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Variation in Travel Time of Public Transportation – Case Study of Micro Bus Routes in Kathmandu

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Abstract
Public transportation is a major mode of transportation for urban as well as rural area. Micro bus is one of the major vehicle used as a public transportation mode in Kathmandu. Congestion and delay are the major problem of public transportation in Kathmandu. Travel time is an important quantitative indicator representing traffic condition, it is also considered as the vital information for both road users and traffic operators. So this research is intended to determine travel time variation and its causes thus recommend appropriate measures for reduction of delay. Case study was carried out in micro bus in five routes of Kathmandu City i.e., Ratnapark - Lagankhel, Ratnapark - Narayan Gopal Chowk, Ratnapark- Kalanki, Ratnapark - Koteshwor and NAC - Chabahil routes of Kathmandu City. Data was collected using a global positioning system (GPS) device. Delay study was made to collect the information concerning the amount, causes, location, duration, nature and frequency of delay in the routes. "Cumulative Frequency Distribution Curve" was drawn to determine the 85th percentile travel time, delay time and moving speed during peak and off-peak hours. Causes of delay were classified according to their nature. Improvements measures were identified according to the nature and quantity of delay. The research shows that, there was variation in travel time of micro bus during peak and off-peak hours in study routes. Also it was found that the main variables that affect the travel time are: The total delay time due operational delay (stopping to pickup and discharge passengers at fixed stop and any intermediate section of stop, turning movement of vehicles, fare collection, fixed delay (intersection delay, stop sign) and moving speed. Travel time can be reduced to a practical and reasonable value by minimizing the delay. Channelization, signalization and implementation of public bus priority system at intersections are the major improvements options to minimize the intersection delay similarly, efficient fare collection system in public vehicle, traffic inspection and placement of bus stops in proper location in most bus stopping section of the routes are the improvement measures for the operational delay and stop delay.

Keywords
Travel time – Congestion – GPS

1. Introduction

Travel time is an important quantitative indicator representing traffic condition. It is also considered as the vital information for both road users and traffic operators. Travel time management is an important study in traffic control and highway improvements. The researchers have observed the importance of travel time and delay and since travel time studies are widely used to document congestion and to quantify the actual impact of highway improvements, they have foreseen important applications of the study. Determining the amount of time required to travel from one point to another on a given route requires travel time study. Various information may also be collected on the locations, duration and causes of delays in conducting such study[1]. Travel time and delay are two of the principal measures of roadway system performance used by traffic engineers, planners and analysts. Since vehicle speed is directly related to travel time and delay, it is also an appropriate measure of performance to evaluate traffic systems[2]. There are different types of delay which can be occurred during travel time and delay study i.e., fixed delay, congestion delay, operational delay and stop delay[3]. The travel

pattern is highly radial with most trips starting or ending in the central business district (CBD) of Kathmandu. The share of low occupancy vehicles such as minibuses, microbuses and tempos operating within Kathmandu Valley accounts for 94% of total public transport vehicles, while share of large buses is only 6% [4]. One of important feature of urban public transport route network is that large number of routes terminates at various points in the central core city area such as Old Bus Park, Ratnapark, and NAC. The top trip origin area was found to be Koteshwor with 6. 54% of passenger originating from the area, followed by Kalanki with 5. 57%. The City core area account for the topmost position with 32. 2% passengers destined for the area. The topmost transit was found to be City core area with 29. 73% passenger passing through this transit which is followed by Lagankhel for second most used transit with 22. 97% passenger [5]. The major objective of the study is to determine variation of travel time of public transport during peak and off peak hours and its causes thus to recommend the improvement measures to minimize the delay.

2. Data Collection

In the study, route information was secondary data for the study. Travel time data and delay data were the primary data of the study. Primary data has been presented below

2.1 Study Area

Public transport routes of Kathmandu City were taken for the travel time and delay analysis. All the selected routes originate from the Ratnapark area and destined at Lagankhel, Koteshwor, Kalanki, Narayan Gopal Chowk and Chabahil. The study routes cover major routes which connects Kathmandu, Lalitpur. The list of selected routes presented below. R1-Ratnapark (Purano Buspark) - Lagankhel, R2 - Ratnapark (Purano Buspark) - Narayan Gopal Chowk, R3- Ratnapark (Purano Buspark) - Kalanki, R4- Ratnapark (Purano Buspark) - Koteshwor, R5- Ratnapark (NAC) - Chabahil.

