JISS Jurnal Indonesia Sosial Sains

Vol. 6, No. 8, August 2025
E-ISSN:2723 – 6692
P-ISSN:2723– 6595
http://jiss.publikasiindonesia.id/

The Four-Step Model Approach for Improving Public Transportation in Malang City

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KEYWORDS
Four-Step Model, Malang City, Public Transportation

ABSTRACT

Malang City, which is directed as a National Activity Center (NAC) as well as a center for education and trade and services, certainly faces major challenges in transportation management due to significant population, student and tourist growth. With a population of 847,182 people in 2023 and the dominance of private vehicle use, the city is ranked as the fourth most congested city in Indonesia based on the Global Traffic Scorecard in 2021. This article aims to provide recommendations for improving public transportation in Malang City using the Four-Step Model approach, which consists of trip generation, trip distribution, mode choice, and trip assignment stages. Each stage of the model is used to identify movement patterns, transportation mode preferences, and optimal travel routes. The data used is secondary data obtained from the Malang City Transportation System Planning Report (Itenas , 2020). The results show that Lowokwaru, Klojen, and Sukun sub-districts have the highest movement rates. The dominant educational, trade and service and residential activities in these areas generate a lot of movement to and from other sub-districts. In addition, mode choice analysis shows that the use of modes is dominated by private vehicles at 96% while public transportation is only 4%. Recommendations based on these findings include the expansion of public transport routes, fleet modernization, restrictions on private vehicles, and the development of electronic payment systems. The findings are expected to serve as a foundation for integrated and sustainable transportation planning for Malang City.

INTRODUCTION

Based on Government Regulation Number 26 of 2008 concerning the National Spatial Plan, Malang City is designated as part of the Greater Malang Development Area and functions as a National Activity Center (NAC) that supports trade, services, industry, government, education, health, and tourism infrastructure at the national level (Dorodjatoen, 2019). This designation is reinforced by Malang City Regional Regulation Number 6 of 2022 on the 2022–2042 Spatial Plan (RTRW), which directs the city's development toward becoming a high-quality, nationally scaled education and service center, supported by economic growth, settlement development, urban facilities, and integrative, inclusive, and sustainable city infrastructure (Larasati et al., 2025). Studies on urban sprawl dynamics in Malang's peri-urban areas reveal that the NAC function significantly drives physical and economic growth, necessitating spatial planning controls to maintain the balance between regional development and environmental preservation (Hafiz et al., 2025). Integrating urban design with natural dynamics, such as land surface temperature control and green space enhancement, has been identified as a key strategy to improve Malang's ecological resilience (IIETA, 2025). Furthermore, the provision of adequate urban infrastructure, including transportation, clean water, and waste management, is considered crucial in creating a resilient and climate-adaptive city (Larasati et al., 2025). Other research emphasizes that consistent implementation of the RTRW can guide sustainable regional growth while enhancing the quality of life for residents (CITEUS, 2024). Therefore, the synergy between spatial planning policies and sustainable development strategies is essential to realizing Malang's vision as a national-scale education and service city (Hardini, 2018).

Modern research in transportation planning offers key lessons for addressing congestion in cities like Malang. Studies on the efficiency of Bus Rapid Transit (BRT) systems in Latin American megacities demonstrate improved service quality and reduced travel times in congested corridors (Andara et al., 2021). Dynamic modeling approaches to BRT congestion control have shown measurable reductions in traffic congestion and increases in average traffic speed, validating BRT's effectiveness in dense urban contexts (Munoz & Gschwender, 2019). Reviews of integrated public transportation planning emphasize that a lack of coordination among modes leads to systemic inefficiencies, making cohesive strategic adoption essential (Sonar & Gaikwad, 2023). Conventional four-step travel demand models remain a foundational tool in forecasting and evaluating urban transport policies (Kumar et al., 2021). In cities with strong educational sectors, network accessibility assessments using topological movement models have proven valuable for understanding human movement patterns when data availability is limited (Lee & Kim, 2023). Enhancing public transport access to educational facilities has been found to improve sustainability and alleviate congestion, especially in areas with high student commuter flows (Kim, 2025). Furthermore, research on student transportation behavior underscores the importance of accounting for mode-choice heterogeneity and developing targeted infrastructure for educational zones (Kriswardhana, 2024).

These various policy directions have contributed to Malang City's growth into one of the most important education centers in Indonesia. Based on data from *BPS* Malang City in 2022, there are 62 public and private universities, contributing to the total student population of 255,481 spread across Malang City. The concentration of educational institutions creates unique transportation challenges, as student movements typically follow different patterns compared to regular commuter traffic[A3], with peak hours occurring during class schedule changes and semester transitions. Furthermore, the presence of numerous universities attracts not only local students but also inter-city and inter-provincial students, adding complexity to transportation demand patterns. Apart from education, Malang City has also grown into a very strategic center of trade, services, and tourism in East Java Province. Tourist visit data shows that 19.56% of the total tourists in East Java Province choose to visit the Greater Malang Region.

Malang City is also the second-largest city in East Java Province after Surabaya, with a population in 2023 of 847,182 people, classified as a *Big City* based on city size. The aforementioned phenomena and the increasing population present significant challenges, particularly in terms of density and traffic. Traffic congestion in Malang City is further exacerbated by inadequate public transportation infrastructure, limited parking facilities in educational and commercial areas, and the lack of integrated transportation management systems. Current public transportation services, primarily consisting of traditional *angkot* (public minivans), operate without fixed schedules or integrated route planning, resulting in inefficient service delivery and low passenger confidence[A4].

