TRIP GENERATION RATES FOR RETIREMENT HOMES AND VILLAGES IN SOUTH AFRICA

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ABSTRACT

The development of land serves to fulfil certain needs, resulting in traffic generation. An assessment of the traffic which is expected to be generated by a newly proposed development is required to mitigate the effect of this new traffic and improve the operational condition of road network. Development generated trips are most commonly estimated by using trip generation rates. These trip generation rates vary with development specific land-use characteristics. This paper considers the appropriate estimation of land use specific trip generation rates for South African retirement facilities.

The study aims to determine whether a unique set of trip generation indicators are needed for retirement facilities, or whether existing residential trip generation rates can be used. Traffic observations were conducted at 10 retirement facilities in South Africa. Trip generation at retirement facilities was found to vary significantly from other residential land uses. The majority of trips generated by residential areas leave the area during the morning peak hour, returning in during the afternoon peak hour, however, since retired people are not leaving their residence to attend work, a unique patter of trips is created, requiring a unique set of trip generation rates.

Trips generated at various retirement facilities also showed significant variation. This led to the partition of retirement facilities into two categories, namely retirement homes and retirement villages. Retirement homes are classified as residential facilities with assisted living services and attached housing units. Retirement villages have primarily detached housing units but may incorporate assisted living facilities. Trip generation rates were calculated for vehicles and pedestrians during all peak periods at retirement homes and villages.

1 INTRODUCTION

Development of land serves to fulfil certain needs, resulting in traffic generation. An assessment of traffic which is expected to be generated by a newly proposed development is required in an attempt to mitigate traffic impact and improve the operational condition of road. This assessment usually forms part of the Traffic Impact Study, which is required within the land-use application process.

Limited trip generation indicators are available for South African retirement facilities. This study aims to determine whether a unique set of trip generation indicators are needed for retirement facilities, or whether existing residential trip generation rates can be used. Different types of retirement facilities and their corresponding traffic generation were investigated and trip generation rates for retirement facilities in South Africa are quantified.

2 TRIP GENERATION

2.1 Trip Generation Rate

A trip generation rate is a factor unique to individual land-uses. This factor relates traffic generated to a development specific land-use characteristic chosen as the independent variable, for example Gross Leasable Area (GLA) or number of employees. Independent variables used as the basis for trip generation equations have to be quantifiable in order to derive a relationship between trips generated and the independent variable. The trip generation rate for a facility is presented in Equation 1 (Montgomery & Runger, 2007). The trip generation rate assumes a linear relationship between the trips generated and the independent variable (Institute of Transportation Engineers, 2008). The number of trips generated by a development can then be estimated as the product of the trip generation rate and the independent variable quantified for the new land-use.

$$Trip\ generation\ rate = \frac{Number\ of\ trips\ generated}{Quantity\ of\ independant\ variable} \qquad (1)$$

In South Africa the “South African Trip Generation Rates” document is used as basis for trip generation estimations (Stander, Kruger, Coetzee, & Lamrecht, 1995). Though this document has 29 distinct land-use cases, retirement facilities are not included.

A Traffic Impact Assessment recently done for a retirement village in Stellenbosch, South Africa estimated the development generated trips by extrapolating the trips generated per attraction in accordance with the “South African Trip Generation Rates” document (Stander, Kruger, Coetzee, & Lamrecht, 1995). The houses in the retirement village were assigned a trip generation rate of 1.1 trips per unit, equal to the peak period trip generation rate of medium income residential areas and cluster housing. The apartments in the retirement village were assigned a trip generation rate of 0.8 trips per unit, which is equal

to average peak period trip generation rate of low and medium income residential areas. The gym/spa/beauty salon/clubhouse/office were assigned a trip generation rate of 2.3 trips per 100 m^2 GLA, equal to the peak period trip generation rate of general suburban offices.

Another South African trip generation database, the "TMH17: South African Trip Data Manual" (South Africa Committee of Transport Officials, 2013), has sub-divisions for both old age homes and retirement villages. Trip generation rates and directional distributions for old-age homes and retirement villages provided in the "TMH17: South African Trip Data Manual" are presented in Table 1. These rates are significantly lower than trip generation rates for general residential areas.