2.2 Survey Method

Travel time data was collected by using a hand held GPS (global positioning system) which measured the total travel time, average vehicle speed, average moving speed and location of points and total travel distance. Delay study was made to collect the information concerning the amount, cause, location, duration, nature and frequency of delay in the routes in field sheet. Data was collected during March - August, 2015 at different times of the day (i.e., peak and off-peak hours. Data was collected in AM peak Hours (9:00 am – 11:00 am) , PM peak hours (4:00 pm to 6:00 pm) and Off peak hours (12:00 pm to 2:00 pm. Public holiday and Saturday was not included in the study.

2.3 Sample Size

The sample size table for all types of travel time study has been prepared in [6] in specified permitted error in confidence level 95% and 99%. This manual concluded that average speed of the route is base for the sampling of the travel time and delay study. According to the average speed data of the route, sample run required for the travel time and delay study can be determine. In this study, sample run was determined in permitted error 3. 5 Kmph and confidence level 95% according to the nature of the study.

3. Methodology

Highway, Roads are designed neither for maximum nor minimum nor mean speed. In general 85th percentile speed is taken as design speed [7]. So it is better to analyze the travel time for 85th percentile vehicle. Cumulative frequency distribution curve of travel time and delay time was plotted. Travel time of 85th percentile of the vehicles was found out which gives the travel time at or below 85th percent of the vehicles are passing from the route. Similarly, 85th percentile delay time was determined by as like travel time by using delay data. Different types of delays were observed in the study routes. Delay were classified according to their nature and determined the average values of each class delay in peak and off peak hours so it made easier to analyzed the causes of variation in travel time by comparing their quantity in peak and off peak hours. 85th percentile moving speed was determined in the study from the determined value of 85th percentile travel time and 85th percentile delay time.

Running Speed (RS) : The vehicle's average speed while

the vehicle is in motion (does not include delay time) it can be calculated by the formula

RS = Distance RT (TT – D)

Delay locations were identified from the field data. In order to identify the severity of congestion level of intersection, average delay in intersection was determined and identify the congested intersection of the route. According to the delay nature and intersection congestion level, improvement measures were recommended.

4. Results and Discussion

Result of the study is related to the travel time, causes of delay and improvements measures in order to minimize the delay.

4.1 Analysis of Variation in Travel Time and Delay Time

85th percentile travel time and delay time of the study routes in outbound and inbound are presented in table 1 and 2. Unit of travel time and delay time is presented in Minute. It was found disaggregated result of travel time in outbound direction. Result shows that, travel time was higher in R1, R2, R4 route during off peak hours rather than peak hours though delay time was not higher in off peak hours in R1 and R2 route. Similarly travel time and delay time was found higher in PM peak hours rather than off peak hours in R3 and R5 route respectively . Result of inbound direction shows the travel time was higher in R1, R4 and R5 route during off peak hours rather than peak hours but delay was not higher in off peak hours. Similarly, PM peak hours travel time was higher in R2 route and AM peak hours travel time was higher in R3 route but at the same time delay was not higher in PM peak hours in R2 route. Delay and travel time were not in same order in the route it can be concluded that indirect causes of delay was speed of the vehicles which was caused longer travel time like other delay but no directly quantify like other delay.

4.2 Analysis of Causes of Delay

In the study, delay was found in different location along the routes. Result of the average delay in percentage value in study routes in outbound and inbound direction has been presented in table 3 and 4 respectively. The

Table 1: 85th Percentile Travel Time in Outbound and Inbound Direction

Route	AM Peak	PM Peak	Off Peak
OR1	24. 01	26. 55	29. 11
OR2	25. 50	29. 28	30. 45
OR3	18. 50	29. 10	24. 37
OR4	21.10	21.26	24. 37
OR5	23. 30	28. 50	23. 33
IR1	31.88	32. 83	36. 81
IR2	18. 43	19. 93	19. 15
IR3	31.65	23. 09	27. 45
IR4	27. 15	26. 68	27. 75
IR5	25. 86	23. 11	26. 33

Table 2: 85th Percentile Delay Time in Outbound and Inbound Direction

Route	AM Peak	PM Peak	Off Peak
OR1	5. 14	8. 8	7. 88
OR2	10. 6	12. 28	7. 27
OR3	3. 2	9. 2	5. 81
OR4	7. 57	10. 29	10. 54
OR5	7. 53	7. 7	5. 14
IR1	8. 20	12. 42	10. 26
IR2	3. 60	5. 04	6. 29
IR3	6. 94	6. 91	6. 25
IR4	8. 55	8. 50	7. 76
IR5	9. 45	6. 57	7. 33

total delay time is due to following types of delay:

- Fixed delay (Delay1) : delay at intersection and at Traffic stop sign and stop delay
- Operational delay (Delay2) : stopping vehicle to pickup and discharge passengers at fixed stop and any intermediate section of stop, turning movement of vehicles, fare collection after discharging passenger, pedestrian road crossing, Passenger's enforcement to stop vehicles at their convenient point
- stop Delay (Delay3) : driver's tendency to wait for passenger in stop points and road section

Result shows the Delay1, Delay2 and Delay3 as a major cause of delay along all the study routes in Outbound direction. In R1 route, proportion of Delay1, Delay2, Delay3 was same but due to variation in moving speed and delay time variation was observed in travel time. In

Table 3: Causes of Delay in Outbound Direction

Route	Peak Hour	Delay1	Delay2	Delay3
OR1	AM	57. 00	28. 79	14. 18
OR1	PM	61.68	21.90	16. 42
OR1	Off	61.98	21.56	16. 47
OR2	AM	9. 49	50. 23	40. 28
OR2	PM	10. 94	27. 03	62. 03
OR2	Off	40. 73	17. 24	42. 03
OR3	AM	48. 28	27. 59	24. 14
OR3	PM	53. 42	38. 82	7. 76
OR3	Off	24. 62	35. 69	39. 69
OR4	AM	83. 73	13. 27	3. 01
OR4	PM	64. 55	24. 51	10. 93
OR4	Off	33. 36	59. 53	7. 11
OR5	AM	44. 29	33. 78	21.93
OR5	PM	73. 92	25. 34	0. 75
OR5	Off	26. 92	52. 81	20. 27

R2 route, Delay2 and Delay 1 were the major causes of variation in travel time. Along R3 route, congestion at intersection, Delay2 and variation in moving speed was the dominant causes for the variation in travel time. In R4 and R5 route, congestion (i.e., Delay1) was the dominant causes of delay in peak hours though travel time was higher in off peak hours due to Delay2. Result

Table 4: Causes of Delay in Inbound Direction

Route	Peak Hour	Delay1	Delay2	Delay3
IR1	AM	51.79	17. 69	30. 51
IR1	PM	27. 62	37. 02	35. 36
IR1	Off	42. 76	36. 18	21.05
IR2	AM	33. 66	29. 99	36. 35
IR2	PM	30. 81	30. 27	38. 92
IR2	Off	25. 82	30. 05	44. 13
IR3	AM	41.20	56. 71	2. 08
IR3	PM	45. 37	54. 63	0. 00
IR3	Off	37. 13	49. 84	13. 03
IR4	AM	42. 95	51.97	5. 07
IR4	PM	40. 97	33. 12	25. 91
IR4	Off	33. 23	46. 86	19. 91
IR5	AM	75. 96	20. 73	3. 31
IR5	PM	50. 18	33. 92	15. 89
IR5	Off	60. 73	22. 48	16. 79

of inbound direction shows that, along the R1 route, in spite of lower congestion (i.e., delay1) , due to delay2 varaiton was occured in travel time during PM and Off peak hours. In R2 routes, there was same congestion level in both peak and off peak hours but due to delay3 travel time was extended in off peak hours. In R3 route, delay1 and delay2 both were the dominant causes of delay in both the peak and off peak hours but delay amount was caused variation in travel time. Congestion was in same level along R4 route during both peak and off peak hours so that travel time was same. In R5 route, delay1 was major causes of higher travel time in AM and Off peak hour in comparison to PM peak hours.

4.3 Variation in Moving Speed

Result of 85th percentile moving speed is presented in Table 5. Disaggregated result was found in 85th percentile moving speed of the study route. Result shows that, moving speed was lower in R2, R3 and R4 routes during off peak hours and during PM peak hours in R3 and R5 route in outbound direction. In inbound direction, it was found lower moving speed in R1 R4 and R5 during Off peak hours. So, besides other delay moving speed was also the one of the major cause of delay in study routes.

