS	Data Collection Survey on Railways in Major Cities in Vietnam
MUCEP	The Project for Capacity Development on Transportation Planning and Database Management in the Republic of the Philippines
NCC	Nairobi City County
NIUPLAN	The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya
OD	Origin Destination
PDCA	Plan, Do, Check, Action
PPP	Public-Private Partnership
RSTP	Project on the Revision and Updating of Strategic Transport Plan for Dhaka
SCZMP	Transport Improvement Master Plan Project for Santa Cruz Metropolitan Area
SDUGA	The Project for the Development of Urban Master Plan in Greater Abidjan
SIM	Subscriber Identity Module
SP	Stated Preference
TAZ	Traffic Analysis Zone
TCM	Transportation Control Measure
TDM	Transport Demand Management
TOD	Transit-Oriented Development
YUTRA	Project for Comprehensive Urban Transport Plan of Greater Yangon

1. INTRODUCTION

1.1. Background

In metropolitan regions of developing countries, various urban transportation problems are being tackled such as rapid urban development, extraordinary increase in population and vehicles, road traffic congestion and low service standard of public transport, and declining traffic safety. Under these circumstances, Japan International Cooperation Agency (JICA) has provided assistance in urban transport planning for over 60 metropolitan regions in developing countries by conducting urban transportation master plan (M/P) studies or feasibility studies (F/S). However, JICA has faced the following three main issues.

1.1.1. Transportation Surveys with a Main Focus on Household Travel Surveys

JICA has conducted many large-scale household travel surveys (HTS) as the main means to understand the existing travel movement situation. While HTS has been conducted in Japan as well, various accuracy-related issues and problems have been raised such as: lack details of traffic analysis zone (TAZ) system; lack of information of choices such as drivers' parking choice, transit users' route choice, and use of monthly passes; lack of consideration in seasonal fluctuation of transport demand; complicated survey form that results in non-participation and invalid sample biases; and difficulty in collecting samples from single-person households living apart from their families[1].

In past HTS in developing countries, it was common to set sampling ratios of 1% to 3% in order to secure statistically effective samples involving a large number of respondents (e.g., minimum sample of 50,000 persons or about 10,000 households in the case of metropolitan regions with a population of 5 million). It was thus a large-scale survey which took a period of 6 to 8 months and required a large budget that included surveyors' training and preliminary survey periods. Furthermore, serious problems about survey quality and data bias have been raised in the case of developing countries.

Meanwhile, for transportation surveys with a main focus on HTS, the data needs to be updated after survey completion; however, in most cases, governments of developing countries cannot secure the necessary budget and manpower, and a more realistic method of updating data is required. Furthermore, it has been widely acknowledged in the US and Europe that direct estimation of OD tables by aggregating and expanding the survey data is not realistic; hence, development and use of disaggregate transportation demand forecast models are given greater priority, and smaller-scale sampling is more common[2,3].

1.1.2. Travel Demand Forecast Methods

As a travel demand forecast method based on the HTS, a trip-based approach represented by the four-step method has been widely used; however, this approach has several drawbacks in that: no consideration is given to a series of activities made by individuals or intra-household interactions (e.g., car sharing and picking up/sending off household members); no consideration is given to hourly fluctuations or changes in travel behavior during peak hours caused by transportation control measures (TCMs) such as pricing policies[4,5].

In order to overcome these drawbacks, new travel demand forecast methods such as activity-based travel demand modeling (ABM) have been researched and developed, and some have already been in practical use in the U.S. and Europe[6]. Some typical travel behaviors of developing countries, such as

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[1] Kitamura, R. (2002). *Modeling Travel Behavior*, p.p. 63-64, Tokyo, Gihoudou.

[2] Smith, M. E. (1979). "Design of Small-Sample Household-Interview Travel Surveys." *Transportation Research Record*, 701, p.p. 29 35.

[3] THE ON-LINE TRAVEL SURVEY MANUAL: A Dynamic Document for Transportation Professionals, Provided by the Members and Friends of the Transportation Research Board's Travel Survey Methods Committee (ABJ40), http://www.travelsurveymanual.org/HomePage.html. Accessed August 1, 2017.

[4] Stopher, P.R. (1993). "Deficiencies of Travel-Forecasting Methods Relative to Mobile Emissions," *Journal of Transportation Engineering*, 119(5).

[5] Deakin, E., and G. Harvey (1993). *A Manual of Regional Transportation Modeling Practice for Air Quality Analysis*, Washington, D.C.: National Association of Regional Councils.

[6] Vovsha, P., M. Bradley, and J.L. Bowman (2004). "Activity-Based Travel Forecasting Models in the United States: Progress since 1995 and Prospects for Future." Paper presented at the EIRASS Conference on Progress in Activity-Based Analysis, Maastricht, The Netherlands

long distance walk and send children to school before going to work in a chauffeur-driven car, could also be reflected allowing for a forecast based on actual situations. Furthermore, devices which can keep track of the users' travel behaviors such as cellular phones and smartphones with a built-in GPS feature have rapidly been adopted in the world. Information obtained from these devices has also been utilized as a new transportation data collection method by various researchers and practitioners. Thus, they have a potential to be utilized by JICA for better efficiency of HTS.

1.1.3. Cooperation Needs in Urban Transportation Sector

While JICA has provided assistance in urban transport planning by conducting urban transportation M/P studies or F/S, there is an increasing need for technical cooperation such as analysis of policies like TCMs within a specific area. Therefore, travel demand forecast for such policy analysis needs to be refined as well.

In the context of these issues, this so-called "project research" aims to identify the issues of transportation surveys and travel demand forecast methods and to study possible improvements with a view to reorganizing the content for future cooperation in the urban transportation sector in developing countries.

1.2. Objective

JICA has conducted many transportation surveys and demand forecasts mainly in the course of M/P studies. Recently, however, there are cases where recommendations from the studies are requested in a short period or M/P studies are repeated. Thus, it is required to design methods of transportation survey and demand forecast that are suitable to the objective, significance, speed, and result needed and expected in each study. Moreover, new tools and data as well as demand forecasting methods are being made available for utilization owing to the progress of research and technology; hence, this research will also organize suitable methods to be selected for each study, thereby seeking a possibility of cost reduction as well.

Considering the above objective, this research consists of the following three types of data collection, analysis, and study:

- To analyze and study issues and improvement measures of transportation surveys and demand forecasts in urban transportation planning in developing countries assisted by JICA;
- To organize methods of socioeconomic data collection that has been conducted in parallel with the transportation surveys; and
- To organize need for cooperation involving transportation surveys in the urban transportation sector in developing countries.

2. REVIEW OF PAST STUDIES ON URBAN TRANSPORTATION MASTER PLAN

This section presents the summarized result of the first step and also the largest parts of the research, that is, review of past urban transportation M/P studies. While M/P studies are the most comprehensive study targeting a metropolitan region in the developing world, JICA generally has a total of five types of study or assistance for urban transportation planning as shown in Table 2.1, and they are all targeted in this research.

TABLE 2.1 Forms of Study or Assistance in Urban Transportation Planning

Type of Study/Assistance.	Description
Master Plan (M/P) Study	The objective of urban transportation M/P is to clarify the future vision of urban transportation and to serve as a guideline for transportation administration. M/P has a role of enhancing accountability by presenting long-term directions for development while it also attempts to solve obvious transportation problems. M/P includes strategies, policies, institutions, organizations, infrastructure development plans, and project priorities to realize itself as well as to tackle the current issues. In M/P study, various benefits and impacts are scientifically evaluated and analyzed.
Short-term Infrastructure Development Planning (differentiated from M/P)	In cases where there is insufficient time for formulation or updating the M/P, short-term infrastructure development plans are needed for a metropolitan region. Short-term infrastructure development planning is conducted by bundling the existing plans followed by selection and prioritization of projects through discussions with high-rank decision-makers. While projects are implemented through demand forecast or F/S, the infrastructure development plans are continuously updated through a PDCA (plan-do-check-action) cycle. If HTS data, census database, or demand forecasting models are available, the infrastructure development plans along with demand forecast models could also be updated by utilizing mobile spatial data and additional HTS or activity diary survey (ADS) as well as supplemental surveys at shopping malls and offices.
Feasibility Study (F/S)	F/S as well as M/P studies are some of the major types of study or assistance that have been provided by JICA. The objective of F/S is to study the feasibility of a specific infrastructure development project such as roads, railways, and bridges. For loan projects, bankability is evaluated in the F/S. Targets of evaluation also include details of the project such as route selection, station plans, and profitability.
Transportation Policy Planning (TCM, TOD, etc.)	Transportation policies are studied in this type of study, including investigation or analysis of changes in travel behavior caused by transit-oriented development (TOD) plans or TCMs as well as tariff settings. Such studies are difficult with a conventional trip-based approach represented by the four-step method because of its weaknesses mentioned earlier. However, there is increasing need for cooperation in transportation policy planning, and it may be necessary to reconsider and improve the method of demand forecast for better accuracy.
Updating Travel Data and/or M/P (for Capacity Development)	This is a technology transfer and capacity development project which aims to assist counterpart agencies so that travel data and demand forecast models for the purpose of revising transportation plans are able to be updated by themselves. Various transportation surveys including HTS need to be updated in order to revise the transportation plans within ten years of the last survey. However, in reality, updating is often difficult due to the previously-mentioned reasons; hence, the need for this type of assistance is increasing.

2.1. Comparison of Fact Data of Past M/P Studies and Travel Surveys

In this research, as listed in Table 2.2, a total of 12 major urban transportation M/P studies in developing countries were reviewed through literature review followed by interviews with ex-JICA experts and/or counterparts who were in charge of the transportation surveys and travel demand forecasting in order to find out issues and tendencies in the transportation surveys with a focus on HTS and in travel demand forecasting methods, as well as cooperation needs of the urban transportation sector.