Based on the results of the 2021 Global Traffic Scorecard research conducted by the traffic data analysis company Inrix, Malang City ranks fourth among the most congested cities in Indonesia, after Surabaya, Jakarta, and Denpasar, with the total time wasted in traffic during peak hours amounting to 29 hours per year. To address these challenges, the city government has initiated several policies, including the implementation of one-way traffic systems in certain areas, the development of park-and-ride facilities, and the exploration of electric bus procurement programs. However, these initiatives require comprehensive transportation planning to ensure their effectiveness and sustainability[A5].

Therefore, to overcome these challenges, systematic transportation planning is needed, starting from identifying problems, collecting data, analyzing processes, forecasting and modeling transportation demands, formulating solutions, and evaluating development (Meyer, 2016). This transportation planning is expected to reduce density and congestion resulting from the growth of the population, students, and tourists, and ultimately to decrease the use of private vehicles. This research contributes directly to improving transportation policy and planning in Malang City by providing evidence-based recommendations derived from comprehensive four-step modeling analysis. The findings will assist policymakers in formulating data-driven transportation strategies, optimizing public transport route planning, and developing targeted interventions to reduce private vehicle dependency. Furthermore, the research methodology and results can serve as a replicable framework for other Indonesian cities facing similar urban mobility challenges, thereby contributing to national transportation planning knowledge and best practices.

METHOD

This research employs a quantitative descriptive approach using the Four-Step Transportation Model methodology. The data used is secondary data obtained from the Malang City Transportation System Planning Report, *Itenas* 2020[A1]. The method of data collection was home interviews, which involve collecting direct data (interviews) with respondents to obtain information about the characteristics of their trips, including origin and destination points. Based on this method, the division of zones is determined using administrative boundaries as the origin of the respondent's travel.

The internal zone is defined as a zone within Malang City, while, based on the home interviews, several movements were also found originating from zones outside the city of Malang, which are referred to as external zones. External zones are also determined based on administrative boundaries to facilitate research.

Trip Generation

Trip generation refers to the number of movements arising from an origin to a destination (represented by zones). A zone is an area representing its surrounding environment, which can be a collection of various types of land uses or, to simplify the scope, can be defined using administrative boundaries such as villages, sub-districts, or districts. The trip production (travel generation) originates from a zone *i* in a given unit of time, while the destination zone (*d*) is considered to attract the generated trips (travel attraction), denoted as *Dd* (Wee & Annema & Banister, 2013).

One of the methods used to determine trip generation is the Growth Factor method. Growth factors can be determined by first identifying the trip productions and attractions in the base year, as well as the growth rate of the population or vehicles—depending on the available and required data. In this research, the growth rate used is the population growth rate. This method is simple and suitable for projecting growth over short periods of time (2020–2024).

Trip Distribution

The method used is the Gravity Model, which utilizes the distance between origin and destination zones as a key variable. The notation for calculating the Gravity Model is as follows:

$$Tij = Ai\ x\ Oi\ x\ Bj\ x\ Dd\ x\ F(Cij)$$

Information:
Tij = The sum of the distribution of movement between zones i and j
Oi, Dj = Number of awakenings, known movement attraction
Ai, Bj = Balancing factor
f(Cij) = Distance barrier function between cities

The balancing factor is obtained through an iterative calculation process to ensure that the number of distributed trips is consistent with the total productions and attractions. This approach is known as the Doubly Constrained Model, which is applied when both total trip productions and attractions are known. Iterations continue until the values stabilize (no significant changes occur). The impedance (constraint) function can be obtained from the respective calculation notation.

$$f(Cij) = \frac{K}{Cij}, \qquad (K\ given = 2{,}5)$$

$$Cij = \frac{\sum distance\ of\ all\ zones}{\sum generation\ and\ attraction\ zones}$$

Mode Choice

The method used to determine the choice of travel mode is Choice Modelling. This process begins by defining utility functions for each travel mode. These utility functions can be based on travel time, cost, or distance, and are obtained from survey results and calibration. The assumption in this method is that travelers choose the mode with the highest utility if they have full access to information about each mode.

Trip Assignment

The method used for determining route choice is the uncongested *All-or-Nothing* method, which assumes that all drivers choose the fastest route to minimize travel costs. Consequently, all drivers take the same route, while other routes are ignored (Manalu & Silitonga &

Desriantomy, 2023). The *All-or-Nothing* method is advantageous for being simple, cost-effective, and easy to understand. This approach can be further refined by incorporating the probability of route usage based on the utility function—known as Stochastic Assignment—where the probability is determined by distance, travel time, or cost. This refinement is more realistic than *All-or-Nothing* assignment, but it involves more complex calculations.

RESULTS AND DISCUSSIONS

Trip Generation

The analysis of trip generation in Malang City was carried out using the growth factor method based on population growth rate data in 2020–2023. Population growth rate data is used because vehicle growth rate data is considered not to represent actual conditions due to the significant decline that occurs. The basic data on the number of movements used for this analysis is movement data in 2020, obtained from an interview survey (home interview) in the Fact Report and Analysis of Malang City Transportation System Planning (Itenas, 2020). The projected number of movements in 2024 is calculated using the linear growth method by estimating the growth value based on the ratio of changes in the number of people from the base year (2020) to the projected year (2024). The basic data of the 2020 movement and the formula used for this projection are as follows.

