Performance Evaluation Of Transport Modes At A Ground Access Area And The Implication For Passenger Delays.

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ABSTRACT

This study evaluates the performance of the transport modes that link the two campuses of Bayero University Kano in North-West Nigeria. It also evaluates passenger departure delays at the access area where taxis, minibuses and bus modes regularly deliver transport services to passengers. Arriving passengers to the access area are free to choose from three modes based on the expected full price for each mode and wait for service if one is not immediately available. Data was collected on both the transport modes and the queuing behaviour of passengers at the access area. The mean service times for the three modes are 42.41s for taxi, 87.10s for the minibus and 105.02s for the bus mode. The trips each mode made per capita is 1.37 for the taxi mode, 11.91 for the minibus mode and 26.52 for the bus mode. The taxi mode was the most underutilized mode per trip. This is due to the taxi high taxi fare and attractiveness of it in terms of convenience. The probabilities of delay predicted by the numerical model agreed closely with the field values at the 95% significant level for the chi-squared test. The average delays associated with each mode are substantial. For the taxi mode the average delay was 12.514mins and 16.337mins for the minibus mode. The delay to bus passengers was 23.518mins. Cumulative delay for all passengers was highest for the bus mode and smallest for the minibus mode. The taxi and the minibus operators have not been engaged specifically to operate their vehicles on the university campuses and therefore operate their vehicles based on market demand. At their discretion, they shift to more lucrative routes in town if they perceive the university demand to be low. The delays suffered by the passengers and the in-vehicle journey times add up to substantial losses in lecture times crucial to the university system. More vehicle units are required for each mode to reduce the delays to acceptable levels.

Keywords-Delays, Ground access, Passengers, University campus**,**Transport modes.

I. INTRODUCTION

Passenger transportation services provide access to people who cannot afford the private automobile or for people who wish to connect for long distance travels. A range of transport modes are available for doing this and each is suited to specific tasks within the transportation system. Well-designed terminals physically connect to different modes of transport so that transfer between modes is efficient, safe and comfortable. Even though passengers make a choice between modes, they do not approach the individual modes but perceive the entire system as an entity and therefore will switch between modes when delays become excessive for their chosen modes or when service for the chosen modes is not immediately available.

Excessive switches by passengers between modes places unanticipated demands on other modes and reduces passenger confidence on their modes of choice as well as leading to level of service reduction on the switched modes. It is thus essential to continually evaluate the performance of the transport modes vis-a-vis passenger delays at an access area. Three transport modes: the taxi, minibus and the bus modes operate at the access area and passengers seeking to be transported to the second campus of the university located 7km away choose any of the three modes based on the expected full price. Passengers seeking transportation at the access area go to their preferred mode to demand for service. If service is not available, they wait until the next available service. However, if a bus arrives before the next preferred choice mode, they may switch to the bus. Thus queued would-be taxi and minibus passengers may switch to the bus mode if one arrives before the next taxi or minibus modes. This paper specifically evaluates the performance of transport modes operating at the Bayero University Kano ground transportation access area with a view to improving accessibility to the two campuses. Thus the paper seeks to evaluate the performance of the transport modes and the delays to passengers at the access area. The rest of the paper is organised as follows: section 2 covers the relevant reviews in the area. In section 3, we present the data collection procedure. Section 4 is devoted to the assessment of the transport modes while section 5 describes the analysis and queuing behaviour of passengers at the access area. Finally we present the conclusions in section 6.

2 LITERATURE REVIEW

Unlimited access to transportation is an important strategy in transportation demand management in universities. Travel indicators point to increasing reliance on the automobile for commuting to work and other non-work related trips (Kingham, Dickinson and Copsey, 2001; Orski, 2000). In university campuses, increasing use of the automobile leads to traffic mitigation and parking pressures and consequently congestion has increased in university campuses. The response to congestion has always been to expand roadways to increase capacity. However, cost and environmental concerns limit lane expansion and new highway constructions. Obviously, one way to alleviate the problems of deteriorating air quality, traffic congestion and parking in universities is to provide incentives for people to use public transport. The character of university campuses such as mix of populations, irregular schedules, and continual movement of people throughout the day require transport availability to service these movements. The uniqueness of each mode further dictates that a single mode of transport will not satisfy the variety of the transport needs for university campuses. A multimodal transport system for university campuses will enhance "Unlimited Access" to transportation for university communities.

