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Original Article

미얀마 만달레이시의 단순화된 교통망을 이용한 전통적인 4단계 교통 모델에 관한 연구

Exercising The Traditional Four-Step Transportation Model Using Simplified Transport Network of Mandalay City in Myanmar

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ABSTRACT

Purpose: The purpose of this study is to explain the pivotal role of the travel forecasting process in urban transportation planning. This study emphasizes the use of travel forecasting models to anticipate future traffic. **Method:** This study examines the methodology used in urban travel demand modeling within transportation planning, specifically focusing on the Urban Transportation Modeling System (UTMS). UTMS is designed to predict various aspects of urban transportation, including quantities, temporal patterns, origin-destination pairs, modal preferences, and optimal routes in metropolitan areas. By analyzing UTMS and its operational framework, this research aims to enhance an understanding of contemporary urban travel demand modeling practices and their implications for transportation planning and urban mobility management. **Result:** The result of this study provides a nuanced understanding of travel dynamics, emphasizing the influence of variables such as average income, household size, and vehicle ownership on travel patterns. Furthermore, the attraction model highlights specific areas of significance, elucidating the role of retail locations, non-retail areas, and other locales in shaping the observed dynamics of transportation. **Conclusion:** The study methodically addressed urban travel dynamics in a four-ward area, employing a comprehensive modeling approach involving trip generation, attraction, distribution, modal split, and assignment. The findings, such as the prevalence of motorbikes as the primary mode of transportation and the impact of adjusted traffic patterns on reduced travel times, offer valuable insights for urban planners and policymakers in optimizing transportation networks. These insights can inform strategic decisions to enhance efficiency and sustainability in urban mobility planning.

Keywords: Traffic Survey, Urban Transportation Planning, Travel Forecasting Models, Urban Transportation Modeling System (UTMS), Mode Choice

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Introduction

Rapid urbanization, population growth, and increased national productivity globally have exacerbated land transportation challenges in numerous cities, adversely impacting environmental, social, and economic conditions. The efficiency of a city's transportation system is pivotal to its economic and social well-being, shaping urban structure, influencing economic progress, and directly impacting residents' quality of life. Urban transportation planning, facilitated through the four-step transportation modeling system (UTMS), is instrumental in addressing these challenges by estimating transportation demand, evaluating the movement of people and goods, and optimizing transportation infrastructure and services within metropolitan areas.

The four-step transportation modeling process, a widely adopted approach in urban transportation planning, involves successive stages: trip generation, trip distribution, modal split, and trip assignment. These steps collectively assess the generation and distribution of trips, mode choices, and route assignments, respectively. Origin-destination surveys, particularly utilizing home interview methods, are integral for gathering data on the movement of persons and vehicles within an urban area.

This study seeks to provide comprehensive insights into public transportation challenges in Asian developing nations, with a specific emphasis on major area in Myanmar. Positioned as a significant trade and transportation hub between China and India, Myanmar faces unique difficulties due to its diverse topography, which includes mountain ranges, hills, and valleys, contributing to infrastructural limitations. The exploration of public transportation issues in Myanmar, exemplified by the examination of Mandalay, aims to enhance our understanding of the complexities inherent in developing effective transportation solutions in the region.

Study Area Profile

The 18 wards(the smallest electoral unit) of Mahar Aung Myay Township of Mandalay City Corporation area have been selected as the study area for this paper (Fig. 1). Then these 18 wards are divided into 5 zones known as TAZ (Traffic Analysis Zone).

