

Doctoral Dissertation

**Optimization of Paratransit System Operation by Considering  
Driver's Quality of Life**

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**Optimization of Paratransit System Operation by Considering  
Driver's Quality of Life**

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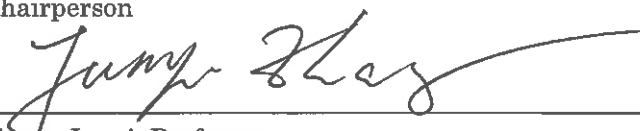
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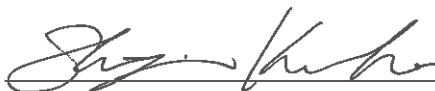


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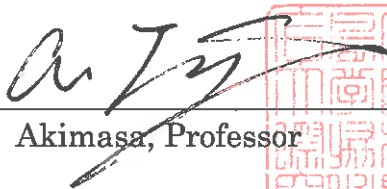


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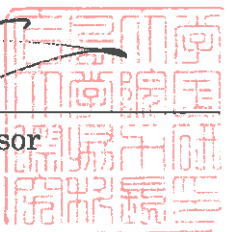
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Sustainable development has been highlighted as a guiding principle for addressing issues associated with rapid urbanization and environmental problems (Joo, 2008). Unfortunately, The path for a transition toward sustainability could not be charted in advance (Nrc Nas, 1999). Therefore, before establishing sustainable development in transportation, the government needs to figure out how to move the current position to the desired future state. In order to achieve that objective it involves the transition sustainability process, which in this process it is believed that the role of paratransit is very important. However, due to the complicated mix of positive and negative impacts of paratransit, it is still understudies whether this informal public transport would still be needed in the future or else whether actually paratransit is much more important in order to support the sustainable development of public transportation. Study of paratransit seizes researcher's attentions in developed and developing countries. The aim of this study is to develop a comprehensive study in order to provide policy suggestions to improve the paratransit service. The policy deliberation is based between evaluations on the optimized paratransit level of service and paratransit drivers' quality of life.

This research is divided into two groups of evaluations, which are subjective and objective evaluations. The research begins by collecting background (in the first chapter) and based on the literature reviews (in the second chapter) the author find problems that were essential to be solved. Although there are so many researchers conducted related to paratransit, there are still some limitations concerning stakeholder's point of views. The evaluations are discussed from chapter 3 to chapter 6 and concluded in the last chapter. The subjective evaluation is the evaluation of paratransit services from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance, while the objective evaluation is the sensitivity analysis of paratransit network optimization. The objective analysis is conducted based on a multi objective optimization model to decide the optimal frequencies, where the objective function is to minimize the generalized cost of paratransit users and the operational cost for paratransit drivers. Then both analyses are combined together, using a jointly ordered-response probit model (ORP) model that can explicitly link the LOS variables with drivers QOL indicators. In the optimization framework, both operators' and users' behaviours are reflected; however the direct service providers are drivers of paratransit vehicles. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not be realized. If paratransit service provision could not improve drivers' QOL, drivers would not make efforts to provide satisfactory and reliable services. With the above consideration, this study suggests introducing drivers' QOL indicators to optimize the paratransit service. Finally, this study conducted sensitivity analysis in order to deliberate the policy suggestion to decide the paratransit future.

Chapter 3 Studies of the Link Performance Function (LiP), which is suitable for the traffic situations in developing countries where on-street occupancy influence is prevalent, are extremely limited. It is expected that the LiP might vary over local characteristics (i.e. Number of paratransit volume and stopping behaviour). The results confirm that the link performance in developing cities highly depends on not only the volume/capacity

ratio, but also the driving contexts such as road link variations, time variations, and/or the influence of on-street occupancy.

Chapter 4 This chapter aims to evaluate paratransit services from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance. Paratransit drivers can be categorized as low-income people, where they are more likely to emphasize on achieving basic level of QOL involving wealth, employment, residence and health before enjoying other life aspects (higher level of QOL). For this purpose, the study implemented a questionnaire survey in September 2011 and collected the questionnaire sheets from 152 drivers from Bandung city. Using the data, a structural equation model with latent variables is built to investigate cause-effect relationships between work performance and driver's life satisfaction (as a proxy variable to indicate QOL) and environmental impacts while at the same time to measure the relationship between work performance and gap revenue and indirectly to work satisfaction. It is found that the existing condition for paratransit system are neither socially nor environmentally sustainable.

Chapter 5 This chapter presents a sensitivity analysis of paratransit network optimization for transportation planning in developing cities. The analysis is conducted based on a multi objective optimization model to decide the optimal frequencies, where the objective function is to minimize the generalized cost of paratransit users and the operational cost for paratransit drivers. Several scenarios are assumed to represent the behavioral features specific to paratransit users and drivers, as follows: scenario 1 changing the scale and shape parameters in the Bureau of Public Road (BPR) function, scenario 2 changing the flexibility of stopping places and scenario 3 combining scenarios 1 and 2 in order to derive practically feasible optimization solutions of paratransit services. The paratransit network in an area located within 1.5 km radius from the central station in Bandung city is used as a case study network. It is found that the influence of updated BPR Function which is analyzed in Chapter 3 is imperative while changing the flexibility of stopping place might not be the best solutions. The latter result is still arguable, therefore we improve the model.

Chapter 6 Our previous chapter showed that the current paratransit systems are not socially sustainable. In this study, it is aimed to clarify how the improvement of paratransit service affects drivers' quality of life (QOL). This was done by integrating the optimization results of a paratransit system (i.e., angkot) from the optimization model (Chapter 5) and the QOL evaluation results (Chapter 4) from a simultaneous-equation ordered probit model by using data collected in Bandung, Indonesia. As a result, it is found that minimizing the total cost of paratransit operation and users does not necessarily increase the operation frequency and total distance traveled for all routes, and the level of paratransit service surely affects drivers' QOL; however, improved paratransit services do not always improve drivers' QOL. It is concluded that driver's QOL needs to be reflected in decisions on paratransit operation

Chapter 7 This chapter provides the conclusions of the whole research by bringing out important findings obtained from the research and deliberate policy recommendation to be applied in the developing countries. This chapter also postulates the development possibility of the research in the future which will enrich the research findings and give more contributions.

備考 論文の要旨はA4判用紙を使用し、4,000字以内とする。ただし、英文の場合は1,500語以内とする。

Remark: The summary of the dissertation should be written on A4-size pages and should not exceed 4,000 Japanese characters. When written in English, it should not exceed 1,500 words.

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*Love you always*



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## ABBREVIATIONS AND ACRONYMS

ADA	- Americans with Disabilities Act
AGFI	- Adjusted Goodness of Fit Index
AIC	- Akaike Information Criterion
ANGKOT	- Angkutan Kota
BPR	- Bureau of Public Road
CFA	- Confirmatory Factor Analysis
DAMRI	- Djawatan Angkoetan Motor Repoeblik Indonesia
DIC	- Deviance Information Criterion
DISHUB	- Dinas Perhubungan
DRT	- Demand-Responsive Transport Systems
DUE	- Deterministic User Equilibrium
EFA	- Exploratory Factor Analysis
GFI	- Goodness of Fit Index
GPS	- Global Positioning System
GTZ	- Gesellschaft für Technische Zusammenarbeit
IHCM	- Indonesian Highway Capacity Manual
IDR	- Indonesian Rupiah
KK	- Kepala Kelompok
KOBANTER	- Koperasi Bandung Tertib Baru

KOBUTRI	- Koperasi Bina Usaha Transportasi Republik Indonesia
KOPAMAS	- Koperasi Angkutan Masyarakat
KPU	- Koordinator Pengawas Unit
LiP	- Link Performance Function
LOS	- Level of Service
MCMC	- Markov Chain Monte Carlo
Menkimpraswil	- Menteri Permukiman, Prasarana, dan Wilayah Tertinggal
O-D	- Origin-Destination
ORP	- Ordered-Response Probit Model
PCE	- Passenger Car Equivalent
QOL	- Quality Of Life
SEM	- Structural Equation Model
St.Hall	- Station Hall
TCQSM	- Transit Capacity and Quality of Service Manual
TCRP	- Transit Cooperative Research Program
TMB	- Trans Metro Bandung
UE	- User Equilibrium
UPTP	- Urban Public Transport Policies
V/C	- Volume to Capacity
WHOQOL	- World Health Organization Quality Of Life

# **Chapter 1 Introduction**

## **1.1 Background**

Sustainable development has been highlighted as a guiding principle for addressing issues associated with rapid urbanization and environmental problems (Joo, 2008). In most developing countries, urbanization and what so called “hyper motorization” (Schipper, 2010) is unavoidable and no longer become uncommon phenomena. The trend of motorization is suppressing the rapid increase of private cars. In order to reduce the need for cars, governments could steer new development toward places that is easily accessible by public transit (Sheehan, 2002). Or else provide safe and attractive streets for pedestrians and bicycles, while making sure that the connection between cycling, rail, bus, and other forms of transportation, including paratransit, are convenient (Sheehan, 2002). The path for a transition toward sustainability could not be charted in advance (Nrc Nas, 1999). Therefore, before establishing sustainable development in transportation, the government needs to figure out how to move the current position to the desired future state.

In order to achieve that objective, it involves the transition sustainability process, which in this process it is believed that the role of paratransit is very important. Sheehan (2002) suggested that paratransit, which is particularly well suited to spread-out in the metropolitan areas, should be developed more. If paratransit can be used in the transition process before it is going to be replaced with mass public transport in the future, then the real contribution of paratransit as “Gap Filler” becomes significant due to the limitation

of government capacity in order to develop the public transport system (Nugroho et al., 2012).

This “Gap Filler (Cervero, 2000)” here means paratransit serve to fill the service voids between the private car and the formal public transportation and provide mobility for the poor (Taiyab, 2007). Taking the advantage of the small size of the vehicle, unrestrained operation, and substitute for public transit without subsidies paratransit can admirably respond to fluctuated markets. They were also recognized as efficient road-utilizing carriers, low cost service, fleet-footedness, and users’ gratifying mode (Cervero & Golub, 2007). In Hong Kong, the performance of integrating resident coach services to urban transport system revealed the capability of the paratransit in getting people out of their private cars (Loo, 2007). Another study revealed that paratransit is both flexible for-hire and fixed route types the possibility to be implemented as a feeder system for mass transits and other public transports (Tangphaisankun et al., 2009). Beneficially, paratransit can be used to provide service as a trunk line for the main haul of public transportation system. A study in Bangkok, Thailand revealed that paratransit has the possibility to be as a feeder system for mass transits and other public transports from the user’s perspective (Tangphaisankun et al., 2009).

Existing studies revealed that paratransit modes play a significant role in the urban transport sectors of developing countries by transporting almost half of the formal public transportation (Cervero & Golub, 2007; Godard, 2006; Joewono & Kubota, 2007; Tangphaisankun, 2010; Vukan, 2007). In Indonesia, it is found that door-to-door paratransit services constitute 18% of the traffic volume, but account for 50% of all

person trips (Pendyala & Kitamura, 2007). Paratransit is a typical and common public transportation system in Indonesian cities. For example Bandung and Surabaya city in Indonesia, paratransit mode has a role to carry almost half of the total public transport demand in the urban transport sectors (Shimazaki & Rahman, 1996). Another positive impact of paratransit, they could also provide job opportunities for those who are unskilled and uneducated migrants from local regions (Senbil et al., 2005).

Unfortunately, the other main problem that developing countries face is not only high use of automobiles, but also poor service quality of public transit (Senbil et al., 2005). The existing qualities of paratransit services are only acceptable but they do not satisfy the user's needs (Tangphaisankun et al., 2009). In case in Jakarta city, based on attitudinal study, shows that the perceived performance of urban public transport system rated very low (Li et al., 2011). Another study mentioned that in Jabodetabek, angkot reach the highest score for operation frequency among all evaluation items while regrettably security in angkot reach the lowest evaluation score (2.87) (Weningtyas et al., 2011). Although in fact, angkot's operation time is already more than 18 hours/ day and the number of the units are very excessive (Subdit Lalu Lintas Perkotaan, 2008).

Besides the beneficial impact that can be obtained from paratransit, it is also known that paratransit have caused negative impacts to the society. Moreover, paratransit transport networks are poorly regulated and can be dangerous, unreliable, and extremely crowded (Pendyala & Kitamura, 2007). Without safe or convenient options, anyone that can afford another alternatives will avoid taking public transportation.



Table 1.1 Paratransit System Advantages and Disadvantages

Advantages	Disadvantages
<p><b>Flexibility (almost the same as DRT):</b></p> <p>The service can be easily opened when needed; and on the other hand, this can be closed when number of users decreases. (Tarigan et al., 2010)</p>	<p><b>Congestion :</b></p> <p>Paratransit systems also create several problems such as traffic congestion, traffic accident, complicated management, environmental pollution and quality control. (Tarigan et al., 2010)</p>
<p><b>Job Opportunity (for non educated and low income) :</b></p> <p>For local community, paratransits have supported society by creating jobs for low-skilled workers and for government its implementation and running costs are relatively low. (Tarigan et al., 2010)</p>	<p><b>Unreliable Service:</b></p> <p>Aggressive and unruly driving among drivers whose very livelihoods depend on filling empty seats all too often causes serious accidents. (Cervero, 2000)</p> <p>Excessive competition has produced too many idling and slow moving vehicles that jam critical intersections. (Cervero, 2000)</p> <p>Fares are frequently kept low to help the poor, however this reduces revenue intake which in turn precludes service improvements. (Cervero, 2000)</p>

Paratransit, for example angkutan Kota (angkot), is most likely to be blamed as the main causal factor of traffic congestion in Indonesian cities. The high number of angkot units that would cause severe competition between each driver, produce too many idling times and slow moving vehicles that jam critical intersections (Cervero, 2000).

Aggressive and unruly driving among drivers also often causes serious accidents (Cervero, 2000).

Because of the complicated mix of the positive and negative impacts of paratransit, it is still understudies whether this type of public transport would still be needed in the future or else whether actually paratransit is much more important in order to support the sustainable development of public transportation. Study of paratransit seizes researcher's attentions in developed and developing countries.

## **1.2 Research Motivation**

As deliberated in the background, the importance's of paratransit are inevitable but in the existing condition the paratransit service show a poor performance. Therefore extensive research about how to improve the paratransit service or performance in the future is needed. Current researches in developing countries mostly concentrated on evaluation of paratransit performance merely based on user's side and evaluation of paratransit performance. Joewono and Kubota (2007) found that, although users are not satisfied with several aspects of paratransit services likewise the competition with the automobile is severe, loyal users of paratransit services still can be found. Their study also identifies several measures that paratransit operators need to undertake to remain competitive but in the contrary avoid loss of patronage. It has contributed to the understanding of what aspects of service quality need be improved for paratransit to retain its current users and to attract new ones (Joewono & Kubota 2007). Based on a confirmatory factor analysis and a structural equations model that examines the impacts

of various factors on user perceptions, the authors conclude that comfort, customer service, safety and security, and information provision are the most important measures of user satisfaction. Service reliability, accessibility, and fare constituted second-tier measures of user satisfaction. Joewono and Kubota (2007) conclude that paratransit should be able to satisfy the need created by the excess of private passenger trips over road transport in the future. Joewono and Kubota (2007) also emphasized in their study the importance of supporting and maintaining strong paratransit services to provide people an affordable alternative to the private automobile and two-wheeler.

While Tarigan (2010) concludes the users are likely to continue to use paratransit even though they suffer negative experiences such as long waiting time, delay of travel time and inappropriate route made by drivers. In other words we can say that in the existing condition paratransit service suffer a degraded service condition due to the excessive number that cause illegal or highly competitive between driver which in turn cause driver have longer idling time and change the routes unexpectedly to gain more passengers.

Kawaguchi et al (2012), tries to apply a scheme in Bogor, Indonesia named “angkot shift program”, which regulate the supply of angkot vehicles by assigning each of the vehicles into one of three shift groups, and only two shift groups are allowed to operate in a given day. The result shows that the program has impacted to the drivers and the owners. It reduced the illegal competition between angkot vehicles, and the owners can expect an increase in net income due to reduction of maintenance costs while drivers can take additional leave. These findings, initiate us as a paratransit researcher that users

perspective is important but we also cannot ignore the viewpoint from the drivers. The research question which arises is the existing service needs to be improved, but whether this improvement would cause a positive or negative effect to the drivers' QOL. How improvement of level of service will influence drivers' QOL? This is an important concern that needs to be emphasized is the network optimization.

In developed countries, more advanced study has already been conducted, focusing on how to optimize paratransit with heuristic and dynamic programming approach. Based on the author's knowledge, there are still few researches that focused on the paratransit network system in developing countries, especially angkot. Initially, the idea is how to implement the theory of optimizing route network with common lines problem that previously implemented for bus system but in this case for paratransit system. The user viewpoint is the consideration of minimizing the user total cost while from the operator viewpoint is the consideration of minimizing the total operational cost and drivers Quality Of Life (QOL). This study could provide useful insights for stakeholders in order to decide the future usage of paratransit.

### **1.3 Research Objectives**

The aim of this study is to develop a comprehensive study in order to provide policy suggestions to improve the paratransit service. The policy deliberation is based between evaluations on the optimized paratransit level of service based on paratransit drivers' quality of life.

To achieve the research goal, there are five specific objectives to be performed as follows:

1. Firstly, we update the Link Performance Function (LiP) to reflect the influence of on-street occupancy (i.e erratic behaviour of angkot and on street parking) in evaluating paratransit network performance. The purpose is to updated the travel time in the network modelling to represent the real situation not the free flow time
2. Secondly, this study evaluates paratransit services from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance.
3. Then, this study presents a sensitivity analysis of paratransit network optimization for transportation planning in developing cities. The analysis is conducted based on a multi objective optimization model to decide the optimal frequencies, where the objective function is to minimize the generalized cost of paratransit users and the operational cost for paratransit drivers.
4. Next, this study analyzes QOL as an external indicator that are required to decide the best solutions obtained from the third study.
5. Finally, based on previous study we deliberate the policy suggestion to provide useful insights for stakeholders to decide the paratransit future.

#### **1.4 Framework**

This research is divided into two groups of evaluations, which are objective and subjective evaluations. The research begins by collecting background, and based on the

literature reviews the author find several problems that was essential to be solved. Although there are so many researches conducted related to paratransit, there are still some limitations concerning stakeholders point of views. The objective analysis is conducted based on a multi objective optimization model to decide the optimal frequencies, where the upper level is to minimize the generalized cost of paratransit users and the operational cost for paratransit drivers.

The subjective evaluation is the evaluation of paratransit services from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance, while the objective evaluation sensitivity analysis of paratransit network optimization. The subjective analysis is conducted using structural equation modelling (SEM) in order to evaluate paratransit services from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance.

Then, both analyses are combined together, using a jointly ordered-response probit model (ORP) model that can explicitly link the LOS variables with drivers QOL indicators. In the optimization framework, both operators' and users' behaviours are reflected; however the direct service providers are drivers of paratransit vehicles. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not be realized. If paratransit service provision could not improve drivers' QOL, drivers would not make efforts to provide satisfactory and reliable services.

With such consideration, this study suggests introducing drivers' QOL indicators to optimize the paratransit service. Finally, this study deliberate the policy suggestion to decide the paratransit future.

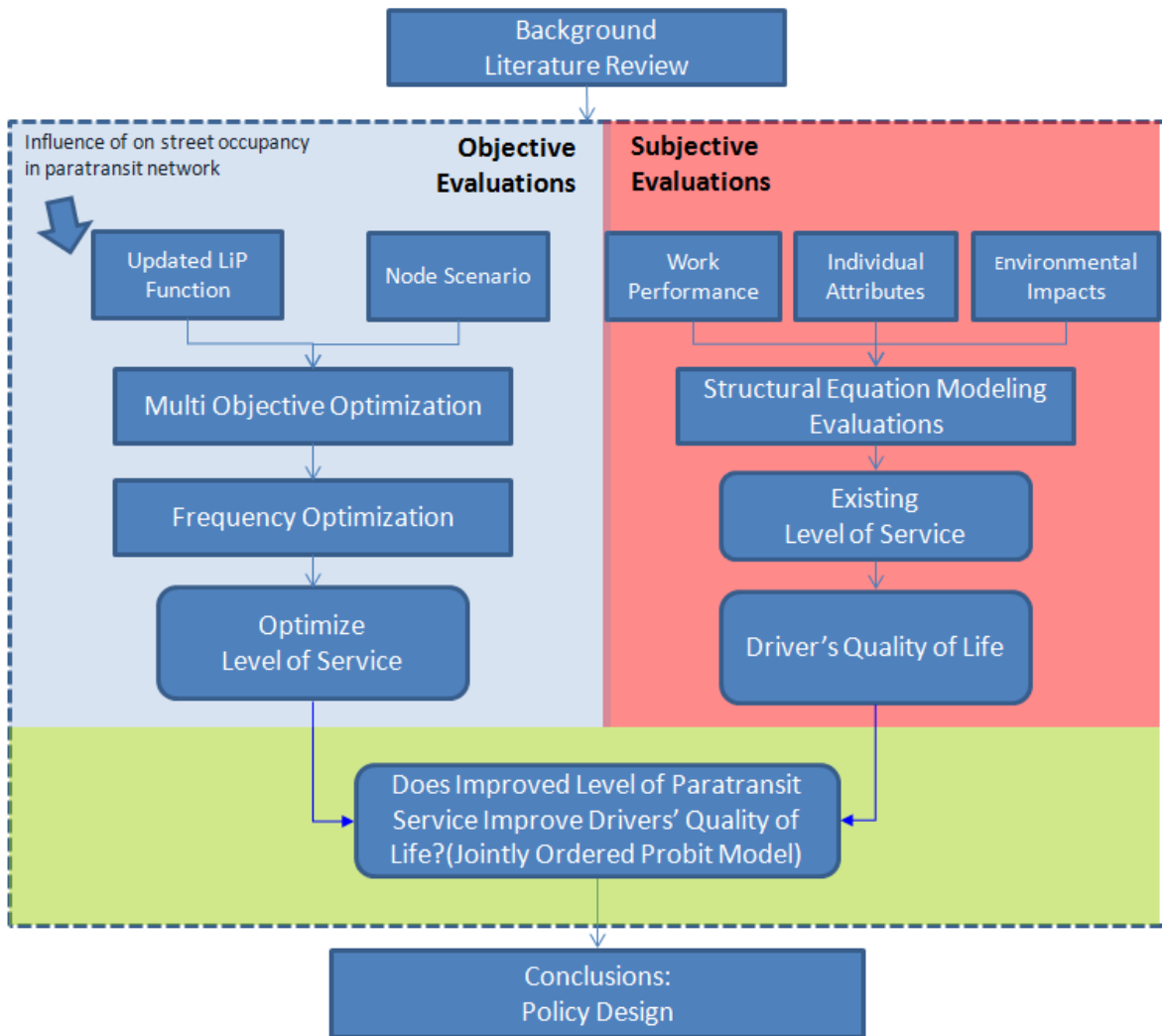


Figure 1.1 Research Framework

### 1.5 Research Scope

This study focuses on one type of paratransit, i.e., angkot. Other types of paratransit, such as ojek (motorcycle taxis), bajaj (motorized tricycles) and becak (pedal

powered tricycles) are not considered for the sake of simplifying the discussion. In the remainder of this paper, the term angkot is used interchangeably with the term paratransit.

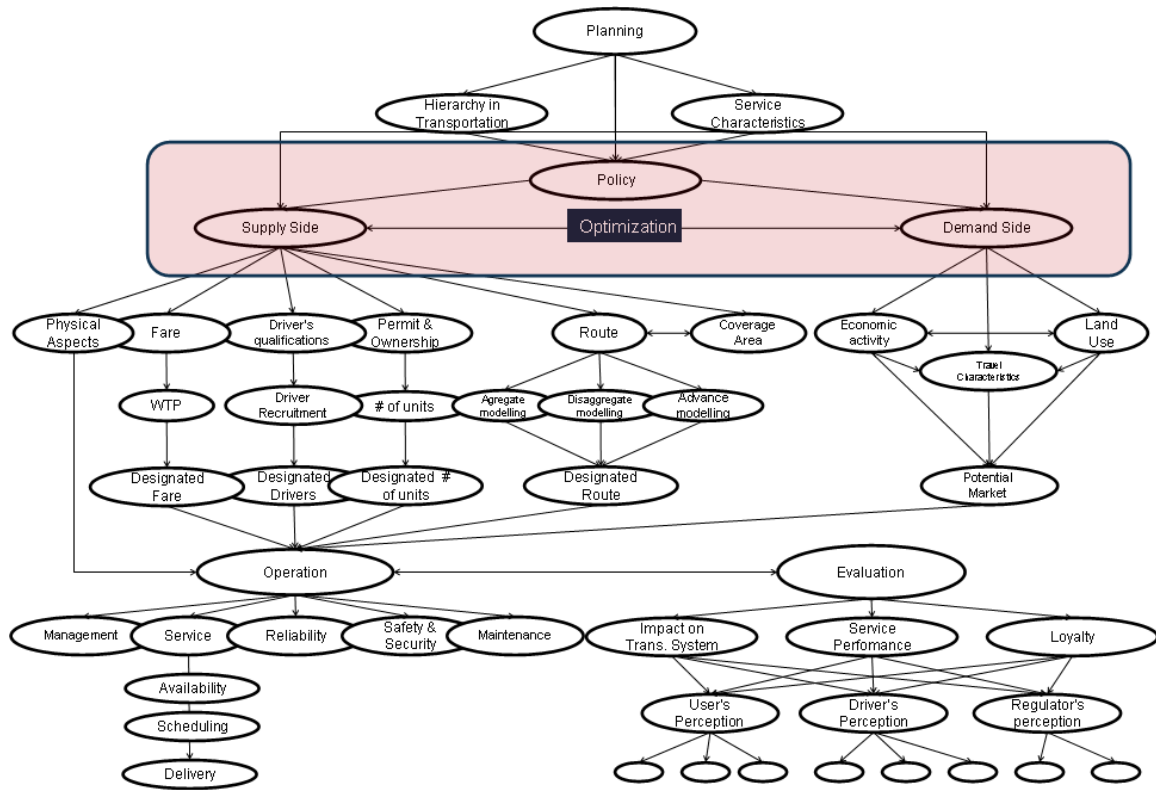


Figure 1.2. Focus Research Area Positioning in Paratransit Study

This study focuses mostly on driver side while combining the user side only from the perspective of minimizing the total cost for each passenger in the modeling estimation. The cost comprises in-vehicle travel cost, waiting cost, and also walking cost. This assumption is considered to be representative for the whole framework to capture the optimum condition that meets both side needs.



## 1.6 Outline of the Thesis

This dissertation contains a total of seven chapters and appendices. The background for this research, the aims and objectives and also the research framework for this research have already been described in this chapter. The remaining chapters and appendices, and their brief contents are arranged as follows:

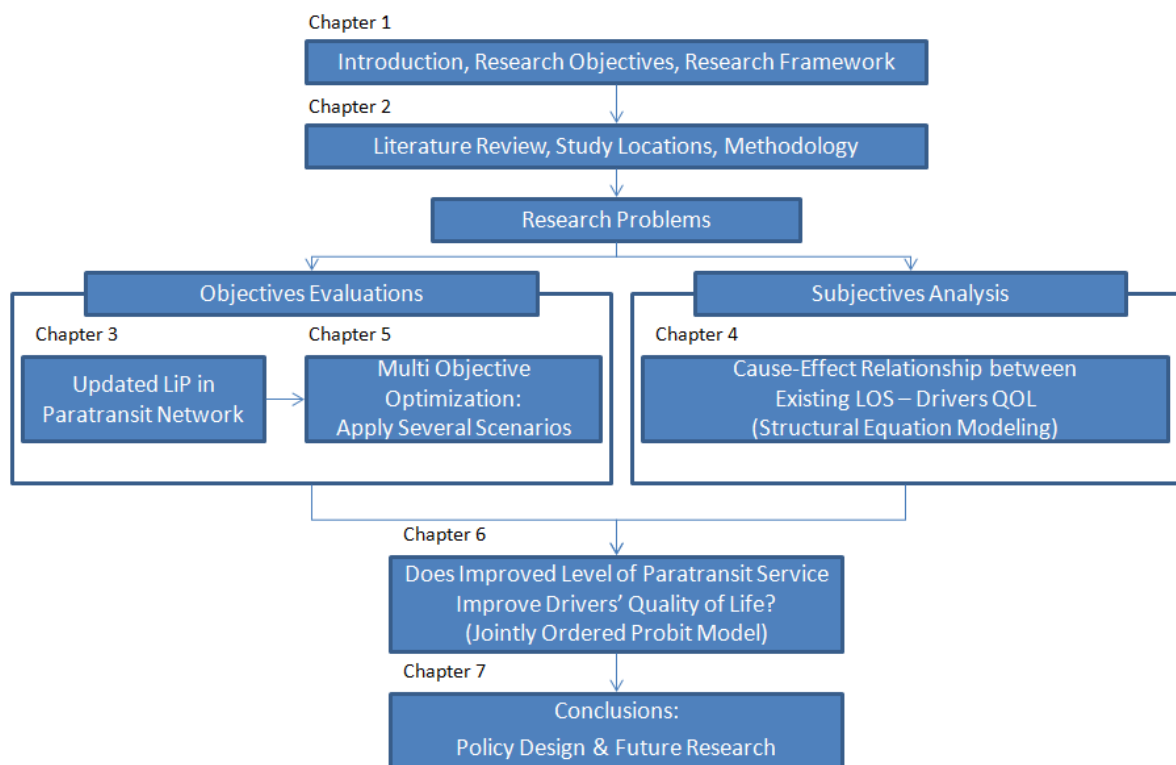


Figure 1.3. Dissertation Chapter Structure

**Chapter 2 presents** a literature review of the relevant researches and ideas are discussed. It includes present situation of the study area, data collection procedure, and collected data are described. The study design of all analysis processes and methodologies applied in each procedure is explicated.

**Chapter 3** describes studies of the Link Performance Function (LiP), which is suitable for the traffic situations in developing countries where on-street occupancy

influence is prevalent, are extremely limited. In the Indonesian Highway Capacity Manual (IHCM: 1997), the influence of on-street occupancy (i.e., aberrant stopping behavior of paratransit vehicles) is already reflected in the capacity calculation, however, it has not been reflected in the calculation of the LiP. It is expected that the LiP might vary over local characteristics (i.e. number of paratransit volume and stopping behavior). To effectively clarify such features, here, a multilevel modelling is applied, where the several variation factors are represented by introducing the corresponding error terms into the original regression model. The model results confirms that the link performance in developing cities highly depends on not only the volume/capacity ratio, but also the driving contexts such as road link variations, time variations, and/or the influence of on-street occupancy.

**Chapter 4** aims to evaluate paratransit services from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance. Paratransit drivers can be categorized as low-income people, where they are more likely to emphasize on achieving a basic level of QOL involving wealth, employment, residence and health before enjoying other life aspects (higher level of QOL). For this purpose, the study implemented a questionnaire survey in September 2011 and collected the questionnaire sheets from 152 drivers from Bandung city. Using the data, a structural equation model with latent variables is built to investigate causal-effect relationships between work performance and driver's life satisfaction (as a proxy variable to indicate QOL) and environmental impacts while at the same time to measure the relationship between work performance and gap revenue and indirectly to work satisfaction. Gap

revenue means the difference between actual revenue and minimum daily based revenue.

Here, environmental impacts are indirectly represented by fuel cost and vehicle age.

**Chapter 5** presents a sensitivity analysis of paratransit network optimization for transportation planning in developing cities. The analysis is conducted based on a multi objective optimization model to decide the optimal frequencies, where upper level is to minimize the generalized cost of paratransit users and the operational cost for paratransit drivers. Several scenarios are assumed to represent the behavioral features specific to paratransit users and drivers, as follows: scenario 1 changing the scale and shape parameters in the Bureau of Public Road (BPR) function, scenario 2 changing the flexibility of stopping places and scenario 3 combining scenarios 1 and 2 in order to derive practically feasible optimization solutions of paratransit services. The paratransit network in an area located within 1.5 km radius from the central station in Bandung city is used as a case study network. It is found that the influence of updated BPR Function is imperative while changing the flexibility of stopping place might not be the best solutions

**Chapter 6** paratransit improvements need to be made in order to provide a better service for users. Whilst improvement on the paratransit level of service (LOS) would somehow have an influence on drivers' job satisfaction, while changes in job satisfaction are significantly affected on drivers' quality of life (QOL). In our previous research as discussed in Chapter 4, we found that the current paratransit systems are neither socially nor environmentally sustainable. By increasing the paratransit LOS would cause lower drivers' QOL. Using the optimized value of LOS obtained from our study as deliberated in Chapter 5. Based on an optimization model we further analyze the influences of LOS

improvement towards driver QOL. It is confirmed that by increase LOS does not necessarily mean higher driver QOL. These findings can be effectively used for proposed operational improvement on Paratransit

**Chapter 7** concludes the research by bringing out keynotes realized from the research and recommends important implications and contributions for applying this research framework in the developing countries. This chapter also postulates possible future prospects for further research that can enrich the validity of the research findings.

## **Chapter 2 Literature Review, Study Locations and Data Collections**

### **2.1 Review Literature**

#### **2.1.1 Motorization in Developing Countries**

In the developing world, motorization has occurred so quickly that road infrastructure and traffic management systems have not been able to keep up (Taiyab, 2007; Schipper, 2010). Buses, cars, rickshaws, motorcycles, cyclists, pedestrians, and even animals (in example: “delman” a human-carriage drawn by horse as tourist attractions in Bandung city) all share the same road space, causing severe motor vehicle traffic disruptions, long idle times, and high fatality rates (Taiyab, 2007). One common question which comes up among us is why are the attendant problems of motorization so much worse in the major developing country cities than the developed world, even though per capita car ownership is so much lower? Taiyab (2007) reckon that part of the answer lies in the speed of motorization and the sheer size and density of the urban populations involved. When developed countries were building their transportation infrastructures, populations were far smaller and the cost of vehicles was higher, allowing cities to develop their road systems gradually (Taiyab, 2007).

In Indonesia, 60 percent of all paved roads do not have sidewalks (Taiyab, 2007). Sidewalks are either not-exists or filled by hawkers and street dwellers. Air pollution is exacerbated by the use of old, cheap technologies, such as two stroke engines and diesel vehicles that emit high volumes of particulate matter (Taiyab, 2007). Reckless driving and violation of traffic laws are rarely punished and the vast majority of fatalities are

borne by cyclists, motor cyclists, and pedestrians. Consequently, the safest place to avoid the chaos on the streets is inside a car (Taiyab, 2007).

In short, the state of urban transport in these cities can be portrayed as: “a growing urban population inadequately served by the transport system, declining standards of public transport, overlaps and conflicts among the agencies responsible, massive growth in the use of minibus services, growing dependence on private transport, inadequate and deteriorating transport infrastructure, and poor facilities for non-motorized transport” (Febrina, 2009)

In GTZ report (2010) it is stated that “the living standard in many developing cities is changing, while developing cities are experiencing economic growth, the aspiring middle class is not longer captive to particular transport services. Higher incomes are translated into higher car ownership and higher expectations in terms of better mobility and better quality of service. Furthermore, in a society based on services, the best companies are competing for the best human resources. The quality of life in and around their workplace is a crucial point for employees when choosing their employer, and transport access becomes a very integral aspect here. Given this, companies are certainly looking to invest and locate themselves in cities with a sound public transport system with integrated ticketing, multi-modal integration, high quality of service and safety, which is a prerequisite of a high quality of living standard.” (GTZ, 2010)

In this context, the role of paratransit becomes debatable as it faces increasing pressure/competition to upgrade its services and to integrate with the formal public transport system in a better way. There is a need to address this issue and ensure that a

city's travel demand is met in a sustainable manner, with the most suitable combination of travel modes.

### **2.1.2 Paratransit Definitions**

In developed countries, paratransit is defined as the full range of demand-responsive services, including complementary, general public dial-a-ride, and human service transportation (Transit Cooperative Research Program, 2003). In developing countries, these privately operated, small-scale services are varyingly referred to as “low-cost transport”, “intermediate technologies”, and “third world transport” (Cervero, 2000). Paratransit can be defined as “a service that is not quite full public transit, utilizing smaller vehicles, and it can be legal or illegal as defined by local rules and regulations” (Graeff, 2008; Grava, 2003).

Paratransit systems can be categorized by route pattern and function, by organization of drivers, kind of stops, and fare type. Most case studies obtained by personal communication and presented by Cervero (2000) indicate that paratransit services are mainly organized as cooperatives operating 8-15 seater vans on fixed routes. Most of the services run in direct competition to a public transport system of a public transit authority. It is known in Indonesia as angkutan kota, as jeepney in the Philippines, as tuk-tuk and songtaew in Thailand, and as mammy wagons (converted trucks) and matatu (converted vans) in some African countries (Joewono & Kubota, 2007).

This type of public transport are mostly owned by individuals owning a fleet of less than a dozen vehicles at the most, which are subcontracted to drivers for a fixed sum (of money), be it daily, weekly or monthly (Cervero, 2000). Vehicles are often locally

assembled or bought second-hand. In their operation, despite the fact whether they have legal credentials, there are rent-seekers in the form of traffic officers, policemen and local thugs who sap their already thin profit. Paratransit systems have distinct characteristics. They are operated along fixed routes that serve as corridors (Neumann & Nagel, 2011), but they have fairly loose timetables, and passengers are usually (though not always) picked up and dropped off anywhere along the routes (Cervero, 2000).

Cervero (2000) coined the term ‘laissez-faire transportation’<sup>1</sup> to shortly define paratransit and informal public transport. In his comprehensive study, he has made classification between formal and informal dimension based on supply as listed in Table 2.1 (in example: service structure, delivery, scheduling, reliability, vehicle type, ownership, market perspective, labor and organization) and demand & price (in example: market focus, main trip purposes, trip distances, customer relations, socio-demographics, and fare structure).

Cervero summarizes, as depicted in Table 2.2, in five-classes which are as follow:

1. Size and Speed: The largest and fastest vehicles occupying the lowest class (class I) and the smallest, slowest ones belonging to the highest (class V).
2. Engine: motorized (classes I through IV) or non-motorized (class V).

