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RESIDENTIAL DENSITY AND VEHICLE MILES TRAVELLED: EVIDENCE FROM HARARE METROPOLITAN REGION

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Abstract: The transport system has always been closely linked to urban development. This study was motivated by the growing concerns over rising fuel prices, vehicle ownership and greenhouse-gas. There has been considerable interest on the effect of residential density on vehicle miles travelled (VMT). While this issue has been extensively researched, there remains uncertainty regarding how effective land-use planning might be used as an arsenal in reducing VMT. The study population was comprised of 530 668 households in Harare Metropolitan. Conferring to Krejcie and Morgan's (1970) formula the sample size for this study was 384 households at 95% confidence level. The study used stratified, convenience and purposive sampling. The researchers used a household survey to collect data from respondents. Exploratory factor analysis (EFA) was performed to test the validity of all the items used in the study. While the research hypothesis was tested using Structural Equation Modelling (SEM) in Amos version 21. The study concludes that residential density positively influences vehicle miles travelled. The fact that travel is a derived demand should encourage planners and policy-makers to consider residential development as an alternative approach to reducing vehicle miles travelled.

Keywords: density, land-use, travel behaviour, traffic congestion, vehicle miles travelled.

1. Introduction

The transport system has always been closely linked to urban development. Until the mid-19th century, journeys in urban areas were mostly done on foot but the emergency of rail and road networks restructured transportation and settlement development (Soteropoulos *et al.,* 2019). Morar and Bertolini (2013) assert that residential development influence people's activities; specifically, the choices and decisions they make about places to work and spend leisure time that in turn generate the need for physical movement between these places. The desire to move between diverse locations is what generates transport or travel demand (Mukherjee *et al.,* 2014; Patel *et al.,* 2019). The fundamental principle that residential density vehicle miles travelled (VMT) is acknowledged by many scholars and supported by empirical findings from different contexts (Izrael & McCarty, 1985; Sarzynski *et al.,* 2006; Cervero, 2013; Wilfred *et al.,* 2015; Ewing *et al.,* 2016; Gulhan & Ceylan, 2016; Kanyepe *et al.,* 2021).

Gordon *et al.* (1989) observe that residential development positively influences VMT. In the same vein, Ogra (2014) and Zhu *et al.*

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(2017) echo that high density residential settlement can influence mode choice by making other means of transportation such as public transport usage, walking and cycling more attractive than private automobiles. After controlling for the effects of self-selection, a number of studies found that there is a statistically significant relationship between residential density and VMT, even if the magnitude of the impact is marginal (Choi, 2018). Brownstone and Golob (2009) used a system of structural equations to control for self-selection biases and found a small but significant association between residential density and fuel usage. A good balance and mixture of land-use in a given urban tract can reduce individual VMT (Spears & Boarnet, 2013; Duranton & Guerra, 2016). Lee *et al.* (2018) examined the relationships concerning the effects of urban character, individual traits and land-use on VMT in 79 Korean cities and found that land-use mix reduces VMT, and that greater diversity result in shorter VMT. This proves the significant role played by land-use diversity in reducing VMT.

In most African countries, contemporary debates over residential development juxtapose on urban sprawl, compact developments and decentralisation of development patterns (Frenkel & Ashkenazi, 2008). Despite the wide range of arguments in this on-going debate (Dieleman & Wegener, 2004; Geurs & Van Wee, 2004), comprehensive studies on the effect of residential density on VMT are scarce in the African soil. Harare Metropolitan Province is experiencing urban sprawling and unplanned growth that has severely affected the distance between economic activities (Kamusoko, Gamba & Murakami, 2013; Marondedze & Schütt, 2019). Although transport and urban settlement plans are under the purview of the metropolitan council, little regard was being made to upgrade, and improve the transportation system within the context of integrated transport land-use planning (Mbara, 2015; Dube & Chigumira, 2011; Magidimisa & Chipungu, 2011; Bandauko *et al.,* 2016; Mbara & Pisa, 2019; Matamanda, 2020).

