A Research on the Evaluation of The Multimodal Transport Strategy For Ulaanbaatar using Micro-Traffic Simulation

Civil and Environmental Engineering Urban Transport Engineering and Planning Laboratory

Erdenebat Badamsuren

1.INTRODUCTION

Ulaanbaatar City, the capital of Mongolia, has a population of 1.6 million. Its rapid population growth in recent years has led to serious urban challenges, particularly traffic congestion, which significantly impacts residents' daily lives. According to a study by JICA (2022), during peak hours, the volume-to-capacity ratio on major roads exceeds 1.2, meaning that car speeds drop below 5 km/h. Currently, 64% of people commute by private car, and this figure rises to 80% in suburban areas. Public transport availability is especially poor in these suburban areas, where infrastructure is underdeveloped. In the suburban areas of Ulaanbaatar, limited public transportation and poor infrastructure force residents to rely on private cars, particularly in locations where large buses cannot operate. Additionally, heavy congestion in the city center reduces bus speeds, reducing the attractiveness of current public transit options. As a result, private car usage continues to rise, further worsening traffic congestion.

Therefore, there is a need for a flexible, last-mile feeder service in the suburbs and a high-capacity, fast transportation system in the city center. This study aims to identify the key factors influencing the adoption of multimodal integration specifically the coordination between feeder systems and mass transit systems and to evaluate its impact on the current level of congestion.

2.LITERATURE REVIEW

Literature review has shown that BRT, Park-and-Ride, and Minibus systems offer unique contributions to urban mobility shaped by distinct theoretical perspectives. BRT provides scalable, high-capacity transit at relatively low cost and fast implementation; Park-and-Ride offers a bridge between car ownership and transit; and Minibus networks deliver flexible, localized mobility where formal transit cannot reach. Empirical evidence from developing and developed cities illustrates the successes and limitations of each mode. Critically, case studies underscore that no isolated mode can achieve full sustainable mobility. Instead, integrated multimodal networks – where BRT corridors link with P&R facilities and feeder minibusses – deliver the greatest improvements in accessibility, efficiency, and equity (Carmo., 2020) (Dimitrios , Andreas, Aimilios , & Apostolos , 2024).

Key insights include: BRT systems tend to flourish where rail is too costly, especially in rapidly urbanizing cities (Campo, BUS RAPID TRANSIT: THEORY AND PRACTICE IN THE UNITED, 2010). However, without attention to fare policy and coverage, even the best BRT can fall short of pro-poor goals (Christo , Gail , Dario , & Andrés , 2017). Park-and-ride can bolster transit use but risks induced driving; planners must evaluate its net effect and situate it carefully within travel demand management frameworks (Dimitrios , Andreas, Aimilios , & Apostolos , 2024) (Aud , Jan , & Kjersti , 2019). Minibus systems are overwhelmingly vital in the Global South, and future planning should engage rather than suppress them (Jacqueline & Clemence , 2019) (Exchange, 2024). Across all modes, the evidence stresses the importance of integration: hubs, unified ticketing, and coordinated services are not optional extras but central to sustainable urban mobility (Dimitrios , Andreas, Aimilios , & Apostolos , 2024) (Carmo., 2020).

The implications of future transport planning are clear. Urban governments should adopt multimodal planning as a principle, ensuring BRT lines are planned in tandem with feeder networks and park-and-ride policies. Transit agencies must include paratransit stakeholders in planning, using tools like corridor mapping to incorporate informal services. Investment in technology (smart cards, real-time information) should span modes to reduce transfer barriers (Dimitrios , Andreas, Aimilios , & Apostolos , 2024). Policies should be equity-focused, such as requiring BRT projects to serve low-income neighborhoods or funding mini-transit shuttles in underserved areas. Lastly, as cities evolve (with ride-hailing and micromobility), the lessons of BRT, P&R, and minibuses underline that **flexibility and coordination** are essential. A sustainable mobility future will be multi-layered: one that leverages dedicated mass transit (BRT) for bulk flows, efficient modal interchanges (P&R hubs) for fringe connectivity, and nimble paratransit for fine-grained coverage.