TABLE 2.2 List of Urban Transportation M/P Studies for Literature Review and Interviews

No.	Project Name	Country	Study Period	Major Transportation Surveys	Remarks
1	Transport Improvement Master Plan Project for Santa Cruz Metropolitan Area (SCZMP)	Bolivia	2016-2017	HTS Commuter Survey (using tablets) ADS	(ongoing study)
2	The Project for Capacity Development on Transportation Planning and Database Management in Manila (MUCEP)[7]	The Philippines	2011-2015	HTS (for updating OD matrices)	HTS conducted by the counterpart
3	Project on the Revision and Updating of Strategic Transport Plan for Dhaka (RSTP)[8]	Banglades h	2014-2016	HTS	
4	Data Collection Survey on Railways in Major Cities (METROS)[9]	Vietnam	2013-2016	HTS	
5	The Roadmap Study for Sustainable Urban Development in Metro Cebu[10]	The Philippines	2013-2015	HTS	
6	The Project for the Development of Urban Master Plan in Greater Abidjan (SDUGA)[11]	Cote d'Ivoire	2013-2015	HTS (first time) ADS	
7	Project for Comprehensive Urban Transport Plan of Greater Yangon (YUTRA)[12]	Myanmar	2012-2015	HTS	
8	Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans)[13]	Sri Lanka	2012-2014	HTS (first time)	Including F/S
9	JABODETABEK Urban Transport Policy Integration Project (JUTPI)[14]	Indonesia	2009-2011	Commuter Survey (with updating OD matrices)	Technical cooperation project
10	The Study on Integrated Urban Transportation Master Plan for Istanbul Metropolitan Area (IUAP)[15]	Turkey	2007-2009	HTS (without updating OD matrices)	Survey and demand modeling conducted by the counterpart
11	Dar es Salaam Transport Policy and System Development Master Plan (DSM)[16]	Tanzania	2007-2008	HTS	Including pre-F/S
12	The Project on Integrated Urban Development Master Plan for the City of Nairobi (NIUPLAN)[17]	Kenya	2013-2014	HTS	Updating past M/P

Note: Yellow-highlighted projects include second (or more) large-scale transportation surveys as well as updating M/P.

[7] Department of Transportation and Communication (DOTC), Republic of the Philippines and Japan International Cooperation Agency (JICA) (2015). *The Project for Capacity Development on Transportation Planning and Database Management in the Republic of the Philippines: MMUTIS Update and Enhancement Project*, prepared by ALMEC Corporation and Oriental Consultants Global Co., Ltd.

[8] Dhaka Transport Coordination Authority (DTCA), People's Republic of Bangladesh and Japan International Cooperation Agency (JICA) (2016). *The Project on the Revision and Updating of the Strategic Transport Plan for Dhaka*, Final Report, prepared by ALMEC Corporation, Oriental Consultants Co., Ltd, Katahira & Engineers International.

[9] Hanoi and Ho Chi Minh People's Committee, Socialist Republic of Vietnam and Japan International Cooperation Agency (JICA) (2016). *Data Collection Survey on Railways in Major Cities in Vietnam (METROS)*, Final Report, prepared by ALMEC Corporation, Oriental Consultants Co., Ltd, Nippon Koei Co., Ltd, Japan Transportation Consultants, Inc.

[10] Metro Cebu Development and Coordination Board (MCDCB), Republic of the Philippines and Japan International Cooperation Agency (JICA) (2014). *The Roadmap Study for Sustainable Urban Development in Metro Cebu*, prepared by ALMEC Corporation and Oriental Consultants Global Co., Ltd.

[11] Ministry of Construction, Housing, Sanitation and Urban Development (MCLAU), Republic of Côte d'Ivoire and Japan

Fact data of the 12 urban transportation M/P studies for literature review and interviews are summarized in Table 2.3. It is understood that the scope of the transportation surveys and travel demand modeling in each M/P study was designed in accordance with its respective background. Overall, in the metropolitan areas where the HTS was conducted for the first time, namely, Santa Cruz, Abidjan, Yangon, and Colombo, comprehensive transportation surveys including a variety of supplemental surveys were conducted to develop travel demand forecast models. As a result, input of experts dispatched by JICA who were in charge for transportation surveys and travel demand modeling in each of these metropolitan areas tended to have more manpower (MMs: man-months) than other metropolitan areas, resulting in a relatively higher price of HTS per sample.

International Cooperation Agency (JICA) (2015). *The Project for The Development of the Urban Master Plan in Greater Abidjan in the Republic of Côte d'Ivoire (SDUGA)*, Final Report, prepared by Oriental Consultants Co., Ltd, Japan Development Institute, International Development Center of Japan, Asia Air Survey Co., Ltd.

[12] Yangon Region Government, Republic of the Union of Myanmar and Japan International Cooperation Agency (JICA) (2014). *Project for Comprehensive Urban Transport Plan of the Greater Yangon (YUTRA)*, Final Report, prepared by ALMEC Corporation, Oriental Consultants Co., Ltd, Nippon Koei Co., Ltd.

[13] Ministry of Transport (MOT), Democratic Socialist Republic of Sri Lanka and Japan International Cooperation Agency (JICA) (2015). *Urban Transport System Development Project for Colombo Metropolitan Region and Suburbs (CoMTrans)*, prepared by Oriental Consultants Global Co., Ltd.

[14] Coordinating Ministry of Economic Affairs (CMEA), Republic of Indonesia and Japan International Cooperation Agency (JICA) (2012). *Jabodetabek Urban Transportation Policy Integration Project in the Republic of Indonesia*, Final Report, prepared by Oriental Consultants Co., Ltd and ALMEC Corporation.

[15] Istanbul Metropolitan Municipality (IMM), Republic of Turkey and Japan International Cooperation Agency (JICA) (2009). *The Study on Integrated Urban Transportation Master Plan for Istanbul Metropolitan Area in the Republic of Turkey*, Final Report, prepared by ALMEC Corporation and Nippon Koei Co., Ltd.

[16] Dar es Salaam City Council (DCC), the United Republic of Tanzania and Japan International Cooperation Agency (JICA) (2008). *Dar es Salaam Transport Policy and System Development Master Plan*, Final Report, prepared by Pacific Consultants International and Construction Project Consultants.

[17] Nairobi City County (NCC), Republic of Kenya and Japan International Cooperation Agency (JICA) (2014). *The Project on Integrated Urban Development Master Plan for the City of Nairobi in the Republic of Kenya*, Final Report, prepared by Nippon Koei Co., Ltd., IDCJ Inc.

TABLE 2.3 Fact Data of the Urban Transportation M/P Studies for Literature Review and Interviews

	No.	1	2	3	4		5	6
	City	Santa Cruz	Manila	Dhaka	Hanoi	Ho Chi Minh	Cebu	Abidjan
	Country	Bolivia	Philippines	Bangladesh	Vietnam		Philippines	Cote d'Ivoire
	Abbreviation for Study Name	SCZMP	MUCEP	RSTP	METROS		Metro Cebu	SDUGA
	Population (million)	1.80	18.05	9.83	7.60	10.93	2.91	4.90
	No. of Households (million)	0.40	5.10	2.40	2.06	2.60	0.65	1.17
HTS	Implementation Year	2016	2014	2014	2014	2014	2014	2013
	First Time?	Yes	No	No	No	No	No	Yes
	Cost for Local Consultant	*1						
	(million JPY)	40.81	20.31	27.19	43.00		17.76	39.64
	(other)	356,920 USD	-	-	-		-	416,262 USD
	Input of JICA Experts (MM)	5	9.0	2	3		2.5	9.30
	Total Cost (million JPY)	53.99	44.03	32.46	50.91		24.35	64.16
	Collected Samples							
	(households)	8,500	51,330	15,897	27,151	20,000	6,527	20,000
	(persons)	34,000	177,489	66,246	100,168	60,551	29,675	74,309
	Sampling Rate (%)	2.00	1.01	0.67	1.00	1.00	1.16	2.00
	Price per Sample (JPY)							
	(per household)	4,407	858	2,042	1,080		3,731	3,208
	(per person)	1,102	248	490	317		821	863
	Trip Rate per person-day	1.74	1.97	2.26	4.00	3.25	2.97	1.60
Other Surveys	Activity Diary Survey	Yes	No	No	No	No	No	Yes
	Cordon Line Survey	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Screenline Survey	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Intersection Traffic Volume	No	No	No	No	No	No	Yes
	Public Transport OD Interview	No	No	Yes	No	No	Yes	Yes
	Parking Survey	Yes	No	No	No	No	No	Yes
	Stated Preference Survey	Yes	No	No	No	No	No	Yes
	Travel Speed Survey	Yes	No	No	Yes	Yes	Yes	Yes
	Freight OD Survey	Yes	No	No	No	No	No	Yes
	Road Inventory Survey	Yes	No	Yes	No	No	No	Yes
Modeling	Modeling Platform	CUBE	STRADA/CUBE	CUBE	STRADA	STRADA	STRADA	CUBE
	Target Time Period	one day	one day	one day	one day	one day	one day	one day
	Traffic Analysis Zones	433	432	190	444	275	389	173
	Household Classes	3	2	3	3	3	4	4
	Purposes	5	5	8	5	5	5	4
	Modes	4	5	5	5	4	5	4

Note: Unit cost of JICA expert (approx. 2.5 million yen per man-month) is evenly applied to all studies.

**1 For calculation of the cost of HTS in Santa Cruz, since it also included cost of a commuter survey (CS) targeting 7,500 households, ratio of unit cost between HTS and CS is assumed to be 2 to 1, which is the same as the ratio of the number of home visits.*

TABLE 2.3 Fact Data of the Urban Transportation M/P Studies for Literature Review and Interviews (cont'd)

	No.	7	8	9	10	11	12
	City	Yangon	Colombo	Jakarta	Istanbul	Dar es Salaam	Nairobi
	Country	Myanmar	Sri Lanka	Indonesia	Turkey	Tanzania	Kenya
	Abbreviation for Study Name	YUTRA	CoMTrans	JUTPI	IUAP	DSM	NIUPLAN
	Population (million)	5.69	5.80	28.00	11.60	3.03	3.66
	No. of Households (million)	1.24	1.50	7.30	-	0.71	1.13
HTS	Implementation Year	2013	2012	*2010*	2007	2007	2013
	First Time?	Yes	Yes	*No*	No	No	No
	Cost for Local Consultant			*(commuter survey)*			
	(million JPY)	28.3	58.89	*94.33*	-	41.3	(unknown)
	(other)	-	574,858 USD	*10,207,185,000 IDR*	-	-	-
	Input of JICA Experts (MM)	6	15	*12*	-	7.20	(unknown)
	Total Cost (million JPY)	44.12	98.43	*125.96*	-	60.28	(unknown)
	Collected Samples						
	(households)	11,330	35,850	*179,000*	72,280	7,694	10,000
	(persons)	44,980	125,000	*657,000*	263,768	26,687	-
	Sampling Rate (%)	1.00	2.30	*2.60*	2.20	1.70	1.02
	Price per Sample (JPY)						
	(per household)	3,894	2,746	*704*	-	7,835	(unknown)
	(per person)	981	787	*192*	-	2,259	(unknown)
	Trip Rate per person-day	2.04	1.87	*1.04*	-	1.51	2.19
Other Surveys	Activity Diary Survey	No	No	Yes*2	No	No	No
	Cordon Line Survey	Yes	Yes	No	Yes	Yes	Yes
	Screenline Survey	Yes	Yes	Yes	Yes	Yes	Yes
	Intersection Traffic Volume	Yes	Yes	No	No	Yes	No
	Public Transport OD Interview	Yes	Yes	No	No	Yes	Yes
	Parking Survey	Yes	No	No	No	No	No
	Stated Preference Survey	No	Yes	No	No	Yes	Yes
	Travel Speed Survey	Yes	Yes	Yes	Yes	Yes	No
	Freight OD Survey	Yes	Yes	No	No	Yes	No
	Road Inventory Survey	No	Yes	No	No	No	No
Modeling	Modeling Platform	CUBE	CUBE	CUBE	TransCAD	STRADA	STRADA
	Target Time Period	one day	one day	one day	one day	one day	one day
	Traffic Analysis Zones	187	475	343	460	170	106
	Household Classes	2	3	3	1	2	3
	Purposes	5	4	5	4	5	4
	Modes	4	5	4	4	3	5

Note: Unit cost of JICA expert (approx. 2.5 million yen per man-month) is evenly applied to all studies.
**2 ADS in Jakarta metropolitan area applied utilization of a mobile device (i.e., GPS logger) and was renamed as Person Tracking Survey.*

On the other hand, trip rate per person-day including walk trips in these metropolitan areas tend to be relatively lower than those in other metropolitan areas. Compared to other metropolitan areas where HTS had been conducted twice or more, this tendency may be related to the early level of mobility development.