Accessibility is an important criterion in the performance evaluation of transport services. Accessibility is the ease at which passengers are reached or being reached (Darek, 2011). In passenger transportation the focus is on the connections and often attention is drawn to the people and the places that are being serviced by the transport modes. Three measures of the value of accessibility are common; the connections approach measures the physical, monetary, travel time and other measurable characteristics of the journey. The behavioral approach uses the measurable characteristics of the journey in combination with the traveler responses to these characteristics. The normative method uses the measurable characteristics in combination with particular standards(Chapman and Weir, 2008). The normative approach is clearly a needs assessment and is not based on the elements of the transport system. Rather it identifies a location, group of people or social needs of an area and targets it for accessibility improvement.

The accessibility needs of the university community can be measured by observing the travel behaviour of the students and residents in the campuses. Thus we attempt to identify the travel needs of university campus community towards improving accessibility for them. An alternative way of measuring accessibility needs is through stated priorities and how these affect the implementation of initiatives to improve accessibility especially when public opinion reveal needs have not been identified or measured. Comparative accessibility measurement is used when attention is focused on the distribution of access opportunities or accessibility gaps by people, group and location Executive, (2003). Comparative need can be assessed using expressed, community or stated measures and in practice common messages from all three approaches define how to close accessibility gaps to tackle social exclusionCurrie, (2003). Stated and comparative accessibility assessments help to identify the practicality of delivery. Sometimes travel horizons are and comparative assessments reveal that a population is poorly served, even though the population considers their bus services to be good. In these cases the accessibility aims might be to raise expectations of people for greater travel to work and other activities as part of healthy working lives. Collectively these measures of accessibility need allow passenger transport planners to identify a level of network coverage, and standards of service consistent with the needs of users and potential users.

3 DATA COLLECTION

To collect data for this study two data collection programs were set up. One program was dedicated to the transport modes plying the two campuses of the university. Automatic traffic counters were set up to generate data on the travel modes and data collected include vehicle arrival times, departure times and the type of vehicle. The number of passengers on each transport mode was noted at the point of departure and this was aggregated to determine the total demand on daily basis. Similarly the number of passengers disembarking at the access area was observed and the aggregated value gave the total number of arriving passengers on daily basis. The second data collection exercise was designed to generate information on the arrival pattern of passengers. A strategic location overlooking the access area was used to estimate the arrival rate every five minutes. Unlike traffic flow, pedestrian movements are multi-directional in nature as such care was exercised in capturing passengers who expressed a demand for transportation by positioning themselves at the access points at any of the three modes. People who were passing through the access area were filtered out. Data was collected for a period of six weeks from September 2011 to November 2011 for from 7.00am to 7.00pm.

4 RESULTS

4.1 ARRIVAL TIMES CHARACTERISTICS OF THE TRANSPORT MODES.

Transport arrivals at the access area have widely differing characteristics. Throughout the observation period, the taxi mode was the first to arrive. There is an average of 45minutes between the first bus arrival and the first taxi arrival. The minibus mode is usually the last to arrive. It appears certain that the preference of the taxi mode over the other two modes is due to their prompt arrival to deliver service. Thus passengers with early schedules at the other campus chose the taxi mode. The first bus arrivals to the access area arrive singly with widely varying headways due mainly to the route characteristics. At peak periods, bus arrivals come in very small headways apparently to clear the bus queues at the access area. Platoon bus arrivals, however, encourages switching from other modes and increases the apprehensiveness of queued bus passengers. Passengers arriving latest into the queues often take advantage of platoon bus arrivals to board the buses ahead of already queued bus passengers. The minibus mode starts operation much later than the taxi and the bus modes during the day but captures a sizeable portion of the passengers once in operation. Their operation to the university campuses is purely discretionary as they switch to more lucrative routes in town when they deem appropriate. As a result they run the smallest number of trips to the university and observations reveal that headways less than 50seconds were uncommon.

4.2 SERVICE TIME CHARACTERISTICS OF THE TRANSPORT MODES.

Service time in the context of this paper is the difference between the arrival and departure times of the three modes of transport. The service time distribution for the three modes of transport obtained from aggregated data is shown in table 1. We distinguish between three service times. They are short, medium and long service times respectively.