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<sup>1</sup> *laissez-faire transportation*’ here refers to the approach taken by authorities of the city with regard to policy, regulations and supervision of the urban public transport sector. As a sub-sector, despite being highly fragmented, paratransit and informal transport actually have a very structured way of operating



3. Passengers: The larger vehicle classes (I and II) represent “collective” carriers – i.e., they serve collections of unrelated individuals, usually 12 or more, along fixed or semi-fixed routes. Providing “shared-ride” services among either related parties or small sets of unrelated passengers (in the range of 4 to 11) heading in the same general direction are the class III minibuses, station-wagons, pick-ups, and jam-packed sedans. Class IV (motorized tri-wheel and motorcycle) and class V (non-motorized pedal- and horse-powered) carriers handle door-to-door trips for individuals or related parties of up to 3 persons (and occasionally one or two more, if small children).
4. Route Definition: In sum, lower class vehicles – I through III – generally ply fixed routes and only make minor detours off of fixed paths. Accordingly, they represent “route-based” and “bus-like” services. Higher class (IV and V) services tend to be more demand-responsive, providing door-to-door services (though some class III services operate similarly). Accordingly, they tend to be more “taxi-like”.

Of course, many informal transport vehicles do not neatly fit into any one category, and are hybrids. In practice, for instance, many minibuses tend to follow fixed routes but will make a detour at a passenger’s request for an additional fare.

Informal (class I) bus services can be found along inter-city routes in parts of South America, sub-Saharan Africa, and East Asia, though overall, class-I buses make up a small fraction of informal carriers worldwide. Below, vehicle characteristics of each class of informal transport services are outlined.

Class I: Included here are standard stage coaches and double-decker buses that provide trunk-line services. Since conventional bus services are predominantly under public-sector control, and if not, operate under franchise arrangements, few are unlicensed and unregistered. Informal buses have long operated between Brazilian cities, though their numbers have dwindled since the 1980s following the franchising of intra- and inter-city bus routes. Today, there are class-1 illegal vehicles plying the highways of Nigeria, Nicaragua, and Vietnam. In Nigeria, vehicles with wooden or metal bodywork built on truck chasses, called molue, boleka, and ongoro, carry between 25 and 100-plus customers (at crush conditions). Similar contraptions are found on the streets of Havana, where trucks pull huge double-jointed buses filled to the brim with passengers, earning them the affectionate title of camellos, Spanish for “camel”.

Class II: Carrying intermediate loads in the range of 12 to 24 riders are a mix of minibuses, elongated jeeps, and passenger-carrying trucks. Included here are Manila’s jeepneys, Jakarta’s mikrolets, and Mexico City’s colectivos, all of which operate as fixed-route, shared-ride carriers, boarding and discharging passengers anywhere along the way, and occasionally deviating routes as custom, traffic, and hour permit. One global study of jitney-like services rated them high in terms of service frequency, speed, load factors, and productivity (cost per passenger), but gave them poor marks for service regularity and dependability (except for peak hours), comfort, and safety. While not truly informal transport in that the services are state-run, these 300-passenger mega-carriers are a bonafide form of home-grown, indigenous public transport.

Table 2.1 Comparison between Formal and Informal Transport Modes

<b>Dimension</b>	<b>Formal</b>	<b>Informal</b>
<b>SUPPLY</b>		
Service Structure	Fixed Route, Standardized	Variable Route, Adaptive
Delivery	Line-Haul, Trunk Line	Distribution, Feeder
Scheduling	Fixed Timetable	Market Driven, Adaptive
Reliability	Reasonably Dependable	Inconsistent
Vehicle Type	Large	Small to Medium
Ownership	Public and Private	Private
Market Perspective	Monopolist	Enterpreneurial
Labor	Semi-Skilled	Semi-to-Non-Skilled
Organization	Bureaucracy	Route Associations
<b>DEMAND &amp; PRICE</b>		
Market Focus	Mixed	Niche
Main Trip Purposes	Work, School, Shopping	Mode Access
Trip Distances	Medium to Long	Short to Medium
Customer Relations	Impersonal	Interpersonal
Socio-Demographics	Low to Moderate Income	Low Income
Fare Structure	Fixed, Uniform	Variable , Differentiated

Table 2.2 Summary of Classes of Paratransit Vehicles that Operate Informally

CLASS	Service Features		Passenger Capacity	Service Niche	Service Coverage
	Routes	Schedules			
I: Conventional Bus	Fixed	Fixed	25-60	Line-Haul	Region/ Subregion
II: Minibus/ Jitney	Fixed	Semi-Fixed	12-24	Mixed	Subregion
III: Microbus/ Pick-Up	Fixed	Semi-Fixed	4-11	Distribution	Subregion
IV: 3-Wheeler/ Motorcycle	Variable	Variable	1-4	Feeder	Neighborhood
V: Pedicab/ Horse-cart	Variable	Variable	1-6	Feeder	Neighborhood

In Indonesia, Angkutan umum or well known as angkot, mikrolet or any other names have legal permit, the route also defined by the local government although their operations are managed by route associations or single individual. The government legalizes them under Undang-Undang no. 22 year 2009 about traffic and public transportation. despite cervero define that angkot or mikrlet as in clasificaaion of class II

in informal public transport, since in our case we found that angkot is legal therefore we consider as formal public transport.

This small-scale paratransit operators is believed to be able to impose significant costs (Cervero, 2000). The most significant are:

1. Erratic scheduling and service: An unregulated system will tend towards erratic and harmful scheduling where headways become very long during off peak periods, while on peak hours an oversupply of vehicles fighting for passengers.
2. Competition “in the market”: With poor planning, revenues are wholly dependent on ridership and operators now are pushed to fight for waiting passengers at bus stops and in terminals. Driving becomes aggressive and dangerous, causing additional congestion and safety problems.
3. “Cream Skimming”: Many small operators attempt only to operate during the peak hours or in busy locations because of perceived costs and higher revenues. This means services on off-peak or low-demand routes are poor or absent.
4. Paratransit vehicle operations have been described as public transport that stops almost anywhere to allow passengers to board or alight, which has been referred to as “collectively damaging behavior” and termed in Latin America, “the war for the cent” (Cervero & Golub, 2007). Their indiscriminate stopping and starting also would hamper the normal flow of the traffic. In Jakarta, opelet routes overlapped with city bus routes results in an adverse effect on the free flow of traffic (Shimazaki & Rahman, 1996). In terms of road space utilization per passenger, it is estimated that a

microbus is 4-5 times more inefficient than a conventional bus and 2-3 times than a mini bus (Shimazaki & Rahman, 1996).

The comparison characteristics between bus and paratransit (angkot=jitney) are listed in the Table 2.3.

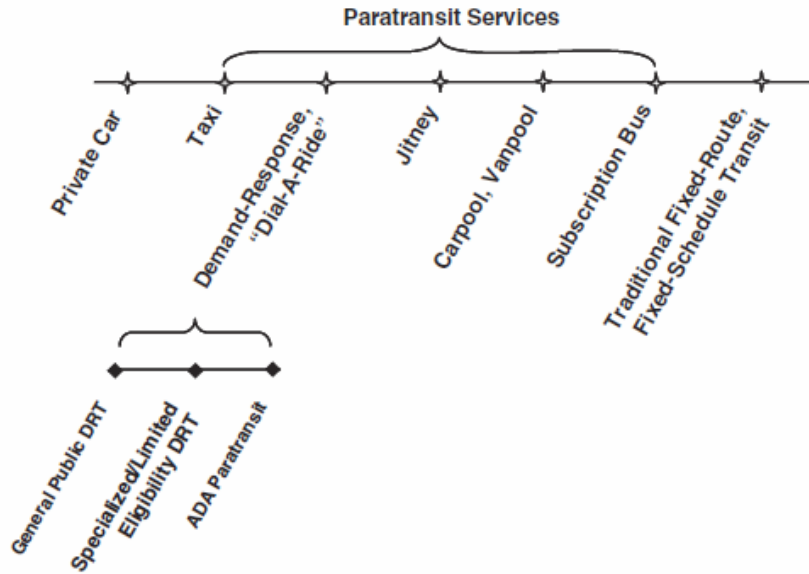


Figure 2.1 Paratransit Position in Public Transportation Services

Source: Adopted from Kirby et al,1974

Table 2.3 Comparison of Characteristics between Bus and Angkot

Characteristic	Bus	Angkot
Boarding or Alighting Points	Fixed	Not Fixed
Supply versus Demand	Supply < Demand	Supply > Demand
Congestion	Passengers in the platform	Vehicle congestion in the road
Schedule	Scheduled (headway and frequencies)	Not Scheduled
Route	Fixed	Fixed, Sometimes Flexible
Competition	No Competition	High Competition
Route Choice Behaviour	Affected by frequency	Affected by available capacity
Total Waiting Time	In the platform only	In the platform plus in vehicle idling time
Fare System	Fixed per trip but added when transfer	Based on driver's perception distance (short, medium, and far)

Source: Collected and adopted from several journals and publications

One must noted that angkot which we discuss in this study is considered as one type of paratransit due to it does not have a fixed schedule, fixed stopping place and it is operated individually or managed by route associations. But since it is legally regulated by the government under the government law no 22 Year 2009 thefefore we stated that angkot is categorized as formal paratransit.

### 2.1.3 Studies on Paratransit

In recent years, studies related to paratransit in developing countries have become more popular. Most of the researches are mostly focusing on satisfaction of service performance based on user perception. Some of the research concludes from the satisfaction level, the sustainability of paratransit can be decided. Some of the researches also examined that paratransit can be a feeder potential based on users' perspectives.

Table 2.4 List of Topics Reviewing about Paratransit

<b>Topics</b>	<b>Year Publication</b>	<b>Authors</b>
Service characteristics and position in transportation hierarchy	1996	Shimazaki and Rahman
	1998	Cervero
	1999	Regidor
	2000	Cervero
Market structures, regulations and impacts of paratransit on transportation system	2005	Diaz and Cal
	2005	Leopairojna and Hanaoka
	2007	Cervero and Golub
Paratransit's feeder potential and performance in urban transportation	2003	Okada et al
	2006	Satiennam et al
	2007	Loo
	2009	Tangphaisankun et al
Public perception as an important tool in evaluating paratransit operation and its future	2006	Joewono and Kubota,
	2009	Tangphaisankun et al
	2010	Tarigan et al
	2011	Nugroho et al

*Source: Collected and adopted from several journals and publications*

## 2.2 Study Locations

The empirical study was conducted in Bandung City, Indonesia. Bandung City as depicted in Figure 2.2 (red circle) is located in the region of West Java and constitutes the Capital of West Java. The population in Bandung City (2010) reached 2.3 million people and more than 5 million people lives in urban fringe and its surrounding cities. In 2007, there are 8,019 vehicles of public transportation in Bandung City in which 5,268 vehicles out of them are angkot.

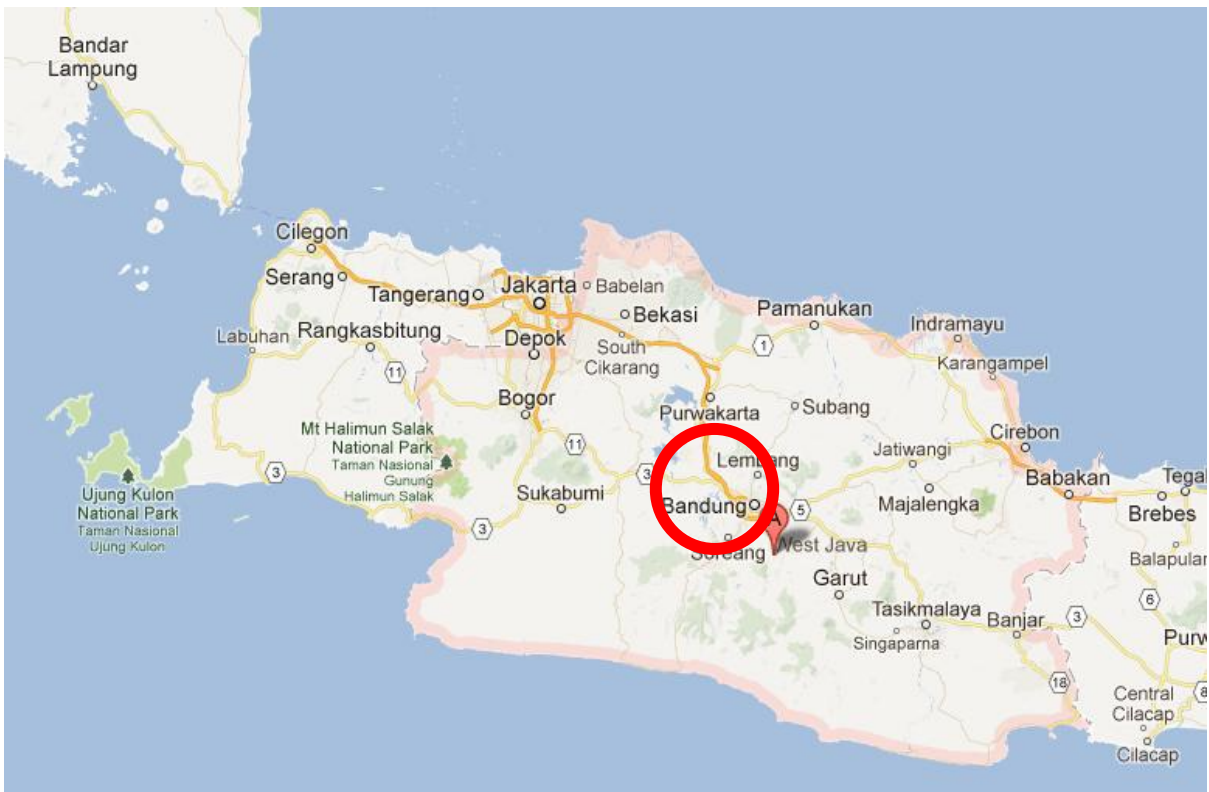


Figure 2.2 West Java Island

*Source: Google Map.*

Approximately the share is 66% out of total operated public transportation (Subdit Lalu Lintas Perkotaan, 2008). In Figure 2.3, one can easily observe that private cars are the dominating travel mode in Bandung City, and mode share of public transport

(including angkot) is only 10.12%. Bandung was dominated by paratransit (angkot) users. These are understandable since, unlike Jakarta and Jogjakarta, Bandung is a city with relatively small and hilly roads and only have 11 bus routes (compared to 38 operated paratransit routes).

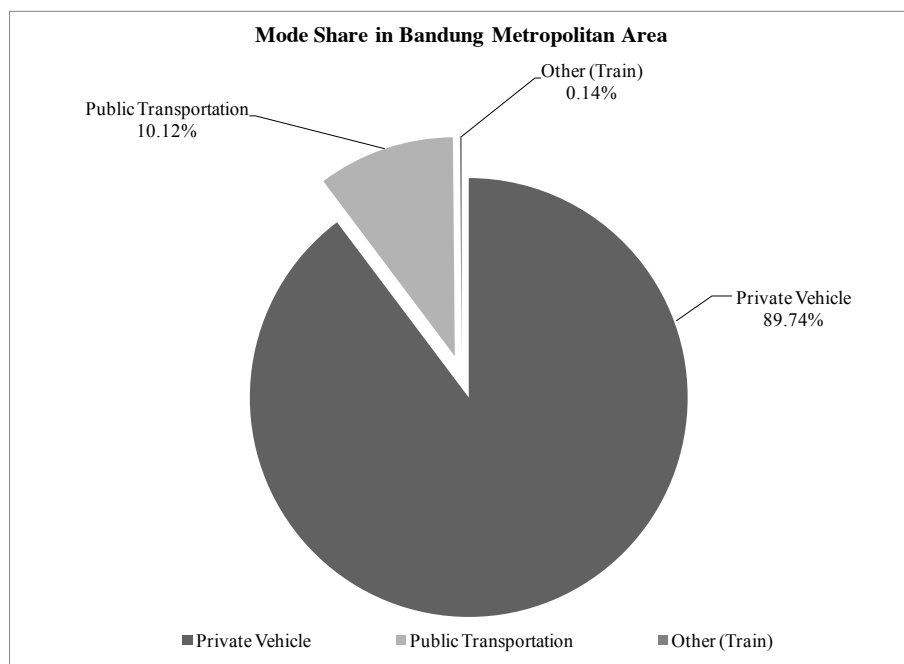


Figure 2.3 Mode Share in Bandung Metropolitan Area

Source: *Subdit Lalu Lintas Perkotaan 2008*

### 2.3 Current Angkutan Kota

Current paratransit system lacks a supervising control level, but nevertheless is not completely unorganized (Neumann & Nagel 2012). Although one-driver-companies like single car owners exist, the most common type of organization is the cooperative, also known as route association. Neumann & Nagel (2012) stated that cooperatives consist of up to hundreds of paratransit drivers, and are founded in order to fend off



renegades and pirate drivers from the cooperative's service area. Although, in most cases, protection from open competition is the main objective, there may be other objectives. Such objectives include the enforcement of minimum standards, facility sharing, or joint negotiation with the administrative or political sector. (Neumann & Nagel 2012)

Currently, there are 38 routes operated in Bandung City, which are organized by the individual operator but managed and organized by the route association or union (coop). There are three route associations in Bandung, which are KOBANTER, KOBUTRI and KOPAMAS.

1. KOBANTER (Koperasi Bandung Tertib Baru) is the largest union which controls 29 angkot routes with 4702 units, where 85.71% are inter city route. The number of angkots per route varies from 24 to 427 (Ministry of Settlement and Regional Infrastructure (Menkimpraswil), 2002). Each route-unit is supervised by a KPU (Koordinator Pengawas Unit). The KPU's functions include monitoring, controlling, protecting the interests of the operators and collecting fees and charges. The KPU's are not a force for service improvement because their primary concerns are to collect fees exclude outsiders and to ensure that the incomes of the drivers on the route are maintained. Each year an annual members meeting is held but only one representative for every 20 angkots is invited to attend. According to members interviewed, there has never been any distribution of profit to members. Income and expenditure is always shown to balance. Kobanter derives a substantial income from the charges it levies on its members. Daily and monthly charges are levied, as well as „compulsory savings“ (simpanan wajib) and „optional savings“ (simpanan sukarela), which remain

available to the member. (Ministry of Settlement and Regional Infrastructure (Menkimpraswil), 2002)

2. KOBUTRI (Koperasi Bina Usaha Transportasi Republik Indonesia) is the second largest union which builds in 1975 in Kabupaten Bandung. KOBUTRI controls 6 angkot routes with 599 units. Kobutri has a similar organizational structure. A head (Kepala Kelompok – KK) is appointed for each route whose function is to monitor and control the departure sequence, headways and routing and collect charges. The KK maintain relationships with the regulatory authorities (DISHUB, Police) and act as intermediaries in case of traffic offences and accidents. It is reported that traffic penalties are often settled by KK by illicit payments to police and DISHUB. (Ministry of Settlement and Regional Infrastructure (Menkimpraswil), 2002)
3. KOPAMAS (Koperasi Angkutan Masyarakat) is the smallest union which controls 4 angkot routes with 220 units. Kopamas has about 316 members, of which 150 are owners and the remainder drivers. It appoints a supervisor for each route, with functions similar to those of the KPU of Kobanter. Probably due to its small size, Kopamas appears to be more accountable to its members than Kobanter. All members have access to the annual meeting and full accounts are presented. (Ministry of Settlement and Regional Infrastructure (Menkimpraswil), 2002)



Figure 2.4 Road Network and Angkot Network in Bandung City

*Source: Subdit Lalu Lintas Perkotaan 2008*

As pictured in Figure 2.4 the angkot network is very dense. However, the perception of a dense network here is misleading. The high route density in the city centre partly reflects a large number of one-way links imposed by the one-way traffic circulation. Although these paratransit have long routes, but in fact the long routes do not reflect passenger demand. In the UPTP (2002) shows that the average length of passenger trips varies relatively little between routes, and in no case exceeds half the route length. While the average route length is 12.3 km, the average passenger trip is only 3.3 km with a range of 1.3 km (Route 25) to 6.0 km (Route 17). On the longest Route 35, (22.0 km) the average passenger trip is only 2.5 km. (Ministry of Settlement and Regional Infrastructure (Menkimpraswil), 2002)

The UPTP report (2002) also discussed that long routes have several negative effects, which are:

- The same capacity may not be warranted by demand at all points along the route, especially at the outer ends. This gives an incentive for operators to increase frequencies on the busy mid-sections of the route by operating “short-workings.”
- Traffic congestion at one point on the route will disrupt service levels in a distant location.
- Every owner of an angkot vehicle operating in kota Bandung must be a member of one of the three cooperatives, and each co-operative maintains an effective monopoly on access to the routes it controls. No vehicle may operate on route unless the vehicle owner or driver is a member and has paid membership fees.

Several problems that were faced by existing paratransit system are summarized in the UPTP report (2002):

1. the lack of a systematic process of monitoring demand and planning by government,
2. the lack of a procedure for operators to initiate changes in routes,
3. the fragmented structure of the angkot industry, the many territorial and operators’ groups and who establish and defend “modal territories”,
4. a highly organized system of illicit control and charging,
5. the limited power of DISHUB to negotiate changes to the network with the strong operators’ groups.

The extent of the rigidity of the network is confirmed by the fact that in the last four years (2008-2011) no new angkot route has been introduced in the city. However,

limited route development occurs by informal means for instance *becak* and *ojek*. Most angkot and DAMRI routes do not consistently follow their official routes. Variations include:

- diversions where all, or some of the vehicles divert from the approved route, turning around short before the official terminus, and
- splitting a route by inserting a mid-route interchange point, thus requiring passengers to change vehicles and pay a second fare

Number of angkutan Kota is now limited by the government due to rapid increase in several years with zero growth as listed in Table 2.5, since year 2009 until present the number is not increased or decreased.

Table 2.5 Angkutan Kota Unit Number Year 2004-2011

Year	Number of Angkutan Kota
2004	5,521
2005	5,306
2006	5,268
2007	5,491
2008	5,272
2009	5,521
2010	5,521
2011	5,521

*Source: Bandung Dalam Angka, 2005-2011*

Table 2.6 Future Recommendation for Each Angkot Route

Route No	Route Name	Operation Time	Length (Km)	Travel Time (min)	Future Recommendation
1	Abdul Muis – Cicaheum via Binong	05:30 – 20:00	29.55	146.0	Remain as Angkot
2	Abdul Muis – Cicaheum via Aceh	05:30 – 19:30	19.74	102.5	Remain as Angkot
3	Abdul Muis – Dago	06:00 – 22:00	19.11	91.0	Remain as Angkot
4	Abdul Muis – Ledeng	05:30 – 21:45	23.74	94.5	Remain as Angkot
5	Abdul Muis – Elang	06:00 – 22:00	16.16	66.0	Remain as Angkot
6	Cicaheum – Ledeng	05:30 – 20:00	26.71	111.5	Remain as Angkot
7	Cicaheum – Ciroyom	05:00 – 21:00	26.84	122.5	Medium Bus
8	Cicaheum – Ciwastra – Derwati	05:00 – 18:30	29.20	128.0	Medium Bus
9	Cicaheum – Cibaduyut	05:00 – 21:30	23.01	81.5	Remain as Angkot
10	Stasiun Hall – Dago	05:30 – 21:00	15.45	64.3	Remain as Angkot
11	Stasiun Hall – Sadang Serang	05:30 – 20:00	17.74	66.0	Remain as Angkot
12	Stasiun Hall – Ciumbuleuit via Eyckman	08:00 – 17:00	9.81	39.5	Remain as Angkot
13	Stasiun Hall – Ciumbuleuit via Cihampelas	06:30 – 18:00	15.40	61.5	Remain as Angkot
14	Stasiun Hall – Gede Bage	07:00 – 19:30	31.57	112.0	Remain as Angkot
15	Stasiun Hall – Sarijadi	05:00 – 20:00	14.45	61.0	Remain as Angkot
16	Stasiun Hall – Gunung Batu	05:00 – 19:00	17.35	72.5	Remain as Angkot
17	Margahayu Raya – Ledeng	05:00 – 19:00	40.92	149.0	Remain as Angkot
18	Dago – Riung Bandung	05:30 – 21:30	41.44	132.3	Remain as Angkot
19	Pasar Induk Caringin – Dago	05:00 – 19:30	32.00	170.5	Big Bus
20	Panghegar Permai – Dipati Ukur – Dago	05:30 – 20:00	36.82	170.0	Medium Bus
21	Ciroyom – Sarijadi	05:00 – 21:00	20.91	94.0	Remain as Angkot
22	Ciroyom – Bumi Asri	04:00 – 19:00	15.86	86.0	Remain as Angkot
23	Ciroyom – Cikudapateuh	05:00 – 22:00	22.09	111.5	Medium Bus
24	Sederhana – Cipagalo	05:00 – 19:00	25.41	108.5	Big Bus
25	Sederhana – Cijerah	05:30 – 20:30	14.36	77.0	Remain as Angkot
26	Sederhana – Cimindi	06:00 – 20:00	16.51	62.5	Remain as Angkot
27	Ciwastra – Ujung Berung	05:30 – 18:00	22.80	100.5	Remain as Angkot
28	Cisitu – Tegalega	05:00 – 22:00	16.19	76.0	Remain as Angkot
29	Cijerah – Ciwastra – Derwati	05:00 – 20:00	34.11	164.0	Remain as Angkot
30	Elang – Gede Bage – Ujung Berung	05:30 – 20:00	37.49	135.5	Medium Bus
31	Abdul Muis – Mengger	06:00 – 20:00	14.89	84.5	Remain as Angkot
32	Cicadas – Elang	06:00 – 20:30	31.42	189.5	Medium Bus
33	Antapani – Ciroyom	05:00 – 21:30	25.06	158.0	Medium Bus
34	Cicadas – Cibiru – Panyileukan	05:30 – 20:30	29.38	84.0	Remain as Angkot
35	Bumi Panyileukan – Sekemirung	05:30 – 20:00	43.90	165.5	Remain as Angkot
36	Sadang Serang – Caringin	05:30 – 21:00	34.24	140.0	Medium Bus
37	Cibaduyut – Karang Setra	05:30 – 20:00	31.08	111.5	Medium Bus
38	Cibogo – Elang	05:30 – 20:00	8.84	20.0	Remain as Angkot

Source: Subdit Lalu Lintas Perkotaan 2008

There are 11 routes are going to be replaced as Trans Metro Bandung (or Bus Rapid Transit), but the establishment of TMB is still an ongoing process (only one corridor that has been operating since 2009). Angkot will be kept in the future several for haul service and trunk (feeder) line for TMB

## **2.4 Data**

### **2.4.1 Objective Data**

A comprehensive survey was conducted in September 2011 to collect the necessary data for the analysis purposes. To simplify the discussion, we limited the study area to a radius of 1.5 km from the central station, and the surveys were conducted during morning peak hours. The paratransit network in this area is used as a case study network shown in Figure 2.6 2.5. The survey was done 4 times which are pilot survey, survey field locations 1, 2 and 3. The list of comprehensive and parallel surveys are:

1. Manual Traffic Counting, using classified manual counting to obtain the traffic volume for each type of vehicle and obtained the frequency of each selected angkot pass by the observe point.
2. Static survey, Observing boarding and alighting passengers to obtained the information of Origin and Destination (O-D) of each passengers in each observed segments.
3. GPS survey: This survey using GPS device, which installed in the angkot vehicle. For each route/ direction in a one day period and the number of samples are 10 samples. This is to obtain day to day variation of driver's activity. Only 8 paratransit lines in

the network are selected. In the future, these lines will not be changed to public bus lines or eliminated by the local government (Subdit Lalu Lintas Perkotaan, 2008); therefore, these lines are chosen for this study.

Table 2.7 Selected Paratransit Lines

Route No	Id Route	Routes/ Lines	Capacity (passengers)	Headway (1/minute)*	Number of Vehicle**
24	0	Kalapa-Sukajadi	14	0.833	276
32	1	Cicadas – Elang	14	0.909	300
10	2	St. hall – Dago	14	2.608	52
12	3	St. hall-Ciumbeluit via Eyckman	14	2.142	53
24	4	Sukajadi – Kalapa	14	0.495	276
28	5	Cisitu – Tegalega	14	1.714	82
13	6	St. hall-Ciumbeluit	14	2.142	30
14	7	St.Hall – Gedebage	14	1.200	200

Source: \*Field survey; \*\* Ministry of Transportation, 2010.

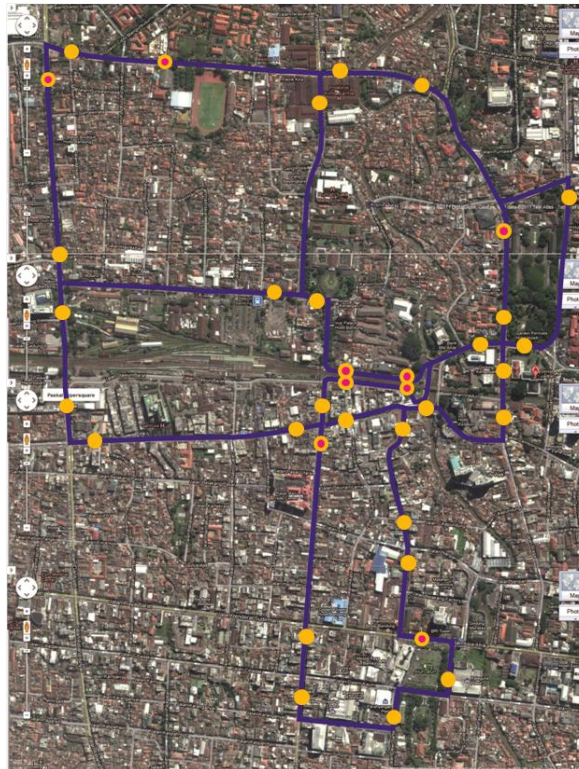


Figure 2.5 Manual Traffic Counting Locations in the Network

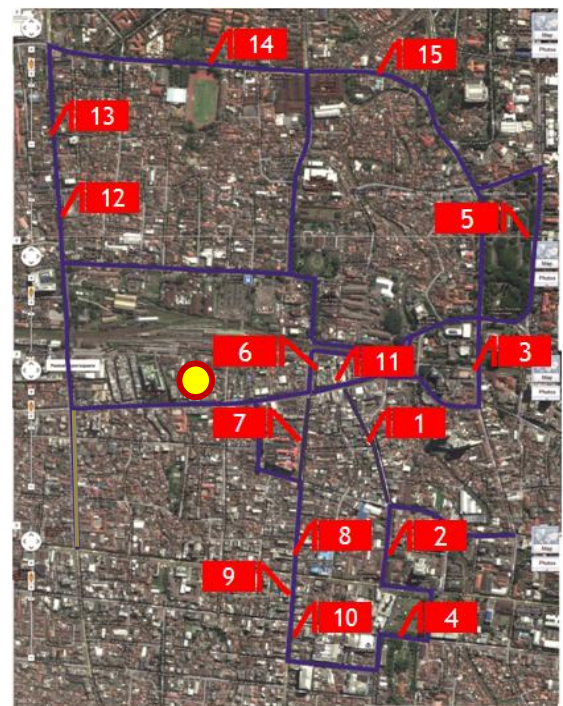


## A. Traffic Data

Traffic volume data were collected during a period of two hours (6:00–8:00 am) from manual traffic counting surveys on each link observed. For each road link, we identified the time of the peak traffic volume. We then overlapped the 45 minutes before and after the peak time for all road links. We define the overall result as the peak hour. As a result, the time from 7:00 to 8:00 am is obtained as the morning peak hour for all road links. From the manual traffic counts, the frequency of angkot vehicle use of each line could also be determined. The traffic volume data collected indicate that the volume of paratransit vehicles is 10–15% of the total traffic volume and the exact percentage varies by link.

Table 2.8 Link Number and Road Name

Link No.	Road Name	No of Lanes
1	Banceuy Street	2/1 UD
2	ABC Street	2/1 UD
3	Braga Street	2/1 UD
4	Dewi Sartika Street	3/1 UD
5	Merdeka Street	3/1 UD
6	Otista Street (North)	2/1 UD
7	Otista Street (South) I	3/1 UD
8	Otista Street (South) II	2/1 UD
9	Otista Street (South) III	2/1 UD
10	Otista Street (South) IV	2/1 UD
11	Suniaraja Street	2/1 UD
12	Pasirkaliki Street (North) II	4/1 UD
13	Pasirkaliki Street (North) I	4/1 UD
14	Pajajaran Street	4/1 UD
15	Perintis Kemerdekaan Street	2/1 UD



Central Station

Figure 2.6 Link Number in The Network

The capacity of each link and the free-flow travel time are calculated as recommended in the Indonesian Highway Capacity Manual (IHCM). In accordance with the IHCM, motorcycles were assigned passenger-car-equivalent values of 0.25 and trucks and buses were assigned passenger-car equivalent values of 1.2. The geometric data used in the calculations consisting of the lane width and number of lanes are obtained from the secondary data provided by the Bandung Transportation Agency.

Table 2.9 Traffic data

Link No	Link Name	Survey date	Link Length GPS	No of lanes	Effective Lane Width	Capacity 2000* (pcu/hour)	Practical Capacity IHCM (pcu/hour)	Practical Free Flow Speed	Traffic Volume		On Street Parking	Angkat route
									Morning	Afternoon		
1	Banceuy (Post Office - Jl. ABC)	19/09	238	2/1 UD	6	2064.5	2216.3	37	1698	1512	N	2,3,6
2	Banceuy (Jl. ABC - Jl. Suniaraja)	19/09	84	2/1 UD	6	2064.5	1108.1	37	923	797	Y	2,3
3	Braga Street (ASTON Hotel)	15/09	260	2/1 UD	6	2064.5	2216.3	37.23	2381	2346	N	2,3,5,6
4	Dewi Sartika Street (KINGS - Alun-alun)	19/09	220	3/1 UD	9	3066.7	2409.0	41.61	3197	2244	Y	2,3,6,7
5	Mendela Street (Intersection - Indonesian Bank)	15/09	436	3/1 UD	10	3231.4	3324.4	38.69	2501	4396	Y	5,6,7
6	Otista (North)	21/09	490	2/1 UD	10	2707.7	2409.0	40.15	1962	1779	Y	1,2,5,7
7	Otista (South) I (Intersection - Jl. ABC)	21/09	292	3/1 UD	12	2429.5	2216.3	38.69	1880	1411	Y	1,2,3
8	Otista (South) II (Jl. ABC - Jl. Asia Afrika)	21/09	69	2/1 UD	8	2429.5	1445.4	43.07	1795	1318	Y	1,2,3
9	Otista (South) III (Jl. Asia - Afrika - Jl. Dalam Kaum)	21/09	156	2/1 UD	8	2429.5	1445.4	43.07	1817	2431	Y	1,2,3
10	Otista (South) IV (Jl. Dalam Kaum - Jl. Kepatihan)	21/09	115	2/1 UD	8	2429.5	1445.4	43.07	1375	1783	Y	1,2,3
11	Suniaraja Street (Jl. Banceuy - Jl. Otista North)	19/09	220	2/1 UD	7	1972.0	1975.4	36.5	1992	1722	Y	1,3,4,7
12	Pasirkaliki (North) I (Jl. Semar - Intersection Istana Plaza)	21/09	330	4/1 UD	12	4078.1	3324.4	38.69	3182	3146	Y	1,3,4,8
13	Pasirkaliki (North) II (Jl. Kebon Kawung - Intersection Jl. Semar)	21/09	330	4/1 UD	12	4078.1	3324.4	38.69	3182	3146	Y	1,3,4,8
14	Pajajaran Street (Dr. Otten - Cioendo)	21/09	100	3/1 UD	12	3706.6	4432.6	38.69	2848	2183	Y	1,3,8
15	Perintis Kemerdekaan (Indonesian Bank - Jl. Wastukencana)	15/09	216	2/1 UD	7	1967.9	2706.0	45.1	1990	1909	N	5,6

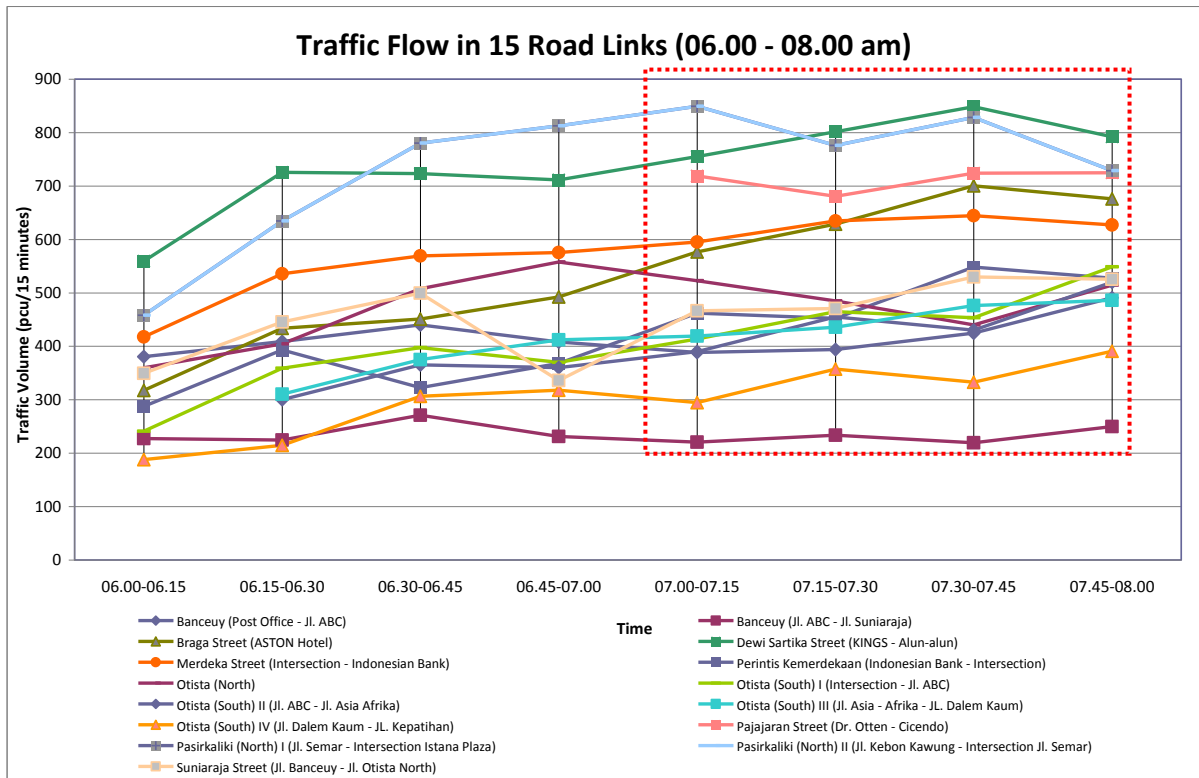


Figure 2.7 Traffic Volume in Morning Peak (15 Lines)

## B. GPS Probe Survey

A GPS-based probe vehicle (i.e., paratransit) survey was conducted to determine the actual travel time and driving route of each link. The probe vehicle survey was conducted by installing GPS devices in 80 paratransit fleets for one day (within working hours). From the GPS-based probe vehicle survey, we could obtain the driving route and link distance between each stopping place. From the GPS probe data, one can observe paratransit driver stopping behavior, stopping places, the number of stops per road segment and also whether a driver's stopping behavior is repetitive. Surprisingly, despite the widely held belief that paratransit vehicles will stop almost anywhere, their stopping places tend to fall into two categories, namely, fixed and random places. Random

stopping places usually are located only on the road links exiting the central station/terminal where the majority of the paratransit vehicles line up and idle to wait for passengers. The presumption that angkot will stop almost anywhere is unconfirmed. Surprisingly, drivers tend to stop at places that are predictable to them and also to the passengers. Drivers' decision-making on where to stop is a repetitive behavior to which passengers become accustomed

Based on the GPS probe data, the fixed stopping places are identified if, in one road segment, a paratransit vehicle usually stops at a point repeatedly, followed by another paratransit vehicle. Although the exact locations of fixed stopping places sometimes vary within  $\pm 10$  meters, in this study, we still considered such points to be fixed stopping places. If paratransit vehicles pass a road segment without showing any repetitive or similar stopping behavior, stopping places along that road segment are categorized as random stopping places. These random stopping places are considered different stopping points even though the distances between them may be very short ( $\pm 100$  meters).

