Creating feeder bus lines for Transjakarta BRT

Understanding spatial patterns of daily destinations from poverty origin zones in Jakarta to determine demand for a new feeder system of Transjakarta BRT

End report for
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Februari 2, 2014

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1 Preface

This bachelor thesis report is the result of a 12-week internship held at PUSTRAL, the centre of Transportation and Logistics Studies, at the Gadjah Mada University in Yogyakarta, Indonesia. I stayed in Yogyakarta from September till November 2013 and had a great stay.

Therefore, I would like to thank Mark Zuidgeest and Mark Brussel proposing the possibility to do my internship in Indonesia and PUSTRAL for inviting me.

I would like to thank the staff of PUSTRAL for helping me with various aspects of the research, including commuter survey data interpretation, GIS software, and the spatial cluster method, but also regarding suggesting me nice spots in the environment and helping with repairing my computer. Especially Arif Wismadi, who was very helpful to me for giving suggestions relating the direction of the research and give some reflections.

I am thankful for the opportunity I had, because I learned new things in many ways: not only regarding the research, also about the culture of Indonesia. It gives me new sights on the situation in the Netherlands.

2 Summery

This study focuses on the accessibility of poor people in Jakarta to good public transport. Because of the free-of-lane busways, Transjakarta bus rapid transit is a reletively fast mode of transport in comparison with the congested roads. Therefore, it could fit the needs of poor people. However, not in every neighborhood of Jakarta there is access to a Transjakarta shelter. Therefore, a feeder system is proposed to connect more neighborhoods to the Transjakarta.

The main research problem in this study is the lack of knowledge on the demand for a feeder system for Transjakarta, especially for poor people. Also it is not known which routes and networks support such a system the best.
The main objective is to determine demand for a new feeder system of Transjakarta and evaluate different feeder systems and routes, especially for the demand of poor people in Greater Jakarta.

The determination of poverty origins to be analyzed for destination patterns is possible in multiple ways. First, the area in which the poverty zones will be selected can differ: the Greater Jakarta area or only the high-density area around Jakarta city. A second distinction can be made between the method of selecting the origins in the chosen region: using the LISA cluster method or the absolute lowest income method.

When revealing the destinations for the four different ways of selecting origin zones, it turns out that the absolute method gives more scattered zone results. The clustered zones in the poverty cluster method are located more close to each other and have the same destinations in a higher degree.

It turns out that for the methods of selecting poverty zones in the Greater Jakarta Area, there are no potential suitable origin-destination relations for creating a feeder bus line. This means, no of the destinations is in the city center of Jakarta. Thus, we can conclude that the Greater Jakarta Area method is not an appropriate method to select poverty origin zones, when the goal is to create feeder bus lines for the Transjakarta.

We see that the absolute lowest income method gives more than one destination for some origins, while the poverty cluster method does not. The poverty cluster method however gives a less spread result: the ratio is lower.

The aim of this research is not to integrate existing non-Transjakarta bus lines in the Transjakarta BRT network, but to create new feeder lines for Transjakarta based on the demand of poor people in Jakarta. Because the goal of creating new feeder lines in this research is to reduce the amount of transfers and transfer time, the direct feeder system is chosen.

Different suitable origin-destination relations are used to design new feeder lines for the Transjakarta. When mapping different proposed feeder bus lines, we can see that these feeder lines can connect to each other. The suggestion is that these feeder lines will be merged in one long feeder line, located in the east of Jakarta city: the east tangent bus line.

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4 Research plan

4.1 Description PUSTRAL

The Center for Transportation and Logistics Studies (PUSTRAL) is the organization in which I did my bachelor thesis. PUSTRAL is a research organization belonging to the Universitas Gadjah Mada (UGM), one of the largest universities in Indonesia, located in Yogyakarta. PUSTRAL is involved in researches on transportation and regional development. It gets assignments from both public and private organizations. Private organizations are for example the airport of Yogyakarta and the railway operator. Public organizations include UGM or the governments of Indonesia.

4.2 Abstract (described by PUSTRAL)

"Understanding spatial patterns of daily destinations from poverty origin zones in Jakarta to determine demand for a new feeder system of Transjakarta BRT".

To provide a basis for designing the feeder system of a transit system, city transport planners need a good understanding of spatial distribution patterns of public transport demand. Toward the provision of better service for the poor, we investigate the demand patterns in the clusters of poverty in the urban metropolitan city of Jakarta. Using the spatial autocorrelation technique of LISA, we select several poverty clusters. With an indicator of frequency of modal transfer from home to the daily destination we describe the spatial pattern of demand for feeder systems required by the poor.

4.3 Introduction

Good transport facilities in a city provide access to several destinations, which enable people to have different activities across the city. As in many cities, transport problems are present in the Greater Jakarta region. A problem is the congestion on the roads and capacity problems of the Transjakarta bus lane system. Another question is how to organize good transport for poor people, because there may be inequities in accessibility of different parts of the city and for different people.

Since the last economic crisis in 1998 in South-East Asia, the economy is growing in countries like Indonesia. This economic growth causes big traffic problems, because the growing traffic demand causes too much pressure on the aged infrastructure (Willoughby, 2013). Jakarta is the capital city and the largest city of Indonesia with an agglomeration of more than 10 million. In Greater Jakarta, the government invested in new toll roads and the Transjakarta bus system, which opened in 2004 and was expanded in the years after. The Transjakarta free-of-way bus lanes are designed for more efficient and democratic use of public roads by carrying much more people per lane per hour compared to regular traffic lanes (Lo, 2010). However, despite the efforts taken, there is still a lot of congestion in the city nowadays.

Besides the problem of congestion, the accessibility of Greater Jakarta differs by the socioeconomic position of people and from a spatial perspective. Service extensions and improvements of public transport that were made in the past did not help the poorest people and they have to rely on other, sub-standard facilities for non-motorizised transport, like bicycles and *becaks* (Lo, 2010).

From a spatial perspective, some parts of the city are in the range of the relatively fast Transjakarta busway system and other parts are not. This means that people in Greater Jakarta living in different neighborhoods may experience different levels of destination accessibility. Poor people often live in settlements on the edge of the metropolitan area and therefore have less fast transportation forms. Substantial development of feeder bus routes and services in Bogota for example, have been designed in substantial part to cater to poorer households (Willoughby, 2013).

4.4 Study area

In Greater Jakarta, a large household survey was conducted in 2010 by JICA (Japan International Cooperation Agency). In this survey many mobility questions were asked to a large group of people, for example about main transport mode and income.

This research was conducted in Greater Jakarta and this area is also the study area of this research. Greater Jakarta is the agglomeration surrounding Jakarta. It consists of both the city of Jakarta (the Special Capital Region of Jakarta) and the suburbs of Jakarta. Jakarta city has around 10 million inhabitants, while in the Greater Jakarta agglomeration about 28 million people have their home.

Several commuter trains serve the commuter transport between suburbs and Jakarta. In Jakarta city, relatively high quality public transport is served by the Transjakarta bus system because of the free-of-way bus lanes, of which a network map can be found in Figure 1.

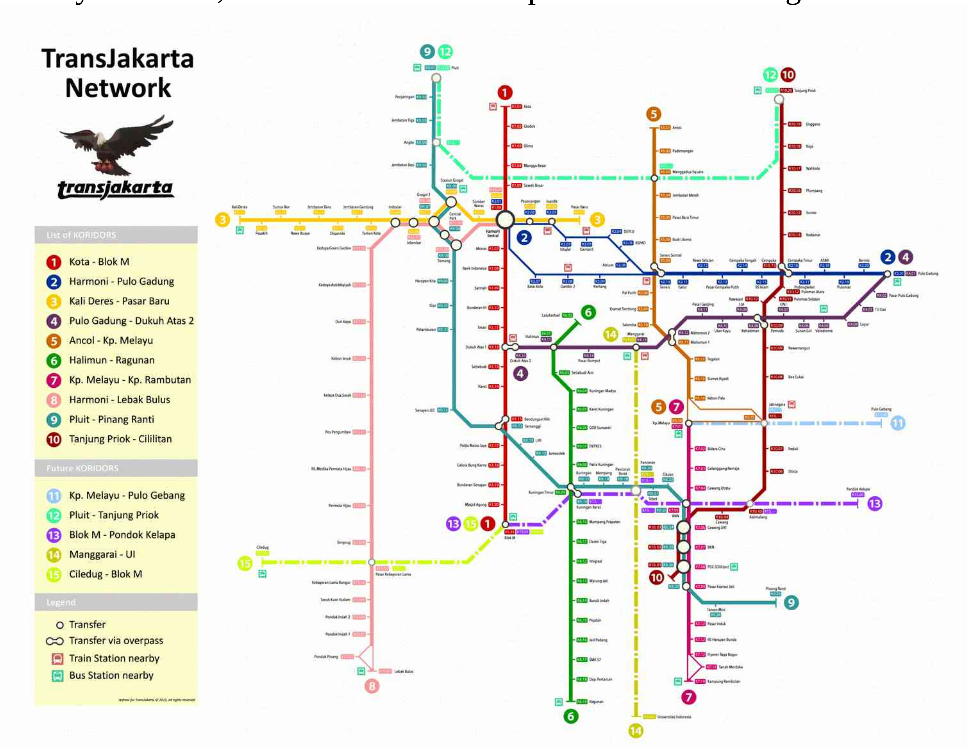

Figure 1: Transjakarta network map

4.5 Research problem

This study focuses on the accessibility of poor people to good public transport. Because of the free-of-lane busways, Transjakarta is a reletively fast mode of transport in comparison with the congested roads. Therefore, it could fit the needs of poor people. However, not in every neighborhood of Jakarta there is access to a Transjakarta shelter. Rich people can reach a far-located Transjakarta shelter more easily by car or motorcycle in that case, but poor people don't have such possibilities and stay unconnected from the Tranjakarta network.

Poor people do not have such access and therefore are dependent on slower ways of (public) transport (paratransit) when a Transjakarta bus stop is not in their neighborhood. They may need numerous transfers to reach a Transjakarta bus stop or their destination.

The main research problem in this study is the lack of knowledge on the demand for a feeder system for Transjakarta, especially for poor people. Also it is not known which routes and networks support such a system the best.

Another problem regarding congestion is also present. During rush hours, the Transjakarta demand exceeds the capacity so long waiting queues arise. Another reasearch problem is the lack of understanding how Transjakarta feeder lines can improve capacity.

4.6 Objectives

The research objectives give the goal what we want to reach with this study. It builds on the research problem.

The main objective is to determine demand for a new feeder system of Transjakarta and evaluate different feeder systems and routes, especially for the demand of poor people in Greater Jakarta. The aim is to create feeder systems that serve a large group of people from poor areas that bring them to common daily places more easily.
If possible, another objective is to find ways to create more capacity for the rising demand of Transjakarta due to feeder lines. This could be achieved by using these same feeder lines to run over the Transjakarta busway lanes to improve their capacity.

4.7 Conceptual framework

In the conceptual framework, main concepts regarding the problem and their relations are described and explained. In Figure 3, a scheme of the main concepts is showed. This scheme is explained below.

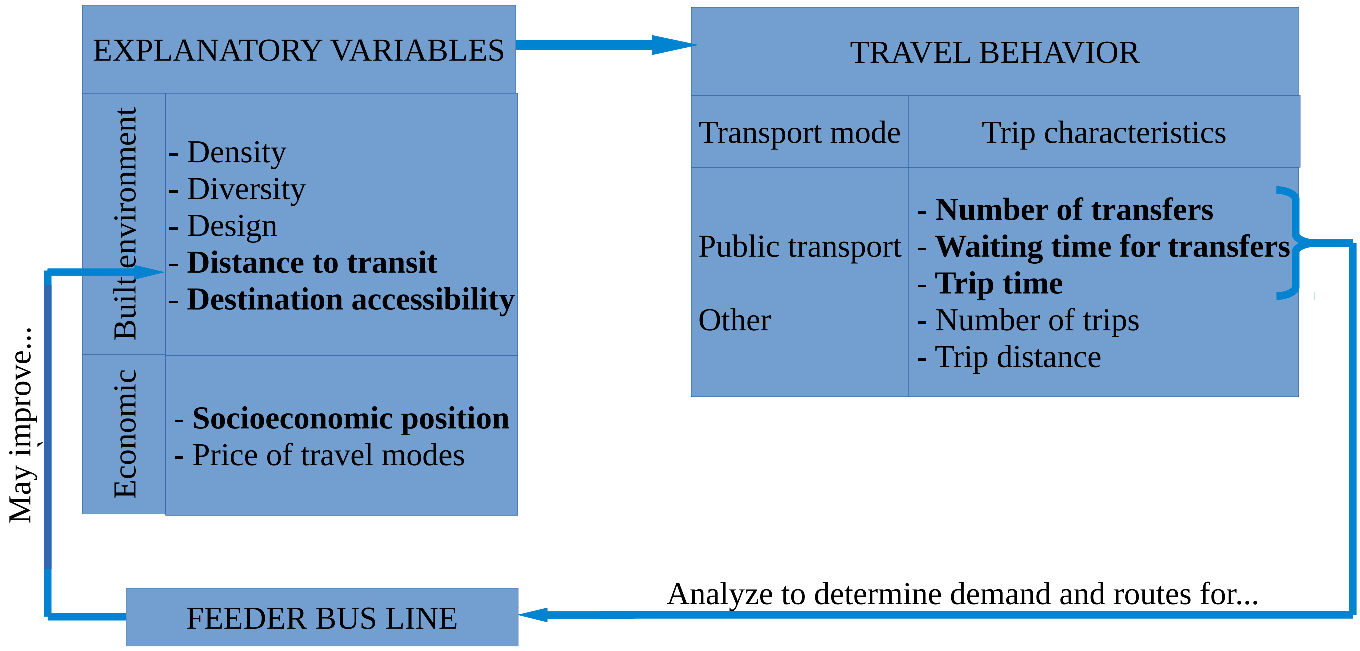

Figure 2: Conceptual framework regarding the problem

There are several **explanatory variables** that influence travel behavior. These include land use and economic aspects of citizens and transport modes. There are more explanatory variables such as person-based preferences, but they are not considered in this study.

In Jakarta, like in almost all cities, the characteristics of the **built environment** differ.
We distinguish the five D's of the built environment (Cervero & Murakami, 2008): density, diversity, design, distance to transit and destination accessibility.
The *density* is the amount of inhabitants, workers and shoppers per area unit. The higher the density in the neighborhood of a transit station, the more riders. With *diversity* we mean the rate of mixture between the land uses of living, working and commercial spaces. *Design* is about the degree in which the environment encourages walking and biking to transit stations. This can be achieved by both physical features and aesthetics.

The *distance to transit* is an important factor for the use of public transport. Of course, when the distance is small, people will use public transport more easily. The research is about feeder systems, which may change the distance to transit. Therefore, this is one of the aspects this research focuses on.
Destination accessibility is about the amount of effort needed to reach different destinations in the Greater Jakarta area using public transport. Feeder systems may reduce the number of transfers and waiting time while transferring, with which the destination accessibility can be improved. Therefore, this is one other aspect this research will focus on.

Next to land use factors, there are some **economic** factors that may influence travel behavior.
First of all, the *socioeconomic position* of people living in Greater Jakarta in combination with the *price of different travel modes* influences the ability of people to choose for some destination or transport mode. Rich people may have more and faster options for transport than poor people. This may cause inequity in access to mobility. Because of this, the research is focused on poor people and therefore we consider their socioeconomic position in this study.

For the ***travel behavior*** in this study, we first consider transport mode because some trip characteristics are only applicable on public transport (such as transfer characteristics, because transfers are only for public transport).
In Jakarta, as an Indonesian city, there are several **transport modes**. This research is about the Transjakarta, so *public transport* is the most important mode of tranport this case. *Other transport modes* include modes which are not Transjakarta, other city bus or commuter train in Greater Jakarta.

In public transport, an important **trip characteristic** is the *number of transfers*. The more transfers, the less comfortable it is to use public transport.
Also a long *waiting time for transfers* and a long *trip time* is a negative effect on public transport use. Because the last three factors may be changed by feeder lines, the research will focus on these.
Other factors are *trip distance*, *number of trips* and more, such as the trip route. These factors are both applicable to public and private transport.

Some existing trip characteristics, such as the number of transfers and the transfer waiting time, can be analyzed to determine demand for a ***feeder bus line*** especially for poor clusters. When the feeder bus line is operating, distance to transit may be shortened and destination accessibility may be improved.
To understand better how feeder lines and Bus Rapid Transit systems work, some concepts are explained below.

4.7.1 Bus Rapid Transit

Transjakarta is a form of Bus Rapid Transit (BRT). BRT systems are being built all over the world, but the most known are these in developing countries in Latin America and Asia. Generally, although capacity can be very high, the investment and operating costs of BRT are relatively low compared to urban rail transport such as LRT (Light Rail Transit) and MRT (Mass Rapid Transit). The following characteristics are typical of a BRT system (Wirasinghe e.a., 2013):

- Running ways/guide ways: the most BRT systems have a free lane without mixed traffic. This allows buses to have a faster travel speed and less conflicts with general traffic.
- Vehicles: Sometimes the vehicles have multiple doors, so boarding and alighting is easier and faster. BRT buses often have more standing spaces than normal buses, which are located near the door(s). Also, the floor of the buses is sometimes high, so there is no need for elevation differences because of the engine.
- Stations: the height of the stations (bus shelters) is adapted to the floor height of the bus,

which makes easy boarding possible and makes BRT more accessible. BRT stations provide a higher rate of comfort for bus passengers.

- Fare collection systems: preferably, the fare collection system is off-board, at the station. This allows for faster stop times, because customers do not have to buy their ticket on board.
- Operations control systems: Several elements of an intelligent transportation system are available for BRT. For example, priority for BRT buses at traffic lights with mixed traffic allow for faster and more predictable travel times.
- Passenger information systems: Real-time information allows passengers to have information about their trip. It turned out that real-time information significantly influences passengers' decisions to use the BRT service.

Because many of these characteristics are similar with MRT except of the infrastructure and vehicles, we can say: "Think rail, use buses!".

4.7.2 Feeder lines

Feeder lines in general are bus lines that serve parts of the city that are not in the range of the BRT system in that city and connect that part to the BRT. Transjakarta has no real feeder integration ("Implementing Direct Service Integration for Transjakarta", 2013), which makes it a trunk-only BRT. Examples of feeder systems are shown in Figure 3: the direct service and trunk & feeder.

