Mode Split Analysis for Transportation in Residential and Office of Transit-Oriented Development (TOD)

Mohammed Ali Berawi, Miranda Calista, Gunawan

Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Kampus UI Depok, Depok 16424, Indonesia

Corresponding author: miranda.calista@ui.ac.id

Abstract. Transit-Oriented Development (TOD) is a city concept that encourages public transport usage (transit). However, the development of the TOD in Jakarta is currently still focused on the development of residential buildings near the station. It causes a shift in the essence of TOD to TAD, Transit Adjacent Development, an area that is close to transit stations but does not trigger transit activities. Mixed land use is essential in the TOD area because the diversity of building functions will affect the transit activities of the community. To maximize the function of TOD, ridership information for each building function is needed to determine transportation mode selection. This study reviews residential and office buildings, while trains, buses, and private vehicles are transportation modes reviewed, to obtain ridership value that is expected to affect TOD area planning. Questionnaire surveys is performed as a data collection technique to acquire information that will be mathematically processed. The result shows that the mode split value of residential buildings is 47.1% for trains, 11.8% for buses, and 41.2% for private vehicles, while mode split value of office buildings for trains, buses, and private vehicles are 43.8%, 18.8%, and 37.5%, respectively. It indicates that train is the public transportation mode widely used by the users of residential and office buildings located in a 0-800 meters from transit stations.

Keywords: Transit oriented development; mode split; residential; office; ridership

1. Introduction

The concept of developing transit-oriented cities (Transit Oriented Development) has been widely applied in several major cities in the world. The definition of TOD itself is a city system that is designed to encourage people to use public transportation more and walk. Because of this goal, TOD is expected to reduce congestion problems due to human travel activities to meet their needs. In order to meet these objectives, an excellent urban infrastructure development design is needed. According to[1], there are several criteria for urban development that affect the transportation system. These criteria are density, diversity and design. Density in predetermined criteria is a variable measured per unit area. The intended variable can be in the form of population, a number of activities, or a number of buildings. While diversity is the diversity of land use functions contained in the region, and the design is a convenient and safe system planning and able to encourage people's willingness to walk. In Jakarta itself, regulations on TOD have been discussed in Minister of Agrarian Regulation and Spatial Planning number 16 of 2017. The regulation is a guideline for developing transit-oriented areas which state that there are several criteria for transit-oriented regions, i.e.
Located at a rail-based, high-capacity mass transit network node;
Served at least two modes of transportation; and
In accordance with the direction of the development of service centres for activities and based on mixed areas.

The term mixed-use used here is the diversity of land use functions in an area. Transit-oriented areas are expected to be able to integrate and connect various types of space for people to meet their daily needs such as offices, housing, retail areas, green open spaces and others. The allotment of land use is expected to be under its portion, and nothing dominates in order to create diversity in land use and make it easier for the community to transit. The effects arising from the diversity of land use functions in the TOD area are the travel that takes place on the land use and the selection of transportation originating and aiming at the land-use area. Because the TOD design is transit-oriented, it is hoped that the trips that people make in the TOD area can result in high public transportation ridership. By definition, ridership is the number of passengers on trips that use the mode of transportation at a particular time. The mode of transportation chosen will also depend on a number of factors such as the characteristics of the travel agent, the characteristics of the trip, the characteristics of the land use and the characteristics of the service [2][3]. The purpose of this study was to determine the effect of residential and office development in the TOD area in the selection of transportation modes as an indicator of the achievement of the objectives of the TOD concept, namely the creation of areas with public transportation ridership, rail-based transportation in particular.

2. Literature Review
This section described about theory research in general, it assisted to contrive from the problem research begin, aim, till variables component.

2.1. Transit-Oriented Development Theory
TOD is defined as a multipurpose community that encourages people to live near transit services and to reduce their dependence on driving[4]. The TOD concept is used as a way to expand the transit system to serve increasing travel demand, provide alternative solutions for traffic congestion in city traffic and increase accessibility[5]. In the application of urban planning development, the TOD concept is used to develop an area by applying the principle of mixed-use and compact which is within walking distance of the mass transit service point and the centre of a commercial area. Mixed-use and compact referred to include the development of mixed land use areas with sustainable mobility through increased use of mass public transport and the development of environmental facilities for non-motorized modes of transportation as well as pedestrian facilities that are integrated with transit nodes[6]. From each of these land uses, an optimization of the use of mass transit networks is carried out. This optimization is achieved by taking into account the technology of the public transport system being operated (MRT, BRT, LRT, and others), the distance between stations, the phasing of station implementation in a corridor, community characteristics and the target of mass transit users[7].