3. OBJECTIVES&METHODOLOGY

Research Objective

There are three main objectives in this research.

i. To identify key factors influencing the adoption of new multimodal transit service using a Stated Preference (SP) survey
ii. To predict the demand for the integration of BRT, minibus, and P&R under different conditions and scenarios
iii. To assess the impact of the proposed transit system on traffic congestion and overall transport efficiency using micro traffic simulation.

Methodology

The research methodology is divided into two phases (Fig 1);

1. Phase One: To identify key factors influencing the adoption of a new multimodal transit service using a Stated Preference (SP) survey and analyze the results using a Multinomial Logit model. Estimate demand using the choice model.

2. Phase Two: Use micro-traffic simulation to evaluate the impact of the proposed transit system on traffic congestion, based on the demand estimation model.

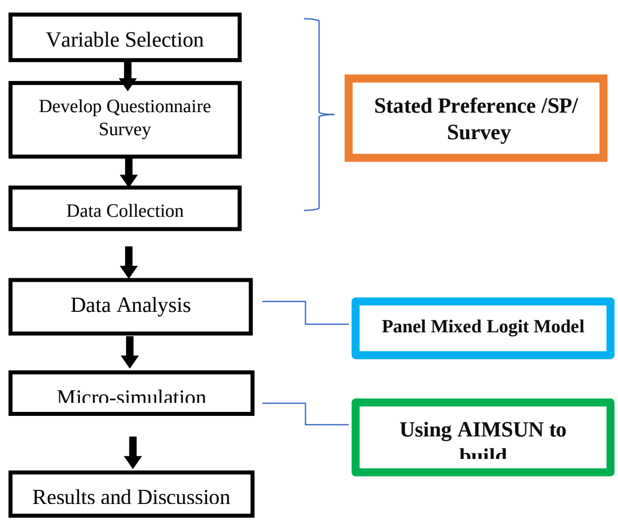

Fig.1 Research Methology

Stated preference survey and Multinomial Logit model analysis

In this research, scenario-based Stated Preference (SP) survey is used as a foundation. In order to implement a new policy or service, effective research is required. Stated preference (SP) surveys help quantify how people might behave in a new situation by showing them "experiments" (SANKO, 2000). In doing so, they indirectly reveal which parts are most important to them. SP surveys are especially useful in cases where no real-world data exists to make conclusions. These surveys can also reveal how changes to infrastructure or services will alter travel behavior (Colloquium, 2020).

The process of establishing variables and attribute levels is crucial for the successful implementation of the SP (Stated Preference) research methodology. In this study, attribute levels were determined by comparing the characteristics of newly introduced transport modes with those of the existing bus system the only public transport mode currently operating in Ulaanbaatar.

In this research, the selected variables are cost, waiting time, travel time, and Distance—each had three attribute levels, resulting in a total of 243 possible scenarios. Presenting all 243 scenarios to respondents would be impractical. To address this, an orthogonal array was employed to reduce the number of scenarios while maintaining statistical validity. In this study, the orthogonal array was generated using SPSS software based on algorithms derived from fractional factorial design principles. As a result, the original 243 scenarios were effectively reduced to 16 representative scenarios, making the survey more manageable for respondents while preserving analytical robustness.

Survey area

This research focused on the urban area of Ulaanbaatar and covered all six major districts: Songinokhairkhan, Bayanzurkh, Chingeltei, Sukhbaatar, Bayangol, and Khan-Uul.

District	Household number	Proportion	Number of private car
Bayanzurkh	104,881	25.4%	130,998
Songinokhairhan	90,231	21.9%	109,264
Chingeltei	38,413	9.3%	56,495
Sukhbaatar	39,302	9.5%	76,563
Bayangol	62,784	15.2%	92,931
Khan-Uul	56,874	13.8%	80658

Table 1. Ulaanbaatar City's District demographic

The six main districts mentioned above account for 95 percent of all households and 97 percent of all private car users in Ulaanbaatar. Additionally, 37 percent of the total population uses private cars, indicating a high level of dependence on private vehicles.