As for the sampling rate in HTS, formerly it was around 3% of the population in past surveys in Hanoi, Ho Chi Minh, Manila, and Jakarta although this is not shown in the table. Meanwhile, the sampling rate trend in JICA's recent urban transportation M/P studies was around 1%, regardless of whether HTS was being conducted for the first time or not.

Moreover, the 12 urban transportation M/P studies were examined for activity diary surveys (ADS), and three such M/P studies are highlighted in Table 2.4 in order to compare the scope and cost. It should be noted that ADS in the Jakarta metropolitan area utilized a mobile device (i.e., GPS logger) and was renamed as Person Tracking Survey. ADS in these three M/P studies was aimed mainly at confirming or adjusting the trip rates obtained by HTS, and it is quite natural for the trip rate analyzed through ADS to be higher than that of HTS.

ADSs usually have smaller sample size and is also smaller in scale. The price of ADS per sample is estimated to be around 1,000 yen (approximately 9 US dollars) per person-day. Compared to HTS, the unit price of ADS is several times higher (as in Jakarta) or around the same range (as in Santa Cruz and Abidjan). The advantage of ADS is that it can capture a series of trips over several days without omission. However, the same level of detailed trip attributes as HTS need to be collected to develop travel demand forecast models. If the collected ADS data does not contain detailed trip attributes as in Jakarta, it will be difficult to develop travel demand forecast models based on it.

TABLE 2.4 Fact Data of ADS Conducted in the Urban Transportation M/P Studies

	No.	1	6	9
General Info.	City	Santa Cruz	Abidjan	Jakarta
	Country	Bolivia	Cote d'Ivoire	Indonesia
	Abbreviation for Study Name	SCZMP	SDUGA	JUTPI
	Population (million)	1.80	4.90	28.00
	No. of Households (million)	0.40	1.17	7.30
Activity Diary Survey	Implementation Year	2016-17	2013	2010
	First Time?	Yes	Yes	No
	Use of Any Mobile Device	None	None	GPS Logger
	Cost for Local Consultant			
	(million JPY)	1.60	6.20	8.24
	(other)	14,400 USD	69,700 USD	891,650,000 IDR
	Collected Samples			
	(households)	900	1,010	600
	(persons)	1,800	3,088	2,461
	Price per Sample (JPY)			
	(per household)	1,777	6,142	13,734
	(per person)	889	2,009	3,348
	(per person-day)	889	1,004	1,116
	Survey Targets			
	Intervals (minutes)	15	15	-
	Duration (days)	1	2	3
	Survey Zones	433	101	95
	Trip Rate per person-day	2.13	3.05	2.37
	Household Attributes	Linked with Commuter Survey	Linked with PT Survey	Yes
	Individual Attributes			Yes
Trip Attributes	Origin/Destination	Yes	Yes	Yes
	O/D Facility Type	No	No	20 types
	Departure/Arrival Time	every 15 min.	every 15 min.	Yes
	Purpose	12 purposes	11 purposes	7 purposes
	Cost	No	No	Yes
	Transfer Points	None	None	6 unlinked trips
	Travel Modes	20 modes	19 modes	27 modes
	Driver/Passenger	No	Yes	Yes
	Number of Occupants	No	No	Yes
	Access/Egress Cost and Time	No	No	Yes
	Transit Wait Time	No	No	Yes
	Parking Place	No	No	No
	Parking Cost	No	No	Yes

Note: ADS in Jakarta metropolitan area applied utilization of a mobile device (i.e., GPS logger) and was renamed as Person Tracking Survey.

Two (or more) M/P studies that JICA conducted in developing countries (see Table 2.2) has enabled investigation of previously developed travel demand forecast models. Comparison of the socioeconomic data from two (or more) M/P studies reveals the gap between what was forecasted and the so called "reality" from the most recent M/P study. Furthermore, the travel demand forecast models were investigated by inputting socioeconomic data from the "reality" condition to the previous travel demand forecast model. Such experiment was applied to several metropolitan regions: Jakarta, Manila, Ho Chi Minh, and Hanoi.

2.2. Investigation of Past Travel Demand Forecast Models

For travel demand forecast models accuracy improvement, the following three major cause of gaps

between previous forecast from the models and actual observations are discussed based on the findings from the case study of the above metropolitan regions, namely: 1) socioeconomic framework, 2) travel demand forecast model and 3) other external factors.

First, gaps in socioeconomic framework between previous projections and actual observations were observed in the case of Jakarta and other metropolitan regions. Although it is important to forecast population distribution by considering inflows to the city center and migration, future socioeconomic framework is often determined through discussion with the counterpart agencies based on their future vision. It may not be easy to maintain both accuracy and to follow the policy of the counterpart agencies. In any case, continuous update of database and models are essential in the long run.

As for travel demand forecast models, according to the analysis of previous studies, errors were observed in trip generation models, trip distribution models, and modal split models of some projects. Meanwhile, based on the findings from the case of Jakarta, it may be concluded that overall trip distribution models were well developed and synthesized OD matrices were reliable, probably because of the abundant trip data that had been collected by HTS at a sampling rate of 3%.

Review of other M/P studies imply that errors encountered in trip distribution models may have been caused by relatively poor quality of travel survey data such as insufficient number of samples from high-income households and other biases arising from complex survey system and design. As for trip generation and modal split models, though further investigation is necessary, transferability of those models may not always apply in urban areas of the developing countries due to the existence of external factors, even though the model structure may remain the same.

On the other hand, for modal split models, it is understood that disaggregate model is widely applied due to accuracy, flexibility in analysis and smaller sample size. Disaggregate approach could also be applied for trip distribution models. In addition, disaggregation of the first, second, and third steps of the four-step method (i.e.: trip generation, trip distribution, and modal split) needs to be discussed in order to develop activity-based model of travel demand in metropolitan regions of the developing countries.

2.3. Issues and Problems

For detailed review and interview result of each urban transportation M/P study, refer to the main report. Based on the result of the reviews and interviews for each of the 12 urban transportation M/P studies, common issues and problems were identified and organized in terms of transportation surveys with a main focus on HTS, travel demand forecast methods, and cooperation needs in the urban transportation sector.

2.3.1. Issues on Transportation Surveys with a Main Focus on HTS

(1) Contents and Purpose of HTS

HTS conducted in a JICA study as a bilateral development assistance project is regarded as important and its output database will be utilized for many projects funded not only by Japan but by other international donors. While it is important to ensure the quality of HTS, it is also becoming difficult because manpower as well as time allotment is expected to be reduced further. HTS is usually conducted by sub-contracting a local consulting firm. Review of past M/P studies has revealed the following problems in terms of HTS quality.

1) Access to the high-income households who tend to use automobiles is often difficult and cooperation from them is least expected. As a result, weight factors often need to be adjusted to avoid bias. While the survey method should be improved to have greater response from high-income households, it is also necessary to obtain accurate socioeconomic data such as vehicle registration data and income statistics.
2) Random sampling based on population census data or residents' registrations usually takes time and increases burden on the surveyors, leading to greater cost. There may also be a problem of outdated data. Meanwhile, sampling by surveyors in the field tends to target easily accessible households, thus causing a bias. Solutions to this may be sampling using satellite images, strict application of the rules in the field like counting a certain number of households to select the target household, etc.; thus, the sampling method need to be well designed by balancing survey efficiency with randomness consideration.
3) HTS conducted only by local consultants with little involvement by the relevant JICA experts often have problems in survey data quality such as data cleaning not being conducted. Sometimes the problems can be fatal with unusable data.

In the past HTS conducted as JICA studies in developing countries, it was common to set a sampling ratio of 3% in order to secure statistically effective samples involving a large number of respondents because the focus was accuracy of OD tables and trip distribution models at the TAZ level. However, in some HTS where a sampling rate of 3% was applied, local consultants were required to complete a HTS of an unprecedentedly large scale in an extremely short period of 2 to 4 months. As a result, problems occurred in many areas such as employment of incapable surveyors, delay in payment to surveyors, and misconduct of surveys in the field. These may have caused further delay in survey implementation and lowered the survey quality.

Meanwhile, the sampling rate of a HTS regardless of whether or not it is conducted for the first time has been fixed at a low level of around 1% in recent years. As confirmed by the result of an experiment on sample size reduction that is explained later, while such a low rate may impair accuracy of OD tables, cross-sectional volumes from the result of network assignment did not fluctuate much. In terms of development of aggregate models, Smith, 1979 has also concluded that estimating accurate current OD tables is not realistic.[18]

While it usually takes nearly one year to implement, complete, and analyze all the necessary transportation surveys including HTS, counterpart agencies find it difficult to wait for the results, especially when part of the M/P study schedule has to be extended due to political reasons because of their expectation of quicker implementation of subsequent F/S projects.

Thus, some government officials who do not thoroughly understand the whole process of urban transportation M/P study may even develop a sense of distrust. Responses of counterparts regarding the time-consuming large-scale HTS that was followed by model development are: “It is generally understandable” (Indonesia); “It is impossible to wait for two years or longer” (Vietnam); and “It is understandable if important and useful outputs can be provided” (Tanzania).

In cities where mass transit system is under-developed and citizens cannot even picture a new mode of public transport, it is difficult to implement the stated preference (SP) survey and to develop a mode choice out of the SP survey. In this sense, adequate method to implement SP survey is necessary to be considered.