### **C. Origin-Destination (O-D) Passengers**

The survey of passengers boarding and alighting was conducted to obtain the origin-destination (O-D) pairs required to develop the O-D matrix of the network. At each observed stopping place, the plate number of each paratransit vehicle, the arrival time of the vehicle, the numbers of passengers boarding and the number of passengers alighting were recorded. Road links are segmented into 50-meter intervals. More passengers board and alight at nodes 0, 8, 15 and 44 than at the other nodes in the

network. Node 15 corresponds to the central station (Station Hall), and node 8 corresponds to the central railway station.

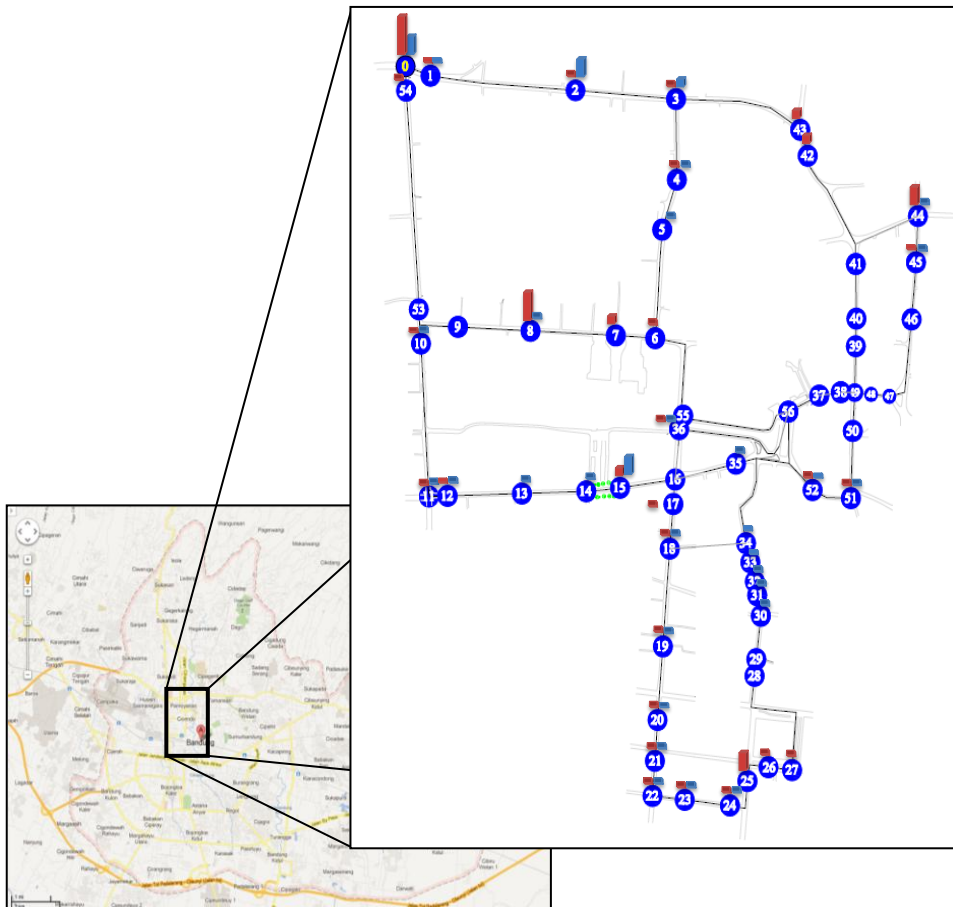


Figure 2.8. Paratransit Network and Passenger Distributions

#### 2.4.2 Subjective Data

Data was collected by a questionnaire survey based on a face-to-face interview on September 2011 from 152 drivers, who were randomly selected from each route. The questionnaires are divided into four parts: one-day trip diary, vehicle operating cost (e.g., fuel cost, vehicle rental fee, fuel type), driver's individual attributes (e.g., age, gender), and driver's satisfaction with the six life domains (i.e., work, residence, health, family, social life, and leisure (free time)). One-day trip diary is recorded by asking drivers to

report each trip they made and number of passengers they transported, distance travelled, travel time and daily income.

Table 2.10 Characteristics of drivers based on questionnaire survey data

Latent Variable	Observed Variable	Definitions	Mean	Std Dev
Individual Attributes	Age	< 55 years old = 0 (84%) ≥ 55 years old = 1 (16%)	43.00	10.10
	Education level	Lower than junior high school = 1 (68%) Higher than junior high school = 2 (32%)	1.29	0.45
Work Performance	Number of round trips	Number of round trips per day	7.92	0.82
	Service time (minutes) (Modeled in categorical)	The length of time a driver provides to passengers per day	694.73	80.20
	Driver's waiting time (minutes)	Average time to wait for passengers	24.10	6.33
	Gap revenue (Rp.)	Actual revenue – Minimum daily revenue	16,569	26,962
	Service distance (km)	Distance traveled per day	104.50	28.50
Environmental Impacts	Fuel cost (Rp.)	Fuel cost spent per day	84,160	10,401
	Vehicle age (years)	Vehicle age (years)	7.91	0.80
Basic Level of QOL	Satisfaction with Work	Measured with a 4-point scale: 1 – very dissatisfied; 2 – dissatisfied; 3 – neutral; 4 – satisfied;	2.83	0.36
	Satisfaction with Health		2.76	0.54
	Satisfaction with Residence		2.97	0.76
Higher Level of QOL	Satisfaction with Social Life		2.67	0.73
	Satisfaction with Free Time		2.75	0.59
	Satisfaction with Family		2.97	0.73

The entire drivers are male, 84% of whom are less than 55 years old, and about 68% of drivers have not received proper education (the education level is lower than junior high school). The average daily revenue observed from the questionnaire survey is about Rp.37,824/day or around Rp.1,100,000/month (120 US dollars). Surprisingly, this average daily revenue was even lower than the minimum standard wage in Bandung City,

which is Rp. 1,123,800/month based on the “Governor Verdict no. 561/Kep. 1564-Bansis/2010”. The detailed information is summarized in Table 2.10, where observed variables are shown under each latent variable.

## 2.5 Methodology

### 2.5.1 Multilevel Models

Multilevel models have gained wide acceptance over the past 20 years in many fields (Leeuw & Meijer, 2008), as an important methodology for dealing appropriately with nested and clustered data. Hox (1995) explained that in multilevel research, the data structure in the population is hierarchical, and the sample data are viewed as a multistage sample from this hierarchical population. In multilevel research, variables can be defined at any level of the hierarchy. Some of these variables may be measured directly at their natural level; In Hox (1995) books, Lazarfeld and Manzel give a typology to describe the relations between different types of variables, defined at different levels

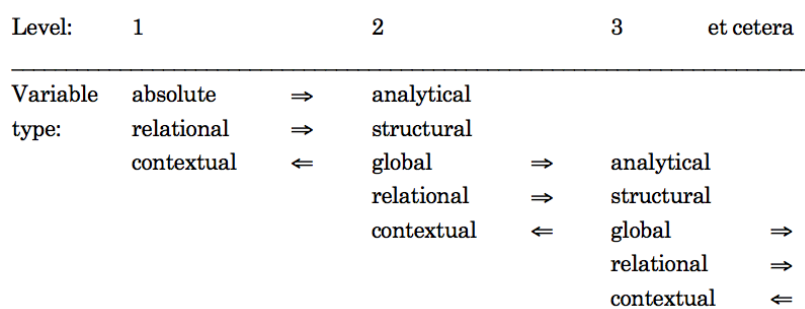


Figure 2.9. The hierarchy of the variable adopted from Hox (1995)

In this scheme, the lowest level (level 1) is usually formed by the individuals. However, this is not always the case. (Goldstein, 2010), for instance, defines roles within



individuals as the lowest level, and in longitudinal designs one can define repeated measures within individuals as the lowest level. At each level, we have several types of variables. Global and absolute variables refer only to the level at which they are defined, without reference to any other units or levels ('absolute variables' is simply the term used for global variables defined at the lowest level).

Relational variables also refer to one single level; they describe the relationships of a unit to the other units at the same level. Many socio metric indices (such as indices of popularity of indices of the reciprocal of relationships) are relational variables. Analytical and structural variables are measured by referring to the subunits at a lower level. Analytical variables refer to the distribution of an absolute or a global variable at a lower level, for instance to the mean of a global variable from a lower level. Structural variables refer to the distribution of relational variables at the lower level; many social network indices are of this type. Constructing an analytical or relational variable from the lower level data involves aggregation (indicated by  $\Rightarrow$ ): data on lower level units are aggregated into data on a smaller number of higher level units. Contextual variables, on the other hand, refer to the super units; all units at the lower level receive the value of a variable for the super unit to which they belong at the higher level. This is called disaggregation (indicated by  $\Leftarrow$ ): data on higher level units are disaggregated into data on a larger number of lower level units. The resulting variable is called a contextual variable, because it refers to the higher level context of the units we are investigating (Hox 1995)

In our study, it is expected that the LiP might vary across links and over the time of a day as well as side frictions. To effectively clarify such features of the LiP, here, a

multilevel modeling approach is applied, where the above variations factors are represented by introducing additional error terms in the original regression model. The time of a day is divided into peak and off-peak hours. Next, we estimated two models: one without any explanatory variables (called the Null Model) and the other with explanatory variables (called the Full Model). The established multilevel models are estimated using the Markov Chain Monte Carlo (MCMC) procedure, respectively.

*Null model*

$$\begin{aligned} y_{ij} &= \beta_{0ij} \\ \beta_{0ij} &= \beta_0 + u_{0j} + e_{ij} \end{aligned} \quad (1)$$

*Full model : random intercept model*

$$\begin{aligned} y_{ij} &= \beta_{0ij} + \beta_1 x_{1ij} \\ \beta_{0ij} &= \beta_0 + u_{0j} + e_{ij} \end{aligned} \quad (2)$$

*Full model : random intercept and slope model*

$$\begin{aligned} y_{ij} &= \beta_{0ij} + \beta_{1j} x_{1ij} \\ \beta_{0ij} &= \beta_0 + u_{0j} + e_{ij} \\ \beta_{1j} &= \beta_1 + u_{1j} \\ u_{0j} &\sim N(0, \Omega_u) \\ u_{1j} & \\ e_{oij} &\sim N(0, \Omega_e) \end{aligned} \quad (3)$$

where

$\beta_0, \beta_1, \beta_2$  : the unknown parameters

$x_{ij}$  : the independent variable ( $i$  – individual,  $j$  – second level variation)

$y_{ij}$  : the dependent variable

$u$  : random effect variables

: the error term, it is estimated by calculating residuals.

## 2.5.2 Structural Equation Modeling

There are many terms and concepts associated with structural equation modelling. Following are some, most often used in “causal-modelling”, though many of them also apply to the other forms of structural equation modelling, path analysis and confirmatory factor analysis.

### A. Terminology

1. Cause, equivalent to regression. A variable (A) is said to be caused by another variable (B) if it is significantly regressed on that variable. Note this is not equivalent to cause as generally understood.
2. Indicator variable, a measured variable
3. Latent variable, a factor that represents an aggregate of two or more indicator variables.
4. Exogenous variable A (latent or indicator) variable that has no cause in the model (i.e., is not regressed on any other variable). It can correlate with other exogenous variables or can “cause” (endogenous) variables.
5. Endogenous variable, A (latent or indicator) variable that is caused by exogenous or endogenous variables.
6. Measurement model, The model linking the indicator variables to the latent variables. The index of this link is a factor loading.
7. Structural model, The model linking endogenous variables to other endogenous and exogenous variables by means of regression coefficients, and exogenous variables to

other exogenous variables by means of correlation coefficients. In most cases, the variables are latent variables as defined by the measurement model.

## **B. Identification**

Identification is a critical condition for structural equation modeling, and although it is fairly straightforward to define, it can often be very difficult to determine. Identification refers to whether or not the estimates in the model are uniquely determined. A necessary precondition for identification is that the degrees of freedom are greater than 0. If the degrees of freedom are equal to 0, the model is said to be just identified, and the model perfectly reproduces the sample covariance matrix (i.e.,  $\chi^2 = 0$ ). Such a model has little value because there is in truth no estimate of error for the model and its generality cannot be determined. If there are fewer than 0 degrees of freedom, the model is said to be under-identified and the parameters cannot even be estimated. This is a very minimal condition, however, and there are other factors that can influence the identifiability of the model. AMOS can detect many of them and if it does it prints the statement “This model is inadmissible”. Often this is associated with negative variance estimates, but sometimes the program detects a potential problem at which it prints that “some parameters may not be identified”. (It is even possible that such a warning may not be given and the model may still not be identified). It is possible that a model that obtains such warnings can be modified to overcome the problem, but this isn’t always the case. Generally, AMOS guards against obvious errors. Thus, for each latent variable, it is necessary to fix the loading of an indicator variable at 1 (this is automatically done if the

instructions given below for running AMOS are followed). It is also necessary to have 1's associated with the measurement errors and with the disturbance terms.

### C. Structural Model

Structural equations model systems are generally defined by the matrix equation system. Consider random vectors are  $\eta' = (\eta_1, \eta_2, \dots, \eta_m)$  and  $\xi = (\xi_1, \xi_2, \dots, \xi_n)$  of latent dependent and independent variables, respectively, and the following system of linear structural relations is:

Structural Equation Model

$$\eta = B\eta + \Gamma\xi + \zeta \quad (4)$$

Measurement model for y

$$y = \Lambda_y\eta + \varepsilon \quad (5)$$

Measurement model for x

$$x = \Lambda_x\xi + \delta \quad (6)$$

Where B (m x m) and  $\Gamma$  (m x n) are coefficient matrices and  $\zeta' = (\zeta_1, \zeta_2, \dots, \zeta_m)$  is a random vector of residuals. The elements of B represent direct effects of  $\eta$  variables to other  $\eta$ -variables and the elements of  $\Gamma$  represent direct effects of  $\xi$ -variables and  $\eta$ -variables. It is assumed that  $\zeta$  is uncorrelated with  $\xi$  and that  $I - B$  is non singular. Vectors  $\eta$  and  $\xi$  are not observed, but instead vectors  $y = (y_1, y_2, y_3, \dots, y_p)$  and  $x = (x_1, x_2, x_3, \dots, x_q)$  are observed.

### D. Measures of Goodness of Fit

There are many measures of goodness of fit of the model. One measure is common to many of them. That is, the  $\chi^2$  measure of goodness of fit. Generally, a good

model would be one where the  $\chi^2$  is roughly equal to the degrees of freedom, but a commonly accepted index is  $\chi^2/df < 2$ . A  $\chi^2$  that is not significant indicates that the fit is fairly good, though there are other measures that have also been proposed. These can be classified in terms of:

1. Comparative Fit, for these indices, the  $\chi^2$  for the model (or some function of it) is compared with the  $\chi^2$  (or some function of it) for a model assuming independence. Examples are NFI, NNFI, IFI, CFI, and RMSEA.
2. Absolute Fit, these indices contrast the  $\chi^2$  for the model with the degrees of freedom for the model. An example is MFI.
3. Proportion of Variance, these indices assess the proportion of variance for the covariance matrix based on the estimated parameters with the original covariance matrix. Examples are GFI, AGFI.
4. Parsimony Fit, these indices take into account the degree of parsimony or complexity of the model. Examples are PGFI, AIC, CAIC.
5. Residual-Based Fit, these indices are based on the difference between the values in the original covariance matrix (S) and those in the covariance matrix (E) calculated on the basis of the estimated parameters. An example is RMR.

### **2.5.3 Optimization Programming Approach**

In the early stages of the research on bus transit route network design problems, traditionally the optimization models are developed to solve very effectively the optimization-related problems for networks of small size and were primarily applied to determine one or several design parameters (e.g., stop spacing, route spacing, route

length, service coverage, bus size and/or frequency of service) on a predetermined transit route network structure (Fan & Machemehl, 2011).

The general optimization programming formulation can be stated as follows:

Upper level :

$$\begin{aligned} \min F, v(\cdot) & \quad (7) \\ \text{subject to } G, v(\cdot) & \leq 0 \end{aligned}$$

Where  $v(\cdot)$  is simplicity defined by:

Lower level:

$$\begin{aligned} \min f, v(\cdot) & \quad (8) \\ \text{Subject to } g, v(\cdot) & \leq 0 \end{aligned}$$

Where:

$F$  = objective function of the upper-level program

$v$  = decision variables of the upper level

$G$  = constraint set of the upper level

$f$  = objective function of the lower-level program

$v$  = decision variables of the lower level

$g$  = constraint set of the lower level.

The development history of optimization model of bus transit route network is listed in

Table 2.11

Table 2.11 Development History of Optimization

<b>Author's Name</b>	<b>Year</b>	<b>Descriptions</b>
Claude Chriqui & Pierre Robillard	1974	Definition of common lines Determination of the expected travel time as an optimization problem
Nguyen and Pallotino	1988	Hyperpath → graph theoretical language
De Cea & Fernandez	1993	Advanced a model that considers limited line capacity. They concentrate congestion at the transfer nodes and a BPR-type function is used to estimate the wait at each transfer node in terms of the “through flow”-to-capacity ratio. Consider important drawbacks for example includes the flow inside the bus and flow outside/ incoming Between transfer nodes is not guarantee following the wardrop equilibrium
Roberto Cominetti & Jose Correa	2001	They presented a framework for congested transit assignment that can incorporate congestion functions obtained from queuing models. The link of waiting time is defined as equal to the inverse of the “effective frequency”, which is itself expressed as a function of the vector of link flows. However, they assumed that the arrival rates of passengers are stable during the period $\Delta t$ travel; hence if we take this period to be an entire day, demand is apparently smaller than the capacity, even if this is not true during peak periods. The model is Network equilibrium model with congestion which the congestion effects includes waiting time & flow distribution
Schmöcker, Jan-Dirk et al	2002	They proposed a time-dependent network loading approach so that passengers who failed to board in one period are carried forward to the next time interval. However, their model does not implement the common-lines problem
Kurauchi et al	2003	Implemented the common-lines problem in the model proposed by Schmöcker et al
Shimamoto et al	2005	Evaluating the effect of transit fare systems on passengers' behaviour using
Schmöcker, Jan-Dirk et al	2011	Frequency-based transit assignment considering seat capacities

Source: Compiled from several journals and publications

The public transportation network design/redesign problem can be posed as a Stackelberg game (Fan & Machemehl, 2011; Fernández et al., 2008) and generally formulated as a bi-level optimization problem to reflect the different aims of two decision makers: the transit network planner and transit users (Fan & Machemehl, 2011).



Theoretically in this model the transit network planner (or leader) is assumed to have knowledge of how the transit users (or follower) would respond to a given strategy (decision on the transit network routes and frequency settings). In the common application mostly the transit users (or follower) are free to choose their routes such that their individual total travel costs (or time) and/or number of transfers are minimized, whereas the transit network planner (or leader) aims to make the best use of limited resources to optimize/improve network performance (e.g., reducing system travel time, minimizing environmental impact, maximizing ridership, etc.), while taking into account users' route choice behavior (Fan & Machemehl, 2011).

#### 2.5.4. Existing Optimization Modelling Studies

In general, the frequency design problem can be described as a bi-level optimization model based on the non-cooperative Stackelberg game (Fernández, de Cea, & Malbran, 2008).

The model developed in previous study is formulated as a bi-level optimization problem, where the lower-level problem is a transit assignment model with common lines (Kurauchi, Bell, & Schmöcker, 2003), as the upper-level problem has the following formulation:

$$\min_{\mathbf{r}, \mathbf{f}} \psi_m(\mathbf{y}, \mathbf{q}, \mathbf{r}, \mathbf{f}), m=1, \dots, M \quad (9)$$

such that

$$(\mathbf{y}^*, \mathbf{q}^*) \text{ satisfy (user equilibrium)} \quad (10)$$

$$C_l(\mathbf{r}_l) \leq C_l^{\max} \quad (11)$$

$$\sum_{l=1}^{|L|} f_l C_l(\mathbf{r}_l) \leq NV \quad (12)$$

where  $\mathbf{f}$  is a vector of the frequencies of each line (decision variables) and  $\psi_m$  are the objective functions. Following the example of Shimamoto et.al. (2010), we adopt two objective functions as follows:

$$\psi_1(\mathbf{y}, \mathbf{q}, r, \mathbf{f}) = \sum_{l=1}^L f_l C_l(\mathbf{r}_l)^2 \quad (13)$$

$$\psi_2(y, q, r, f) = \sum_{rs \in W} \sum_{p \in h_{rs}^*} y_p \cdot g_p(y, q) \quad (14)$$

Eq. 13 and Eq. 14 represent the operators' costs and passengers' costs, respectively. Note that we only consider direct costs in the operators' costs. Eq. 10 means that the passengers' flow should satisfy the UE condition. In this study, passengers are assumed to choose their route to minimize the following cost:

$$g_p = \sum_{a \in A_p} \alpha_{ap} c_a + \eta w \sum_{k \in S_p} \frac{\beta_{kp}}{\sum_{a \in OUT_p(k)} f_l(a)} - \theta \ln \left( \prod_{k \in F_p} (1 - q_k)^{\beta_{kp}} \right) \quad (15)$$

The first and second terms represent the moving cost and the waiting cost, respectively, at the platform.  $C_a$  represents the cost of arc  $a$ .  $\alpha_{ap}$  and  $\beta_{kp}$  represent the probabilities that passengers on hyperpath  $p$  traverse arc  $a$  and node  $k$ , respectively. As Eq. 15 can be separated by the subsequent node, Bellman's principle can be applied to find the minimum-cost hyperpath. Finally, the CapCon-CL is formulated with a complementarity problem involving hyperpath flows and failure-to-board probabilities that satisfy both user equilibrium and capacity constraint conditions. The complementarity problem can be solved by combining the method of successive averages and absorbing Markov chains (see Kurauchi et al. 2003).

## A. Operator Costs

In previous study Ibeas et al (2006) defined that the operator's cost are taken to be the sum of all the direct costs (DC) plus the indirect costs (IC). The direct costs are made up three factors; rolling costs (km covered) (CK), hourly costs due to standing still with the engine running (CR), personnel costs (CP), and fixed costs (CF). His studies have shown that the indirect costs (exploitation, human resources, administrative-financial, depot and supplies, management and general costs) tend to be about 12% of the direct cost (Ibeas et al, 2006).

The total cost of the kilometres covered will be equal to:

$$CK = \sum_l L_l f_l \sum_k CK_{kl} \quad (16)$$

where

$L_l$  = length of route l (km per bus)

$f_l$  = frequency of route l (bus per hour)

$CK_k$  = unit costs per kilometre covered by bus type k ( monetary value per km)

$_{kl}$  = mute variable worth 1 if bus type k is assigned to route l and 0 if not.

The cost of buses being stationary with the engine running will depend on the time they spend at bus stop dealing with passengers:

$$CR = (t_{sb} / 60) \sum_l \sum_k CR_k \times \text{---} \times Y_l \quad (17)$$

Where

$t_{sb}$  = average time for passengers getting on and off the bus (min per passenger)

$CR_k$  = unit cost per hour of bus type standing still with engine running (monetary value per hour)

$Y_l$  = journey demand on line  $l$  (passenger per hour)

While in Shimamoto et al (2010) study, they formulated all direct costs with the exception of CR as being proportional to total mileage. Thus, if CR is ignored for simplicity, operator cost can be regarded as proportional to total mileage, as shown in Eq. 13. The total mileage for the operator is the sum of the product of line frequencies and square of the line length, because the sum of the product of line frequencies and line length (the left-hand term of Equation (12)) represents the number of vehicles required to operate line  $l$ , multiplied by the cost for each line.

### **B. Lower Level Problem (User equilibrium)**

The transit-planning problem discussed here can be formulated using the MPEC (mathematical programming with equilibrium constraints) problem, as shown in Equation (9) and Equation (10). Let us assume that passengers use a hyperpath of minimum cost in Eq.15. Therefore, the transit assignment model can be formulated as a fixed-point problem, which defines the equilibrium

Find  $(\mathbf{y}^*, \mathbf{q}^*)$  such that

$$\mathbf{y}^* \cdot \mathbf{u}(\mathbf{y}^*, \mathbf{q}^*) = \mathbf{0} \quad , \quad \mathbf{u}(\mathbf{y}^*, \mathbf{q}^*) \geq \mathbf{0} \quad , \quad \mathbf{y} \in \Omega \quad (18)$$

$$\mathbf{q}^* \cdot \mathbf{v}(\mathbf{y}^*, \mathbf{q}^*) = \mathbf{0} \quad , \quad \mathbf{v}(\mathbf{y}^*, \mathbf{q}^*) \geq \mathbf{0} \quad , \quad \forall \mathbf{0} \leq \mathbf{q} \leq \mathbf{1} \quad (19)$$

Where

$$u_p(\mathbf{y}^*, \mathbf{q}^*) = g_p(\mathbf{y}^*, \mathbf{q}^*) - m_{rs}^* \quad (20)$$

$$v_{kl}(\mathbf{y}^*, \mathbf{q}^*) = f_l z_l - x_{w_{kl}} - (1 - q_{h_{kl}}) x_{b_{kl}} \quad (21)$$

As shown in Equation (20),  $u$  denotes a vector of the cost difference between  $g_p(\mathbf{y}^*, \mathbf{q}^*)$  and the minimum cost from the origin of hyperpath  $p$  ( $r$ ) to the destination ( $s$ ).

Therefore, Equation (18) represents the user equilibrium condition. Moreover, as shown in Equation (21),  $v$  denotes the vector of vacancies on the line arc on line  $l$  from platform  $k$ . Therefore, Equation (19) represents the capacity constraint condition. The existence of a fixed point is intuitive, since any excess demand simply implies non-zero failures to board. However, because of the non-linear relationship in Equation (19), there is a possibility of multiple fixed points. This fixed-point problem can be solved by combining the method of successive averages and absorbing Markov chains (Kurauchi et al., 2003).

#### **D. Non-Dominated Sorting Genetic Algorithm II (NSGA-II)**

Many authors have proposed methods to tackle the multi-objective optimisation problem. To solve the upper problem formulated in the previous section, we utilise the elitist non-dominated sorting Genetic Algorithm (GA) proposed by Deb et al. (2000), which requires fewer parameters than other methods. Note that the result might be biased because of the possibility of multiple fixed points in the CapCon-CL. This bias is well known in MINLP (Mixed Integer Non-linear Programming) and is still a challenging problem

#### **Overview of the Procedure**

NSGA-II is based on the GA (Genetic Algorithm) and the algorithm is outlined below:

(1) Initialisation

$t:=0$

**Set** a random (parent) population ( $P_0$ ) of charging level ( $s$ ) of size  $N$ ;

(2) Create offspring population

Create offspring population  $Q_t$  (Size N) from  $P_t$  using binary tournament selection (with a crowded tournament operator described later) and crossover and mutation operators;

(3) Combine  $P_t$  and  $Q_t$

Combine parent and offspring population and create  $R_t = P_t \cup Q_t$ ;

Perform non-dominated sorting (described in the next section) of  $R_t$  and identify fronts:  $F_i, i=1,2,\dots$

(4) Selection

$i:=1$ ;

**Set** a new population  $P_{t+1} = \emptyset$ ,

**While**  $|P_{t+1}| + |F_i| < N$ , perform  $P_{t+1} = P_{t+1} \cup F_i$  and  $i:=i+1$ ;

(5) Crowding distance sorting

**If**  $|P_{t+1}| + |F_i| > N$  **then**

Perform the crowding-sort procedure (described later);

Eliminate  $(|P_{t+1}| - N)$  solutions in worse order of crowding distance value;

(6) Iteration

$t:=t+1$ ;

**Repeat** (2) to (6) until  $t$  reaches the fixed number of iterations.

Since all previous and current members are included in  $R_t$  at procedure (3), elitism is ensured in NSGA-II

### **Non-domination Sort**

The goal for this multi objective optimization problem is to find *pareto front*, which is a set of non-dominated solutions. Given a set of objective functions,  $f_1, \dots, f_m$  (assuming the minimisation of all objectives without loss of generality), a solution,  $x^{(1)}$ , is said to dominate another solution,  $x^{(2)}$ , if both of the conditions below are satisfied:

- a) Solution  $x^{(1)}$  is no worse than  $x^{(2)}$  in all objectives, or  $f_m(x^{(1)}) \leq f_m(x^{(2)})$  for all  $m$ ,  
and
- b) Solution  $x^{(1)}$  is strictly better than  $x^{(2)}$  in all objectives, or  $f_m(x^{(1)}) < f_m(x^{(2)})$  for at least one  $m$

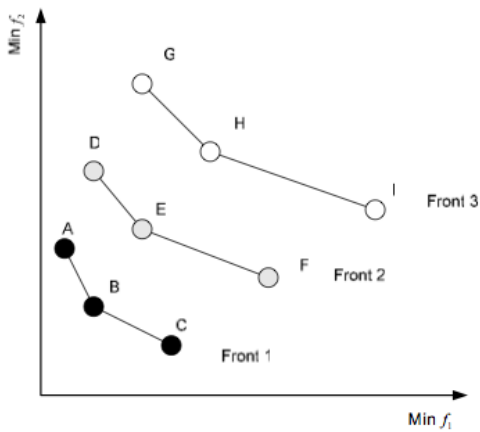


Figure 3. Non-dominating Levels

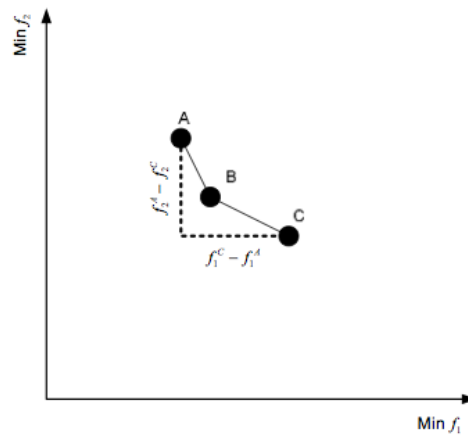


Figure 4. Crowding Distance

In NSGA-II, the population is sorted into different non-dominated levels. Figure 3 shows an example of this process for a problem with two objective functions. The axis shows the values of the objective functions. Since Chromosomes A, B, and C are not dominated by any other chromosomes, these three chromosomes are at the highest level of non-domination and are referred to as Front 1. Chromosomes D, E, and F in Figure 3 are the second level of non-domination and are referred to as Front 2. Similarly, Chromosomes G, H, and I are at the third level of non-domination and are referred to as Front 3.

## Crowding Distance and Crowding-sort

Generally, it is important for heuristic solutions to search from a wide space. NSGA-II can define how spread out each population is without using any parameters, although other solutions need parameters to define them. In NSGA-II, the density of the population in the solution space is adopted as the main indicator of how well the solution performs on the *Pareto Front*. To estimate the density of solutions surrounding a particular solution,  $i$ , in the population, the average distance of two solutions on either side of solution  $i$  along each axis of the objectives is adopted. This measure,  $(d_i)$ , represents an estimate of the perimeter of the cuboid formed by using the nearest neighbours as the vertices (called the crowding distance). Figure 4 shows an example of the crowding distance. The algorithm for calculating the crowding distance of each point in set  $F$  is as follows:

(1) Initialisation

Count the number of populations in  $F$  as  $l=|F|$ ;

**Set**  $d_i:=0$  for  $i:=1,2,\dots,l$ ;

(2) Calculate the crowding distance

For each objective function  $m=1,2,\dots,M$

Sort the set in worse order of  $f_m$ ;

For each populations  $j=1,2,\dots,l$

**If**  $j=0$ , or  $j=l$  then

$d_i^m :=$  ;

else



$$d_{I_j^m} := d_{I_j^m} + \frac{f_m^{(I_j^m)} - f_m^{\min}}{f_m^{\max} - f_m^{\min}}$$

where,

$f_m$  denotes the value of the objective function and  $I_j^m$  and  $I_j$  denote the solution index of the  $j$ -th member in the sorted list.

### Crowded Tournament Selection Operator

- The crowded comparison operator compares two solutions and returns the winner of the tournament. It assumes that a solution,  $i$ , wins a tournament with another solution,  $j$ , if and only if any of the following conditions are true: ((i) if solution  $i$  has a better rank than solution  $j$ , that is,  $r_i < r_j$ ;
- if two solutions have the same rank, but solution  $i$  has a better crowding distance than solution  $j$ , that is,  $r_i = r_j$  and  $d_i > d_j$

### 2.5.5 Ordered probit model

The ordered probit model includes two parameters, which are constant and other threshold parameters. These two parameters indicate the range of normal distribution associated with specific values of the explanatory variables.

$$y_t^* = \beta X_t + \varepsilon_t, \text{ with } \varepsilon_t \sim N(0,1) \quad (22)$$

where

$y_t^*$  = observed category per person  $t$ , coded as 0, 1, 2, ..., J;

$X_t$  = influential factors of person  $t$ ;

$\beta$  = vector of coefficient; and

$\varepsilon_t$  = error term of person t

The observed category of  $y_t^*$  and can be defined as:

$$\begin{aligned} y = 0 & \text{ if } y^* \leq 0 \\ y = 1 & \text{ if } 0 \leq y^* \leq \gamma_1 \\ & \dots \\ y = J & \text{ if } \gamma_{J-1} \leq y^* \end{aligned}$$

where

$\gamma_1$  = estimable threshold parameters

The following probabilities result from the normal distribution:

$$\begin{aligned} \Pr = (y = 0) &= \Phi(-\beta' x) \\ \Pr = (y = 1) &= \Phi(\gamma_1 - \beta' x) - \Phi(-\beta' x) \\ & \dots \\ \Pr = (y = J) &= 1 - \Phi(\gamma_{J-1} - \beta' x) \end{aligned}$$

Therefore, the probability that  $y_i$  falls into  $j$  th category is given by

$$\Pr = (y = J) = \Phi(\gamma_j - \beta' x) - \Phi(\gamma_{j+1} - \beta' x) \quad j = 0, 1, \dots, J$$

where  $\gamma_0$  and  $\gamma_1$  denote the upper and lower threshold values for category  $J$ .

The log likelihood function is the sum of the individual log probabilities:

$$\text{Log} = \sum_{j=1}^J \sum_{y_i=j} \log[\Phi(\gamma_j - \beta' x_i) - \Phi(\gamma_{j-1} - \beta' x_i)] \quad (23)$$

## **Chapter 3 A Multilevel Analysis of Link Performance Functions for Paratransit Networks**

This section is a part of the subjective analysis. The result from the analysis is used to define the congestion level in the network, which is included in the optimization programming.

### **3.1 Introduction**

The link performance function (LiP), usually represented in the form of the BPR function (Bureau of Public Roads, 1964), is one of the key tools used in road design and for supporting decisions concerning transportation planning and management. Capacity functions are important in modeling users' route choice behaviour on the basis of perceived travel time. This is because a capacity function represents the relationship between traffic volume and travel time on the link (Suh & Park, 1990). However, Spiess (1990) noted that the widely used BPR volume-delay functions have some inherent drawbacks.

Countries other than the United States have distinctive demographic, economic, cultural, and behavioral characteristics that might require capacity functions customized for their unique environments (Suh & Park, 1990). In cities in developing countries, the popularity of illegal on-street parking and shops, as well as the erratic stopping behavior of paratransit vehicles, usually cause serious reductions in travel speed. Because

congestion is a nonlinear function, as a road approaches its maximum capacity, small changes in traffic volumes can cause large changes in congestion delays (Litman, 2009).

Studies on the LiP suitable for developing countries are extremely limited. Although, in the Indonesian Highway Capacity Manual (IHCM, 1997), the influence of the above-mentioned factors on on-street occupancy is already reflected in the capacity and free-flow calculations, it has not been reflected in the calculation of the LiP.

On-street occupancy is influenced by pedestrian crossings, slow vehicles (for example becak, horse carriages), vehicles entering or exiting from buildings on the side of the street and paratransit vehicle stopping behavior. In the IHCM, in contrast to the highway capacity manuals used in developed countries, the influence of the conflict between on-street occupancy and vehicle flow is given great attention. In the IHCM, to simplify the calculation of on-street occupancy, 5 levels of on-street occupancy are defined. On-street occupancy is defined as a function of the number of events that occur in the observed road segment.