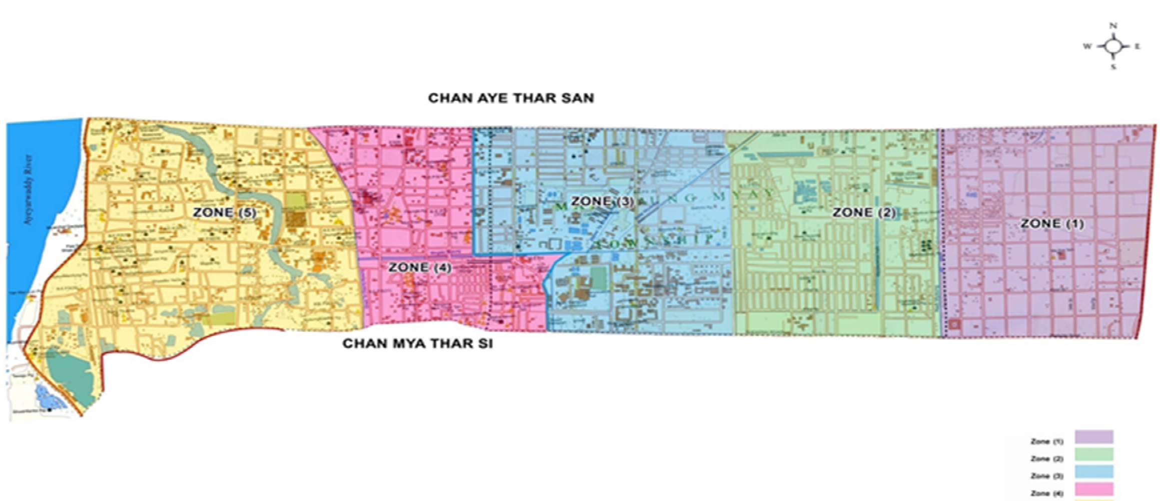

Fig. 1 Network for Mahar Aung Myay Township

Methodology of the Research

The traditional four step transportation modeling system has been taken to achieve the objectives. This is a macro-level working procedure. The following four steps to performed in the next stage:

Trip generation

Trip generation is the first stage in the traditional four-step transportation planning method,which is extensively used for projecting travel demand.It forecasts the number of trips that originating in or destined for a particular traffic analysis zone.

Trip generation employs trip rates that are averages for a wide portion of that study area. Trip production are defined as the return end of a home-based trip or the starting point of a non-home based excursion.Some of the factors considered as predictor for trip production include family income, vehicle ownership, and the number of worker per home. For example, a household with four people and two vehicles may be assumed to produce 3.00 work trips per day. Trips per household are then expanded to trips per zone. Trip attractions are typically based on the level of employment in a zone. For example a zone could be assumed to attract 1.32 home based work trips for every person employed in that zone. Trip generation is used to calculate person trips.

This stage determines trip production and trip attraction after ten years (2023) (based on 2013). To begin, present trip production and attraction characteristics are estimated using 10-year growth rates (Table 1). These growth rates are based on a country-by-country aspect. Regression equation for production model is based on household characteristics of the study area. In this study, household characteristics used in production model are average income, average household size and average worker as shown in Table 2. Calculation of the attraction model is based on the zonal floor areas such as retail

Table 1. Growth rates of different variables after 10 years

Variable	Growth Rate
Population	0.88%
Income Level	14.07%
Vehicle rate	20%
Employment	53.5%

Table 2. Zonal information of Mahar Aung Myay Township of Mandalay

Zone	Average household size	Average income(dollar)	Average worker
Zone-1	4.5526	446.7836	2.3947
Zone-2	5.2703	310.3604	2.6486
Zone-3	5.3133	307.6305	2.3253
Zone-4	5.4138	308.1738	2.6092
Zone-5	4.9322	307.6271	2.1280

areas, non-retail areas and other areas of the study area. They are obtained from Mandalay City Development Committee (MCDC) and shown in Table 3.

Table 3. Retail, non-retail and other areas in Mahar Aung Myay Township

Zone	Retail area	Non retail area	other area
1	0.0000	5.2720	0.3099
2	0.9918	12.3247	12.3761
3	0.6335	3.1187	219.8143
4	6.1701	13.2409	6.3286
5	8.4270	13.9693	2.8229

Regression model is useless in null hypothesis (H0). Under the null hypothesis, the ratio of the means of the two respective sums of squares is denoted F. The null hypothesis is rejected if F > Fp, (n-p-1) for the level of significance. The mathematical expression is

$$F = \frac{V_R}{V_E} \quad (1)$$

where; VR = the mean of the sum of square due to regression

VE = the mean of the sum of square residual

VR and VE can be calculated by the following equations.

$$V_R = SS_R / \text{degree}\, of\, freedom \quad (2)$$

Trip distribution

Trip generation is the first stage in the traditional four-step transportation planning method, which is extensively used for projecting travel demand. It forecasts the number of trips that originating in or destined for a particular traffic analysis zone.