Table 1: Service Time Distribution for the Three Modes

Service Time Duration (seconds)	Number of Observations		
	Taxi Mode	Minibus Mode	Bus Mode
< 10	76	-	-
10-20	160	7	2
20-30	141	24	13
30-40	140	19	8
40-50	83	22	23
50-60	77	25	21
60-70	43	23	20
70-80	21	10	23
80-90	25	7	30
90-100	10	7	31
100-110	7	8	16
>110	40	46	145

Short service times are those up to but less than 60seconds and indicates a breakdown of queue discipline at the access area for the bus mode. Medium service times are those greater than 60 seconds but less than or equal 110 seconds. For the bus mode an orderly queuing situation prevails. Service times greater than 110 seconds are considered long and represent situations in which the queue discipline is largely first-in-first-out (FIFO). In this situation passengers await their turn to board the buses in an orderly manner. In some cases, the long service times are due to disembarking passengers unable to do so during peak hours. Thus for the bus mode 20% short, 36% medium and 44% long service times were observed respectively.

The taxi mode offered the least service time compared to the two other modes. There were 82% short, 13% medium and 5% long term service times respectively for this mode. Service times in the first category represented an orderly queuing situation in which passenger arrival surges were absent such as at the end of a lecture session or similar discharges of large number of passengers to the access area. Quite clearly, the taxi mode offered more prompt service because it carried fewer passengers per trip and had the least loading and disembarking times of its passengers. Service times greater than 110 seconds represented situations in which fewer than the maximum number of passengers was available at the loading point.

For the minibus modes the service time categories are 49% short, 28% medium and 23% long. The performance of the minibus mode lies in-between the taxi and the bus modes. Short term service time delivery for the minibus mode was more than 145% higher than the bus mode and 40% less than the taxi mode. When a minibus arrival coincides with a bus, queued minibus passengers switch to the bus sometimes for no discernible reason. Passengers way back in the minibus queue switch to gain advantage in boarding the bus ahead of queued bus passengers. Table 2 summarizes the service time characteristics for the three modes of transport. Service at the access area is characterized by random arrivals indicating that the operations of the transport modes are not scheduled. In particular the taxi and minibus modes do not seem to be guided by any schedule.

4.3 TRIP DEMAND AT THE ACCESS AREA

The distribution of passenger arrival times to the access area is shown in figure 1. A clear indication from the results is that the passenger arrival patterns for the three modes of transport show similar trends. For all the modes, the arrival patterns at the access area indicated time-varying arrivals. The bus mode attracted the largest number of passengers. For much of the time single passenger arrivals occur but surges of arrivals are seen occasionally after lecture periods or the end of other major gatherings. The bus passenger

Table 2: Service Time Characteristics for the Three Modes

Date	Mode	Sample Size	Mean Service Time	Standard Deviation	Coefficient of Variation
Week 1	Taxi	165	48.15	43.18	0.90
	Minibus	50	80.90	54.60	0.67
	Bus	62	120.05	66.10	0.55
Week 2	Taxi	144	51.67	30.81	0.60
	Minibus	39	79.26	51.79	0.65
	Bus	53	111.00	52.67	0.47
Week 3	Taxi	138	47.40	48.16	1.02
	Minibus	34	107.26	78.80	0.73
	Bus	52	92.30	48.85	0.53
Week 4	Taxi	153	31.51	20.83	0.66
	Minibus	38	106.74	70.00	0.66
	Bus	58	96.00	35.97	0.37
Week 5	Taxi	134	32.63	22.16	0.68
	Minibus	32	56.97	43.49	0.76
	Bus	67	100.75	54.61	0.54
Week 6	Taxi	86	38.73	33.84	0.87
	Minibus	15	91.67	62.82	0.69
	Bus	40	110.58	59.09	0.53
Overall Aggregate Data.	Taxi	820	42.41	43.06	1.02
	Minibus	208	87.10	61.85	0.71
	Bus	332	105.02	54.07	0.51

arrivals are characterized by three peaks during weekdays and two peaks during Saturdays. The number of passengers carried by each mode and the number of each mode of transport arriving at the access area are shown in table 3. The table reveals that for the aggregated data, the bus mode carried an average of 27 passengers per trip, the minibus bus mode 12 per trip and the taxi mode 1 passenger per trip. Clearly, the taxi mode is the most underutilized mode. This is due to the charter services offered by the taxi mode and the value of time of taxi passengers. Switching of taxi passengers to the minibus and bus modes is also a contributing factor attributable to the random operations of the two modes.

4.4 TRIP TIMES FOR THE THREE MODES OF TRANSPORT.

One of the important parameters to evaluate in assessing the performance of a transport mode is itsregularity. Mode regularity describes the bus arrivals.It is affected by the headway distribution. Mode arrivals are also affected by in-vehicle travel time. Inthis section, we look at the

Table 3: Average Trip Demand at the Access Area.