Despite its advantages and its significant role in urban transport, paratransit has been criticized for causing disorder in the traffic system, which creates pressure to eliminate it rather than to try to improve it (Joewono & Kubota 2005). A significant effect of paratransit (angkot/mikrolet) on the speed/flow relationship in Jakarta was observed by Shimazaki et al. (1996). His study showed that for low-quality dual carriageways (less than 10 m wide), when the proportion of paratransit increase from 10% to 25% of the vehicles in the traffic stream, the average peak hour traffic speed reduces from 16.2 km/hour to 6.7 km/hour. The purpose of this study is to update the LiP

to reflect the influence of on-street occupancy in evaluating paratransit network performance.

The Paratransit network is described in the Chapter 2 subsection 2.5.2 and depicted in Figure 2.8. This chapter employs the survey data obtained from the first data collection explained in Chapter 2, Section 2.4.2. To estimate the scale and shape parameters of the LiP for the paratransit network, the original BPR-type LiP is first log-transformed into a simple linear regression model, where the dependent variable is the ratio of the actual to the free-flow travel time, and the independent variable is the ratio of traffic volume to capacity ( $V/C$ ). It is expected that the LiP might vary across links and over the course of a day and might also depend on on-street occupancy. To clarify the role of such factors in the LiP, a multilevel modeling approach is applied. First, we consider a model without explanatory variables (called the null model). This model represents fundamental variation properties that indicate what types of variations actually exist in the ratio of actual to free-flow travel time. Then, in the full model, some of the total variation is expected to be reduced due to the introduction of the explanatory variable.

### **3.2 Indonesian Highway Capacity Manual 1997**

Passenger car equivalent, value of passenger car equivalent for Motorcycle equals to 0.25 and 1.2 for truck and bus. Capacity, IHCM defines the practical capacity as the maximum vehicle volume, which constantly passes through a defined road section within a set time interval (i.e. 1 hour).

$$C = C_0 \times (FCW \times FCsp \times FCsf \times Fcs) \quad (24)$$

Where:

$C_0$  : Free flow capacity (passenger car unit/hour)

FCW : Link width capacity factor

FCSP : Link separated capacity factor

FCSF : On street occupancy capacity factor

FCS : City size factor

$$S = (S_0 + FSW) \times (FCsf \times Fcs) \quad (25)$$

Where:

$S_0$  : Basic free flow speed (km/hour)

FSW : Effective width factor

FSSF : On street occupancy factor

FCS : City size factor

### 3.3 Link Performance Function

The relationships between mean journey speed and flow of traffic per unit time on the links of urban road networks are primary inputs for capacity restraint methods of assigning traffic to networks. Hence functions used to relate journey speed or its reciprocal, journey time per unit distance, and flow of traffic on networks are often termed “link capacity functions” (Branston, 1976).

Capacity functions are important in the model that accounts for the user’s route choice behavior based on the modelling’s perception of the travel time. This is because a

capacity function represents the relationship between the traffic volume and the travel time on the link. The capacity function developed by the U.S. Bureau of Public Roads (BPR) has been used in many countries (Suh & Park, 1990).

Branston (1976) noted that many different types of link performance functions (LiP) have been proposed and used in practice in the past. By far the most widely used volume-delay function is the BPR function (Bureau of Public Roads, 1964), which is defined as follows:

$$Ta_i = T0_1 \left( 1 + \alpha \left( \frac{V_i}{C} \right)^\beta \right) \quad (26)$$

Where

*Ta<sub>i</sub> = travel time in link i*

*T0<sub>1</sub> = Free – flow travel time in link i*

*V<sub>i</sub> = Traffic volume in link i*

*C = Link capacity*

*α and β are parameters*

In this equation, the alpha parameter is the ratio of travel time per unit distance at practical capacity to travel time per unit distance at free flow, while the beta parameter determines how rapidly the curve increases from the free-flow travel time (Anwar, Fujiwara, & Zhang, 2011). The BPR function was developed in the late 1950s by fitting data collected on uncongested freeways. When the traffic volume is very low, the predicted travel time is approximately equal to the free-flow travel time. The BPR function does not explicitly consider congested conditions and the influence of on-street occupancy. Thus, it may be of limited use in some developing countries. For example, in the case of Bangladesh, the influence of on-street occupancy is immense. Anwar et al.

(2011) observed that in LiP functions developed for use in Bangladesh, the multipliers are monotonically increasing function of on-street occupancy. This means that the estimated speed will drop at the value of  $\alpha$  corresponding to a V/C ratio close to 1.

### **3.4 Methodology**

To estimate the scale and shape parameters of the LiP for the paratransit network, the original BPR-type LiP is first log-transformed into a simple linear regression model, where the dependent variable is the ratio of the actual to the free-flow travel time, and the independent variable is the ratio of traffic volume to capacity (V/C). It is expected that the LiP might vary across links and over the course of a day and might also depend on on-street occupancy. To clarify the role of such factors in the LiP, a multilevel modeling approach is applied. First, we consider a model without explanatory variables (called the null model). This model represents fundamental variation properties that indicate what types of variations actually exist in the ratio of actual to free-flow travel time. Then, in the full model, expectedly some of the total variation is to be reduced due to the introduction of the explanatory variable.

#### **3.4.1 Linear Regression**

Linear regression was performed to obtain estimates of the LiP model parameters using the statistical software package SPSS version 16.0. The original BPR-type LiP is first log-transformed into a simple linear regression model, where the dependent variable is the ratio of the actual to the free-flow travel time, and the independent variable (only



one) is the ratio of traffic volume to capacity (V/C). The log-transformed model is as follows:

$$\ln\left(\frac{Ta}{T0} - 1\right) = \ln(\alpha) + \beta \ln\left(\frac{V}{C}\right) \quad (27)$$

Where

$Ta_i$  = travel time in link  $i$

$T0_1$  = Free – flow travel time in link  $i$

$Vi$  = Traffic volume in link  $i$

$C$  = Link capacity

$\alpha$  and  $\beta$  are parameters

### 3.4.2 Multilevel Modeling for Link Performance Functions for Paratransit Networks

It is expected that the LiP might vary across links and over the course of a day as well as with on-street occupancy. To clarify the role of such features in the LiP, a multilevel modeling approach is employed, in which the above potentially contributing factors to variation are represented as additional terms in the regression model. The link performance in cities in developing countries is highly dependent not only on the V/C ratio but also on the details of the driving context, such as road link variations, time variations, and/or the influence of on-street occupancy. In this study, we developed two models: one without any explanatory variables (called the null model, equation 28) and the other with explanatory variables (called the full model, equation 29). The parameter values of the multilevel models are estimated using a Markov Chain Monte Carlo (MCMC) procedure.

$$y_i = \beta_{0i} + \gamma_{link(i)} + \gamma_{freq(i)} + \gamma_{stop(i)} + \varepsilon_i \quad (28)$$

$$y_i = \beta_{0i} + \beta_1 x_{1i} + \beta_2 x_{2i} + \gamma_{link(i)} + \gamma_{freq(i)} + \gamma_{stop(i)} + \varepsilon_i \quad (29)$$

$$\gamma_{link(i)} \sim N(0, \sigma_{link/i}^2)$$

$$\gamma_{freq(i)} \sim N(0, \sigma_{link/i}^2)$$

$$\gamma_{stop(i)} \sim N(0, \sigma_{link/i}^2)$$

$$\varepsilon_i \sim N(0, \sigma_{0/i}^2)$$

where

$\beta_{0i}, \beta_1, \beta_2$  : unknown parameters

$x_{ni}$  :  $\ln\left(\frac{V}{C}\right)$ , dummy variable for morning peak hours

$y_i$  :  $\ln\left(\frac{Ta}{To} - 1\right)$

$\gamma_{link(i)}, \gamma_{freq(i)}, \gamma_{stop(i)}$  : random effect variables

$\varepsilon_i$  : error term, it is estimated by calculating residuals.

### 3.5 Model Estimation

#### 3.5.1 Linear Regression Analysis

Using equation 23, we obtained results for the linear regression model. In general, the recommended values of the model parameters for the original BPR function are  $\alpha = 0.15$  and  $\beta = 4.00$ . This means that if the  $V/C$  is nearly 1.00, then the actual travel time will increase 15%. In the linear regression performed for this study, values of  $\alpha = 1.888$  and  $\beta = 1.116$  were obtained, with the model  $R^2 = 0.17$ . This model is depicted in Figure 3.1. The results indicate that the  $\alpha$  value is greater than 1.00 and the  $\beta$  value is reduced from 4.00 to nearly 1.00, which means that when the  $V/C$  is nearly 1.00, either the speed will decrease or the travel time will increase by 118%. The smaller the  $\beta$  value, the more travel time increases with increasing  $V/C$  to nearly 1.00. On-street occupancy has a

significant influence in decreasing the speed, although the value of  $V/C$  is still small and the rate of decrease in speed is greater when the  $V/C$  value is close to 1.

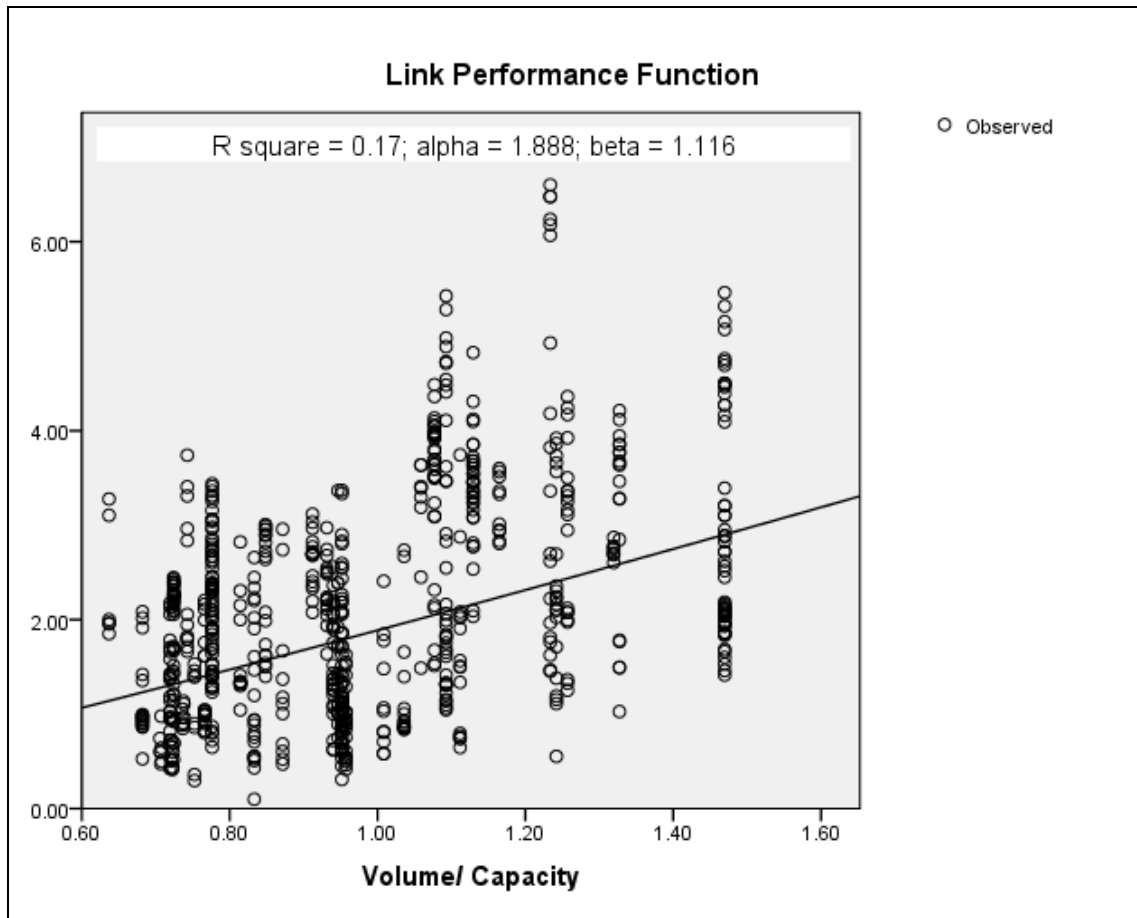


Figure 3.1 Updated BPR Function

### 3.5.2 Multilevel Analysis

In parameter estimation for the null model, the explanatory variable is not introduced. In this step, we want to clarify the influence of the variance components on the travel time calculation. As mentioned before, travel time may vary with road link variations, time variations, and/or on-street occupancy. To represent the influence of on-street occupancy, we introduced two variations: angkot volume variation and angkot stopping behavior (how many stops are made in the link by each angkot). The random components are introduced in a cross-classification structure in the model. The road link

variations and the influence of on-street occupancy are introduced as random components, while time variations (morning and noon peak hours) are introduced using the dummy variable as a fixed component. From the model estimation (for the null model), the value of the road link variance (interlink) component is 0.135 and the observation-level estimate is 0.110.

Table 3.1 Estimation Results of Multilevel Analysis

Items		Null Model			Full Model			The amount of variations reductions (%)	
		var	std. error	t stat	var	std. error	t stat		
<b>Constant</b>		0.870	0.285	3.053	1.101	0.296	3.720		
<b>Random effects</b>									
Stopping behaviour variation	$\sigma^2_{\text{stop}}$	0.395	1.074	0.368	0.395	0.915	0.432	0.000	0%
Angkot volume variation	$\sigma^2_{\text{freq}}$	0.065	0.037	1.757	0.081	0.040	2.025	-0.016	-25%
Inter-link variation	$\sigma^2_{\text{link}}$	0.135	0.077	1.753	0.074	0.048	1.542	0.061	45%
Intra-link variation	$\sigma^2_0$	0.110	0.006	18.33	0.098	0.005	19.60	0.012	11%
Total			0.705			0.648		0.057	8%
<b>Explanatory variables</b>									
Peak Hour (dummy variable)					-0.394	0.041	-9.610		
Volume/ Capacity (V/C)					0.881	0.225	3.916		
Var $\beta_1(x)$					0.069				
log[mean( $\pi(x \theta)$ )]			479.45			388.18			
log[ $\pi(x \text{mean}(\theta))$ ]			449.01			355.82			
pD			30.44			32.36			
DIC			509.89			420.54			

Note; “log[ $\pi(x|\text{mean}(\theta))$ ]” represents the log likelihood with the posterior means of parameters.

“log[mean( $\pi(x|\theta)$ )]” represents the posterior mean of the log likelihood. “pD” is defined as  $2(\log[\text{mean}(\pi(x|\theta))] - \log[\pi(x|\text{mean}(\theta))])$ , which is used as the Bayesian measure of model complexity. “DIC” is defined as  $-2(\log[\pi(x|\text{mean}(\theta))] - \text{pD})$ .

This suggests that 15.6 % of the variation is explained by the road link and the remaining variation is explained by other random components. If we could obtain perfect

information about factors that influence the dependent variable, the unexplained variation components would have values of zero, but usually some unexplained variation still remains (Chikaraishi et al., 2010). In this study, the stopping behavior variation was the only one of the random components that was not found to be significant ( $t \text{ stat} = 0.368$ ).

Next, in the full model we introduce only one explanatory variable, V/C, and we introduce time variation as a dummy variable. Theoretically, including an explanatory variable in the full model results in all of the estimates of the components of unexplained variation being smaller than they are the null model because  $\text{var}(\beta_{1i}x_{1i})$  explains a part of the total variation. We can confirm this by comparing the value for  $\text{var}(\beta_{1i}x_{1i}) = 0.069$  with the total amount of variation reduction (0.057). Approximately 8% of the variation observed is explained by the explanatory variable. In the full model, the influence of the time slot is introduced into the equation as a dummy variable with a fixed effect.

The introduction of the time slot as a fixed effect clearly explains more about within-link variance, reducing the within-link variation. The effect of the morning peak hour on the dependent variable is -0.394, where this negative sign means that an increase in the morning peak hour value will decrease the ratio of actual travel time to free-flow travel time. In contrast, the effect of the afternoon peak hour (dummy variable = 0) means that it will result in increased travel time compared to the morning peak hour. This means that during the morning peak hour, traffic is less congested than during the afternoon peak hour. To confirm the fit of the model, we employ the deviance information criterion (DIC) diagnostic introduced by Spiegelhalter et al. (2002). The DIC is an extension of the Akaike information criterion (AIC) diagnostic that can be calculated directly from the

chains produced by an MCMC run. Generally, differences in  $DIC > 10$  are substantial. Introducing the explanatory variable into the full Model decreases the DIC by 89.35 points, which means that the model becomes significantly better. The estimated value of the alpha is given by  $\ln(\alpha) = 0.707 \pm 0.337$  (dummy peak hour = 1.00), or  $1.440 \leq \alpha \leq 2.84$ . The estimated range for beta is  $0.656 \leq \beta \leq 1.106$ .

### **3.6 Estimations Based on Number of Lanes**

The multilevel analysis indicates that the variation between links is significant and achieves the greatest reduction in variation of the random effects considered (45%). Therefore, the variation between links warrants further analysis based on the characteristics between links. All of the road links in this paratransit network are of the same functional class, namely, secondary arterial roads. Based on the IHCM, urban roads are classified based on the number of lanes. Therefore, to support the estimations based on IHCM, we examine the updated BPR function based on the number of lanes in each link.

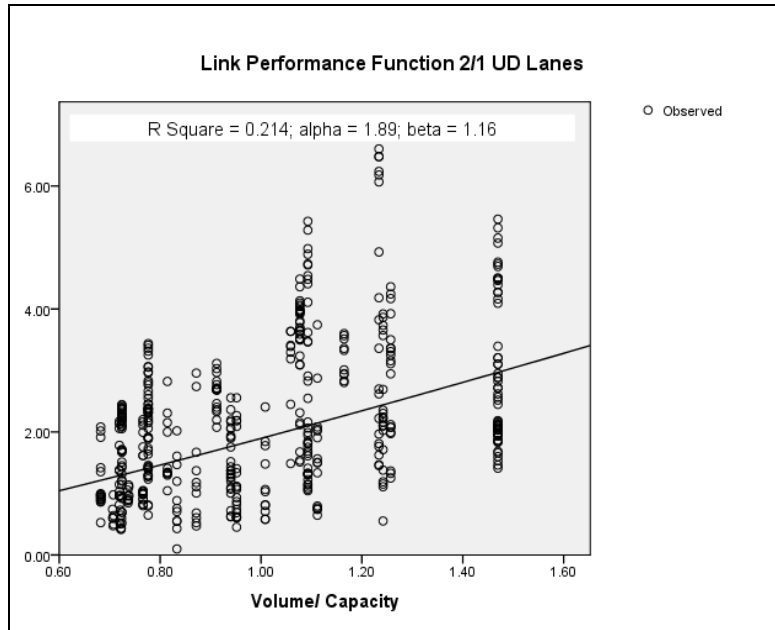


Figure 3.2 Updated BPR Function (2 Lanes)

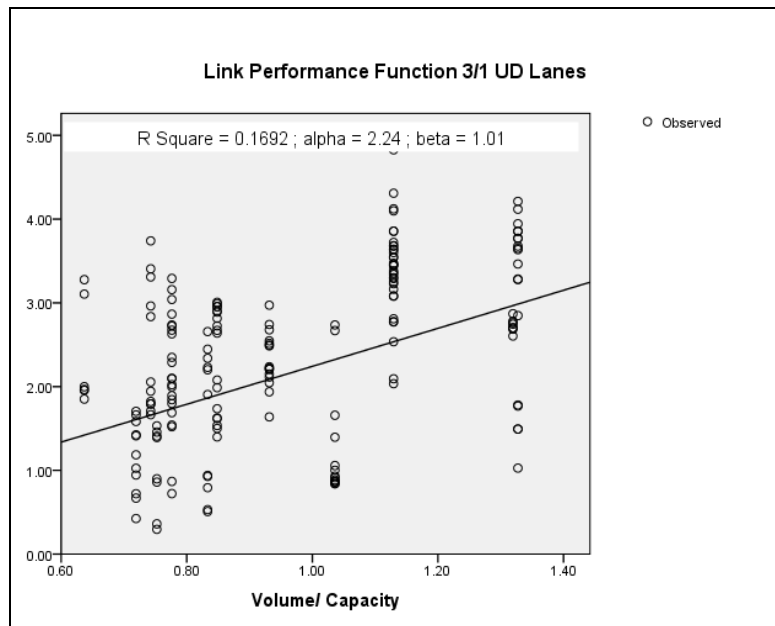


Figure 3.3 Updated BPR Function (3 Lanes)

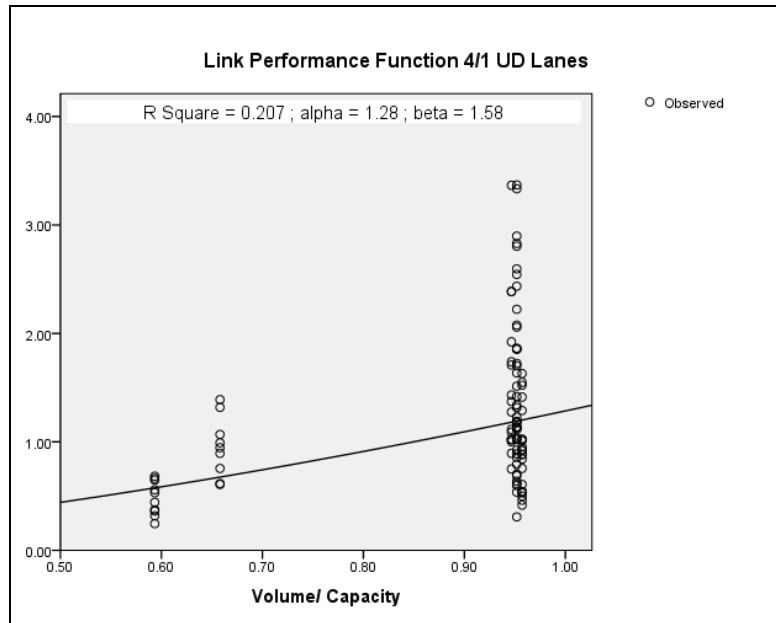


Figure 3.4 Updated BPR Function (4 Lanes)

The values obtained for alpha and beta for 2, 3, and 4 lanes are shown in the legend of Figure 3.5. The curves in the figure illustrate the change in speed value as a function of V/C for different combinations of alpha and beta (i.e., for different numbers of lanes). The upper curve is the original BPR curve, and the next three curves down from the BPR curve represent, in order, the updated LiP functions for 4 lanes, 2 lanes, and 3 lanes. These curves illustrate that the worst of the scenarios considered is road with 3 lanes. The LiP function for 4-lane roads is slightly less sensitive to changes in V/C than the functions for 2- and 3-lane roads. For 4-lane roads, the speed does not decrease as drastically as V/C increases from zero as it does for 2- and 3-lane roads. The smaller value of  $\alpha$  and the larger value of  $\beta$  in the LiP function of 4-lane roads indicate that speed is less sensitive to changes in traffic flow to this type of road.



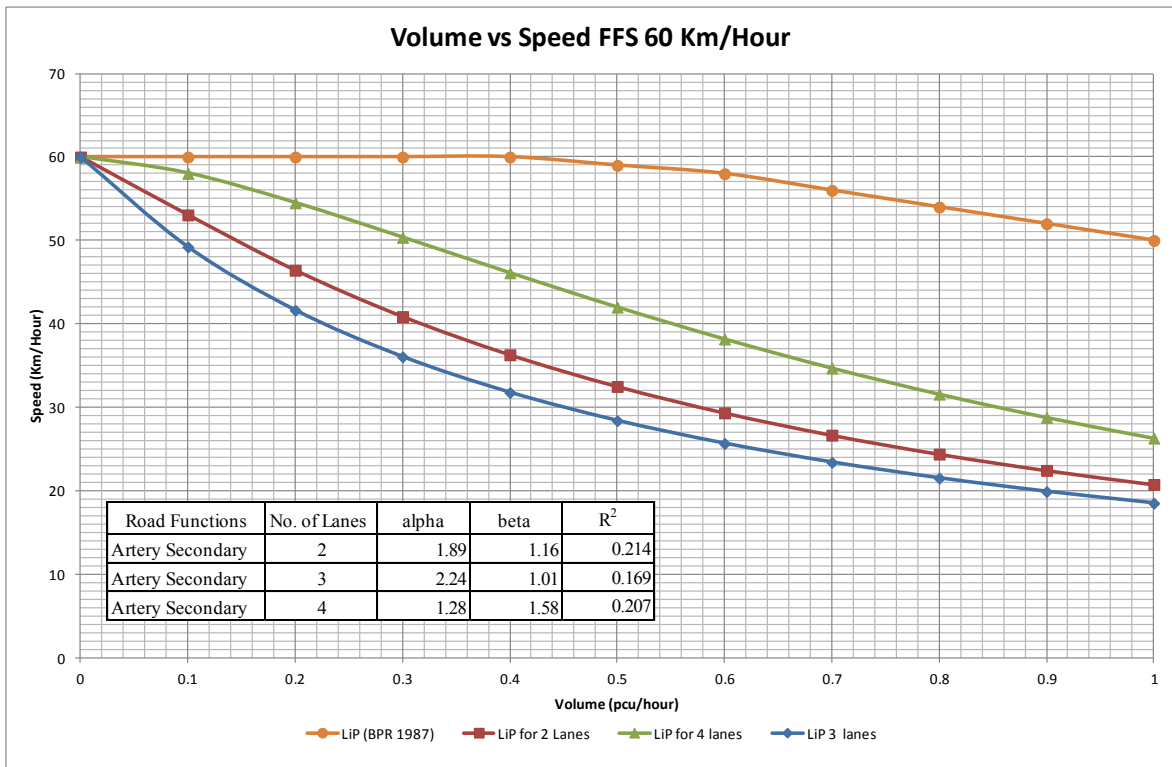


Figure 3.5. Volume/Speed (Free-Flow Speed = 60 km/hour)

### 3.7 Summary

In this study, we have successfully updated the LiP function, which incorporates the influence of on street occupancy in evaluating paratransit network performance, to reflect specific traffic situations in cities in developing countries. In the multilevel analysis performed in this study, we found that the values of the LiP function vary from driving context and are influenced by factors such as road link variations, time variations, and/or the influence of on-street occupancy. The most significant influence (at the 95% confidence level) of the variations is the between-link variation and the angkot volume variation. Stopping behavior exhibits the greatest variance but is not statistically significant. The multilevel analysis results suggested that it was necessary to further refine the LiP based on the characteristics between links. Therefore, linear regression

based on the number of lanes was conducted. The results show that a road link with 4 lanes performs better than links with 2 or 3 lanes. On-street occupancy significantly reduces speed even when the value of  $V/C$  is small and reduces speed even more dramatic when the value of  $V/C$  approaches 1. This is an important finding that could also be useful in determining congestion levels in the optimization model for a paratransit network.

## **Chapter 4 Evaluation of Paratransit Services from the Perspective of Environmental Impacts and Drivers' Quality of Life**

This section is the part of the subjective analysis. Emphasizing the drivers point of view is the main concern in our study. Since direct service providers are drivers of paratransit vehicles then drivers would not make efforts to provide satisfactory and reliable services if paratransit service provision could not improve drivers' QOL. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not be realized.

### **4.1 Introduction**

Paratransit, is legally admitted by the government but it is operated by private unions or individual owners. Cooperatives and route associations serve to organize the member firms in ways to increase the total ridership and profit of the routes (Cervero & Golub, 2007). Drivers are obliged to pay a daily vehicle rent fee to the owners and earn the salary from the surplus. Thus, drivers' profitability depends on revenues while owner's profitability is determined by the number of the vehicle fleet. While the owners tend to maximize their profit by increasing the number of the vehicle fleet, they do not realize that the number of fleet would cause high competition in the market and also "cream skimming<sup>2</sup>" attitudes which would also degrade the quality of service. This

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<sup>2</sup> cream skimming here means many small operators attempt only to operate during the peak hours or in busy locations because of perceived costs and higher revenues

situation leads many drivers seek to optimize the vehicle usage and daily earning through a variety of means. Drivers try to maximize daily earnings and frequent passenger turnover produces high patronage counts (Cervero, 2000).

Paratransit drivers' daily income is usually spent on daily rental fee, fuel cost, and sometimes small maintenance (varies among drivers), while the surplus becomes their salary. The net returns vary sharply between and within cities due to differentials in rates of vehicle ownership as well as in levels of competition and affordability of fares of low-income population (Cervero, 2000). Hence, their daily salaries are only enough to make ends meet or even sometimes not (Cervero, 2000). In this sense, studies about paratransit system cannot ignore the influence of its service supply on drivers' lives.

In the theory of quality of life (QOL), QOL is determined by not only people's wealth and employment, but also the built environment, physical and mental health, education, recreation and leisure time, and social belonging and so on (Gregory, Johnston, Pratt, Watts, & Whatmore, 2009). In developing countries or third world countries, like Indonesia, its community still holds on to the paradigm that the value for QOL is mostly formed as three hierarchy levels of needs: primary needs (e.g., "pangan" (food), "sandang" (clothes), and "papan" (house)) (Widyosiswoyo, 1991), secondary needs (e.g., nutritious food, higher education, fine clothes, and better housing), and tertiary needs (e.g., luxury needs like car, cell phone, television). That is why the paradigm of high social status means, such as having brand new and high technology vehicles (cars or motorcycles) or devices (like cell phone, laptop, and others) is more likely to be the indicator to define that those people already reach the highest level in the hierarchy of the

society. Unsurprisingly, for low-income people like paratransit drivers, achieving only the primary needs already requires very heavy struggle likewise to achieve higher level of needs (physical, mental health, education, and so forth). Their definition of good quality of life is when they could achieve the level of wealth (more likely suitable income rather to achieve the definition of wealth itself), employment status, adequate house and health.

Despite paratransit is playing an important role in urban public sectors of developing countries, these drivers' economic sustainability is at stake. It is necessary to undertake a number of actions, which will result in more effective use of paratransit and improved urban mobility as well as good quality of drivers' lives. Therefore, this study makes an effort to evaluate paratransit services from the perspectives of not only environmental impacts, but also drivers' quality of life, aiming to improve paratransit systems as a promising sustainable transport mode in developing countries. Drivers' work performance is also focused. For this purpose, this study used the data inquire from the questionnaire survey to paratransit drivers in Bandung City and then builds a structural equation model (SEM) with latent variables to quantitatively examine the cause-effect relationships related to drivers' quality of life and paratransit systems.

#### **4.2 Descriptive Statistics of Data**

Data was collected by a questionnaire survey based on a face-to-face interview on September 2011 from 152 drivers, who were randomly selected from each route. The entire drivers are male, 84% of whom are less than 55 years old, and about 68% of

drivers have not received proper education (the education level is lower than junior high school).

Table 4.1 Characteristics of driver based on questionnaire survey data

Latent Variable	Observed Variable	Definitions	Mean	Std Dev
Individual Attributes	Age	< 55 years old = 0 (84%) ≥ 55 years old = 1 (16%)	43.00	10.10
	Education level	Lower than junior high school = 1 (68%) Higher than junior high school = 2 (32%)	1.29	0.45
Work Performance	Number of round trips	Number of round trips per day	7.92	0.82
	Service time (minutes) (Modeled in categorical)	The length of time a driver provides to passengers per day	694.73	80.20
	Driver's waiting time (minutes)	Average time to wait for passengers	24.10	6.33
	Gap revenue (Rp.)	Actual revenue – Minimum daily revenue	16,569	26,962
	Service distance (km)	Distance traveled per day	104.50	28.50
Environmental Impacts	Fuel cost (Rp.)	Fuel cost spent per day	84,160	10,401
	Vehicle age (years)	Vehicle age (years)	7.91	0.80
Basic Level of QOL	Satisfaction with Work	Measured with a 4-point scale: 1 – very dissatisfied; 2 – dissatisfied; 3 – neutral; 4 – satisfied;	2.83	0.36
	Satisfaction with Health		2.76	0.54
	Satisfaction with Residence		2.97	0.76
Higher Level of QOL	Satisfaction with Social Life		2.67	0.73
	Satisfaction with Free Time		2.75	0.59
	Satisfaction with Family		2.97	0.73

The average daily revenue observed from the questionnaire survey is about Rp.37,824/day or around Rp.1,100,000/month (120 US dollars). Surprisingly, this average daily revenue was even lower than the minimum standard wage in Bandung City, which is Rp. 1,123,800/month based on the “Governor Verdict no. 561/Kep. 1564-Bansis/2010”. The detailed information is summarized in Table 4.1, where observed variables are shown under each latent variable.