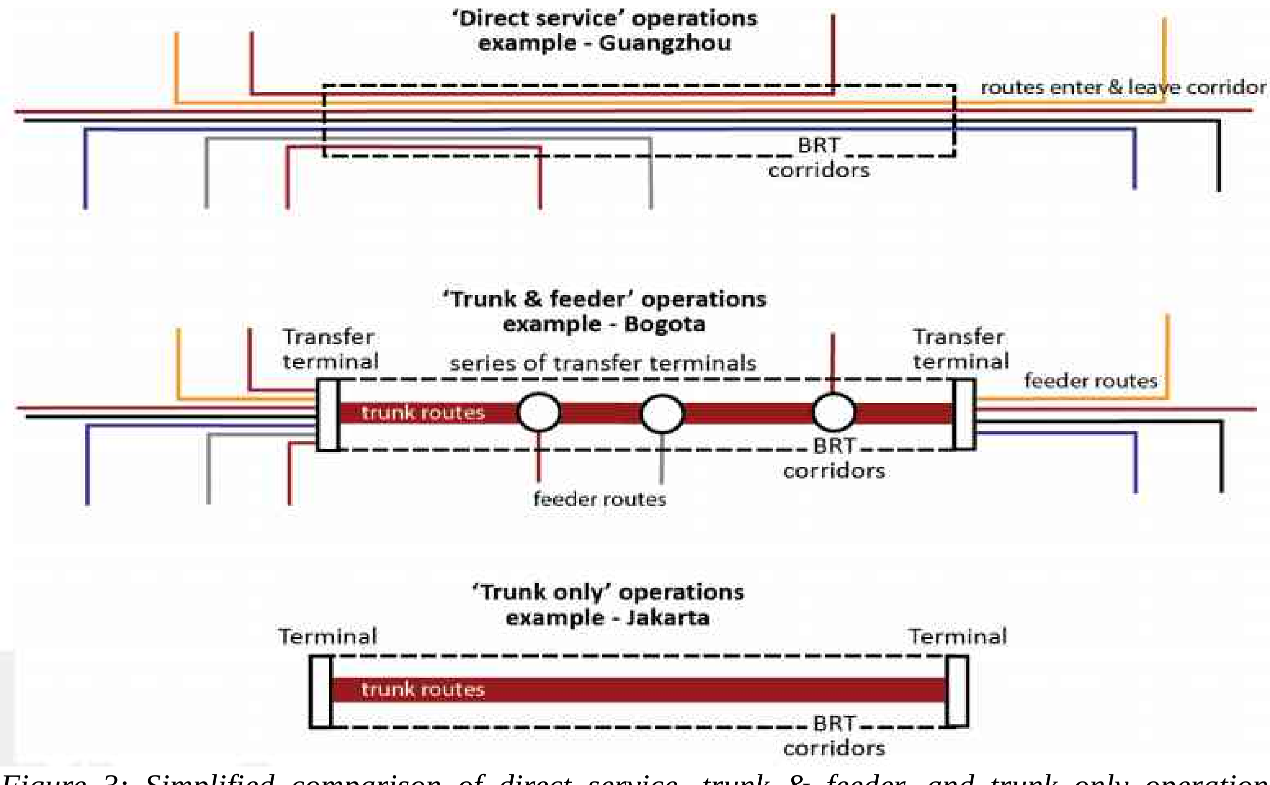

Figure 3: Simplified comparison of direct service, trunk & feeder, and trunk only operations ("Implementing Direct Service Integration for Transjakarta", 2013)

Direct service feeder lines have buses that run both at the BRT line and at normal mixed traffic streets. This reduces the need for changing buses, but also reduces predictability. With trunk & feeder lines, passengers need to change buses to the feeder line, but the predictability of buses running in the BRT lane is better.

4.8 Research questions

During the research, we try to search for an answer for the main research question. This question can be answered by researching some sub-topics, the sub questions.

The main question is: *What feeder bus systems and routes for Transjakarta can be designed to serve poor people in Jakarta the best?*

Sub questions are:

- How can we locate poverty clusters and where are they located? (Step 1)
- What is the demand for a feeder bus line from poverty clusters to the Transjakarta busway? (Step 3)
- What routes of a feeder system can improve demand and accessibility of the poor? (Step 5)
- What system of feeder lines can improve capacity of Transjakarta? (Step 5)

Step numbers refer to the steps in the research plan (see next paragraph 4.9).

4.9 Research plan

In this research plan is described what the steps are to be taken to answer the research questions (see paragraph 4.8) and meet the objectives (see paragraph 4.6). As there is a lot of data available in the JICA survey and via GIS, this research is mainly an analysis of existing data. To get an impression of the existing problems and the current state of Transjakarta a visit of Jakarta is included in the research.

1. Several poverty clusters in the Greater Jakarta area are selected (*socioeconomic position* in conceptual framework). Finding these clusters is based on JICA survey data and selecting them is on a basis of LISA autocorrelation. With this technique a cluster can be found if the socioeconomic data differs significantly from the data around it. The LISA for each observation gives an indication of the extent of significant spatial clustering of similar values around that observation (Anselin, 1995).

2. In Jakarta, I get an impression of Transjakarta in general, and some poverty clusters and their connections to Transjakarta.

3. In order to investigate the spatial demand for public transport, the JICA survey results are used that are in the selected clusters of poverty. This is done by only using the survey results of respondents that live in a selected cluster (selection location criteria: survey form 1 question 4). Of these survey results, the daily destination is revealed (use survey form 2A questions V8 and IV3). The daily destinations are located on a map to get a good view of the spatial demand.

4. Using the map with spatial daily demand, the daily destinations are clustered that are near to each other and of which the trips have their origin in the same poverty cluster. For these destination clusters, the transit trip characteristics are revealed (by using survey form 2B): *number of transfers*, *waiting time* for a transfer and *trip time*. These are trip characteristics, as in the conceptual framework. Only the survey trips that have too many transfers, waiting and trip time are selected.

5. Several new feeder lines for these selected trips from poverty clusters to daily destinations clusters are proposed (see *feeder bus lin*e in conceptual framework).

6. The proposed feeder lines will be evaluated according to criteria that meet the objectives of this research. One proposed feeder line per relation poverty cluster – daily destination cluster is selected using a multi-criteria analysis.

5 Locating poverty origin zones

In the first chapter, the method to select poverty zones in the Greater Jakarta area is described. The income data in combination with geographic information in the commuter survey is used to create a map with average income per month per zone code. A zone code is an area or neighborhood in Greater Jakarta area with an indication of 6 digits. This income map is used to select poverty zones on the basis of LISA autocorrelation. With this technique a cluster can be found if the socioeconomic data differs significantly from the data around it.

In the commuter survey, the income is saved as an income class instead of real income data. First, these classes have to be converted to real income data by taking the average of the boundaries, as in Figure 4. The real income in the first and last class cannot be calculated by average and are assumed to be respectively 500.000 and 27.000.000 Indonesian rupiah.

Income class	Income range		Real income
1	<	1.000.000	500.000
2	1.000.000	1.500.000	1.250.000
3	1.500.000	2.000.000	1.750.000
4	2.000.000	3.000.000	2.500.000
5	3.000.000	4.000.000	3.500.000
6	4.000.000	5.000.000	4.500.000
7	5.000.000	6.000.000	5.500.000
8	6.000.000	8.000.000	7.000.000
9	8.000.000	10.000.000	9.000.000
10	10.000.000	12.500.000	11.250.000
11	12.500.000	15.000.000	13.750.000
12	15.000.000	17.500.000	16.250.000
13	17.500.000	20.000.000	18.750.000
14	20.000.000	22.500.000	21.250.000
15	22.500.000	25.000.000	23.750.000
16	25.000.000	>	27.000.000

Figure 4: Conversion income range to real income (in Indonesian Rupiah)

By taking the average of the real incomes for every zone code, a map is created with average monthly incomes per zone code in Greater Jakarta. This map is called a shapefile, which contains information in a Geographic Information System (GIS), which is displayed in Figure 5. The Kel zone format and JUTPI zones 2009 format is used to link the survey income data to the GIS.

As we can see in the map, the lowest incomes tend to cluster in the southern part of Greater Jakarta area. Average and high incomes can be found in the city center and some suburbs around it.

We can also see that some parts of north-east and north-west Greater Jakarta have no income data. Several reasons can explain this:

- There are no or a few households living in these areas. This is true for some zones, which are industrial or commercial areas.
- The survey was not held in these areas. This is true for the other zones, where it is clear that households are located here.

Intentionally, zones are not merged to keep the available information on a detailed level. The zones without socioeconomic data are not considered in further analysis.

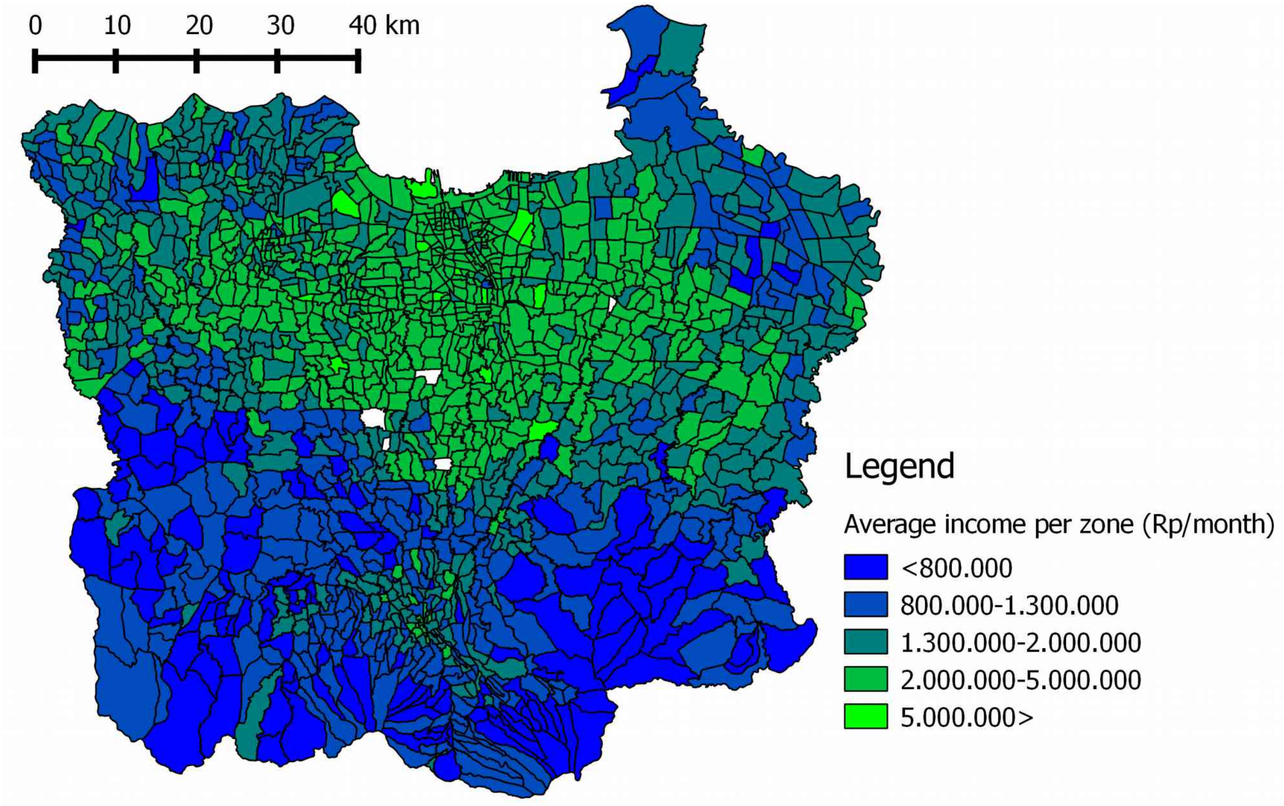

Figure 5: Average income per code zone

The determination of poverty origins to be analyzed for destination patterns is possible in multiple ways. First, the area in which the poverty zones will be selected can differ: the Greater Jakarta area or only the high-density area around Jakarta city (also known as kota or province). A second distinction can be made between the method of selecting the origins in the chosen region: using the LISA cluster method or the absolute lowest income method.

Method ↓ Area →	Greater Jakarta area	Jakarta city area
LISA poverty cluster method	Figure 9	Figure 11
Absolute lowest income method	Figure 10	Figure 12

Reason to choose for the Greater Jakarta area could be higher chance to locate poverty zones that the bigger area has. As we can see in Figure 5, most poor people live outside Jakarta city.
Reasons to choose for the Jakarta city area could be the higher density in this area (Figure 6). By only considering this area, more people are reached in the analyzes when selecting poverty zones. Moreover, as the area of interest is the Transjakarta busway, the Jakarta city area can better connect to the existing busways.

Using the absolute lowest income method, the absolute lowest incomes of a chosen region will be selected.
Choosing the LISA poverty cluster method will not locate the absolute lowest incomes of the chosen region, but selects clusters of poverty. This means that different zones will be clustered together, which have at least income below the average.
The different methods of selecting poverty zones will be discussed in more detail now.

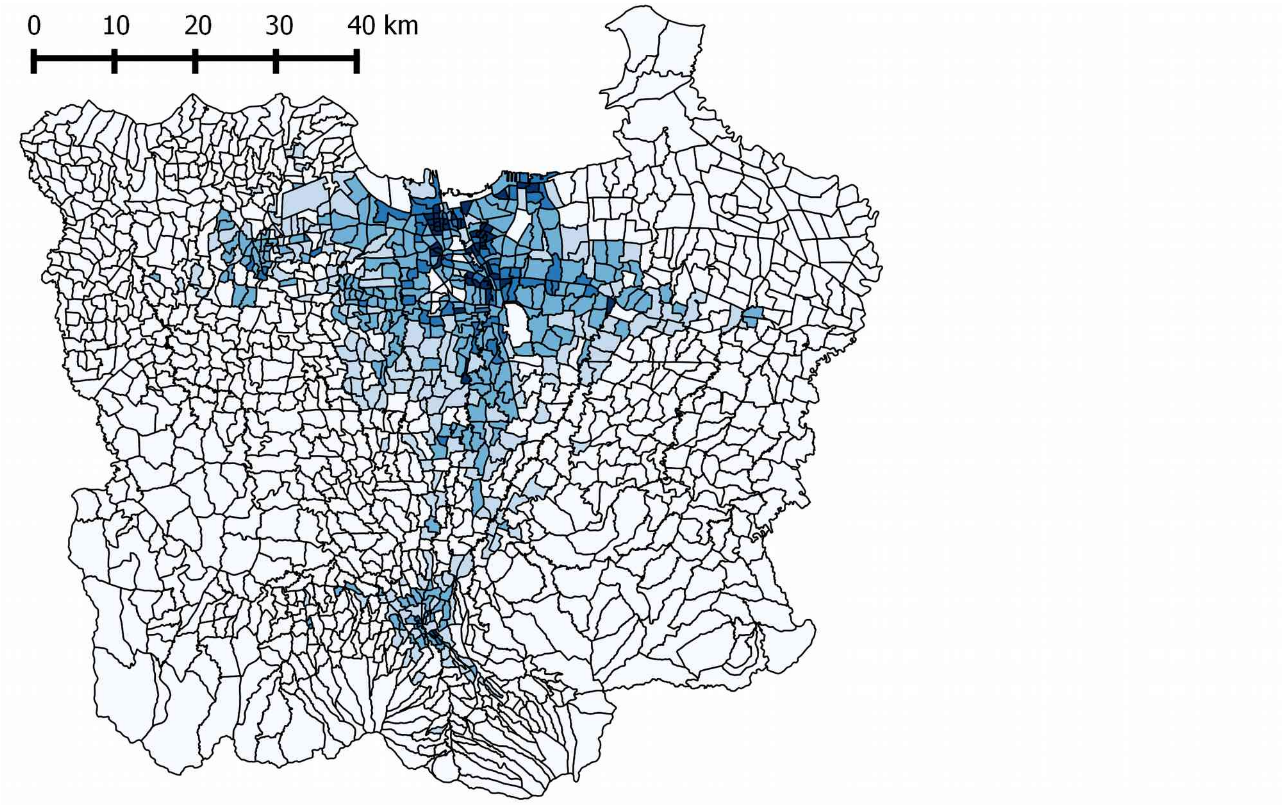

Figure 6: Population density in Greater Jakarta area. In the Jakarta city area, which is in the north of Greater Jakarta area, the highest densities occur.

5.1 Greater Jakarta area

Loading the shapefile of Figure 5 in Geoda, the LISA autocorrelation calculation is done to select the poverty clusters. With this technique a cluster can be found if the socioeconomic data differs significantly from other observations in the file. The LISA for each observation gives an indication of the extent of significant spatial clustering of similar values around that observation (Anselin, 1995).

To calculate the LISA for each of the zones in the shapefile, we first have to define a neighbor. We want to consider all zones around the zone that will be calculated, so also the zones that only have a vertex in common. This is called a queen matrix, because it defines a neighbor as an area with a shared border and a shared vertex. A rook matrix defines a neighbor as an area with only a shared border. This is illustrated in Figure 7 (part of Figure 5 in detail): of the considered zone 1, zones 2, 3, 4, 6 and 8 only have a shared border, while zone 5, 7 and 9 also have a shared vertex. As we want to consider all surrounding zones, we choose a queen matrix.

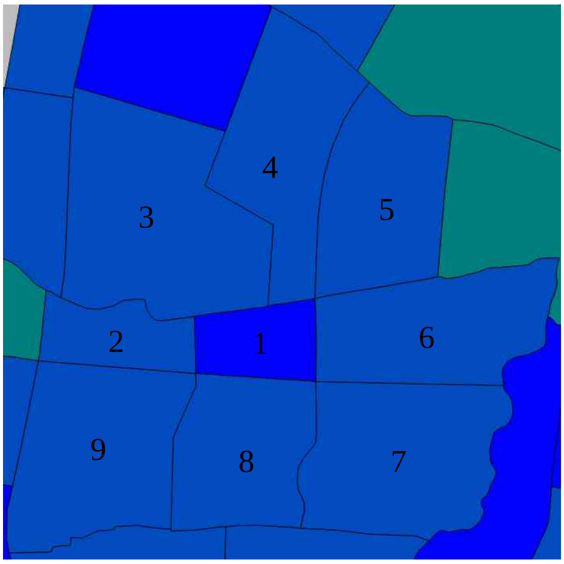

Figure 7: Rook versus queen matrix

The Moran scatter plot as in Figure 8 displays the correlation between the average income in a particular zone and the average incomes in the surrounding zones (lagged income). A particular correlation can be noted: zones with a high income tend to have surrounding zones with a high income (this is true for the zones represented by blue dots in the upper-right and under-left corner), but this is not always the case (for zones in the left-upper and down-right corner). Because most zones are in the under-left and upper-right corner, a certain correlation can be found, which is represented by the purple line.