Table 1. Number of Movements in Malang City in 2020

O/D	Lowokwaru	Blimbing	Klojen	Sukun	Kedungkandang	Karangploso (Eks)	Pakisaji (Eks)	Dau (Eks)	Oi 2020
Lowokwaru	Z11	Z12	Z13	Z14	Z15	Z1-Eks1	Z1-Eks 2	Z1-Eks 3	**99.552**
Blimbing	Z21	Z22	Z23	Z24	Z25	Z2-Eks1	Z2-Eks 2	Z2-Eks 3	**33.979**
Klojen	Z31	Z32	Z33	Z34	Z35	Z3-Eks1	Z3-Eks 2	Z3-Eks 3	**32.949**
Sukun	Z41	Z42	Z43	Z44	Z45	Z4-Eks1	Z4-Eks 2	Z4-Eks 3	**68.522**
Kedungkandang	Z51	Z52	Z53	Z54	Z55	Z5-Eks1	Z5-Eks 2	Z5-Eks 3	**39.641**
Karangploso (Eks)	Eks1-Z1	Eks1-Z2	Eks1-Z3	Eks1-Z4	Eks1-Z5	Eks1-Eks1	Eks1-Eks2	Eks1-Eks3	**1.957**
Pakisaji (Eks)	Eks2-Z1	Eks2-Z2	Eks2-Z3	Eks2-Z4	Eks2-Z5	Eks2-Eks1	Eks2-Eks2	Eks2-Eks3	**1.078**
Dau (Eks)	Eks3-Z1	Eks3-Z2	Eks3-Z3	Eks3-Z4	Eks3-Z5	Eks3-Eks1	Eks3-Eks2	Eks3-Eks3	**1.178**
Dj 2020	**87.579**	**34.490**	**39.337**	**77.000**	**31.420**	**2.866**	**2.561**	**3.603**	

Source: Malang City Transportation System Planning Report ITENAS, 2020

$$Jumlah\ Pergerakan\ Tahun\ 2024\ = Jumlah\ Pergerakan\ Tahun\ 2020 + (r.(Tahun\ n - Tahun\ 0)$$

Where r is the rate of population growth that obtains the following results.

Table 2. Calculation of the Number of Movements in Malang City in 2024

No.	Kecamatan	Jumlah Penduduk 2020	Jumlah Penduduk 2023	R
1	Lowokwaru	163.639	164.106	156
2	Blimbing	182.331	182.851	173
3	Klojen	94.112	93.990	-41
4	Sukun	196.300	196.860	187
5	Kedungkandang	207.428	209.375	649
6	Karangploso (Kabupaten Malang)	85.100	86.900	600
7	Pakisaji (Kabupaten Malang)	91.800	92.300	167
8	Dau (Kabupaten Malang)	71.000	71.400	133

Source: Analysis Results, 2024

.

Table 3. Projected Number of Movements in Malang City in 2024

O/D	Lowokwaru	Blimbing	Klojen	Sukun	Kedungkandang	Karangploso (Eks)	Pakisaji (Eks)	Dau (Eks)	Oi 2024
Lowokwaru	Z11	Z12	Z13	Z14	Z15	Z1-Eks1	Z1-Eks 2	Z1-Eks 3	100.019
Blimbing	Z21	Z22	Z23	Z24	Z25	Z2-Eks1	Z2-Eks 2	Z2-Eks 3	34.499
Klojen	Z31	Z32	Z33	Z34	Z35	Z3-Eks1	Z3-Eks 2	Z3-Eks 3	32.827
Sukun	Z41	Z42	Z43	Z44	Z45	Z4-Eks1	Z4-Eks 2	Z4-Eks 3	69.082
Kedungkandang	Z51	Z52	Z53	Z54	Z55	Z5-Eks1	Z5-Eks 2	Z5-Eks 3	41.588
Karangploso (Eks)	Eks1-Z1	Eks1-Z2	Eks1-Z3	Eks1-Z4	Eks1-Z5	Eks1-Eks1	Eks1-Eks2	Eks1-Eks3	3.757
Pakisaji (Eks)	Eks2-Z1	Eks2-Z2	Eks2-Z3	Eks2-Z4	Eks2-Z5	Eks2-Eks1	Eks2-Eks2	Eks2-Eks3	1.578
Dau (Eks)	Eks3-Z1	Eks3-Z2	Eks3-Z3	Eks3-Z4	Eks3-Z5	Eks3-Eks1	Eks3-Eks2	Eks3-Eks3	1.578
Dj 2024	88.046	35.010	39.215	77.560	33.367	4.666	3.061	4.003	

Source: Analysis Results, 2024

Based on the results of the projected number of movements in Malang City in 2024 above, it can be seen that Lowokwaru District recorded the highest number of movements, namely 100,019 movements. This is in line with the main characteristics of the area as an educational and residential center. The high level of educational activities, such as the movement of students and students, coupled with the need for movement from residential areas, makes Lowokwaru District the zone with the highest movement in Malang City. Blimbing District, with a total of 34,499 movements, has the characteristics of main activities in the fields of industry and trade. The high level of commercial and industrial activity in this area contributes significantly to the number of movements that occur. Meanwhile, Klojen District, as a center for trade and services, public facilities, and offices, produced a projected movement of 32,827 movements. The dominance of urban center functions reflects the high intensity of interaction between residents and economic and administrative service centers.