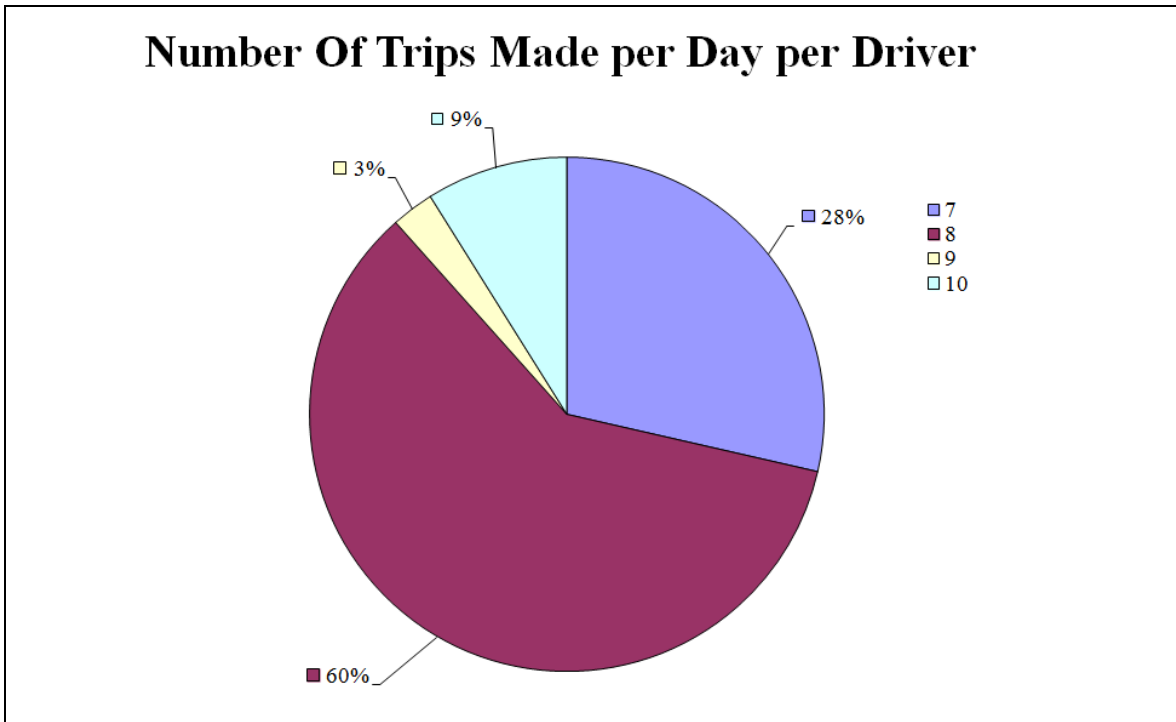


Figure 4.1. Number of Trips Made per Day per Driver

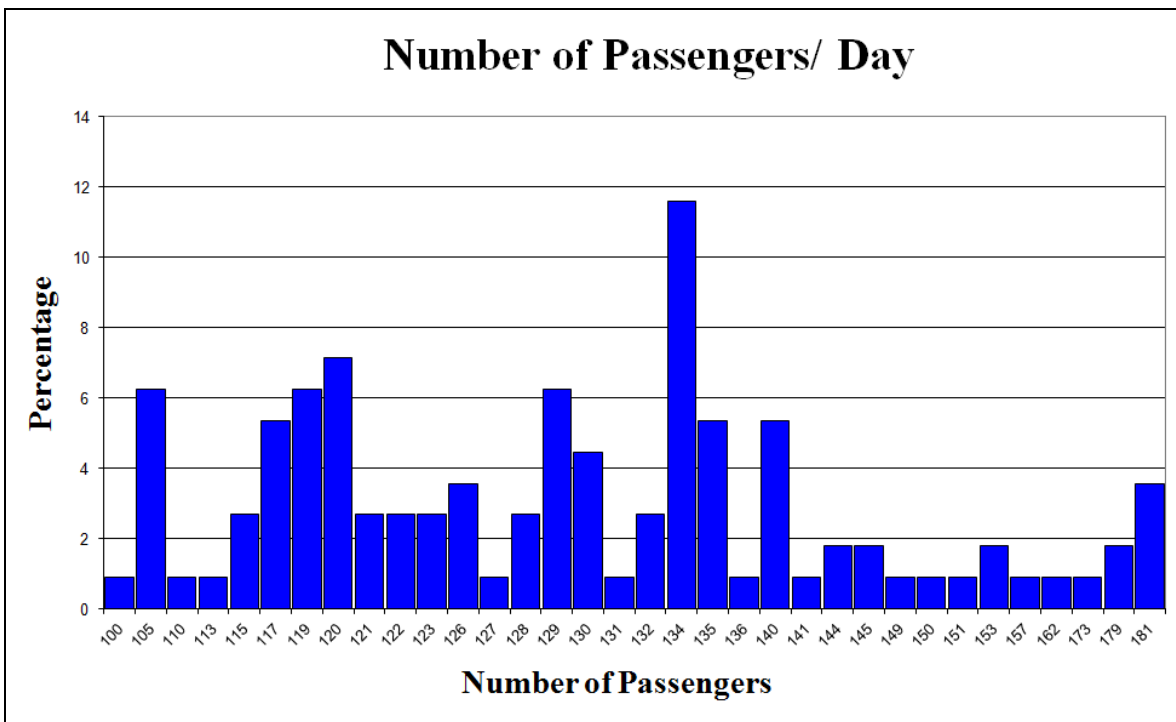


Figure 4.2. Number of Passengers/ Day

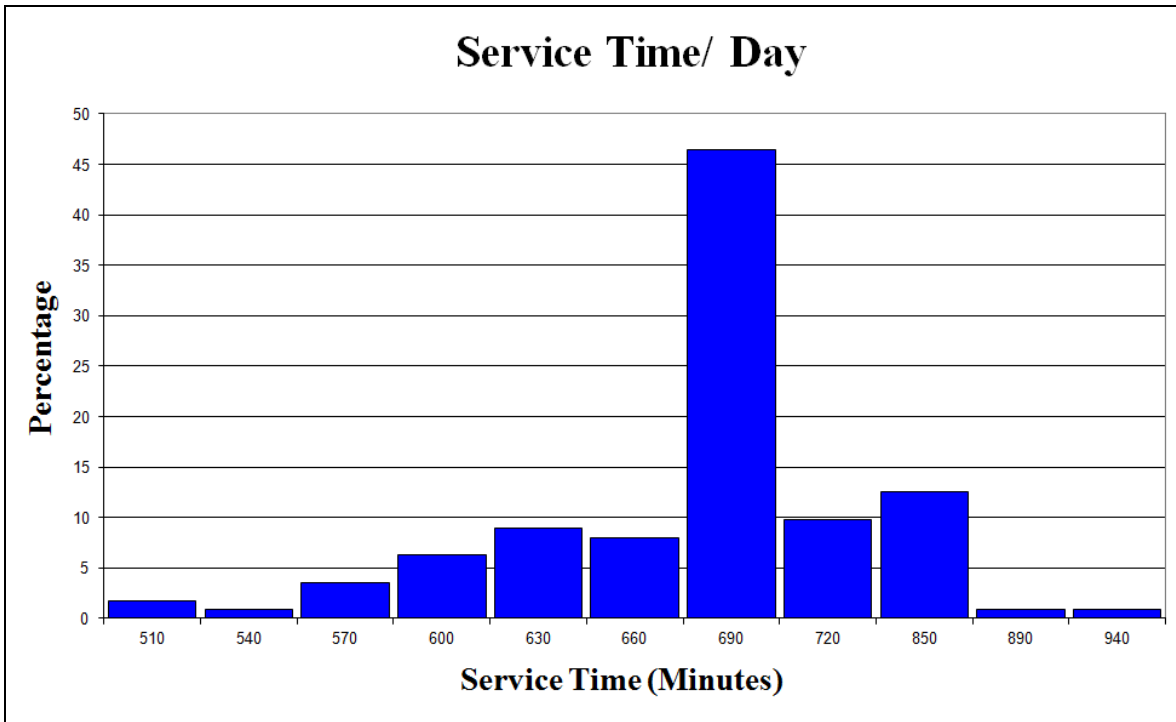


Figure 4.3. Service Time/ Day

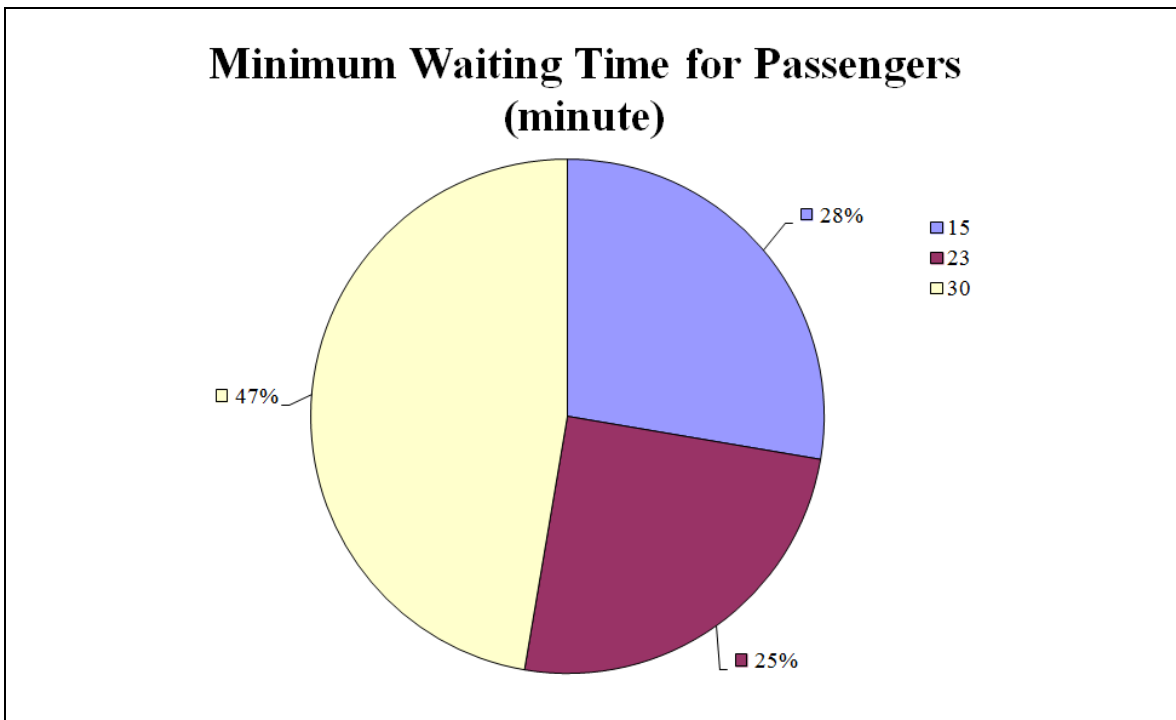


Figure 4.4. Minimum Waiting Time for Passengers (minute)



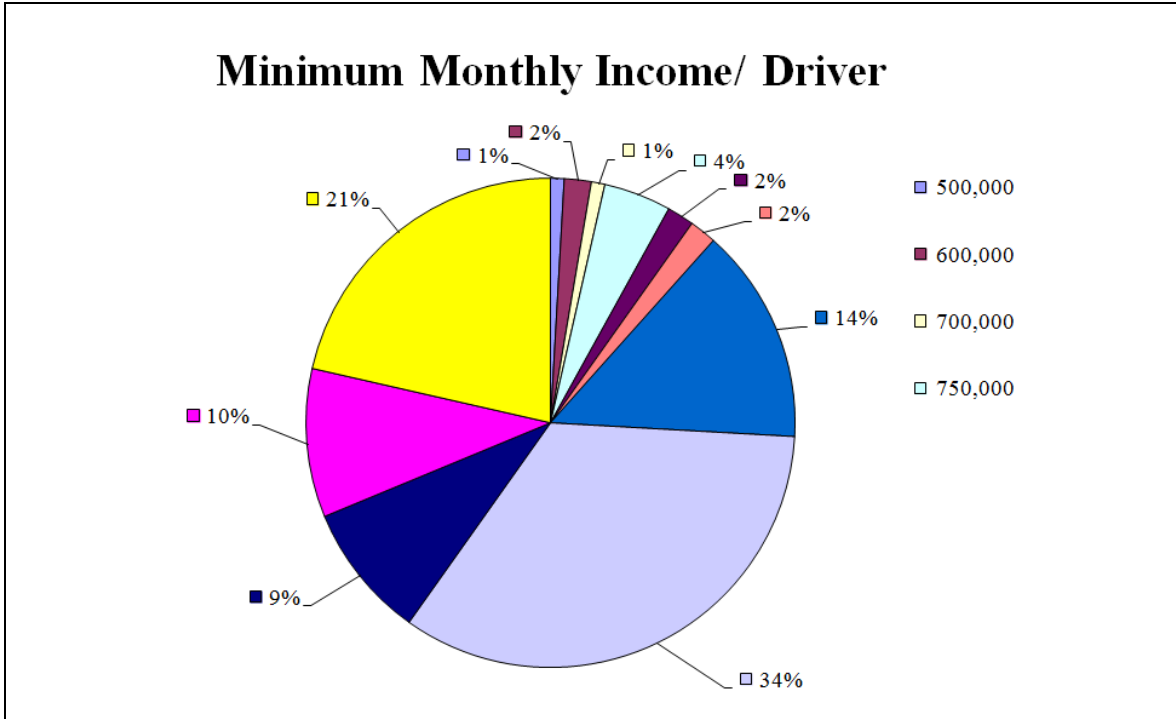


Figure 4.5. Minimum Monthly Income/ Driver

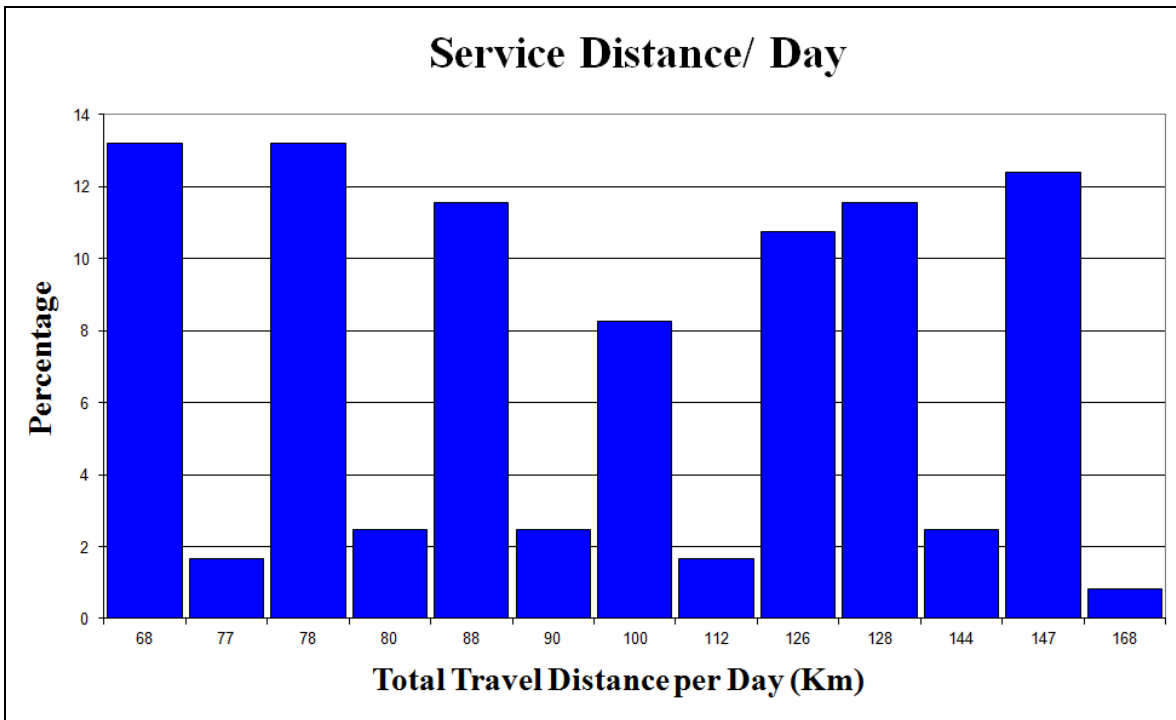


Figure 4.6. Total Travel Distance/ Day

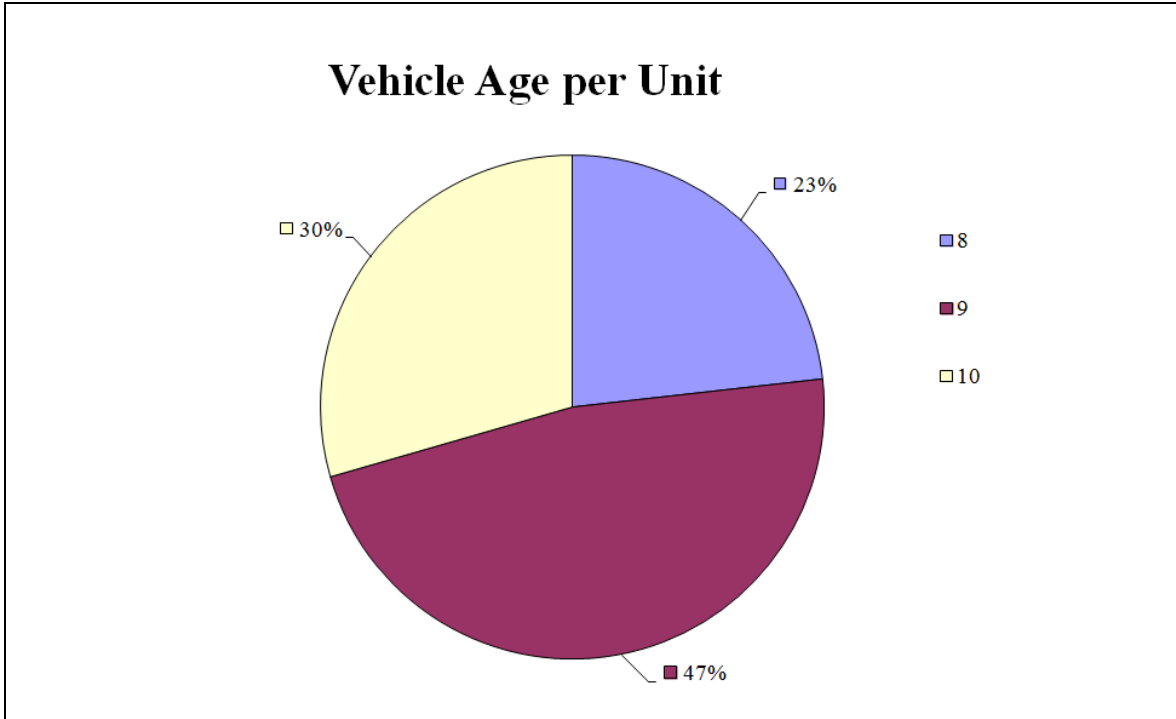


Figure 4.7. Vehicle Age per Unit

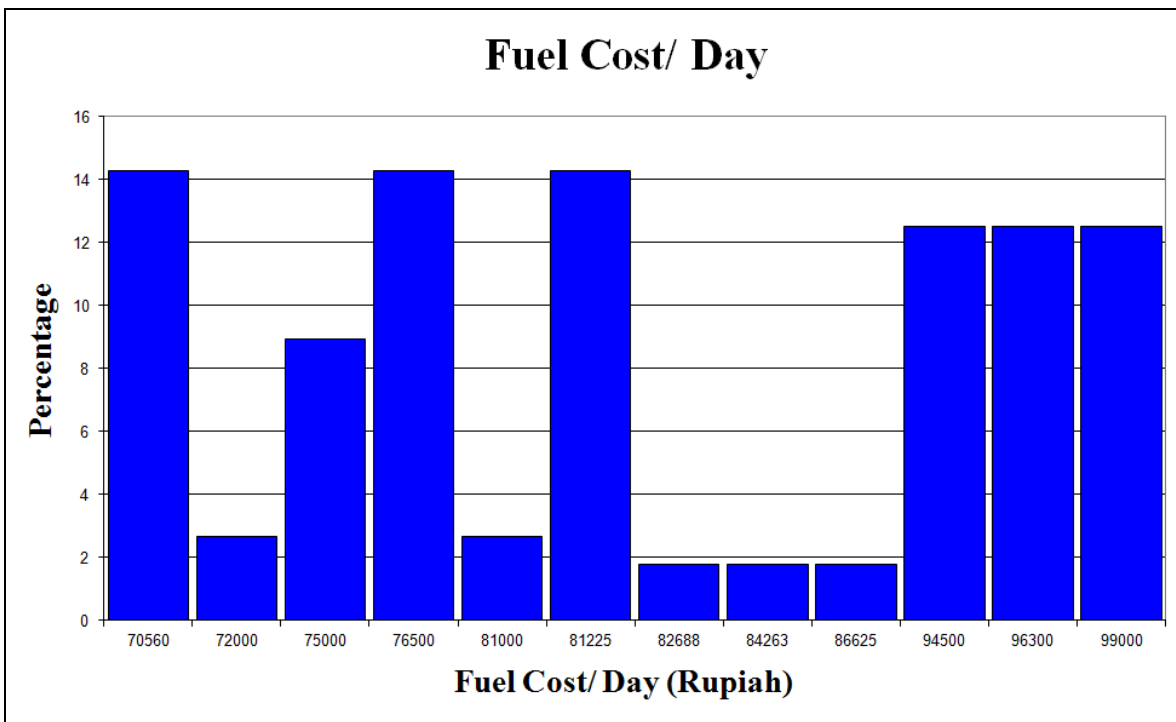


Figure 4.8. Fuel Cost/ Day

### **4.3 Methodology: Subjective Analysis**

Quality of life (QOL) is defined by the World Health Organization Quality of Life (WHOQOL) group (1998) as “the perception of individuals regarding their goals, expectations, standards, and concern”. The concept of QOL has become important in the field of international development, since it allows development to be analyzed based on a measure, which is broader than the standard of living. QOL is a multidimensional construct, and may be defined as the extent to which important values and needs of people are fulfilled (Diener & Lucas, 1999). Failure to meet people’s basic needs can negatively impact on their quality of life (Feng & Hsieh, 2009). Organizations such as the World Bank defined poverty as a lack of basic human needs, such as food, water, shelter, and freedom, access to education, healthcare, or employment (World Bank, 2006). In other words, poverty is regarded as a low level of quality of life.

Statistical models can be used to quantitatively examine the QOL and its influential factors. Statistical models usually consist of a series of formal assumptions that can be supported by mathematical proofs (Barofsky, 2012). The empirical question here is whether a particular model (e.g., factor analysis, path analysis, or a more general structural equation modeling approach) adequately characterizes the data (Barofsky, 2012).

As QOL is a multidimensional concept that is best evaluated by a number of latent constructs, it is well recognized that latent variable models, such as exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) are useful tools for analyzing QOL data (Lee, Song, & Skevington, 2009). Recently, QOL researchers have

realized the potential of structural equation modeling (SEM), which is a generalization of EFA and CFA in formulating a regression type equation in the model for studying the effects of the latent constructs related to the QOL.

In the paratransit study, driver's job can be considered as a self-employed job, which is entirely different from company-based employment. The entire decisions are made by drivers themselves, not by the owner or the government. They freely decide when to start or stop the service. Their decisions are based on their acceptable daily earnings where each driver, in fact, has a different standard. This uncertain decision making will result in the service unreliability, where the service performance would highly depend on filling in empty seats, not based on fixed income (Cervero, 2000; Susantono, 1998).

Existing studies reported a positive correlation between individuals' job attitudes (satisfaction to work) and their performance (correlation = 0.17; Light 2004). Moreover, a recent meta-analysis found a substantive correlation between individual job satisfaction and individual performance (correlation = 0.30; Cook 2008). However, the above existing studies only deal with formal employment, and to the authors' best knowledge, no study has been done with respect to paratransit drivers' QOL. With the above consideration, this study aims to evaluate paratransit services by simultaneously focusing on paratransit drivers' work performance, environmental impacts and drivers' QOL.

Since paratransit drivers belong to the low-income group, meeting their basic life needs might be the top priority in their jobs and consequently other life domains might regarded as secondary needs. In other word, QOL of paratransit drivers might mostly

concern about fulfilling the basic needs before achieving a higher level of needs. Therefore, it might be a good idea to divide the structure of life domains into two hierarchical levels: basic level and higher level of QOL.

Literature review (Phillips, 2006) suggests that there are various definitions of QOL and none of them has been universally accepted across disciplines, but one consensus has been achieved that subjective elements play a major role in the measurement. Life satisfaction, which is an overall assessment of feelings and attitudes about one's life at a particular point in time, is one of common core subjective elements. The domains of life literature reveal that life can be combined as a general construct of many specific domains. Life satisfaction can be understood as the result of satisfaction in the domains of life, for example, the domains are specified as health, economic, job, family, friendship, personal, and community environment. With the above supporting evidence, here, driver's life satisfaction is used as a proxy of paratransit drivers' QOL. Considering the specific living conditions in Indonesia, six life domains are considered: work, residence, health, family, social life, and leisure (free time), where the first three correspond to the basic needs and the last three to the higher needs.

As for paratransit drivers' satisfaction with work, revenues from paratransit services and work performance become relevant. This is dissimilar with regular employee whose satisfaction with work is also determined by high involvement in work system linked with the company contributions (Bohlander & Snell, 2007). As mentioned previously, paratransit drivers belongs to the low-income group, it is expected that they may have a minimum requirement about income. To reflect this, instead of directly using

the revenue, here, the gap between actual revenue and minimum daily income (i.e., actual revenue – minimum daily income; hereafter, called “gap revenue”) is adopted.

Related to the work performance, both service quality and benefits to drivers should be emphasized. For the service quality, it can be represented by service time and distance. On the other hand, drivers’ benefits can be explained by the above-defined gap revenue and drivers’ waiting time for having enough passengers. Here, environmental impacts are indirectly represented by fuel cost and vehicle age. Fuel cost is considered as a proxy indicator to represent how much of fuel is consumed for each angkot, and vehicle age is used to indicate the level of emission control (Hickman, Hassel, Joumard, Samaras, & Sorenson, 1999). Both are important indicators to measure the level of air pollutant (refers to environmental impacts, here). Some indicators might be related to both service quality and benefits to drivers. These will be empirically clarified in the case study.

In this study, we will test several hypotheses related to paratransit driver’s QOL.

H1: Paratransit drivers’ work performance positively affects the basic level of QOL.

H2: Paratransit drivers’ work performance leads to negative environmental impacts.

H3: The basic level of QOL positively affects the higher level of QOL.

H4: The gap between actual revenue and minimum daily income is positively influential to the satisfaction with work.

H5: Different drivers have different evaluation about the work performance and the basic level of QOL (i.e., the heterogeneity exists among drivers).

To examine the above cause-effect relationships, a SEM with the model structure shown in Figure 4.9 is adopted, where five latent variables are introduced: “individual

characteristics”, “work performance”, “environmental impacts”, “basic level of QOL”, and “higher level of QOL”.

#### **4.4 Structural Equation Model (SEM) Analysis**

This chapter employs the survey data obtained from the first data collection explained in chapter 2, subsections 2.4.1. Observed variables that are explained by “individual characteristics”, “work performance”, and “environmental impacts” in Figure 4.9 are selected based on a preliminary study. The model estimation results of standardized directs, indirect and total effects are depicted in Table 4.2, where all the selected observed variables are listed. The model accuracy is assessed by the goodness of fit index (GFI) and adjusted goodness of fit index (AGFI), which is 0.605 and 0.436, respectively. Even though the model’s accuracy value is not sufficiently high, but as a model to explore cause-effect relationships, it is acceptable. Observing the structural models, significant cause-effect relationships are observed from “work performance” to “individual attributes”, from “work performance” to “environmental impacts”, from “work performance” to “basic level of QOL”, from “basic level of QOL” to “higher level of QOL”. Unexpectedly, the cause-effect relationship between individual attributes and basic level of QOL is not statistically significant, suggesting that there is no significant difference of life satisfaction related to the basic level of QOL across individuals.

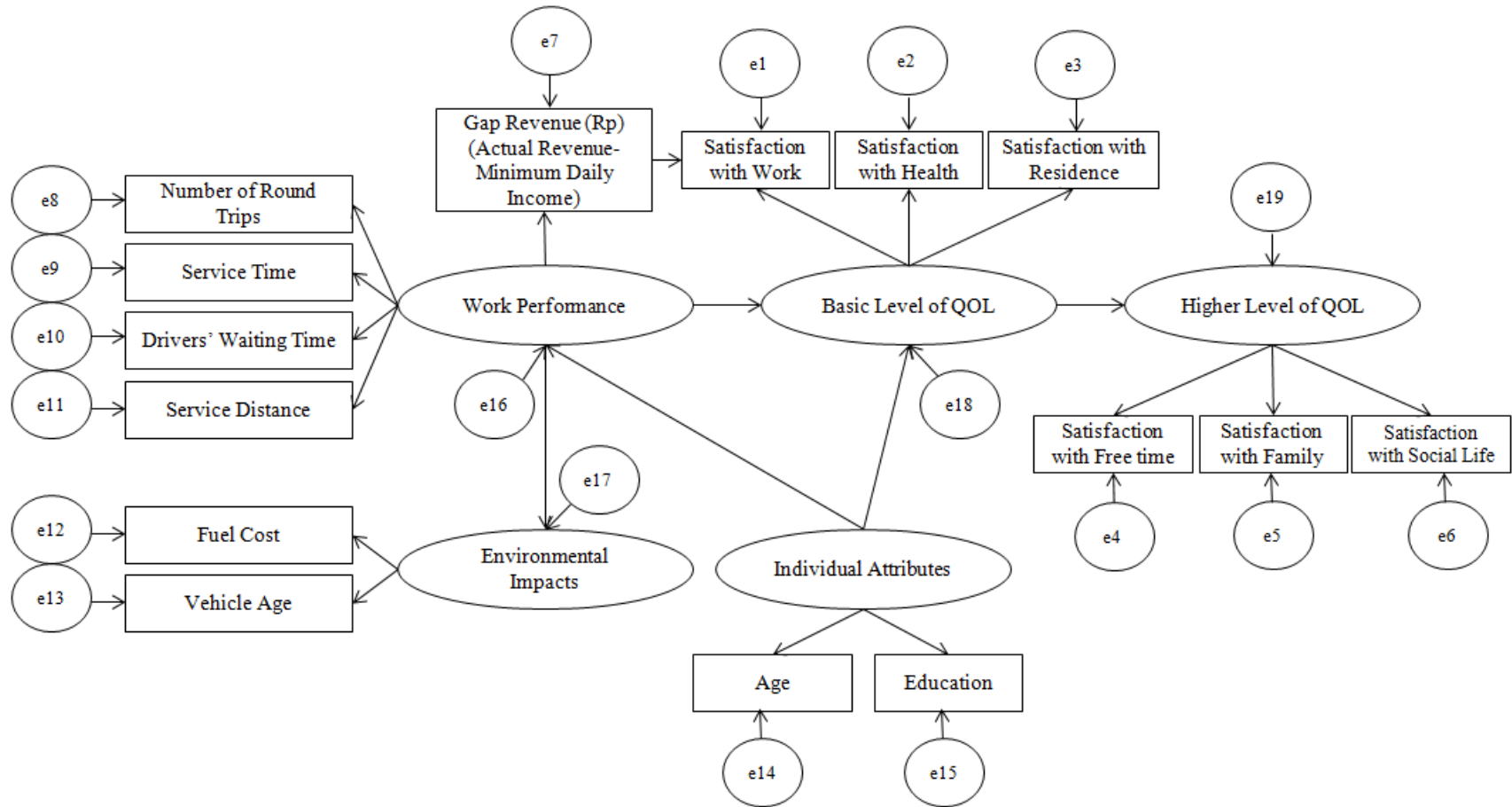


Figure 4.9 Model Structure of Structural Equation Modeling



The above results suggest that the cause-effect structures assumed in this study are suitable to the data. Furthermore, it is shown that the hypotheses raised in the previous section are supported. First, the hypothesis 1 (H1) is supported because the parameter sign of the effects of “work performance” on “basic level of QOL” is positive. Looking at the observed variables that are explained by these two latent variables, only service time and distance travelled are significantly influential to the basic level of QOL, i.e., longer service time and longer distance traveled per day results in lower satisfaction with residence, work and health. Related to the satisfaction with work, it is positively affected by the gap revenue. In other words, the more actual revenue, the more satisfied with the work, implying that the hypothesis 4 (H4) holds. In addition, “work performance” is also positively associated with the higher level of QOL via the basic level of QOL. These results imply that improving the work performance could enhance drivers’ QOL. Because longer service time and longer distance traveled per day indicate better service quality of paratransit systems, improving the work performance from the perspective of service quality of paratransit systems may not always be beneficial to drivers.

Focusing on the influence of “work performance” on “environmental impacts”, it is negative, implying that the hypothesis 2 (H2) holds. At the first glance this relationship may not be logical, but if we look through the observed variables of “work performance”, this observed relationship is reasonable, because “work performance” is defined to

explain the number of round trips, service time, waiting time for passengers, service distance and gap revenue. As observed from Table 4.2, increasing service time and distance significantly decreases the “work performance” value. This result further means that increasing service time and distance results in higher fuel cost and older vehicle age, which would worsen the environmental performance of paratransit systems.

In this study, considering the specific economic situations in Indonesia, we have assumed a hierarchical structure of QOL, i.e., the basic level of QOL is associated with the higher level of QOL, instead of the standard parallel structure. The direct effect of “basic level of QOL” on “higher level of QOL” is estimated to be positive. Thus, our assumption (i.e., the hypothesis 3: H3) is supported. The positive sign of the direct effect of “basic level of QOL” means that in order to increase the higher level of QOL, driver’s satisfaction with free time and family must be improved. Unfortunately, the satisfaction with social life is not influential, probably because social life is not important to paratransit drivers. As mentioned above, the indirect effects of “work performance” and “individual attributes” on “higher level of QOL” via “basic level of QOL” are significant. These observations support that the “basic level QOL”-centered cause-effect structure is suitable to evaluate the performance of paratransit systems.

Furthermore, the influence of “individual attributes” on “work performance” and both levels of QOL are significant and only the education level is influential. Surprisingly, higher education level is linked with a lower evaluation of drivers’ QOL. With this

observed interrelationship, one might say that the older and lower educated drivers would have higher work performance. This statement is logical as one must noted that higher work performance, here, means shorter operation period and less coverage area. Older driver would already know how to obtain more passengers due to his experiences. Usually older driver would have less education as this job does not require higher formal education.

All the above results suggest that, at least in this case study, the current paratransit systems in Bandung City are not beneficial to both drivers and the environment. In the current system, earning more money requires drivers to work longer. By improving the service (i.e., to have a longer operation period and cover a wider service area), drivers would experience less satisfaction with their quality of life and higher environmental impacts would be resulted in. It is necessary to think of it this way, users prefer to have a good level of service quality and meanwhile the driver life satisfaction would be worsened when they work harder. In other words, the current system is not sustainable at all from both social and environmental perspectives. The socially sustainable here means that the current paratransit job is one of the job opportunity for low income people. While environmentally sustainable here means that the current system should supported for environmental friendly. This finding has important policy implications. The supply side of paratransit system (either local government or private owner) must make efforts to improve the sustainability of paratransit system rather than from the driver side. It will

require some actions taken to change the current operation and contract systems of paratransit services. First, drivers income need to be reviewed because, as mentioned in Chapter 3, their average daily revenue was lower than the minimum standard wage in Bandung City. It is necessary for the local government to evaluate the feasible fare or to suggest minimum income for paratransit driver. Second, demand and supply condition needs to be further reviewed whether the existing conditions are in oversupply condition or not. The government could limit the number of fleet to maintain the optimum frequency. From the environmental impacts view point, high environmental impacts may cause by vehicle conditions itself which are not environmental friendly. The local government could start the introduction of environmental friendly vehicle.

This finding has important policy implications. Improving the sustainability of a paratransit system requires some actions taken to change the current operation and contract systems of paratransit services. More effects should be made from the supply side (i.e., owner side) of paratransit system, rather than from the driver side.

#### **4.5 Summary**

Various studies have been done with respect to the evaluation of paratransit systems. However, most existing studies have mainly focused on the users' side and drivers' issues have been poorly represented. Paratransit systems in developing countries are currently a "must" travel mode because of insufficient formal public transportation

systems. At the same time, many low-income people are working as drivers of paratransit systems. In this sense, paratransit systems are playing a dual role in developing countries, i.e., providing convenient and flexible transport services and employment opportunities to low-income people. Unfortunately, in reality, discussion about sustainable transport policies in developing countries has ignored or at least has attached less importance to such social equity issues.

With the above consideration, this study presented a case study to evaluate paratransit services from the perspective of environmental impacts and drivers' quality of life as well as work performance. Using the driver questionnaires data, a structural equation model with latent variables is built to examine several hypotheses related to the purpose of this study. Especially, reflecting the actual situations in Indonesia, drivers' quality of life is focused by classifying it into the basic level and higher level.

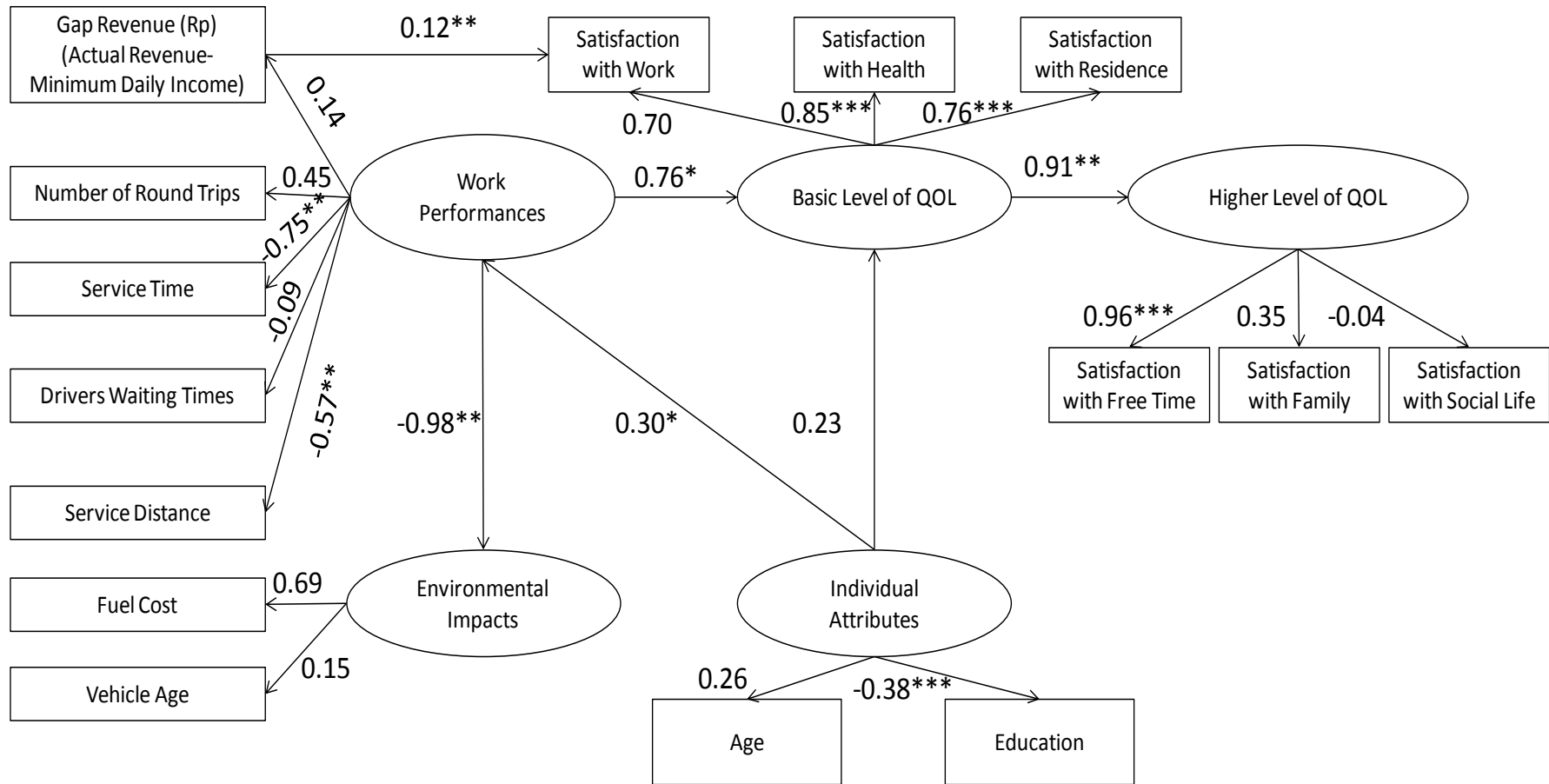


Figure 4.10 Estimation Results of Structural Equation Modeling

Table 4.2 Estimation Results of Structural Equation Modeling

Exogenous variables \ Endogenous variables	Cap revenue			Individual attributes			Work performance			Environmental impacts			Basic level of QOL			Higher level of QOL		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
<u>Latent variables</u>																		
Work performance				0.30 *		0.30 *												
Environmental impacts					-0.30	-0.30	-0.98 **			-0.98 **								
Basic level of QOL				0.23	0.23	0.46 ***	0.765 *		0.765 **									
Higher level of QOL					0.42 **	0.42 **		0.70 **	0.70 **				0.914 **		0.914 **			
<u>Work performance</u>																		
Cap revenue					0.044	0.04	0.144		0.144									
Service time					-0.23	-0.23	-0.75 **		-0.75 **									
Number of round trips					0.136 *	0.14 *	0.449		0.449									
Drivers' waiting time					-0.03	-0.03	-0.09		-0.09									
Service distance					-0.17 *	-0.17 *	-0.57 **		-0.57 **									
<u>Environmental impacts</u>																		
Vehicle age					-0.04	-0.04		-0.14	-0.14	0.145		0.145						
Fuel cost					-0.21	-0.21		-0.68 **	-0.68 **	0.694		0.694						
<u>Basic level of QOL</u>																		
Satisfaction to residence					0.348 ***	0.348 ***		0.58	0.58				0.758 ***		0.758 ***			
Satisfaction to work	0.12 **		0.12 **		0.327 **	0.327 **		0.554	0.554				0.70		0.70			
Satisfaction to health					0.393 ***	0.393 ***		0.656	0.656				0.857 ***		0.857 ***			
<u>Higher level of QOL</u>																		
Satisfaction to social					-0.02	-0.02		-0.03	-0.03					-0.04	-0.04	-0.04		-0.05
Satisfaction to free time					0.40 ***	0.40 ***		0.673	0.673				0.88 **	0.88 **	0.963 ***		0.973 ***	
Satisfaction to family					0.147 **	0.147 **		0.246	0.246				0.321 **	0.321 **	0.352		0.348	
<u>Individual attributes</u>																		
Age				0.261		0.261												
Education level				-0.38 ***		-0.38 ***												

Note: \* significant at the 90% level; \*\* significant at the 95% level; \*\*\* significant at the 99% level;

This is because for low-income people, they are more likely to emphasize on achieving a certain satisfaction level of employment, residence and health before enjoying the higher level of life satisfaction. As a result, we defined the basic level of QOL using drivers' satisfaction with work, residence and health and the higher level using drivers' satisfaction with family, leisure (free time) and social life. Our estimation results first confirmed such hierarchical structure of QOL is statistically significant. Such "basic level of QOL"-centered cause-effect model structure is suitable for the evaluation of paratransit services. Enhancing drivers' education level cannot contribute to the improvement of the QOL, and social life is not relevant to the driver's higher level of QOL. The most important finding is that the current paratransit systems in Bandung City are neither socially nor environmentally sustainable. The current paratransit services should be improved from the supply side (i.e., owner side), by carefully reconsidering the current operation and contract systems. The actions that can be done by the government are reviewing and renewing the contract system, evaluating the feasible fare, evaluating the demand and supply side, and also triggering the usage of environmental friendly vehicles.