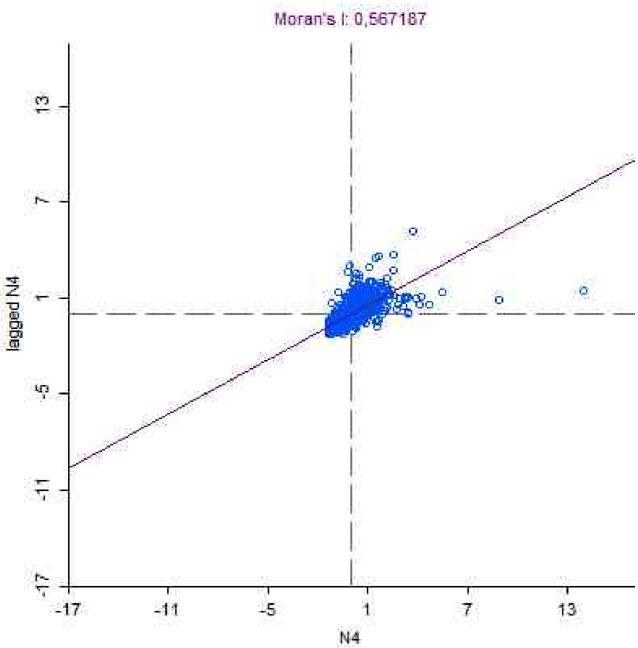

Figure 8: Moran scatter plot

In this study, we search for poverty clusters: zones with a low income and with low income surrounding zones. This way, the influence of randomness is minimized and the biggest population of poor people can be helped. These zones can be found in the down left corner of the scatter plot (Figure 8) and in the Greater Jakarta area zone map indicated by Low-Low (dark blue in Figure 9).

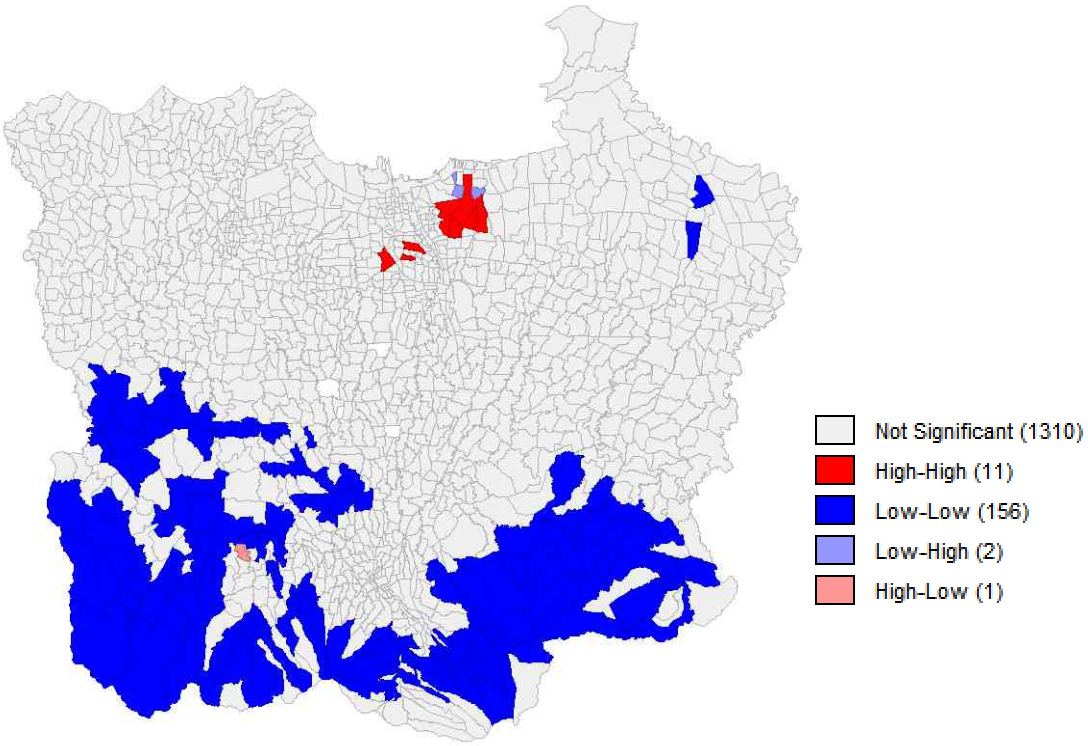

Figure 9: LISA cluster map of income in Greater Jakarta area (significance level: 0,1%)

Now we have selected the poverty clusters for Greater Jakarta area, we now select poverty zones with the absolute lowest income method. With this method, we select the same amount of zones as in the LISA cluster method as this gives the best comparison (156 zones). In Figure 10, the 156 zones with the lowest income are displayed.

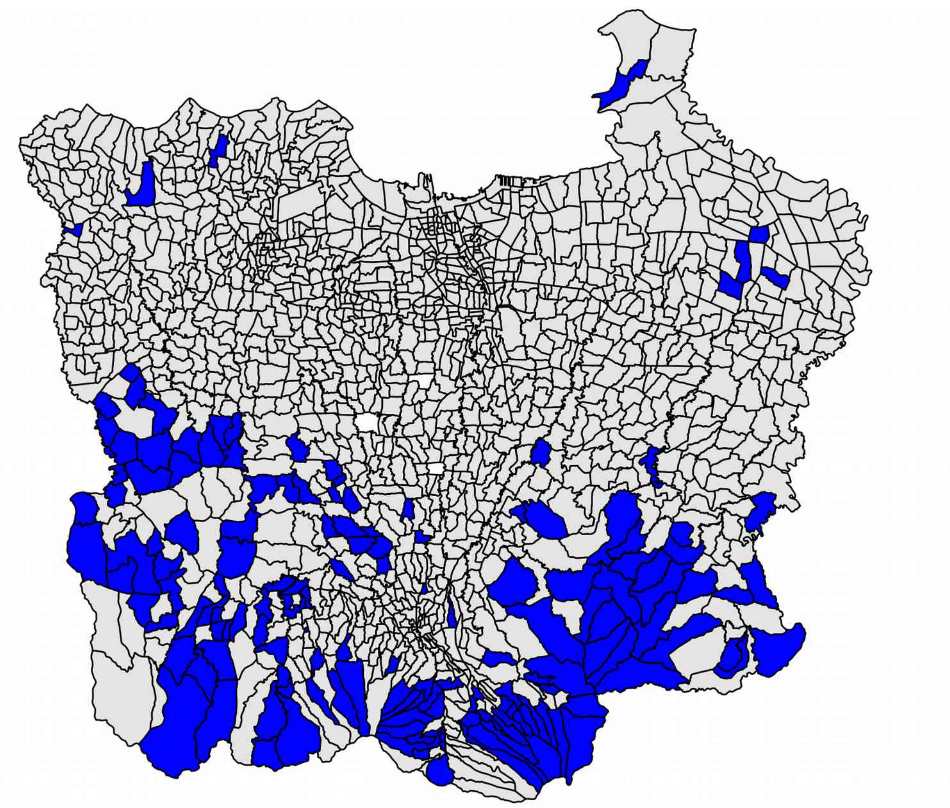

Figure 10: Absolute lowest income zones in Greater Jakarta area (blue)

On first sight, the map looks quite the same as the LISA cluster method map. When one looks better, visible is that the zones are more scattered around the region.

5.2 Jakarta city area

Using the same neighbor definition as for locating poverty clusters in the Greater Jakarta area (queen matrix definition), poverty clusters in Jakarta city area are selected. In Figure 11, these 53 zones are indicated by Low-Low (dark blue).

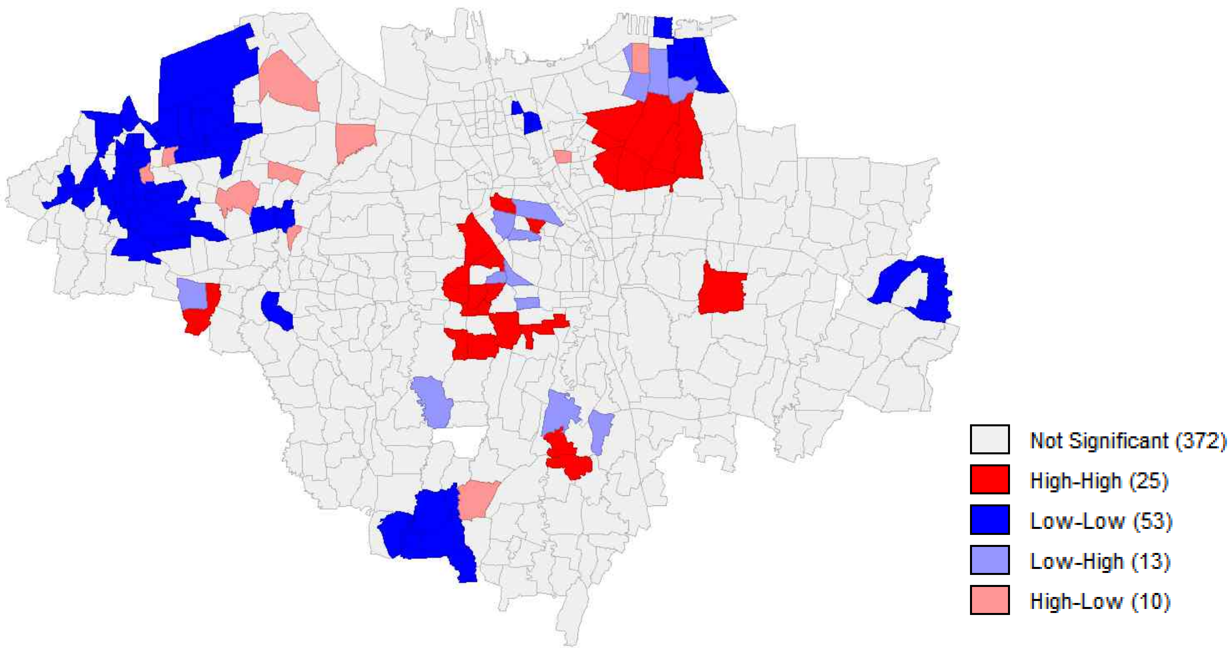

Figure 11: LISA cluster map of income in Jakarta city area (significance level: 5%)

Now we have selected the poverty clusters for Jakarta city area, we now select poverty zones with the absolute lowest income method. With this method, we again select the same amount of zones as in the LISA cluster method (53 zones). In Figure 12, the 53 zones with the lowest income are displayed.

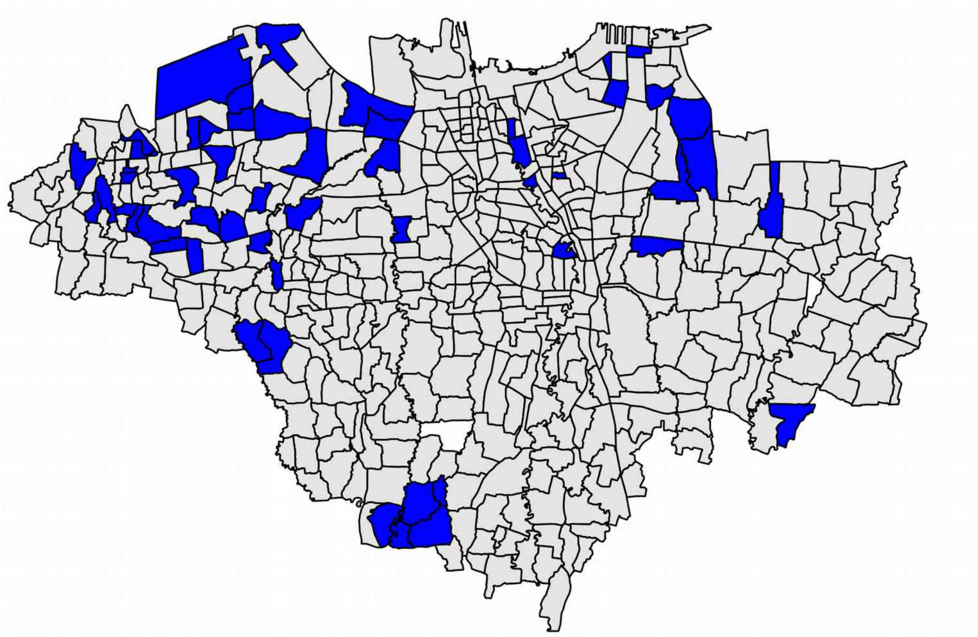

Figure 12: Absolute lowest income zones in Jakarta city area (blue)

Again, the map of poverty zones looks quite the same, but the lowest income method gives a more scattered zone result. This method selects the absolute lowest incomes in the area, while the poverty cluster method selects zones that have a surrounding zones with low income. Therefore, the poverty cluster method gives results with zones that are more often next to each other, while the absolute lowest income method gives a more scattered result.

5.3 Results

The determined origin (poverty) zones for the four methods of selecting poverty zones, is shown in the first column of the tables in attachment 2.

6 Selecting destination zones with preconditions

Now that different ways of selecting origin zones are described, using four different approaches of defining poverty zones, we will describe how well these methods fit to the purpose of creating feeder bus lines for the Transjakarta. This can be achieved by revealing the destination zones for each method of selecting poverty zones.

Again, the JICA commuter survey data is used to accomplish this task. In this survey, a distinction is made between households and household members, the commuters. One household can contain more household members, who go to school or work. For revealing destinations, the data of these individual commuters is used, in contrast to locating origin zones, where the household income data was used.

When analyzing all destination zones per origin zone, it turns out that many of the destinations have just a few observations, which does not make these destinations real, significant destinations for that particular origin zone. Therefore, some *preconditions* are applied to reveal only the significant destination zones for a particular origin zone:

- The destination zone has at least 5 trips from the origin zone. This requires the origin-destination relation to have a significant number of trips and this minimizes the chance that the origin and destination have a relation by chance.
- The destination zone is destination for more than 5% of the trips generated by that origin zone. This requires the destination zone to be a destination for a significant share of trips generated by the origin. Thus a significant share of the origin population is a potential costumer of a new bus line to the destination.

This process of extracting the significant destination zones is shown in Figure 13, of which the Matlab script is included in attachment 3.

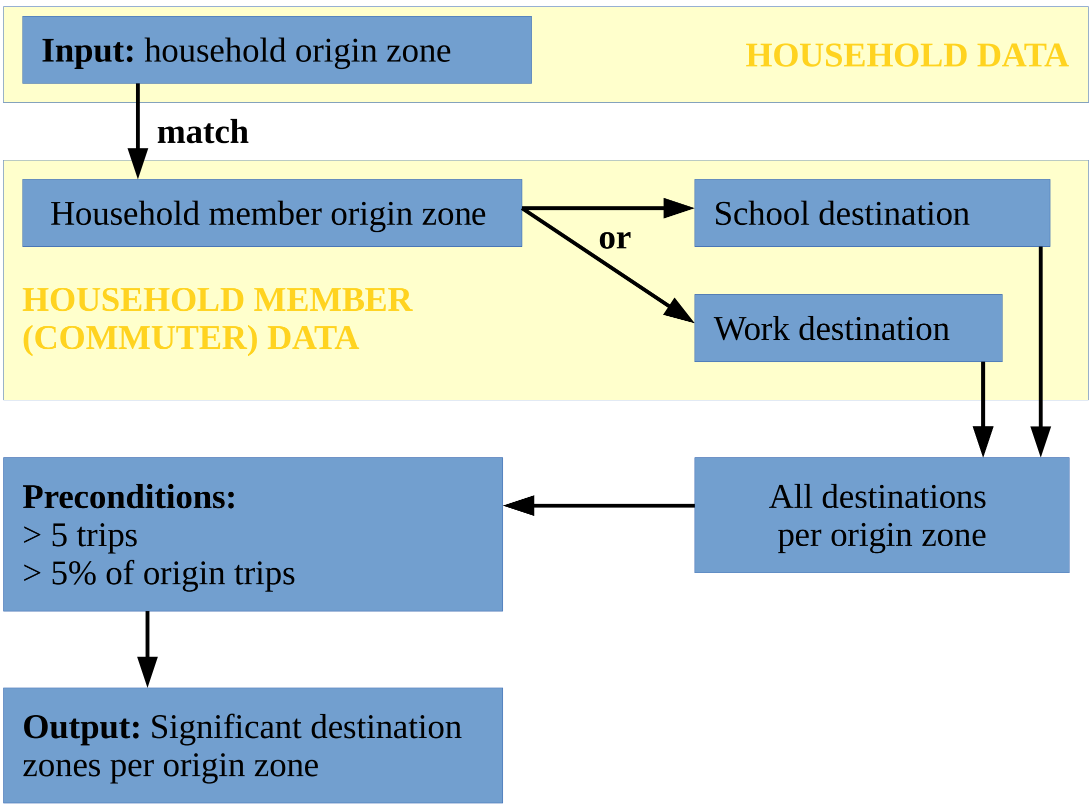

Figure 13: Process of revealing significant destination zones

6.1 Discussion of results

The destination zones for each selection of origin (poverty) zones that fits the preconditions, is shown in attachment 1 (for the 4 selections of poverty zones, see the table on page 12). In this section, the 4 methods of selecting origin zones will be evaluated.

The amount of significant destination zones is an indicator for the spreading around the area for different origin zones. There are two ways of counting the amount of destination zones. The amount of non-unique destination zones is the total number of destination zones for all destinations and counts some destination zones double when it is the destination for more than one origin zone. The amount of unique destinations counts every destination just one time, even if it occurs for more origins.

The less the amount of unique destination zones is compared to the amount of non-unique zones, the less spread is the distribution of traffic and the better it is possible to create feeder bus lines. This can be explained as follows. Combining different origin zones or destination zones in one feeder bus line may be a good idea, to serve more people. This can be achieved by starting the bus line in more zones (origins) or reaching more destination zones.

		Greater Jakarta area		Jakarta city area	
		Cluster	Absolute	Cluster	Absolute
Origins	Amount of origins	156	156	53	53
Significant destinations	Amount of non-unique destination zones	229	245	115	90
	Amount of unique destination zones	168	188	61	67
	Ratio $\frac{\text{amount of unique destination zones}}{\text{amount of non}-\text{unique destination zones}}$	**0,73**	**0,77**	**0,53**	**0,74**

As we can see in the table, the ratio $\frac{\text{amount of unique destination zones}}{\text{amount of non}-\text{unique destination zones}}$ is lower for the poverty cluster method for both Greater Jakarta area and Jakarta city area, which means it should be easier to bundle more relations origin-destination in feeder bus lines.
This could be explained by the fact that the absolute method gives more scattered zone results. The clustered zones in the poverty cluster method are located more close to each other and have the same destinations in a higher degree. Thus spatial spreading of destinations is higher when the spatial spreading of origins is high as well.

Yet, we cannot say anything of the appropriateness of a chosen area (Greater Jakarta area or Jakarta city area), because both methods give enough appropriate destination zones.