Travel times are in the form of a matrix; each cell represents the time it takes to travel from one zone to another zone. They are shown in Table 4 and Table 5.

The travel time and cost for each mode are basic parameters of modal split model. Household characteristics, travel time and cost of the traveler are used independent variables to get the typical utility equation for each mode. In this study, household income is used as household characteristics.Mean speed is obtained from speed study and number of vehicle per hour and length are obtained from ground count, shown in Table 6.

Table 4. Zone to zone travel time

Zone	1	2	3	4	5
1	9	12.5	15	25	30
2	13.3	8	17.5	22.5	25
3	15	18.3	9	16.7	18.3
4	25	26.3	14.2	9	14
5	30	25	16	16.3	9

Table 5. Observed trip distribution matrix, Qij0

Zone	1	2	3	4	5
1	247	93	31	155	93
2	296	355	711	770	239
3	64	128	767	192	192
4	69	277	277	832	346
5	93	281	1029	1216	2338
Total	769	1134	2815	3165	3208

Table 6. Number of vehicle per hour, Vf, mean speed and length for each link

Link	Number of Vehicle per Hour(PCU)	Mean Speed(Km/h)	Length(km)
1-20	1061	26.8703	0.12198
20-21	4200	21.6732	1.1735
21-22	3294	21.6732	1.1735
22-23	3185	21.6732	1.5088
23-24	5198	22.0433	0.701
24-25	1148	19.1471	1.0363
25-26	1778	19.1471	0.4268
26-5	834	19.1471	0.2591
25-4	3074	19.1471	0.3352
24-27	5198	22.0433	0.5029
27-28	1994	15.2372	1.0363
28-4	3180	19.1471	0.1677
4-5	699	24.5212	0.4115
21-2	2993	28.1575	0.3352
22-31	3451	11.9710	0.6706
31-3	1781	27.3530	0.4545
3-30	2059	31.3755	0.3125
30-37	2509	31.3755	0.2083
30-29	1477	24.5212	0.5208

Table 6. Continue

Link	Number of Vehicle per Hour(PCU)	Mean Speed(Km/h)	Length(km)
29-27	3658	22.0433	0.1042
29-32	3235	22.0433	0.1042
32-36	3235	22.0433	0.1042
32-33	1477	26.1463	0.2083
33-34	1477	26.1463	0.4167
33-35	2390	22.0433	0.1042
35-29	1398	24.5212	0.2083
34-28	3180	19.1471	0.2083
36-37	2542	15.2855	0.5208
37-38	2439	15.2855	1.1458
38-2	3436	28.1575	0.7292
1-39	1061	26.8703	0.9848
39-38	2685	15.2855	0.7292

Result

Modal split

Mode choice analysis is the third step in the conventional four-step transportation planning model. Trip distribution's zonal interchange analysis yields a set of origin destination tables which tells where the trips will be made; mode choice analysis allows the modeler to determine what mode of transport will be used.

In this study, utility function is used to calculate utility of each mode. Four modes are considered as car, motorbike, bicycle and bus. Three independent variables are considered in calculation of utility equation. They are income, travel time and travel cost. The dependent variables are considered by the number of utility of mode choosing of travelers.

Multinomial logit model

In light of its simplicity of estimate and grounding in utility theory, the multinomial logit (MNL) model is an extremely often used model to explain and forecast discrete decisions. The MNL model is a generalization of the binomial choice model to more than two possibilities. The multinomial logit model calculates the probability of choosing mode 'K' if disaggregate or the proportion of travelers in the aggregate case that will select a specific mode 'K' according to the relationship.

$$P(k) = \frac{e^{U_k}}{\sum_{x=1}^{n} e^{U_x}} \tag{3}$$

In this study, multinomial logit model is used to determine the probability of each mode by using Equation 3. Then, zone to zone O-D matrix by each mode is received by multiplying probability of each mode and zone to zone trip interchange volume obtained from distribution model. These results are shown in Table 7 to Table 10.