## **Chapter 5 Sensitivity Analysis of Paratransit Network Optimization**

This section is the part of the objective analysis. Neumann & Nagel (2012) discussed that the success of a public transport system highly depends on its network design. While transport companies try to optimize a line with respect to running costs, they also have to take care of the demand: The best cost structure will not be sustainable if potential customers leave the system and opt for alternatives, e.g. private cars (Neumann & Nagel, 2012). The result from the analysis in Chapter 3 is used to define the congestion level in the network, which is included in the optimization programming to update the travel time calculation in the model. Several scenarios are examined in this chapter that is assumed to represent the behavioral features specific to paratransit users and drivers.

### **5.1 Introduction**

The high number of angkot units causes severe competition between drivers and results in too much idling time (Cervero, 2000). However, despite these negative impacts, paratransit plays a positive role in developing countries, i.e., providing convenient and flexible transport services and employment opportunities to low-income people (Weningtyas et al., 2012c). Despite the positive and negative impacts of paratransit, little attention has been paid to the question of whether this type of public transport will be needed in the future or whether other transit modes will become more important in

supporting the development of public transportation in developing cities. Recently, research has emerged about the optimization of paratransit, focusing on uncertain demand or demand-responsive transport systems (DRT). Cortes (2003) proposed a concept for a high-coverage point-to-point transit system with a focus on real-time updates of shuttle routes. Fernández et al. (2008) and (Sáez et al., 2008) further developed this model. However, studies of paratransit in developing countries are still very limited. To the best of the authors' knowledge, this study is the first attempt in the transportation field to explore optimization of paratransit systems from both the demand and supply sides in developing countries. The analysis is conducted using a multi objective optimization model to decide the optimal frequencies, where the objective function is to minimize a cost function for both the user and the operating company. Paratransit have some unique characteristics compared with public buses, for example, buses usually have a higher demand than their supply and on the contrary, in paratransit system the supply is much more excessive than the demand.

## **5.2 Methodology: Optimization Model**

From the operators side a transit line can be optimized by optimizing its headways and stop spacing, its service frequency and bus size or by adding limited-stop services with high-frequency unscheduled services (Neumann & Nagel, 2012). In addition, optimization should consider the interrelation with other transit lines, i.e. optimization of

one single transit line may induce deterioration of quality of another line. Thus, network design and its optimization has been studied

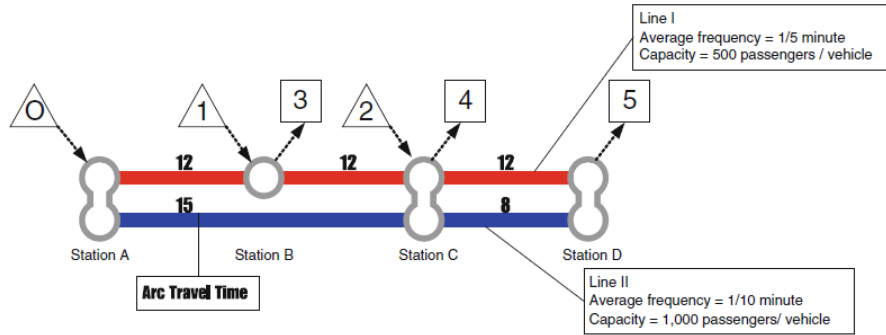
### **5.2.1 Definitions in the model**

The same terms as previous literature, which is used in this study, are related to various components, i.e., lines, itineraries, routes (or paths), line-segments, line-sections, route-sections (or links), and attractive lines (or common lines). As defined in previous literatures, a “transit line” or just a “line” is defined as a group of vehicles that run back and forth between two nodes in urban road networks. All vehicles in the same line always travel on the network by going through the same sequence of links and nodes (or stops), referred to as an “itinerary.” A “route” is any path that a transit passenger can use to travel between the origin node and destination node. A “line-segment” is a portion of a transit line between two consecutive nodes (or stops). A “line-section” is any portion of a transit line between two non-consecutive nodes of its itinerary. A “route-section” is a portion of a route between two consecutive transfer nodes. “Attractive lines” on a route-section are the set of lines that minimizes a passenger’s expected route-section travel time.

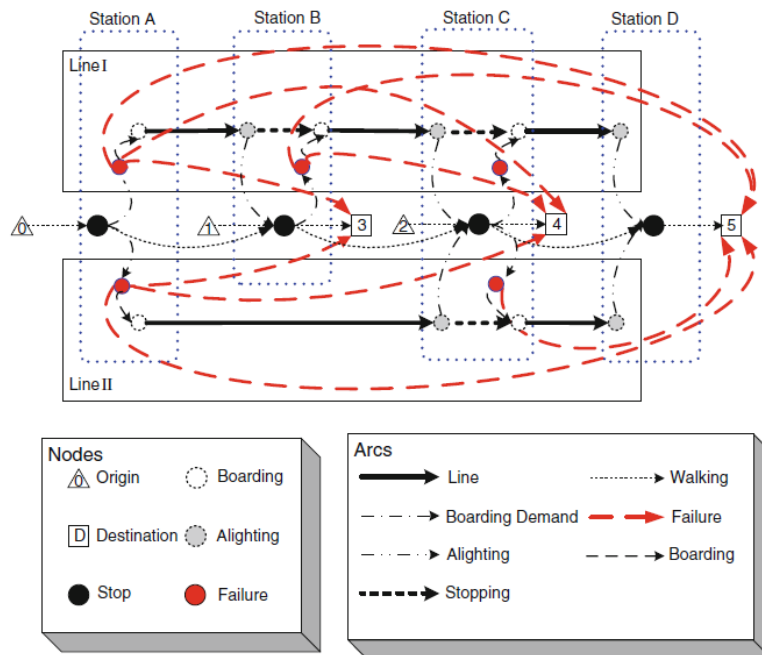
### **5.2.2 Network Development**

Basically, a transit network is comprised of a set of transit lines and a set of stops where passengers can wait, board, alight, and transfer, as shown in Figure 5.1 (De Cea and Fernández, 1993). In this model we assume that a passenger waiting at a starting node of a route-section use the first arriving vehicle among the vehicles that belong to the

attractive lines when the network is not congested. To consider transit line capacities together with the common-lines problem, the transit network shown in Figure 5.1a can be transformed into a graph model, as shown in Figure 5.1b. An origin node represents a trip start node.



(a)



(b)

Figure 5.1 Transit network

Source: Shimamoto et al, 2010

It has no predecessors and at least one successor. A destination node represents a trip end node. It has no successors and at least one predecessor. A stop node represents a platform at a station. Any transit lines stopping at the same platform are connected via boarding demand arcs, failure nodes, and boarding arcs. At stop nodes, passengers can either take a bus or walk to a neighboring bus stop. If they take a bus, they are assigned to any of the attractive lines in proportion to the arc transition probabilities.

A boarding node is a line-specific node at the platform where passengers board. An alighting node is a line-specific node at the platform where passengers alight. A failure node is a node that explains failure to board. When a transit line capacity is exceeded (if all passengers board), some passengers are forced to use the failure arc. One arc is connected to the corresponding boarding node and the others are connected to each destination node. For statistical reasons, we assumed that those who fail to board at some stations do not have priority to board at the next time step.

A line arc represents a transit line connecting two stations. A boarding demand arc denotes an arc connecting the stop node to the failure node. The flow on this arc represents the boarding demand for the transit line from a specific platform. An alighting arc denotes an arc from an alighting node to a stop node. A stopping arc denotes a transit line stopping on a platform after the passengers alight and before new passenger's board. This arc is created to express the available capacity on the transit line explicitly. A walking arc connects an origin to a platform (access), a platform to a destination (egress)

and between neighboring platforms (walk to neighbor platforms). A failure arc denotes the demand that failure to board. This excess demand is sent directly to its respective destination via this arc. A boarding arc, which represents the movement of passengers who can actually get on a vehicle, is an arc connecting a failure node to a boarding node. This network representation requires considerable computer memory because of its many arcs and nodes, but this problem is not insurmountable considering recent progress in computer technology. The network can be constructed automatically once it is developed, as shown in Figure 5.1. (Shimamoto et al., 2010)

#### Notations

The following notations are used in the transit assignment model; other notations will be defined when needed.

$A_p$	Set of arcs on hyperpath $p$
$L$	Set of line arcs
$L_l$	Set of line arcs on line $l$
$U_l$	Set of platforms on transit line $l$
$WA$	Set of walking arcs
$BD$	Set of boarding demand arcs
$S_p$	Set of stop nodes on hyperpath $p$
$D_s$	Set of failure arcs destined to $s$
$OUT_p(i)$	Set of arcs that lead out of node $i$ on hyperpath $p$

$w_{kl}$	Stopping arc of line l on platform k
$b_{kl}$	Boarding demand arc of line l on platform k
$h_{kl}$	Failure node of the line l on platform k
$l(a)$	A transit line that is included in arc a
$g_p$	The cost of hyperpath p
$c_a$	Arc cost on arc
$t_a$	Travel time on arc
$\xi$	The on board value of time
$\zeta$	The value of time for walking
$\eta$	The value of time for waiting
$\alpha_{ap}$	Probability that traffic traverses arc a
$\beta_{ip}$	Probability that traffic traverses node I
$f_l$	Frequency of line l (1/min)
$x$	A vector of arc flows
$y$	A vector of hyperpath flows
$N_i$	The number of passengers of OD pair I
$CR_i$	Connectivity reliability of OD pair I
$I$	The number of OD pair
$P_i^*$	Optimal set of hyperpaths of OD pair I
Pf	Transit fare (which does not depend on the distance in this study),

### 5.2.3 Transit Assignment Model with Common Lines Hyperpath

To obtain an attractive set of transit lines that minimises the expected travel time, we adopt the idea of the hyperpath proposed by (Nguyen & Pallottino, 1988). The hyperpath connecting an origin,  $r$ , to a destination,  $s$ , is defined as sets of stops, arcs, and arc transition probabilities,  $H_p=(I_p,A_p,T_p)$  where  $H_p$  is a hyperpath connecting  $r$  to  $s$ , if:

- $H_p$  is acyclic with at least one arc;
- Node  $r$  has no predecessors and  $s$  no successors;
- For every node  $i \in I_p \setminus \{r,s\}$ , there is a path from  $r$  to  $s$  traversing  $I$ , and if node  $i \notin R$ , then  $I$  has at most one immediate successor;
- The vector,  $t_p$ , contains the arc split probabilities that satisfy

$$\sum_{a \in OUT(i)} a_{ip} = 1, \quad i \in I_p, \quad \text{and} \quad a_{ip} \geq 0, \quad a \in A_p \quad (30)$$

### 5.2.4 Model Development

Where there are several arcs leading out of nodes on a hyperpath, traffic is split according to  $\tau_{ap}$  as shown in Figure 5.1, traffic may be split at either stop, failure, or alighting nodes.

#### Stop nodes

We adopt the following assumptions regarding the common line problem:

- Passengers arrive randomly at every stop node, and always board the first arriving carrier of their choice set; and
- All transit lines are independent statistically with given exponentially distributed headways, and a mean equal to the inverse of line frequency



- Considering these assumptions,  $\tau_{ap}$  is calculated as follows

$$\tau_{ap} = f_{l(a)} / F_{ip}, \quad i \in S_p, \quad a \in OUT_p(i) \quad (31)$$

### Alighting nodes

There may be several arcs leading out of alighting nodes. However, more than one waiting and alighting arc are never included in an optimal hyperpath because getting on the next vehicle on the same line as one gets off is irrational.

### The cost of hyperpaths

In this paper, the cost of a hyperpath is represented as a generalized cost, which consists of four elements: the fare, the monetary value of travel time, the monetary value of walking time and the monetary value of the expected waiting time. The travel time and travel fare are charged on arc  $a$ , as shown below, in order to represent the cost of a hyperpath as a generalized cost. Note that in this paper, passengers are charged another fare when they change vehicle.

$$c_{a=} \begin{matrix} \alpha_a & (a \in \{L\}) \\ \alpha_a & (a \in L_l) \\ p_f & (a \in b_{kl}, k \in U, l \in L) \\ 0 & (a \in D_s) \\ 0 & (else) \end{matrix}$$

The model developed in this study is formulated as an optimization problem, which considers a transit assignment model with common lines hyperpath, which has the following formulation:

$$\min_{\mathbf{f}} \psi_m(\mathbf{y}, \mathbf{f}), m=1, \dots, M \quad (32)$$

where  $\mathbf{f}$  is a vector of the frequencies of each line (decision variables) and  $\psi_m$  are the objective functions. Following the example of Shimamoto et.al. (2010), we adopt two objective functions as follows:

$$\psi_1(\mathbf{y}, \mathbf{f}) = \sum_{l=1}^L f_l C_l^2 \quad (33)$$

$$\psi_2(\mathbf{y}, \mathbf{f}) = \sum_{r \in W} \sum_{p \in h_{rx}} y_p \cdot g_p(\mathbf{y}) \quad (34)$$

Eq. 34 and Eq. 35 represent the operators' costs and passengers' costs, respectively. Note that we only consider direct costs in the operators' costs. Eq. 33 means that the passengers' flow should minimize the cost of hyperpath. In this study, passengers are assumed to choose their route to minimize the following cost:

$$g_p = \sum_{a \in A_p} \alpha_{ap} C_a + \eta \sum_{k \in S_p} \frac{\beta_{kp}}{\sum_{a \in OUT_p(k)} f_{l(a)}} \quad (35)$$

$$\begin{aligned} F_{ip} &= \sum_{a \in OUT_p(i)} f_{l(a)} \\ i_p &= \sum_{a \in A_p} \alpha_{ap} \cdot l \cdot V_p \\ i_p &= 1, \\ a_p &= \sum_{i \in V_p} \alpha_{ip} \cdot a \cdot A_p \\ i_p &= \sum_{i \in V_p} \alpha_{ip} \cdot i \cdot I_p \end{aligned} \quad (36)$$

The first and second terms in the Equation 36 represent the moving cost and the waiting cost, respectively, at the platform.  $C_a$  represents the cost of arc  $a$ .  $\alpha_{ap}$  and  $\beta_{kp}$  represent the probabilities that passengers on hyperpath  $p$  traverse arc  $a$  and node  $k$ ,

respectively. A passenger's expected total travel time on a route-section consists of waiting time, in-vehicle time, and overload delay time due to the restrained capacity of the line-segment. As mentioned above, the waiting time is proportional to the inverse of the total frequency of the lines passing through a route-section. The in-vehicle time can be calculated by simply averaging the in-vehicle time of each line passing through a route-section.

### **5.2.5 Parameter setting**

Before formulating the optimization model for this study, the following assumptions are made:

1. For the proposed model, it is assumed that each route can be seen as a paratransit line operated by one cooperative (operator).
2. All paratransit vehicles stop at all stops they pass; the travel time between stops is constant. In this model the dwelling time at a paratransit stop is not considered, but the cost of passenger waiting time at paratransit stops is considered.
3. The O-D matrix is fixed, regardless of the network configuration.
4. The maximum number of paratransit vehicles for each line is fixed.
5. Paratransit frequency is taken from the average frequency (lines/minute).
6. The fare systems are classified into 3 groups; fixed, metered and decided through negotiation (Shimazaki & Rahman, 1996). In angkot system, the fares are decided through negotiation between passengers and drivers. The fare usually increases with

distance (although it is not intentionally calculated on a per-kilometer basis), although the fixed fare already regulated by the government. The exact level of earning of paratransit drivers is difficult to determine and very few studies estimate the operating cost, including fuel, rent and repair, and revenues (Shimazaki & Rahman, 1996).

For the purposes of this study, we assume a flat fare because the maximum travel distance in this network does not exceed 3.0 km. Based on the data obtained from the survey of passengers responses, the average fare for a short distance ( $< 3.0$  km) is 2,000 IDR and that for a longer distance ( $> 3.0$  km) is 3,000 IDR.

7. An angkot is a type of minibus or station wagon that has a capacity of 12–14 passengers (Tarigan et al., 2010). For all eight of the lines in the study network, the type of vehicle is the same.

Table 5.1 Comparison of Original Model and the Modified Model

Original Model	Modified Model
Line configuration and frequency optimization	Frequency optimization
Failure to board probability is considered	As the number of units of paratransit is excessive than the failure to board probability term is not considered in the model
For the proposed model, it is assumed that each route can be seen as a bus line operated by one cooperative (operator).	Although, the operator of the paratransit is individuals but in the model we assumed as operated by one single cooperation
All <u>bus vehicles</u> stop at all stops they pass; the travel time between stops is constant.	All <u>paratransit vehicles</u> stop at all stops they pass; the travel time between stops is constant. In this model the dwelling time at a paratransit stop is not considered, but the cost of passenger waiting time at paratransit stops is considered.
The O-D matrix is <u>fixed</u> , regardless of the network configuration.	O-D matrix obtained from the survey and assumed it doesn't adjust automatically regardless of the frequency configuration
The maximum number of bus vehicles for each line is fixed.	The maximum number of paratransit vehicles for each line is fixed.
bus frequency is taken from the average frequency (lines/minute).	Paratransit frequency for each line is taken from the average frequency (lines/minute) obtained from the survey.
Flat rate 150 yen	flat fare because the maximum travel distance in this network does not exceed 3.0 km (2,000 IDR)
Capacity 45 passengers	An angkot is a type of minibus or station wagon that has a capacity of 12-14 passengers (Tarigan et al. 2010). For all eight of the lines in the study network, the type of vehicle is the same and has capacity 14 passengers
Travel Time = distance/speed	Updated BPR Function (discussed in Chapter 3)
Value of Time (per minute) Board = 13 yen Wait = 26 yen Walk = 50 yen	Value of Time (per minute) Board = 200 IDR Wait = 200 IDR Walk = 200 IDR

### **5.2.6 Updated Link Performance Function (LiP)**

In a previous chapter, titled “A Multilevel Analysis on Link Performance Functions for Paratransit Networks,” we successfully updated the LiP function that incorporates the influence of on-street occupancy in the evaluation of the paratransit network performance to reflect specific traffic situations in developing cities. The entire road links in the paratransit network considered in this study function as secondary arterial roads. Based on the 1997 Indonesian Highway Capacity Manual (IHCM), an urban road is classified based on the number of lanes it has. Therefore, to support estimations based on IHCM, we defined an updated Bureau of Public Roads (BPR) function, based on the number of lanes, as a new type of link performance (LiP) function. Estimated values of the scale (alpha) and shape (beta) parameters for the LiP function are illustrated in Figure 3.5 as parameters for determining the changing speed for various volume-to-capacity ratio ( $V/C$ ) conditions. The uppermost curve is the original BPR curve, and the next curves down are updated LiP functions for 4-lane roads, 2-lane roads, and 3-lane roads, respectively. From this figure, one can observe that the 1987 BPR curve is less sensitive to traffic volume than the updated LiP curves

### 5.3 Scenario Analysis

Here, we apply the proposed model to examine several scenarios that are assumed to represent the behavioral features specific to paratransit users and drivers. Details are given below.

- 1) Scenario 1: Changing the scale and shape parameters in the BPR function.
- 2) Scenario 2: Changing the flexibility of stopping places.
- 3) Scenario 3: Combining Scenarios 1 and 2.

This chapter employs the survey data obtained from the first data collection explained in chapter 2, section 2.4.2. The optimization problem is first solved for each of the above scenarios individually by changing the relevant values of parameters and variables. The performance results for the paratransit network are then compared. The results of the model calculations are illustrated in Figure 5.2 to Figure 5.11. Using Figure 5.2, we can compare the results of frequency optimization, where we assume a free-flow speed (the left curve) and also model the actual situation by introducing alpha and beta values (the right curve) to estimate the actual travel time using the updated BPR function (i.e., an LiP function) (Weningtyas et al., 2012b).

As a result by changing the scale (alpha) and shape (beta) parameters of the BPR function shifts the curve to the right, which indicates a higher total user cost as well as a higher operating cost. This is true, for free-flow conditions, the travel time would be much faster and the average speed of angkot vehicles in each link would be higher.

Introducing the alpha and beta parameters reduces the speed and increases the travel time. By applying the updated BPR function, one can observe that the number of solutions (Pareto Front) for the optimization is reduced and the difference in the cost values between solutions becomes greater. This means that the number of solutions that can be offered is not as great as for free-flow conditions and that the sensitivity of the solutions to changes in the suggested frequency for each line is also higher. Therefore, updating the BPR function is important to obtain a true picture of the paratransit network, and the influence of an updated BPR function cannot be ignored.

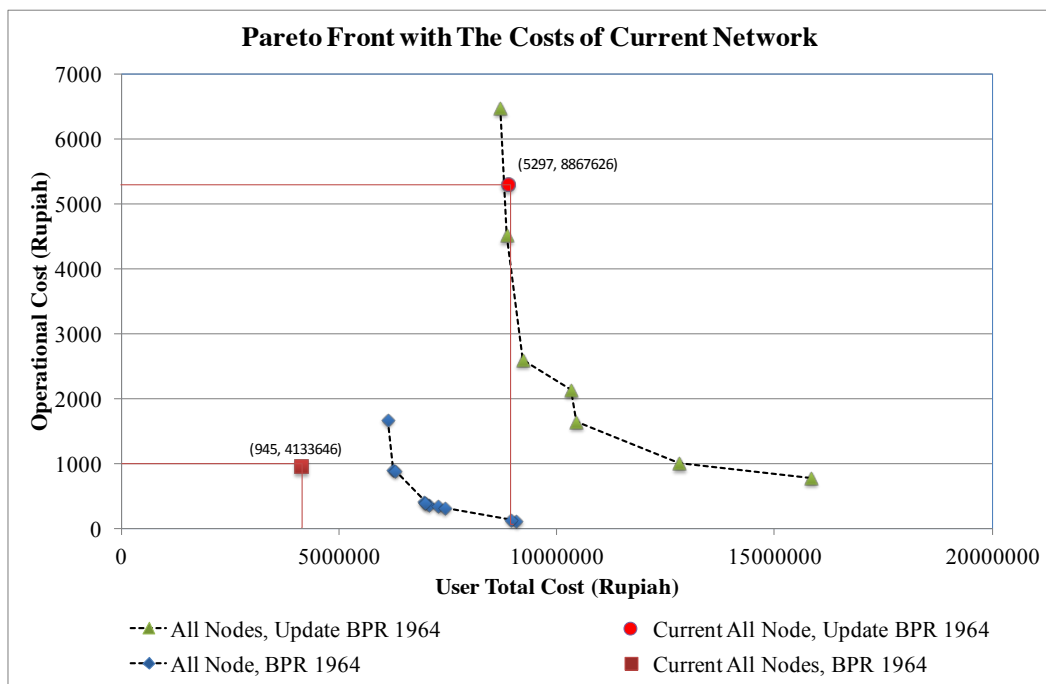


Figure 5.2 Pareto Front with the Costs of the Current Network for All Nodes



By observing in the graph above, in the curve of updated BPR function, one can see that in the first three suggested solutions the operational cost is more sensitive than the user total cost. While starting from the 4<sup>th</sup> solution the sensitivity of user total cost is much more significant than the operator cost. This condition happened due to the order number of solution is in line with the degraded service supplied by the operator. For instance the 1<sup>st</sup> suggested solution is the maximum operation where no line is halted or stop operating. While in the last suggested solution, there are more units that is halted or no service. The cause of some of the line were suggested to be halted or no service, because of there are several overlapped route between each line. This means that when several lines are halted the other line performed as a substitute.

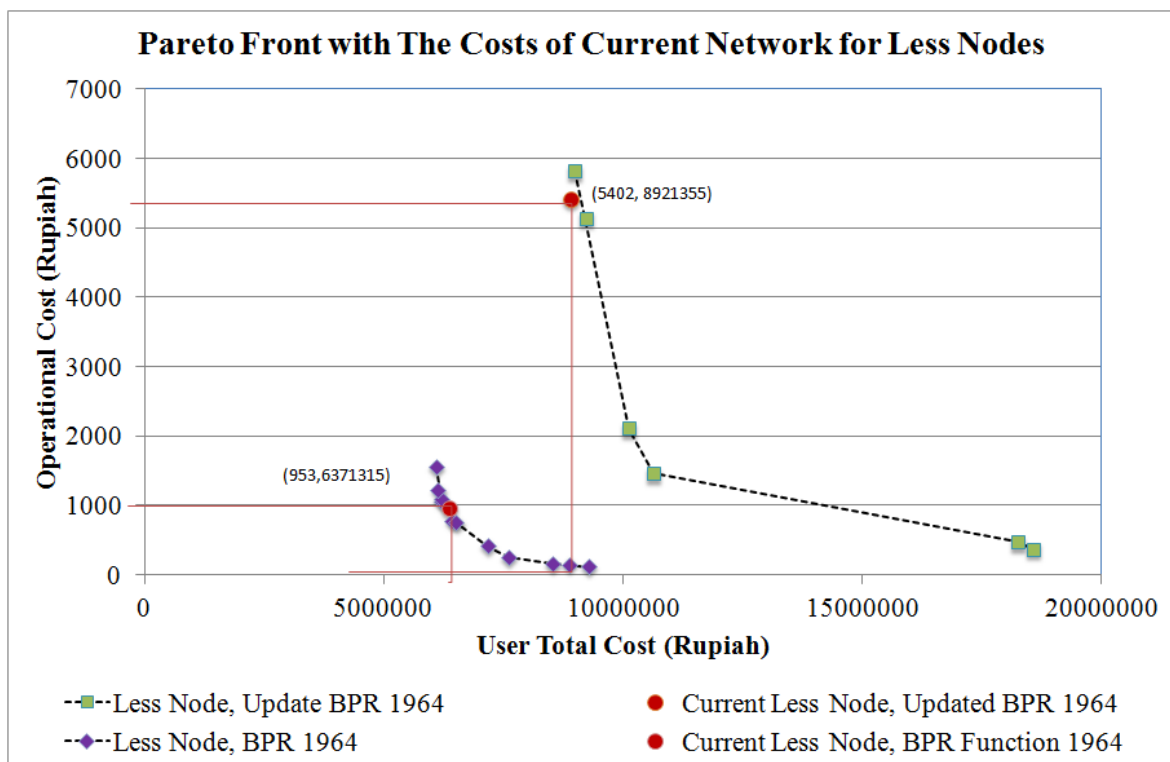


Figure 5.3 Pareto Front with the Costs of the Current Network for Less Nodes

Flexibility is one of the advantages of paratransit services (Cervero, 2000). In this study, it is assumed that a paratransit vehicle is allowed to stop at any place on a link (street) and that some stops are fixed and others are not. We also attempted to examine the influence of a reduction in the number of stops by aggregating several stopping points into one point and summing the demands for boarding and alighting from the vehicle. This results, as seen in Figure 5.3, is an optimization curve that is similar to optimization curve of the estimations for all nodes for free-flow conditions as depicted in Figure 5.2. There are no significant changes; only the number of solutions is reduced. This result occurs because, in this study, we assume that the travel time between stops is constant (dwell time is not considered).

A combination of the above scenarios is examined to derive practically feasible optimization solutions for paratransit services in cities in developing countries. By reducing the number of stops and updating the BPR function, it is found that the number of solutions is reduced and the current condition cost is located far before the Pareto front curve, which means that the current conditions are much more efficient than the proposed optimization. Therefore, the number of stops should not be reduced. This is supported by the curves shown in Figure 5.3.