Table 1: South African Trip Generation Rates for Retirement Facilities

Period of indicator	Old-age homes		Retirement villages	
	Trip generation rate	Directional distribution	Trip generation rate	Directional distribution
Morning peak hour	0.15	65 : 35	0.35	40 : 60
Afternoon peak hour	0.20	40 : 60	0.35	50 : 50
Recommended	0.25	Not provided	0.37	Not provided

2.2 Trip Generation Equation

Trip generation equations, otherwise known as regression equations, are also used to estimate the trips expected to be generated by a proposed development. Neither of the South African trip generation databases provide trip generation equations.

Trip generation equations are determined through regression analysis techniques and can be linear or non-linear equations. The equation corresponding to the highest coefficient of determination (that fits empirical data the best) is selected as the representative equation.

3 METHODOLOGY

The development specific land-use characteristics and the number of vehicles entering and leaving a facility per hour are the two main categories of information needed. The technique used for data collection regarding number of vehicles entering and leaving a facility during this study, is the observation of traffic movements at existing developments. The observation of traffic movements involves the recording of the number of trips during a period, moving across a boundary around the development and were recorded through manual counts in this study.

A "Data Collection: Categorization" form was set up for the collection of development specific land-use characteristics. This form allowed for the identification of development

specific land-use characteristics, used as independent variables, and the categorisation of the developments. The “Data Collection: Categorization” form further obtained information regarding the availability of public transportation and socio-economic factors of the developments which were considered to be related to trip generation.
Development specific land-use characteristics used as independent variables have to influence the number of trips that are generated by a land-use in a logical way. Additionally, data for trip generation characteristics should be readily available and quantifiable for new proposed developments (Institute of Transportation Engineers, 2004).

Once all information is collected, sorted and possible independent variables are identified, the calculation of trip generation indicators can be calculated according to Equation 1. Number of housing units and number of employees were selected as the independent land-use characteristics to which trip generation has been compared for retirement facilities. This is due to the residential nature of the land-use, for which trip generation is usually associated with number of units, as well as the fact that assisted living environments are employment generators.

4 DATA COLLECTION

Traffic surveys took place at ten individual retirement facilities between 15 March and 13 April 2016. The first four surveys were conducted from 06:00 to 17:45, while the remaining six surveys were done only during the peak periods of the road network, from 06:00 to 09:30 and then again from 16:00 to 17:45. During the surveys, it was noted that the number of trips generated by various retirement facilities, with approximately the same number of housing units and employees, varied significantly. Following this observation, retirement facilities were divided into two categories based on the type of accommodation and services provided by the facilities. Retirement facilities were accordingly categorised as either retirement homes or retirement villages. In line with this classification, three surveys were conducted at retirement homes, and seven surveys at retirement villages.

The majority of the surveys were performed in towns and suburban areas in the Western Cape, more specifically in the Cape Town Metropolitan Municipality and Cape Winelands District. A single survey was performed in Limpopo at a retirement village located in the Waterberg district. This allowed for the comparison of traffic patterns outside of the primary study area.

4.1 Retirement Homes

A retirement home is classified as a residential facility with single-bedroom attached living units. At a minimum it provides the residents with housekeeping, dining and medical services. Additional services are often provided by retirement homes, which could include a hair salon, transportation and recreational activities.

It was found that vehicle ownership among residents at retirement homes is low. Consequently, the majority of trips generated at retirement homes are generated by

employees and visitors. Further, three vehicle peak periods were noted during the period of a day at retirement homes as shown in Figure 1 (grey line). The first and third peak periods fall within the morning and afternoon peak periods of the surrounding road network (7:00 to 8:00 AM and 16:00 to 17:00 PM) whilst the second peak period (the peak hour of the generator) is between 09:30 and 10:30 AM. This additional peak period of the generator occurs as result of visitors for the frail care units arriving and leaving between 09:30 and 10:30, the established visiting hours of the facilities.

The daily traffic distribution is provided in Figure 1, which displays the number of trips generated per hour. The “trips generated per hour” value corresponds to the “starting time of hourly indication” representing the trips generated for the hour following the “starting time of hourly indication”. As an example, the value of “40 trips per hour” corresponding to the time of 07:15 represents the number of vehicle trips generated from 07:15 to 08:15 at retirement villages.