Table 5: 85th Percentile Moving Speed in Outbound and Inbound Direction

Route	AM Peak	PM Peak	Off Peak
OR1	16. 76	17. 92	14. 75
OR2	21.44	20. 46	15. 01
OR3	18. 82	14. 47	15. 51
OR4	21.29	26. 21	20. 81
OR5	19. 01	14. 42	16. 48
IR1	15. 96	18. 52	14. 23
IR2	21.44	21.34	24. 71
IR3	12. 86	18. 71	15. 00
IR4	17. 10	17. 05	15. 90
IR5	18. 64	18. 49	16. 45

4.4 Identification of Delay Location

In order to recommend the improvement measures to reduce the delay time, delay location was identified in the study routes and delay in intersection was analyzed by determination of average value of delay. Improvements measures were recommended according to the nature and quantity of delay.

4.4.1 Delay location and causes of delay in R1 Route

In R1 route, there is four intersection viz. Singadarbar, Maitighar, Thapathali and Jawalakhel intersection.

Result of average delay is presented in table 6. Result

Table 6: Average Delay in Intersections in Outbound and Inbound Direction

Intersection	AM Peak	PM Peak	Off Peak
O-Singadarbar	22. 28	67. 55	44. 86
O-Maitighar	37. 18	3. 17	17. 76
O-Thapathali	40. 54	29. 29	37. 38
I-Singadarbar	0	0	0
I-Maitighar	7. 34	4. 00	10. 39
I-Thapathali	92. 66	96. 00	89. 61

shows the Thapathali and Singadarbar intersection as a congested intersection of the route in comparison to Maitighar intersection in outbound and inbound direction. Singadarbar intersection is not lies in the inbound direction due to using new diversion road from Maitighar to Bhadrakali section instead of Singadarbar section. In Thapathali bus stop and Pulchowk bus stop delay was observed due to stop delay similarly, in Pulchowk-Jawalakhel-Manbhawan-Kumaripati section, frequency of stopping vehicles was higher to pickup and discharge passenger along the road section where passenger were also contributing for delay by enforcing the driver to stop vehicles as per their convenience point. Result of average delay at intersections in percentage value of the route is presented in table 6.

4.4.2 Delay location and causes of delay in R2 Route

There are two intersections along the route viz. Lainchaur and Lazimpat intersection. Delay occurred at Lainchaur intersection during peak and off peak hours in outbound and inbound direction. Frequency of picking and discharging passenger was found higher along Jamal, Lazimpat, Pani Pokhari and Maharajgunj section during both peak and off peak hours. Teaching Hospital section was found as a delay location due to operational delay. Vehicle turning movement was found in Maharajgunj and Panipokhari section.

4.4.3 Delay location and causes of delay in R3 Route

Three intersections along the route viz. Tripureshwor, Teku and Kalimati. Delay occurred in all intersections of the route in both peak and off- peak hours. Frequency of stop delay was occurred in Kalimati Bus stop, Sahidgate Bus Stop similarly, delay was occurred in Soltimode section due to picking and discharging passenger. Average delay presented in percentage at intersections. Result of average delay presented in Table 7. Result of average delay analysis shows the congested intersection of the route is Tripureshwor and Teku for both outbound and inbound direction.

Table 7: Average Delay in Intersections in Outbound and Inbound Direction

Intersection	AM Peak	PM Peak	Off Peak
O-Tripureshwor	2. 94	70. 75	39. 22
O-Teku	72. 06	28. 3	43. 14
O-Kalimati	25	0. 94	17. 65
I-Tripureshwor	6. 25	19. 15	23. 48
I-Teku	50. 86	71.28	56. 82
I-Kalimati	42. 88	9. 57	19. 7

4.4.4 Delay location and causes of delay in R4 Route

There are four intersection along the route viz. Singadarbar, Maitighar, Baneshwor and Tinkune. Delay occurred at Singadarbar, Maitighar, Baneshwor and Tinkune intersection during peak and off- peak hours. Result of average delay at intersections is presented in percentage value in table 8. Result shows the most congested intersection of the route was Baneshwor. Moderate congestion was found at Singadarbar intersection. Babarmahal, Minbhawan and Tinkune bus stop exist in the route, where delay was found due to driver's tendency to wait for passenger. Bhrikutimandap, Babarmahal, Bijulibazar, Minbhawan, Shantinagar were the delay section due to picking and discharging passenger along the road section. Vehicle turning movement was found in Shantinagar and Maitighar section.