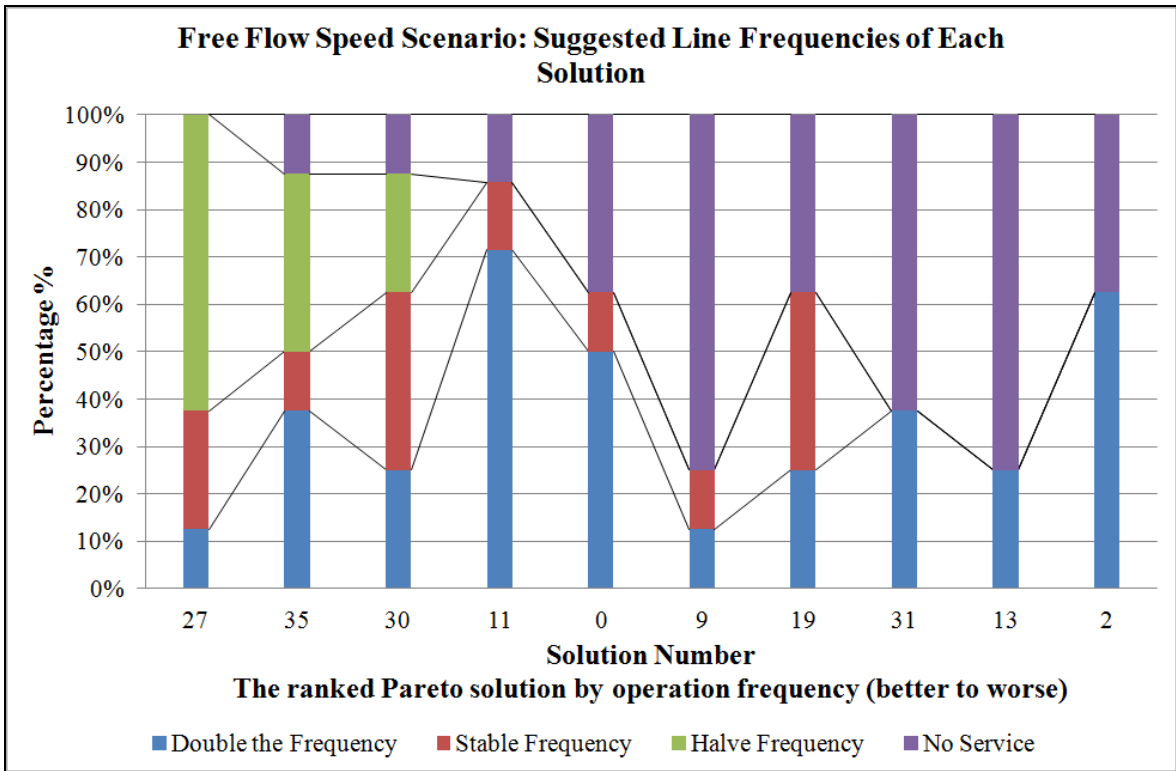


Figure 5.4 Free Flow Speed Scenario: Suggested Line Frequencies of Each Solution

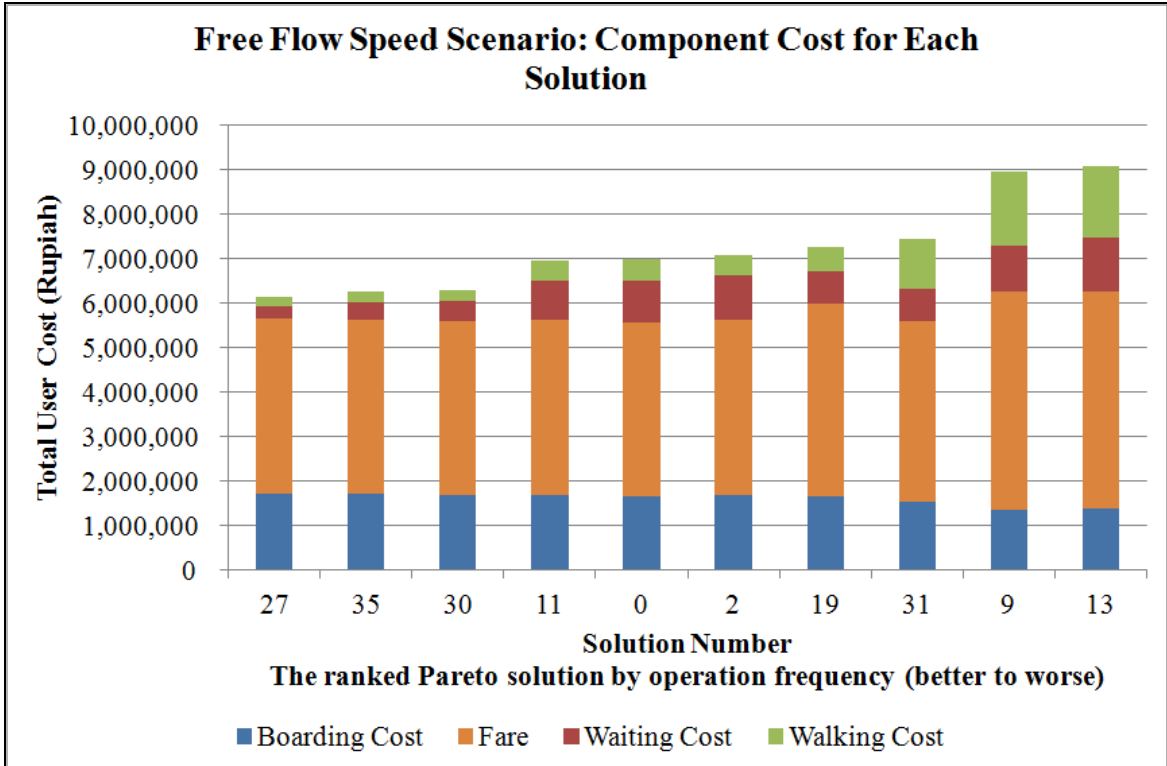


Figure 5.5 Free Flow Speed Scenario: Component Cost for Each Solution

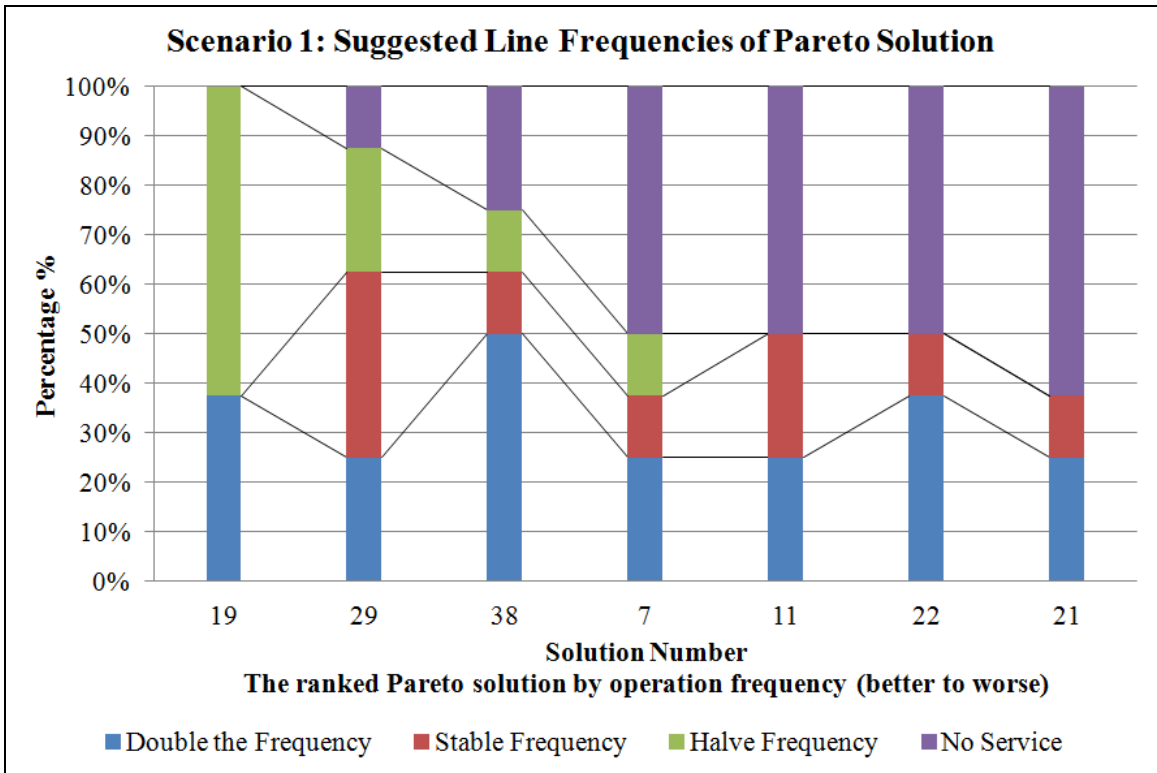


Figure 5.6 Scenario 1: Suggested Line Frequencies of Each Pareto Solution

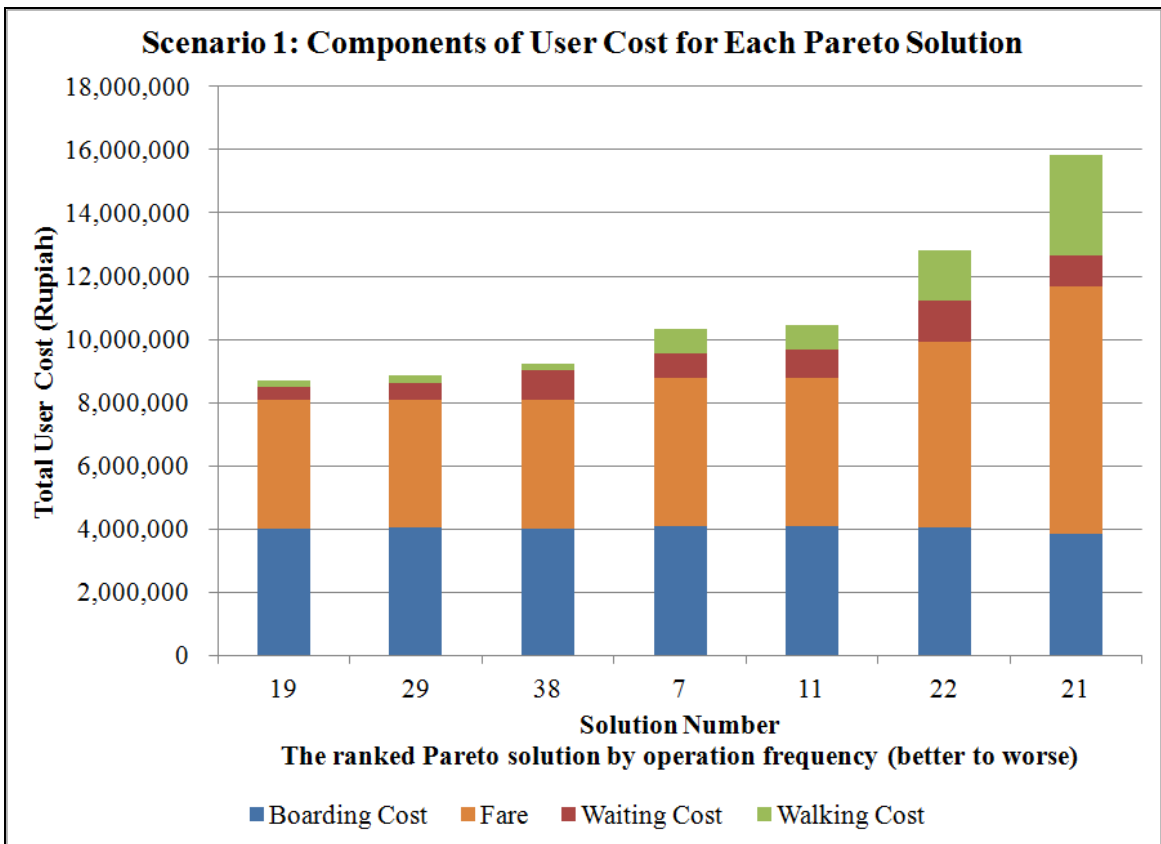


Figure 5.7 Scenario 1: Components of User Cost for Each Pareto Solution

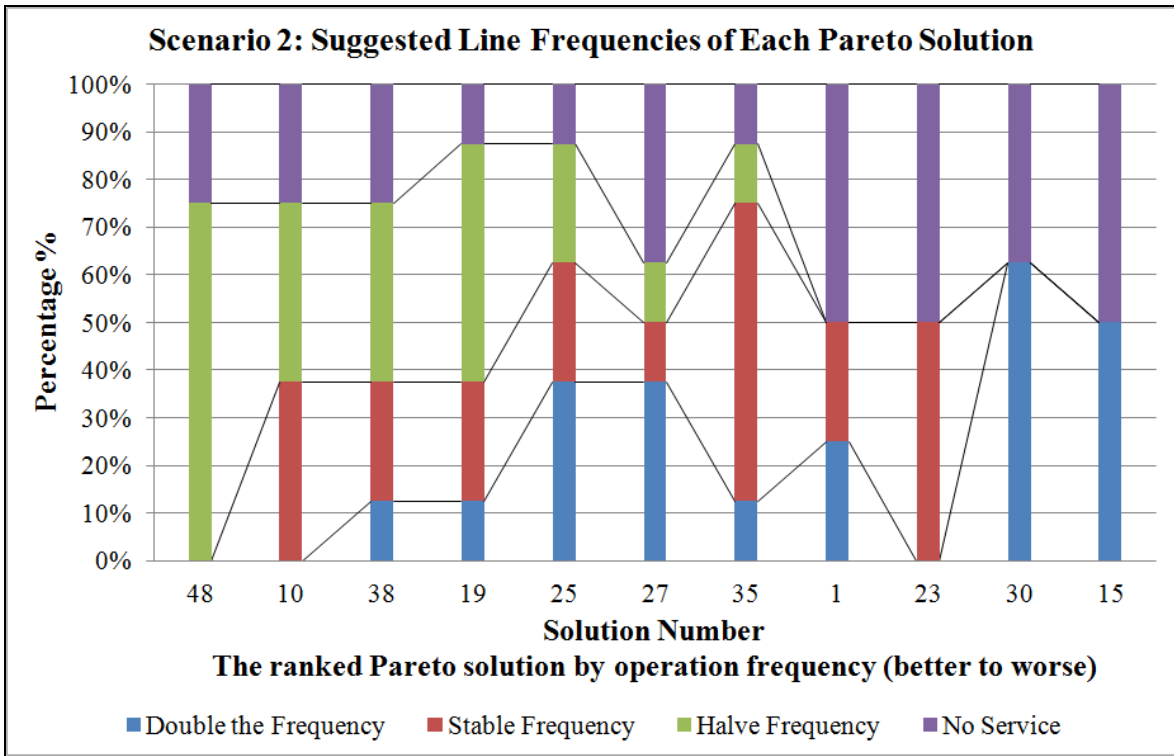


Figure 5.8 Scenario 2: Suggested Line Frequencies of Each Solution

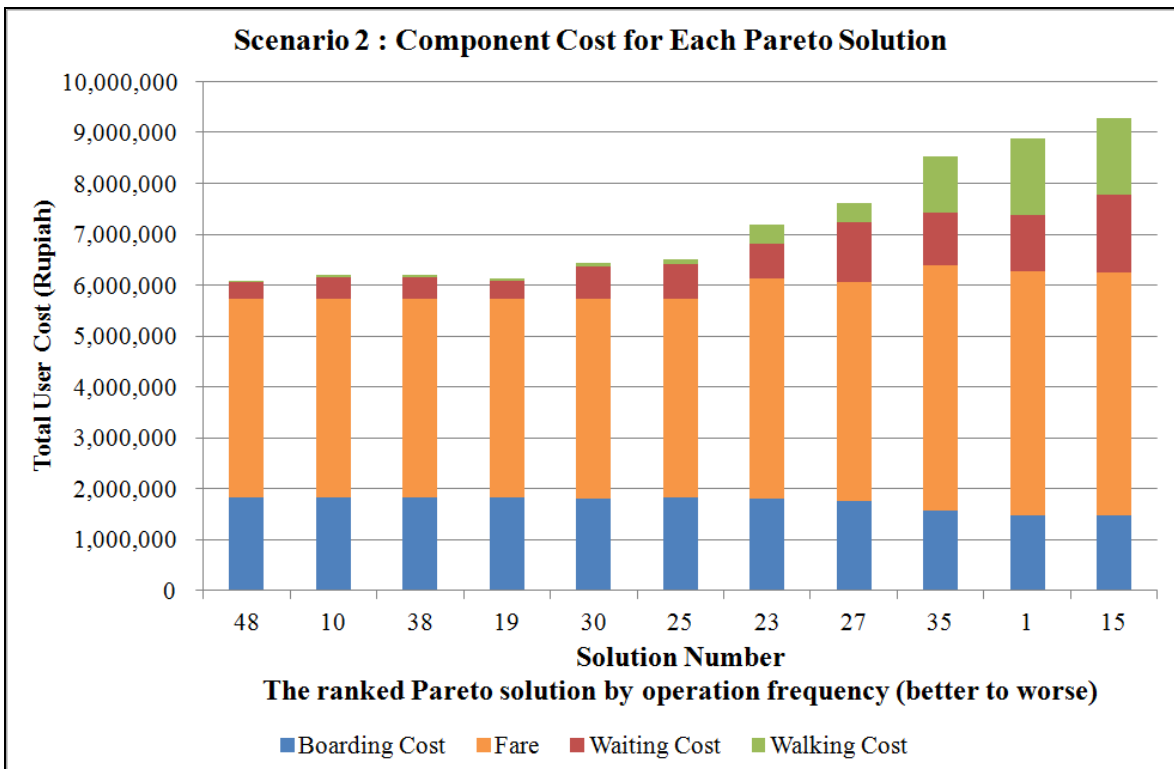


Figure 5.9 Scenario 2: Component Cost for Each Pareto Solution

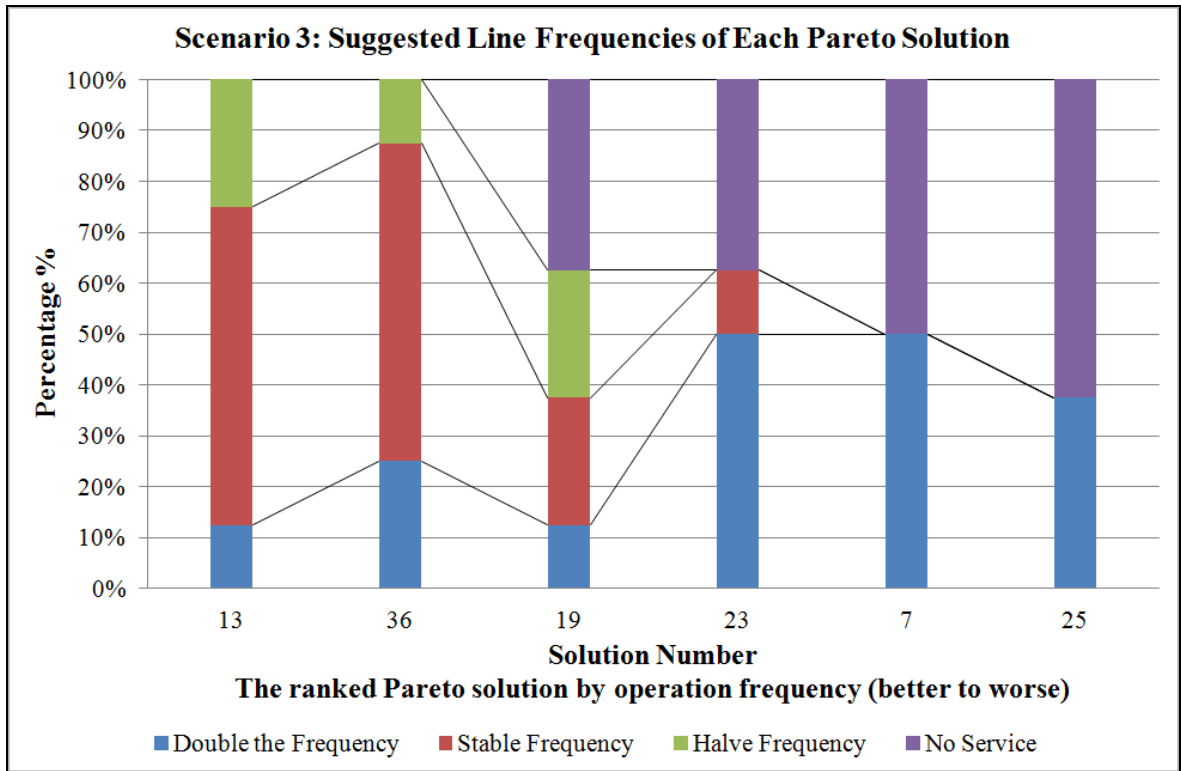


Figure 5.10 Scenario 3: Suggested of Each Pareto Solution

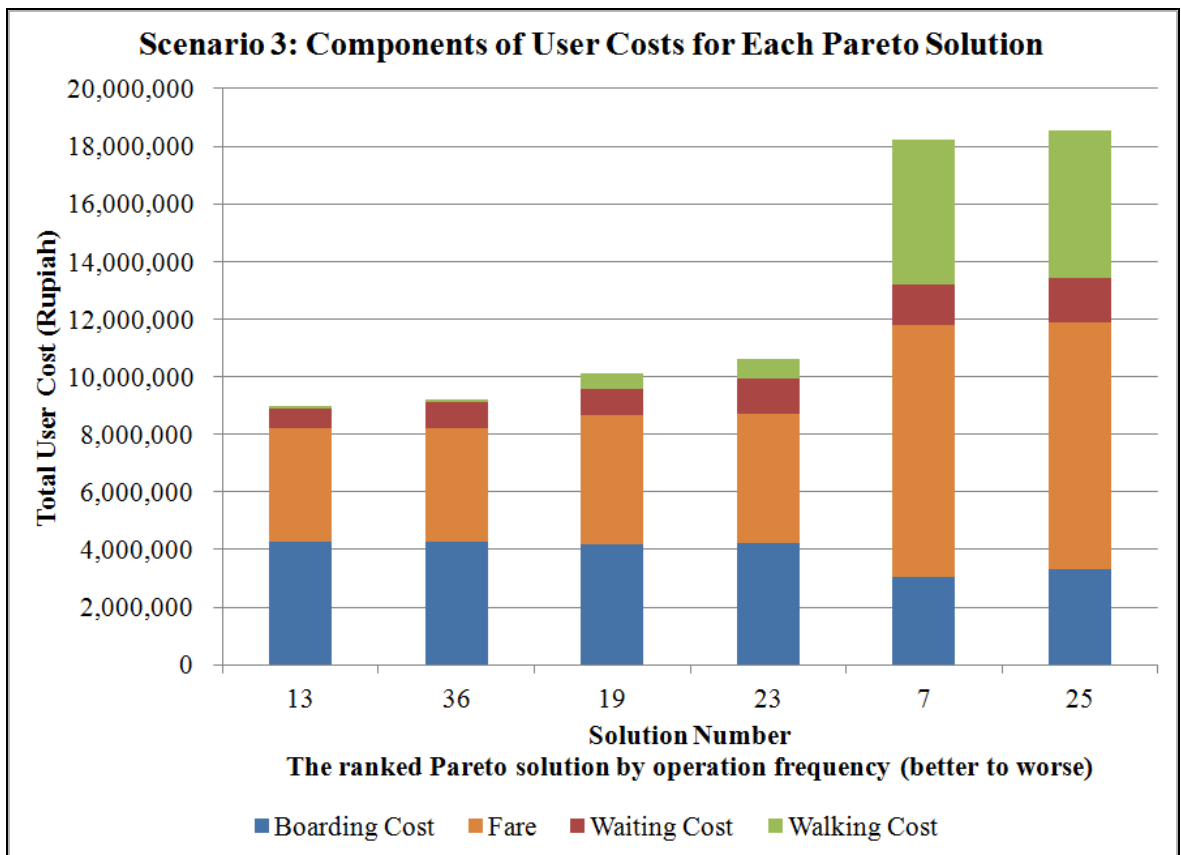
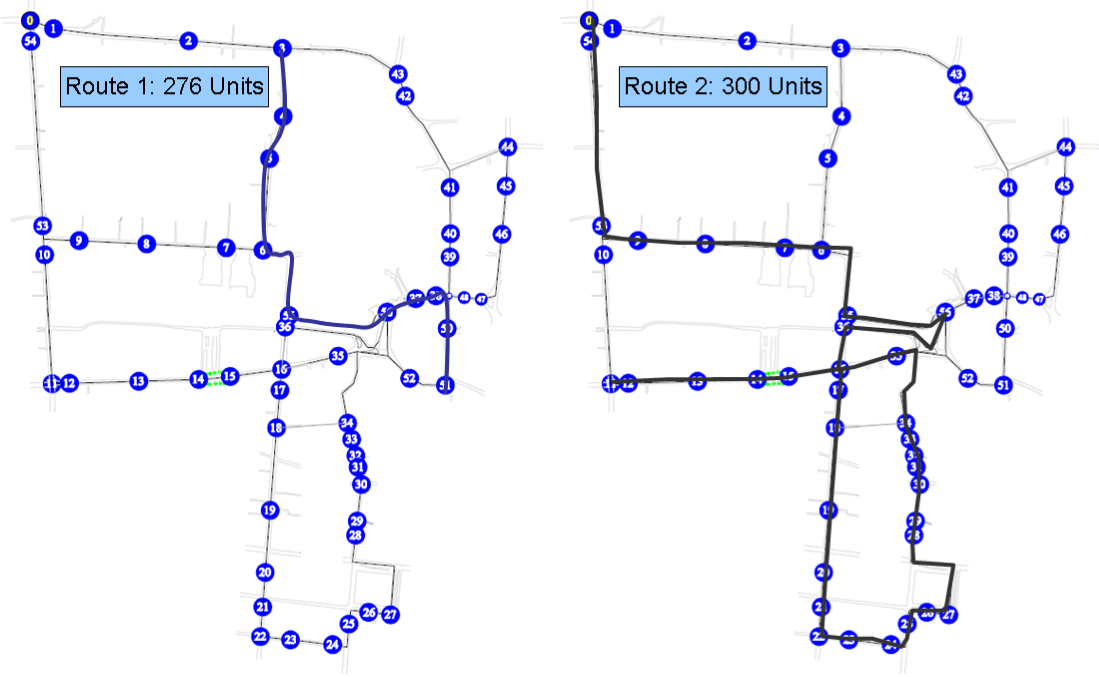


Figure 5.11 Scenario 3: Component Cost of User Costs for Each Pareto Solution

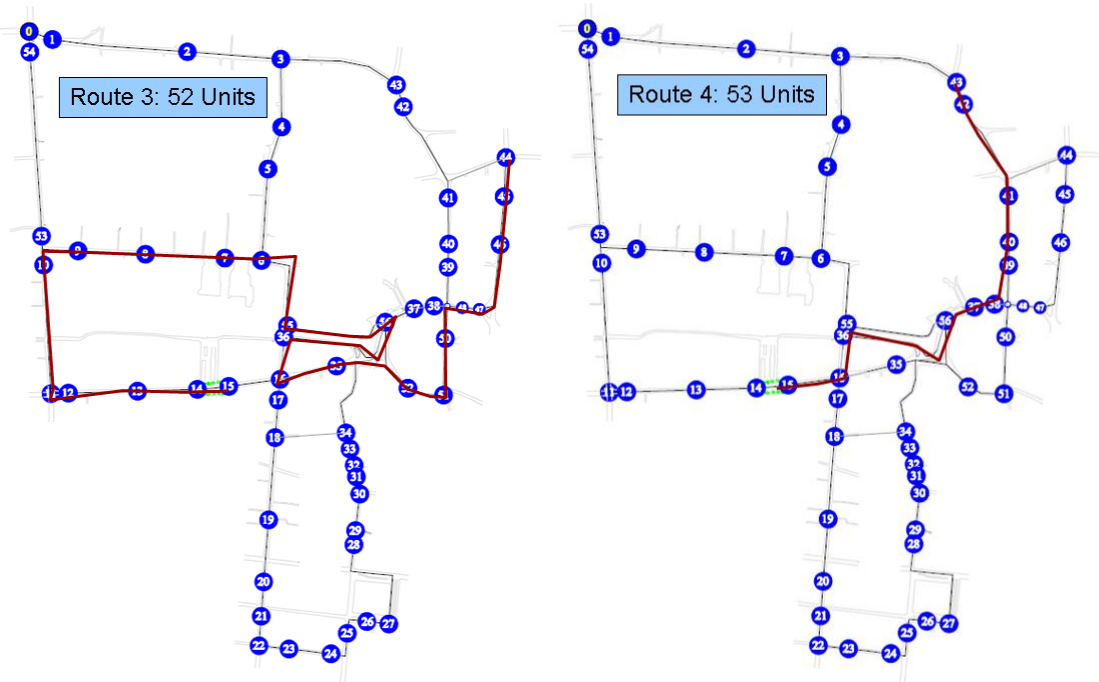
In Figure 5.4 to Figure 5.11, one can observe the suggested line frequencies of each solution and their component costs. In all three scenarios, the best scenario is scenario 1 (depicted in Figure 5.6 and Figure 5.7), in which all nodes are considered and the BPR function is updated. From Figure 5.7, one can see that the order number of the solutions and the increase of total user cost is in line, while in the contrary the cost of operational is decreasing in line with the degraded service. In the Figure 5.12 we depicted the route line for each angkot route. One can observed that the route 2,5 and 6 had overlapped route sections while route 7 and 8 also had some overlapped sections.

Table 5.2 shows the optimized frequency for each line. Looking at Solution 19, the operation frequency should be doubled for 35% of the lines (i.e., Routes 2, 4, and 5) and reduced by half for the remaining 65% of the lines (i.e., Routes 1, 3, 6, 7, and 8). There are no route lines being halted. Observing Solution 29, the frequency should be doubled for 25% of the lines (i.e., Routes 1, 3, and 5), kept unchanged for 44% of the lines (i.e., Routes 4 and 7), reduced by half for 11% of the lines, and reduced to zero for 20% of the lines (i.e., Routes 2 and 7). While in the last suggested Solution 21, Routes 7 and 8 are doubled and Route 4 is stabled while the rest are halted. The reason why the costs are also changing is because the number of vehicle units for each line are different. For example, Routes 3, 1 and 5 have the higher number of units than the other routes. Therefore substituting these routes with the other routes would result in greater effects on the costs.



(a)

(b)

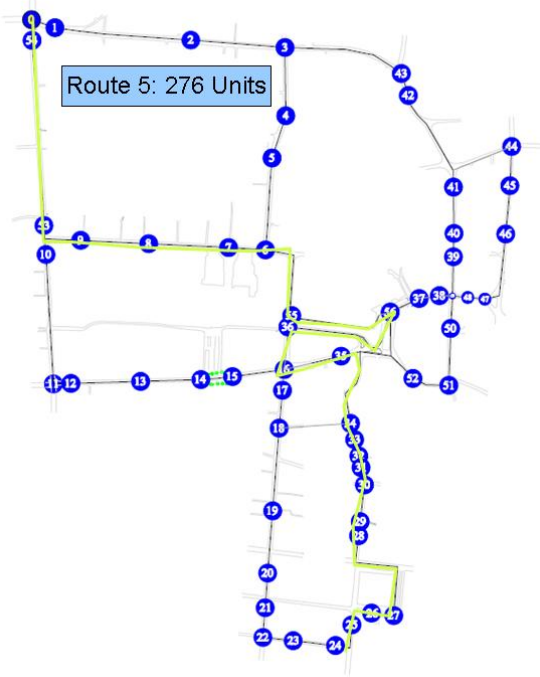


(c)

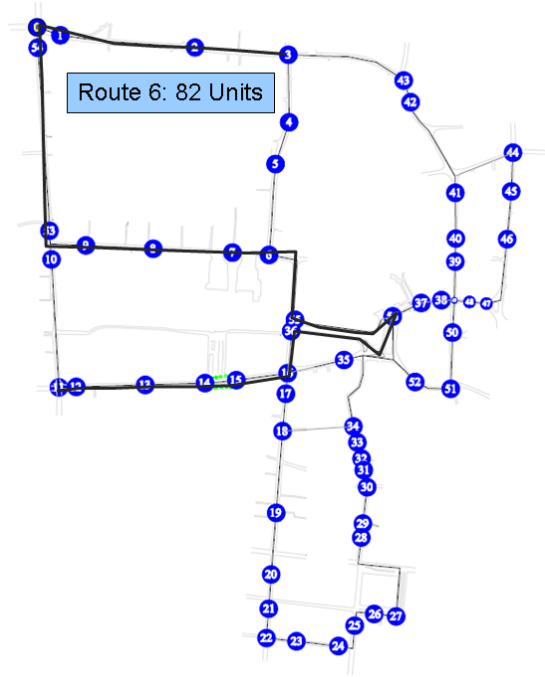
(d)

Figure 5.12 Route for each Angkot Line

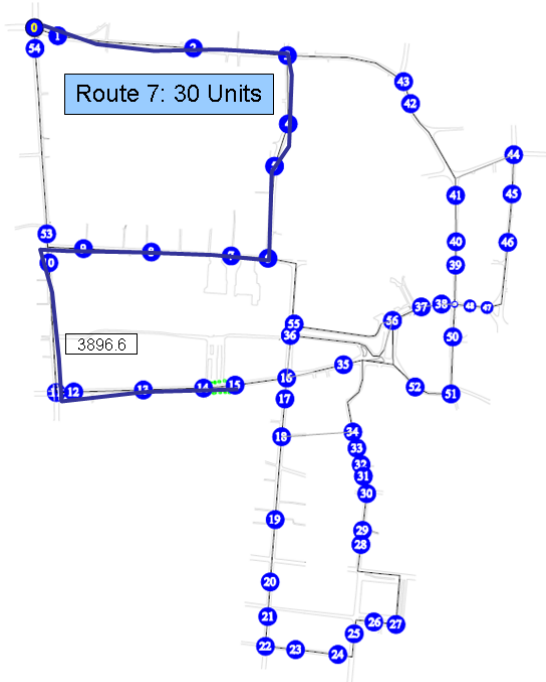




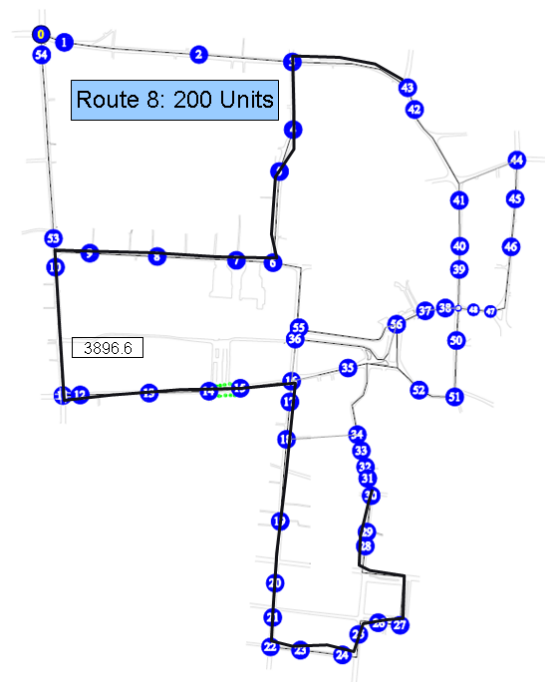
(e)



(f)



(g)



(h)

Figure 5.12 Route for each Angkot Line (continued)

Table 5.2 Frequency Breakdown for Each Route Line in Scenario 1: All Nodes and Updated BPR Function

Route Line	No. 19	No. 29	No. 38	No. 7	No. 11	No. 22	No. 21
1	0.5	2	2	2	2	n/a	n/a
2	2	n/a	n/a	n/a	n/a	n/a	n/a
3	0.5	1	2	1	1	2	n/a
4	2	1	0.5	n/a	n/a	1	1
5	2	2	2	n/a	n/a	n/a	n/a
6	0.5	1	1	0.5	1	n/a	n/a
7	0.5	n/a	n/a	n/a	n/a	2	2
8	0.5	0.5	2	2	2	2	2

\* 2 = Doubled the frequency, 1 = stabled, 0.5 = halve the frequency, n/a = halted

In summary, the same trends as noted before were confirmed: decreasing operational costs increases passenger costs and increases inequity of service levels among scenarios, and while introducing the updated BPR Function is important; reducing the number of stops might not be the best solution.

## 5.4 Summary

This study successfully analyzes the sensitivity of paratransit optimization from both the demand and supply sides during the morning peak hour in Bandung, Indonesia. A previously constructed bus network optimization model, which can identify optimum frequencies, is applied using an improved link performance function. A comprehensive field survey was conducted to support the research objective. The sensitivity analysis of different scenarios confirmed that the passenger and operational costs in the current network are sensitive to the congestion level. Comparison of the current paratransit

network and the model output from the scenario involving updating the BPR function without reducing the number of stops confirmed that the current paratransit network is close to the Pareto front if the total costs for passengers and operators are adopted as objective functions. Therefore, updating the BPR function is important to obtaining a true picture of the paratransit network, and the influence of an updated BPR function cannot be ignored. Reducing the number of stops might not be a better solution because the results show that the current cost situation is much more efficient than the solution obtained from the optimization model. The second findings might be arguable due to in this study the dwell time is considered to be constant therefore further research and model improvement might need to be done. Future research should include more of the distinct characteristics of paratransit networks to obtain more realistic results.

## **Chapter 6 Does Improved Paratransit Level of Service Improve Drivers' Quality Of Life?**

This section is a part of the subjective analysis. In this study, it is aimed to clarify how the improvement of paratransit service affects drivers' quality of life (QOL). This was done by integrating the optimization results of a paratransit system (i.e., angkot) from a optimization model and the QOL evaluation results from a simultaneous-equation ordered probit model by using data collected

### **6.1 Introduction**

In our previous chapter with the title of Evaluation of Paratransit Services from the Perspective of Environmental Impacts and Drivers' Quality of Life QOL in Bandung city (Weningtyas et al., 2012c), we investigate the causal-effect relationships between work performance and driver's life satisfaction (as a proxy variable to indicate QOL) while at the same time to measure the relationship between work performance and gap revenue and indirectly to work satisfaction. Work performance is explained by operation frequency, service time, drivers' waiting time for passengers, total distance serviced and gap revenue. The first four terms are representing the level of service of paratransit. This will be discussed further in the next subsection about paratransit LOS. The most important finding from this study is that the current paratransit systems in Bandung City

are neither socially nor environmentally sustainable. . It is found that by improving the paratransit LOS (here refers to increasing the work performance) would cause an increase in environmental impacts and worsen drivers' QOL.

Kawaguchi et al (2012) stated that in the case of angkot in Bogor, it turns out that paratransit owners and drivers suffer operational, regulatory and financial problems. His study was conducted based on a so-called "angkot shift program", which purpose was to regulate the supply of angkot vehicles by assigning each of the vehicles into one of three shift groups, and only two shift groups are allowed to operate in a given day. Results showed that illegal competition among angkot vehicles was reduced, and owners' net income increased due to the reduction of maintenance costs while drivers could take additional leave.

From the above two studies, we can say that by reducing the paratransit service could cause positive impact on the drivers and more on the owners. This finding is interesting, which provides a contrary observation to recent studies (Cervero et al., 2007; Joewono et al., 2007; Tangphaisankun et al., 2009; Tarigan et al, 2010; Neumann et al., 2012) showing that the LOS should be increased based on user perceptions on satisfaction. Then, one question that is worth rising is that by balancing the needs of both supply and demand sides, whether the improvement of LOS is always better? Several existing studies clearly defined the LOS classification for public transportation, but no

studies have clearly defined standards for classifying the level of paratransit services. Especially, little has been done to look at the role of drivers' QOL in decisions on paratransit services.

Motivated by the above observations, this study aimed to clarify how the improvement of paratransit service affects drivers' quality of life (QOL). This was done by integrating the optimization results of a paratransit system (i.e., angkot) from a optimization model (Weningtyas et al., 2012a) and the QOL evaluation results from a simultaneous-equation ordered probit model by using data collected in Bandung, Indonesia. The objective function is to minimize paratransit system operation cost and user cost by minimizing the shortest hyperpath. This study has significant policy implications, considering that paratransit drivers' economic sustainability is at stake and is expected to provide additional insights into policy making from the perspective of more effective use of paratransit, improved urban mobility and better quality of drivers' lives.

## **6.2 Level of Service**

Several existing studies provided the definition of Public Transportation's LOS classification. Unfortunately, to the authors' knowledge, none of the studies have clearly defined the LOS classification of paratransit.

### 6.2.1 Public Transportation LOS

TRB Transit Capacity and Quality of Service Manual (TCQSM) (2003) defined the public transportation LOS classifications as listed in Table 6.1, which shows the measures presented in the TCQSM. The measures are divided into six categories, corresponding to transit service availability and quality for transit stops, route segments, and systems. The measures shown in capital letters are the measures for which A-F levels of service are provided, while the remaining measures are discussed in details in the manual, but no levels of service are provided for them

Table 6.1 Quality of Service Framework in the TCQSM 2003

Category	Service & Performance Measures		
	Transit Stop	Route Segment	System
Availability	FREQUENCY accessibility passenger loads	HOURS OF SERVICE accessibility	SERVICE COVERAGE % person-minutes served indexes
Quality	PASSENGER LOADS amenities reliability	RELIABILITY travel speed transit/ auto travel time	TRANSIT/ AUTO TRAVEL TIME travel time safety

Source: *Transit Capacity and Quality of Service Manual (TCQSM), 2003*

The question is, can we also use the same classification of LOS for the paratransit system? Table 6.2 and Table 6.3 present examples for service frequency classification and hours of service classification, respectively. Table 6.4 shows examples of existing paratransit frequency and hours of service. One can observe that if we use the same

classification of LOS as the standard public transportation system, then all the paratransit services are already classified in the level A for frequency (headway < 4 min) and B for hours of service (17-18 hours). In other words, the current paratransit services do not need any improvements.

Table 6.2 LOS Classification based on Fixed-Route Service Frequency

LOS	Avg. Headway (min)	veh/ hr	Comments
A	<10	>6	Passengers do not need schedules
B	10-14	5-6	Frequent service, passengers consult schedules
C	15-20	3-4	Maximum desirable time to wait if bus/ train missed
D	21-30	2	Service unattractive to choice riders
E	31-60	1	Service available during the hour
F	>60	<1	Service unattractive to all riders

Source: *Transit Capacity and Quality of Service Manual (TCQSM), 2003*

Table 6.3 LOS Classification based on Fixed-Route Service Hours

LOS	Hours of Service	Comments
A	19-24	Passengers do not need schedules
B	17-18	Frequent service, passengers consult schedules
C	14-16	Maximum desirable time to wait if bus/ train missed
D	12-13	Service unattractive to choice riders
E	4-11	Service available during the hour
F	0-3	Service unattractive to all riders

Source: *Transit Capacity and Quality of Service Manual (TCQSM), 2003*

### 6.2.2 Level of Paratransit Service

With the above discussion, it seems necessary to provide another method for defining a better or improved level of paratransit services. In line with such consideration, one of



our studies on paratransit system (Weningtyas et al., 2012a) made an effort based on the optimization model of service frequency, where the objective function is to minimize the sum of paratransit operation cost and total user cost by considering the shortest hyperpath in the transit assignment model with common lines.

Table 6.4 Paratransit Frequency and Hours of Service in Bandung City Year 2008

Route Code	Route Description	Operational Time	No of Fleet	Roundtrip Length (km)	Load Factor	Travel Time per Roundtrip (min)	Average Speed (km/h)	No of roundtrip (interview)	Passenger per Roundtrip	Average Headway (min)
1	Abdul Muis-Cicaheum via Binong	05:30-20:00	325	29.6	0.6	146.0	12.1	5.6	64.0	0.8
2	Abdul Muis-Cicaheum via Aceh	05.30-19:30	86	19.7	0.8	102.5	11.6	6.6	54.0	1.5
3	Abdul Muis-Dago	06:00-22.00	244	19.1	0.7	91.0	12.6	9.8	47.0	1.2
4	Abdul Muis-Ledeng	05:30-21:45	223	23.7	1.0	94.5	15.1	8.1	50.0	0.7
5	Abdul Muis-Elang	06:00-22:00	91	16.2	0.4	66.0	14.7	9.5	40.0	1.7
6	Cicaheum-Ledeng	05:30-20:00	159	26.7	0.9	111.5	14.4	5.6	47.0	0.7
7	Cicaheum-Ciroyom	05:00-21:00	191	26.8	0.8	122.5	13.2	6.1	72.0	2.6
8	Cicaheum-Ciwastra	05:00-18:30	169	29.2	0.6	128.0	13.7	6.0	69.0	0.8
9	Cicaheum-Cibaduyut	05:00-21:30	110	23.0	0.7	81.5	16.9	8.6	55.0	1.3
10	Stasiun Hall-Dago	05:30-21:00	43	15.5	0.7	64.3	14.4	10.0	41.0	3.4

Source: (Subdit Lalu Lintas Perkotaan, 2008)

### 6.3 Paratransit Drivers Quality of Life

The driver's task is mentally demanding because of having to cope with conflicting requests (Kompier, 1996). The company and the public want the driver to maintain good contact with passengers and to be service-oriented, for instance to travelers (providing information about timetables, routes, stops, fares, etc.). These are also important aspects for job satisfaction. In the operator's daily life, the demand for service by the individual passenger often conflicts with the need to keep to a tight

schedule in dense traffic. The third demand on the driver, also conflicting with the other two, is the demand to drive safely according to traffic regulations (Kompier, 1996).

Kawaguchi *et al* (2012) stated that the total working days per month have decreased for drivers due to the aforementioned “angkot shift program”. For example, roughly 70% of the drivers of a route and roughly 50% of the drivers of another route reported that their QOL had been improved because the time spent with their family members had increased. It was also reported that roughly 20% of drivers were working with another job, thus making use of the additional time off. In general, the free time created by the program had a positive impact on the drivers.(Kawaguchi & Kuromizu, 2012).

As stated in our previous study (Weningtyas *et al.*, 2012c), drivers’ job can be considered as a self-employed job, which is entirely different from company-based employment. Drivers make the entire decisions by themselves, independently of both owners and the government. They freely decide when to start or to stop the service. Their decisions are based on their acceptable daily earnings and each driver, in fact, has a different standard. This uncertain decision making however results in the service unreliability, where the service performance highly depends on filling in empty seats, rather than on fixed income that can guarantee a stable service (Susantono *et al*, 1997; Cervero, 2000).

Since paratransit drivers belong to the low-income group, meeting their basic needs may be given the top priority in their jobs and consequently other life domains may be regarded as secondary needs. In other words, QOL of paratransit drivers may mostly concern about fulfilling the basic needs before achieving higher level of needs. Therefore, it may be a good idea to divide the structure of life domains into two hierarchical levels: basic level and higher level of QOL (see Weningtyas et al., 2012c).

Life satisfaction, which is an overall assessment of feelings and attitudes about one's life at a particular point in time, is one of common core subjective elements (Phillips, 2006). The domains of life literature reveal that life can be combined as a general construct of many specific domains. Life satisfaction can be understood as the result of satisfaction in the domains of life, for example, the domains are specified as health, economic, job, family, friendship, personal, and community environment. With the above supporting evidence, here, drivers' job satisfaction is one of the domains in drivers' life satisfaction and driver's life satisfaction is used as a proxy of paratransit drivers' QOL. Considering the specific living conditions in Indonesia (Widyosiswoyo, 1991), six life domains are considered: work, residence, health, family, social life, and leisure (free time), where the first three correspond to the basic needs and the last three to the higher needs.

#### **6.4 Unresolved Issues**

In our previous study (Weningtyas et al., 2012c), we applied a structural equation model (SEM) with latent variables to investigate causal-effect relationships between work performance and driver's life satisfaction (as a proxy variable to indicate QOL) as well as environmental impacts. At the same time we also measured the relationship between work performance and gap revenue and indirectly to work satisfaction. It is found that the current paratransit systems in Bandung City are not beneficial to both drivers and the environment. Earning more money requires drivers to work longer. This finding has important policy implications. Improving the sustainability of a paratransit system requires some actions taken to change the current operation and contract systems of paratransit services. More effects should be made from the owner side of paratransit system, rather than from the driver side. Especially, in the analysis, reflecting the actual situations in Indonesia, drivers' quality of life is measured by classifying it into the basic level and higher level. Our estimation results confirmed such hierarchical structure of QOL is statistically significant and such "basic level of QOL"-centered cause-effect model structure is suitable to the evaluation of paratransit services.