For analysis of panel data or for time-series comparison of HTS, it may be better not to drastically change the survey form design. However, if ADS is to be conducted in place of the HTS, the survey form design shall be changed drastically to a more complex one, causing a burden on the respondents, as well. As such, the issue is whether to select an existing HTS plus supplemental ADS or comprehensive ADS from the beginning. Furthermore, based on the cooperation needs in urban transportation sector, it is important to understand which kind of forecast the counterpart truly needs, transportation demand on the planned infrastructure(s) (i.e., trips) or reaction in the travel behavior to some transportation policies such as TCM (i.e., activities); then, the most appropriate transportation survey contents should be proposed accordingly. It should also be noted that a travel diary survey using mobile devices such as smartphones that can automatically detect trips is one way to reduce the respondents’ burden of filling out complicated survey forms. In any case, it is important to obtain an understanding or an agreement of the counterpart agencies beforehand about the process and approach of the M/P study.

(2) Issues on Socioeconomic Data Collection

Socioeconomic zonal aggregation data should be collected from the latest population census. However, in reality, implementation of population census is often delayed and the data is not available for the study. In such a case, the only option is for experts to utilize and modify old population census. Even if the latest population census result becomes available, redoing the analysis will be a further burden. The on-time delivery of the latest population census is most important.

As for large-scale development, if official development plans of satellite cities are available, future socioeconomic values should be modified based on the degree of maturity after the plans being reviewed. However, if development plans have been politically proposed and but the realization seems questionable, it is usually difficult to turn down the plans in the formulation of the master plan.

Based on the result of investigation of past travel demand forecast models, gaps in demand forecast between previous projections and actual observations were found in the case of Jakarta and other metropolitan regions. Such gaps tend to become larger in the longer term. Although it is important to forecast population distribution by considering inflows to city centers and migration, future

[18] Smith, M. E. (1979). “Design of Small-Sample Household-Interview Travel Surveys.” Transportation Research Record, 701, p.p. 29 35.

socioeconomic framework is often decided through discussion with counterpart agencies based on their future vision. It may not be easy to maintain both accuracy and follow the policy of the counterpart agencies. Hence it should be noted that some M/Ps are based on ideal socioeconomic settings which may lead to a gap between the demand projections and actual observations. Demand forecast in the long term should be considered as one of the materials to discuss the future vision of a metropolitan region in the target year.

(3) Issues on New Transportation Survey Methods and Relevant data

Tablet devices with 8-inch display were utilized for the HIS and the CTS in Santa Cruz, Bolivia. The tablet application automatically saved a photo image, coordinates and time to the secured section of the tablet memory, thus making it difficult for surveyors to cheat. The application also had a function to upload the surveyed data online when the internet was available. On the other hand, program errors and bugs were observed during the survey implementation though the pilot survey had also been conducted prior to the main survey.

In the travel diary survey using smartphones conducted in Tanzania, several issues were revealed such as: respondent's knowledge limitation to operate smartphone and the application, limitation of data bundle/package, network coverage problem, SIM cards taken out by the respondent for some reasons/purposes, battery life, "jump" issue of GPS pointer, and time stamp error. If the above-mentioned issues are cleared, use of mobile devices will have a great potential for expansion.

Passive data such as CDR (call detail record) is a preferable choice for a base data of OD matrices estimation even in developing countries in terms of required cost and time. In addition, the increasing diffusion of smartphones in developing countries could supplement CDR data. However, problem of CDR is that the data is not attached to the demographic data and it contains neither trip purpose nor activity contents. Since profiles of the travelers are not identifiable, it cannot replace HTS or ADS for demand modeling. Thus, currently the usage is limited.

2.3.2 Issues on Travel Demand Forecast Methods

(1) Issues on the Conventional Demand Forecast Models

With respect to each model of the conventional four-step method, review of past M/P studies and investigation of demand forecast models have revealed the following problems.

Trip Generation Model: First, investigation of the past travel demand forecast models has shown that some trip generation models could not properly forecast the total number of trips even with "correct" socioeconomic input because structures and/or parameters of trip generation models seem to have changed drastically with economic growth and change in people's lifestyles.

Trip Distribution Model: In most cases, R^2, coefficient of determination, of trip distribution models where gravity models are applied is not that close to 1, implying an issue in the model validation. Thus, trip distribution models are considered as the hardest in the four-step method, and the disaggregated approach including ABM shall be discussed as an alternative.

Modal Split Model: Though modal split models were developed as an aggregate model, there were some unexpected factors that affected modal split such as the rocketing increase of motorcycles as in the case of Jakarta. The rise in the number of registered motorcycles was due to increasing traffic congestion and unsatisfactory public transport services in those days, resulting in people trying to find a more "economical" and fast mode of transport or motorcycles which are small in size and relatively easy to finance. Such behavior was not properly reflected in the aggregate modal split models.

Network Assignment: As for the choice of daily trips or peak-hour trips for travel demand forecast, daily trips are usually modeled in M/P studies unless there is a request to analyze peak-hour traffic from the counterpart agencies, because calculation of benefit of the proposed projects or programs is necessary on a daily basis to obtain the annual benefit for cost-benefit analysis. If peak-hour traffic has to be forecasted in an F/S, directional peak-hour ratios are calculated from the survey data and utilized to estimate the peak-hour traffic. It is true that there is an issue in terms of forecasting accuracy, but it usually takes an enormous amount of time and cost to redevelop the demand forecast models.

Thus, many issues have been pointed out in the conventional aggregate approach, and it is necessary to fundamentally improve the demand forecasting method. Meanwhile, the total number of experts that can be assigned for the task of travel demand forecasting tends to be fewer, although the same or more detailed output is required. In short, there is realistically not enough time for elaborating the models.

Furthermore, although large-scale transportation surveys such as HTS are conducted in urban transportation M/P studies for the purpose of developing OD matrices and demand forecast models that are as accurate as possible, it is difficult to develop freight demand forecast models for freight vehicle trip distribution and often times simple future estimation is made based on future socioeconomic indicators such as zonal GDP and population of workers. Likewise, forecasts of external OD matrices that are estimated from cordon line surveys often follow a simple methodology.

Regarding freight trip distribution models and demand forecast of external ODs issues, it may be worth analyzing how much these problems contribute to the gap between forecasted values and actually observed data. Meanwhile, practical application of ABM as a disaggregated approach is also worth trying, since final output from ABM is usually OD trips for each time of day. However, according to interviews with experts of ABM, reduction in the required manpower and time cannot be expected. ABM will simply reduce the cost and time necessary to collect the smaller number of samples for the ADS.

(2) Issues on Demand Forecast Software

There is no major issues on the selection of commercial software such as TransCAD, CUBE, VISUM, and EMME. However, urban transportation conditions in developing countries are often very chaotic with many types of vehicles share the road space and disturb the traffic, too many transit and paratransit lines with no schedule and route information, and so on. Since network assignment is conducted regardless the demand forecast method (i.e., conventional trip-based or new activity-based approach), regenerating the transportation network has such inevitable problems while it is also important.

JICA-STRADA, which is demand forecasting software developed by JICA, has several basic modules with GUI (Graphical User Interface) and is relatively easy for beginners to learn to use. Thus, it may be suitable for beginner training as part of technology transfer to developing countries. However, JICA-STRADA is lacking flexibility and will not fit new demand forecast models including iterative calculations.

On the other hand, while commercial software applications are flexible enough to solve these issues, they are more expensive and complicated, and they require basic knowledge of transportation planning, mathematics, and computer science, as well as considerable time to learn. However, for the new activity-based approach, any commercial software enables iterative calculations by reciprocally incorporating outputs from the network assignment (i.e., LOS (Level of Service) data) and outputs from ABM (i.e., OD matrices).

(3) Issues on Socioeconomic Indicators and External Factors

To set the future zonal socioeconomic indicators, there should be an expert in charge of socioeconomic framework or land use planning who is capable of considering the existing upper-level national and or regional development plans along with planned macro-values of socioeconomic indicators in the metropolitan area and distributing the total values of the metropolitan area to each administrative district and then to each zone. However, it is often the case that M/P study lacks for such expert, and some other experts in charge of transportation surveys or demand forecasting end up taking on this important and difficult task.

As mentioned earlier, in metropolitan areas of developing countries there is rapid change in urban structure, economy, and travel behavior such as rapid motorization or sudden economic recession. Developing countries are subject to such external factors which are difficult to foresee. Since travel demand forecast is a kind of future mathematical simulation of the future based on assumed conditions, forecasted figures should be treated as values within a range. As such, there is a trade-off between the degree of accuracy versus cost and time.

In order to identify which of the zonal socioeconomic settings (unexpected external factors, transportation surveys, and demand forecast models) caused the gap between initial forecasts and actually observed values, it is necessary to investigate past M/P studies. The impact of these differences to accuracy of travel demand model can be analyzed by inputting actually observed socioeconomic and network variables to the previous demand forecast models with parameters unchanged. If the model

outputs are similar to the actual observations, it can be concluded that the model is valid and socioeconomic framework caused the gap.

In this research, gaps of socioeconomic framework between previous projections and actual observations are observed in in the case of Jakarta. Although it is important to forecast population distribution considering concentration to the capital region and migration, future socioeconomic framework is often determined by agreement with counterpart agencies based on their future vision. It may not be easy to maintain both accuracy and accordance with policy of the counterpart agencies. In any case, continuous update of the socioeconomic database as well as the models are essential in the long run.

If demand forecasts are just figures within a range, there may be a view that disaggregate models such as ABM based on ADS would be better rather than conducting a large-scale HTS. Hence, practical application of demand forecast methods based on disaggregate models using a smaller number of samples may be worth studying. In this case, issues on socioeconomic framework are replaced by issues on development of population synthesis. It is a big challenge in developing countries because micro data is not available and census data may not be so reliable, even though population synthesis is important and the method to be applied to these countries is not so difficult. Even with lower percentage of samples, synthesizing population is still able to be done as long as the surveys are conducted in random.

2.3.3 Issues on Cooperation Needs in Urban Transportation Sector

(1) Issues on the Development Directions

According to interviews with counterpart agencies that have utilized M/P as well as HTS data and whether it satisfied the stakeholders' needs, their answers were: 1. Adhering to the M/P although progress is slow (Vietnam); 2. Adopting only the development directions and policies (Tanzania); 3. Incorporating some of the proposed projects from the M/P without any reference (Tanzania); and 4. Basically following the M/P along with some top-down "ad hoc" projects implemented in parallel (Indonesia). Thus, the M/P is being utilized in various ways.

Overall, developing countries' interests in urban transportation sector are toward public transport development rather than road development despite in countries where road network development has been implemented, they are faced with problems of road maintenance and management. As for development of relatively inexpensive public transport such as bus rapid transit (BRT), it is often combined with road development as the road sector is a key infrastructure. Metropolitan areas relying on public-private partnerships (PPP) for infrastructure development are increasing in number as well.