Survey Structure

This survey is structured into three main parts. The first part provides instructions for completing the survey, along with a brief introduction to the proposed new modes of transportation—Bus Rapid Transit (BRT), minibus, and Park-and-Ride—and explains how these modes can be integrated. The second part presents the stated preference scenarios and offers respondents the opportunity to rank their most preferred options and indicate their mode choice. The final part includes questions for evaluating the newly proposed minibus service, as well as a section for collecting respondents' personal information.

In the second part of the survey, a total of nine scenarios are presented, each offering five transport mode options. Instead of asking respondents to select only one preferred mode, a ranking system is employed in which participants indicate their first, second, and third choices. This ranking approach serves two key purposes:

1. To avoid inconsistencies in the responses of non-car users.
2. To mitigate the potential bias caused by the dominance of private car use.

Number	1	2	3	4	5
Mode	**Car**	**Car+BRT**	**Bus**	**Minibus+BRT**	**Taxi**
Waiting time	8 min	6 min	20 min	5 min	10 min
Travel time	32 min	26 min	50 min	40 min	32 min
Total time	**40 min**	**32 min**	**70 min**	**45 min**	**42 min**
Parking cost	5000₮	1000₮	-	-	-
Total cost	**6700₮**	**3000₮**	**1000₮**	**3000₮**	**13000₮**

Choice 1st:… Choice 2nd:... Choice 3rd:…

Table 2. Example of Scenario in SP survey

Data Collection and Survey Distribution

The data collection process was a crucial step in this research. Due to local constraints, the survey was conducted entirely online. Data collection took place across Ulaanbaatar from late February to mid-March. The survey was distributed to approximately 1,500 individuals through both official and personal email addresses, as well as via social media platforms such as Facebook, Twitter, and Instagram among the most widely used platforms by Ulaanbaatar residents. The survey was shared in the form of a QR code. A total of 338 participants took part in the survey. Among those who completed the survey fully and satisfactorily, 275 respondents were feasible to use.

Data Analysis Method

In this research, discrete choice models are used to analyze respondents' preferences and behaviors when selecting a particular transport mode. Two discrete choice models—the Conditional Logit Model (CLM) and the Panel Mixed Logit Model (PMLM)—are employed for comparison due to their ability to capture various dimensions of traveler behavior, including preference heterogeneity and repeated choices by individuals. However, the Panel Mixed Logit (PML) model serves as an extension of the traditional Conditional Logit Model. Unlike the CLM, the PML model assumes that responses provided by the same respondent across multiple scenarios are correlated. In this research, the PML model is employed to capture these correlations without incorporating random parameters. By using the PML model, repeated choice situations for each respondent are more accurately represented, leading to more reliable and realistic parameter estimates (Htun, 2025).

4.RESULTS AND DISCUSSION

Model Estimations from PML model are shown in Fig.2 below.

Minibus&BRT			Car&BRT		
Alternative Specific Independent Variables					
Variables	**β**	**P value**	**Variables**	**β**	**P value**
Wait time	-0.035	0.001	**Wait time**	-0.035	0.001
Travel cost	-0.00004	0.042	**Travel cost**	-0.00004	0.042
Private Car as Base Alternative					
Income	-2.52	0.000	**Age**	-0.02	0.000
Private Car	-1.01	0.000	**Private Car**	-0.71	0.000
Cons	1.74.	0.000	**Cons**	1.26	0.001
Bus as Base Alternative					
Gender	0.26	0.048	**Age**	-0.03	0.000
Education	0.18	0.027	**Education**	0.3	0.000
Private car	1.29	0.00	**Private car**	1.59	0.000
Cons	-0.99	0.006	**Income**	1.58	0.007
-	-	-	**Cons**	-1.47	0.001
Regular Taxi as Base Alternative					
Income	-8.6	0.000	**Income**	-6.5	0.000
Cons	6.05	0.000	**Private car**	0.76	0.005
-	-	-	**Cons**	5.57	0.000

Figure.2 PML Model Estimations for new multimodal system

The alternative-specific variables from the model indicate that wait time ($p < 0.05$) and travel cost ($p < 0.05$) are statistically significant factors influencing respondents' mode choice decisions. The negative coefficient for wait time suggests that as the wait time for a transport mode increases, the probability of that mode being chosen decreases. The odds ratio of 0.9605 implies that a one-unit increase in wait time decreases the odds of choosing that mode by 3.95%. The coefficient for travel cost is -0.00004, indicating that as the travel cost increases, the probability of choosing the mode decreases.