7 Selecting suitable origin-destination relations for creating feeder bus lines

In the process of revealing significant destination zones, several origin-destination relations were selected. Since the purpose of this research is to create feeder bus lines for the Transjakarta BRT busway, not all origin-destination relations are suitable to use. Therefore, the general requirements for these relations are:

- The feeder bus line carries poor people from home to daily destination (work or school). This requirement is fulfilled by selecting poverty zones in chapter 5 and select their daily destinations in chapter 6.
- The feeder bus line connects in some way to an existing Transjakarta busway.

When we specify the second requirement more detailed:

- The feeder bus line connects to at least one of the existing 13 Transjakarta busways. This implies that either the origin zone or the destination zone has to be in the city center (province of Jakarta), near an existing Transjakarta busway. That this is true, can more easily be understood if we look at the map in Figure 14: Transjakarta busways are only in the city center, which is zone 1. This has an administrative cause.

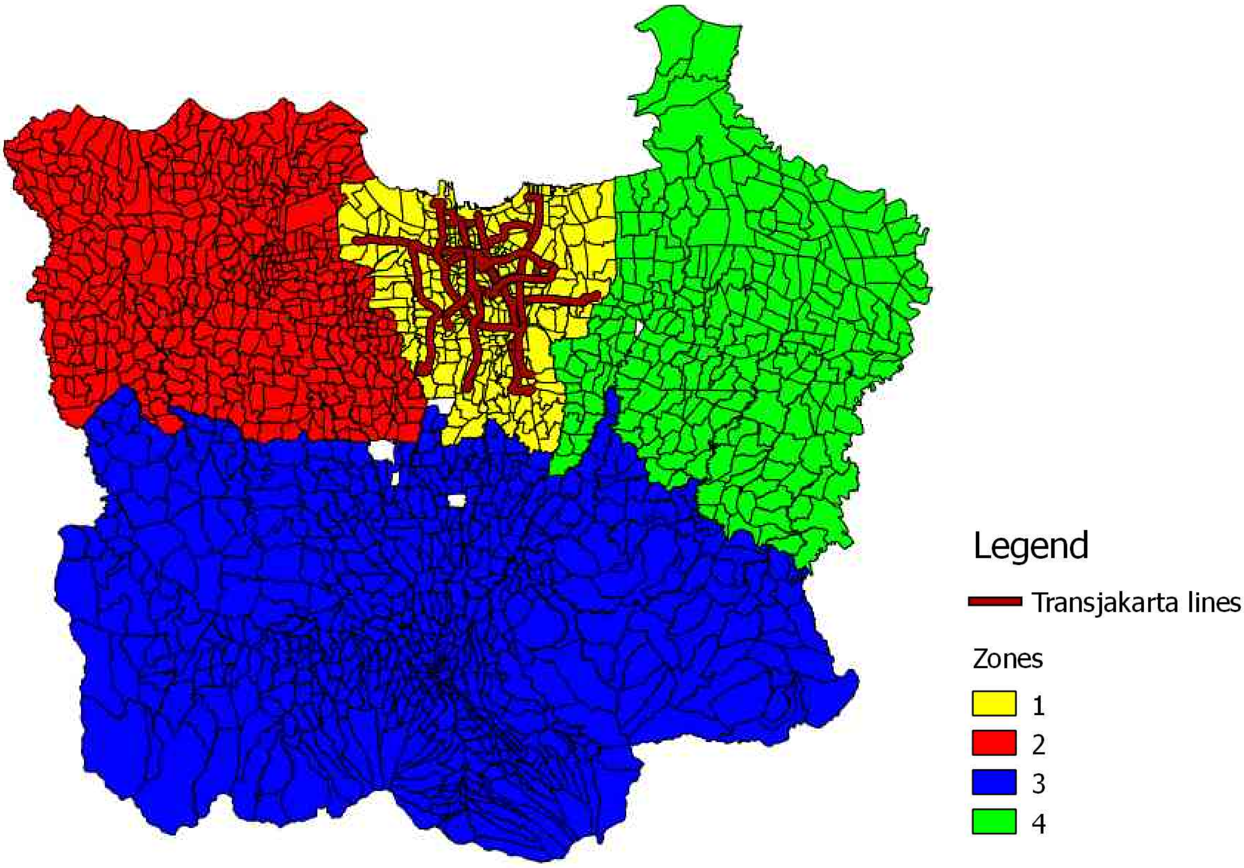

Figure 14: Transjakarta busways are only in the city center

- The origin zone has to be not the same zone or very close to the destination zone, because the goal of creating the feeder line is not to serve trips at short distances. For short distances, the walking modality is often the best and most used option and public transport should not compete with that. Demand for public transport is high enough at a certain origin-destination distance. Therefore, a minimal distance is required for the origin-destination relation to be included. In the trip length frequency distribution of Jakarta in Figure 15, we can see that from a distance 1,5-2 km public transport has a high enough share and walking is less than 30%. Therefore, the minimal distance for a origin-destination relation to be included in the potential suitable origin-destination relations is 2 km.

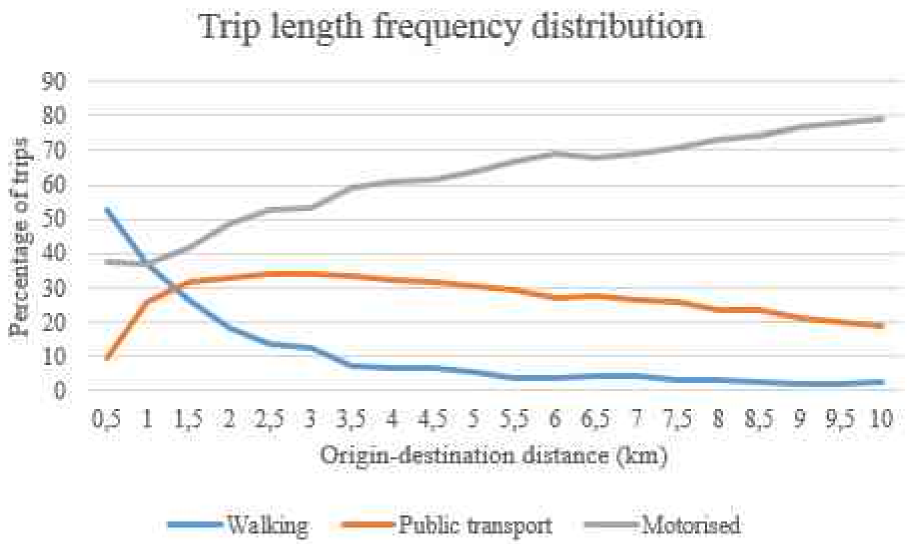

Figure 15: Trip length frequency distribution of Greater Jakarta area

The distance between origin and destination zones is calculated using the centroid coordinates of these zones and the formula $distance = \sqrt{(x_{origin} - x_{destination})^2 + (y_{origin} - y_{destination})^2} = \sqrt{(\Delta x)^2 + (\Delta y)^2}$ (Pythagoras), whereby x_{origin} and y_{origin} are the coordinates of the centroid of the origin zone and $x_{destination}$ and $y_{destinations}$ are the coordinates of the centroid of the destination zone (see Figure 16). As this is an as the crow flies distance, it only gives a global comparison with distances between other zones.

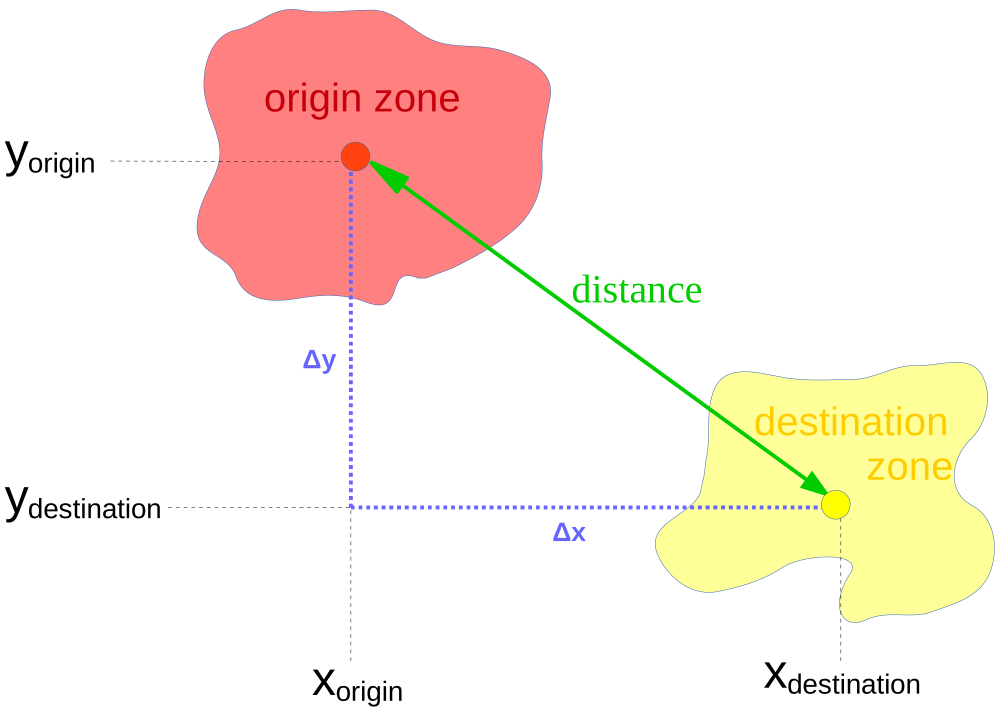

Figure 16: Distance calculation between origin and destination zones

The process of selecting suitable origin-destination relations is shown in Figure 17, of which the Matlab script is included in attachment 3.

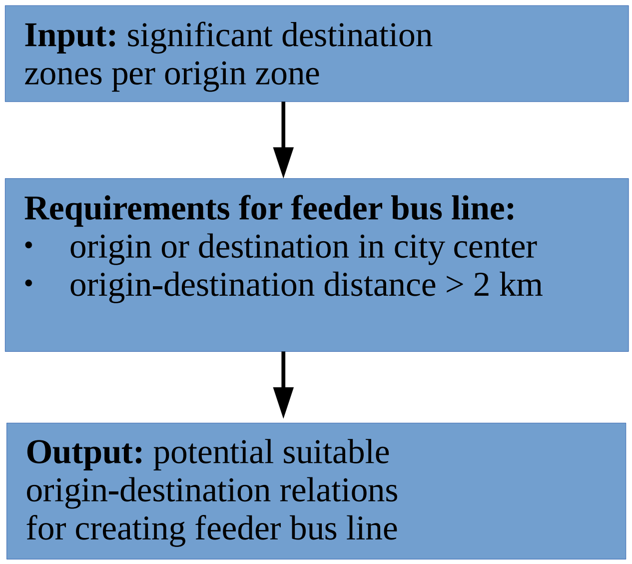

Figure 17: Process of selecting suitable origin-destination relations

7.1 Discussion of results

It turns out that for the methods of selecting poverty zones in the Greater Jakarta Area, there are no potential suitable origin-destination relations for creating a feeder bus line. This means, no of the destinations that fit the preconditions, is in the city center of Jakarta. This can be explained by the fact that for both the poverty cluster method and the absolute lowest income method in the Greater Jakarta Area give origin zones far outside the city center (Figure 9 and Figure 10). It turns out that people living in these zones don't make such long daily destination trips.

Thus, we can conclude that the Greater Jakarta Area method is not an appropriate method to select poverty origin zones, when the goal is to create feeder bus lines for the Transjakarta.

For the Jakarta city area, there are potentially suitable origin-destination relations, and they are as follows:

Poverty cluster method

Origin	Potential suitable destination
3103030	1103020
3103040	1103020
3103010	1103020
1504040	1503070
2110030	1403060
1504060	1503070
1504030	1503070

Absolute lowest income method

Origin	Potential suitable destinations	
1207070	1206040	
1210070	1209060	1210020
1403010	1403060	
1504010	1504070	1505010
1504070	1504030	1505010
2101070	1101020	
2306010	1102010	
3103010	1103020	
3103030	1103020	
3103040	1103020	

In these origin-destination relation tables, destination zones that are the same have the same color to see fast which origin zones have the same destination zones.

When we perform the same destination analyzes, as after selecting significant destination zones as in paragraph 6.1 (also further explained there):

		Jakarta city area	
		Cluster	Absolute
Origins	Amount of origins	53	53
Potential suitable destinations	Amount of non-unique destination zones	7	13
	Amount of unique destination zones	3	10
	Ratio $\frac{\text{amount of unique destination zones}}{\text{amount of non-unique destination zones}}$	**0,43**	**0,77**

We see that the absolute lowest income method gives more than one destination for some origins, while the poverty cluster method does not. The poverty cluster method however gives a less spread result: the ratio is lower.

Because both methods give reasonable destination results, they are both suitable for further analysis. Therefore, the origin-destination relation tables of the poverty cluster method and absolute lowest income method will be merged:

Origin	Potential suitable destinations	
1207070	1206040	
1210070	1209060	1210020
1403010	1403060	
1504010	1504070	1505010
1504030	1503070	
1504040	1503070	
1504060	1503070	
1504070	1504030	1505010
2101070	1101020	
2110030	1403060	
2306010	1102010	
3103010	1103020	
3103030	1103020	
3103040	1103020	

The trip characteristics of these origin-destination relations will be further examined in the next chapter.

8 Determine trip characteristics

Selecting potentially suitable origin-destination relations is a process that can be done automatically based on some criteria, such as the minimum distance between origin and destination, as we have seen in chapters 6 and 7.

As there are still more than 15 origin-destination relations and some of them may be not suitable for creating a feeder bus line for the Transjakarta, some further manual selection could be necessary. Therefore, a table is created with the following trip characteristics for each origin-destination relation:

- Trip time
- Trip distance (as the crow flies)
- Average speed = $\frac{\text{trip distance}}{\text{trip time}}$
- Number of vehicles = Number of transfers +1 (for observations using public transport)
- Total transfer waiting time (for observations using public transport)

The process of determine trip characteristics is shown in Figure 18.

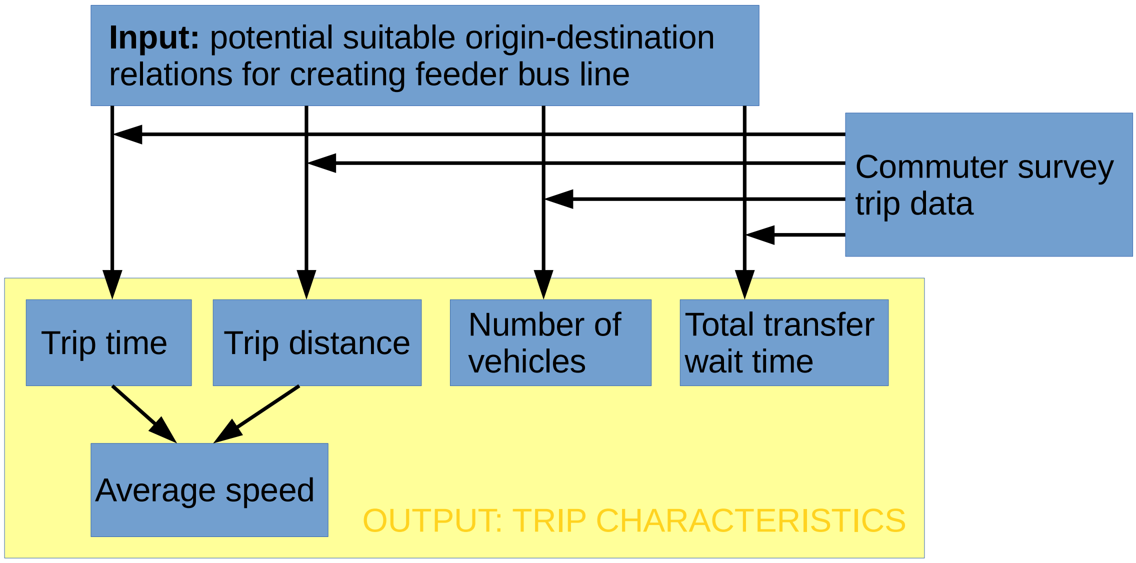

Figure 18: Process of revealing trip characteristics

Some remark has to be made on the number of transfers and waiting time for a transfer: in many observations, no data is available regarding these trip characteristics. Therefore, these characteristics are only based on available data and could be not representative for the origin-destination relation.

The trip characteristics can be used to determine the effort needed for a daily destination trip. The more the effort, the less attractive the current trip conditions and the more attractive is a direct (feeder) bus line. See also the conceptual framework (see Figure 3 on page 9).

8.1 Selecting origin-destination relations

For the 17 potentially suitable origin-destination relations, the trip characteristics table is given as follows:

Origin	Destination	Number of observations	%Tot. observations	Distance (km)	Average trip time (min)	Average speed (km/h)	#Vehicles	%PT	#Vehicles(PT=1)	Total transfer wait time(PT=1)
1207070	1206040	25	5%	**2,3**	25,8	**5,4**	1,5	42%	**2,2**	8
1210070	1209060	16	8%	**2,3**	35,0	**4,0**	1,1	19%	**1,3**	
1210070	1210020	12	6%	**2,8**	30,0	**5,5**	1,6	67%	**1,7**	5
1403010	1403060	40	8%	**3,5**	22,4	**9,4**	1,1	24%	**1,5**	8
1504010	1504070	25	9%	**3,0**	17,5	**10,2**	1,0	12%	**1,0**	
1504010	1505010	16	6%	**2,7**	25,5	**6,4**	1,5	50%	**2,0**	9
1504030	1503070	51	7%	**4,0**	28,2	**8,6**	1,2	35%	**1,5**	3
1504040	1503070	36	6%	**3,5**	25,8	**8,2**	1,1	24%	**1,4**	
1504060	1503070	33	10%	**2,4**	25,8	**5,6**	1,2	30%	**1,7**	4
1504070	1504030	23	6%	**2,1**	21,4	**5,8**	1,4	52%	**1,8**	
1504070	1505010	19	5%	**4,9**	24,5	**12,0**	1,3	26%	**2,3**	8
2101070	1101020	24	12%	**9,0**	46,8	**11,5**	1,1	8%	**1,0**	
2110030	1403060	8	6%	**14,2**	62,5	**13,6**	1,3	13%	**2,0**	1
2306010	1102010	5	10%	**7,3**	31,3	**13,9**	1,4	20%	**3,0**	2
3103010	1103020	7	5%	**8,4**	35,4	**14,3**	1,2	43%	**1,5**	5
3103030	1103020	21	12%	**5,1**	42,1	**7,2**	1,0	24%	**1,0**	
3103040	1103020	19	7%	**6,2**	27,5	**13,5**	1,2	58%	**1,3**	6

Origin-destination relation 1207070-1206040 is a good relation for a new bus feeder line, because many commuters have to transfer for this relative short distance with low average speed. (Set A)

1504010-1505010 has a high use of public transportation, but on average, everybody has to transfer for this very short distance with low average speed. A direct feeder bus line would be a great improvement. (Set B)

Origin-destination relations 1210070-1209060 and 1210070-1210020 have the same origin and therefore could be interesting. The use of public transport is different but the average speed is very low. (Set C)

There are three origins which have 1503070 as destination. Commuters which use public transport for these relations, often have to transfer. Also the average speed is very low. (Set D)

The last 3 origin-destination relations have the same destination 1103020. The distance is relatively far and many people have to transfer. But the most interesting is that these relations can be clustered into one bus line. (Set E)

9 Defining and evaluating feeder line alternatives

In this chapter, several feeder systems are proposed and evaluated regarding some requirements to the feeder bus lines, connecting the selected origin-destination relations.