Date	Mode	Morning Trip Time	Afternoon Trip Time	Evening Trip Time	Daily Average
Week 1	Taxi	13.55	13.12	12.29	12.99
	Minibus	18.27	19.02	20.14	19.14
	Bus	23.15	22.49	22.19	22.48
Week 2	Taxi	14.18	13.56	14.11	13.95
	Minibus	19.13	19.06	18.33	18.84
	Bus	21.28	22.16	24.06	22.37
Week 3	Taxi	12.44	13.33	13.38	13.05
	Minibus	19.12	19.24	18.44	18.93
	Bus	23.37	21.44	22.58	22.46
Week 4	Taxi	12.19	13.27	12.48	12.65
	Minibus	18.53	18.22	18.57	18.44
	Bus	21.01	21.14	21.18	21.11
Week 5	Taxi	12.51	12.15	13.09	12.58
	Minibus	19.07	18.59	18.41	18.69
	Bus	20.37	22.43	22.32	21.70
Week 6	Taxi	13.11	12.47	12.43	12.67
	Minibus	20.13	19.22	19.26	19.54
	Bus	20.18	23.11	23.52	22.27
Global Average	Taxi	12.99	12.98	12.96	12.98
	Minibus	19.04	18.89	18.85	18.93
	Bus	21.56	22.13	22.64	22.07

round trip time for each mode. This is shown in table 4. The trip times were observed for three periods during the day. The morning, afternoon and evening periods. These observations were made in order to see if traffic conditions on the main artery linking the twocampuses have significant effect on the performance and delay suffered by passengers at the access area.

Table 4: Mean Trip Times for the Transport Modes.

Date	Mode	Morning Trip Time	Afternoon Trip Time	Evening Trip Time	Daily Average
Week 1	Taxi	13.55	13.12	12.29	12.99
	Minibus	18.27	19.02	20.14	19.14
	Bus	23.15	22.49	22.19	22.48
Week 2	Taxi	14.18	13.56	14.11	13.95
	Minibus	19.13	19.06	18.33	18.84
	Bus	21.28	22.16	24.06	22.37
Week 3	Taxi	12.44	13.33	13.38	13.05
	Minibus	19.12	19.24	18.44	18.93
	Bus	23.37	21.44	22.58	22.46
Week 4	Taxi	12.19	13.27	12.48	12.65
	Minibus	18.53	18.22	18.57	18.44
	Bus	21.01	21.14	21.18	21.11
Week 5	Taxi	12.51	12.15	13.09	12.58
	Minibus	19.07	18.59	18.41	18.69
	Bus	20.37	22.43	22.32	21.70
Week 6	Taxi	13.11	12.47	12.43	12.67
	Minibus	20.13	19.22	19.26	19.54
	Bus	20.18	23.11	23.52	22.27
Global Average	Taxi	12.99	12.98	12.96	12.98
	Minibus	19.04	18.89	18.85	18.93
	Bus	21.56	22.13	22.64	22.07

The average trip times indicate no significant differences between travel times for the periods observed. The bus mode travelled for 22.07mins on the link between the two campuses. Similarly, the minibus mode and the taxi mode required 18.93 and 12.98 minutes respectively. Considering the activities inside a university campus, the trip times for each mode indicated above could result in significant lecture time losses if students were leaving one campus to catch a lecture at the other. A single trip to the old campus would require half the round trip time observed for each mode. The campuses are located 7km away from each other so that journey speed for each mode will be 64.82km/hr for the taxi mode, 44.38km/hr for the minibus mode and 38.06km/hr for the bus mode. The pavement condition for the link is very good with adequate shoulder and no interference from adjoining property. The minibus and the bus modes will need to improve their journey times to minimize delays to passengers at the access area.

5.0 PASSENGER ANALYSIS AND DELAYS.

The main characteristics of passengers at the access area are the queues arising from the lack of immediate service from the transport modes. Passengers arriving at the access area select the mode of their choice based on the expected full price and wait for service if one is not immediately available. Service by each transport mode is a bulk service queuing problem. The bulk service solution is therefore stated as in equations 1 to 3.

