TRIP GENERATION RATES FOR SOUTH AFRICAN GOLF CLUBS AND ESTATES

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ABSTRACT

There has been a surge in the development of golf estates in South Africa; however, adequate information regarding the trip generation potential of this land use is still not available. This study aims to determine trip generation rates for South African golf clubs and estates and ascertain an independent characteristic specific to all golf estates to which the trip generation rates relate. Two golfing land uses were investigated during this study, namely recreational golf courses and residential golf estates. Trip generation rates have been investigated primarily for recreational golf courses. The applicability of these rates to describe golf related traffic at residential golf estates was then considered.

Traffic counts were conducted at six golf courses and estates in the Boland region during the winter months of July, August and September of 2008. Trip generation rates are expected to represent the top 75 percentile of occurring traffic volumes, consequently, rates are required for the peak summer season. This study therefore includes the application of statistical methods for converting counted winter traffic volumes into equivalent summer traffic. These data manipulation methods were developed during the course of this project, and have applications in other traffic engineering circumstances. This paper also considers the use of previously unused trip generation characteristics. It was determined that the starting period of a golfing session, a newly defined characteristic, produced the most accurate trip generation rates for recreational golf courses. Additionally, it was found that these rates can be applied to residential golf estates when multiplied with an applicable capture rate to reduce total traffic volumes.

INTRODUCTION

Trip generation information is used to estimate the number of vehicular trips that are produced and attracted by a particular land use. Estimated traffic volumes are used to assess the traffic impact of a new development and aid in the correct design of golf estate entrances, parking facilities and internal roads. Adequate trip generation information regarding golf estates in South Africa is however not available. The aim of this report is to provide a greater understanding of traffic patterns produced by golf estates and to determine trip generation rates applicable to South African golf courses at relevant peak hours. These rates are linked to an independent characteristic specific to all golf estates, which presents a good correlation to the traffic and should be a measurable quantity such as area or number of employees.

This report details the process by which traffic data was collected at six golf courses and estates in the Boland region during the winter months of July, August and September of 2008. This data has been used to calculate trip generation rates for winter traffic. Trip generation rates are expected to represent the top 75 percentile of occurring traffic volumes (Stander, Kruger, Coetzee, & Lamprecht, 1995, p. iii); consequently, rates are required for the peak summer season. This study therefore includes the application of statistical methods for converting winter traffic volumes to equivalent summer traffic. Trip generation rates were determined with independent characteristics used in the United States of America, as well as with newly defined characteristics. The most applicable and accurate characteristic was established which can easily be used by traffic engineers.

INTRODUCTION TO TRAFFIC GENERATED AT GOLF ESTATES

Various factors influence the traffic generation potential of a land use. For a golf estate, these factors include the type of golf estate, site specific factors and weather patterns.

Golf estate category

Two land uses fall under the general grouping of golf estates; namely: recreational golf courses and residential golf estates. Recreational golf courses are used purely for recreational purposes. Residential golf estates incorporate housing developments that are comparable to gated security villages. Golf courses either follow a single or double tee start. A single tee start allows players to tee off for a longer duration in the morning from the first tee alone, while a double tee start divides the golfing day into two periods, a morning and an afternoon session. In this format, golfers tee off simultaneously from the first and tenth tee, allowing more golfers to use the course at the same time.

Site specific factors

Site specific factors are characteristics that are present at all golf courses, for example area and number of employees. Site specific factors are often used as the independent characteristic in conjunction with trip generation rates to describe produced traffic volumes at land uses. *Trip Generation* (Institute of Transportation Engineers (ITE), 1991) lists golf estate area (in acres), number of holes and the number of golf club employees as characteristics that could influence traffic. Additional factors include the number of golf club members, Gross Leasable Area (GLA) of the club house and length of the golf course.

Seasonal influences

Golf is an outdoor recreational activity and seasonal weather patterns will influence the number of golf players and therefore trips generated by golf estates. Consequently, the highest traffic volumes are produced by a golf course during the summer season.