4.2 Retirement Villages

A retirement village is classified as a residential facility fulfilling various elements of senior living. Retirement villages consist of mostly independent, as well as some dependant residential units. Independent residential units include detached and attached houses, while dependant residential units includes rooms and frail care units aggregated in one building. Retirement villages are required to provide a basic level of medical care, while services such as catering, gardening and housekeeping, may or may not be provided.

The daily trips distribution patterns of individual retirement villages were found to be very similar. This consistency in trip patterns, together with the relatively high amount of available resident parking and high vehicle ownership levels, leads to the conclusion that the majority of trips are generated by the residents of retirement villages. As the majority of the trips are generated by the residents, the daily trip patterns provide a decent indication of their typical routines.

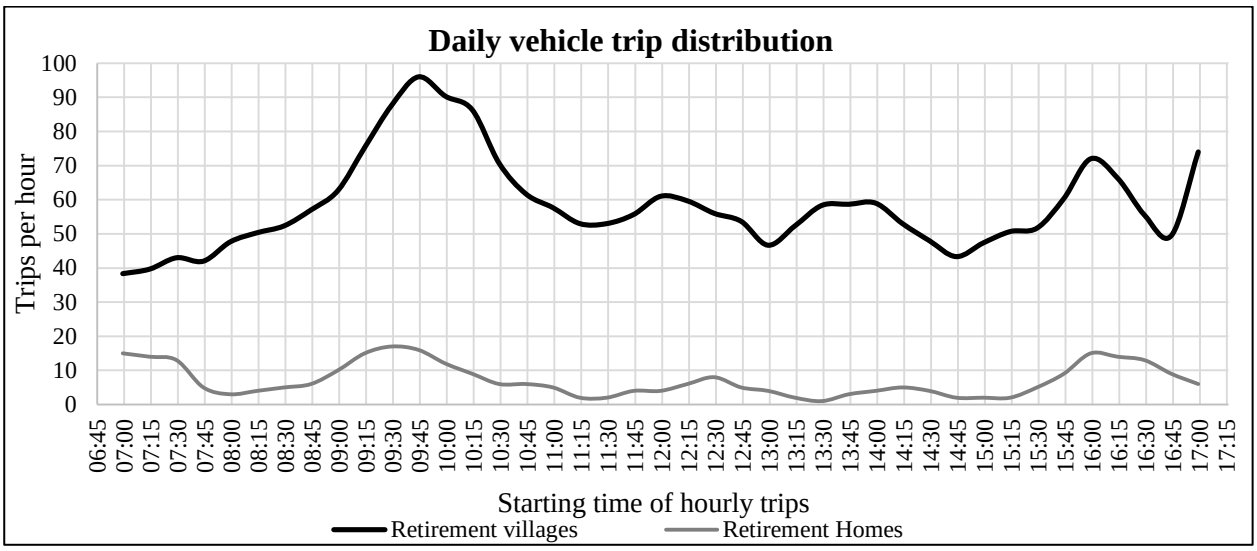

Figure 1: Daily vehicle trip distributions

The routine observed from the daily trip pattern, as shown in Figure 1 (black line) obtained as the average of daily traffic at four retirement villages, coincides with the routine description as provided by a retirement village manager and resident. The routine typically start as residents are leaving the retirement village between 09:00 and 10:30 for their daily excursions. Residents typically start leaving the facility by this time as to avoid the road network during its period of highest traffic demand. Thereafter a stabilised level of activity is present, decreasing slightly around 15:00. Activity in the number of trips generated start increasing again at 15:30, forming a defined peak at 16:00 when residents return home in the afternoon.

Figure 1 indicates a higher trip generation for retirement villages than retirement homes. This could be due to the fact that the retirement villages surveyed generally had higher numbers of residents than retirement homes and will be investigated further in the following section.

5 RESULTS

5.1 Traffic Patterns at Retirement Homes

The number of trips observed during the morning and afternoon peak hours, as well as the peak hour of the generator at retirement homes is presented in Table 2. The number of housing units and employees are also indicated. Retirement homes are referred to numerically to protect the privacy of the residents.