Table 7. Zone to zone O-D matrix by car

Zone	1	2	3	4	5
1	655	456	172	648	542
2	546	1201	2756	2223	957
3	218	806	5398	1009	1400
4	234	1720	1930	4164	2410
5	186	1073	4433	3371	8775

Table 8. Zone to zone O-D matrix by motorbike

Zone	1	2	3	4	5
1	1144	779	289	1013	808
2	1105	2486	5443	4191	1749
3	434	1597	11208	1977	2658
4	434	3252	3773	8640	4835
5	330	1967	8414	6768	18219

Table 9. Zone to zone O-D matrix by bicycles

Zone	1	2	3	4	5
1	546	378	142	532	443
2	498	1101	2506	2019	867
3	198	734	4958	925	1278
4	212	1565	1765	3823	2197
5	168	973	4047	3075	8059

Table 10. Zone to zone O-D matrix by bus

Zone	1	2	3	4	5
1	559	401	155	591	501
2	525	1123	2689	2197	958
3	215	788	5054	972	1370
4	234	1702	1856	3897	2279
5	189	1075	4339	3188	8215

According to the results of above tables, it is found that zone-5 has the maximum percentage of flow for each mode. Moreover, zone to zone trip distribution by motorbike is more than other modes. Therefore motorbike trips are the maximum among all zones.

Trip assignment

Trip assignment, traffic assignment or route choice concerns the selection of routes (alternative called paths) between origins and destinations in transportation networks. It is the fourth step in the conventional transportation planning model. Mode choice analysis tells which travelers will use which mode. To determine facility needs and costs and benefits, we need to know the number of travelers on each route and link of the network.

The task of the assignment process is to establish the loading, or user volume on each link of a transportation network. Therefore, the length of each link and the volume of traffic flows on that links are necessary for this assignment model. Also, the mean speed for specific route is needed. Free-flow speed (FFS) of each link is calculated by using Equation 4. The results of free-flow speed (FFS) for each link are shown in Table 11.

$$FFS = S_{FM} + 0.0125 \frac{v_f}{f_{HV}} \tag{4}$$

Table 11. Free flow speed

Link	Observed Flow Rate, vf(PCU)	Mean Speed, SFM (Km/h)	FFS(m/h)
1-20	1061	26.8703	26.6213
20-21	4200	21.6732	52.7866
21-22	3294	21.6732	44.3031
22-23	3185	21.6732	43.2824
23-24	5198	22.0433	62.3614
24-25	1148	19.1471	22.6399
25-26	1778	19.1471	28.5390
26-5	834	19.1471	19.6997
25-4	3074	19.1471	40.6743
24-27	5198	22.0433	62.3614
27-28	1994	15.2372	28.1335
28-4	3180	19.1471	41.6669
4-5	699	24.5212	21.7729
21-2	2993	28.1575	45.5113
22-31	3451	11.9710	39.7481
31-3	1781	27.3530	33.6629
3-30	2059	31.3755	38.7640
30-37	2509	31.3755	42.9777

Table 11. Continue

Link	Observed Flow Rate, vf(PCU)	Mean Speed, SFM (Km/h)	FFS(m/h)
30-29	1477	24.5212	29.0578
29-27	3658	22.0433	47.9413
29-32	3235	22.0433	43.9804
32-36	3235	22.0433	48.7185
32-33	1477	26.1463	30.0670
33-34	1477	26.1463	30.0670
33-35	2390	22.0433	36.0681
35-29	1398	24.5212	28.3181
34-28	3180	19.1471	41.6669
36-37	2542	15.2855	33.2948
37-38	2439	15.2855	32.3303
38-2	3436	28.1575	49.6595
1-39	1061	26.8703	26.6213
39-38	2685	15.2855	34.6338

In the calculation of free-flow speed (FFS), mean speed (SFM) is obtained from speed study and vf is the number of vehicle per hour. It is also known as the observed flow rate for the period and obtained from ground count. The flow of traffic with unrestricted mixing of different vehicle classes on the roadways forms the mixed traffic flow. Therefore, the observed flow rate, vf is converted to the homogeneous traffic consisting of passenger cars only by using Passenger Car Unit (PCU). The heavy vehicle adjustment factor of 0.829 is calculated by using Equation 5.