2.2. Mode Split Theory
The split mode is the process of separating a person's journey based on the mode of transportation he uses. In general, the modes of transportation used are divided into two outlines, namely the modes of private transportation and public transportation. The primary purpose of the split mode is to predict road user decisions and the effects of those decisions[8]. There are 11 factors that influence mode choice, that is the size of a city, ownership of private vehicles, income, age, households with children, public transportation rates, public transportation services, rain, population density, travel distance, and mixed land use[9]. Several studies have been conducted to explore the factors that determine the tendency of people to choose the mode of transportation. The factor of ownership of private vehicles (private cars) has a negative effect on the tendency of using public transport. People who have private vehicles choose to use their vehicles[10][11] Regional factors with mixed land use tend to have a positive effect on the use of public vehicles in travelling back and forth[12][13].
2.3. Commercial Property Theory

Commercial property is a non-financial asset which aims to get defined income in five broad categories, namely retail, hotel, office, apartment, and industrial building[14]. In the TOD concept, there is a grouping process to filter the characteristics of station characters in the TOD area to create a more homogeneous station area called the TOD typology approach. The typology approach in implementing TOD has divided into two namely, a normative approach and a positive approach. The normative approach is a general division based on density, type of housing and transit services. This approach was put forward by [15] by dividing the TOD area into two parts, namely Neighbourhood TOD and Urban TOD. Neighbourhood TOD relates to buses, and Urban TOD relates to trains. [16]. While the positive approach is a grouping based on specific criteria using clustering based on the latent class model (Latent class model-based clustering). Ideally, there are five measurement variables in the latent class model, namely Density, Design, Diversity, Distance to Transit and Destination Access [17].

3. Method and Data Resource
3.1. Questionnaire Distribution

The data used for research is based on filling out the questionnaire in the form of a google form online. A questionnaire is an object that contains a list of questions that are shown to respondents that can be answered by filling in the form of sentences, in the type of a checklist that is choosing answers by marking the place provided and in the form of a scale that is answering by giving a certain level [18]. In this study, the answer is used to form a checklist of the choices provided. There are two types of questionnaires used in this study, the questionnaire for daily travel trips to residential areas and questionnaires for work trips to office areas. The process of filling out the questionnaire began with filling in a statement whether they lived or worked in a radius of 0-800 meters from the station. If the respondent answers yes, then the respondent can proceed to the next question. If the respondent answers no, then the respondent cannot continue to the next question. Respondents who meet the requirements will fill out the question, which is mode selection to determine the effect of residential and office development on transportation selection. The choice of transportation modes in this questionnaire is train, bus and private vehicle. In its implementation, 34 out of 64 respondents were eligible for the residential questionnaire and 16 out of 34 respondents were eligible for the office questionnaire. Questionnaire data is then processed using the Statistical Product and Service Solution (SPSS) program to conduct validity and reliability testing and then the main modes of transportation were drawn for each type of questionnaire based on mode value.

| Table 1. Research Questionnaire |
|---------------------------------|
| **Questionnaire Type** | **Distance with Station Confirmation** | **Transportation Mode Choice** |
| | **Question** | **Answer Choice** | **Question** | **Choice** |
| Residential | Is the location of your home at a distance of 0-800 m from the station? | Yes | What are the main modes of transportation that you use for daily trips? | Train |
| | | No | | Bus |
| Office | Is the location of your office at a distance of 0-800 m from the station? | | What are the main modes of transportation that you use for daily work trips? | Private Vehicle |
4. Result and Discussion
After the answer data from the questionnaire is collected, then the validity test and the reliability test questionnaire are done using SPSS software. After testing the questionnaire, a percentage of the distribution of transportation modes is calculated for each questionnaire. From the percentage distribution of these modes, the most widely used modes of transportation by residential communities who live within a radius of 0-800 meters from the station and office communities who work at a radius of 0-800 meters was concluded.