Machakaire (2015) observed that the post-independence urban trajectory in Harare could follow development trends experienced in the United States and Britain in the post-World War II era, where cities such as Detroit, Boston, Massachusetts and Michigan in the United States and Birmingham and Bristol in the United Kingdom have experienced a strong residential dispersion towards the periphery. He added that the dispersion has transcended to commercial, office and industrial activities forming the Central Business Districts, extending towards shopping centres, office areas and industrial areas. This is supported by Munzwa and Wellington (2010) who observe that Harare is developing outwards and is now merging with Ruwa in the east, Epworth in the south-east, Chitungwiza in the South and Norton in the West. This has changed the spatial relationship between residences and workplaces, shops and other destinations (Machakaire, 2015; Marondedze & Schütt, 2019). The separation between residence, work places and other destinations has been blamed for increasing about one third of the time spent in driving. In a quest to address the spatial disparities between economic activities, the city fathers have decentralised activities through the establishment of out-of-town shopping malls such as Westgate, Sami Levi and High Glen Shopping Centre among others. However, this was met with a mixture of successes and failures. For instance, High Glen Shopping Centre failed to attract many shoppers because

of being far from most residential areas in Highfields. It has however attracted more affluent shoppers from Marimba Park near Mufakose suburb as they can afford to drive to the centre (Chikede, 2015). Despite this, no known study has been conducted to attest the effect of residential density on VMT in Harare Metropolitan, thus this study intends to fill this gap. The findings from this will be similarly beneficial to policy makers as well serving as reference material for future researchers. The rest of this paper is organized as follows: The methodology is described in Section 2. Section 3 focuses on research findings and discussion. Section 4 addresses the conclusions.

2. Methodology

A pragmatic research philosophy was employed in this study to provide a practical approach to solve the problem under study. The study also adopted a cross-sectional survey design. The population for this study was comprised of 530 668 households in Harare Metropolitan Region (ZimStats, 2017). The Harare Metropolitan Region covers approximately 17°40' and 18°00' south, and between 30°55' and 31°15' east, covering an area of about 942 km^2 and an average altitude of approximately 1500 m above sea level. The map for the Harare Metropolitan Province is shown on Fig 1.

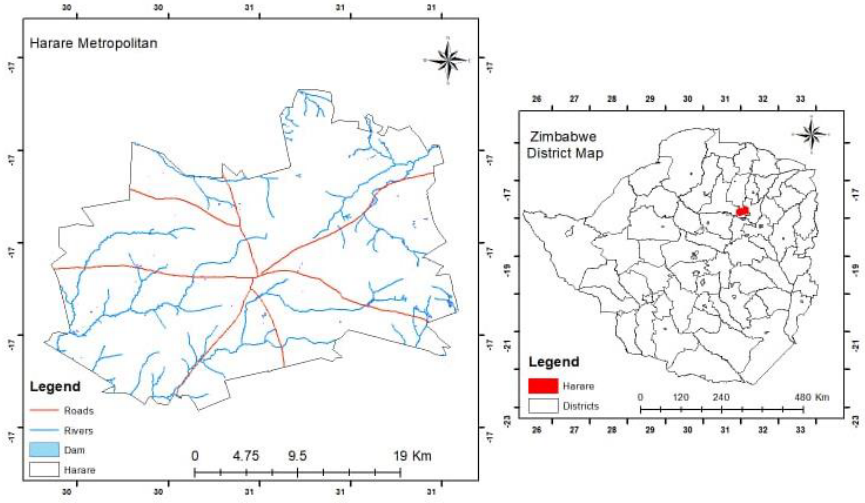

Fig. 1.
Harare Metropolitan Region

The sample size for this study was determined using Krejcie and Morgan's 1970 formula (1).

$$S = \frac{X^2NP(1-P)}{d^2(N-1) + X^2P(1-P)} \quad (1)$$

Where:
x^2 = the table value of chi-square for one degree of freedom at the desired confidence level (3.841);

N = the population size;
P = the population proportion (assumed to

be 0.50 since this would be the maximum sample size); and
d = the degree of accuracy expressed as a proportion (0.05).

Conferring to Krejcie and Morgan's (1970) formula the sample size for this study was 384 households at 95% confidence level. The researchers created strata based on the characteristics of each residential area for example low-density, medium density and high-density residential locations. From these strata, the researcher applied convenience sampling to select respondents. In addition, key informants such urban planners, transport planners and motorists were purposively selected. The researcher used a household survey to collect data from all residential areas while an interview guide was used to collect data from key informants in the Harare Metropolitan Region. The household survey was designed to gather information on residential density and VMT. In addition, the study used GIS maps to show the extent of change of land-use and land-use cover for years 1980, 1990, 2010 and 2020 as shown on Fig 2. This was important in providing evidence of urbanization and growth in terms of built-up areas in the Harare Metropolitan region.