INTRODUCTION TO CHARACTERISTICS AND METHODS IN THIS STUDY

Distinction of recreational and residential golf estate studies

Many golf estates which have recently been developed in South Africa are residential golf estates. Without formal trip generation information regarding golfing land uses, traffic engineers consider all traffic produced by a residential golf estate collectively. One trip generation rate is measured, typically linked to number of housing units. This is however unacceptable considering the wide range of golf estates. Some incorporate privately owned dwellings, others holiday or time-share units or are linked to retirement villages. These land uses have different traffic production potentials and are described by separate trip generation rates. Additionally, this study has proven that golf associated traffic is not related to residential traffic and therefore cannot be linked to number of housing units.

A residential golf estate is what is referred to as a multi-use development in *Trip Generation* (ITE, 1991). To determine the total number of trips generated, the number of trips produced by each land use is calculated separately and then summed. For a residential golf estate, separate trip generation information is required for golf orientated traffic and residential related traffic. A single trip generation rate has therefore not been calculated for an entire residential golf estate, rather, the applicability of recreational golf course rates have been analysed for their capacity to describe golf related traffic at residential golf estates.

Traffic counts have been conducted at a sufficient number of recreational golf courses to produce reliable trip generation values with an adequate level of confidence. The trip generation manual used in the United States of America, *Trip Generation* (ITE, 1991), recommends a minimum sample size of four studies to allow for adequately accurate statistical calculations.

Trip generation characteristics

Four characteristics were identified as trip generation characteristics in this study. Two of these characteristics are used for golf course trip generation in *Trip Generation* (ITE 1991), namely the area of the golf course and the number of employees. Additionally, two newly defined characteristics have been investigated for potential use for trip generation; namely the number of members of a golf club and the starting period of a golf session.

The first three characteristics are relatively self explanatory, however the fourth characteristic, namely the starting period of a session requires clarification. This period is the duration in minutes that is provided for all golfers playing a round of golf during a morning or afternoon session to begin their games at the first or tenth tee. For the A.M peak hour this value is determined for the morning session. When trip generation information is determined for the P.M peak hour and the peak hour of the generator, the time for tee off is determined for the afternoon session. For a double tee start, the duration is doubled because two four-balls tee-off simultaneously. This time is standardized by the management of golf courses.

Trip generation information is required at the planning stage of a golf course when accurate values of the four identified trip generation characteristics may not be known. This would limit the applicability of the determined trip generation rates. Information that is generally known at the planning stage of a golf course includes the gross leasable area (GLA) of the clubhouse, the number of holes of the course and its desired par rating. *Trip generation* indicates that the number of holes correlates poorly to traffic generation (ITE, 1991). Additionally, this characteristic was not considered because all observed courses had 18 holes. The GLA of the clubhouse was not considered, as the principal users of this amenity are golfers, who are attracted by the golf course. It was determined through oral surveys that most vehicles entering the golf clubs had the primary purpose of playing golf.

The par rating of the course indicates the number of shots that a scratch (zero handicapped) golfer would require to complete the course. The average par rating of a golf course is 72, and ratings do not vary greatly. In fact, all golf courses considered in this study had a par rating of 72, except Mowbray Golf Club with a rating of 71. More golfers can use a course with a lower par rating in a day. To allow more golfers access to the course, management must lengthen the starting period of the golfing session. This characteristic was considered the most applicable in this study. Although exact starting period times will not be known at the planning stage, an estimate can be made from the anticipated length and par rating of the course. A longer course with a higher par rating should be allocated a smaller starting period time value than a short, low par rated course. Applicable time units for the starting period of the session range between 180 and 280 minutes during summer months. Traffic engineers can also assume a value for this characteristic by investigating nearby golf courses within the same climatic regions.

Additional methods used in study

Golf estates in the Western Cape, a winter rainfall region, have exclusively been studied. Traffic counts were conducted during July, August and September of 2008. This is unfortunate, as the traffic production records for the golfing peak season are required to effectively establish useful trip generation information. Consequently, a large part of this study has been dedicated to the conversion of winter traffic data into equivalent summer traffic volumes.

The conversion of winter data has been conducted in two parts. Firstly correlations between traffic and the number of players were investigated for the counted winter traffic volumes. These correlations were formulated as equations with “number of players” as the independent variable. Summer traffic volumes were then determined by substituting the number of players on a typical summer day into the correlation equations. This process is discussed in further detail in Chapters 6.1 and 6.2.

DATA COLLECTION

This chapter describes the accumulation of time dependant traffic volume data.