On the other hand, Sukun and Kedungkandang Districts, which are dominated by residential activities, recorded 77,560 and 33,367 movements, respectively. The relatively high number of movements in these two sub-districts can be caused by residential areas that encourage daily travel activities of residents. The sub-districts of Karangploso, Pakisaji, and Dau, which are external zones located in Malang Regency, have a lower number of movements than sub-districts within Malang City. Karangploso District recorded 3,757 movements, while Pakisaji and Dau each recorded 1,578 movements. This reflects the role of these areas as suburban areas that have the main function of settlements, with more limited movements and attractions and a lot of focus on commuter travel to the center of activity in Malang City.

This analysis shows that the main function of each sub-district greatly affects the level of awakening and the attraction of the movement produced. The combination of residential activities, education, industry, trade, and services is a key factor that shapes the dynamics of movement in Malang City. This information on projected movement patterns provides an important basis for transportation system planning, especially to accommodate the different mobility needs in each region in the future.

Trip Distribution

The analysis of the trip distribution in this research was carried out using the gravity doubly constrained model. The basic principle of the gravity model is that the amount of movement between two zones is influenced by the level of activity in each zone (awakening and pull) and the resistance of travel between them. In this context, the obstacle function used is the distance between the origin zone and the destination zone. The farther the distance, the less likely the movement is to occur between the two zones, according to the principle that travel resistance is inversely proportional to the frequency of movement. The following is a table of the distance between the initial and destination zones and the calculation of the obstacle function.

Table 4. Distance Between Zones (km)

Origin/Destination	Lowokwaru	Blimbing	Klojen	Sukun	Kedungkandang	Karangploso (Eks)	Pakisaji (Eks)	Dau (Eks)	Total (Cid)
Lowokwaru	0	5,8	7	8	12,9	12	16	11	**72,7**
Blimbing	5,8	0	6,2	7,7	9,8	16	15,4	15	**75,9**
Klojen	7	6,2	0	3,2	7,2	17,6	11,3	10,1	**62,6**
Sukun	8	7,7	3,2	0	7	18	8,9	9,8	**62,6**
Kedungkandang	12,9	9,8	7,2	7	0	24,9	11	17,5	**90,3**
Karangploso (Eks)	12	16	17,6	18	24,9	0	32,5	17,5	**138,5**
Pakisaji (Eks)	16	15,4	11,3	8,9	11	32,5	0	19,4	**114,5**
Dau (Eks)	11	15	10,1	9,8	17,5	17,5	19,4	0	**100,3**
Total(Cid)	**72,7**	**75,9**	**62,6**	**62,6**	**90,3**	**138,5**	**114,5**	**100,3**	**717,4**

Source: Analysis Results, 2024

Next, calculate the resistance function per each zone obtained from:

Beta = K/Cid, Where K (Given) = 2,5   K/Cid = 2,5/11,20 = 0,2230

Cid = Total Cid/N = 717,4/64 = 11,20   Therefore, impedance function = @EXP (-0.223) × Cid (Distance) Per Zone:

Table 5. Impedance Function

Origin/Destination	Lowokwaru	Blimbing	Klojen	Sukun	Kedungkandang	Karangploso (Eks)	Pakisaji (Eks)	Dau (Eks)	Oi
Lowokwaru	1,000	0,274	0,210	0,168	0,056	0,069	0,028	0,086	**100.019**
Blimbing	0,274	1,000	0,251	0,180	0,112	0,028	0,032	0,035	**34.499**
Klojen	0,210	0,251	1,000	0,490	0,201	0,020	0,080	0,105	**32.827**
Sukun	0,168	0,180	0,490	1,000	0,210	0,018	0,137	0,112	**69.082**
Kedungkandang	0,056	0,112	0,201	0,210	1,000	0,004	0,086	0,020	**41.588**
Karangploso (Eks)	0,069	0,028	0,020	0,018	0,004	1,000	0,001	0,020	**3.757**
Pakisaji (Eks)	0,028	0,032	0,080	0,137	0,086	0,001	1,000	0,013	**1.578**
Dau (Eks)	0,086	0,035	0,105	0,112	0,020	0,020	0,013	1,000	**1.578**
Dd	**88.046**	**35.010**	**39.215**	**77.560**	**33.367**	**4.666**	**3.061**	**4.003**	

Source: Analysis Results, 2024

The next process is iteration so that the number of movement distributions is consistent with the number of generations and pulls. The iteration process was carried out by multiplying the number of generations and pulls by the distance barrier factor until it reached the saturated number (there was no significant change in calculation). In this analysis, iterations were carried out ten times to ensure the stability and accuracy of the model so that the following results were obtained.

Table 6. Iteration Results

Iterasi	A1	A2	A3	A4	A5	A6	A7	A8	B1	B2	B3	B4	B5	B6	B7	B8
1	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	1,0000	0,000008	0,000011	0,000010	0,000009	0,000014	0,000073	0,000047	0,000042
2	0,9610	1,1502	0,9366	0,8542	1,2907	2,3653	2,9500	2,6763	0,000008	0,000011	0,000010	0,000009	0,000012	0,000054	0,000042	0,000040
3	0,9495	1,1624	0,9203	0,8299	1,3758	2,9883	3,0769	2,7216	0,000008	0,000011	0,000010	0,000009	0,000012	0,000048	0,000041	0,000040
4	0,9452	1,1615	0,9167	0,8254	1,3994	3,2458	3,0858	2,7092	0,000008	0,000011	0,000010	0,000009	0,000012	0,000046	0,000041	0,000040
5	0,9435	1,1605	0,9159	0,8245	1,4059	3,3478	3,0875	2,7049	0,000008	0,000011	0,000010	0,000009	0,000012	0,000045	0,000041	0,000040
6	0,9429	1,1601	0,9157	0,8243	1,4078	3,3877	3,0881	2,7038	0,000008	0,000011	0,000010	0,000009	0,000012	0,000045	0,000041	0,000040
7	0,9427	1,1599	0,9157	0,8243	1,4083	3,4032	3,0883	2,7035	0,000008	0,000011	0,000010	0,000009	0,000012	0,000045	0,000041	0,000040