$$f_{HV} = \frac{41}{[1+P_T(E_T-1)+P_R(E_R-1)]} \tag{5}$$

Capacity is expressed as the maximum number of vehicles in a lane that can pass a given point in unit time, usually an hour, i.e., vehicle per hour. Capacity for each link can be calculated by using Equation 6. Effective green time to cycle length ratio, q is considered as 0.5. The results of capacity for each link are shown in Table 12.

$$C = 1900 \times L \times q \tag{6}$$

Travel time, T can be calculated by using Equation 7.The results of capacity and travel flow of each link are used in the calculation of travel time. Free- flow travel time is the ratio of length to free-flow speed. The results of travel time are shown in Table 13.

$$T = T_0[1+0.1519v/C_p)^4] \tag{7}$$

Table 12. Assigned travel flow and travel time

Link	Capacity(veh/h)	Link	Capacity(veh/h)
1-20	288	3-30	1188
20-21	4156	30-37	792
21-22	4156	30-29	990
22-23	5344	29-27	396
23-24	1655	29-32	396
24-25	2447	32-36	396
25-26	1008	32-33	396
26-5	306	33-34	1583
25-4	792	33-35	396
24-27	1188	35-29	396
27-28	2447	34-28	792
28-4	396	36-37	1979
4-5	486	37-38	4354
21-2	792	38-2	2771
22-31	792	1-39	3742
31-3	1727	39-38	2771

Table 13. Travel time $T(x_0)$

Link	Length(mile)	Free-Flow Travel Time, T_0(min)	Travel Time, $T(x_0)$ (min)
1-20	0.0758	0.1707	0.29
20-21	0.7292	0.8288	0.83
21-22	0.7292	0.9875	0.99
22-23	0.9375	1.2996	1.30
23-24	0.4356	0.4191	0.42
24-25	0.6439	1.7066	1.77
25-26	0.2652	0.5575	0.80
26-5	**0.1610**	**0.4903**	**25.92**
25-4	0.2083	0.3073	0.31
24-27	0.3125	0.3007	0.35
27-28	0.6439	1.3733	1.37
28-4	0.1042	0.1500	0.55
4_5	0.2557	0.7046	2.31
21-2	0.2083	0.2747	0.28
22-31	0.4167	0.6290	0.63
31-3	0.4545	0.8102	0.81
3-30	0.3125	0.483 7	1.03
30-37	0.2083	0.2908	0.30
30-29	0.5208	1.0754	1.71
29-27	**0.1042**	**0.1304**	**6.26**
29-32	0.1042	0.1421	0.15

According to the Table 13, link (26-5) and link (29-27) are congested by comparing free-flow travel time. Travel flows of link (26-5) and link (29-27) are shifted by using Frank-Wolf algorithm. The travel flows on link (26-5) are shifted to link (25-26), (25-4) and (4-5). The travel flows on link (29-27) are shifted to link (29-32), (32-33), (33-34), (34-28) and (27-28).Table 14 shows the results of travel flow and travel time after shifting the links.

Table 14. Assigned travel flow and travel time

Link	Assigned Travel Flow, v(PCU)	Travel Time, $T(x_0)$ (min)
1-20	426	0.29
20-21	426	0.83
21-22	586	0.99
22-23	526	1.30
23-24	526	0.42
24-25	1758	1.77
25-26	1670	**1.19**
26-5	967	**7.85**
25-4	791	**0.35**
24-27	1232	0.35
27-28	698	**1.37**
28-4	813	0.55
4-5	1311	**6.31**
21-2	474	0.28
22-31	61	0.63
31-3	61	0.81
3-30	1964	1.03
30-37	570	0.30
30-29	1394	1.71
29-27	**1401**	**3.20**
29-32	565	**0.23**
32-36	651	0.30
32-33	616	**0.44**
33-34	644	**0.83**
33-35	29	0.17
35-29	29	0.44
34-28	644	**0.32**
36-37	651	0.94
37-38	1222	2.13
38-2	1193	0.89
1-39	29	2.22
39-38	29	1.26

After shifting the links, travel time on link (26-5) is reduced from 25.92 minutes to 7.85 minutes and link (29-27) is reduced to 6.26 minutes to 3.2 minutes. Zone to zone travel times are obtained by combining link travel times. They are shown in Table 15.

