PUBLIC TRANSPORTATION AND LAND USE IMPACTS ON ACCESSIBILITY FOR SUSTAINABLE PUBLIC TRANSPORTATION SYSTEM IN BLOEMFONTEIN

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ABSTRACT

Accessibility is the centre of a sustainable urban area (UN Habitat, 2013). Most developing countries have not achieved accessibility and sustainability of public transportation systems. Cities have deployed mass transit systems, high speed trains and enabled advanced Information and communication Technology (ICT) solutions in public transportation as ways of improving accessibility. Although, ICT has been studied over the years as the possible and ultimate solution to urban transportation problems, it has its failures. Therefore, concerns to improve sustainability of public transportation systems should also focus on socio- economic and land use characteristics of the cities to assess viability of ICT solutions as means to improved, sustainable public transportation systems.

This paper focuses on evaluating accessibility of public transportation services and locations where essential activities are performed in the city of Bloemfontein. The relationships between activity location, availability of direct public transportation services, travel time as well as number of trips undertaken during weekdays and weekends are evaluated and used to assess the accessibility. Further, the possibilities of impacts of ICT on accessibility of public transportation and services are also highlighted. Location of places for services and activities as well as their accessibility affects ridership of public transportation or lack thereof, which influences public transportation sustainability.

Keywords: Accessibility, Mobility, Sustainability, Public Transportation, Land Use

1. INTRODUCTION

Accessible transportation services in a city, to all residents, improves both economic and social sustainability of the city. Reduced travel times, waiting time, number of trips and the need for travel could save money, save time and increase the ease of completing a journey. Transportation and mobility create accessibility to the services and activities located in different areas of a city, therefore should be prioritized with regards to land use zoning and development of cities. Mobility is useful for assessing the quality and performance of the public transportation system (Cheng and Chen, 2015).

Most countries are trying to address sustainability in urban areas by improving public transportation (Pojani and Stead, 2015). However, improved public transportation alone cannot sufficiently address sustainability. Land use and zoning are some of the important factors that contribute in achieving sustainable urban areas. The purpose of land use as argued by Xiong and Xhang (2016), is to support people's lives, economic activities and protect the environment. Functional urban areas, land use and transportation should be

complimentary to each other for economic and social growth as well as for the spatial dispersion of activities (Jahromi et al, 2014)

Further, the surge in technological solutions for transportation and travel problems should not prevent consideration of limitations of Information and communication Technology (ICT). ICT cannot reduce activity-travel due to growing car dependence in developing countries and most of the technologies are outside the financial reach of most developing countries (Pojani and Stead, 2015).

1.1 Study area

The city of Bloemfontein is in Central South Africa. It is the capital city of the Free State Province and subsequently the major city in the Mangaung Metropolitan Municipality (MMM), serving as South Africa's judicial capital and has a population of 503 000.

Bloemfontein was no exception to South Africa's political history. Racial disparities and segregation resulted in residents living in settlements and suburbs based on their economic status. Majority of the city's poor and middle-income residents live on the South-Eastern parts of Bloemfontein and travel on an average of 15 kilometres to the city centre for jobs (Mangaung Local Municipality,2010). The city centre has become a mixed land use area, with commercial, and residential areas within proximity to each other. Bloemfontein is a rapidly growing city, with the increase in new residential, commercial and mixed land use areas which are recently completed or currently under development. There is also growth of unlawful land ownership especially in the poor areas of the city along public transportation routes and in the areas that far from the city centre and job opportunities (Toba et al, 2012).

Public transportation vehicles used in the city are mini-bus taxis and buses. Public bus services are offered solely by Interstate Bus Lines, which operates under government subsidy. Its terminals are in the city centre, and the buses operate in some parts of the city on schedule.

The study focuses on seven locations, Bloemanda, Bochabela, Rocklands and Sports, located to the South and Southern- East of the city, Willows in the central Bloemfontein and Brandwag and Westdene located to the North of the National Road-N8, and North West of the city centre.

2. LITERATURE REVIEW

Accessibility, as defined by (Boisjoly and El-Geneidy, 2017) is the ease of reaching destinations. It is the centre of a sustainable urban area (UN Habitat, 2013). Many researchers have used different methods in efforts to measure accessibility (Cheng and Chen, 2015), having stated that it can be measured by distance from one's house to the stop, place of work and length of journey using public transportation. Previously, Golob (2003) made arguments on the measurement of accessibility in the ICT era, citing that accessibility could no longer be measured by time, distance and cost as a result of e-activities, which do not need travel to perform or access. The argument however, would only apply where e-activities have replaced the need to travel, therefore cannot be used in cases of cities where e-activities are inaccessible (Lila and Anjaneyulu, 2016).