Golf estates surveyed

Golf estates in the Western Cape have exclusively been included in this study with golf courses selected in Cape Town, Stellenbosch, Strand and Paarl providing a study area that includes city bound and rural golf courses. Recreational golf courses that have been surveyed are Stellenbosch Golf Club, Stand Golf Club, Durbanville Golf Club and Mowbray Golf Club. Two residential golf estates were also considered, namely De Zalze Winelands Golf Estate and Pearl Valley Signature Golf Estate.

Vehicle distinction

The number of vehicles entering and exiting a golf estate was noted in 15 minute intervals throughout the day, specifically during periods including anticipated peak hours. Vehicular direction was noted; and heavy vehicles, vehicles of golf course employees and vehicles of golfers were recorded separately. At residential golf estates, traffic produced by the residential land use and by the golf course was discerned. For this purpose, a verbal survey was conducted of each vehicle passing through the estate's security gate.

Periods surveyed

Golf estates reserve Wednesdays and Saturdays for club competitions and Fridays for golf tournaments or corporate events. These days are expected to produce the most traffic. Traffic studies were therefore conducted on Friday and Saturday. Golf sessions start between 7:30 and 8:00 A.M. during winter months. To capture the required traffic, counts began at 6:45 and continued to 18:00 to observe traffic during the adjacent street traffic peak hours between 7:00 and 9:00 and again between 16:00 and 18:00.

Golf course archive data

In order to compare traffic volumes to the number of golfers, time sheets for each surveyed day were examined as well as time sheets for typical summer days; namely Friday and Saturday, 1 and 2 February 2008. Time sheets indicate how many players teed off at what time. Information regarding the size in hectares of the golf course, number of staff members and the number of members of the golf club was also ascertained.

RESULTS OF DATA COLLECTION: TRAFFIC PATTERNS

Traffic patterns produced by recreational golf courses

Traffic patterns produced at golf courses tend to follow an identifiable trend which appears to correlate to the time at which players tee-off. The incoming traffic volume increases in all instances just before a tee-off session begins, yet remains at a low and fairly constant magnitude between these peaks. This trend is exhibited in Figure 1, which compares Saturday incoming traffic to the number of players teeing off at Durbanville Golf Club. These identifiable patterns lead to the assumption that a correlation between traffic volumes and the number of golfers playing in a session existed.

