Investigating factors affecting Paratransit Travel Times: Perspectives from two Paratransit Routes in Kumasi, Ghana.

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Abstract. Paratransit trips on minibus vehicles have reportedly been unreliable, and users are unsatisfied with the quality of service they receive. Providing travel-related information, such as travel time information and introducing interventions along the roadway, may improve service quality and user experiences. To do this, there is a need to understand the nature of paratransit travel time and the factors affecting it. The study investigated factors affecting travel times of paratransit at the route and segment levels on two selected routes in Kumasi. A travel time survey onboard the vehicle was used to collect GPS, stop related and other information with the help of a mobile application. The Backward Stepwise Regression technique was used to determine the most significant factors which were drawn from literature and a careful study of paratransit operations. The results indicated that dwell times rather than stops contributed to paratransit travel times. Deviation from the route was found to increase travel time, contrary to the logic of using deviation to bypass apparent traffic congestion ahead. The study proffered interventions that can help improve travel time and the quality of service and made policy suggestions.

1 Introduction

All trips on the roadway, whether by private car or public transport vehicles, are associated with uncertainties due to daily fluctuations in demand and supply-related factors [1]. This is more so for buses that stop frequently along the route. However, in most sub-Saharan African cities and cities of the global south, the uncertainties in trip times take a different dimension due to the nature of the means of public transport services on the road. Public transport is largely informal [2], otherwise known as paratransit. Paratransit is a term conventionally used to describe a flexible mode of public passenger transportation that does not follow fixed schedules, typically by small- to medium-sized buses [3]. It includes motorized vehicles with carrying capacities ranging from 1 to 4 for motorized three-wheelers and up to 50 for large buses, with the popular minibus taxis having 10 to 15 passengers [4].

In the developing world, paratransit services are provided at a far larger scale for the general population, often by weakly regulated or illegal operators within the informal sector [3]. They go by different terminology in the cities where they operate. It is called *daladalas* in Tanzania, *danfos* in Nigeria, *matatus* in Kenya, *trotros* in Ghana, *car rapides* in Senegal, *gbakas* in Côte d'Ivoire, *chapas* in Mozambique, and 'minibus-taxis' in South Africa. Paratransit services have been reported to be of low quality and unreliable, and users are unsatisfied [5]–[7]. This is unconnected with paratransit services' setup, nature, and operation. Providing travel-related information has proven successful at easing anxiety associated with formal bus services and improving user experiences and has been recommended for paratransit. Another solution to the users' dissatisfaction could be introducing interventions along the roadway that can reduce variabilities in trip times.

Travel time information is an important travel-related information that users understand and, if provided, can help improve their experiences and quality of service. It is also important to transport planners and engineers to assess the impact of interventions that have been introduced. However, to provide travel time information or introduce interventions that can improve paratransit travel times and eventually improve service quality and user experiences, one must first understand the nature of paratransit travel times and determine the factors affecting it.

While much is reported in the literature for formal bus services on studies investigating factors affecting bus travel times and its reliability, not much is reported for paratransit operations. Some of the earliest studies were the work by [8], which modeled mean running time and its deviation using data collected for 10 and 12 weekdays on two transit routes in Cincinnati. [9] employed a modeling approach that shared the study segment into a dwelling and nonstop travel segments and separate simple regression models developed for each part to estimate the value of factors affecting total trip time for a single bus route in one direction in Portland, USA. Several studies have investigated the causes of service travel time variability at the route and segment levels of analysis, usually involving one or two routes and in one or both directions [10]–[12]. Link length, stops, land use, signalized intersections, time periods, and congestion levels were some of the most significant factors affecting travel time variation. A typical study that demonstrates how the route and segments of route level analysis of travel time reliability can be used to proffer solutions to improve the bus service was conducted by [13]. The analysis at the route level generated performance measures, while the

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regression models generated at the time point level of analysis were used in reliability evaluation. Timepoint distance, number of scheduled and actual stops, and passenger activities were some variables significantly affecting runtimes.

All these studies were in formal bus services, which run a markedly different operation from paratransit such that some of the factors investigated cannot apply. [14] reported the African perspective on factors affecting paratransit travel time. They investigated the correlation between paratransit stops and dwell times on travel time. Their study was limited and did not consider traffic and other related variables that may be affecting paratransit travel time. This paper, therefore, investigated the factors affecting paratransit travel times on two selected road corridors in Kumasi. Travel time in this context is the time spent when a trip begins after boarding to its arrival at a downstream point or the trip end. The investigation was carried out at route and segment levels.