In Figure 3 on page 9, two different types of BRT feeder systems (direct service and trunk&feeder) and the trunk-only system are indicated. Currently, the BRT system in Jakarta is most similar with the trunk-only system. Several semi-formal buses (Kopaja and Metromini) also have services in Jakarta, but they do not form an integrated system with the Transjakarta BRT.

Current plans for improving Transjakarta include the implementation of a direct service feeder system. Existing semi-formal buses Kopaja and Metromini which have routes parallel to Transjakarta busways, are prepared to use the busway too ("Implementing Direct Service Integration for Transjakarta", 2013), to allow for faster average speeds and integration with Transjakarta. In Figure 19, a bus design is proposed to serve both Transjakarta corridors (with high entrance at the right side) and feeder routes (with entrances and exits at street level at left side).

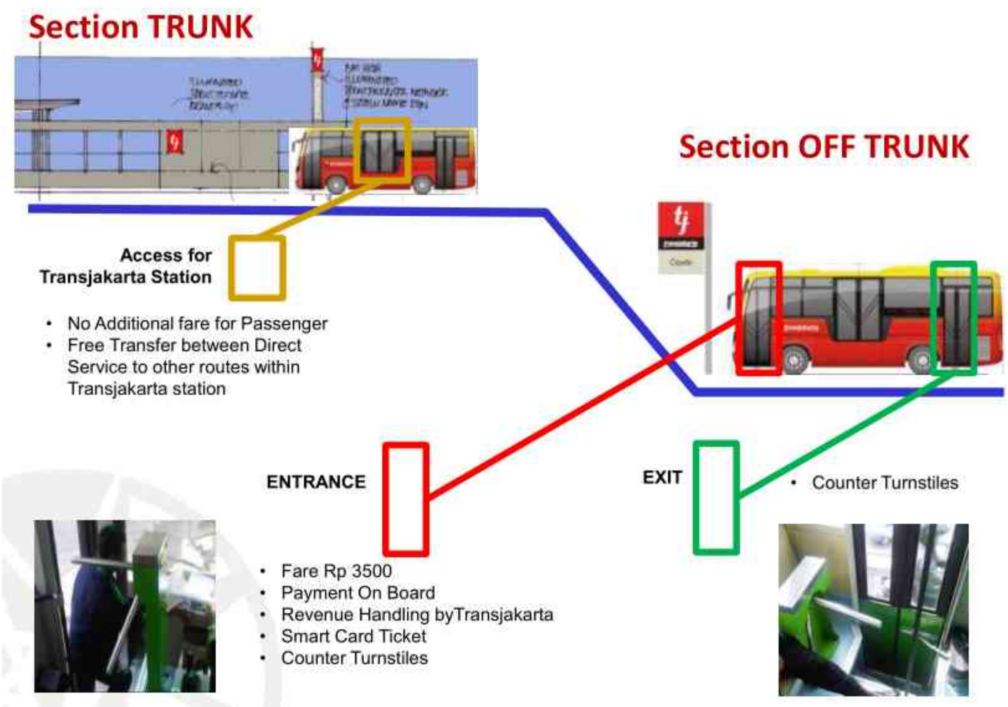

Figure 19: Bus and fare design for impementing direct service ("Implementing Direcct Service Integration for Transjakarta", 2013)

The aim of this research is not to integrate existing non-Transjakarta bus lines in the Transjakarta BRT network, but to create new feeder lines for Transjakarta based on the demand of poor people in Jakarta. Because the goal of creating new feeder lines in this research is to reduce the amount of transfers and transfer time, the direct feeder system is chosen (the first example in Figure 3 on page 9). Also, this serves people using the existing trunk busway by not using the existing capacity and even add capacity to the trunk line, which is a requirement in this research.

9.1 Different types of direct feeder systems

The proposed buses in Figure 19 are used to serve the new feeder bus lines designed in this research. The different types of direct feeder systems will be explained in this paragraph.

- Extending existing Transjakarta busway

In this situation, the origin or destination zone is already near an existing Transjakarta busway and the busway currently stops near that origin or destination zone. To connect the origin and relation, the existing busway needs to be extended (Figure 20).

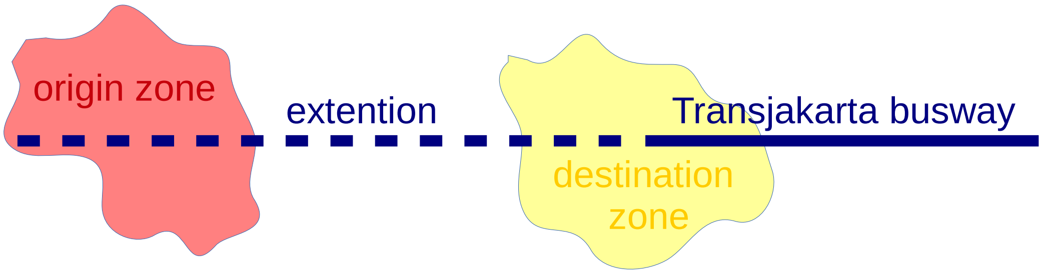

Figure 20: Extending existing Transjakarta busway

- Direct service feeder line from origin

In this situation, the destination zone is already connected to the Transjakarta busway, but the origin zone not. The direct service line starts in the origin zone and continues its way along the Transjakarta busway to the destination zone (Figure 21).

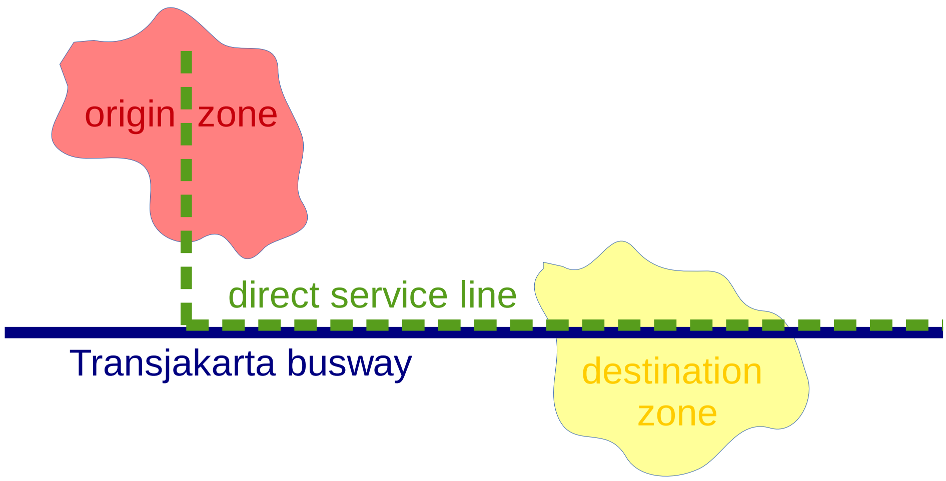

Figure 21: Direct service line from origin

- Direct service feeder line to destination

In this situation, the origin zone already is connected to the Transjakarta busway, but the destination zone not. The direct service line starts in the existing Transjakarta busway and separates after a while from this busway to continue to the destination zone (Figure 22).

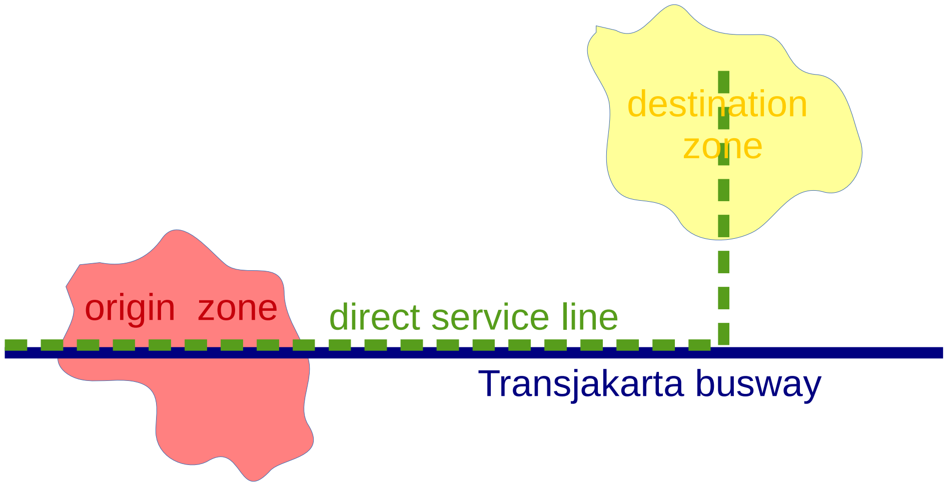

Figure 22: Direct service feeder line to destination

- Direct service feeder line from origin to destination

In this situation, both origin and destination zones are not connected to the existing Transjakarta busway. The busway is located somewhat outside the zones and can be connected by a direct service line from the origin zone, via the Transjakarta busway to the destination zone.

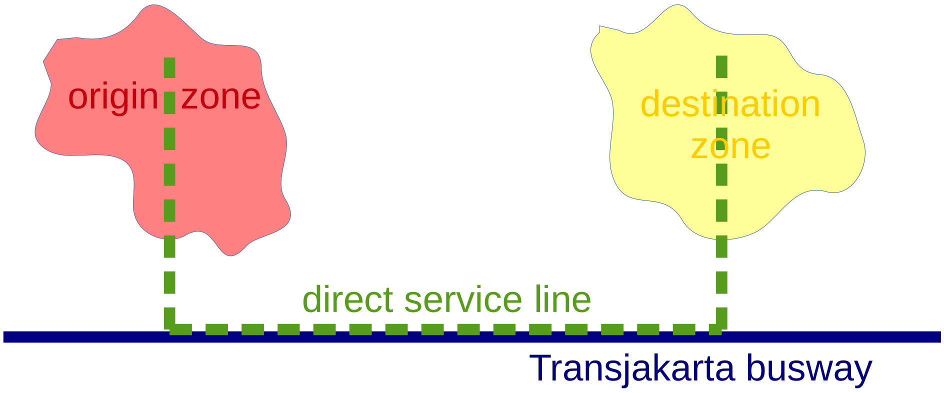

Figure 23: Direct service feeder line from origin to destination

These are the most important types of feeder systems for connecting one origin zone with one destination zone. When the amount of origin or destination zones is more than one, the picture will change but is still based on these basic types of feeder systems.

9.2 Requirements

As we can see, different types of feeder systems are possible. When the type is chosen, different routes are possible. Requirements for choosing the *type* of feeder system and the *route* of the feeder bus are:

- The bus line has to be as much profitable as possible: it has to connect origins and destinations as fast as possible to attract more people. This can be achieved by creating a feeder bus line with a short route or by using existing busways.
- At the same time, combining different origin zones or destination zones in one feeder bus line may be a good idea, to serve more people. This can be achieved by starting the bus line in more zones (origins) or reaching more destination zones. This goal may interfere with the goal to create the most fast bus line possible.

Additional requirements for the *route* of the feeder bus from origin to destination are:

- The feeder bus line has to follow the existing roads when outside the Transjakarta busway. This can be achieved to overlay with the existing road network of Jakarta, of which an example is given in Figure 24.

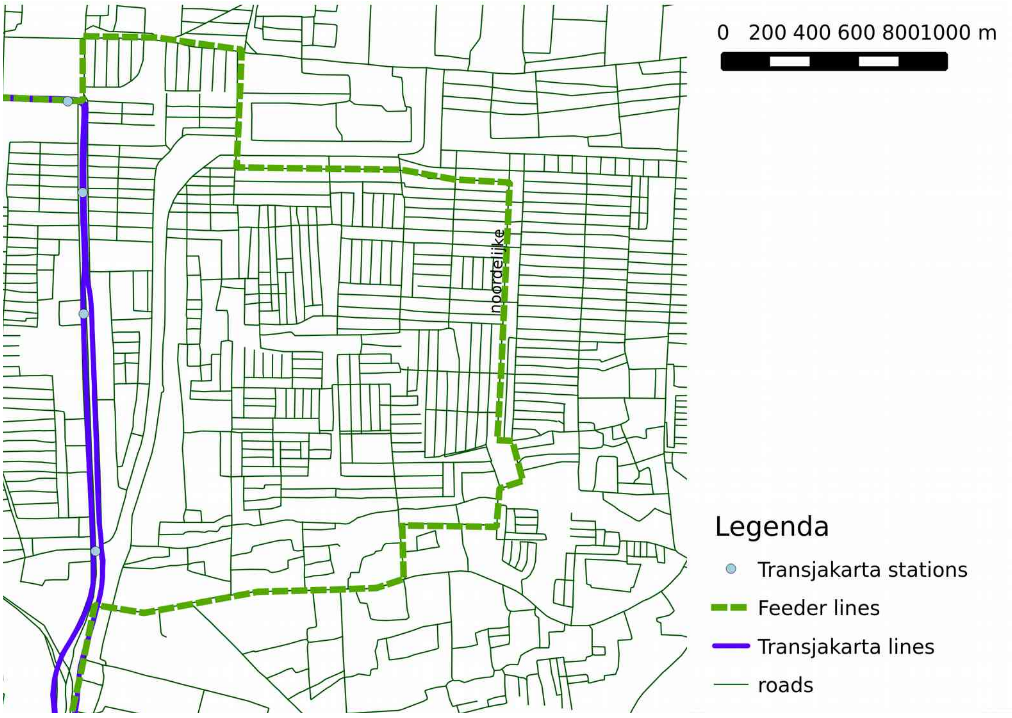

Figure 24: Overlay the feeder bus line with existing road network

- The feeder bus line in the destination zone, as far as not connected to an existing Transjakarta busway, has to connect with work and school destinations (industry, commercial, education). An example is given in Figure 25. The feeder line only connects with work destinations in the destination zone.

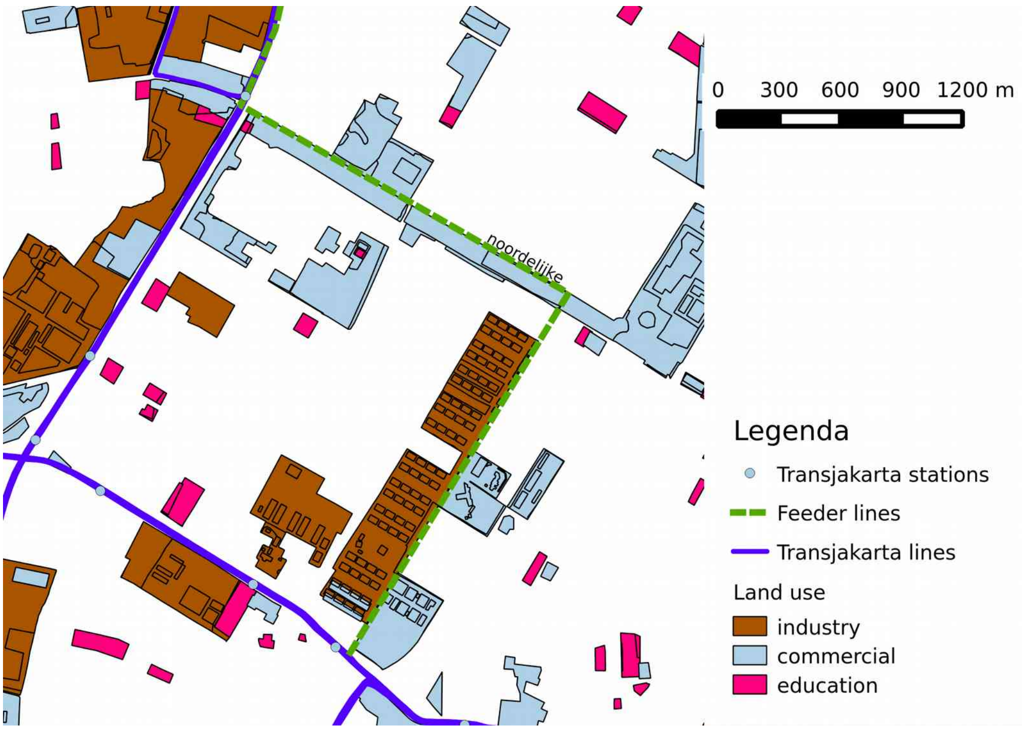

Figure 25: Feeder bus line goes to work destinations in the destination zone

9.3 Evaluating

For the chosen origin-destination relations, a feeder bus line route will be proposed.

9.3.1 Sets A & B

For the proposed origin-destination relation sets A and B, a combined feeder bus line is proposed. It will run two times over the busway and connects several origins and destinations. It is the model in Figure 23 two times.

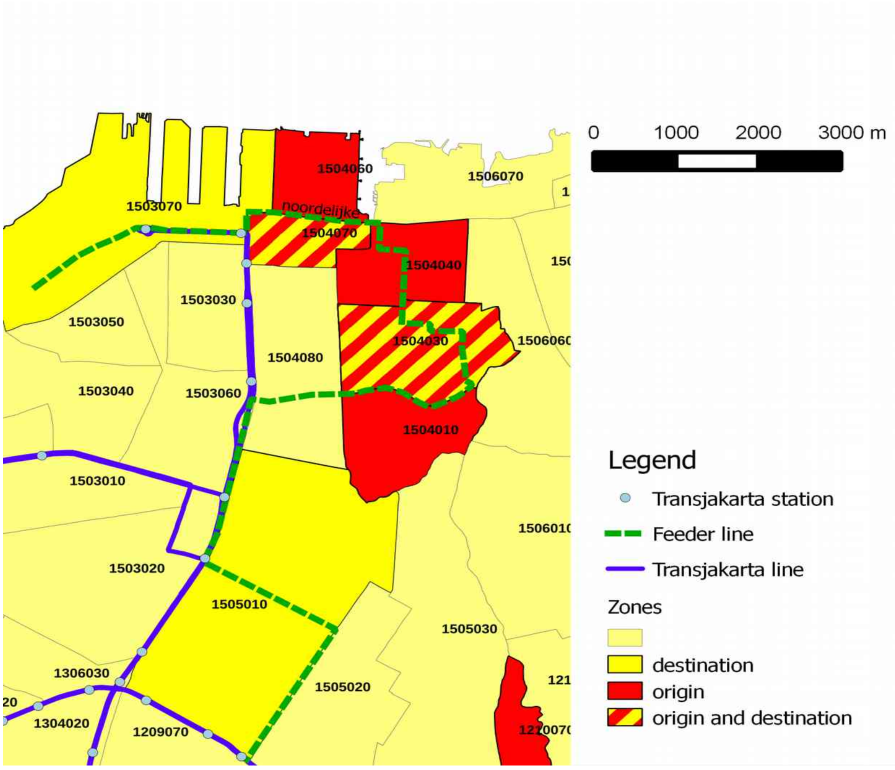

Figure 26: Set A&B

9.3.2 Set C

Origin-destination relation 1210070-1209060 can be easily connected to the existing busways. This is a form of the model in Figure 21. The line is also extended to the east, to serve the destination 1210020l, although there is no Transjakarta busway here. This will be explained later.