Table 8: Average Delay in Intersections in Outbound and Inbound Direction

Intersection	AM Peak	PM Peak	Off Peak
O-Singadarbar	24. 72	36. 54	39. 11
O-Maitighar	2. 6	4. 33	10. 75
O-Baneshwor	68. 65	51.92	45. 43
O-Tinkune	4. 03	7. 21	4. 7
I-Singadarbar	1.85	0	2. 51
I-Maitighar	28. 68	29. 75	34. 54
I-Baneshwor	49. 91	63. 64	58. 22
I-Tinkune	19. 57	6. 61	4. 74

4.4.5 Delay location and causes of delay in R5 Route

Kamaladi, Kamalpokhari, Gyaneshwor, Gaushala, Jaya Bageshwori and Mitrapark intersection are in outbound direction of the route and Dillibazar and Putalisadak is additional intersection in inbound direction by changing route due to one way provision from Kamalpokari to Kamaladi inbound direction. Result of average delay in percentage value is presented in Table 9. Average delay

Table 9: Average Delay in Intersections in Outbound Direction

Intersection	AM Peak	PM Peak	Off Peak
O-Kamaladi	46. 19	43. 32	18. 34
O-Kamalpokhari	28. 94	35. 52	62. 81
O-Jayabageshwori	11.08	1.9	0
O-Mitrapark	11.6	7. 73	13. 82

was found comparatively higher in Kamalpokhari and Kamaladi intersection in outbound direction. Picking and discharging passenger was found along Gyaneshwor, Ratopul, Gaushala and Mitrapark section in outbound and inbound direction. Stop delay was found at Jamal bus in outbound direction. In inbound direction, turning movement of vehicle from main road to subway caused the delay along Dillibazar and Putalisadak section of the route. In inbound direction, it was found the congestion

Table 10: Average Delay in Intersections in Inbound Direction

Intersection	AM Peak	PM Peak	Off Peak
I-Gaushala	29.35	46.69	85.84
I-Jayabageshwori	16.1	11.26	0
I-Mitraprak	28.44	9.77	0
I-Putalisadak	4. 51	16. 06	9.83
I-Dillibazar	16. 33	0	0

in Gaushala intersection during peak and off peak hours.

4.5 Possible Improvement Measures

Improvements is needed to reduce the stop delay, operational delay and stop delay of the route according to the severity. Following are the possible improvements measures for the all study routes in order to reduce the delay.

- Signalization of intersection, Public vehicle priority system, Diversion of the private vehicles introducing the bypass road are the possible option to reduce the delay in congested intersections of all study routes.
- Efficient fare collection system can be implemented in public vehicles, hence reduce the delay during the passenger discharging time. During the study it was found the extra delay due to fare collection from passenger, generally passenger pay the fare after detrain from the vehicle.
- In R3 Route, there are three unchannelized intersection in very small distance. First, it is necessary to channelized to reduce the delay due to hapazoid turning movements of the vehicles.
- In R5 route, frequency of stopping vehicles to pickup and discharge passenger was high in Kamaladi, Gyaneshwor, Ratopul and Gaushala section. So to reduce this delay bus stop has to introduce in proper location.
- In R1 Route, frequency of stopping vehicles from Kopundole to Pulchowk and Pulchowk to Jawalakhel section was higher. During the study, It is found only one bus stop from Kopundole to Lagankhel in outbound direction of the route. Bus stop in proper location in that section may reduce the delay due to picking and discharging passenger in the road section.
- To control the delay by stopping vehicles along non allowable section of the route, strong traffic inspection has to manage by the Metropolitan Traffic Police department.

5. Conclusion and Recommendation

This research work was conducted for analysis of variation of travel time of public transport in Kathmandu city. Study the variation in travel time of peak and off-peak hours in all the study routes. It was found the main variables that affect the travel time are: Fixed delay, operational delay, stop delay and moving speed. Variation in travel time was found not only due to delay but also due to moving speed of the vehicle in Ratnapark – Lagankhel, Ratnapark – Narayan Gopal Chowk and Ratnapark – Chabahil route in outbound and inbound direction. In cogestion (i.e., fixed delay) was dominant cause of delay in Ratnapark – Kalanki and Ratnapark

– Koteshwor route in outbound and inbound direction. efficient fare collection inside the vehicle, traffic inspection in more stopping section, placement of bus stop in proper location are major improvements measures to reduce the operational delay and stop delay. Improvement options for intersection delay are: signalization of intersection, public bus priority system in intersection and channelization of unchannelized intersection.

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