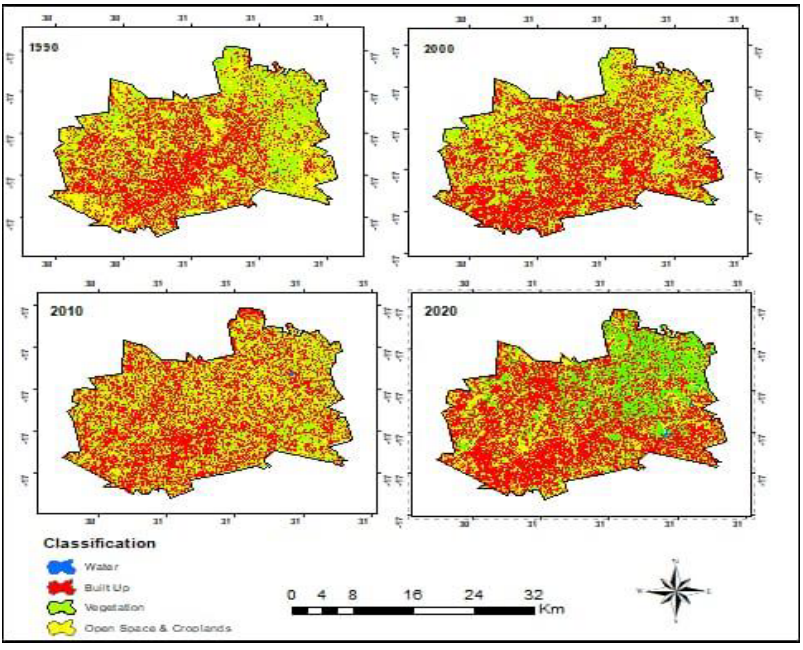

Fig. 2.
Land-Use and Land Cover In the Harare Metropolitan Region for the Years 1990, 2000, 2010 and 2020
Source: Author (2021)

Additionally, exploratory factor analysis (EFA) was performed to test the validity of all the items used in the study. This allowed the researcher to transform the data, to test the hypothesis and to map and scale the data of this study. Furthermore, the research hypothesis was tested using Structural Equation Modeling (SEM) in Amos version 21.

3. Results and Discussion

Hair *et al.* (2013) observed that the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) should be conducted to ensure that the conditions for factor analysis are satisfied. Results for the test are presented on Table 1.

Table 1
KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO)		.643
Bartlett's Test of Sphericity	Approx. Chi-Square	297.534
	df	253
	Sig.	.000

Source: Survey Data (2021)

Table 1 shows a KMO of 0.643, Aprox. Chi-square = 297.534 and Degrees of freedom [df] =253; $p < 0.001$ were registered indicating that the sample was acceptable and thus allowed explanatory factor analysis (EFA) to be performed (Field and Miles, 2009). Pallant (2011) suggested that the lower expected threshold for KMO test should be 0.5 with high values more desirable. Field and Miles (2009) pointed out that for a measure of multivariate normality that is the Bartlett's test the p-value should be significant at $p<0.05$. Table 2 achieved a cut-off point for factor loadings as recommended by Bagozzi and Yi (1988).

Table 2
Construct, Items and Factor Loadings

Construct	Items	Factor loadings
Residential Density (DEN)	DEN1	.711
	DEN2	.764
	DEN3	.602
	DEN4	.814
	DEN5	.655
Vehicle Miles Travelled (VMT)	VMT1	.723
	VMT2	.745
	VMT3	.732
	VMT4	.673

Source: Survey Data (2021)

From Table 2, the study established that the rotation converged in 4 iterations and the total variance explained by the data was 68.857% that is above the acceptable limit of 60% (Atalay *et al.,* 2013). The researchers also tested the research hypothesis after identifying factors underlying the constructs. This was done to determine the nature and strength of relationship that exist between residential density (DEN) and vehicle miles travelled (VMT). Likewise, the corresponding hypothesis was:

H_1: Residential density has a positive effect on Vehicle Miles Travelled

Using SEM technique hypothesised relationships (H_1) were tested in AMOS version 21. The structural model was estimated using the Maximum Likelihood Estimation (MLE) as suggested by (Field and Miles, 2009). The SEM was opted because it is able to determine relationships between variables and suggest a general fit between the research model and the observed data (McQuitty & Wolf, 2013).The values of GFI, AGFI, NFI, TLI and CFI indicate a good fit when close to 1 (Bagozzi & Yi, 1988; Fornell & Larcker, 1981; Nasution *et al.,* 2011) whilst RMSEA must be in the range of 0.05 to 0.10 for a model to be accepted (Monteiro & Soares, 2017). In line with these recommendations, the structural model showed satisfactory model fit indices (CMIN//DF = 3.179; GFI = .891; AGFI = .903; NFI = .939; TLI = .840; CFI = .811 and RMSEA = .041). The results of the hypothesis test as presented on Table 3.