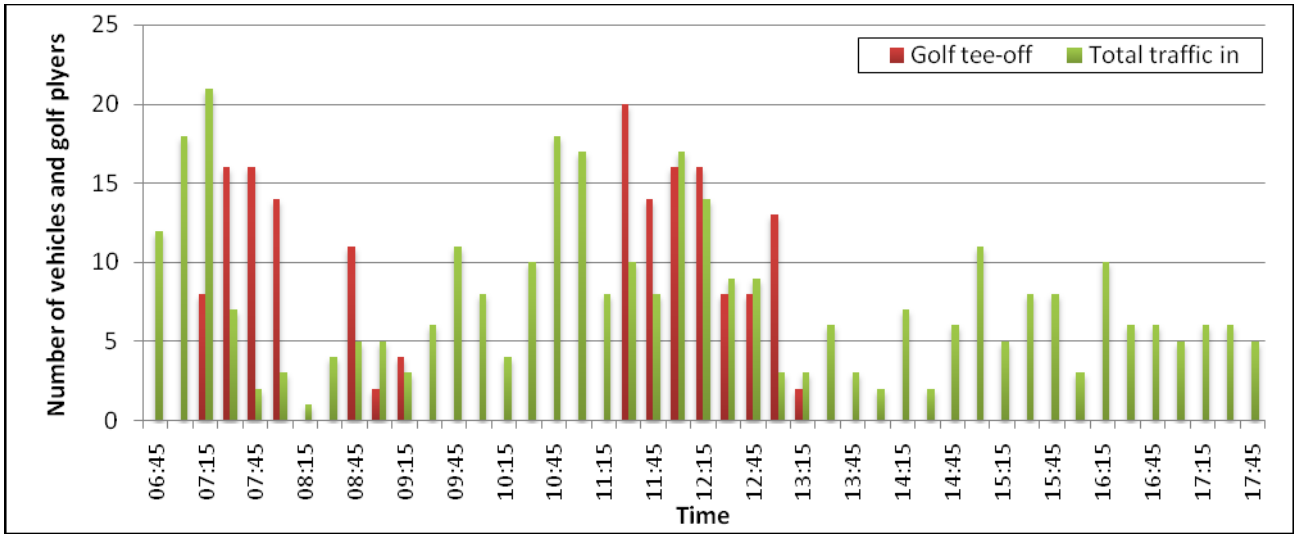

Figure 1: Friday incoming traffic compared to tee-off times for Durbanville

Outgoing traffic was more difficult to describe in terms of a pattern. Outgoing peaks are visible; however, they are never of the same magnitude or as condensed as incoming peaks. Figure 2 presents incoming and outgoing traffic on Saturday at Durbanville Golf Club and is a good graphical explanation of this trend. Incoming and outgoing peaks are spaced about six hours apart, which is consistent with the duration of a game of golf.

Traffic patterns produced by residential golf estates

Golf orientated traffic produced by a residential golf estate is similar to that of a recreational golf course. This similarity refers to the increase in incoming traffic before and during a tee-off session. The golf traffic volumes are less however than those generated by recreational courses. This is attributed to the fact that residents at golf estates are members of the golf club. These players consequently do not enter through the main gate of the establishment, which is where traffic counts were conducted. This decreases the expected traffic volumes depending on the number of non-members (players who do not own a home and reside on the estate) who play golf on any particular day.

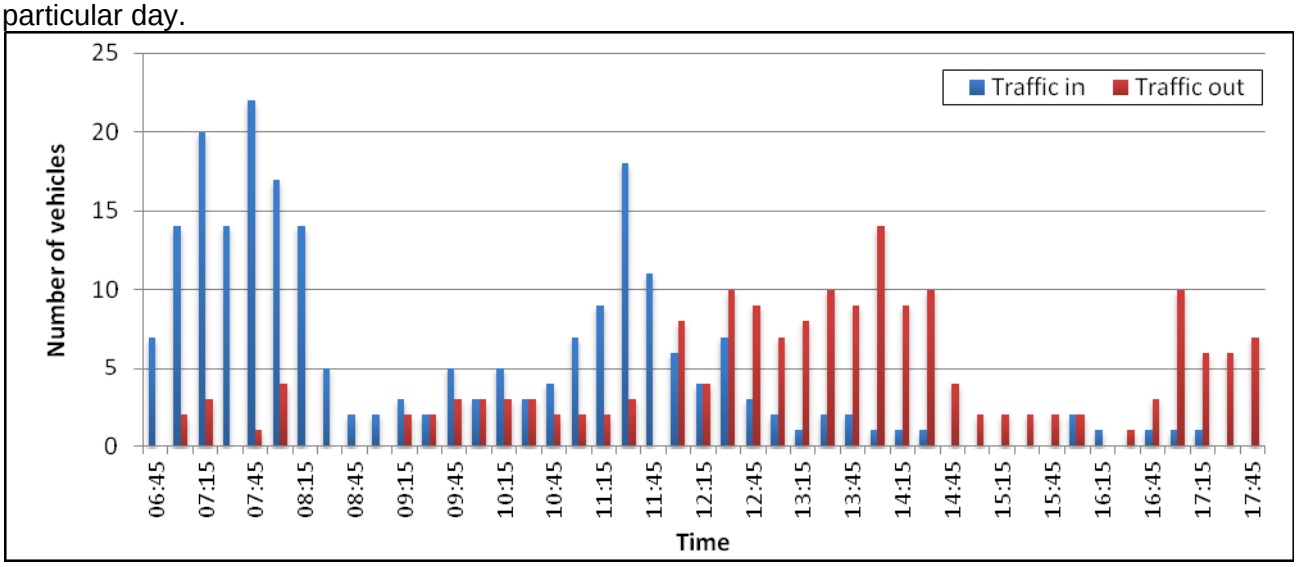

Figure 2: Saturday total incoming and outgoing traffic for Durbanville Golf Club

DATA ANALYSIS OF RECREATIONAL GOLF COURSE TRAFFIC

This chapter details the conversion of raw traffic volume data to useful trip generation information. Correlations between the number of players and counted winter traffic were investigated. These correlations produced equations that allowed equivalent summer traffic to be calculated. Trip generation information was then calculated using this traffic.