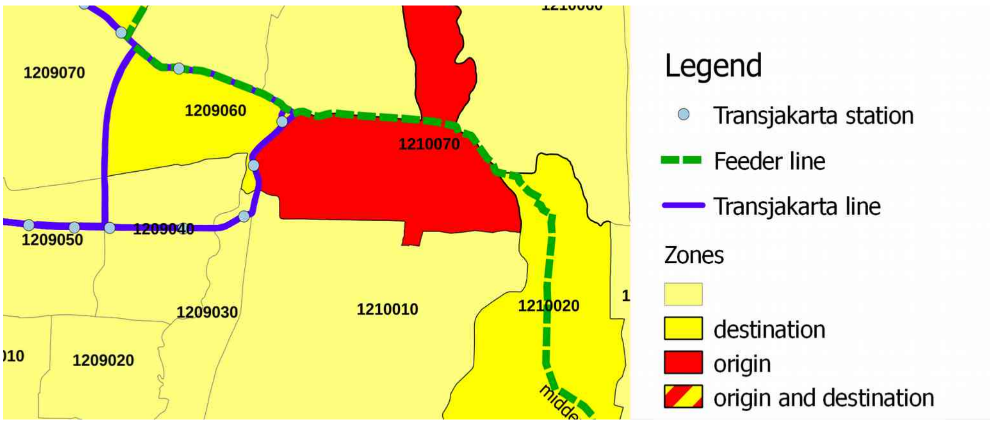

Figure 27: Set C

9.3.3 Set D

For origin-destination relation 1207070-1206040 the model of Figure 23 is applied. It starts in living areas, continuing at the Transjakarta busway, and ends in working areas.

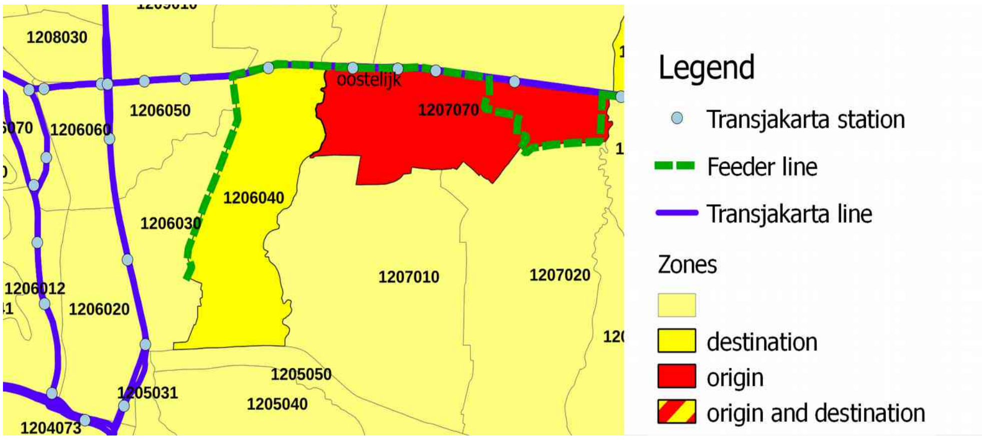

Figure 28: Set D

9.3.4 Set E

For the origin-destination relations which have zone 1103020 as destination, the model of Figure 20 is applied. This connection is an extension of corridor 6 and connects not only the origin zones to Transjakarta. The destination zone is also better connected to the existing network.

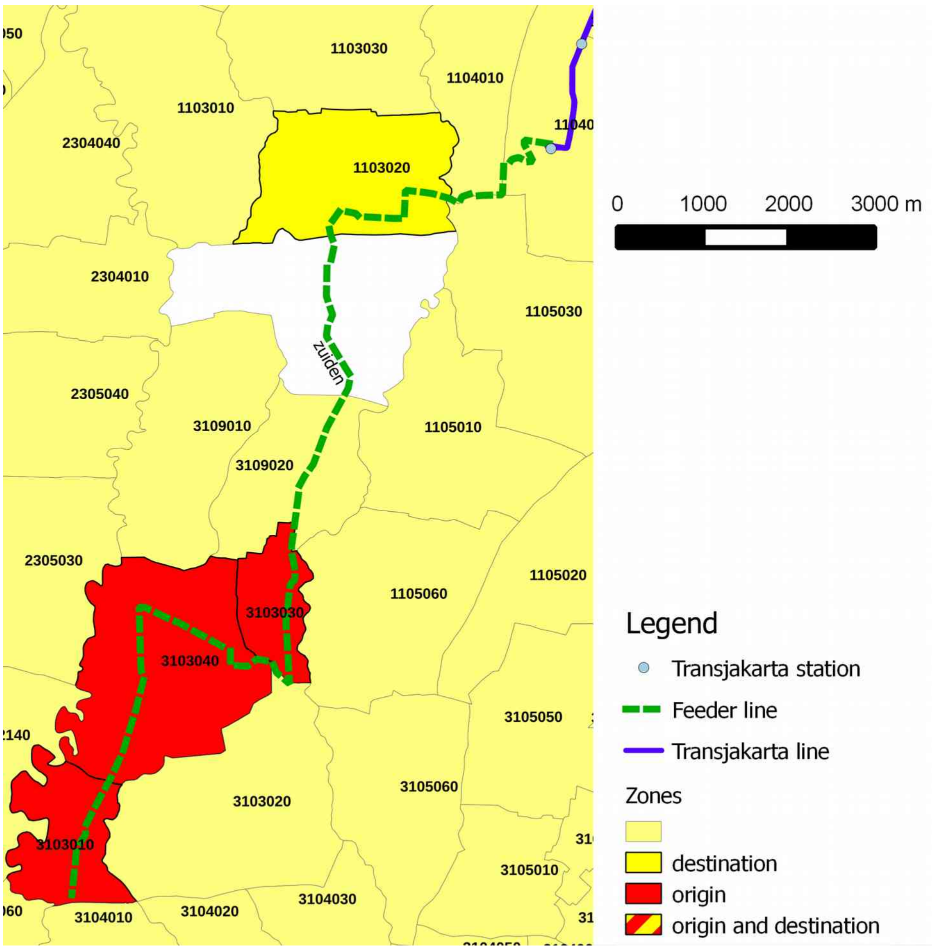

Figure 29: Set E

9.4 East tangent bus line

When we show the feeder lines of set A&B, C and D in one map, we can see that these feeder lines can connect to each other. The suggestion is that these feeder lines will be merged in one long feeder line, located in the east of Jakarta city: the east tangent bus line. The advantage is that buses do not have to turn and commuters have more destination zones in reach without transfer. This will make this bus line even more attractive.

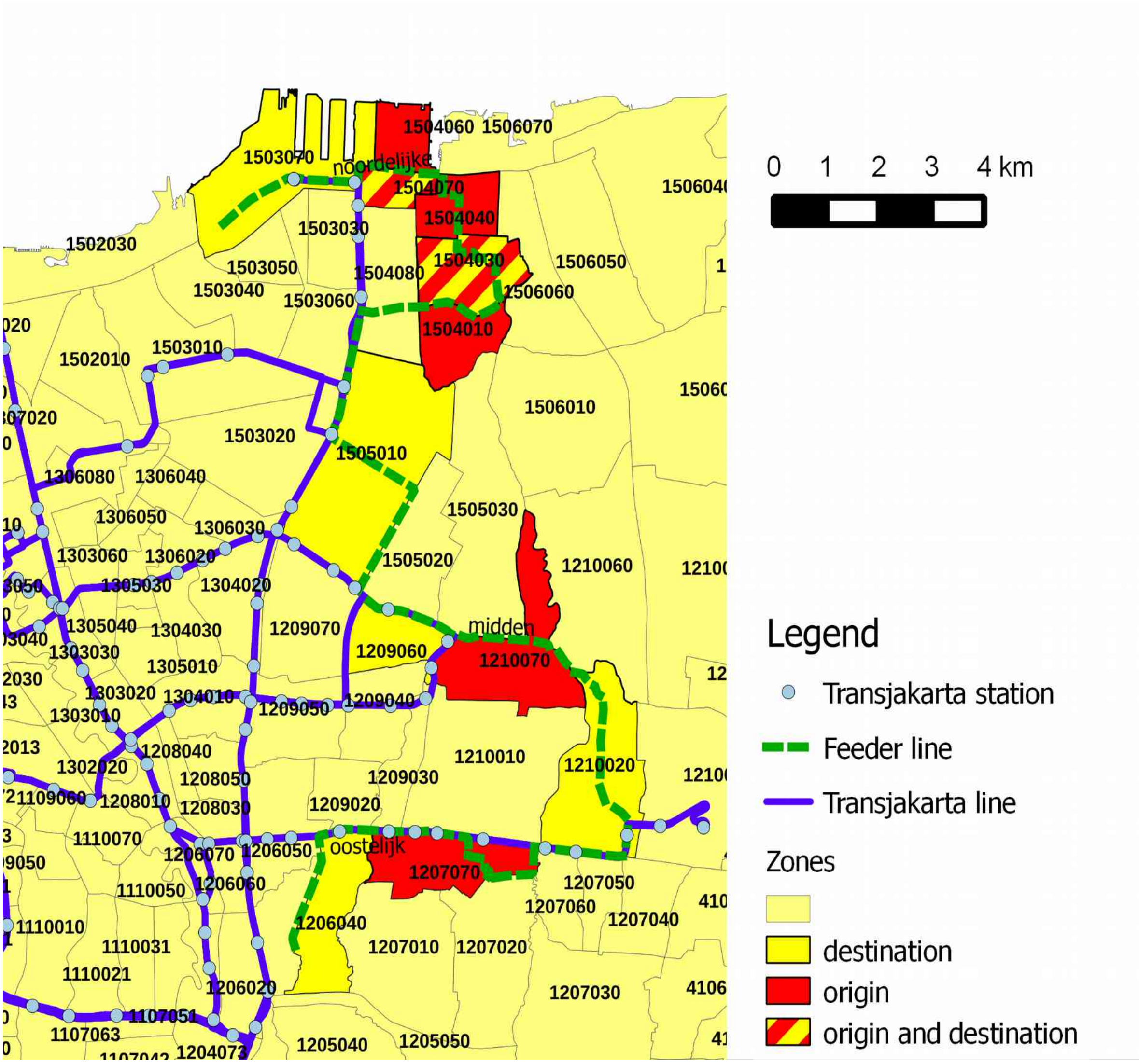

Figure 30: Eastern tangent bus line

10 Conclusion and recommendation

In Jakarta, different feeder systems are proposed ("Implementing Direcct Service Integration for Transjakarta", 2013) and in study to be integrated in the Transjakarta busway system. These proposed feeder lines are based on integrating existing non-Transjakarta buses (such as Kopaja and Metromini) in the Transjakarta network. The aim of this study is to propose feeder systems based on the demand.

This study combines spatial GIS data and the commuter survey data in several ways. The commuter survey income data is used to create income maps and to perform the spatial LISA analyzes. Distance calculation between origin and destination zones is used to further select origin-destination relations. At last, the suitable origin-destination relations from the commuter survey are used to project potential feeder bus lines on the map.

This study also aims to evaluate some used methods to determine demand for a feeder bus system:

- *Poverty cluster vs absolute lowest income method:* in general, when choosing the poverty cluster zones as origins, the destinations will show a less spread result. This can be explained by the fact that the origin zones are more close to each other and inhabitants of these close zones have more or less the same travel behavior.
- *Greater Jakarta area versus Jakarta city area:* it turns out that when choosing poverty origin zones in the Greater Jakarta area, the destinations are not in the neighborhood of Transjakarta busways, so these are not located in Jakarta city. The distance for the daily trip is simply too long. This does not mean the Greater Jakarta area is not suitable for spatial pattern analysis. If the goal would be to determine demand in the more rural zone of this area, the Greater Jakarta area should be considered.
- *Origin- and destination-based displaying:* the method of showing destinations per origin zone and mark same destinations with the same color is a good method to combine multiple origin and/or destination zones in one bus line.

This study shows that there could be demand for many new direct bus lines in many places in Jakarta. Choosing other origin zones would give other destination results and thus other proposed feeder bus lines. Changing requirements for significant destination zones or changing requirements for potentially suitable origin-destination relations would do the same. In that view, the proposed feeder bus lines are just examples. Fortunately, it is now very easy to do this again with the same Matlab scripts in attachment 3.

The quantity of the JICA commuter survey data used in this study is very good. In Greater Jakarta, ten thousands of people were questioned about their travel behavior. For many origin-destination combinations of zones, data is available, which makes the quantity of the data for this research good. All proposed feeder lines have significant amount of origin-destination relations on which the design of this feeder line is based (preconditions in chapter 6).

For the quality of the data, there is a range in quality, depending on which aspect of the data is considered. Income data is unfortunately only provided in ranges, so these ranges had to be converted to real incomes and this reduces accuracy. But it gives a general view which zones are among the poor zones.

Moreover, although the location data gives a detailed level of origins and destinations of trips, this detailed level cannot be processed automatically. Only on zone level, automatic processing is possible. A notable conclusion for this research is that many trips in the data set are based on relatively short trips, which stay in the same zone code. It makes this trip data not useful, because there is no automatic exact location gathering method. Therefore, only relatively long trips (more than 2 kilometer as the crowd flies) are selected. As earlier indicated, still enough trips were available for further processing.

While trip characteristics average trip time and share of public transport are well registered for every trip on the origin-destination relation, this is not the case for the number of transfers and the total transfer waiting time (see table on page 23).Therefore, the last two trip characteristics are just based on a part of registered trips and are taken into account less seriously.

A recommendation to future research involving combining spatial data and the Jakarta commuter survey results is to improve the Jakarta GIS zone data. In this research, tried is to combine data from different sources, because none was complete for the whole Greater Jakarta area.

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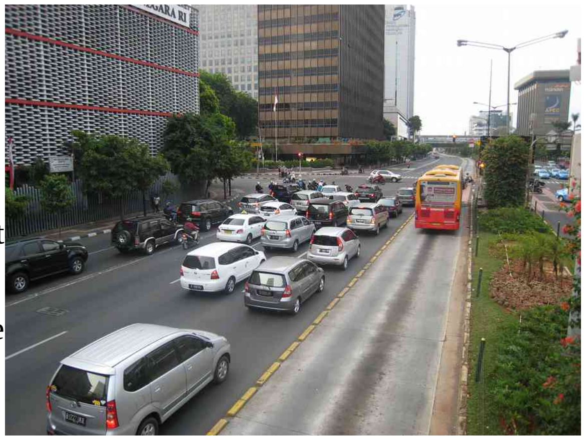
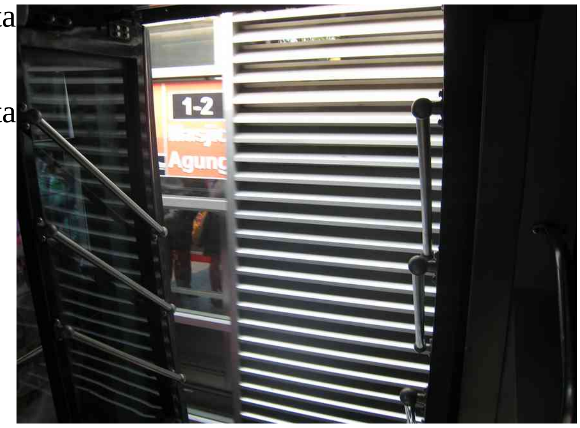
12 Attachment 1: Transjakarta findings

12.1 General

- Very extended network (map in Figure 1)
- Distance between stations smaller than metro (MRT)
- Due to extremely crowded buses, sometimes not possible to exit the bus at your destination
- Changing buses is free as long you stay in the Transjakarta system
- Price: 3500 rupiah, from 5 to 7 a.m.: 2000 rupiah



- Metro is under construction parallel to Transjakarta Korridor 1 but will not replace it
- No Transjakarta connection to the Soekarno-Hatta international airport
- Sometimes empty buses → reason?
- Three types of buses:
  - non-articulated (1 door)
  - non-articulated (2 doors)
  - articulated (3 doors)



- The rear door of buses with 3 doors sometimes has no connection to the stations
- Multiple operators, all have own bus colors, but the Transjakarta sign is the same across different korridors
- Safety: some pickpockets are present, Transjakarta staff warns for this

12.2 Reasons for irregularity of exploitation

- When no separator between busway and regular traffic is available, the Transjakarta suffers greatly from traffic jams
- Sometimes poor busway road condition (holes in the lane) → Transjakarta has to break
- At crossings with regular traffic, long waiting times
- Cars and regular buses driving on busway

12.3 Feeder lines

- Other bus operators: Kopeja and Metro mini, using regular roads and thus suffer from traffic

- These buses may be considered as feeder because some stops are near Transjakarta stations
- However, these buses run also parallel to Transjakarta
- Blok M is an example of bus station with several buses from different parts of Jakarta area, and has connection to Transjakarta
- Luxury long distance buses from suburbs go to Blok M, Fx, Kota and give change opportunity to Transjakarta Korridor 1

12.4 Harmony central busway station

- Very busy bus station: long queues for the bus
- Buses are also queuing to reach the bus stations
- At the station, there are different substops for different corridors and 2 lanes per direction to allow buses to pass each other
- The crossing with traffic light direct after Harmony central bus station causes big delays

13 Attachment 2: Results

Origin-destination relations after preconditions: Greater Jakarta Area, poverty cluster method