Results of Case-specific independent variables

To assess the potential shift to a proposed new system**,** a panel mixed logit model was estimated using three different base alternatives: private car, bus, and regular taxi.

(1) Private Car as Base Alternative:

For Minibus and BRT combination

When taking the private car as the base alternative, income ($p = 0.000$) and private car ownership ($p = 0.000$) significantly reduce the likelihood of switching to the Minibus-BRT combination. This indicates a strong preference for private car use among higher-income individuals and those who own a car.

For Car and BRT combination

When a private car is used as the base alternative, the model indicates that private car ownership ($p = 0.000$) and age ($p = 0.000$) significantly reduce the probability of switching to the Park-and-Ride BRT system. This demonstrates a strong resistance to modal shifts among older individuals and those who already own a car, underlining the challenge of attracting car users to P&R systems.

(2) Bus as Base Alternative:

For Minibus and BRT combination

Using the bus as the base alternative, the results show that gender ($p = 0.048$), education ($p = 0.027$), and private car ownership ($p = 0.000$) significantly increase the likelihood of choosing the Minibus-BRT mode over the existing bus service. This implies that individuals with higher education levels, males, and car owners are more likely to find the current bus service unsatisfactory and, therefore, prefer the new mode.

For Car and BRT combination

Using the existing bus service as the base alternative, the model reveals that private car ownership ($p = 0.000$), education ($p = 0.000$), and income ($p = 0.007$) significantly increase the likelihood of choosing the Park-and-Ride BRT option. These results imply that higher-income, more educated individuals and those who own a private car are more likely to prefer the P&R BRT system over the conventional bus, possibly due to dissatisfaction with current bus service quality or a desire for more comfortable and reliable commuting alternatives. Conversely, age has a significant negative effect ($p = 0.000$), suggesting older people are more inclined to remain with traditional bus services.

(3) Regular Taxi as Base Alternative:

For Minibus and BRT combination

When considering the regular taxi as the base alternative, income emerges as a highly significant factor ($p = 0.000$), indicating that higher-income individuals are significantly less likely to choose the taxi over other alternatives like BRT or minibus, possibly due to cost concerns.

For Car and BRT combination

In the case where the regular taxi is the base alternative, income is the most significant determinant ($p = 0.000$), with a strong negative effect indicating that individuals with higher income levels are significantly less likely to choose taxis over the Park-and-Ride BRT or private car modes—likely due to the high cost associated with taxi travel. Private car ownership ($p = 0.005$) is also a statistically significant and positive factor, showing that car owners are more likely to choose the P&R BRT system over taxis, possibly due to the ability to integrate car use with BRT for longer trips.

Goodness-of-Fit Metrics

The mixed logit model demonstrates excellent fit statistics. The log-likelihood of -3296.48 indicates a solid likelihood fit, and McFadden's pseudo-R^2 value of 0.92 suggests the model captures over 90% of the variability in individual choice behavior, which is unusually high and indicative of a very strong model.

Demand estimation

After estimating the model, utility function and probability functions can be formulated as follows.

$$Utility = \beta_{wait} \text{ x Wait time} + \beta_{cost} \text{ x Cost}$$

$$P_i = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

To simplify the analysis and facilitate interpretation, the collapse (mean) function in Stata was employed to compute the average predicted probabilities for each transportation mode.

Different cost and waiting time values can be input into the utility functions to conduct a sensitivity analysis, illustrating how changes in Level of Service (LOS) affect mode choice. Shown in Figure 3 and Figure 4.