In the other study on paratransit system (Weningtyas et al., 2012a), we present a sensitivity analysis from both demand and supply sides in Bandung, Indonesia. The analysis was conducted based on a optimization model to decide the optimal operation frequency of paratransit system. The objective function is to minimize the generalized

cost of paratransit users and the operational cost for paratransit drivers by considering the shortest hyperpath in the transit assignment model with common lines. Total user cost can be defined as generalized cost for total user cost. These include the fare and monetary value of travel time and waiting time. The sensitivity analysis of different scenarios confirmed that the passenger and operational costs in the current network are sensitive to the congestion level. Comparison of the current paratransit network and the model outputs from the scenarios confirmed that the current paratransit network is close to the Pareto front if the total costs for passengers and operators are adopted as objective functions. The suggested solutions of the optimized operation frequency and the comparison between total user costs for each solution are depicted in Figure 5.6.

Based on the results obtained from the second study, in fact, we cannot endogenously decide which solution provides the best option for the win-win situation between the paratransit operator and users. This means that some external indicators are required to decide the best option. In the optimization framework, both operators' and users' behaviors are reflected; however the direct service providers are drivers of paratransit vehicles. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not be realized. If paratransit service provision could not improve drivers' QOL, drivers would not make efforts to provide satisfactory and reliable services. With the above consideration, this study suggests introducing drivers' QOL indicators to optimize the paratransit service.

The unresolved issues are, however, 1) how the improved LOS of a paratransit system influences drivers' QOL, and 2) how to quantitatively measure such influence. The first study introduced above clarified the cause-effect relationship between LOS and drivers' QOL, but the SEM model is not suitable for the prediction. Therefore, it is required to develop a tool to predict the influence of the improved LOS of a paratransit system on drivers' QOL.

### **6.5 Methodology: Quality Of Life Measurement Model**

As stated before, our previous study (Weningtyas et al., 2012c) successfully investigated the causal-effect relationships between work performance and driver's QOL. Unfortunately, the adopted method, i.e., SEM, cannot be used for the prediction of dependent variables since SEM estimations are usually done by minimizing the discrepancy between observed and estimated variance-covariance matrices, rather than the discrepancy between observed and estimated dependent variables. Therefore, we propose to build a simultaneous-equation ordered probit model that can explicitly link the LOS variables with correlated drivers' QOL indicators (in this study, six QOL indicators), which were, in fact, identified in our previous study, as shown in Figure 4.10 (Weningtyas et al., 2012c). In order to simplify the analysis we only consider the LOS as explanatory variables and employing the paratransit drivers' life satisfaction (measured as ordered responses) with six life domains as dependent variables. The resulting functions

for the simultaneous-equation ordered probit model (hereafter called QOL measurement model) are shown below.

The observed category of a life satisfaction indicator (n: driver; i: life domain) is defined via a latent variable, as follows:

$$\begin{aligned}
 y_{ni} &= 0 \text{ if } y_{ni}^* \leq 0 \\
 y_{ni} &= 1 \text{ if } 0 \leq y_{ni}^* \leq \gamma_1 \\
 &\dots \\
 y_{ni} &= J \text{ if } \gamma_{J-1} \leq y_{ni}^*
 \end{aligned}$$

The latent variable is further specified for each life domain, by reflecting the hierarchical structure of between basic level and higher level of QOL, identified in our previous study (Weningtyas et al., 2012c), as follows:

$$y_{ni}^* = \eta_{ni} + \varepsilon_{ni}, \text{ with } \varepsilon_{ni} \sim N(0,1) \quad (37)$$

$$y_{n2}^* = \lambda_2 \eta_{n1} + \varepsilon_{n2}, \text{ with } \varepsilon_{n2} \sim N(0,1) \quad (38)$$

$$y_{n3}^* = \lambda_3 \eta_{n1} + \varepsilon_{n3}, \text{ with } \varepsilon_{n3} \sim N(0,1) \quad (39)$$

$$y_{n4}^* = \eta_{n2} + \varepsilon_{n4}, \text{ with } \varepsilon_{n4} \sim N(0,1) \quad (40)$$

$$y_{n5}^* = \lambda_5 \eta_{n2} + \varepsilon_{n5}, \text{ with } \varepsilon_{n5} \sim N(0,1) \quad (41)$$

$$y_{n6}^* = \lambda_6 \eta_{n2} + \varepsilon_{n6}, \text{ with } \varepsilon_{n6} \sim N(0,1) \quad (42)$$

$$\eta_{n1} = \beta_1 x_{n1} + \beta_2 x_{n2} + \beta_3 x_{n3} + \beta_4 x_{n4} + \beta_5 x_{n5} \quad (43)$$

$$\eta_{n2} = \beta_6 y_{n1} + \beta_7 y_{n2} + \beta_8 y_{n3} \quad (44)$$

where, all “x”s are explanatory variables and all “y”s are QOL indicators, all terms are error terms and others are unknown parameters.

In the first three functions for “Satisfaction to Work ( $y_{n1}$ )”, “Satisfaction to Health ( $y_{n2}$ )”, and “Satisfaction to Residence ( $y_{n3}$ )” we introduce a common variable ( $\eta_1$ ) to describe the latent variable “Basic Level of QOL” as structured in the SEM model depicted in the Figure 4.10 above.. Where this common variable is explained by the five explanatory variables which are “gap revenue ( $x_1$ )”, “number of round trips ( $x_2$ )”, “service time ( $x_3$ )”, “drivers’ waiting time ( $x_4$ )” and also “service distance ( $x_5$ )”. While the later three utility function, which are “Satisfaction to Free time ( $y_{n4}$ )”, “Satisfaction to Family ( $y_{n5}$ )”, and “Satisfaction to Social Life ( $y_{n6}$ )”, we introduce another common variable ( $\eta_2$ ) to describe the latent variable of “Higher level of QOL”. These common variables are explained by “Satisfaction to Work ( $y_{n1}$ )”, “Satisfaction to Health ( $y_{n2}$ )”, and “Satisfaction to Residence ( $y_{n3}$ )”. We estimate the six ordered probit model jointly in order to maximize all the log likelihood function at the same time.

The above QOL measurement model also includes another two sets of parameters: one are constant terms and the other are threshold parameters related to the assumed normal distribution.

## **6.6 Quality of Life Measurement Model Analysis**

This chapter employs the survey data obtained from the first data collection explained in chapter 2, section 2.4.2. The results of the estimated parameter value of each explanatory variable using the ordered probit model are listed in Table 6.5.



Table 6.5 Estimation Results of the QOL Measurement Model

Explanatory Variable	Parameter value	t-value	
Gap Revenue	0.00004	0.705	
No. of Round Trips	-0.165	-1.004	
Driver Waiting Time	0.189	5.208	**
Service Time	-0.269	-2.183	**
Service Distance	-0.035	-4.178	**
Satisfaction with Work	0.373	2.687	**
Satisfaction with Health	1.117	3.594	**
Satisfaction with Residence	0.846	3.744	**
Constant term for Work	3.556	1.990	**
Constant term for Health	3.768	3.295	**
Constant term for Residence	3.033	4.327	**
Constant term for Free Time	-3.048	-4.246	**
Constant term for Family	0.840	1.416	
Constant term for Social Life	2.035	3.115	**
$\lambda_2$ in equation (2)	0.492	3.063	**
$\lambda_3$ in equation (3)	0.243	1.906	**
$\lambda_4$ in equation (5)	0.253	2.903	**
$\lambda_5$ in equation (6)	0.052	0.611	
Threshold $\gamma_1$ for Work	0.654	6.668	**
Threshold $\gamma_2$ for Work	1.359	15.558	**
Threshold $\gamma_1$ for Health	1.415	10.495	**
Threshold $\gamma_2$ for Health	1.539	18.715	**
Threshold $\gamma_1$ for Residence	1.407	10.442	**
Threshold $\gamma_2$ for Residence	1.049	15.552	**
Threshold $\gamma_1$ for Free Time	1.639	13.065	**
Threshold $\gamma_2$ for Free Time	1.760	19.279	**
Threshold $\gamma_1$ for Family	1.389	10.425	**
Threshold $\gamma_2$ for Family	1.132	17.113	**
Threshold $\gamma_1$ for Social Life	1.514	12.197	**
Threshold $\gamma_2$ for Social Life	1.075	15.513	**
Initial Log-likelihood	-2366.506		
Converge Log-likelihood	-603.600		
McFadden's Rho Squared	0.745		
Adjusted Mc Fadden's Rho Squared	0.732		
Number of Samples	152		

\*\* is significant at 1% level

The model accuracy is good enough with the value of McFadden's Rho Squared being 0.745 and the adjusted value being 0.732. The significant LOS explanatory variables are drivers' waiting time, service time and service distance for the first three QOL indicators:

satisfaction with work, health, and residence, These three indicators represent the basic QOL level, which is significantly influential to the later three life domains: social life, free time, and family.

With the above estimation results, we will evaluate the influence of improved paratransit services (see Figures 6.1, 6.2, and 6.3) optimized in our previous study (Weningtyas et al., 2012a) on drivers' QOL. Figure 6.1 illustrates the suggested line frequencies of each Pareto solution while Figure 6.2 shows the components of user costs of each Pareto solution ranked by the line frequency. First, we identified which line frequency needs to be doubled, stabled, or halved or even halted based on Figure 6.1 and then these frequency changes were transferred to adjusted values of number of round trips and service distance obtained from the questionnaire survey while keeping service time and drivers' waiting time unchanged. It is assumed that service time does not need to be changed, since the optimization model did not include it. For drivers' waiting time, it is, in fact, very short due to the high frequency of actual operation (average headway is only 0.5 seconds). Therefore, we assume that the value will not change significantly although, for example, we halve or double the frequency. Observing from the Figure 6.3, we can know how much the operational cost is reduced due to the LOS optimization. This percentage of the reduction is used to adjust the gap revenue value from the data.

From Figure 6.3, it is obvious that the three Pareto solutions (Solutions 19, 29, and 38) shown in the left part are close to the existing condition (i.e., the red dot), where the suggested solutions are in green triangles. In order to evaluate which solutions could give a better driver QOL, the effects of optimized LOS on drivers' QOL are compared. The comparison is done for the aforementioned three suggested solutions. It can be easily observed that the operation cost for the three solutions are more sensitive than the total user cost. While starting from the 4<sup>th</sup> solution counted from the left part, the sensitivity of total user cost is much higher than the operation cost because the service becomes worse and worse from the left to the right. For instance, the 1<sup>st</sup> suggested solution is the best operation where no line frequency is halted or the service is stopped. While in the last suggested solution, there are more lines that are halted or no service is provided. The reason why some lines was are suggested to be halted is because there are several routes which are overlapped. This means that when some lines are halted, the other lines perform as a substitute.

In Solution 19 and Solution 38, the number of round trips is increased: 6.25% of the existing frequency in Solution 19 and 18.75% in Solution 38. Meanwhile in Solution 29 the existing frequency is decreased by 6.25% and as a result the gap revenue is also increased due to the operational cost is reduced by 15% as depicted in Figure 6.3

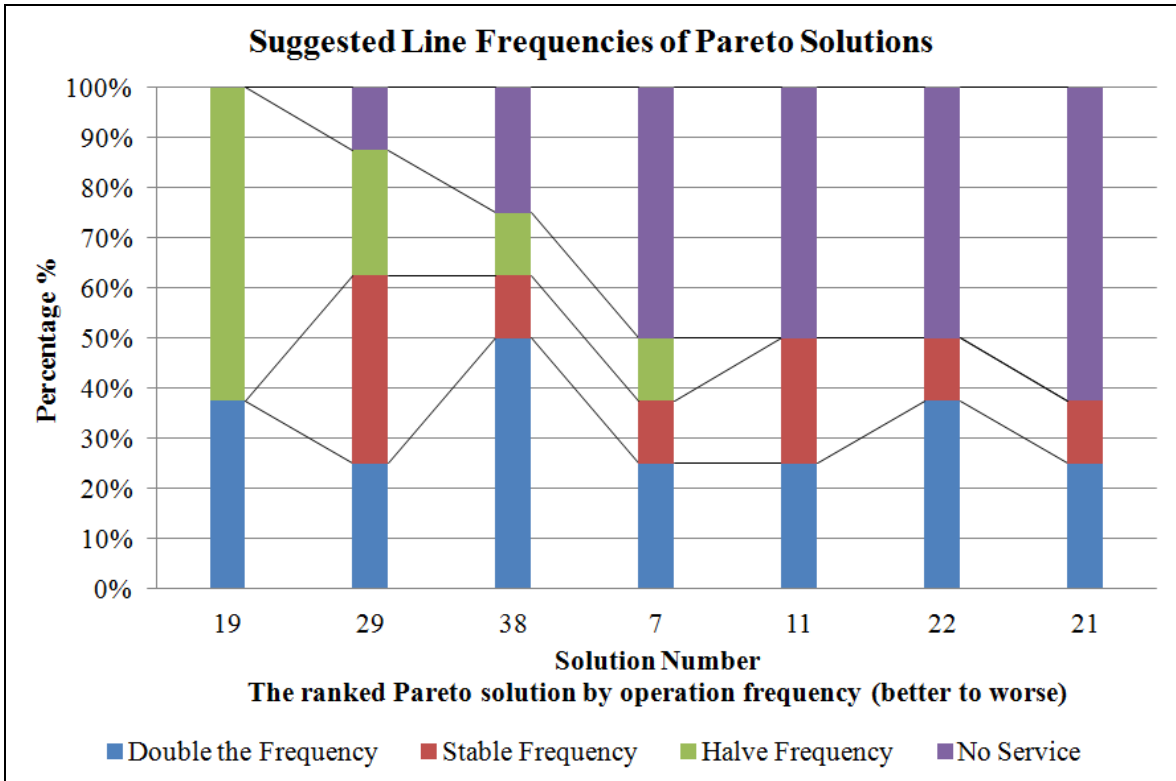


Figure 6.1 Suggested Line Frequencies of Pareto Solutions

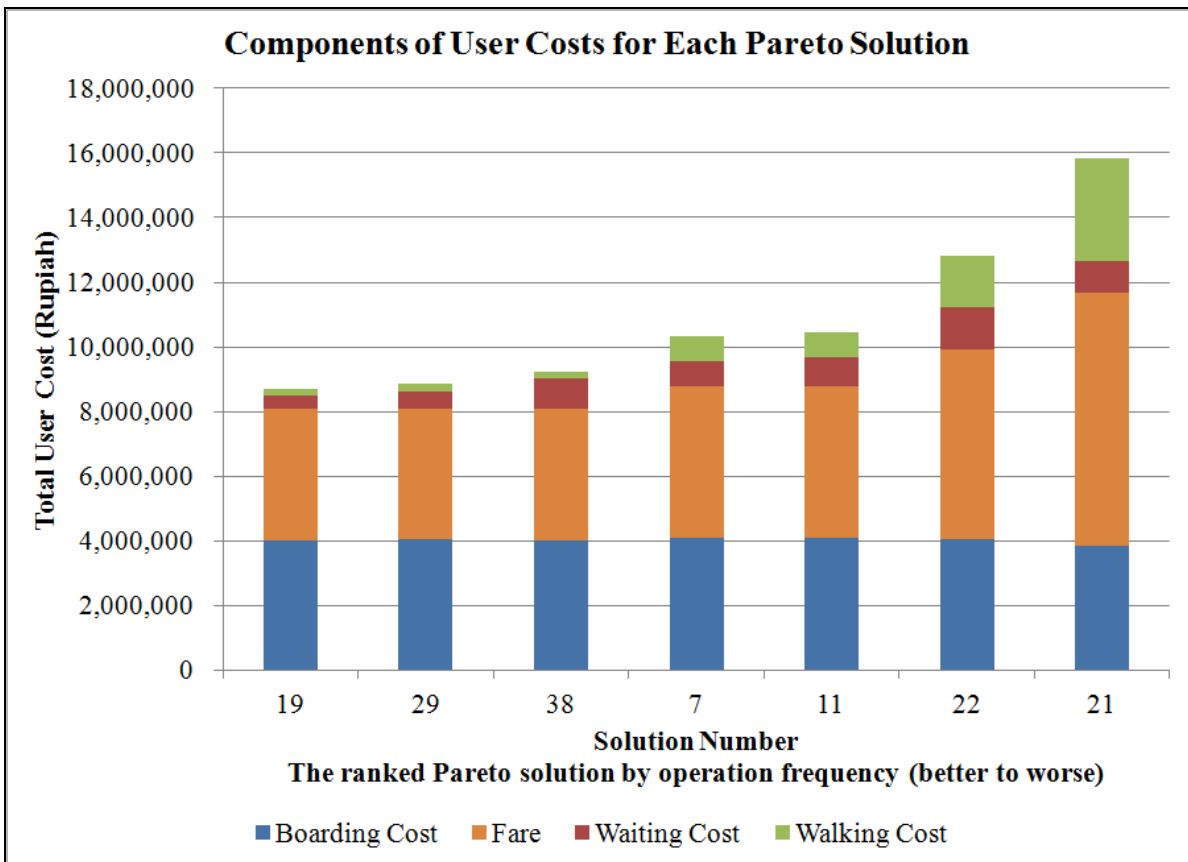


Figure 6.2 Components of User Costs for Each Pareto Solution

Although in Solution 38 the operational cost is reduced significantly but drivers' QOL somehow decreases. This result might be reasonable because a very high frequency would mean that drivers need to work longer. This may be arguable on the other hand. How the increased frequency results in decreased operational cost? As depicted in Table 5.2, the lines that are suggested to be increased have shorter travel distance and lower frequency. In this sense, this result is understandable.

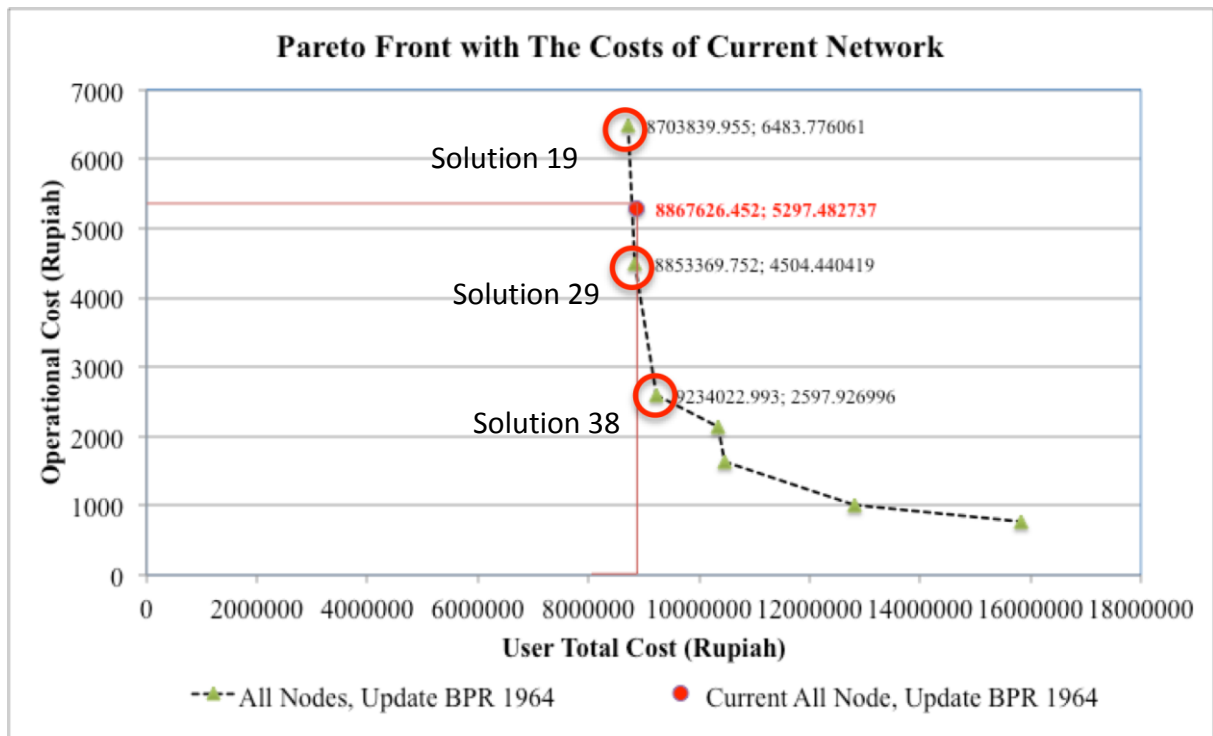


Figure 6.3 Pareto Solutions for Optimized Paratransit Network

From Table 6.6, one can observe that QOL varies sensitively with different solutions of optimized LOS. Solution 29 gives a better QOL value than the existing condition, while Solution 19 worsens the QOL and the worst QOL is observed in

Solution 38, which reduces the QOL value by 13% in the worst case. From the driver viewpoint, one can say that Solution 29 is the best solution, since it not only gives a better QOL value but also leads to a bigger value of gap revenue than the existing condition. Moreover, Solution 29 is also a better solution from the user viewpoint since the total user cost is less than the existing condition

Table 6.6 Evaluation on Drivers' QOL based on Optimized Paratransit Services

	Existing Condition	Solution 19	Solution 29	Solution 38
<b>Explanatory Variables</b>				
Gap Revenue (Rp.)	16,569	-1,061	30,919	61,133
No. of Round Trips	7.919	8.415	7.425	9.405
Driver Waiting Time (min)	24.098	-	-	-
Service Time (categorical value)	6.839	-	-	-
Service Distance (km)	104.384	110.908	97.859	123.956
<b>QOL Variables</b>				
Satisfaction with Work	1.260	1.008 (-20.0%)	3.195 (38.7%)	3.15 3 (-50.6%)
Satisfaction with Health	2.638	2.514 (-4.5%)	3.469 (9.1%)	3.44 9 (-11.9%)
Satisfaction with Residence	2.475	2.415 (-2.5%)	2.839 (4.8%)	2.83 0 (-6.3%)
Satisfaction with Free Time	2.465	2.180 (-11.5%)	4.449 (22.3%)	4.40 4 (-29.2%)
Satisfaction with Family	2.234	2.163 (-3.2%)	2.756 (6.2%)	2.74 5 (-8.2%)
Satisfaction with Social Life	2.321	2.306 (-0.6%)	2.423 (1.2%)	2.42 1 (-1.6%)
<b>Latent Variables</b>				
Basic QOL	-2.853	-2.583 (9.5%)	-0.77 (73.1%)	-0.88 4.79 (69.3%)
Higher QOL	5.513	5.229 (-5.1%)	6.062 (10.0%)	3 (-13.1%)

Using the QOL measurement model we could also observe the changes of the shares of drivers with different QOL categories, as detailed in Table 6.7. More than 60% of drivers show neutral feelings with their jobs and more than 15% were satisfied with their jobs. This result suggests that most drivers are keen with their work. This is important because it means that the job is suitable to most drivers. Unfortunately, for other life domains the situation is totally different. In general almost more than 40% of drivers are neutral and more than 30% is not satisfied with these life domains. Concretely, more than 30% is not satisfied with health and more than 50% are dissatisfied with free time.

All these life domains need further attention. It is true that these drivers are very prone to experience more health risk due to the long driving which is associated with stress-related health effects and physical ailments such as back pain and heart disease. It is also true that these paratransit drivers are lack of free time due to the very long service hours and since they depend on daily income it is very more likely to work every day without having a holiday. These evaluations successfully captured the existing condition of paratransit drivers from the perspective of QOL

Table 6.7 Shares of Drivers with Different QOL Categories

	Existing Condition	Solution no. 19	Solution no. 29	Solution no 38
<u>Probability QOL</u>				
Satisfaction to Work				
1 – very dissatisfied;	10.4%	15.7%	4.0%	26.7%
2 – dissatisfied;	9.9%	12.4%	5.3%	15.6%
3 – neutral;	64.2%	61.7%	60.8%	52.8%
4 – satisfied;	15.5%	10.2%	29.8%	4.9%
Satisfaction to Health				
1 – very dissatisfied;	0.4%	0.6%	0.2%	1.0%
2 – dissatisfied;	25.8%	29.8%	18.8%	36.4%
3 – neutral;	69.6%	66.4%	74.2%	60.6%
4 – satisfied;	4.2%	3.2%	6.8%	2.0%
Satisfaction to Residence				
1 – very dissatisfied;	0.7%	0.8%	0.5%	1.0%
2 – dissatisfied;	30.3%	32.3%	26.4%	35.6%
3 – neutral;	41.7%	41.5%	41.7%	41.0%
4 – satisfied;	27.3%	25.3%	31.4%	22.4%
Satisfaction to Free Time				
1 – very dissatisfied;	0.7%	1.5%	0.1%	4.1%
2 – dissatisfied;	58.1%	67.9%	37.0%	78.6%
3 – neutral;	41.2%	30.7%	62.6%	17.3%
4 – satisfied;	0.0%	0.0%	0.3%	0.0%
Satisfaction to Family				
1 – very dissatisfied;	1.3%	1.5%	0.9%	2.0%
2 – dissatisfied;	36.8%	39.3%	32.0%	43.1%
3 – neutral;	45.5%	44.5%	47.0%	42.5%
4 – satisfied;	16.5%	14.7%	20.1%	12.4%
Satisfaction to Social				
1 – very dissatisfied;	1.0%	1.1%	0.9%	1.1%
2 – dissatisfied;	47.8%	48.4%	46.8%	49.2%
3 – neutral;	38.2%	37.9%	38.7%	37.4%
4 – satisfied;	13.0%	12.7%	13.6%	12.2%

## 6.7 Summary

Generally, improvements of public transportation services are commonly equal to increasing the service, e.g., higher frequency, longer service time, and longer service



distance. But, this is not always the case in paratransit services. To the authors' knowledge, there has been no literature of specifying the level of paratransit service. It is therefore hard to determine how to improve the level of paratransit service. There is no doubt that paratransit services need to be improved. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not be realized. If paratransit service provision could not improve drivers' QOL, drivers would not make efforts to provide satisfactory and reliable services.

This study provided additional evidence on how improvements of paratransit services do not necessarily increase the operation frequency and total distance traveled for all routes, and the level of paratransit service surely affects drivers' QOL. This was done by using two models: the one is the optimization model of paratransit service frequency that minimizes the operation cost and the total user cost, and the other is a simultaneous-equation ordered probit model that measures drivers' QOL with six life domains. The optimization model was developed in one of our previous studies (Weningtyas et al., 2012a) and the ordered probit model was newly developed in this study for predicting the values of QOL indicators with an interrelated structure that were identified in the other of our previous studies (Weningtyas et al., 2012c). The conclusion that can be derived from this study is that the improvement of paratransit LOS in this

specific case of paratransit network does not always improve drivers' QOL. It is further concluded that driver's QOL needs to be reflected in decisions on paratransit operation.

It must be emphasized that the job of paratransit drivers plays an important role in providing employment opportunities for low-income and low-skilled people in developing countries. However, since this job is, in fact, self-employed, paratransit services are basically depending on drivers' efforts, which are essential to their QOL. Therefore actions must be taken by the government to solve this revolving issue between paratransit services and drivers' QOL. We may suggest two options to solve this problem. One is that the government must re-evaluate the agreement contract system, where the daily rental fee is set by the owner and actually accounts for a huge part of drivers' expenses. The other option is that the government could try to "buy the service" (Agency of Transportation, 2012) using the local government budget. With such a "buy the service" policy, the government may effectively control the entire operation by paying drivers' salary based on their performance and operators' operation cost based on better service coverage and management.

Future studies should be done by collecting more samples in more cities in order to generalize our findings.

## **Chapter 7 Conclusions and Recommendations**

### **7.1 Conclusions**

This study successfully provides comprehensive studies in order to develop policy deliberation. The policy deliberation is based between evaluations on optimized paratransit level of service and paratransit drivers' quality of life. The optimization is done using a optimization framework. In the optimization framework, both operators' and users' behaviors are reflected; however the direct service providers are drivers of paratransit vehicles. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not be realized. If paratransit service provision could not improve drivers' QOL, drivers would not make efforts to provide satisfactory and reliable services. With the above consideration, this study suggests introducing drivers' QOL as indicators to optimize the paratransit service. Finally, this study deliberate the policy suggestion to decide the paratransit future.

#### **7.1.1 Summary Findings**

This research is divided into two groups of evaluations, which are objective and subjective evaluations. First, the objective analysis is conducted based on a multi objective optimization model to decide the optimal frequencies, where the objective function is to minimize the generalized cost of paratransit users and the operational cost for paratransit drivers. The subjective evaluation is the evaluation of paratransit services

from the perspective of environmental impacts and drivers' quality of life (QOL) as well as work performance, while the objective evaluation sensitivity analysis of paratransit network optimization. Then both analyses are combined together, using a jointly ordered-response probit model (ORP) model that can explicitly link the LOS variables with drivers QOL indicators.

### **7.1.2 Updated the Link Performance function (LiP)**

The link performance function (LiP), mainly represented in the form of the BPR function (Bureau of Public Roads, 1964), is one of key tools for the road design and for supporting decisions on transportation planning and management. The LiP function could be useful in determining congestion levels in the optimization model for a paratransit network. However, studies of the LiP suitable to developing countries are extremely limited. Although, in the Indonesian Highway Capacity Manual (IHCM, 1997) the influence of the above side frictions is already reflected in the capacity and free flow calculation; however, it has not been reflected in the calculation of the LiP. In chapter 3 we have successfully updated the LiP function, which incorporates the influence of on-street occupancy in evaluating paratransit network performance, to reflect specific traffic situations in cities in developing countries.

To estimate the scale and shape parameters of the LiP for the above target paratransit network, the original BPR-type LiP is first log-transformed into a simple linear regression model, where the dependent variable is the ratio of the actual and free

flow travel time, and the independent variable (only one) is the ratio of traffic volume and capacity ( $V/C$ ). It is expected that the LiP might vary across links and over the time of a day as well as depending on side frictions. To effectively clarify such features of the LiP, here, a multilevel modeling approach is applied, where the above variation factors are represented by introducing the corresponding error terms into the original regression model.

In the multilevel analysis performed in this study, we found that the values of the LiP function vary from driving context and are influenced by factors such as road link variations, time variations, and/or the influence of on-street occupancy. The most significant influence (at the 95% confidence level) of the variations is the between-link variation and the angkot volume variation. Stopping behavior exhibits the greatest variance but is not statistically significant. The multilevel analysis results suggested that it was necessary to further refine the LiP based on the characteristics between links. Therefore, linear regression based on the number of lanes was conducted. The results show that a road link with 4 lanes performs better than links with 2 or 3 lanes. On-street occupancy significantly reduces speed even when the value of  $V/C$  is small and reduces speed even more dramatic when the value of  $V/C$  approaches 1.

### **7.1.3 Subjectives Analysis: Evaluation of paratransit services from the perspective of drivers' quality of life (QOL)**

In Chapter 4, the most important finding is that the current paratransit systems in Bandung City are neither socially nor environmentally sustainable. It is found that by improving the paratransit level of service (also means reducing the work performance) would cause an increase in environmental impacts and lower drivers' QOL as well as their revenues. The current paratransit services should be improved from the supply side (either local government or private owner), by carefully reconsidering the current operation and contract systems. The actions that can be done by the government are reviewing and renewing the contract system, evaluating the feasible fare, evaluating the demand and supply side, and also triggering the usage of environmentally friendly vehicles

### **7.1.4 Objective Analysis: Optimization model to decide the optimal frequencies**

In Chapter 5, this study successfully analyzes the sensitivity of paratransit optimization from both the demand and supply sides during the morning peak hour in Bandung, Indonesia. A previously constructed bus network optimization model, which can identify optimum frequencies, is applied using an improved link performance function. The sensitivity analysis of different scenarios confirmed that the passenger and operational costs in the current network are sensitive to the congestion level. Comparison of the current paratransit network and the model output from the scenario involving

updating the BPR function (discussed in Chapter 3) without reducing the number of stops confirmed that the current paratransit network is close to the Pareto front if the total costs for passengers and operators are adopted as objective functions. Reducing the number of stops might not be a better solution because the results show that the current cost situation is much more efficient than the solution obtained from the optimization model. This result might be arguable, and further research might need to be done. Future research should include more of the distinct characteristics of paratransit networks to obtain more realistic results.

#### **7.1.5 Joint Analysis: Link the LOS variables with drivers QOL indicators.**

In Chapter 6, This study provided additional evidence on how improvements of paratransit services do not necessarily increase the operation frequency and total distance traveled for all routes, and the level of paratransit service surely affects drivers' QOL. Generally, improvements of public transportation services are commonly equal to increasing the service, e.g., higher frequency, longer service time, and longer service distance. But, this is not always the case in paratransit services. To the authors' knowledge, there has been no literature of specifying the level of paratransit service. It is therefore hard to determine how to improve the level of paratransit service. There is no doubt that paratransit services need to be improved. If paratransit drivers could not provide satisfactory and reliable services, benefits for both operators and users would not

be realized. If paratransit service provision could not improve drivers' QOL, drivers would not make efforts to provide satisfactory and reliable services.

Since there is no literature that specified the LOS classification it is hard to define the improvement of paratransit LOS. Therefore, in objectives analysis in Chapter 5, using a multi objective programming we analyse the sensitivity analysis of optimization paratransit networks. This study successfully obtained pareto front solution, which minimizes the total operational cost for the operator and total cost for the user by optimizing the LOS, which is the value of frequency. As SEM cannot be used to predict or forecast the influences of QOL changes due to the LOS changes therefore we implement jointly ordered probit model. Jointly ordered probit model is used to re-estimate based on the SEM model structure from the subjective analysis in Chapter 4 then finally evaluate the changes of driver QOL based on the optimize value of LOS as analyzed in Chapter 5. The conclusion that can be derived from this study is that the improvement of paratransit LOS in this specific case of paratransit network does not always improve drivers' QOL. It is further concluded that driver's QOL needs to be reflected in decisions on paratransit operation.

## **7.2 Policy Deliberations**

As mentioned in the main purpose, this dissertation, finally, proposes some policies that can be summarized as follows;



### **7.2.1 LOS policy**

Generally, the improvements on LOS in public transportation is commonly equal to a increasing the service, for instance higher frequency, longer service time, long distance service, etc. Based on the analysis results, this is not the case in paratransit LOS. The current condition is not efficient for both stakeholders, users and operators. As analyzed in Chapter 6 introducing drivers' QOL as indicators to optimize the paratransit service is appropriate. Therefore deciding the improvement LOS is suggested based on the optimization analysis and considering drivers' QOL as the indicator to decide which suggested solutions should be used.

### **7.2.2 Overlapped Route Policy**

According to best solution which is solution number 29, vehicle frequency should be doubled to 25% of the lines, left unchanged for 44% of the lines, reduced by half from 11% of the lines, and reduced to zero for 20% of the lines. Among these routes there is two routes that needs to be halt since this route is overlapped with other route.

### **7.2.3 Number of stopping place**

From the GPS probe data, one can observe paratransit driver stopping behavior, stopping place, the number of stops per road segment and also whether a driver's stopping behavior is repetitive. Surprisingly, despite the widely held belief that paratransit vehicles will stop almost anywhere, their stopping places tend to fall into two categories, namely, fixed and random places. Random stopping places usually are located

only on the road links exiting the central station/ terminal where the majority of the paratransit vehicles line up and idle to wait for passengers. The presumption that angkot will stop almost anywhere is unconfirmed. Surprisingly, drivers tend to stop at places that are predictable to them and also to the passengers. Drivers' decision-making on where to stop is a repetitive behavior to which passengers become accustomed. Therefore in the fixed stopping places the government could build related infrastructure for angkot stop in order to provide better service to the user.

#### **7.2.4 Environmental Friendly Vehicle and Fuel type policy**

In order to sustain the sustainability of paratransit in the future, further considerations of using environmental friendly vehicle and fuel type is necessary. This is confirmed in chapter 3 that existing paratransit is not environmental friendly since they are mostly old vehicle and accordingly have inefficient fuel consumption.

#### **7.2.5 On-street parking policy**

In the multilevel analysis of LiP function it is found that the stopping behavior exhibits the greatest variance but is not statistically significant ( $t \text{ stat} = 0.368$ ). The most significant influence (at the 95% confidence level) of the variations is the between-link variation and the angkot volume variation. Therefore, linear regression based on the number of lanes was conducted. The results show that a road link with 4 lanes performs better than links with 2 or 3 lanes. This is also supported by the value of V/C in 4 lanes is lower than in 2 or 3 lanes. Some of the 2 lanes road doesn't have on street parking

therefore the performance of LiP function is better than the 3 lanes road. It is concluded that on street parking would have a great impact on the Road Capacity. The more capacity can be provided if the government eliminates the regulation to allow the on street parking since it will directly effect on decreasing the road capacity and consequently increase the travel time.

### **7.3 Research Limitations and Recommendations for Future Research**

In future, joint survey and research will be important and each government may need to change their policy and to find a cooperative measure to use a wide range of public transport modes including paratransit system in order to provide an appropriate transportation service. The research limitations and further recommendations are:

1. Data Collection: conducted not only On-Peak hour, the survey method is not manual, and it is nesecarry to develop a better method survey.
2. Study Locations: wider network scope, the current observed network is a small part from the total paratransit network in Bandung. The number of paratransit line which is considered in the model also only a few considering that these lines will be preserved in the recent years and not to be changed into bigger bus.
3. Modelling: modelling improvements, the current modeling still does not reflect the whole actual paratransit behaviour due to the time and model limitation. Therefore,

model improvement is necessary considering that the other behaviour might have a greater effect to the result.

4. The Paratransit Line Scope: the number of paratransit line which is considered in the model also only a few considering that these lines will be preserved in the recent years and not to be changed into bigger bus.
5. Modelling Assumptions: the optimization should consider the interrelation with other paratransit line and public bus, in this study we only concerns about one type of paratransit which is angkot. Where in the real situations there are other type of paratransit and also public bus. Although the public buses have route limitations and other types of paratransit are only concentrated in some areas not wide spread in the whole city.
6. Modelling Simulations: the optimization should also consider the simulation of the paratransit lines that will be change into bus line in the future into the model as public bus.
7. Future Research: expanding the model into three levels of optimization which are optimization of QOL, optimization of LOS, and also optimization on User Satisfaction.

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## APPENDIX A

### SUBJECTIVE QUESTIONNAIRE SURVEY



## **APPENDIX B**

### **OBJECTIVE QUESTIONNAIRE SURVEY**