Conversion of winter traffic: traffic volume – player correlations

The traffic patterns described in Chapter 5 indicated a probable correlation between traffic volumes and number of players. In this section the method of determining these correlations using regression analysis of surveyed peak hour traffic volumes and actual number of golfers is described. This was done separately for the morning and afternoon peak hours for Friday and Saturday. Additionally, incoming and outgoing vehicle volumes were dealt with separately. The regression analysis yielded equations linking traffic volumes to player numbers at particular time intervals. These intervals indicate the position of the peak hour relative to the time at which golfers first tee-off. The method by which the correlations were determined is as follows:

1. Calculate the number of golfers playing in the session for each golf course by examining the time sheets collected on the days surveyed;
2. Sum four consecutive 15 minute intervals of counted traffic volumes (traffic for an hour) for the periods of 30 minutes before the first tee-off, every 15 minutes up to 60 minutes after the first tee off (that is 30 minutes before, 15 minutes before, etc.;
3. Determine the peak hour for each golf course from the volumes found in step 2 and note the time this period occurs relative to the time of the first tee-off of the session;
4. Set up graphs that present number of players as the independent variable and the hourly traffic volume as the dependant variable. This must be done for the intervals described in step 2 as well as for the peak hour found in step 3. Total and private vehicle traffic for each golf course is represented as a separate point on the graph.
5. Create a linear regression curve using the “trend line” function of Microsoft Excel and display the R^2 value to quantify the fit of the curve to the data.

The process described above was repeated for incoming and outgoing traffic for the morning and afternoon tee-off session on both Friday and Saturday. The R^2 value or *coefficient of determination*, introduced in point 5, is a measure of how well a regression equation fits the actual data points (Montgomery & Runger, 2007). R^2 can obtain values between 0 and 1. The closer the R^2 value is to 1.0, the less the actual data varies from the equation. A R^2 value of greater than 0.75 indicates a good correlation between data points.

The result of applying the above method to the incoming traffic associated with the morning tee-off session on a Saturday (for example) was a set of graphs representing the relationship between players and traffic for the actual peak hour, and for hourly traffic volumes at 15 minute intervals relative to the start of the session. The time interval that produced the best correlation between traffic and players was assumed to be the interval relative to the start of the golfing session in which the peak hour will occur. Figure 3 represents the actual peak hour traffic volumes corresponding to number of golfers for the Saturday morning session. The coefficients of determination of the two regression curves are both very close to 1.0 indicating a good correlation of the actual data to the calculated regression curve. The traffic volumes are higher for total traffic than for private vehicles, because employees add trips to the total traffic.