As the concept of transit-oriented development (TOD) becomes widely prevalent, there have been requests to include it in the transportation demand forecast in some cases. The issue to be considered is to what degree of detail the TOD should be reflected in the forecast. While applying additional population to the zones around the target public transport may involve only a slight increase of tasks, evaluating the effect of shorter walking distance may require complicated and time-consuming work.

(2) Issues on TCMs and Short-term Measures Policies

In some cases there is a political request to share the results in a short time and/or to propose more short-term projects. While a short-term project may involve several TCMs, the accuracy required from transportation surveys and demand forecast will differ from accuracy required for large-scale infrastructure development projects. Therefore, it is necessary to obtain consent from the counterpart agencies about the policies to be prioritized at the initial stage of the M/P study which usually takes time to complete. Eventually, when accountability is required for decision-making, how well future demand of not only the metropolitan region but also the individuals can be explained becomes important; for example whether the project will be utilized by high-income or low-income people.

TCM policies will be alternatives to be discussed in the M/P studies only in cities where the road and public transport developments have been completed to some extent. Furthermore, the effect and necessity of traffic demand management policies including intelligent transport system (ITS) will highly depend on the local custom and situation of each city such as driving manners; in other words, education and enlightenment on transportation may be a key "input" in the demand forecast models. Introduction of TCM policies that involves new technology system will require capacity development and technology transfer. Furthermore, for evaluation of TCM policies, since it is essentially difficult to forecast the change in travel behavior through the conventional four-step method, disaggregate models including

ABM should be used and applied only to cities where milestones infrastructure development have been completed and there is an increasing need for TCMs.

(3) Issues on Technology Transfer

GIS and travel demand forecast are often the subjects of technology transfer and require significant amount of time and profound lesson to learn. However, counterpart's capability to update transportation database and M/P will not be as it is expected if the targeted technology transfer group have no engineering or computer background or no interest at all. What is important for decision-makers is to acquire a sense of judgement from output figures while, for capacity building of technical personnel, it should be longer and deeper than the project period.

In any case, necessity and scope of technology transfer need to be well discussed prior to the start of projects. Selection of trainees and use of JICA-STRADA, which is suitable for beginners, should be taken into consideration. Among others, introduction of conventional four-step method should be done if basic technology transfer is requested.

In order to utilize the new transportation survey and demand forecast methods, appropriate logic is necessary to persuade and obtain consent from the decision-makers. If the training is conducted in a more advance way, personnel for policy analysis shall be requested to join and special capacity building program/project using disaggregate models may be needed apart from the framework of the existing project or study.

3. PRESENT CONDITIONS AND ISSUES ON TRANSPORTATION SURVEYS, SURVEY METHODS, AND RELEVANT DATA

3.1. Transportation Surveys

HTS is a large-scale sample survey, therefore, long survey period and considerable cost are required. Problems of implementation and operation of survey such as bias of sampling or cheating etc. are observed. ADS is used for essential transportation survey to build ABM in Europe and the U.S. ADS is a survey for personal activity and travel information along the time axis for several days, therefore, it is easy to obtain non-motorized short distance trip or non-home based trip than HTS. It should be noted that considerable effort of respondent and analysis are required because of a lot of survey items. Issues and countermeasures are summarized in the table below.

TABLE 3.1 Points to be Considered for Transportation Survey Implementation

Surveys	Issues	Countermeasures
HTS	Difficult survey form for respondent	・Adoption of ADS ・Adoption of Commuter Survey
HTS, Commuter Survey	Lack of information on activities and trips	・Adoption of ADS
HTS, Commuter Survey	Management of large-scale survey	・Reduction of sample size ・Consideration of technical competency for procurement of local consulting firms ・Reconsideration of main objectives of the HTS (from TAZ-level current OD estimation to model development)
HTS	Impact of reduction of sample size	・Reconsideration of main objectives of the HTS (from TAZ-level current OD estimation to model development)
HTS, Commuter Survey, ADS	Data collection of high income group and high trip rate respondents	・Utilization of smartphone application and web-based questionnaire ・Supplemental survey at shopping malls and offices
HTS, Commuter Survey	Reduction of burden of sampling bias	・Sampling using satellite images and rule-based sampling
HTS, Commuter Survey, ADS	Identifying address of trips	・Utilization of smart phone application ・Interview survey using tablets
HTS, Commuter Survey, ADS	Quality control	・Utilization of smart phone application ・Interview survey using tablets
Commuter Survey	Trips of non-commuters	・Utilization of ADS
ADS	Burden of respondent	・Simplifying survey method ・Utilization of smartphone application
SP Survey	Credibility	・Appropriate survey design
	Stability	・Appropriate survey design and reduction of the number of questions

3.2. Survey Methods

Travel surveys will continue to be one of the most important ways of obtaining critical information needed for transportation planning and decision making despite the methods that have undergone tremendous changes over last decades. Significant changes in modern urban lifestyles have replaced the traditional face-to-face survey with more advanced methods.

As technology advances, the use of paper has decreased with a switch toward electronic versions (web-

based, smartphone, tablet, and so on). With an internet connection, the electronic survey will shorten the duration of a typical survey by allowing direct access to check for missing answers and inconsistency; revise responses; automatic branching; eliminate falsification; cost savings; data record; and instantaneous upload. Few would argue that electronic versions offer several advantages compared to paper, some of which are; reduction/elimination of data entry process, potential entry errors, and concerns regarding security and transportation of physical data[19].

Referring to MDPI (Multidisciplinary Digital Publishing Institute) Journal of Social Science, the cost per completed interview for a tablet-based survey was 74% less than paper-based. The average time per interview was 46% shorter. Research revealed that the cost savings came primarily from a lower need for data cleaning and surveyor fees. The time saved comes primarily from faster data entry[20].

The smartphone-based survey method distributes the survey interface as a downloadable smartphone application with a "machine learning" algorithm attached. The important point is to ensure that the application is extensively tested for technical issues and usability before the main survey. Some of the challenges faced by smartphone-based surveys are: dealing with people who do not use smartphones; compatibility with different application platforms (iOS, Windows, Android, Blackberry); explanation and consideration with regard to battery consumption and privacy protection; included incentives; and advertisement such as posters, leaflets, broadcasting, and social networking services to improve the response rate[21].

Thanks to innovative development of technology, the possibility of conducting an efficient transportation survey using electronic means is high. However, the level of technology adaptation and people's way of thinking especially in developing countries may be an issue and lead to bias – internet bandwidth, security, and regulation limiting internet access such as in China. There could be a risk to the integrity of the data when internet access is unreliable. It will be challenging to conduct this type of survey in areas with limited or unreliable internet connection[22].

Regardless the method of survey implementation, the tendency for a declining number of respondents representing middle- to high- income population requires an alternative data collection method. Respondents from this demographic group tend to refuse home-visit surveys for reason of privacy and confidentiality. In deciding whether to use an intercept survey or different methodology, key selection factors include the ability of the methodology to reach the targeted population, quality of response to questions, response rate, schedule, costs, and length and complexity of the survey. The most common places to contact potential middle- to high- income respondents are office areas and shopping malls. Since offices and shopping malls are more public than homes, surveys could be conducted in more presentable ways. A typical respondent may consider participating in a survey in public as being safer than inviting "strangers" into their homes. However, such a survey is often constrained by the survey duration and respondent's "free time" as people typically has allocated a specific time to conduct a specific activity in office areas and shopping malls. Therefore, proper design of survey duration and survey language needs to be properly setup to conduct this survey[23].

3.3. Relevant Data

Issues and countermeasures of relevant data and statistics are summarized in the Table 3.2. Passive data such as CDR is a preferable choice for a base data of OD matrices estimation even in developing countries in terms of required cost and time. However, the issue of CDR is that the data is not attached to the demographic data. For analyzing CDR data, mode detection is usually more difficult than purpose detection. While the increasing diffusion of smartphones in developing countries could supplement OD matrices which contain neither trip purpose nor activity contents, locations collected from BTS (base transceiver station) and not as accurate as GPS points; as a result, obtained locations maybe not as detailed as village or TAZ level.

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TABLE 3.2 Issues and Countermeasures of Relevant Data and Statistics

Relevant Data	Issues	Countermeasures
Input data for models of the past master plan study	・Difficulty in acquiring household income ・Estimation of No. of workers at work place and No. of student at school place ・Land use data for future population distribution ・Update of transportation network	・Collection of socioeconomic information by implementation of commuter survey ・Request of raw data of statistics and consideration of required cost for it ・Plan and implementation of required supplemental survey such as road inventory survey
Census data	・Accuracy (if it is sample survey) ・Difference of zone system of Census and travel demand model ・Estimation of adjustment factor in case the latest data is not available ・Difficulty in acquiring detail data	・Additional data collection and analysis in case census data is not up to date ・Input of additional human resource for preparation of population framework
Satellite images	・Expensive acquiring cost for images with high resolution ・Time and cost for image analysis	・Input of additional human resources for satellite image analysis and land use analysis ・Data collection from cadastral map
CDR	・Difficulty in data acquisition ・Technical issues ・Sampling bias ・Limitation in data acquisition	・Utilization of CDR data for OD table update utilizing existing HTS and for long-term trend analysis
MAC address matching	・Estimation of expansion factor ・Limitation in data acquisition ・Spoof of MAC address	・Application for specific purpose such as travel speed analysis and traffic flow analysis of specific area

4. STUDY ON WAYS TO IMPROVE TRAVEL DEMAND FORECAST

Taking the above mentioned issues on travel surveys and travel demand forecast methods in developing countries into consideration, ways to improve travel demand forecast are discussed below.

4.1. Lessons Learned from the Past Travel Demand Forecasts

Lessons learned from the past travel demand forecasts are summarized from four perspectives. 1) Discrepancy is observed in a socioeconomic framework such as population in suburban areas of Jakarta, Dar es Salaam and Nairobi due to new urban developments. 2) Issues of transport surveys are observed such as insufficient number of high-income samples in Manila. 3) Issues of travel demand forecast model are identified such as an inappropriate choice of models, lack of trip information of non-commuting purpose and ignorance of intermediate stop and individual behaviors. 4) Several external factors affected the results such as surge in the number of Chinese motorcycle due to business promotion strategy in Vietnam and dissemination of motorcycle purchase loan in Jakarta. Some government policies also significantly affected urban development as well as traffic conditions.

The conventional travel demand forecast method is, in principle, an analysis of zonal averaged index based on heuristic approach. Although it is simple and easy to understand, discrepancies are observed comparison to actual observations of traffic volume for some cases. Furthermore, there are issues of accountability in terms of evaluating TCM policies, impact of economic and social policies of the government and new complicated policy such as shared ride service.