$$\frac{dP_o(t)}{d(t)} = -\lambda(t)P_o(t) + \mu_1(t)P_1(t) \quad 1$$

$$\frac{dP_n(t)}{d(t)} = \lambda_{n-1}(t)P_{n-1}(t) - \left[\lambda_n(t) + \mu_n(t)\right]P_n(t) + \mu_{n+1}(t)P_{n+1}(t) \quad 2$$

$$\frac{dP_k(t)}{d(t)} = \lambda_{k-1}(t)P_{k-1}(t) - \mu_k(t)P_k(t) \quad 3$$

Equation 1 arises when an empty system is considered for each mode. Equation 2 represents the system when there are n of the possible k passengers requiring service at the access area. Finally equation 3 represents the system when all k passengers are present. The passenger arrivals to the access area have already been shown to be time-varying arrivals as in figure 1. The queues arising from the three modes are analysed using the system of equations 1 to 3. The set of equations are ordinary differential equations with variable coefficients. The fourth order Runge-Kutta is used to solve the finite set of differential equations 1 to 3. The classical fourth order method requires four evaluations of the first derivative to obtain a Taylor series approximation through terms of order h^4.

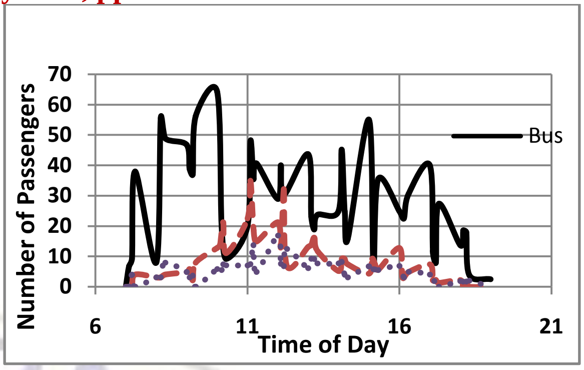

Figure 1: Time-Varying Passenger Arrivals for the three Modes.

The results of the simulations in terms of the probability of delay for each mode are shown in figures 2 to 4 together with the field observations.

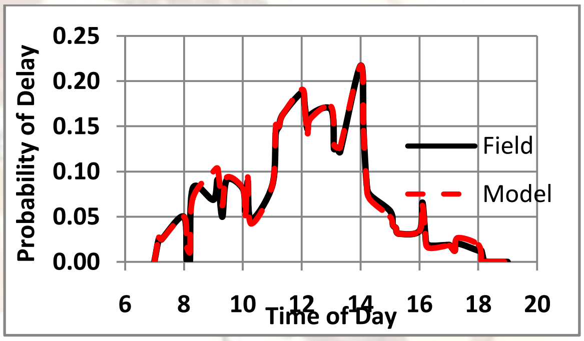

Figure 2: Probabilities of Delay for Taxi Mode

Each mode has unique maximum delay periods. For the taxi mode the delay is highest from 11.00am and peaks at 2.00pm. Subsequently, there is easing of the delay up to the end of the day's operations. For the minibus mode, the delay peaks at 11.00am and dropsdramatically at 12.00noon. Thereafter, there isprogressive decline up to the end of the day'soperations.

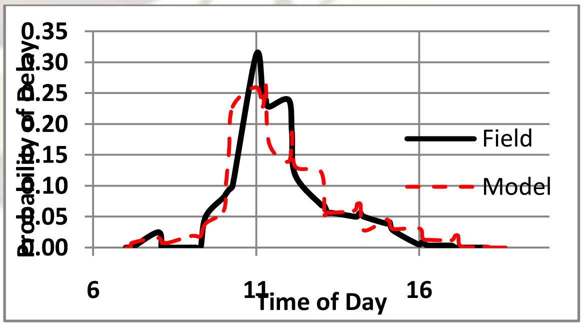

Figure 3: Probabilities of Delay for Minibus Mode

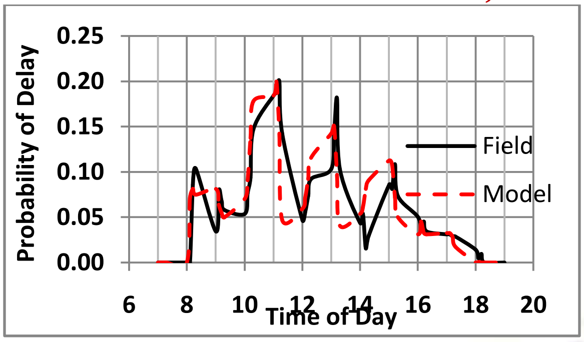

Figure 4: Probabilities of Delay for Bus Mode

The bus mode has three observed peaks at 11.00am, 1.00pm and at 3.00pm. The delay decreases thereafter to the close of the day's operations. In between the peak delays, there are times of minimal delay for the bus mode. These are at 12.00noon, and 2.15pm. These periods also coincide with the maximum delay periods for the taxi and the minibus modes respectively. Thus it is elucidating why the bus mode acts as a mechanical reneging for the taxi and minibus passengers.