This paper makes significant contributions to the paratransit literature and practice. It bridges the gap in the literature existing between studies that investigated factors affecting travel time in formal bus services and that of informal bus services. The findings of the investigations also yield crucial insights that can help planning authorities implement interventions that can impact the quality of services paratransit users receive. Furthermore, the efforts made in this paper are an essential step towards modeling the travel time of paratransit vehicles to predict travel times and provide information that can help users plan their trips and ease the anxiety and dissatisfaction associated with their journeys. The remaining part of the paper reports the approaches adopted in data collection and the analysis conducted. This is followed by the results and discussion on some of the findings. The paper ends with a concluding segment where some policy suggestions and recommendations for further studies were made.

2 Materials and Methods

The description of the study location, route, data collection design, data processing, and analysis are presented in this section.

2.1 Description of the study area and selected study routes.

The study was carried out in Kumasi. Kumasi is the second largest city in Ghana after the capital Accra. It is the capital of the Ashanti region. It is located at Latitude 6°6666′N and Longitude 1°6163′W. Kumasi is the heart of the Ashanti people, with a rich heritage of culture and tourism, and is a robust commercial hub. Public transport in the city is predominantly private sector supplied, comprising taxis, minibuses (*trotro*), buses, and three-wheelers in recent times (Poku-Boansi and Adarkwa, 2011). *Trotros* are second-hand minibuses with a carrying capacity of 10 to 20 passengers (Saddier *et al.*, 2016), including the driver and his assistant, popularly called a "mate." This particular mode is prevalent and was selected as the focus of the study.

Two *trotro* routes were selected for the investigation. Route 1 is the *trotro* route from Adum to Ejisu, while Route 2 runs from Tech Junction to Deduako. Details of the study route are presented in Table 1. The routes were selected for the volume of *trotro* trips occurring on them, uniformity in roadway geometry, and the presence of signalized and unsignalized intersections.

Table 1: Summary of roadway features for both study routes

Road Features	Route 1 (Adum to Ejisu)	Route 2 (Tech Junction to Deduako)
Roadway description, carriageway type, and lanes	Urban Arterial, double carriageway, double lane in both directions	Feeder/urban street road, single lane road.
Number of roundabouts	4	1
Number of signal intersections	5	1
Length of study section	16.25km	4.75km

2.2 Field data collection

A travel time survey was designed to collect data onboard *trotro* on the selected study routes. Trained enumerators used a developed mobile application called Trands to collect GPS traces, stop related and other information onboard the vehicles. Mobile applications have become popular in collecting data onboard paratransit vehicles. It has successfully collected sufficient data at a decent cost [15]–[17] and has therefore been adopted. On any given trip, the trip direction and the number of passengers were entered in the app. When a stop is made for boarding or alighting purposes, a stop indication is pressed on the app, and the number of passengers boarding and alighting is entered at the end of the stop when the vehicle resumes the trip again. A control delay stop indication was provided for stops at the approach to a traffic control signal. A field book was kept by each enumerator in which certain trip events were recorded along the trip.

Events like rain, deviation from the route, transfer (disembarking from *trotro* and boarding another to continue), police or law enforcement stops, the stops associated with the vehicle getting bad, stop to fuel the car, traffic incidents, passenger-requested stops for issues other than alighting that occured during a trip was noted. Traffic incident here is defined as any of three scenarios; accident resulting in blockage of portions of the section of the road the enumerator is traveling on, road construction or related works on or beside the road such that parts of the road are cordoned off, and broken-down vehicle blocking portions of the section of the route traversed by the enumerator. All stops not directly connected to passenger boarding, and alighting were categorized as Non-Trip Stops in the study. Data were collected for eight weeks on Route 1 in both directions, from morning (6: 00 am) to evening (6: 00 pm), and two weeks on Route 2.

2.3 Data Cleaning, Processing, and Analysis.

The collected data was downloaded from the backend of the app as CSV files and processed in Excel. The study route was partitioned into segments for analysis at the segment level based on significant intersections and roundabouts along the routes. Details of the various segments and their link lengths are shown in Table 2.

Table 2: Details of route segments on the selected study routes.