Land use and zoning in urban areas impact the way accessibility is perceived and measured. Within zones of an urban area, different activities in which people need to travel to access are located and separated into various land uses. The main goal of land use and transport policies, according to (Wee, Geurs and Chorus, 2013), is t*o" improve accessibility".* Land use and transportation systems should therefore allow people to travel, and complete their

journeys with the least possible trips, distance and time to perform activities. Geographic features as well as land use features imposed by cities dictate travel and trip characteristics. The spatial organisation of residential, commercial and industrial areas (where most people spend their work days) have become mixed use areas due to growing cities. Transport systems do not allow travellers the freedom of choice of how to travel, when to travel, where to start and end their public transportation trips.

Mobility and accessibility of public transportation services is limited, but they can connect people with locations and zones within an urban area to perform different activities. Public transportation services are essential for sustainability, liveability and equity of cities (Diab, Lierop and El-geneidy, 2017). For public transportation to be accessible, its users should be able to begin and complete a journey successfully using public transportation services. An accessible public transportation system should also allow for ease of access to places of work, study and public services, therefore providing coverage and enabling easy mobility of people within the areas they operate in.

Earlier, ICT and travel research forecasted that there would be significant substitution of travel for ICT based activities (Wee, Geurs and Chorus, 2013). Travel to perform activities is still prevalent in cities and countries with limited ICT access and awareness. There is limited choice in either opting not to travel based on ICT access or freedom to choose e-activities instead of travel. This is a result of lack of existence or exploitation of e-activities by employees, companies, schools public service providers and retailers.

3. RESEARCH METHODOLOGY

3.1. Study sample

Questionnaires were used to gather data and a selected sample of 153 respondents were selected from a sample size of 415. Table 1 presents the survey sample. The 153 respondents were selected based on their area of residence. Respondents used in the study reside in the following areas; Bloemanda, Bochabela, Rocklands, Sports, Willows, Brandwag and Westdene. These areas were selected based on the prevalence of human activity, specifically, the areas where most people reside, spend their day or perform majority of activities. By clustering the respondents into different areas of residence, activity location and concentration can thereafter be easily de-clustered, i.e., visibility of where certain activities take place is increased and noticeable.

Table 1: Survey sample

Variable	*Group*	*Survey*
Age	18 - 25	44.4%
	25 – 35	37.3%
	36 - 45	13.1%
	46 - 55	5.2%
Gender	Male	60.1%
	Female	39.9%
Race	African	93.5%
	White	2%
	Coloured	4.6%
Occupation	Student	38.6%
	Part-Time employee	9.2%
	Self employed	5.9%
	Full-Time employee	30.1%
	Unemployed	6.5%
	Student + Part time employee	9.8%
Personal income/month	Mean	R6764.38
	Median	R3000

The following parameters were selected as measures of accessibility of public transportation, accessibility of locations and accessibility of ICT.

i. Distance (distance from home to public transportation stops and place of school or work),
ii. Time (Travelling time from home to public transportation stops and place of school or work)
iii. Availability of direct public transportation.
iv. Number of trips per typical weekday or typical weekend day.
v. Suburbs where respondents spend their normal work days and suburbs where they perform selected activities.
vi. ICT awareness and Internet access.

3.2. Research questions

1. Is public transportation and activity-based locations in Bloemfontein accessible?
2. Where are the most essential services and activities located within the city?
3. Would ICT play any role in improving accessibility of services and activities in the city?

3.3. Purpose of study

The study evaluates accessibility of public transportation and ICT for selected suburbs of residence in the city and various activity-based locations, time and distance, ultimately evaluating land use and zoning in Bloemfontein.

4. RESULTS AND DISCUSSION

4.1. Activity Location

Tables 2 and 3 are presentations of location-based activity results, showing the different locations people from the sample areas perform most activities.

4.1.1. Shopping

The results indicate that most shopping activities are undertaken in the CBD, Willows, Westdene and Brandwag. Some of the biggest shopping malls in the city are in Brandwag (Mimosa mall) and Willows (Lochlogan waterfront) respectively. The CBD is a very busy commercial zone with both formal and informal retailers and a few shopping malls.