4.1. Validity Test
Data validity testing is testing the validity of measuring devices that show the ability to measure devices to measure the object to be measured. Validity testing conducted in this study using the SPSS program using the moment product correlation technique between the scores of each item questionnaire with a total score that is the Pearson test. Qualitative data obtained from filling out the questionnaire is then processed into a nominal scale by giving numbers as symbols to distinguish objects or events from one another without any level. This figure only functions as a category label [19]. Then, nominal scale data is entered into the SPSS program, and a Pearson test is performed to measure the closeness of the relationship between the two variables. The range of relations coefficients ranges from -1, 0, and 1. A value of -1 means that the variable is negatively correlated perfectly, 0 has no correlation, and 1 has a perfectly positive correlation [20]. Pearson validity test is done by comparing the R table with the calculated R where R is the correlation value. If the value of R count is higher than R table, then the questionnaire is declared valid. Conversely, if R count is smaller than the R table, then the questionnaire is declared invalid. Based on the calculation results, the value of R is as follows for residential and office areas.

Table 2. The results of the validity of the residential and office questionnaire

| No. | Variable     | Pearson Correlation-Total Score | R Table (N=34) | Validity Test |
|-----|--------------|----------------------------------|----------------|---------------|
| 1   | Mode Choice  | 0.962                            | 0.339          | VALID         |

| No. | Variable     | Pearson Correlation-Total Score | R Table (N=16) | Validity Test |
|-----|--------------|----------------------------------|----------------|---------------|
| 1   | Mode Choice  | 0.971                            | 0.497          | VALID         |

Based on the above results, it was found that the two Pearson Correlation-total scores for both questionnaires were higher than the R table values according to the sum of each data. From this statement, it can be concluded that the residential and office questionnaire is valid.

4.2. Reliability Test
After the questionnaire is declared valid, then the reliability test is conducted with the same program, SPSS. Data reliability testing aims to determine the consistency level of a questionnaire used by researchers. The reliability test in this study was based on Cronbach's Alpha coefficient. Cronbach's Alpha coefficient can be interpreted as a positive relationship between one item with another question [21]. According to [22], there is a decision making in the reliability test that is if the Cronbach's Alfa value is higher than the R table then the questionnaire is declared reliable, and if the Cronbach's Alpha value is smaller than the R table value then the questionnaire is declared unreliable. Based on the calculation results, the reliability test results obtained in the residential and office questionnaire are as follows.
Table 3. The results of the reliability of the residential and office questionnaire

|                      | Residential Questionnaire |                      | Office Questionnaire |
|----------------------|---------------------------|----------------------|---------------------|
|                      | Reliability Statistics   |                      |                     |
| Cronbach's Alpha     | 0.547                     | 0.536                |                     |
| N of items           | 2                         | 2                    |                     |
| R Table (N=34)       | 0.339                     | 0.497                |                     |
| Reliability Test     | RELIABLE                  |                      |                     |

Based on the data in the table, the Cronbach's Alpha value for residential and office questionnaires is higher than the table's R-value according to the amount of each data. From this statement, it can be concluded that the residential and office questionnaire has been reliable.

4.3. Percentage of Transportation Mode Choice in Residential and Office Areas

After the questionnaire is declared valid and reliable, then the recapitulation of the distribution of transportation modes in residential areas and offices is recorded as a percentage listed in the table below.

Table 4. Percentage of transportation mode choice in residential and office areas

| Type of Mode | Choice's Percentage | Residential | Office  |
|--------------|---------------------|-------------|---------|
| Train        | 47.1%               | 43.8%       |         |
| Bus          | 11.8%               | 18.8%       |         |
| Private Vehicle | 41.2%           | 37.5%       |         |

Respondent data that is processed is data that meets the requirements, that is 34 respondents in the residential questionnaire and 16 respondents in the office questionnaire. From the table, it is found that the people who live in the 0-800 radius of the meter station most choose a train for their daily trips in residential areas with a percentage of 47.1% and the people who work in the 0-800 meter radius from the station most choose a train for their work trips with a percentage of 43.8%. From the two data, it is concluded that the train is the most widely used transportation mode for residential and office areas with a radius of 0-800 meters from the station.