Table 2: Results of surveys at Retirement Homes

Development	Housing Units	Employees	AM Trips	PM Trips	Generator Peak Trips
RH1	56	49	12	11	12
RH2	125	70	13	15	17
RH3	96	50	12	18	13
Directional Split (in:out)			60:40	45:55	50:50

It is observed that the number of vehicle trips generated by retirement homes remained relatively constant throughout the day, despite the variation in number of housing units and employees between the retirement homes. The uniformity in the number of trips made can be attributed to the majority of trips being generated by the employees and not the residents.

During the afternoon peak period an increase in the number of trips generated per housing units was observed. The increase observed may be attributed to shift changes, and more significantly, visitors arriving after their workday.

It was further observed from the directional distributions that there was a similar traffic flow in both directions throughout the day. This can be attributed to visitors and services providers coming and leaving within a short period of time. Additionally, daytime and night-time employees will enter and leave the facility simultaneously, resulting in an evenly spread directional distribution.

The minor disparity in vehicle trips entering and exiting the retirement homes during the morning and afternoon peak periods are due to more vehicles entering than leaving the facility in the mornings and the reverse for the afternoons. This observation is contradictory to what is observed for general residential areas, when more vehicles leave an area in the morning, heading to work, and returning in the afternoon.

5.2 Traffic Patterns at Retirement Villages

Table 3 summarises the observed trips during the morning and afternoon peak hours, as well as the peak hour of the generator for retirement villages. The retirement villages are referred to numerically to protect the privacy of the residents. The number of trips plotted as a function of the number of housing units during the three peak periods is presented in Figure 2.

Table 3: Results of surveys at Retirement Villages

Development	Housing Units	Employees	AM Trips	PM Trips	Peak of Generator Trips
RV1	109	17	19	16	19
RV2	137	24	44	35	47
RV3	310	117	50	64	51
RV4	300	35	53	83	99
RV5	104	8	21	27	34
RV6	449	37	96	97	107
RV7	640	130	99	89	158
Directional split (in:out)			35:65	55:45	40:60

From the results of the traffic counts, it was observed from Figure 2 that the number of vehicle trips generated at retirement villages became constant as the number of housing units and employees at these facilities increased above a particular threshold. This observation of vehicle trips generated could be attributed to an increase in carpool and public transportation opportunities as the number of employees and residents increase, decreasing overall trip generation by private car.

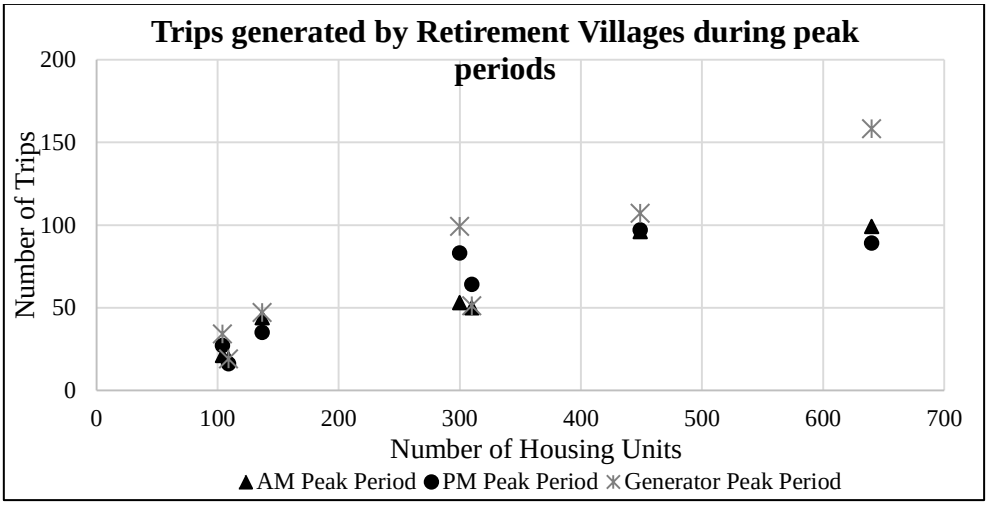

Figure 2: Number of Trips at a Retirement Village According to Number of Units

The number of vehicle trips generated during the additional peak period at retirement villages (peak hour of the generator) does not coincide to this pattern. During this period, a linear increase in the number of trips generated with regards to number of housing units at the facility was observed. Two reason may contribute to this disparity. The first reason being that that this peak is caused by residents leaving the facility for their daily excursions. The second reason is a decrease in public transportation opportunities during this period of the day, as it falls outside the period of the highest traffic demand.