Table 15. Zone to zone travel time

Zone to Zone	Links	Travel Time $T(x_1)$ (min)
1 to 2	(1-20) → (20-21) → (21-2)	1.4
1 to 3	(1-20) → (20-21) → (21-22) → (22-31) → (31-3)	3.55
1 to 4	(1-20) → (20-21) → (21-22) → (22-23)→ (23-24) → (24-25) → (25-4)	5.95
1 to 5	(1-20) → (20-21) → (21-22) → (22-23) → (23-24) →(24-25) → (25-26) →(26-5)	14.64
2 to 1	(21-2) → (20-21) → (1-20)	1.4
2 to 3	(38-2) → (37-38) → (30-37) → (3-30)	4.35
2 to 4	(38-2) → (37-38) → (36-37) → (32-36) → (32-33) → (33-34) → (34-28) → (28-4)	6.4
2 to 5	(21-2) → (21-22) → (22-23) → (23-24) → (24-25) → (25-26) → (26-5)	13.8

In Table 13, interzonal travel time of zone-3 and zone-5 has 17.1 minutes which is the longest travel time among the proposed networks of the study area. Because of that path contains two congested links, 29-27 and 26-5 which have the travel time of 3.2 and 7.85 minutes respectively.

Conclusion

The study area is divided into four wards, with a sample size of 400 established for the home interview survey. The generation model considers average income, household size, and vehicle ownership as independent factors, while the number of trips is the dependent variable. Coefficients for the trip generating model are calculated using the Linest formula, and the model is validated using R2 and F-test. Zone-5 produces the highest number of trips at 86863.

In the attraction model, retail locations, non-retail areas, and other places are used as independent variables. The regression equation is employed to compute attraction trips for each zone, and the model is validated using R2 and F-test. Zone 3 records the highest attraction trips at 71325. The distribution model involves four iterations to estimate the friction factor, Fij. The modal split model, utilizing the multinomial logit model, considers four forms of transportation: automobile, cycle, bicycle, and bus. Results show that motorbikes are the most popular means of transportation in the five zones.

The assignment model establishes linkages and nodes for the research area, utilizing trip interchange matrix data for each connection. Survey ground counts and traffic volume counts are considered in the analysis and design of traffic signals. The assignment model factors in the use of car, motorcycle, and bicycle, converting person trips to car trips and then to peak hour and Passenger Car Unit journeys. Travel times for specific links are assessed, revealing crowded connections. After adjusting traffic patterns, travel times for certain links are significantly reduced. Interzonal travel times, calculated by adding link travel time, show the longest trip time in the planned networks is 17.1 minutes from zone-3 to zone-5 due to crowded links on that path.

References

[1] Ahmed, B. (2012). "The traditional four steps transportation modeling using simplified transport network: A case study of Dhaka City, Bangladesh." International Journal of Advance Science,Engineering,Technology & Research, Vol. 1, No. 1, Article #03.

[2] Aminzadeh, B., Levinson, D. (2020). Transportation Impacts of Automated Vehicles. In Autonomous Vehicles and Future Mobility, Elsevier, Netherlands, pp. 101-119.

[3] Chakirov, A., Susilo, Y., Kottenhoff, K. (2020). "Intermodal connectivity and passenger travel behavior: A systematic review." Transport Reviews, Vol. 40, No. 2, pp. 235-262.

[4] Curtis, C. (2015). The Congestion Myth: Living with Traffic Jams. Reaktion Books, London, United Kingdom

[5] Hensher, D.A., Mulley, C., Ho, C. (2017). "What drives bus rapid transit system patronage? A comparative analysis of metropolitan cities with different levels of bus rapid transit system development." Transport Policy, Vol. 54, pp. 43-52.

[6] Mahmassani, H.S. (2018). "Smart mobility: Connecting everyone and everything." Transportation Research Part A: Policy and Practice, Vol. 115, pp. 4-5.

[7] Zhang, J., Gao, Z., Wang, D.Z.W., Chen, Z. (2017). "Traffic congestion management in smart cities: Challenges, methodologies, and opportunities." IEEE Communications Magazine, Vol. 55, No. 1, pp. 106-112.