5. Conclusion

Based on the results of the questionnaire that has been distributed, it was found that people who live within a radius of 0-800 meters from the station choose the mode of train transportation for daily trips with a percentage of 47.1%, buses with a percentage of 11.8% and private vehicle with a percentage of 41.2% and people who work in offices at a radius of 0-800 meters from the station choose the mode of transportation of trains for working trips with a percentage of 43.8%, buses with a percentage of 18.8% and private vehicle with a percentage of 37.5%. From these data, it can be concluded that the train transportation mode is the most widely used transportation mode for people who live and work at a radius of 0-800 meters from the station.
Acknowledgement
This research was fully supported by Center for Sustainable Infrastructure Infrastructure Development and Universitas Indonesia.

References

[1] W. Wey, H. Zheng and Y. J. Chang, "Alternative Transit-Oriented Development Evaluation in Sustainable Build Environment," pp. 109-123, 2016.

[2] L. D. Frank, J. Cahpman and M. Bradley, "Urban form, travel time and cost relationship with tour complexity and mode choice," Transportation, 2008.

[3] L. Henry, Ridership Forecasting Considerations in Comparisons of Light Rail and Motor Bus Modes, 1989.

[4] A. S. Petkar and S. S. Hamand, "Technical Journal of the Institution of Engineers (India)," Transit Oriented Development, vol. 36, pp. 13-17, 2012.

[5] K. A. Ratner and A. R. Goetz, The reshaping of land use and urban form in Denver through, no. 0264-2751, pp. 31-46, 2012.

[6] Peraturan Menteri Agraria dan Tata Ruang/Kepala Badan Pertahanan Nasional Republik Indonesia nomor 16 tahun 2017, "Peraturan Menteri Agraria dan Tata Ruang/Kepala Badan Pertahanan Nasional Republik Indonesia nomor 16 tahun 2017," 2017.

[7] Alvinsyah, "Indonesian Urban Transport Institute," Penerapan Konsep TOD Sebagai Instrumen Penguatan Jaringan Angkutan Massal Perkotaan, 2016.

[8] H.S.Sathish, D. H.S.Jagadeesh and S. Kumar, "Journal of Mechanical and Civil Engineering," Travel Delay and Modal Split Analysis – A Case Study, pp. 40-45, 2013.

[9] G. Santos, H. Maohc and D. Potogloua, "Factors influencing modal split of commuting journeys in medium-size European citiesFactors influencing modal split of commuting journeys in medium-size European cities," Journal of Transport Agency, pp. 127-137, 2013.

[10] R. Kitamura, "A dynamic model system of household car ownership, trip generation, and modal split: model development and simulation experiment," 2009.

[11] A. R. Pinjari, R. M. Pendyla, C. R. Bhat and P. A. Waddel, "Modeling residential sorting effects to understand the impact of the built environment on commute mode choice," Transportation, 2007.

[12] M. Zhang, "The Role of Land Use in Travel Mode Choice: Evidence from Boston and Hong Kong," Journal of The American Planning Association, 2004.

[13] L. D. Frank, J. Cahpman and M. Bradley, "Urban form, travel time and cost relationship with tour complexity and mode choice," Transportation, 2008.

[14] K. Amadeo, "Commercial Real Estate and Economy," The Balance, 28 February 2019. [Online]. Available: https://www.thebalance.com/what-is-commercial-real-estate-3305914. [Accessed 3 June 2020].

[15] P. Calthrope, The New American Metropolis, London: Princetont Architectural Press, 1993.

[16] G. Currie, "Strengths and Weakness of Bus in Relation to Transit Oriented Development," 2014.

[17] R. Huang, A. Grigolon, M. Madureira and M. Brussel, "Measuring transit-oriented development (TOD) network complementarity based on TOD node typology," The Journal of Transport and Land Use, 2018.

[18] J. Noor, Metode Penelitian : Skripsi, Tesis, Disertasi dan Karya Ilmiah, Jakarta: Kencana Prenada Media Group, 2007.

[19] Junaidi, Memahami skala-skala pengukuran, Jakarta, 2015.
[20] A. Hidayat, "Uji Pearson Product Moment dan Asumsi Klasik," 1 July 2012. [Online]. Available: https://www.statistikian.com/2012/07/pearson-dan-asumsi-klasik.html. [Accessed 1 Juni 2020].

[21] Sugiyono, Metode Penelitian Kuantitatif, Kualitatif, dan R&D, Bandung: Alfabeta, 2012.

[22] J. Widiyanto, SPSS For Windows, Badan Penerbit-FKIP UMS, 2012.