In the morning it was observed that more vehicles left than entered the facility. The reverse of this observation was made in the evenings, when more vehicles entered the facility than left. This may be explained by the typical routine of the residents.

5.3 Trip Generation Indicators

The trip generation indicators in the "TMH 17: South African Trip Data Manual" (South Africa Committee of Transport Officials, 2013) are presented as the average trip generation rate obtained from the various individual trip generation rates, while the trip generation indicators in the "South African Trip Generation Rates" documents are provided as the 75th percentile rates (Stander, Kruger, Coetzee, & Lamrecht, 1995). The 75th percentile rates are used to minimize the influence of sites with great variances from the mean. In this study, both the average and the 75th percentile trip generation rates were calculated. Table 4 and 5 summarise the resulting average and 75th percentile trip generation rates, as well as the average directional split per peak period.

Table 4: Trip generation rates for Retirement Homes

Characteristic	Trip Generation Rates				Directional split (in:out)		
		AM Peak	PM Peak	Gen Peak	AM	PM	Gen.
Housing Unit	Average	0.148	0.168	0.162	60:40	45:55	50:50
	75th %tile	0.187	0.196	0.190			
Employees	Average	0.224	0.266	0.249			
	75th %tile	0.246	0.321	0.256			

Table 5: Trip generation rates for Retirement Villages

Characteristic	Trip Generation Rates				Directional split (in:out)		
		AM Peak	PM Peak	Gen Peak	AM	PM	Gen.
Housing Unit	Average	0.201	0.214	0.260	35:65	55:45	40:60
	75th %tile	0.239	0.251	0.311			
Employees	Average	1.553	1.714	2.099			
	75th %tile	2.131	2.448	2.984			

For the purpose of being concise in this paper, the trip generation results for the afternoon peak period for retirement homes and villages are presented in Figure 3 and 4 respectively. Figure 3 and 4 display the data and the calculated trip generation rates and equations. Trip generation rates are indicated as straight lines that intercept the origin (0,0). The average trip generation rate is presented as a dotted line, while the 75^{thh} percentile trip generation rate is indicated as a solid black line. Best fit linear and logarithmic regression curves are also indicated.