4.2. Characteristics of Aggregated and Disaggregated Models and Application in Developing Countries

(1) Aggregated and Disaggregated Models

The phrase of ‘disaggregated model’ contrasts the conventional aggregated model which analyzes aggregated values such as by zones or trip purpose. For instance, diversion curve is estimated based on modal share by OD pairs and generalized travel time while disaggregate model is developed based on the individual choice behavior. Thus, disaggregate model is also called as ‘disaggregate behavioral model’ or ‘discrete choice model’ as it is a mathematical model of choice behavior of individuals or households.

(2) Trip-based Approach and Activity-based Approach

The conventional trip-based approach contains the following issues.

- Aggregation by zones, trip purposes and groups
- Interdependent relations of travel behaviors and activity (example: choosing car due to overtime work at late night)
- Ignorance of time-space constraint (example: going to shopping on the way back to home after working hours before dinner)
- Ignorance of relations between household members (example: going to office after dropping kids off)

Travel behavior is determined by activity of individuals considering mobility and accessibility constraints of transport systems in the activity-based travel demand models (ABMs) as transport demand is a derivative function of activities demand. ABMs have become more widely used in practice in the U.S. and Europe. Various types of ABMs have been proposed by city for policies to be evaluated and researchers. The following components can be considered in the models.

- Concept of tour
- Population Synthesizing
- Choice of time of activity (trip)
- Intermediate stop
- Day activity pattern
- Usual work (and school) locations
- Transit pass and parking pass ownership
- Joint household day pattern and joint (half) tour generation

These enable us to simulate activities and travel behaviors, TDM policies such as pricing and staggered working hours, and activity change due to infrastructure development.

(3) Travel Demand Models in Developed Countries

Interview was conducted to officers of the City Planning Survey and Information Office of Ministry of Land, Infrastructure, Transport and Tourism of Japan. Needs of travel demand forecast is changing to variety in evaluation items, validity of forecasting process and accountability of policies. Therefore, the concept of 'Smart Planning' which utilizes disaggregated models and big data for facility location planning has been studied. For example, there is a plan of converting conventional model to ABM in Tokyo metropolitan area.

In the U.S., which leads development of travel demand forecast, large-scale household travel surveys (HTS) and conventional aggregated models were applied in many cities for the purpose of transportation infrastructure development in 1940's to 60's. However, limitations of this method were revealed after 1970's. The main policy options were shifted from large-scale transportation infrastructure development to the policies encouraging behavioral change such as TDM and cross-modal policies. Besides, evaluation criteria also have been diversified such as equity analysis and quality of life of individuals. Thus, ABMs, which enable various policy options by considering individual behavior, have been developed and applied in practice. As of 2017, travel demand model of 20 out of 25 metropolitan areas have been utilizing ABM.

(4) Application in Developing Countries

Considered Points for Travel Demand Models for Urban Areas in Developing Countries

As discussed in the section reviewing past studies on urban transportation master plan, many cities in developing countries have unique characteristics which are not evident in developed countries.

Economic changes, including both economic growth and even depression, are rapid due to a smaller market size compared to developed countries. Besides, motorization is faster as people start to own a vehicle once they reach a certain income level. When the majority of households reach this income level, the pace of motorization is significantly rapid. For instance: the number of motorcycles increased by a factor of four in just eight years in the Jakarta metropolitan area. TCM policies which directly affect individual travel behavior are often applied in developing countries as most of these policies are inexpensive. Besides, new types of transportation modes such as online ride service are rapidly expanding their market share in developing countries in addition to conventional paratransit modes. As modeling of shared ride services requires transaction among several agents, user, driver and dispatcher; the model should be able to describe transactions among agents.

Other issues to be discussed in developing countries are accountability of travel demand models. Even in developing countries, transparency in policy making process is highly evaluated. It is required for travel demand models to be able to describe rapid changes of socioeconomic conditions, individual travel behaviors, various and drastic policy changes in various fields. In this sense, disaggregated models are awaited for developing countries.

Application of Conventional Aggregated Models

Conventional aggregated models might be suitable for capacity development as it does not require an understanding of discrete choice models, and there are lots of reference documents available. However, disaggregated models including ABM should be considered considering the characteristics of transportation in developing countries; rapid economic changes, frequent changes of government policies, application of TCM, new transport modes, unique travel behavior and accountability of the model.

Application of Disaggregated Models

As disaggregated models can describe time-space constraint and household and individual behaviors, it can also be applied for various policy evaluations including TDM policies. Since disaggregated models also can be developed with smaller sample size, survey cost reduction is expected. They can be applied in travel demand models in developing countries. However, reduction in terms of duration of model development cannot be expected. There are also intermediate models such as an aggregated tour-based model and a disaggregated four-step model. Characteristics of these intermediate models are also intermediate. A model can be selected by taking regional context, possible policy options and needs of capacity building into consideration.

Issues of Other Models in Developing Countries

There are several practical land use models in the U.S. and Europe, thus, application of these models

have increase in practice. Population synthesizer is a tool to generate household and individual information as an input data for disaggregated models. Several software packages such as "PopGen" and "SimPop" are available. In terms of a vehicle ownership model, even static disaggregated model, which is relatively simple, can contribute to consideration of rapid motorization trend in developing countries.

(5) Sample Size of Household Travel Survey in Developing Countries

Impact of Reduction of Sample Size of Aggregate Model – Case Studies in Jakarta and Manila

Case studies were conducted using the Jakarta metropolitan area and Metro Manila as examples. With the HTS and model developed for the formulation of the master plan, the case studies examined the processes of transport modeling and demand forecasting based on two datasets that were created by grouping odd and even household sequential serial numbers. When the sampling ratio is reduced from the original 3% to 1.5% and sample size reduced by half, aggregated results including generated trips, modal shares, and total traffic and passenger volumes on roads and transit lines would bring about results that are close to those of the original dataset. Meanwhile, the significance of OD matrices may fall especially when ODs between TAZs are focused on for transportation planning. Thus, it is essential to take this conclusion carefully when conducting a more in-depth analysis such as traffic flow on a local network and operation planning for transit lines including station design.

However, requirement in sample size should be examined carefully. Is accuracy required for all OD pairs of current TAZ-level OD tables including OD pairs of less number of trips that take required time and cost for key travel surveys into consideration? With clear objectives of the survey, the sample size should be studied from various aspects considering issues in survey implementation such as quality control of the field survey.

Sample Size of Disaggregate Model

The sampling strategy was studied taking characteristics of developing countries into consideration. While 500 to 1,000 persons are required to develop a person-based disaggregate model[24], one of biggest issues of survey design is collecting high income household data as they are usually dependent on private mode of transport. Considering quality control issue of a large-scale ADS and HTS, an approximately 5,000-person sample might be enough. This is also consistent with the examples of travel surveys for ABM development in the U.S. Complementary survey targeting high income households such as surveys at shopping malls and work place might work while results of further studies are awaited.

4.3. Activity Diary Survey as a Main Travel Survey

Travel demand forecast methods and travel surveys should be discussed simultaneously as the travel survey is a main input to the model. ADS can solve issues of conventional HTS as it can capture the relationship of activities and travel behaviors among household members and time use change. In addition, the observed trip rate of ADS is significantly higher than that of HTS as a concept of trip is not properly understood by respondents in the case of HTS. Since ADS collects information on all the activities of a respondent, ADS is suitable for developing ABM. By utilizing ADS, a more advanced ABM model can be developed. By developing a discrete choice model rather than an aggregated model which discard huge individual behavioral information by averaging, the sample size can be much smaller. As the sample size can be reduced, resources can be re-allocated to reward respondents and to employ experienced surveyors.

In developing countries, detailed socioeconomic data such as individual-level database of national census is often not available. Thus, a commuter survey could be conducted for population synthesizing and preparation of zonal indicators.

[24] Ortúzar, J. D. and Willumsen, L. G. (2011) "Modelling Transport." 4th Edition. 2011. Aptara Inc., New Delhi, India

5. SUGGESTED TRAVEL SURVEYS AND DEMAND FORECAST METHODS MEETING LOCAL NEEDS

5.1. Needs and Suggested Travel Surveys and Demand Forecast Methods that would Fit with Various Urban Maturation Stages

In order to propose travel surveys and demand forecast methods that will best match the cooperation needs of the metropolitan regions in developing countries, Figure 5.1 presents needs and suggested travel surveys concept, relevant data, survey means as well as demand forecast models and necessary software that would suit various urban maturation stages as applicable travel surveys and demand forecast methods. The maturation stage of a metropolitan region is not measured by economic indices or scales, but it is generally expressed by the degree of difficulty in urban life. Among others, in terms of transportation, it could be expressed by the degree of chaos or orderliness in the urban transportation system in which numerous and varied vehicles randomly move in and out to create many obstacles on the road while public transportation, for which a route map is not available, is served only by the most complicated paratransit.

Generally speaking, cooperation needs for M/P study or F/S could arise anytime regardless of the maturation stage of a metropolitan region. Key travel surveys such as HTS and ADS as well as census database or its equivalent (large-scale) commuter travel survey are necessary regardless of which stage a metropolitan region may belong to. Supplemental surveys at shopping malls or offices and surveys using tablet devices are also considered to be effective regardless of the maturation stage. In addition, disaggregate models are basically applicable for demand forecast modeling, except for in cases where the developing country requests for a basic technology transfer for demand forecast modeling.

Furthermore, depending on the surrounding conditions, for metropolitan regions that need to update its M/P and/or travel survey data, satellite image data may be useful for updating socioeconomic indicators, and a web-based survey and travel surveys using smartphone applications can be effective in some cases. For metropolitan regions where not enough time is given for the formulation or updating of the M/P despite continuing urban socioeconomic growth and a need for short-term infrastructure development planning with some transportation policies, a disaggregate model approach combined with a smaller-scale travel surveys is recommended. Likewise, for transport policy planning such as TCMs and TOD, analysis using disaggregate models may also be valuable in enhancing accountability in terms of technology, logic, and detail. Furthermore, for capacity building in transportation planning, disaggregate models could also be utilized to analyze transportation policies as part of a capacity building program attached to the study or as another technical cooperation project.

Table 5.1 presents suggested travel surveys, survey means, relevant data, and demand forecast models that would fit with each type of cooperation, namely, M/P study (for the first time and for updating), short-term infrastructure development planning, F/S, transportation policy planning, and updating travel data and/or M/P for the purpose of capacity development.