S/N	FROM	TO	LENGTH (km)
ROUTE 1 SEGMENTS			
1	Asafo Market	Amakom Junction	0.9
2	Amakom Junction	Anloga Junction	1.2
3	Anloga Junction	Susanso	1
4	Susanso	Bomso	1
5	Bomso	KNUST Police Station	1.5
6	KNUST Police Station	Boadi Roundabout	2
7	Boadi Roundabout	Oduom Roundabout	0.95
8	Oduom Roundabout	Fumesua Junction	2.6
9	Fumesua Junction	Jachie Junction	1.7
10	Jachie Junction	Zongo Junction	3.4
	TOTAL		**16.25**
ROUTE 2 SEGMENTS			
1	KNUST Maingate	Ayeduase Gate	1.6
2	Ayeduase Gate	Adwaase Station	0.55
3	Adwaase Station	Manchester Hostel	0.7
4	Manchester Hostel	Kotei Police Station	0.6
5	Kotei Police Station	Amina Junction Deduako	1.3
	TOTAL		**4.75**

The GPS coordinates of the points of segmentation were noted. The time a trip passed these points were identified and used to estimate trip times. Trips with excessively large travel times and trips with defective data were removed. Factors affecting bus travel times that are relevant to the paratransit setup were selected from the literature, while other factors which are unique to the paratransit operations were included for the analysis. Multiple linear regression was used in the investigation, specifically the backward stepwise techniques that take input variables and yield only the most significant variables was used. Equation 1 shows the regression expression.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \varepsilon \qquad (1)$$

Where,
Y is the dependent variable
β_0 is the y-intercept. The constant term
β_1, β_2, β_n are the slope coefficients of the independent variable
X_1, X_2, X_n are the independent variables
ε is the error term

Details of the independent variable used for the analysis at the route level are shown in Table 3.

Table 3: Details of selected independent variables for investigating factors affecting paratransit travel time at the route level

INDEPENDENT VARIABLE	DESCRIPTION
STOP	Total number of stops made on a trip
BOARD	Total number of passengers boarding on a trip
ALIGHT	Total number of passengers alighting on a trip
DWELL	Total amount of time in mins spent for boarding and alighting
SIGDELAY	Total amount of time in mins spent due to traffic signal indication
LF	Average load factor for a trip
DEV	Deviation from the route. 1 if a deviation occurred and 0 otherwise
RAIN	1 if there was rainfall during the trip, 0 otherwise
DIRECT	The direction of the trip. 1 if the trip is inbound to CBD and 0 if outbound
NONSTOP	Stops not connected to boarding, alighting, and signal delays. 1 if such a stop occurred on a trip and 0 otherwise
TRAFFIC	Traffic incidence. 1 if there was a traffic incidence, 0 otherwise
TRANS	Transfers. 1 if passengers were transferred to another vehicle, 0 otherwise
AMPEAK	1 if the trip began between 6 am – 10 am, 0 otherwise
OFFPEAK	1 if the trip began between 10 am – 3 pm, 0 otherwise
PMPEAK	1 if the trip began between 3 pm – 6 pm, 0 otherwise
RCI	A proxy index representing recurrent traffic conditions during a trip

The variables used in the analysis at the segment level are similar to those in Table 3 and include the segment length, the level of frontal activity of the segment, the number of signals, and roundabouts per segment. Each of the variables was estimated for each trip at the route and segment level. The trip data was clustered in space (according to the segments), time (morning peak, off-peak and evening peak) and trip direction for the segment-level analysis. Any category that had less than ten trips was excluded from the analysis. The recurrent congestion index (RCI) advanced by [11], [12] was adapted using the median travel time. A collinearity test was carried out for the independent variables. Variables correlated at the threshold of 0.7 [18] and above were carefully considered, and a decision was made on which variables to exclude. The regression analysis used all the independent variables left after the collinearity test to determine factors affecting paratransit travel time.

3 Results and Discussion

This section reports the results of investigations into factors affecting travel times at route and segment levels on two *trotro* routes in Kumasi. The data collection efforts yielded 1,894 trips in both directions on Route 1 and about 554 trips on Route 2. These were then cleaned, processed, and used in the analysis earlier described.

3.1 Factors affecting paratransit travel time on the study routes.

On Route 1, the number of passengers boarding and alighting, stops, and dwell times were correlated at the stated threshold. Dwell times and stops were retained in the analysis because of their relevance to the paratransit operations and are more directly related to the travel time. The number of stops, dwell times, and signal delays are expected to increase travel times as they increase. A positive sign is therefore expected for these variables in the regression output. The load factor and RCI increase are expected to reduce travel time. As the load factor increase, the need to make stops for boarding purposes reduces, leading to faster travel times. Drivers use deviations to bypass an apparent congestion situation downstream of the route. Travel times should therefore reduce as a result. A negative sign is therefore expected.

On Route 2, the variable rain, number of roundabouts, and signals were constant and were excluded. The number of passenger alighting was excluded after the collinearity test. An increase in the segment length is expected to increase segment travel time, while a segment's frontal activity level should increase travel time. The regression analysis results on both study routes are presented in Tables 4 and 5.