4.1.2. Education

From the various samples, most respondents who are students indicated that their educational institutions are based in Willows. 75% of people residing in Rocklands indicated that their institutions are in the CBD. Willows is home to the Central University of Technology, which is one of the biggest higher education institutions in the city. Majority of vocational training institutions are in the CBD.

4.1.3. Religious centres

The results indicate that majority of the respondent's religious centres are in their suburbs of residence, except for residents of Westdene. Most of the residents of Westdene goes to the CBD for religious activities. Westdene is largely a commercial area with many business complexes and multi-residential complexes and night-clubs.

4.1.4. Banking

Most banking activities occur in the CBD as indicated by residents of all the areas except Brandwag. Brandwag residents bank in Brandwag. Mimosa Mall and Brandwag centre accommodates most of the banking institutions.

4.1.5. Public services

Majority of public services (post office, municipal services) are carried out in the CBD. The main post office together with the Mangaung Metro Municipality head offices are in the CBD. Rocklands also has some services such as the labour and home affairs department and municipal offices.

Table 2: Activity location by suburb of residence

RESIDENCE	SHOPPING		EDUCATION	RELIGIOUS CENTRE	BANKING
BOCHABELA	CBD		Willows	Bochabela	CBD
	68.4		75	53.3	52.6
WILLOWS	Willows		Willows	Willows	CBD
	47.6		70.7	38.9	35.7
ROCKLANDS	CBD		CBD	Rocklands	CBD
	60.9		75	57.9	75
BLOEMANDA	CBD		Willows	Bloemanda	CBD
	61.9		50	47.4	57.1
BRANDWAG	Brandwag	Westdene	Willows	Brandwag	Brandwag
	40	40	66.7	30.8	41.7
SPORTS	CBD		Willows	Sports	CBD
	52.9		50	58.8	62.5
WESTDENE	Westdene		Willows	CBD	
	50		50	37.5	

Table 3: Activity location by suburb of residence. Continued...

RESIDENCE	SPORTING ACTIVITIES	PARKS	CLUBS			PUBLIC SERVICES	STADIUM
BOCHABELA	Willows	Willows	Willows			CBD	Rocklands
	42.9	50	42.9			61.5	80
WILLOWS	Willows	Willows	Willows			CBD	Willows
	50	66.7	32.3			76.7	78.6
ROCKLANDS	Rocklands	Rocklands	Rocklands			Rocklands	Rocklands
	63.6	35	50			70	77.8
BLOEMANDA	CBD	Willows	Sports	Westdene	Willows	CBD	Rocklands
	50	40	25	25	25	62.5	55.6
BRANDWAG	Brandwag	Willows	Westdene			CBD	Willows
	50	44.4	37.5			85.7	75
SPORTS	Sports	Willows	Sports			CBD	Willows
	40	42.9	46.2			81.3	57.1
WESTDENE	Westdene	Willows	Westdene			CBD	Willows
	28.6	55.6	77.8			77.8	62.5

4.2. Trips and Transportation

It is found that 54.2% of people living in these selected areas have access to direct public transportation services from their areas of residence to the areas they typically spend most of their day (assumed to be 8hr work day). However, 45.8% do not have direct public transportation services. On weekdays, 66% of people take only 2 trips per day, while 46%

take 4 trips per day. On weekends 69.7% take only 2 trips while 9.9% take 4 trips per weekend day (Table 4).

Table 4: Number of trips (Weekdays vs Weekends)

Number of trips per weekday		Frequency	Valid Percent
Valid	0	2	1.3
	1	1	.7
	2	101	66.0
	3	3	2.0
	4	46	30.1
	Total	153	100.0

Number of trips per typical weekend day		Frequency	Valid Percent
Valid	0	23	15.1
	1	3	2.0
	2	106	69.7
	3	5	3.3
	4	15	9.9
	Total	152	100.0

Further, independent sample t-tests were carried out for the sample to find the relationship between availability of direct public transportation services or lack thereof and the number of trips taken by people per weekday or weekend day. The tests were performed for those with and without direct public transportation and number of trips taken during both weekdays and weekends. Both comparisons were made based on a null hypothesis that the variances of number of trips for respondents with direct public transportation and those with no direct public transportation are equal or not significantly different.

$H0$: $\mu 1 = \mu 2$

$\mu 1$= Direct public transportation, while $\mu 2$ = Lack of direct public transportation

Table 5 indicates that with people with direct public transportation (N=83), who were associated with a lower number of trips per day while those without direct public transportation (N = 70) were associated with a higher number of trips per weekday. The mean number of trips per day for people with direct transportation during the week is 2.66, compared to 2.50 for those without direct public transportation.