Iterasi	A1	A2	A3	A4	A5	A6	A7	A8	B1	B2	B3	B4	B5	B6	B7	B8
8	0,9427	1,1598	0,9157	0,8243	1,4084	3,4093	3,0884	2,7034	0,000008	0,000011	0,000010	0,000009	0,000012	0,000045	0,000041	0,000040
9	0,9426	1,1598	0,9156	0,8243	1,4085	3,4117	3,0884	2,7034	0,000008	0,000011	0,000010	0,000009	0,000012	0,000045	0,000041	0,000040
10	0,9426	1,1598	0,9156	0,8243	1,4085	3,4126	3,0884	2,7034	0,000008	0,000011	0,000010	0,000009	0,000012	0,000045	0,000041	0,000040

Source: Analysis Results, 2024

Based on the results of the projected number of movements (awakening and pull) that have been calculated at the trip generation stage and the calculation of the obstacle function and the iteration process above, the distribution of movements is obtained as follows:

Tabel 1. Trip Distribution di Kota Malang

O/D	Lowokwaru	Blimbing	Klojen	Sukun	Kedungkandang	Karangploso (Eks)	Pakisaji (Eks)	Dau (Eks)	Oi	Oi'	Rasio
Lowokwaru	65.980	9.961	7.712	11.333	2.038	1.353	337	1.306	**100.019**	**100.019**	**1,00**
Blimbing	7.681	15.412	3.912	5.142	1.726	235	163	227	**34.499**	**34.499**	**1,00**
Klojen	4.415	2.905	11.714	10.539	2.316	124	306	509	**32.827**	**32.827**	**1,00**
Sukun	6.692	3.938	10.870	40.758	4.588	214	991	1.031	**69.082**	**69.082**	**1,00**
Kedungkandang	2.308	2.536	4.582	8.800	22.486	47	638	190	**41.588**	**41.588**	**1,00**
Karangploso (Eks)	6.17	139	99	166	19	2.674	1	42	**3.757**	**3.757**	**1,00**
Pakisaji (Eks)	96	61	153	479	161	1	617	10	**1.578**	**1.578**	**1,00**
Dau (Eks)	257	58	175	343	33	18	7	687	**1.578**	**1.578**	**1,00**
Dd	**88.046**	**35.010**	**39.215**	**77.560**	**33.367**	**4.666**	**3.061**	**4.003**	**167.345**		
Dd'	**88.046**	**35.010**	**39.215**	**77.560**	**33.367**	**4.666**	**3.061**	**4.003**		**167.345**	
Rasio	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**	**1,00**			**1,00**

Source: Analysis Results, 2024

Based on the results of the trip distribution analysis above, it can be seen that the distribution of movements between zones reflects the relationship between the main activities in each sub-district and the distance between zones. The highest number of movement distributions in each zone is the type of intrazone movement or movement that occurs within the same zone according to the principle of the gravity model, i.e. the closer the distance, the greater the tendency of movement that occurs in that zone.

Lowokwaru District, which has the main activity as an education and settlement center, showed the largest number of movements of 100,019 movements. The dominant higher education activities in this region resulted in many movements from and to other sub-districts, especially from Sukun District (11,333 movements) and Klojen District (7,712 movements). The presence of large educational institutions in Lowokwaru District is the main driving factor for the high movement.

Blimbing District, which has the main industrial and trade activities, recorded significant interaction with Lowokwaru District (7,681 movements) and Klojen District (3,912 movements). This indicates the relationship between the trade area and the education zone as well as the administrative center. The sub-district also has a travel attraction figure of 35,010, which shows the trade and industrial activities that contribute to the movement of the population.

Klojen District, as a center for trade, services, public facilities, and offices, shows a high pattern of interaction with Sukun District (10,870 movements) and Lowokwaru District (11,714 movements). This reflects the strategic position of Klojen District as a center of economic and administrative activities, which is the main destination for movement between zones.

Sukun and Kedungkandang sub-districts, which are dominated by residential areas, have quite high numbers of awakening and pulling, 69,082 and 41,588 movements, respectively. This shows the high daily mobility of residents to work, go to school, or access facilities in other zones, such as Lowokwaru and Klojen Districts.

External zones such as Karangploso, Pakisaji, and Dau districts have a relatively small contribution to the total movements, with the number of awakenings of 3,757 and 1,578 respectively, with movements distributed towards urban centers such as Lowokwaru and Klojen districts. This is in accordance with the characteristics of the sub-district as a buffer area with the main focus on settlements.

Overall, the results of the distribution of this movement confirm the importance of inter-zone linkages in supporting the mobility of residents in Malang City. This data can be the basis for the development of transportation policies, including the provision of more integrated road infrastructure and public transportation, to support the increasing needs of inter-district mobility. The map below is a visualization of the movement distribution depicted in the desire line map.