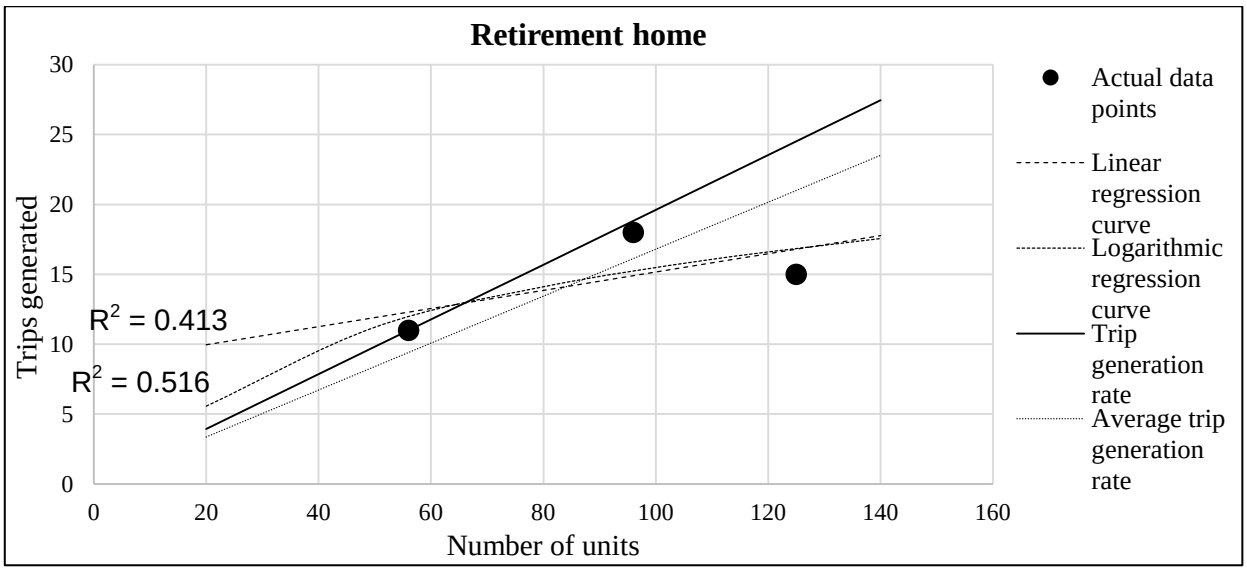

Figure 3: Afternoon peak period vehicle trip indicators per retirement home unit

During the afternoon peak period an association can be made between the increasing size of retirement homes and a higher amount of trips generated, as shown in Figure 3. Due to the limited sample size and low coefficients of determination for the afternoon peak period at retirement homes, the regression curve should not be used. The 75th percentile trip generation rates are the recommended trip generation indicators for the afternoon peak period of retirement homes.

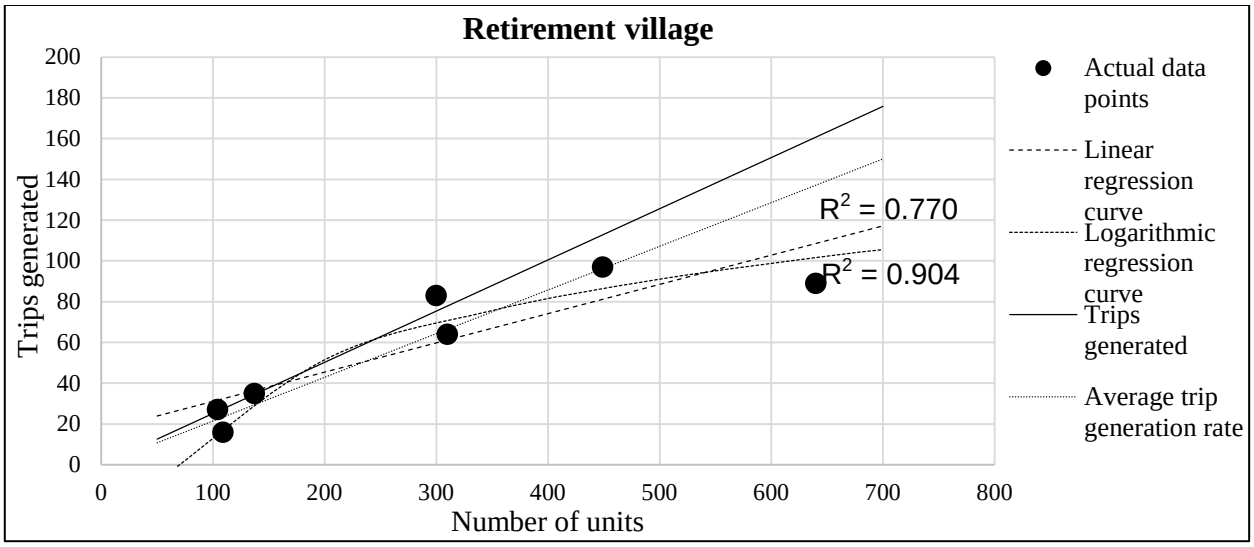

Figure 4: Afternoon peak period vehicle trip indicators per retirement village unit

Figure 4 indicates that the number of trips generated do not increase significantly relative to the number of retirement village housing units as the number of housing units becomes higher. This results in the trip generation rates presenting increasingly inaccurate estimations as the size of the retirement village increases. Trip generation equations therefore provide more reliable estimations. The logarithmic trip generation equation per housing unit for the afternoon peak hour has a higher coefficient of determination compared to the coefficient of determination for the linear regression equation. According to the Guidelines for Using Trip Generation Rates or Equations document (Institude of

Transportation Engineers Techinal Council Committee, 1990), the closer the coefficient of determination is to one, the more reliable is the equation it represents, the logarithmic trip generation equation is therefore the recommended trip generation indicator.

5.4 Recommended Trip Generation Indicators

The most reliable and therefore recommended land-use characteristic, independent variable for the majority of vehicle trip generation indicators obtained from retirement homes is the number of housing units, despite the trips being predominantly generated by the staff and service providers. The study found a correlation between the number of housing units and vehicle trips, as the opportunity for services increased with increasing number of housing units, leading to an increase in vehicle trips generated. Additionally, the number of trips made by visitors to retirement homes increases with the number of units, and not necessarily number of employees.