Table 3

Hypothesis Testing

Hypotheses	Hypothesized Relationship	SRW	CR	Remark
H_1	Residential density → Vehicle Miles Travelled	.414	19.335***	Supported

Source: Survey Data (2021)

Table 3 indicates that H_1 was statistically supported. The study findings indicate that residential density positively influence Vehicle Miles Travelled as evidenced by a critical ratio of 19.335***. This implies that job-housing balance, land-use mixture, design of pedestrian and cycling facilities, distance to transit and job accessibility influences car ownership, the number of vehicle trips generated, mode choice and the vehicle distance travelled. A number of empirical studies have reached similar findings (Spears *et al.,* 2013; Hong, 2017; Kusumastuti *et al.,* 2017; Choi, 2018) that residential density has positive impact on Vehicle Miles Travelled. This consolidates the position of these findings that are consistent with a majority of empirical studies, attaining conclusive results as more studies report similar findings. The study findings also revealed that the distance between economic activities and residential areas is a key determinant in the relationship between residential density and VMT. Despite the fact that Harare city fathers introduced out of town shopping centres such as like Sam Levi, Avondale, and High Glen to reduce distance travelled by residents to access economic activities, there is evidence that this strategy has failed to achieve desired results. For example, High Glen Shopping Centre near Budiriro and Highfields has failed to attract many shoppers since of it far from most residential areas. It however attracts more wealthy shoppers form Marimba Park or the nearby Mufakose suburb who can afford to drive to the centre (Chikede, 2015).

In addition, the study confirmed that lack of affordable housing closer to the CBD has forced some people to stay in the outer suburbs of the cities, in places such as Epworth where rentals are relatively low; thus, making a trade-off between rentals and transport costs. However due to poor and unreliable public transport system, the majority of residents may end up using private vehicles or pirate taxis to commute. This is validated by Mbara

(2015) who observed that the pulling away of the ZUPCO between 2000 and 2010 resulted in automobile dependence and opened operating space for privately owned transporters popularly known as "*mushika-shika*". In addition, the results of the current study are in conformity with an earlier study by Diao and Ferreira (2014) that one-standard-deviation variation in residential density is associated with as much as 5000-mile differences in annual VMT per household. This suggest that households tend to drive significantly more as they live further from the centre city. In a way, living at fringes of the city influences space-time threshold. Due to physical, psychological and other reasons, pedestrians would tolerate certain limits of walking time and distance (Durand *et al.,* 2016). The study findings also revealed that the distance to transit stations in Harare is not reasonable, especially for low-density dwellers thus promoting vehicle usage. Beaudoin Farzin and Lawell (2015) suggest that investments in public transit may have a co-benefit of congestion reduction. They further remarked that owing to the substitution effect, increases in public transit supply lead to a reduction in the demand for automobile travel, but this reduction can be offset at least in part by induced demand. Moreover, the magnitude of the effect of public transit on the demand for automobile travel is subject to heterogeneity across urban areas. This shows that for both the substitution effect and the equilibrium effect (that incorporates both the substitution effect and induced demand), public transit supply does not reduce the demand for automobile travel until the demand for automobile travel exceeds a minimum threshold and that beyond this threshold the magnitude of the negative elasticity of the demand for automobile travel with respect to transit capacity increases with the demand for automobile travel in Harare Metropolitan Region.

4. Conclusion

This section endeavours to draw a spectrum of conclusions and implications from findings and discussion of the study findings. The study concludes that the separation between economic activities due to urban sprawling, lack of affordable houses near the CBD, poor land-use mix, poor ease to move from home to access urban facilities the CBD, and poor urban design of pedestrian and cycling facilities have influenced VMT. The increase in vehicle ownership has increased trip frequency especially for those living in the fringes of the Harare Metropolitan Region. In addition, the poor mixture of land-uses, particularly in rapidly growing communities of Harare (such as Hopely Farm, Caledonia, Hatcliff and Whitecliff) is forcing low income earners to generate trips to where these activities are found. The study suggests that VMT of households and individuals can be managed through increasing the number of urban villages, balancing jobs and housing balance, and developing pedestrian-friendly site designs. Increasing the proximity of housing units may shorten the delay time for travellers and reduce congestion level. Such effort would influence people's travel patterns and activities, thereby improving efficiency of the transport network to deal with travel demand. Other strategies that can be used include an-incentive based approach to encourage vendors to locate themselves in residential locations rather in the city centre. This will improve accessibility and proximity that in turn reduces VMT. In addition, policy-makers should also consider increasing the density of allowed development and encouraging urban infill to reduce VMT. Lastly, policy-makers should to consider

changing individual behaviour by making policies related to sustainable transportation realizable, effective and economically efficient. These include increasing the cost of driving private vehicles so that driving becomes more expensive and less convenient.

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