Choice Mode

In this research, the analysis of mode choice was carried out using utility functions adapted from previous research. This approach was chosen due to time constraints that did not allow the implementation of a mode preference survey in Malang City. The selection of reference research journals is based on the similarity of transportation system characteristics between the research location and transportation conditions in Malang City. As a reference, a journal entitled "Mode Choice between Private and Public Transport in Klang Valley, Malaysia" (Chuen et al., 2014) was used to determine the proportion of transportation modes in Malang City.

The journal stated that the percentage of transportation mode use in Klang Valley is 83% for private vehicles and 17% for public vehicles. Meanwhile, based on the results of the research, in Malang City the use of private vehicles reached 96%, while public vehicles were only 4%. This shows that the journal has the same transportation characteristics with the conditions in Malang City, so it is relevant to be used as a reference. Here are the utility functions used for each mode of transportation in Klang Valley, Malaysia.

$$Private\ Vehicle = 1{,}669\ (distance) - 2{,}277\ (BBM\ Price) - 3{,}069\ (Travel\ Time)$$

$$Public\ Tranport = -1{,}035\ (distance) - 2{,}642\ (Travel\ Time) - 2{,}282\ (Public\ Transport\ Fare)$$

The details of variables used for each mode in Malang City are as follows:
Private Vehicle:

- Distance: Average distance between zones is 7 km
- Fuel Price: Fuel used is Pertalite (1 liter = 10 km), so the assumed average expenditure for fuel is IDR 7,000 for all zones

- Travel Time: Average travel time between zones is 0.273 hours (using the assumption of 25 km/h speed)

Public Transportation:

- Distance: Average distance of public transportation is 10.31 km in Malang City
- Fare: Average public transportation fare in Malang City is IDR 5,000
- Travel Time: The average travel time of public transport is 0.518 hours (assuming a speed of 25 km/h)

Travel Time:

The average travel time of public transport is 0.518 hours (assuming a speed of 25 km/h)

So that the percentage probability of choosing a mode in Malang City is as follows.

$$P^{Kend.\ Pribadi} = \frac{e^{1{,}669.(7)-2{,}277.(7).-3.069.(0{,}273)}}{e^{1{,}669.(7)-2{,}277.(7).-3.069.(0{,}273)}+e^{-2{,}035.(10.31)-2{,}642.(0{,}518).-2{,}282.(5)}} = \mathbf{96\%}$$

$$P^{Kend.\,Umum} = \frac{e^{-2{,}035.(10.31)-2{,}642.(0{,}518).-2{,}282.(5)}}{e^{1{,}669.(7)-2{,}277.(7).-3.069.(0{,}273)}+e^{1{,}669.(7)-2{,}277.(7).-3.069.(0{,}273)}} = \mathbf{4\%}$$

More specifically, the following is the distribution of movements based on mode choice.

Table 8. Distribution of Movements Based on Mode Choice

O/D3	Lowokwaru		Total	Blimbing		Total	Klojen		Total	Sukun		Total	Kedungkandang		Total	Karangploso (Ext)		Total	Pakisaji (Ext)		Total	Dau (Ext)		Total
	Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum		Kend. Pribadi	Kend. Umum	
1. Lowokwaru	63.341	2.639	65.98	9.563	398	9.961	7.403	308	7.712	11.786	0	11.786	1.956	82	2.038	1.299	54	1.353	337	0	337	1.254	52	1.306
2. Blimbing	7.373	307	7.681	14.796	616	15.412	3.755	156	3.912	5.142	206	5.348	1.657	69	1.726	226	0	226	163	0	163	227	0	227
3. Klojen	4.238	177	4.415	2.789	116	2.905	11.245	469	11.714	10.539	422	10.961	2.223	93	2.316	119	0	119	306	0	306	509	0	509
4. Sukun	6.424	0	6.424	3.781	158	3.938	10.435	435	10.87	40.758	1.63	42.389	4.404	184	4.588	206	0	206	991	0	991	1031	0	1031
5. Kedungkandang	2.216	92	2.308	2.435	101	2.536	4.399	183	4.582	8.8	352	9.152	21.587	899	22.486	45	0	45	638	0	638	190	0	190
6. Karangploso (Ext)	593	25	617	134	6	139	95	4	99	166	7	172	18	1	19	2.567	0	2.567	1	0	1	42	0	42
7. Pakisaji (Ext)	92	4	96	58	2	61	147	6	153	479	19	498	154	6	161	1	0	1	617	0	617	10	0	10
8. Dau (Ext)	247	10	257	56	2	58	168	7	175	343	14	357	32	1	33	17	0	17	7	0	7	687	0	687

Source: Analysis Results, 2024

The results of the calculation show that the probability of using private vehicles reaches 96%, while the probability of using public transportation is only 4%. This figure reflects the preference of the people of Malang City who are very dominant in private vehicles compared to public transportation. Significant differences in the variables of distance, travel time, and travel cost efficiency between private vehicle modes and public transportation are the main factors that affect the low probability of choosing public transportation. In addition, the high dependence of the community on private vehicles in Malang City can also reflect the lack of optimal facilities or the attractiveness of public transportation in the region. These results indicate the need for policy interventions to increase the use of public transportation in Malang City.