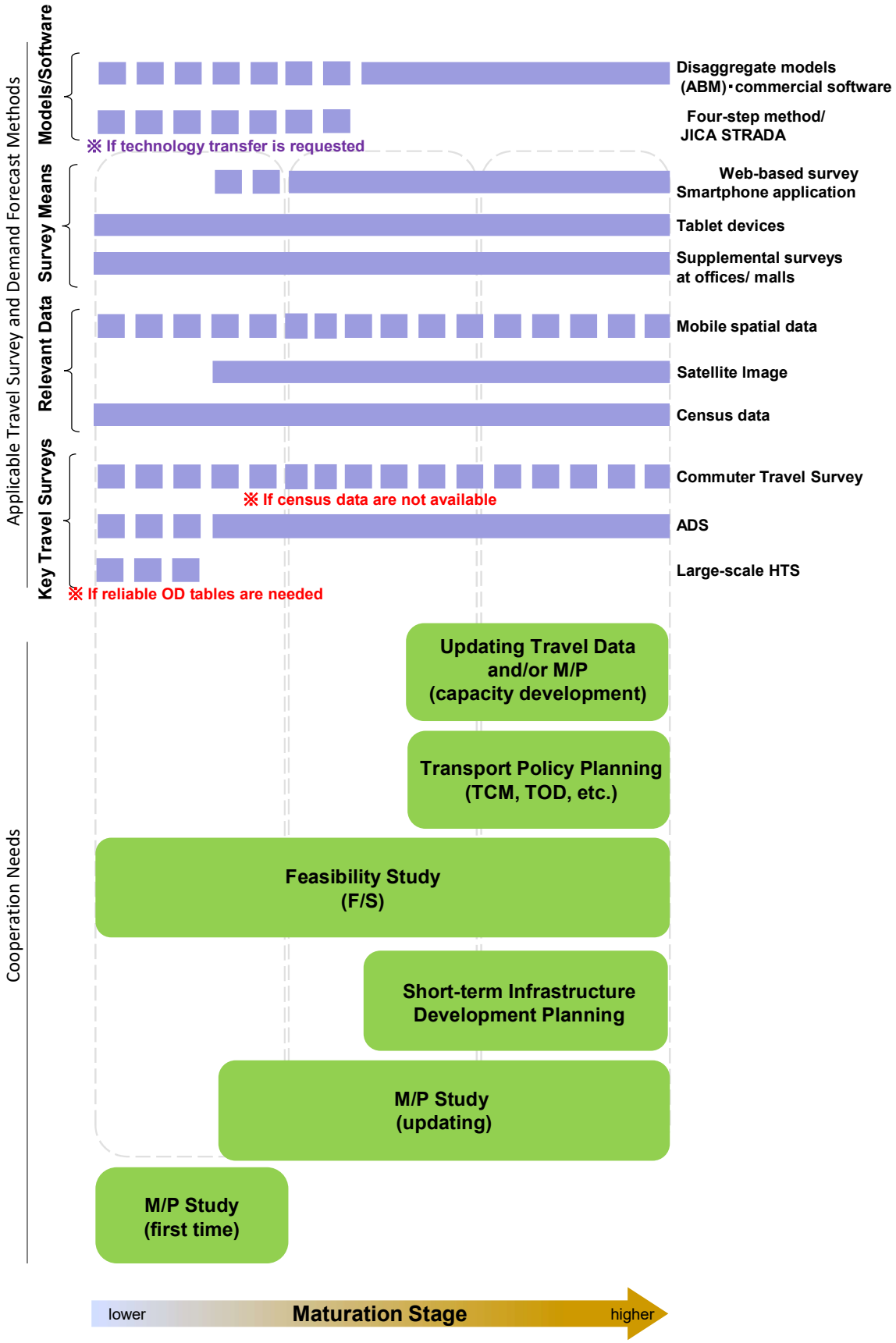

FIGURE 5.1 Concept of Needs and Suggestions that would Fit with Various Urban Maturation Stages

TABLE 5.1 Suggested Travel Surveys, Survey Means, Relevant Data, and Models for Each Type of Cooperation

Form of Study/Assistance	Key Travel Survey(s)	Commonly Needed Transport Surveys	Survey Means	Relevant Data	Models/Forecasting Methods	Remarks
M/P Study (first time)	If reliable OD tables are needed ・Large-scale HTS + Supplemental survey（ADS）	[For supplementing OD tables] Cordon line survey, Public transport corridor OD interview survey, OD interview survey at large-scale facilities, Truck OD interview survey [For calibration] Screenline survey, Travel speed survey	Tablets/Mobile devices/Paper-based survey, Web-based survey/Supplemental survey at malls and offices, Manual counting, Video capturing with CCTV cameras, etc.	Census, Road inventory	・Aggregate models (if technology transfer is needed or policy analysis such as TCM is not involved) ・Disaggregate models (otherwise)	Well coordinated survey management as well as enough survey duration and budget is needed since better accuracy of analysis based on aggregate models would lead to enormous number of samples. Developed OD tables and/or models may be utilized in the subsequent F/S. Use of JICA-STRADA is an option if aggregate models are developed for technology transfer.
	Otherwise ・ADS + Commuter travel survey			Individual census data, Road inventory	Disaggregate models	Efficient development/updating is desired as OD tables and models are subject to frequent change.
M/P Study (updating)	ADS	Out of the surveys above, those which have not been recently conducted.		Input data for the previous M/P model, Census, CDR, Satellite image (for changes in land/building use)	・Aggregate models (if technology transfer is needed) ・Disaggregate models (otherwise)	Use of JICA-STRADA is an option if aggregate models are developed for technology transfer.
Short-term Infrastructure Development Planning	If M/P study already exists ・ADS	If necessary: [For supplementing OD tables] Cordon line survey, Public transport corridor OD interview survey, OD interview survey at large-scale facilities, Truck OD interview survey [For calibration] Screenline survey, Travel speed survey	Tablets/Mobile devices/Paper-based survey, Web-based survey/Supplemental survey at malls and offices, Manual counting, Video capturing with CCTV cameras, etc.	Input data for the previous M/P model, Census, CDR, Satellite image (for changes in land/building use)	Previous M/P models (aggregate or disaggregate)	Demand forecast modeling should be in parallel with the planning process and plans should be continuously updated. Though demand forecast models from the previous M/P study (if any) could be utilized to some extent, it is necessary to check in detail whether they match with the current conditions such as average vehicle occupancy, trip rates, and mode preference.
	Otherwise ・ADS + Commuter travel survey			Individual census data, Road inventory	Disaggregate models	
F/S（large infrastructure）	If M/P study already exists ・ADS + Supplemental survey（SP）	If necessary: [For supplementing OD tables] Cordon line survey, Public transport corridor OD interview survey, OD interview survey at large-scale facilities, Truck OD interview survey [For calibration] Screenline survey, Travel speed survey	Tablets/Mobile devices/Paper-based survey, Web-based survey/Supplemental survey at malls and offices	Input data for the previous M/P model, Census, CDR, Satellite image (for changes in land/building use)	Previous M/P models (aggregate or disaggregate)	For utilizing demand forecast models from the previous M/P study (if any), it is necessary to check in detail whether they match with the current conditions such as average vehicle occupancy, trip rates, and mode preference. If impact on the whole network is limited, it is also possible to study by limiting a certain corridor as the target area.
	Otherwise ・ADS + Commuter travel survey + Supplemental survey（SP）			Individual census data, Road inventory	Disaggregate models	
F/S（intersection improvement, etc.）	If a drastic change in the surrounding situation is expected and M/P study already exists ・Intersection traffic count + Supplemental survey（ADS）	If necessary: [For supplementing OD tables] Cordon line survey, Public transport corridor OD interview survey, OD interview survey at large-scale facilities, Truck OD interview survey [For calibration] Screenline survey, Travel speed survey	Tablets/Mobile devices/Paper-based survey, Web-based survey/Supplemental survey at malls and offices, Manual counting, Video capturing with CCTV cameras, etc.	Input data for the previous M/P model, Census, CDR, Satellite image (for changes in land/building use)	Previous M/P models + meso/micro-simulation	If not long after the latest M/P formulation, previous models could be utilized while it is necessary to check in detail whether they match with the current conditions such as average vehicle occupancy, trip rates, and mode preference.
	If a drastic change in the surrounding situation is expected while no M/P study exists ・Intersection traffic count + ADS + Commuter travel survey			Individual census data, Road inventory	Disaggregate models + meso/micro-simulation	It may take time and cost since models need to be redeveloped as in a M/P study.
	If no drastic change in the surrounding area is expected ・Intersection traffic count ・Number plate matching survey	Travel speed survey	Manual counting, Video capturing with CCTV cameras, MAC address matching (for vehicle OD)	Road geometrical structure	Micro-simulation	Long-term forecast may be difficult though future travel demand shall be in line with socioeconomic macro values, Areas to be benefitted and impacted are also limited.
Transport Policy Planning (TCM, TOD, etc.)	If M/P study already exists ・ADS + Supplemental survey（SP, Commuter travel survey）	If necessary: [For supplementing OD tables] Cordon line survey, Public transport corridor OD interview survey, OD interview survey at large-scale facilities, Truck OD interview survey [For calibration] Screenline survey, Travel speed survey	Tablets/Mobile devices/Paper-based survey, Web-based survey/Supplemental survey at malls and offices, Manual counting, Video capturing with CCTV cameras, etc.	Road geometrical structure (for micro-simulation) Input data for the previous M/P model, Individual census data, CDR, Satellite image (for changes in land/building use)	Disaggregate models (utilize previous M/P models if they are disaggregate)	Since it is necessary to forecast travel behavior by directly reflecting hourly changes and distance to stations, development of disaggregate models is assumed.
	Otherwise ・ADS + Commuter travel survey + Supplemental survey（SP）			Road geometrical structure (for micro-simulation) Individual census data, Road inventory	Disaggregate models	
Updating Travel Data and/or M/P (capacity development)	ADS	If necessary: [For supplementing OD tables] Cordon line survey, Public transport corridor OD interview survey, OD interview survey at large-scale facilities, Truck OD interview survey [For calibration] Screenline survey, Travel speed survey	Tablets/Mobile devices/Paper-based survey, Web-based survey/Supplemental survey at malls and offices	Input data for the previous M/P model, Census, CDR, Satellite image (for changes in land/building use)	Aggregate or disaggregate models (as requested by the C/P)	If only for the capacity development purpose, medium zone level would also be possible. If forecasting is based on aggregate models or network assignment only, use of JICA-STRADA is an option. Coordination with local research institutes such as universities or consulting firms is also necessary.

5.2. Specifications of Key Travel Surveys

Specifications of the above-mentioned key travel surveys, namely, HTS, commuter travel survey, and ADS, are based on the subsequent table. However, exceptions may be conceived if alternative survey types that are more suitable with a smaller scale are proposed by utilizing the existing data or by improving the analysis method to obtain necessary data in a specific survey area. Particularly in the case of surrounding zones (approximately 20% of the entire zones) with lower urbanization ratios, reconsideration for more efficient surveys will be necessary in order to obtain the desired OD trips.