Origin	Destinations			
3339030	3320210	0	0	0
3339010	0	0	0	0
3336060	3302080	0	0	0
3336070	3302080	0	0	0
3336080	3302080	3302050	0	0
3336010	1503070	3302080	0	0
3338100	0	0	0	0
3336040	3302080	0	0	0
3338080	0	0	0	0
3336020	3302080	0	0	0
3338060	0	0	0	0
3336030	3301080	0	0	0
3337060	0	0	0	0
3338070	0	0	0	0
3338010	0	0	0	0
3338040	0	0	0	0
3337050	3305130	0	0	0
3337040	3307080	0	0	0
3337030	0	0	0	0
3337020	3205110	0	0	0
3331230	3331230	0	0	0
4223120	4223120	0	0	0
4212030	4212030	0	0	0
3328040	3328040	0	0	0
3327070	3327180	3327070	3327080	0
3327030	3327030	3327080	0	0
3327080	3327080	0	0	0
3328020	3328020	0	0	0
3326170	3326170	3326130	0	0
3327040	3327180	3327040	0	0
3328010	3328010	0	0	0
3324090	3324110	3324090	3324070	0
3326160	3326160	0	0	0
3330220	3330220	3322150	3330210	3330100
3326150	3326150	0	0	0
3322170	3322160	3322150	3322170	0
3325190	3325190	0	0	0
3326130	3326130	0	0	0
3330110	3330110	0	0	0
3325220	3325220	0	0	0
3314200	3314200	0	0	0
3330060	3330060	0	0	0
3330070	3330100	3330070	0	0
3320280	3320280	0	0	0
3325170	0	0	0	0
3325120	3325120	0	0	0
3314140	3314180	3314140	0	0
3326080	3326080	3326040	0	0
3320270	3320270	0	0	0
3326030	3326030	0	0	0
3321020	3321020	3320210	0	0
3314150	3314150	0	0	0
3320210	3325180	3320210	0	0
3325110	3325110	0	0	0
3331230	3331230	0	0	0
3320220	3322160	3322140	3320220	0
3324020	3324020	0	0	0
3325130	3325130	0	0	0
3314100	3314100	0	0	0
3334090	3316170	3334090	0	0
3313150	3313150	0	0	0
3324010	3324010	3302080	0	0
3326070	3326070	0	0	0
3334080	3334080	0	0	0
3303290	3303290	3305190	3302080	0
3314110	3314110	0	0	0
3334120	3334120	0	0	0
3313140	3313140	0	0	0
3313110	3313110	0	0	0
3302190	3302190	3302080	0	0
3303300	3303300	0	0	0
3329090	3329090	0	0	0
3303280	3303280	3305110	3303270	0
3334020	3334020	0	0	0
3329100	3329100	3329050	0	0
3329070	3329070	0	0	0
3329080	3329080	0	0	0
3334070	3334070	0	0	0
3303240	3303240	0	0	0
3301100	3302080	3301100	3301050	0
3301090	3302080	3301090	0	0
3333030	3333030	0	0	0
3334010	3334010	0	0	0
3334030	3334030	0	0	0
3333010	3333150	3333010	3319060	0
3303270	3303280	3305110	3303270	0
3329050	3329050	0	0	0
3333020	3333150	3333020	0	0
3303150	3303150	0	0	0
3334040	3334040	0	0	0
3301080	3301080	0	0	0
3334050	3334050	0	0	0
3329040	3325100	3329040	0	0
3301060	3301060	0	0	0
3302040	3302040	0	0	0
3301050	3301050	0	0	0
3307010	3307010	0	0	0
3329030	3329030	0	0	0
3301040	3302080	3301050	3301040	0
3301030	3301030	0	0	0
3329010	3329010	0	0	0
3304120	3304120	0	0	0
3312110	3312110	3312020	0	0
3334060	3334060	0	0	0
3329020	3329020	3301010	0	0
3312100	3312100	3311090	0	0
3304070	3304070	0	0	0
3304110	3304110	0	0	0
3301010	3301010	0	0	0
3302020	3302020	0	0	0
3335060	3335080	3335050	3335060	0
3311120	3311120	3311110	0	0
3308170	3205110	3308170	0	0
3304100	3304100	0	0	0
3311150	3312100	3311150	0	0
3301020	3301030	3301020	0	0
3304050	3304050	0	0	0
3311100	3312110	3311150	3311100	3311090
3304010	3304010	3304020	0	0
3308140	3308170	3308140	3308130	3308120
3312070	3312080	3312070	0	0
3312040	3312100	3312040	3312050	0
3311110	3311110	0	0	0
3201140	3201150	3201140	0	0
3308160	3201070	3308160	0	0
3304030	3304030	0	0	0
3311090	3311090	3311050	0	0
3308150	3308170	3308160	3308150	0
3311080	3311090	3311080	0	0
3308130	3308130	0	0	0
3311070	3311090	3311070	3311060	0
3312060	3312060	0	0	0
3312030	3312030	0	0	0
3309110	3310170	3309110	0	0
3310060	3202060	3310170	3310060	0
3311040	3311090	3311040	0	0
3310070	3310070	0	0	0
3312050	3312050	0	0	0
3312020	3312020	0	0	0
3308120	3308120	0	0	0
3310050	3310170	3310050	0	0
3311050	3311090	3311050	0	0
3310020	3310170	3310020	3310030	3310010
3312010	3312050	3312010	0	0
3309100	3309100	0	0	0
3310030	3310100	3310030	0	0
3308100	3308100	0	0	0
3310010	3310010	0	0	0
3308110	3308110	0	0	0
3309070	3309070	3309060	0	0
3309090	3309100	3309090	0	0
3309060	3309110	3309060	0	0
3308070	3308070	0	0	0
3308080	3308080	0	0	0
3310040	3310050	3310040	0	0
3308050	3308050	3308030	0	0

Origin-destination relations after preconditions: Greater Jakarta Area, absolute lowest income method

Origin	Destinations			
3326070	3326070	0	0	0
3301030	3301030	0	0	0
3327060	3327180	3327050	3327060	0
3308140	3308170	3308140	3308130	3308120
3308120	3308120	0	0	0
3334050	3334050	0	0	0
3334040	3334040	0	0	0
3301010	3301010	0	0	0
3301020	3301030	3301020	0	0
2212030	2212030	0	0	0
3320270	3320270	0	0	0
3313120	3313120	0	0	0
3303260	3303260	3302080	0	0
3327050	3327180	3327050	0	0
3303300	3303300	0	0	0
4212040	4212040	0	0	0
3337050	3305130	0	0	0
3312020	3312020	0	0	0
3308080	3308080	0	0	0
3336020	3302080	0	0	0
3334020	3334020	0	0	0
3335050	3335050	0	0	0
3313130	3313170	3313130	0	0
3319030	3319030	3312100	3312090	3312080
3312010	3312050	3312010	0	0
3310040	3310050	3310040	0	0
4204090	4204090	0	0	0
3336030	3301080	0	0	0
3308130	3308130	0	0	0
3327080	3327080	0	0	0
3334030	3334030	0	0	0
3338030	0	0	0	0
3334080	3334080	0	0	0
3327030	3327030	3327080	0	0
3338090	0	0	0	0
3328060	3328060	0	0	0
3308090	3308090	0	0	0
3325110	3325110	0	0	0
3328090	3328070	0	0	0
3302190	3302190	3302080	0	0
3334060	3334060	0	0	0
3333030	3333030	0	0	0
3314110	3314110	0	0	0
3312110	3312110	3312020	0	0
3313110	3313110	0	0	0
3311050	3311090	3311050	0	0
3332080	3332080	0	0	0
3334070	3334070	0	0	0
3326170	3326170	3326130	0	0
3316130	0	0	0	0
3304010	3304010	3304020	0	0
3302050	3302100	3302080	3302050	0
3309100	3309100	0	0	0
3320190	0	0	0	0
3303220	3303230	3302080	3303220	0
3328050	3328050	0	0	0
3322120	3322160	3322120	3320280	0
3310090	3310170	3310090	3310100	0
3303250	3302080	3303250	0	0
3302100	3302100	3302080	3302050	0
3304100	3304100	0	0	0
3311060	3311060	0	0	0
3328030	3328030	3327180	0	0
3325140	3325140	0	0	0
3329080	3329080	0	0	0
3320220	3322160	3322140	3320220	0
3322200	3322200	3330210	3322190	0
3308150	3308170	3308160	3308150	0
3312030	3312030	0	0	0
3309050	3309050	0	0	0
3326150	3326150	0	0	0
3304020	3304020	0	0	0
3332070	3332070	0	0	0
3312040	3312100	3312040	3312050	0
3334090	3316170	3334090	0	0
4205180	4205180	4205150	4217020	0
3326160	3326160	0	0	0
4215030	4215030	4215020	0	0

3326140	3326130	3326140	0	0	0
3304110	3304110	0	0	0	0
3324070	3324070	0	0	0	0
3310030	3310100	3310030	0	0	0
3314150	3314150	0	0	0	0
3314200	3314200	0	0	0	0
3311070	3311090	3311070	3311060	0	0
3301100	3302080	3301100	3301050	0	0
3328020	3328020	0	0	0	0
3310020	3310170	3310020	3310030	3310010	0
3337020	3205110	0	0	0	0
3326080	3326080	3326040	0	0	0
3325170	0	0	0	0	0
3204070	3204070	3204030	0	0	0
3331250	3331010	3331250	3331020	0	0
3326090	3326090	0	0	0	0
2215100	2215100	2215080	0	0	0
3308160	3201070	3308160	0	0	0
3339020	0	0	0	0	0
3301070	3301070	3301080	0	0	0
3314100	3314100	0	0	0	0
3304030	3304030	0	0	0	0
3338050	0	0	0	0	0
3336060	3302080	0	0	0	0
3337010	0	0	0	0	0
4212010	4212010	0	0	0	0
3310080	3310170	3310080	0	0	0
3329050	3329050	0	0	0	0
3315100	3315210	3315100	0	0	0
3301040	3302080	3301050	3301040	0	0
3203090	3203090	3319060	3205090	0	0
3338020	0	0	0	0	0
3311120	3311120	3311110	0	0	0
3317070	3317070	3317050	0	0	0
3327040	3327180	3327040	0	0	0
3328010	3328010	0	0	0	0
3311040	3311090	3311040	0	0	0
3312050	3312050	0	0	0	0
3303230	3303230	3302080	0	0	0
3308070	3308070	0	0	0	0
3330080	3322150	3330080	3330070	0	0
3326030	3326030	0	0	0	0
3323010	3323090	3323010	0	0	0
3301050	3301050	0	0	0	0
3326040	3326060	3326040	0	0	0
3320210	3325180	3320210	0	0	0
3304090	3304090	3304050	0	0	0
3325160	3325160	0	0	0	0
4212060	4212060	0	0	0	0
3321040	3321050	3321040	0	0	0
3308180	3308180	0	0	0	0
3301090	3302080	3301090	0	0	0
3308030	3308030	0	0	0	0
3304080	3302080	3304080	0	0	0
2220160	2220160	0	0	0	0
3320260	3320260	0	0	0	0
3310010	3310010	0	0	0	0
3334120	3334120	0	0	0	0
3309090	3309100	3309090	0	0	0
3310050	3310170	3310050	0	0	0
3314130	3314130	0	0	0	0
3301080	3301080	0	0	0	0
3302060	3302080	3302060	0	0	0
3330110	3330110	0	0	0	0
3303190	3302080	3303200	3303190	0	0
3322190	3322160	3322150	3322190	0	0
3308170	3205110	3308170	0	0	0
3201130	3201120	3201160	3201130	3201150	3201140
3309080	3309070	3309080	3308020	0	0
3308060	3308060	0	0	0	0
3325090	1407080	3325140	3325090	3325100	0
3330020	3330020	3330010	0	0	0
3328080	3328080	0	0	0	0
3314160	3314160	0	0	0	0
3311110	3311110	0	0	0	0
3324080	3324080	0	0	0	0
3308110	3308110	0	0	0	0

Origin-destination relations after preconditions: Jakarta city area, poverty cluster method

Origin	Destinations					
1307030	1307040	1307030	0	0	0	0
1307040	1307040	0	0	0	0	0
1408070	1408070	1408030	0	0	0	0
1504030	1503070	1506060	1504030	0	0	0
1504040	1503070	1504040	0	0	0	0
1504060	1503070	1504060	1504040	0	0	0
1506060	1506060	1504040	1504030	0	0	0
2102090	2102090	2102010	0	0	0	0
2103030	2103030	2110050	2103050	0	0	0
2103050	2103050	0	0	0	0	0
2103060	2103060	2103050	0	0	0	0
2103080	2210040	2103080	2103050	0	0	0
2104010	0	0	0	0	0	0
2105010	2105010	2105030	2103030	2103050	0	0
2105020	0	0	0	0	0	0
2105040	0	0	0	0	0	0
2105050	0	0	0	0	0	0
2105060	0	0	0	0	0	0
2106040	2106040	0	0	0	0	0
2106050	2106050	2106040	0	0	0	0
2108030	2108030	2108010	0	0	0	0
2109030	2109030	2103050	0	0	0	0
2109070	2103050	2109070	0	0	0	0
2109110	2103050	2109110	0	0	0	0
2110010	2110010	2110020	2103050	0	0	0
2110020	2110020	0	0	0	0	0
2110030	1403060	2110010	2104020	2110030	0	0
2110040	2110010	2110040	2110020	2104020	0	0
2110050	2110050	2103050	2104020	0	0	0
2110060	2110010	2110060	2110050	2103050	2110030	0
2110070	2110070	2103050	2110030	0	0	0
2110080	2110130	2110080	2110100	2110070	2110030	0
2110100	2110100	2110090	2110070	2110010	2110050	2103050
2110110	0	0	0	0	0	0
2110130	2110130	2103050	0	0	0	0
2110150	0	0	0	0	0	0
2111010	2110010	2111010	0	0	0	0
2111040	2110010	2111040	0	0	0	0
2111060	0	0	0	0	0	0
2112040	2112040	2103050	0	0	0	0
2112050	2112050	2110010	2103050	0	0	0
2113020	2113040	2113020	2112050	0	0	0
2113050	2106050	2113010	2113050	2103050	0	0
2113060	0	0	0	0	0	0
2306040	2101020	2101050	0	0	0	0
3102140	3102140	3102070	0	0	0	0
3103010	1103020	3103040	3103010	3104010	0	0
3103020	3103020	0	0	0	0	0
3103030	1103020	3103030	3103020	0	0	0
3103040	1103020	3103040	3103020	0	0	0
3104030	3103020	3104030	0	0	0	0
4104070	4104060	4104070	0	0	0	0
4222060	4222060	4216040	0	0	0	0

Origin-destination relations after preconditions: Jakarta city area, absolute lowest income method

Origin	**Destinations**					
1110050	1110070	1110060	1110050	0	0	0
1207070	1206040	1207070	0	0	0	0
1210060	0	0	0	0	0	0
1210070	1210070	1209060	1210020	0	0	0
1303040	1303040	1303010	1302030	0	0	0
1305020	1304030	1305020	1305010	0	0	0
1307010	0	0	0	0	0	0
1307040	1307040	0	0	0	0	0
1401030	1401030	1401020	1401010	0	0	0
1401070	1401070	1401080	0	0	0	0
1403010	1403060	1403010	0	0	0	0
1403030	0	0	0	0	0	0
1403040	0	0	0	0	0	0
1404020	0	0	0	0	0	0
1404050	1404050	0	0	0	0	0
1503060	0	0	0	0	0	0
1504010	1504070	1504030	1504010	1505010	0	0
1504070	1504070	1504030	1505010	0	0	0
1506010	0	0	0	0	0	0
2101070	2108010	2101070	1101020	0	0	0
2102050	2102050	2102040	2102010	2103050	0	0
2103040	2103040	2103050	0	0	0	0
2103050	2103050	0	0	0	0	0
2105020	0	0	0	0	0	0
2105040	0	0	0	0	0	0
2105060	0	0	0	0	0	0
2106020	0	0	0	0	0	0
2106030	0	0	0	0	0	0
2106050	2106050	2106040	0	0	0	0
2108070	2108070	2108010	2101020	0	0	0
2109010	2109010	0	0	0	0	0
2109060	2103050	2109060	0	0	0	0
2109080	2103050	2109080	2109070	2109100	0	0
2109100	2103050	2109110	2109100	0	0	0
2109110	2103050	2109110	0	0	0	0
2110020	2110020	0	0	0	0	0
2110040	2110010	2110040	2110020	2104020	0	0
2110070	2110070	2103050	2110030	0	0	0
2110080	2110130	2110080	2110100	2110070	2110030	0
2110150	0	0	0	0	0	0
2110160	0	0	0	0	0	0
2111010	2110010	2111010	0	0	0	0
2111050	0	0	0	0	0	0
2112030	0	0	0	0	0	0
2306010	2107040	2101020	1102010	0	0	0
2306020	0	0	0	0	0	0
3102140	3102140	3102070	0	0	0	0
3103010	1103020	3103040	3103010	3104010	0	0
3103020	3103020	0	0	0	0	0
3103030	1103020	3103030	3103020	0	0	0
3103040	1103020	3103040	3103020	0	0	0
4103040	4103040	0	0	0	0	0
4110050	4110050	0	0	0	0	0