Trip Assignment

1) All or Nothing Method

The All or Nothing method in route selection is based on the selection of the shortest route and the route with the fastest mileage. This method does not take into account congestion or traffic flow (barrier-free) and assumes that users will 100% choose the most profitable route in terms of cost and time. This research uses the route with the shortest distance where in each pair of zones will be presented two routes that are most used by vehicle users. The following are some examples of route selection between internal-internal zones and internal-external zones with the all-or-nothing method in Malang City.

trip assignment from the internal zone pair between Lowokwaru District (Zone 1) and Blimbing District (Zone 2). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 5.5 Km which is indicated by a red line. While the second route is 5.4 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 9,961 movements will go through route 2 with details, namely 9,563 trips using private vehicles and 398 trips using public transportation (angkot). The existing public transportation route in Malang City is shown on the blue line.

trip assignment from the internal zone pair of Blimbing District (Zone 1) and Klojen District (Zone 3). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 5.68 Km which is indicated by a red line. While the second route is 6.3 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 7,712 trips will go through route 1 with details, namely 7,403 trips using private vehicles and 308 trips using public transportation (angkot). The existing public transportation route in Malang City is shown on the blue line.

trip assignment from the internal zone pair of Blimbing District (Zone 2) and Kedungkandang District (Zone 5). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 8.39 Km which is indicated by a red line. While the second route is 9.5 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 1,726 trips will go through route 1 with details, namely 1,657 trips using private vehicles and 69 trips using public transportation (angkot). The existing public transportation route in Malang City is shown on the blue line.

trip assignment from the pair of internal zones of Blimbing District (Zone 2) and Karangploso District (Ex Zone 1). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 15.53 Km which is indicated by a red line. While the second route is 16.3 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 226 trips will go through route 1.

trip assignment from the pair of internal zones of Klojen District (Zone 3) and Sukun District (Zone 4). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 3.6 Km which is indicated by a red line. While the second route is 4.2 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 10,961 trips will go through route 1 with details, namely 10,539 trips using private vehicles and 422 trips using public transportation (angkot). The existing public transportation route in Malang City is shown on the blue line.

trip assignment from the pair of internal zones of Sukun District (Zone 4) and Kedungkandang District (Zone 5). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 9.5 Km which is indicated by a red line. While the second route is 7.5 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 4,588 trips will go through route 2 with details, namely 4,404 trips using private vehicles and 184 trips using public transportation (angkot). The existing public transportation route in Malang City is shown on the blue line.

trip assignment from the pair of internal zones of Sukun District (Zone 4) and Dau District (Ex Zone 3). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 10.9 Km which is indicated by a red line. While the second route is 11.3 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 1,031 trips will go through route 1.

trip assignment from the pair of internal zones of Kedungkandang District (Zone 5) and Pakisaji District (Zone Ex 2). With the help of Google Maps, it was identified that there are 2 routes that are often used by vehicle users. The first route has a distance of 9.8 Km which is indicated by a red line. While the second route is 12.8 km long with a black line. Therefore, based on the all or nothing method, it is estimated that as many as 638 trips will go through route 1.

Stocastic Assignment Method

Stocastic assignment serves to enrich the route selection that has been carried out in the all or nothing method and to determine the probability of route use based on utility functions. The utility function used in the stocatis assignment method for route selection in Malang City is to use distances in kilometers. The following is a calculation of the percentage of possible choices for each route in each pair of zones, both internal-internal zone pairs and internal-external zones. Not only in the form of percentages but also the number of trips for each route will be generated based on that percentage.

Zone 1 (Lowokwaru District) (Zone 2 (Blimbing District)

In Zone 1 to Zone 2 and vice versa, motorists are faced with several route options. Route 1 has a distance of 5.5 Km while route 2 has a distance of 5.4 Km. In addition, there are also 3 options of existing public transportation routes. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows.

$$P(Rute\ 1) = \frac{e^{-5,4}}{e^{-5,5} + e^{-5,4}} = 52\%$$

$$P(Rute\ 2) = \frac{e^{-5,5}}{e^{-5,5} + e^{-5,4}} = 48\%$$

The probability of route selection by private vehicle users traveling from Zone 1 ((Zone 2 obtained results, namely route 1 which is the shortest route at 52% or around 5,020 trips and route 2 at 48% or around 4,543 trips. The percentage of route selection between route 1 and route 2 which only has a gap or a small difference is because the distance between the two routes has a difference that is not much different, which is only 0.1 meters. It is necessary to pay attention to these two alternative routes, because based on survey data (Itenas, 2020) route 1 of Jalan Soekarno Hatta and route 2 of Jalan Mayjen Panjaitan already have a very low level of LOS, namely LOS F. These two routes have a capacity that is not proportional to the volume of passing vehicles so that the speed and flow of vehicles are low and there are frequent traffic jams.

Zone 1 (Lowokwaru District) ((Zone 3 (Klojen District)

In Zone 1 to Zone 3 and vice versa, motorists are faced with several route options. Route 1 has a distance of 5.68 Km while route 2 has a distance of 6.3 Km. In addition, there are also 2 options of existing public transportation routes. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows

$$P(Rute\ 1) = \frac{e^{-5,68}}{e^{-5,68} + e^{-6,3}} = 65\%$$

$$P(Rute\ 2) = \frac{e^{-6,3}}{e^{-5,68} + e^{-6,3}} = 35\%$$

The probability of route selection by private vehicle users traveling from Zone 1 ((Zone 3 obtained results, namely route 1 which is the shortest route by 65% or around 4,814 trips and route 2 by 35% or around 2,589 trips.