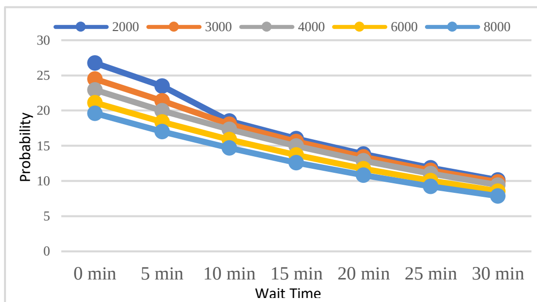

Figure 3. Probability of Choosing new Multimodal system at 8 km Distance

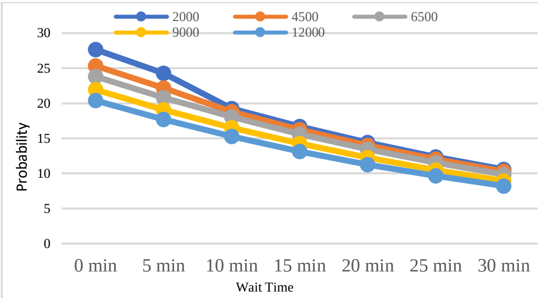

Fig 4. Probability of Choosing new Multimodal system at 14 km Distance

The results of the sensitivity analysis show that the probability of choosing both the Minibus+BRT and Park and Ride services increases for long-distance trips when the cost and waiting time are equal.

However, in calculating the probability of choosing the proposed multimodal service, only the five transport modes included in this study were considered. To estimate demand more accurately, it would be preferable to incorporate real-time data and account for a wider range of influencing factors. The modal split of passenger transport, based on a study conducted by the Ulaanbaatar Public Transport Department, is presented in Figure 9 [MMCG, Defining Origin Destination matrix of Ulaanbaatar city (15000 households), 2022].

To test the validity of the model, we incorporated the actual current costs, waiting times, and the newly introduced multimodal transport service. Model used real-time data in the model, including the current average waiting time and cost for buses and taxis. Model results are predicted the modal split closely matched existing conditions shown in Fig.5.

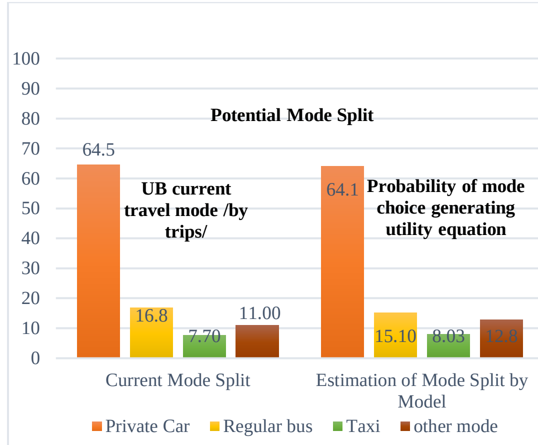

Fig 5. Potential Modal Split

The final objective of this research was to evaluate how the model's outcomes align with real-world behavior using microscopic traffic simulations. Specifically, we aimed to estimate how many private car users would shift to alternative modes of transport. By observing the variation in car usage under different price levels, waiting times, and travel distances, the model estimates that, on average, 29% of private car users would switch to the new mode

Micro-Traffic Simulation Estimation

In the final phase of this study, micro-traffic simulation results were used to assess the potential impact of the proposed interventions on current traffic conditions in Ulaanbaatar.

The simulation model was first developed by targeting the main arterial roads, the central business district (CBD), and key intersections known for heavy traffic congestion. To ensure realistic and representative conditions, the simulation incorporated a one-day Origin-Destination (OD) matrix derived from the 2022 study *"Determining the Origin-Destination of Ulaanbaatar City Traffic"* (MMCG, 2022). This study divided traffic flows into 224 Transport Analysis Zones

(TAZs), grouped according to the city's eight primary zones.

For modeling purposes, 75 of the 224 zones were directly input into the simulation, while the remaining 149 zones were aggregated into four larger zones—north, south, east, and west—to simplify the model while preserving traffic flow accuracy and repeatability. Shown in Figure 6.

Fig 6. Distribution of simulations in the TAZ

Modeling and Simulation of the BRT Line

The Bus Rapid Transit (BRT) system, considered a core element of the proposed multimodal transport framework, was modeled with 12 stops along the south-north corridor and 21 stops along the west-east corridor. Due to the scope of this study, route optimization for integrating a minibus feeder service was not included in the simulation.

To evaluate the system's impact, a simulation scenario was created in which vehicle usage in the OD matrix was reduced by 29%, representing the anticipated modal shift resulting from the introduction of a two-lane BRT system in four directions, along with additional multimodal services.