Table 5: Group statistics (Weekday trips)

	Direct public transportation availability from suburb of residence to suburb day spent at	N	Mean	Std. Deviation	Std. Error Mean
Number of Trips per weekday	Yes	83	2.66	.979	.107
	No	70	2.50	.959	.115

From Table 6 it is revealed that the significance value of the Levene's test for equality of variance (p-value) is greater than 0.05, (0.263), which means there is no significant difference in variance. This implies that the variances are approximately equal. The significance value is 0.303, which is bigger than 0.05, therefore accepting the null hypothesis that the mean number of trips for respondents with and without direct public transportation on weekdays is the same.

Table 6: T-test (Weekday trips)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Number of Trips per weekday	Equal variances assumed	1.261	.263	1.033	151	.303	.163	.157	-.148	.474
	Equal variances not assumed			1.035	147.605	.302	.163	.157	-.148	.473

From the Table 7 it is found that people with direct public transportation (N = 82) were associated with a lower number of trips per day compared to those with no direct public transportation (N=70). The results indicate a lower mean and standard deviation, (1.84, 1.012) for those with direct public transportation compared to those without direct transportation (1.99, 1.042).

Table 7: Group statistics (Weekend trips)

Group Statistics

	Direct public transportation availability from suburb of residence to suburb day spent at	N	Mean	Std. Deviation	Std. Error Mean
Number of Trips per typical weekend day	Yes	82	1.84	1.012	.112
	No	70	1.99	1.042	.125

Table 8 indicates that the significance value of the Levene's test for equality of variance (p-value) is greater than 0.05, (0.801), which means there is no significant difference in variance. This means that the variances are approximately equal. The significance value is 0.389, which is significantly higher than 0.05. Therefore, the null hypothesis is acceptable.

On weekdays, people with direct public transportation take more tips compared to those without. Even though, there are less trips taken on weekends than during the week, those without direct transportation take more trips compared to those with direct public transportation.

Table 8: Independent sample t-test for weekend trips

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Number of Trips per weekend day	Equal variances assumed	.064	.801	-.864	150	.389	-.144	.167	-.474	.186
	Equal variances not assumed			-.862	144.824	.390	-.144	.167	-.475	.187

4.2.1. Private and Non-Motorised Transportation

Table 9 shows the percentage use of all modes considered for different activities including the use of private and non-motorised transportation modes by people living in all selected areas. These are the total percentages of people using each given mode for the activities. There is low usage of bicycles and motorcycles (ranging from 0 – 0.7%) for all activities. The low bicycle usage could be a result of lack of infrastructure such as bicycle lanes in the city. Walking trips are considerably higher than bus trips but lower than taxi trips for most activities. Majority of work trips are by taxi (34.9%) while most trips to educational trips are by walking (32.9%).

Table 9: Modal split (percentages)

ACTIVITY / **MODE**	***Shopping***	***Work***	***School***	***Personal***	***Leisure***	***Sport***	***Sightseeing***	***Family obligations***
Bus	2.6	4.6	2.0	2.0	1.3	2.0	1.3	7.2
Taxi	57.9	34.9	30.3	44.1	25.7	22.4	22.4	40.8
Cab	26.3	4.6	5.3	16.4	17.8	2.6	6.6	3.3
Private vehicle	15.8	9.2	8.6	18.4	15.8	11.2	11.8	23
Motorcycle	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Bicycle	0.7	0	0	0	0.7	0	0	0
Walking	39.5	18.4	32.9	39.5	28.3	25.0	20.4	15.1

4.3. Spatial Parameters and ICT

Table 10 shows the spatial accessibility as well ICT parameters. Availability and accessibility of direct transportation from the area of residence to the area where most of the day is spent. Lack of direct transportation means the individual takes more than 2 trips, from home-school/work- home again. It is evident that most of the respondents spend their day in the CBD (24.2%) and Willows (41.8%) areas respectively. The main taxi and bus terminals/ stations and ranks are located within the CBD, which means majority of the public transportation routes begin and end in the CBD. This indicates that there is high probability of these commuters only taking 2 trips per day. Willows however, does not have the same advantage as the CBD, leaving people to complete their journeys by either walking or another paid trip by public transportation.