An alternative independent variable to that of housing units is the number of employees, especially during the morning peak period at retirement homes. In this period, daytime employee's shifts start while night time employee's shifts end, resulting in a high number of trips being generated by employees entering and exiting the facility. Retirement homes typically have more daytime employees than night-time employees, as housekeeping and dining employees only work during the day. Additionally, daytime employee's shifts may all start during the morning peak hour, but may not all end at the same time, resulting in the trips generated by retirement homes being more significantly influenced by the number of employees that the number of housing units during the morning peak period.

Similar to retirement homes, the recommended independent variable for vehicle trip generation for retirement villages is the number of housing units. The majority of trips are generated by residents, therefore an increase in the number of housing units correlates to an increase in the number of trips generated. Furthermore, there is a high variation in the number of employees at individual retirement villages, likely because each village offers different levels of assisted living and facilities. This variation makes the use of employees as an independent variable to estimate trip generation less accurate.

The trip generation rates and equations for retirement facilities in South Africa are presented in Table 6 below. As indicated above, the morning peak hour traffic generation of retirement homes can be described in terms of number of employees as well as housing units. All other trip generation indicators use only the number of housing units according to the best fit to the collected data. The 75^{th} percentile rates are recommended for use as they are consistently more conservative, and are less influenced by outliers. Where trip generation rates provide a better fit to the data than an equation, only the rate is provided. It is clear that retirement villages generate more traffic than retirement homes per number of housing units.

Table 6: Recommended trip generation indicators

Peak Period	Characteristic	Retirement Homes		Retirement Villages	
		Rate	Equation	Rate	Equation
AM Peak	Employees	0.25	0.0487(X) + 9.5903	NA	NA
	Housing Unit	0.19	0.0136(X) + 11.077	0.24	0.152(X) + 10.075
PM Peak	Housing Unit	0.20	NA	0.25	45.154ln(X) - 177.48
Gen Peak	Housing Unit	0.19	0.0287(X) + 10.346	0.31	0.2342(X)+5.0197

6 COMPARISON WITH CURRENT TRIP GENERATION RATES IN SA

This study found no correlation between the trips generated by retirement facilities and the general residential trip generation indicators currently in use in South Africa. This indicates that the number of trips expected to be generated by a retirement facility cannot be accurately determined with general residential trip generation indicators, and a unique set of trip generation indicators is required. Trip generation rates per unit for retirement facilities are found to be much lower than recommended by the “South African Trip Generation Rates” document (Stander, Kruger, Coetzee, & Lamrecht, 1995). Additionally, the most traffic generated hourly by a retirement village occurs in the peak hour of the generator during the mid-morning period, which is not consistent with general housing.

The trip generation rates determined from this study for retirement homes were found to coincide to those listed in the “TMH 17: South African Trip Data Manual” (South Africa Committee of Transport Officials, 2013), indicated in Table 1, however, no generator peak hour is indicated in the Manual. Retirement villages were found in this research to have lower trip generation rates than this Manual. This study indicates that the impact of retirement facilities on the road network traffic is relatively low.

7 CONCLUSION

1. No correlation was found between the trip generation for retirement facilities and general residential trip generation in use in South Africa, consequently it is required for retirement facilities to have a unique set of trip generation indicators.

2. An additional peak period of retirement facilities was identified between 09:30 and 10:30 for retirement homes and between 09:00 and 10:30 for retirement villages. The additional peak period at retirement homes coincides with visiting hours of the frail care units and can be attributed to the visitors of residents. The additional peak period at retirement villages can be attributed to the typical routine of retirement village residents as they depart on their daily excursions. These peak periods

influence the surrounding road network outside of the period during which it experiences the highest traffic demand, therefore the resulting impact of these facilities on the road network are subsequently minimalised.

3. The most reliable and therefore recommended independent variable for the majority of vehicle trip generation indicators obtained from both types of retirement facilities in this study is the number of housing units.

4. The morning trip generation rates of retirement homes determined in this research correlate to those provided in the “TMH 17: South African Trip Data Manual”, while the afternoon rate was found to be similar.

5. The trip generation indicators obtained during this study, and show in Table 2 are recommended for future traffic impact assessments of retirement facilities in South Africa.

8 REFERENCES

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