Table 4: Output of regression analysis investigating factors affecting route travel time on Route 1.

Variables	Standardized Coefficients	t	Sig.
(Constant)		144.403	0.000
STOPS	-0.033	-4.139	0.000
DEV	0.041	7.01	0.000
NONSTOP	0.024	4.252	0.000
DIRECT	0.034	5.803	0.000
DWELL	0.503	66.799	0.000
SIGDELAY	0.402	69.952	0.000
RCI	-0.614	-97.741	0.000
N = 1267.	Adjusted R Squared = 0.961		

Table 5: Output of regression analysis investigating factors affecting route travel time on Route 2.

Variables	Standardized Coefficients	t	Sig.
(Constant)		54.13	0.000
DEV	0.197	8.885	0.000
DIRECT	-0.148	-6.488	0.000
DWELL	0.474	24.332	0.000
SIGDELAY	0.097	5.013	0.000
RCI	-0.769	-29.768	0.000
PMPEAK	0.071	3.416	0.001
N = 349.	Adjusted R Squared = 0.876		

The number of stops was significant on Route 1, but the regression output sign was inconsistent with the hypothesized sign. The variable was, therefore, not considered a significant factor. Stops are correlated to dwell time and are inferior to dwell time in determining travel time. This finding is consistent with those of [14]. Non-trip stops were a significant variable on Route 1 but not on Route 2, while the time period was significant on Route 2 but insignificant on Route 1. The presence of law enforcement stops was the only missing component of the non-trip stop on Route 2 and may be why the variable was insignificant. The deviation was significant on both routes and had a different sign from that hypothesized, and rather than reduce travel time, travel times increased when a deviation was made. The explanation for this might need further investigation; however, one reason could be passenger stops along the bypass and congestion along the approach from the bypass to merge again with the main route.

The analysis results at the segment level on both routes are presented in Tables 6 and 7. The results show that signal delay was significant in Route 1 but insignificant in Route 2. Route 2 is a typical urban street with only one control signal on one segment. This explains why it was not significant in the output. Load factor and time period were significant factors on Route 2 but not Route 1. Increasing the link length by a further 500 meters will add about 21 seconds to travel time on Route 1 and 18 seconds on Route 2, keeping other variables constant.

Table 6: Output of regression analysis investigating factors affecting segment-level travel time on Route 1.

Variables	**Standardized Coefficients**	**t**	**Sig.**
(Constant)		8.006	0.000
LENGTH	0.692	16.26	0.000
DWELL	0.178	4.86	0.000
SIGDELAY	0.682	18.876	0.000
DIRECT	0.043	1.685	0.098
RCI	-0.388	-9.164	0.000
N = 60.	Adjusted R Squared = 0.963		

Table 7: Output of regression analysis investigating factors affecting segment-level travel time on Route 2.

Variables	**Standardized Coefficients**	**t**	**Sig.**
(Constant)		4.071	0.001
LENGTH	0.578	9.202	0.000
DWELL	0.43	6.177	0.000
LF	-0.136	-2.996	0.007
RCI	-0.221	-4.427	0.000
PMPEAK	0.117	2.461	0.023
N = 26	Adjusted R Squared = 0.955		

The impact of dwell time on segment travel time on Route 2 more than doubles that of Route 1. The reason for this might require more careful investigation and analysis. The finding, however, does suggest that efforts at managing paratransit stops and the corresponding dwell times should be given priority on single-lane urban streets.

4 Conclusion, Recommendations, and Further Research Direction

The paper investigated factors affecting travel times on two paratransit minibus routes in Kumasi, Ghana. The study revealed the most significant factors at the route and segment levels. Based on the study's findings, interventions geared at a general improvement in the traffic congestion levels on the routes will yield improvements for paratransit vehicles, as RCI was a significant variable in all levels of analysis. Furthermore, interventions geared at managing paratransit stops and the corresponding dwell times will yield improvements in travel times. A strategy for optimizing paratransit vehicle stops (based on data of stop locations along the route) and setting dwell time limits should be explored.

Activities of transport planning and regulatory agencies that oversight *trotro* operations are mainly revenue-focused. Enforcing compliance to obtaining a permit and licenses occupy their activities. The needs of the users have to be given cardinal attention. Users are dissatisfied with the quality of services they get, and putting their interest on the front burner of policy consideration might help improve service quality. The study found that deviation from the route increases travel time. This finding was against the logic for using the deviation by the drivers and would require further investigation. There may be unique features of paratransit operations in other cities that may not have been captured in the factors investigated. Other studies that capture these variables will make the literature investigating paratransit travel times more complete.

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