TABLE 5.2 Standard Specifications of Each Key Travel Survey (tentative)

Survey	Objective	Contents	Scale
Household Travel Survey (HTS)	To collect daily trips made by residents in the study area in order to estimate existing travel patterns (i.e., ODs) and forecast future travel demand	− Purpose (to-work, to-school, business, shopping, going home, etc.) − Travel mode (walk, bicycle, motorcycle, car, taxi, bus (large, medium, small), etc. − Driver/passenger and number of occupants − Departure place and time − Arrival place and time − Cost (fare, toll, parking, etc.) − Transfer point − Household attributes (income/expense, number of vehicles, members, etc.) − Individual attributes (age/sex, work/school type and place, number of employees, industrial category, income, vehicle availability, etc.)	− Zoning: about 100-400 zones depending on the urban scale − Sampling rate: about 3% in the city, and 2% in surrounding municipalities * The above specifications are to be determined after overall considerations including survey purpose, local consultant's experience and capacity, etc. − Base data for sampling: latest census data − Survey method: surveyors visiting households (usually twice) and leaving survey forms
Commuter Travel Survey	To substitute for population census that has no commuting information or no individual data available, and/or to update the database of HTS that was previously conducted	− Household attributes (income/expense, number of vehicles, members, etc.) − Individual attributes (age/sex, work/school type and place, number of employees, industrial category, income, vehicle availability, etc.)	− Zoning (if not specified yet): about 100-400 zones depending on the urban scale − Sampling rate: about 100-400 household samples for each analysis zone, or about 1% if population synthesis is to be developed − Base data for sampling: latest census data − Survey method: surveyors visiting households (usually once) as a paper-based survey or by carrying a mobile device (tablet) and directly inputting into electronic survey forms
Activity Diary Survey (ADS)	To collect data of short trips, trip chains and household member interactions (picking up/sending-off, etc.) that are difficult to obtain in HTS but are useful for modeling activity-based demand forecast and adjusting trip rates analyzed from HTS	− Activities (in and outside home) and movements (places (OD) and travel modes, cost, etc.) for several continuous days − Household attributes (income/expense, number of vehicles, members, etc.) − Individual attributes (age/sex, work/school type and place, number of employees, industrial category, income, vehicle availability, etc.)	− Sampling rate: about 5,000 households depending on the urban scale and the number of survey days (about 500-1,000 persons for the purpose of adjusting the trip rates only) − Base data for sampling: latest census data − Survey method: surveyors visiting households (usually twice) and leaving survey forms or alternatively utilizing respondents' mobile devices such as smartphones

6. CONCLUSION

The outcomes of this research project are (1) improvement of accuracy in travel demand forecast, (2) transportation surveys and travel demand forecasting methods tailored for study objectives and cooperation needs, (3) reduction of time required for transportation survey and travel demand forecast and (4) reduction of cost for transportation survey and travel demand forecast.

6.1. Objectives of Transportation Planning by JICA

JICA has provided assistance in urban transport studies for many metropolitan regions in developing countries by conducting urban transportation master plan (M/P) studies as a main scheme. Most of them utilized demand forecasting for the purpose of "a basis of M/P formulation" or "an investment decision tool for infrastructure development."

However, essentially, objectives of various transportation surveys and, especially, transportation demand forecasts that are conducted in the course of M/P studies are not only to present infrastructure development plans but also serve as an evidence to bring out citizens' directions toward their envisaged future city by arranging transportation, land use, and facilities and to support their plans and policies in various ways. Transportation surveys and demand forecasts could also serve as a platform based on which various stakeholders get involved in urban planning with a common vision.

Thus, demand forecast in urban transportation can be utilized as "a tool for supporting decision-making and consensus building of policies and plans based on the same urban vision" in addition to the above-mentioned two purposes. As discussed in the review of past studies, it is not easy to accurately forecast future travel demand in developing countries where the environment, government policies and even individual behaviors are rapidly changing. However, travel demand forecast plays a key role as the basis of urban transportation M/P and infrastructure investment.

6.2. Conclusions Concerning about Issues in This Project Research

6.2.1. Improvement of Accountability in Travel Demand Forecast

Gaps in socioeconomic framework between previous projections and actual observations are observed in some M/P studies that were reviewed by this paper. Although it is important to forecast population distribution considering inflows to the city center and migration, future socioeconomic framework is often decided upon through discussion with counterpart agencies. It is not easy to maintain accuracy as "a basis of M/P formulation" or "an investment decision tool for infrastructure development" while adhering to the policy of counterpart agencies through "a tool for supporting decision-making and consensus building of policies and plans based on the same urban vision."

The impact of these differences and a travel demand model on accuracy can be analyzed by inputting actually observed socioeconomic and network variables to the previous four-step demand forecast models with parameters unchanged. If the model outputs are similar to the actual observations, it can be concluded that the model is valid and that the socioeconomic framework caused the gap. According to the result of these exercises, errors were observed in trip distribution models and modal split models of some past studies. Further detailed analysis was conducted to identify the cause of the errors by inputting current socioeconomic and network data to the previously estimated model with the same parameters. Fundamental causes in the travel demand model were due to the changes in citizens' life styles as well as the limitation of forecasting based on the trip-based approach while methodological mistakes such as a lack of distinction between home-based and non-home-based trips were also revealed.

For modal split models, it is understood that a disaggregate model is widely applied due to accuracy, flexibility of analysis and smaller sample size. The disaggregate approach can also be applied for trip distribution models. Furthermore, joint mode and destination choice models that could improve accuracy could also be included in analysis. In addition, disaggregation of first to third steps of the four-step method, namely, trip generation/attraction, trip distribution and modal split, that is, development of ABM would also be worth trying.

If travel demand forecast is to be utilized with a key role "a tool for supporting decision-making and consensus building of policies and plans based on the same urban vision," it should serve as a powerful communication tool for policy making with various stakeholders to bring out their intentions. In this sense, the model should be able to describe the impact of policy intervention taking behavioral changes of individuals brought about by a policy into consideration. It should also be noted that regular revision

of the plans is necessary in a developing country where the conditions are rapidly changing.

6.2.2. Transportation Survey and Travel Demand Forecasting Methods Tailored for Study Objectives and Cooperation Needs

Level of accuracy is considered as prerequisite for urban transportation M/P study especially for pre and post implementation of short-, intermediate- and long-term projects. It should be noted that future demand sometimes depends on a grand vision of urban development according to the review of past M/P studies.

Review of past M/P studies also showed that quality of transportation surveys and travel demand forecast has never been compromised. In case expeditious work is expected especially for a specific project, F/S can be commenced earlier while M/P can be carried out in parallel. It also should be noted that the accurate transportation database of M/P are utilized by other F/S including ones conducted by other development partners.

In terms of sample size, a 5,000-person sample is expected for disaggregate modeling for several categories and ABM development. If there are constraints such as the local consulting firm's capacity for survey implementation, the sample size can theoretically be reduced further although there is a risk that the sample size for model development for a specific group might be too small. Impact of reduced sample size of HTS and ADS are examined using case studies.

For the F/S, accurate forecast for relatively short and intermediate terms are required. Since F/S is usually based on M/P forecast and data, it is generally easy to maintain the accuracy of demand forecast in the F/S as long as M/P data is utilized.

For the evaluation and travel demand forecast of TCM policies, conventional method with daily passenger analysis is not accurate enough for policy evaluation. While SP surveys can be conducted to analyze TCM policies, it is not easy to apply in some countries and areas. This is because it is quite difficult for some respondents to imagine new policies. Therefore, ABM is considered to be the appropriate method for TCM policy evaluation.

6.2.3. Reduction of Required Time for Transportation Surveys and Demand Forecast

According to the interview survey in the U.S., reduction of time was not expected with utilization of mobile devices; in fact, a minimum 3 to 5 months are required for survey implementation. In terms of travel demand modeling, development of ABM also requires almost the same amount of human resources as the conventional aggregate four-step method. Therefore, one cannot expect a reduction in time required for transportation surveys and travel demand forecast.

6.2.4. Reduction of Cost for Transportation Surveys and Demand Forecast

As the total manpower needed for implementing ABM and the conventional four-step method are nearly the same, a reduction in cost is also not expected. If it is possible to reduce the number of samples, then this will lead to lowering the cost of transportation surveys. However, it should be noted that availability of population census data is a prerequisite.

6.3. Future Research

6.3.1. Utilization of Activity Diary Survey (ADS) and Disaggregate Demand Forecasting Method

As study objectives and cooperation needs are different depending on the type of project such as M/P, F/S and others (e.g., TCM policies), the most appropriate transportation surveys and methods, relevant data, and demand forecast models are to be utilized. As described in Chapter 5, implementation of an ADS with a smaller sample size (about 5,000 households depending on the urban scale and the number of survey days) than that of a conventional HTS is recommended, while a commuter travel survey (about 100-400 household samples for each analysis zone, or about 1% if population synthesis is to be developed) is recommended for the purpose of collecting socioeconomic data, though it depends on the cooperation needs and conditions of a city. As for demand forecasting, it is understood that; due to accuracy, flexibility of analysis, and smaller sample size; a disaggregate model such as ABM shall be widely applied in order to better meet the needs of policy-making and planning in developing countries. Disaggregate models are also considered to be the appropriate method for TCM policy evaluation. Meanwhile, aggregate models or four-step models shall be applied in cases that: there is a need for technology transfer using the conventional aggregate models; TCM policy evaluation is not required; or

there is a need of updating the existing aggregate models. Likewise, a conventional large-scale HTS will be the basis for demand forecast if it is necessary to develop present OD matrices with a certain degree of significance that are statistically ensured.

As such, continuous efforts of trial and error are necessary to seek for the best practice of transportation survey and travel demand forecast.

6.3.2. Studying Possibility of Utilizing New Devices for Transportation Surveys

With regard to transportation survey method, the following method will be analyzed utilizing ICT and state-of-the-art survey method.

Utilization of tablet devices can improve accuracy of HTS. By examining the practice of HTS in Santa Cruz, Bolivia and a number of applications listed in the "Survey Solutions" by the World Bank for interview survey, one can analyze improvement in accuracy and efficiency. Inputs from the ongoing use of tablet devices for commuter travel survey and paper-based ADS as a part of "Project for Urban Transport Master Plan in Kinshasa City" should also be taken into account.

For an area with previous HTS data, a smaller-scale survey such as ADS and survey using respondents' own smartphones can be utilized for analysis. As there is no example of such an application in developing countries, feedback from an ongoing project, the "JABODETABEK Urban Transport Policy Integration Project Phase 2" (JUTPI2) can be included in the further analysis.

As for the problem of difficulty in collecting travel data from high-income households, supplemental transportation surveys that have been conducted at shopping malls or office buildings could be considered as well as web-based travel surveys. In particular, investigation of results from the above-mentioned ADS using respondents' own smartphones will be the target of future research. As for utilization of new devices, since technologies are rapidly evolving, it is important to seek for the next possibility.