The performance of the three modes in terms of their delay characteristics are presented in table 5.

The probability of delay is highest for the minibus mode for the field result and lowest from the predicted model. Quite unexpectedly, the model predicted a higher probability of delay for the taximode than was obtained from the field results. The average delay predicted by the models was consistent with the field results for all the transport modes. The highest delay of 23.518mins came from the bus mode. This was followed by the minibus mode with 16.337mins. The bus and the minibus modes in particular have a low journey speed from campus to campus and that explains the higher delays suffered by the passengers to these modes. In terms of overall cumulative delay the minibus mode recorded the lowest.

Parameter	**Mode**	**Field Value**	**Model Value**	**Differences (%)**
Probability of Delay	Taxi	0.069	0.112	+4.3
	Minibus	0.073	0.069	-0.4
	Bus	0.064	0.088	-2.4
Average Delay	Taxi	12.514	12.439	-7.5
	Minibus	16.337	16.401	+6.4
	Bus	23.518	23.462	-5.6
Cumulative Delay	Taxi	660.278	662.345	+6.7
	Minibus	443.371	444.432	-6.1
	Bus	1132.569	1231.628	+5.9

6.0 CONCLUSIONS.

We have examined the performance of the three transport modes and the delays that occur to passengers at the surface transport access area of Bayero University Kano, new campus. The study involves an empirical evaluation of the taxi, minibus and bus modes operations and a probabilistic modeling of the queuing behaviour of passengers at the access area. We therefore draw the following conclusions from the study.

The three transport modes serving the university have widely differing service times at the access area. Theservice times comprise of disembarking and boarding times for the three modes of transport. Short service times are characterized by poor queue discipline, switching of passengers between modes and reneging. Medium service time have good queue discipline with less switching between passengers for mode access. Long service times are those for which there were fewer passengers than the capacity of the each mode and vehicles have to wait to fill the short fall before departure. The mean service times for the three modes are 42.41s for taxi, 87.10s for the minibus and 105.02s for the bus mode.

The cumulative demand for transportation by passengers at the access area during the study period show a bus demand of 8804 passengers, 2477 passengers for the minibus mode and 1124 passengers for the taxi mode. The trips each mode made per capita is 1.37 for the taxi mode, 11.91 for the minibus mode and 26.52 for the bus mode. The taxi mode was the most underutilized mode per trip. This is due to the taxi high taxi fare, attractiveness of it in terms of convenience and the charter services often demanded by passengers.

To see if the in-vehicle journey time affected the performance of the transport modes, assessment of the round trip times indicated 12.98mins for the taxi mode, 18.93mins for the minibus mode and 22.07mins for the bus mode. Thus for a single trip the average journey speed for each mode was determined to be 64.82km/hr for the taxi mode, 44.38km/hr for the minibus mode and 38.06km/hr for the bus mode. Evidently, the minibus and the bus modes need to improve on the enroute speed to minimize delays to their passengers.

The analysis of passenger queues at the access area revealed a time-varying arrival process and a bulk service solution with mechanical reneging of queued up passengers for the taxi and minibus modes. The probabilities of delay predicted by the numerical model agreed closely with the field values at the 95% significant level for the chi-squared test. The resulting probabilities of delay for the three modes are 0.069 for the taxi mode, 0.073 for the minibus mode and 0.069 for the bus mode. Even though the probabilities of delay are small, the delays associated with each mode are substantial. For the taxi mode the average delay was 12.514mins and 16.337mins for the minibus mode. The delay to bus passengers was 23.518mins. Cumulative delay for all passengers was highest for the bus mode and smallest for the minibus mode.

These findings have a number of implications for the new campus access policy. There appears to be no commitment from the taxi and minibus operators on the transportation of passengers to and from the university campuses. As a result it is impossible to determine the number of vehicle units for both modes that are required to meet the transportation demand from the university on daily basis. These modes need to be encouraged to commit a specific number of vehicle units to serve the university campuses.

To improve mode access and minimize delays, the round trip times for the three modes need to be reduced. Careful observations reveal that the delays that occur are consistent with the round trip times for the three modes. The delays suffered by the passengers and the in-vehicle journey times add up to substantial losses in lecture times crucial to the university system. More vehicle units are required for each mode to reduce the delays to acceptable levels.

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