Results from micro traffic simulation

Traffic Density:

Fig 7 compares traffic density in the Ulaanbaatar network before (Figure 16 (a)) and after (Figure 16 (b)) BRT implementation. The overall density decreased by 23.2%, with car traffic density declining from 8.84 vehicles/km to 6.44 vehicles/km and bus traffic density decreasing from 0.06 vehicles/km to 0.05 vehicles/km.

(a)

(b)

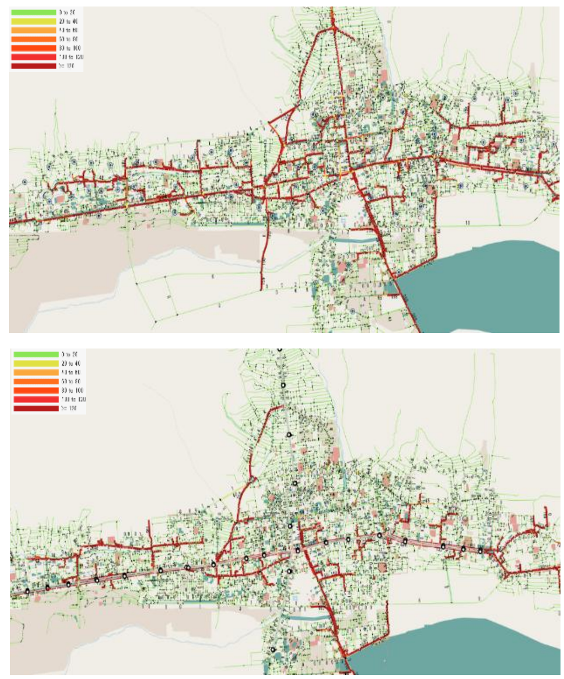

Fig 7. Comparison after simulation /traffic density/

Vehicle Speed:

Fig.8 illustrates the change in average vehicle speeds before (Figure 17 (a)) and after (Figure 17 (b)) BRT implementation. The average vehicle speed increased by 10.4%, rising from 27.31 km/h to 30.15 km/h. Average bus speed increased by 16.6%, from 17.06 km/h to 19.90 km/h.

(a)

(b)

Fig 8. Comparison after simulation /traffic speed/

Delay Time:

As shown in Figure 9, The simulation during the morning peak (8:00–10:00) revealed a reduction in total traffic delay time from 170.6 seconds to 128.0 seconds, a 24.9% decrease. Delay per kilometer also improved, falling from 170.5 seconds/km to 129.0 seconds/km, indicating a 24.4% reduction.

(a)´

(b)

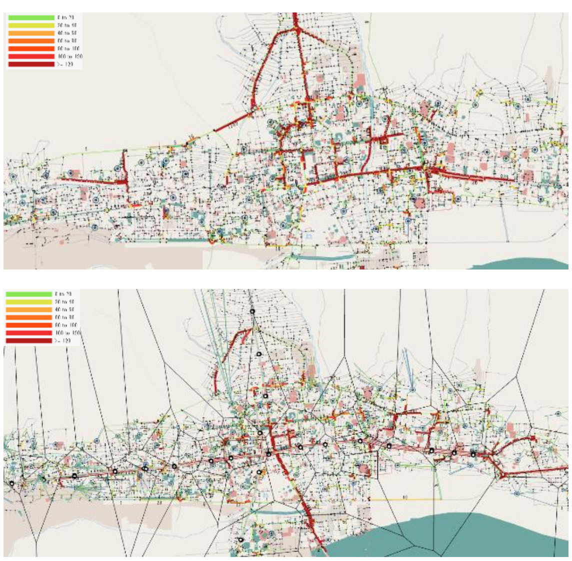

Fig 9. Comparison after simulation /traffic delay time/

5.CONCLUSION

The stated-preference survey (n=275) and subsequent Panel Mixed Logit analysis identified travel cost and waiting time as the dominant factors influencing commuters' mode choice. In particular, shorter waiting times and lower fares significantly increased the likelihood of selecting the new multimodal option (BRT with feeder minibuses and P&R), whereas private-car users were generally reluctant to shift modes. The model also found that higher-education and higher-income individuals were more inclined toward Park-and-Ride, and that middle- and lower-income, educated males showed a relative preference for minibuses over standard buses. Based on the estimated utility functions, the demand forecast suggests that approximately 29% of current private-car trips could be diverted to the new multimodal system under the proposed service conditions.