Zone 2 (Blimbing District) ((Zone 5 (Kendungkandang District)

In Zone 2 to Zone 5 and vice versa, motorists are faced with several route choices. Route 1 has a distance of 8.39 Km while route 2 has a distance of 9.5 Km. In addition, there is also 1 choice of existing public transportation routes. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows

$$P(Rute\ 1) = \frac{e^{-8,39}}{e^{-8,39} + e^{-9,5}} = 75\%$$

$$P(Rute\ 2) = \frac{e^{-9,5}}{e^{-8,39} + e^{-9,5}} = 25\%$$

The probability of route selection by private vehicle users traveling from Zone 2 ((Zone 5 obtained results, namely route 1 which is the shortest route of 75% or around 1,246 trips and route 2 of 25% or around 411 trips.

Zone 2 (Blimbing District) ((Former Zone 1 (Karangploso District, Malang Regency)

In Zone 2 to Ex Zone 1 and vice versa, motorists are faced with several route options. Route 1 has a distance of 15.35 km while route 2 has a distance of 16.3 Km. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows.

$$P(Rute\ 1) = \frac{e^{-15,35}}{e^{-15,35} + e^{-16,3}} = 72\%$$

$$P(Rute\ 2) = \frac{e^{-16,3}}{e^{-15,35} + e^{-16,3}} = 28\%$$

The probability of route selection by private vehicle users traveling from Zone 2 ((Zone Ex. 1 obtained results, namely route 1 which is the shortest route at 72% or around 163 trips and route 2 at 28% or around 163 trips.

Zone 4 (Sukun District) ((Zone 5 (Kedungkandnag District)

In Zone 4 to Zone 5 and vice versa, motorists are faced with several route options. Route 1 has a distance of 9.5 Km while route 2 has a distance of 7.5 Km. In addition, there are also 2 options of existing public transportation routes. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows

$$P(Rute\ 1) = \frac{e^{-9,5}}{e^{-9,5} + e^{-7,5}} = 12\%$$

$$P(Rute\ 2) = \frac{e^{-9,5}}{e^{-9,5} + e^{-7,5}} = 88\%$$

The probability of route selection by private vehicle users traveling from Zone 4 ((Zone 5 obtained results, namely route 1 by 12% or around 525 trips and route 2 which is the shortest route by 88% or around 3,879 trips. The percentage of route selection between route 1 and route 2 which has a very long difference because the distance offered on both routes also has a very long difference, which is 2 Km.

Zone 4 (Sukun District) ((Ex Zone 3 (Dau District, Malang Regency)

In Zone 4 to Ex 3 and vice versa, motorists are faced with several route options. Route 1 has a distance of 10.9 Km while route 2 has a distance of 11.3 Km. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows

$$P(Rute\ 1) = \frac{e^{-10,9}}{e^{-10,9} + e^{-11,3}} = 60\%$$

$$P(Rute\ 2) = \frac{e^{-11,3}}{e^{-10,9} + e^{-11,3}} = 40\%$$

The reusability of route selection by private vehicle users traveling from Zone 4 ((Ex Zone 3 obtained results, namely route 1 which is the shortest route of 60% or around 617 trips and route 2 of 60% or around 414 trips.

Zone 5 (Keudngkandang District) ((Former Zone 2 (Pakisaji District, Malang Regency)

In Zone 5 to Ex 2 and vice versa, motorists are faced with several route options. Route 1 has a distance of 9.8 Km while route 2 has a distance of 12.8 Km. The calculation of the percentage probability of route selection for private vehicle users based on the utility function (distance in Km) for route 1 and route 2 can be described as follows.

$$P(Rute\ 1) = \frac{e^{-9,8}}{e^{-9,8} + e^{-12,8}} = 95\%$$

$$P(Rute\ 2) = \frac{e^{-12,8}}{e^{-9,8} + e^{-12,8}} = 5\%$$

The probability of route selection by private vehicle users traveling from Zone 5 ((Zone Ex 2 obtained results, namely route 1 which is the shortest route of 95% or about 617 trips and route 2 of 5% or around 414 trips. The percentage of route selection between route 1 and route 2 which has a very long difference because the distance offered on both routes also has a very long difference, which is 3 Km.

CONCLUSION

Based on the description and results of the analysis in the previous chapter, several conclusions can be drawn as follows:

Based on the results of the trip generation analysis, it can be seen that *Lowokwaru* District recorded the highest number of movements, namely 100,019 movements. This aligns with the main characteristics of the area as an educational and residential center. The high level of educational activities—particularly the movement of students—combined with mobility needs from residential areas makes *Lowokwaru* the zone with the highest movement in Malang City.

Based on the results of the trip distribution analysis, it can be seen that the distribution of movements between zones reflects the relationship between the main activities in each sub-district and the distance between zones. *Lowokwaru* District, with its primary function as an educational and residential center, showed the largest number of movements at 100,019. The dominance of higher education activities in this area has resulted in many inter-district trips, especially from *Sukun* District (11,333 movements) and *Klojen* District (7,712 movements).

Based on the results of the mode choice analysis, it is evident that the usage of private vehicles is very high, reaching 96%, while public transportation accounts for only 4%. The variables used to compare these two modes include cost (fuel and fares), distance, and travel time.

Based on the trip assignment analysis, alternative routes with shorter distances are generally more preferred by users. These selected routes are also the main corridors in Malang City, which naturally require careful consideration in terms of capacity and traffic volume. The availability and optimization of public transportation routes should serve as an alternative to current travel patterns, thereby reducing the high percentage of trips concentrated on these main routes.

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