An average of 6.5 kilometres distance is travelled on a one-way trip to school/ work, and on average 20 minutes of travel time. About 54.2% of respondents indicated availability of direct public transportation services, which explains the 20 minutes of average travel time for people taking single trips to the CBD. Those without direct public transportation, especially in the Willows-Brandwag- Westdene area walk and perform most of the activities in the same areas, which means they walk, taking the same time as people travelling from further locations.

The results also indicate the high levels of ICT awareness and internet access among the people living in the selected areas, but they do not spend most of their work-days at home. This indicates lack of e-activities. Areas where most individuals spend their day in are

commercial and mixed land-use areas where educational institutions, retail outlets, banking and public services are located. These activities can however, be substituted through ICT, therefore reducing the need for travel.

Table 10: Spatial accessibility and ICT

RESIDENCE	DAY SPENT	Direct transportation (Percentage)		Walking distance to bus stop (Km)	Distance to work / school (Km)	Time spent travelling (Minutes)	ICT Awareness (%)	Internet Access (%)
		Yes	No					
BOCHABELA	Willows, CBD, Westdene	47.4	52.6	0.2 - 1	2 - 10	10 - 45	100	89.5
WILLOWS	Willows, CBD, Park West	36.4	63.6	0.1 - 1	0.5 - 6	5 - 30	78.6	92.9
ROCKLANDS	CBD, Rocklands, Willows	72	28	0.1 - 2	5 - 25	20 - 45	72.7	90.9
BLOEMANDA	CBD, Bloemanda, Willows	42.9	57.1	0.5 - 1	4 - 15	20 - 45	80	85
BRANDWAG	CBD, Brandwag, Willows	73.3	26.7	0.2 - 2	4 - 6	15 - 30	86.7	86.7
SPORTS	CBD, Westdene, Willows	70.6	29.4	0.2 – 0.8	4 - 10	10 - 30	88.2	94.1
WESTDENE	CBD, Westdene	66.7	33.3	0.1 - 1	2 - 10	10 - 20	91.7	91.7

5. CONCLUSIONS

Sustainable public transportation is a challenge to most cities. Improved accessibility has the potential to increase chances of sustainability in an area. It remains a challenge for governments and municipalities to bring effective solutions to public transportation problems in cities. Cities with fractured taxi systems and monopolistic bus systems disadvantage the public. Public transportation should be beneficial to the public which has limited choices and access to transportation.

Areas with dense infrastructure, such as the city centre (CBD), and those with continued activity throughout the day such as Willows (where one of the largest educational institutions, Stadium, park, hospital and companies are located) are where people spend most of their average day, and these areas are also frequently visited for various reasons. These areas however, have limited disorganised public transportation infrastructure and services, crowded and unutilised taxi ranks located far apart as well as limited public transportation stops.

Public transportation would be classified as inaccessible based on walking distances to stops as well as the availability of direct public transportation. Services, workplaces and schools are also not easily accessible based on the average travelling time, direct public transportation availability and activity location. To increase accessibility of services, mobility should be eased, the people should be able to access transportation services and infrastructure with ease, time and distance, as well as possibility of e-activities should be considered. As much as mobility eases accessibility, it is still a challenge for people to complete a journey with ease. In most instances, a single journey consists of two or more trips because of lack of direct transportation services from various suburbs/ areas to other areas. Limited infrastructure also limits possibilities of Non-Motorised Transportation options such as bicycles aiding the existing modes of transportation. Public transportation in the city is disorganised and unsustainable because of the poor accessibility of transportation services as well as spatial accessibility. ICT could therefore play a major role in improving the accessibility.

Inaccessible public transportation which lacks in mobility leaves captive demographics, specifically lower-income families that cannot afford private vehicle travel and young people

without driving licences have no choice but to walk long distances and wait for very long times at bus terminals, stops and stations to access public transportation service. They are also forced to take multiple trips just to complete one journey due to lack of ICT integration, connectivity and co-modality between the existing modes of public transportation. The transportation system in Bloemfontein is not integrated/ connected, all the available forms of public transportation operate independently under different governing bodies. It does not allow co-modal trips (multi-modal public transportation system in which available modes of transportation within the system work together as an integrated system, sharing routes, integrated payment systems and working as each other's feeder), especially for the people who must take many trips to complete a journey. This limits the accessibility of transportation services and increases the travel time as time is lost in starting another trip to complete a journey. The city of Bloemfontein's transportation and land use zoning can currently be classified as adverse to sustainability with regards to accessibility.

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