These projected mode shifts were then tested in an AIMSUN micro-simulation of Ulaanbaatar's network (with a 33-stop bidirectional BRT line and a 29% reduction in cars). Compared to the base case, the integrated multimodal scenario yielded substantial network-wide improvements: total travel time fell by ~14.6%, average delay per kilometer decreased by ~24.9%, and vehicle density dropped by ~27.2%, while mean traffic speed rose by ~10.4%. In sum, the results demonstrate that implementing the combined BRT, feeder-minibus, and P&R strategy can significantly ease congestion and improve traffic flow in Ulaanbaatar's network, confirming its effectiveness under the modeled conditions.

6.LIMITATIONS & FUTURE WORK

Several methodological and data limitations may affect these results. The mode-choice model relies solely on stated-preference survey data, so hypothetical choices may not fully reflect real-world behavior. The survey included only travel-time and cost attributes, omitting factors such as comfort, safety, and weather that can influence actual mode choice. Notably, active and informal modes (bicycling, walking, scooters, carpooling, etc.) were excluded, which could lead to an overestimation of demand for the proposed system. The microsimulation was also simplified: only the planned BRT line was modeled (feeders and park-and-ride facilities were not included due to pending route/terminal design), and pedestrians or dynamic events (inclement weather, roadworks, festivals) were not represented. Finally, the analysis assumed a relatively optimistic 29% modal shift and full policy enforcement, which may overstate benefits; actual mode changes could be more modest.

To strengthen these findings, future research should expand the survey design and modeling scope. The stated-preference experiment could incorporate additional attributes (trip urgency, comfort, safety, weather) and include active and informal modes (cycling, walking, scooters, carpooling) to capture broader travel behavior. Microsimulation studies should integrate the full multimodal network, for example by optimizing feeder-minibus routes and locating park-and-ride facilities using spatial analysis. It would also be valuable to test a range of scenarios (e.g. lower assumed mode shifts, partial policy uptake, or worst-case conditions) to assess the robustness of congestion-reduction benefits. Such extensions would improve the realism and applicability of the model results, providing a more comprehensive evaluation of Ulaanbaatar's multimodal strategy.

7.REFERENCES

1. Aud , T., Jan , U. H., & Kjersti , V. Ø. (2019). Developing a tool for assessing park-and-ride facilities in a sustainable mobility perspective. Urban, Planning and Transport Researc, 23.

2. Campo, C. (2010). *BUS RAPID TRANSIT: THEORY AND PRACTICE IN THE UNITED.* Georgia: Carlos Campo.

3.Carmo., L. P. (2020). *Multimodal Transport Hub /good practice quidelines/.* paris: AFD.

4.Christo , V., Gail , J., Dario , H., & Andrés , F. P. (2017). The equity impacts of bus rapid transit: A review of the evidence and implications for sustainable transport. *International Journal of Sustainable Transportation*, 34.

5.Colloquium, S. S. (2020, may 12). *Stated Preference Surveys for Transportation.*

6.Dimitrios , M. P., Andreas, S., Aimilios , M., & Apostolos , M. (2024). Advancing Sustainable Urban Mobility: Insights from Best Practices and Case Studies. *Science direct*, 18.

Exchange, U. S. (2024, August 15). *Rea Vaya - Bus Rapid Transit System*. l

7.Htun, K. K. (2025). *Identifying the key factors and predicting demand to implement shared taxi services using Stated Preference Survey* . Nagaoka city : Khant Kyaw Htun.

8.Jacqueline , M., & Clemence , C. (2019). Mapping minibuses in Maputo and Nairobi: engaging paratransit in transportation planning in African cities. *Transport Reviews*, 19.

9.MMCG. (2022). *Defining Origin Destination matrix of Ulaanbaatar city (15000 households).* Ulaanbaatar city: MMCG Co.Ltd.

10.SANKO, N. (2000). *Guidelines for Stated Preference Experiment Design.* Paris: Nobuhiro SANKO. f