14 Attachment 3: Matlab scripts

14.1 To determine income

```
clear, clc, format compact, format long

disp('Importing files...')
kodeZonaIncome=dlmread('Kode_zona_and_income.csv',';');  %column  1:  codezona,
column 2: range income
aveIncomePerZone(:,1)=dlmread('Zones.csv'); %column 1: each code zona occurs 1
time in this file
length_kodeZonaIncome=length(kodeZonaIncome);
length_Zones=length(aveIncomePerZone);

%Conversion from income range to real income:
for n=1:length_kodeZonaIncome
    if kodeZonaIncome(n,2)==1 %column 2: range income
        kodeZonaIncome(n,3)=500000; %column 3: real income
    elseif kodeZonaIncome(n,2)==2
        kodeZonaIncome(n,3)=1250000;
    elseif kodeZonaIncome(n,2)==3
        kodeZonaIncome(n,3)=1750000;
    elseif kodeZonaIncome(n,2)==4
        kodeZonaIncome(n,3)=2500000;
    elseif kodeZonaIncome(n,2)==5
        kodeZonaIncome(n,3)=3500000;
    elseif kodeZonaIncome(n,2)==6
        kodeZonaIncome(n,3)=4500000;
    elseif kodeZonaIncome(n,2)==7
        kodeZonaIncome(n,3)=5500000;
    elseif kodeZonaIncome(n,2)==8
        kodeZonaIncome(n,3)=7000000;
    elseif kodeZonaIncome(n,2)==9
        kodeZonaIncome(n,3)=9000000;
    elseif kodeZonaIncome(n,2)==10
        kodeZonaIncome(n,3)=11250000;
    elseif kodeZonaIncome(n,2)==11
        kodeZonaIncome(n,3)=13750000;
    elseif kodeZonaIncome(n,2)==12
        kodeZonaIncome(n,3)=16250000;
    elseif kodeZonaIncome(n,2)==13
        kodeZonaIncome(n,3)=18750000;
    elseif kodeZonaIncome(n,2)==14
        kodeZonaIncome(n,3)=21250000;
    elseif kodeZonaIncome(n,2)==15
        kodeZonaIncome(n,3)=23750000;
    elseif kodeZonaIncome(n,2)==16
        kodeZonaIncome(n,3)=27000000;
    else
        kodeZonaIncome(n,3)=0;
    end
end

disp('Summing up incomes per zone...')
aveIncomePerZone(:,2)=zeros(length_Zones,1);  %column  2:  sumIncome  (=0  in
beginning)
aveIncomePerZone(:,3)=zeros(length_Zones,1); %column 3: counting numbers (=0 in
beginning)
kodeZonaIncome(:,4)=0;
for j=1:length_Zones %short list
    for c=1:length_kodeZonaIncome; %long list
        if kodeZonaIncome(c,1)==aveIncomePerZone(j,1) && kodeZonaIncome(c,2)~=99
```

```
&&  kodeZonaIncome(c,4)~=1%column 1: JUTPIzones
                aveIncomePerZone(j,2)=aveIncomePerZone(j,2)+kodeZonaIncome(c,3);
%column 2: SumIncome
              aveIncomePerZone(j,3)=aveIncomePerZone(j,3)+1; %column 3: counting
numbers
            kodeZonaIncome(c,4)=1;
         elseif floor(kodeZonaIncome(c,1)./10)==floor(aveIncomePerZone(j,1)./10)
&& kodeZonaIncome(c,2)~=99 &&  kodeZonaIncome(c,4)~=1
                aveIncomePerZone(j,2)=aveIncomePerZone(j,2)+kodeZonaIncome(c,3);
%column 2: SumIncome
              aveIncomePerZone(j,3)=aveIncomePerZone(j,3)+1; %column 3: counting
numbers
            kodeZonaIncome(c,4)=1;
        end
    end
end

%Computing average income per zone:
for j=1:length_Zones
    if aveIncomePerZone(j,3)>0
             aveIncomePerZone(j,4)=aveIncomePerZone(j,2)./aveIncomePerZone(j,3);
%column 4: Average Income
    else
        aveIncomePerZone(j,4)=0;

    end
end

%Write to comma seperated value file:
dlmwrite('Average_income_per_zone.csv',aveIncomePerZone,'precision','%.0f'),
disp('Ready')
```

14.2 To determine destination zones and trip effort

- **Mainfile**

```
tic, clear, clc, format compact, format short

%INPUT:
Area=2; %0=ask me,1=Greater Jakarta area, 2=Jakarta city area
Method=2; %  0=ask me, 1=Poverty cluster method, 2=absolute lowest income method
minDistance=3; %minimal distance between origin and destination in km

[povertyClusters] = determineOriginZones(Area,Method);

[destinations] = determineDestinations(povertyClusters);

[ODmatrix ODmatrixShare] = createODmatrix(povertyClusters,destinations);

[originBasedClustering          originBasedPrecond          output]          =
clusterOriginBased(ODmatrix,ODmatrixShare,minDistance);

[output]=determineEffort(output, ODmatrixShare);

xlswrite('output.xlsx',output,1,'A4'), toc

DetermineOriginZones
function [povertyClusters] = determineOriginZones(Area,Method)
%UNTITLED6 Summary of this function goes here
%   Detailed explanation goes here

if Area==0
```

```
Area = input('AREA: Greater Jakarta area (enter "1") or Jakarta city area (enter "2")?');
end

if Area==1
    Area='Greater'; disp('GREATER Jakarta area')
elseif Area==2
    Area='City'; disp('Jakarta CITY area')
end

if Method==0
Method = input('METHOD: Poverty cluster method (enter "1") or absolute lowest income method (enter "2")?');
end

if Method==1
    Method='Clusters'; disp('poverty CLUSTER method')
elseif Method==2
    Method='Absolute'; disp('ABSOLUTE lowest income method')
end
file=[Area,Method,'.txt']; povertyClusters=dlmread(file); clear file

end
```

- **DetermineDestinations**

```
function [destinations] = determineDestinations(povertyClusters)
%UNTITLED5 Summary of this function goes here
%   Detailed explanation goes here

ODschool=dlmread('Origin_destination_school.csv');
ODwork=dlmread('Origin_destination_work.csv');

destNo=zeros(length(povertyClusters),1);
for pC=1:length(povertyClusters)

    destinations(pC,1)=povertyClusters(pC);
    destNo(pC)=2;

    for ODs=1:length(ODschool)
        if povertyClusters(pC)== ODschool(ODs,1)
            destinations(pC,destNo(pC))=ODschool(ODs,2);
            destNo(pC)=destNo(pC)+1;
        end
    end
    for ODw=1:length(ODwork)
        if povertyClusters(pC)== ODwork(ODw,1)
            destinations(pC,destNo(pC))=ODwork(ODw,2);
            destNo(pC)=destNo(pC)+1;
        end
    end
end

end
```

- **CreateODmatrix**

```
function [ ODmatrix ODmatrixShare ] = createODmatrix( povertyClusters,destinations )
%createODmatrix: This function creates the Origin Destination matrix
%   Input arguments: povertyClusters, destinations

destinationZones=dlmread('C:\Users\Justin\Dropbox\Bacheloreindopdracht\1 Locate poverty clusters\Zones.csv');
```

```
ODmatrix=zeros(length(povertyClusters)+1,length(destinationZones)+1);
ODmatrix(1,2:length(destinationZones)+1)=destinationZones;    %define    column
headers
ODmatrix(2:length(povertyClusters)+1,1)=povertyClusters; %define row headers

%Create origin destination matrix ODmatrix
%vertical: origins (poverty clusters), horizontal: destinations
for pC=1:length(povertyClusters)
    for destNo=1:length(destinations)
        for Zone=1:length(destinationZones)
            if destinations(pC,destNo)==destinationZones(Zone)
                ODmatrix(pC+1,Zone+1)=ODmatrix(pC+1,Zone+1)+1;
            end
        end
    end

end
ODmatrix=ODmatrix(:,all(ODmatrix(2:length(povertyClusters)+1,:)==0)'==0);
%Delete unused destinations


%Define ODmatrixShare:
ODmatrixShare=ODmatrix;                    length_destinations=size(ODmatrix,2);
length_origins=size(ODmatrix,1);
for pC=2:length(povertyClusters)+1 %rows: origins/poverty clusters

    for destNo=2:length_destinations+1
                             ODmatrix(pC,length_destinations+1)=sum(ODmatrix(pC,
[2:length_destinations] )); %Sum up trips for each origin in the last column
        ODmatrixShare(pC,destNo)=ODmatrix(pC,destNo)/ODmatrix(pC,size(ODmatrix,2
));
                                                ODmatrix(length(povertyClusters)
+2,destNo)=sum(ODmatrix([2:length_origins],destNo));
    end
end


end
```

- **ClusterOriginBased**

```
function      [originBasedClustering      originBasedPrecond      output]      =
clusterOriginBased(ODmatrix,ODmatrixShare,minDistance)
%UNTITLED3 Summary of this function goes here
%   Detailed explanation goes here

%origin-based clustering:
length_destinations=size(ODmatrix,2); length_origins=size(ODmatrix,1);

originBasedClustering(2:length_origins,1)=ODmatrix(2:length_origins,1);
destCount=2.*ones(length_origins,1);
for pC=2:length_origins-1
    for destNo=2:length_destinations-1
          if ODmatrixShare(pC,destNo)>0.05 && ODmatrix(pC,destNo)>=5 %these are
the requirements to individual zones to be included or not
            originBasedClustering(pC,destCount(pC))=ODmatrixShare(1,destNo);
            destCount(pC)=destCount(pC)+1;
        end
    end
end
originBasedClustering(:,size(originBasedClustering,2)+1)=zeros(size(originBasedC
lustering,1),1);
```

```
%{

Origin-based precondition clustering:
Preconditions are:
-or origin is in jakarta, or destination is in jakarta
-destination is not origin
-destination and origin have a minimal distance

%}
for pC=2:size(originBasedClustering,1)
    destNo(pC)=2;
    while originBasedClustering(pC,destNo(pC))>0
        origin=originBasedClustering(pC,1);
        destination=originBasedClustering(pC,destNo(pC));
        distance=determinedistance(origin,destination);
                if (floor(origin/10e5) ==1 ||floor(destination/10e5) ==1) && destination~=origin && distance>minDistance %these are the requirements to relations origin-destination to be included or not
            originBasedPrecond(pC,1)=origin;
            originBasedPrecond(pC,destNo(pC))=destination;
        end
        destNo(pC)=destNo(pC)+1; clear origin destination

    end
end

%Create output file
output=zeros(1000,16);
ODno=1;
for n=1:length(originBasedPrecond)
    if originBasedPrecond(n,1)>0
        for m=2:size(originBasedPrecond,2)
            if originBasedPrecond(n,m)>0
                   output(ODno,1)=originBasedPrecond(n,1); %column 1 of output: origin zones
                   output(ODno,2)=originBasedPrecond(n,m); %column 2 of output: destination zones
                ODno=ODno+1;
            end
        end
    end
end
clear m n ODno
output=output(output(:,1)>0,:);


end
```

- **determineDistance**

```
function [ distance ] = determinedistance( origin,destination )
%UNTITLED Summary of this function goes here
%   Detailed explanation goes here

coordinates=dlmread('coordinates.csv');
for n=1:length(coordinates)
    if origin==coordinates(n,1)
        originCoordinates=coordinates(n,[2 3]);
    end
    if destination==coordinates(n,1)
        destinationCoordinates=coordinates(n, [2 3]);
    end
end
```

```
distance=(sqrt(     (abs(originCoordinates(1)-destinationCoordinates(1)))^2     +
(abs(originCoordinates(2)-destinationCoordinates(2)))^2))/1000;

end
```

- **determineEffort**

```
function [output] = determineEffort(output, ODmatrixShare)
%UNTITLED4 Summary of this function goes here
%   Detailed explanation goes here

disp('CLOSE THE "output.xlsx" FILE')

% Import files
effort=[dlmread('school_effort.csv');dlmread('work_effort.csv')];

%---------------------------------------------------------------------------
%Step 1: Determine number of observations per relation origin-destinations

for ODno=1:size(output,1) %doorloop elke relatie origin-destination (16)
    for e=1:length(effort)
        if output(ODno,1)==effort(e,1) && output(ODno,2)==effort(e,2)
               output(ODno,3)=output(ODno,3)+1; %column 3 of output: number of
observations
        end
    end

    origin=output(ODno,1);destination=output(ODno,2);
    for pC=2:size(ODmatrixShare,1)
        for destNo=2:size(ODmatrixShare,2)
                                          if    origin==ODmatrixShare(pC,1)    &&
destination==ODmatrixShare(1,destNo)
                output(ODno,4)=ODmatrixShare(pC,destNo);   %column 4 of output
            end
        end
    end
    output(ODno,5)=determinedistance(origin,destination); %column 5 of output
end
clear ODno e

%---------------------------------------------------------------------------
% Step 2: Determine average trip time per relation origin-destination

for ODno=1:size(output,1) %loop every relation origin-destination
    obsNo=0;
    times=zeros(output(ODno,3),6);
    for e=1:length(effort)
        if output(ODno,1)==effort(e,1) && output(ODno,2)==effort(e,2)
             obsNo=obsNo+1; %obsNo=observation number for a particular relation
origin-destination

              %Determine average trip time HOME -> work/school, in column 6 of
output
            if effort(e,4)>=10
                times(obsNo,1)=effort(e,3)*60+effort(e,4);
            else
                times(obsNo,1)=effort(e,3).*60+effort(e,4).*10;
            end
            if effort(e,6)>=10
                times(obsNo,2)=effort(e,5)*60+effort(e,6);
            else
                times(obsNo,2)=effort(e,5).*60+effort(e,6).*10;
            end
```

```
                    if  times(obsNo,1)<times(obsNo,2)  &&  times(obsNo,1)~=0  &&
times(obsNo,2)~=0;
                  times(obsNo,3)=times(obsNo,2)-times(obsNo,1); %travel time in
minutes (home-> school/work)
            end
            A=times(times(:,3)>0,:); output(ODno,6)=mean(A(:,3)); clear A

              %Determine average trip time WORK/SCHOOL -> home, in column 7 of
output
            if effort(e,25)>=10
                times(obsNo,4)=effort(e,24)*60+effort(e,25);
            else
                times(obsNo,4)=effort(e,24).*60+effort(e,25).*10;
            end
            if effort(e,27)>=10
                times(obsNo,5)=effort(e,26)*60+effort(e,27);
            else
                times(obsNo,5)=effort(e,26).*60+effort(e,27).*10;
            end
                    if  times(obsNo,4)<times(obsNo,5)  &&  times(obsNo,4)~=0  &&
times(obsNo,5)~=0;
                  times(obsNo,6)=times(obsNo,5)-times(obsNo,4); %travel time in
minutes (school/work -> work)
            end
            A=times(times(:,6)>0,:); output(ODno,7)=mean(A(:,6)); clear A

                 output(ODno,8)=(output(ODno,6)+output(ODno,7))/2; %column 8 of
output
             output(ODno,9)=output(ODno,5)/( (output(ODno,8)) / 60 ); %column 9
of output
        end
    end
    ODno; times; clear times
end
clear ODno e obsNo

%--------------------------------------------------------------------------
% Step 3: Determine average number of transfers    per relation origin-
destination
% AND       Determine average total waiting time     per relation origin-
destination

for ODno=1:size(output,1) %loop every relation origin-destination
    obsNo=0;
    transfer=zeros(output(ODno,3),6);
    for e=1:length(effort)
        if output(ODno,1)==effort(e,1) && output(ODno,2)==effort(e,2)
            obsNo=obsNo+1;

               %Determine average amount of transfers home -> work/school, in
column 10 of output
            if effort(e,7)>0
                transfer(obsNo,1)=1;
                if effort(e,9)>0
                    transfer(obsNo,1)=2;
                    if effort(e,11)>0
                        transfer(obsNo,1)=3;
                        if effort(e,13)>0
                            transfer(obsNo,1)=4;
                            if effort(e,15)>0
                                transfer(obsNo,1)=5;
                                if effort(e,17)>0
                                    transfer(obsNo,1)=6;
                                    if effort(e,19)>0
```

```
                                        transfer(obsNo,1)=7;
                                        if effort(e,21)>0
                                            transfer(obsNo,1)=8;
                                            if effort(e,23)>0
                                                transfer(obsNo,1)=9;
                                          end, end, end, end, end, end, end,
end, end
            A=transfer(transfer(:,1)>0,:); output(ODno,10)=mean(A(:,1)); clear A

            %Determine share of Public Transport, home -> work/school, in column
11 of output
            if any(effort(e,7)== [2 10:25])
                transfer(obsNo,2)=1; %transfer column 2: public transport (1) or
not (0)
            end
            output(ODno,11)=mean(transfer(:,2));

            %Determine average number of transfers for observations using public
transport, home -> work/school, in column 12 of output
            A=transfer(transfer(:,2)>0,:); output(ODno,12)=mean(A(:,1)); clear A

             %Determine average total waiting time for observatings using public
transport, home -> work/school, in column 13 of output
            if effort(e,8)>0
                transfer(obsNo,3)=effort(e,8);
                if effort(e,10)>0
                    transfer(obsNo,3)=transfer(obsNo,3)+effort(e,10);
                    if effort(e,12)>0
                        transfer(obsNo,3)=transfer(obsNo,3)+effort(e,12);
                        if effort(e,14)>0
                            transfer(obsNo,3)=transfer(obsNo,3)+effort(e,14);
                            if effort(e,16)>0
                                transfer(obsNo,3)=transfer(obsNo,3)+effort(e,16)
;
                                if effort(e,18)>0
                                    transfer(obsNo,3)=transfer(obsNo,3)+effort(e
,18);
                                    if effort(e,20)>0
                                        transfer(obsNo,3)=transfer(obsNo,3)+effo
rt(e,20);
                                        if effort(e,22)>0
                                            transfer(obsNo,3)=transfer(obsNo,3)+
effort(e,22);
                                        end, end, end, end, end, end, end, end
            A=transfer(transfer(:,3)>0,:); output(ODno,13)=mean(A(:,3)); clear A

                %Determine average amount of transfers work/school -> home, in
column 14 of output
            if effort(e,28)>0
                transfer(obsNo,4)=1;
                if effort(e,30)>0
                    transfer(obsNo,4)=2;
                    if effort(e,32)>0
                        transfer(obsNo,4)=3;
                        if effort(e,34)>0
                            transfer(obsNo,4)=4;
                            if effort(e,36)>0
                                transfer(obsNo,4)=5;
                                if effort(e,38)>0
                                    transfer(obsNo,4)=6;
                                    if effort(e,40)>0
                                        transfer(obsNo,4)=7;
                                        if effort(e,42)>0
                                            transfer(obsNo,4)=8;
```

```
                                                   if effort(e,44)>0
                                                       transfer(obsNo,4)=9;
                                                     end, end, end, end, end, end, end,
end, end
            A=transfer(transfer(:,4)>0,:); output(ODno,14)=mean(A(:,4)); clear A

                %Determine share of Public Transport, work/school --> home, in
column 15 of output
            if any(effort(e,28)== [2 10:25])
                transfer(obsNo,5)=1; %transfer column 5: public transport (1) or
not (0)
            end
            output(ODno,15)=mean(transfer(:,5));

            %Determine average number of transfers for observations using public
transport, home -> work/school, in column 16 of output
            A=transfer(transfer(:,5)>0,:); output(ODno,16)=mean(A(:,4)); clear A

             %Determine average total waiting time for observatings using public
transport, home -> work/school, in column 17 of output
            if effort(e,29)>0
                transfer(obsNo,6)=effort(e,8);
                if effort(e,31)>0
                    transfer(obsNo,6)=transfer(obsNo,6)+effort(e,31);
                    if effort(e,33)>0
                        transfer(obsNo,6)=transfer(obsNo,6)+effort(e,33);
                        if effort(e,35)>0
                            transfer(obsNo,6)=transfer(obsNo,6)+effort(e,35);
                            if effort(e,37)>0
                                transfer(obsNo,6)=transfer(obsNo,6)+effort(e,37)
;
                                if effort(e,39)>0
                                    transfer(obsNo,6)=transfer(obsNo,6)+effort(e
,39);
                                    if effort(e,41)>0
                                        transfer(obsNo,6)=transfer(obsNo,6)+effo
rt(e,41);
                                        if effort(e,43)>0
                                            transfer(obsNo,6)=transfer(obsNo,6)+
effort(e,43);
                                        end, end, end, end, end, end, end, end
            A=transfer(transfer(:,6)>0,:); output(ODno,17)=mean(A(:,6)); clear A
        end
    end
    ODno; transfer; clear transfer
end

end
```