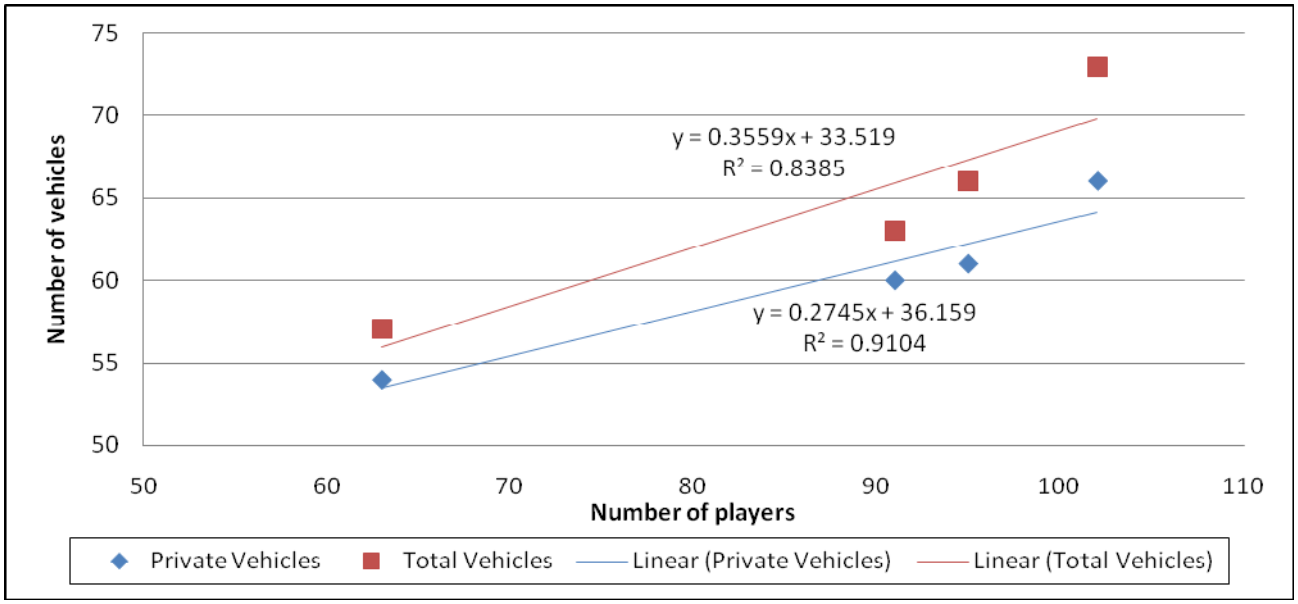

Figure 3: Peak hour volumes compared to players for Saturday morning incoming traffic

As expected, incoming traffic volumes all presented a good correlation (as determined by examining the R^2 values) to number of players. No correlation could be found that related the outgoing traffic peak associated with the morning golfing session and the number of players for either Friday or Saturday. The reason that this correlation does not exist has to do with the social nature of golf. Players may stay for lunch or a prize giving ceremony after their round of golf, but might not. Afternoon outgoing traffic presented a better correlation to number of players than the morning outgoing traffic, albeit that it was not high enough to be regarded as adequate. The maximum R^2 value was equal to 0.576 for Friday peak hour outgoing traffic, which is lower than the threshold R^2 value of 0.75 that represents a good fit of the regression curve to the actual data.

Conversion of winter traffic: summer player substitution

The equations for peak incoming traffic determined in Chapter 6.1 were considered accurate enough to allow summer incoming traffic volumes to be estimated. The number of players in each session for a typical summer Friday and Saturday (1 and 2 February 2008) were substituted into these equations as the independent x variable to estimate summer peak hour traffic volumes. Table 1 provides an example of the conversion from winter to summer traffic for Saturday morning. Table 1 includes the number of players in summer and the time of the first tee-off of the session. The time at which the peak hour is expected to occur was calculated by subtracting the relative time between the first tee-off and the actual peak hour (determined in Chapter 6.1) from the time of the first tee-off of the session.

Table 1: Incoming summer traffic for the Saturday morning session

Golf Club	Equation	Relative time of peak hour	Number of players **(x)**	Time of first tee-off	Peak hour incoming traffic **(y)**	Time of peak hour
Stellenbosch	$y = 0.356x + 31.519$	15 minutes before first tee-off of session	111	7:15	71	7:00-8:00
Strand			120	7:00	74	6:45-7:45
Durbanville			119	7:00	74	6:45-7:45
Mowbray			131	7:04	78	6:45-7:45

Albeit that the correlation for afternoon field outgoing traffic is poor, these equations were still used for conversion of winter traffic. No correlation for outgoing morning traffic was found; consequently summer traffic was not determined using those figures. The equations for total traffic determined in Chapter 6.1 have been used to convert the traffic, even though the accuracy is sometimes slightly less than for private vehicle traffic, but not greatly so. The reason for using these equations is that

trip generation requires total traffic and because morning traffic especially includes traffic by employees. Summer tee-off times are earlier than in winter causing private traffic to peak earlier than in winter, but it is expected that employees will arrive earlier as well. It has therefore been assumed that the use of the total traffic equations will describe summer traffic adequately.

Directional traffic calculations

The correlations determined in Chapter 6.1 and consequently, the summer traffic volumes calculated in Chapter 6.2 provide information regarding traffic in only one direction. A trip generation rate gives information regarding the total traffic in both directions. Directional traffic volumes are calculated by using a ratio that is supplied with the rate which gives the percentage of incoming and outgoing traffic compared to the total, written in the form “IN:OUT”, for example 35:65.

This ratio was calculated from the counted winter traffic for each period and golf club, as incoming and outgoing traffic volumes are known. It was assumed that this directional ratio would remain constant throughout the year. This enabled summer peak incoming traffic to be converted to outgoing traffic using Equation 1, allowing the total peak hour traffic required for the trip generation rate to be calculated.

$$outgoing\ traffic = \frac{\%OUT}{100} \times \frac{incoming\ traffic}{\frac{\%IN}{100}} \quad \textbf{(1)}$$

Trip generation

Methods of producing trip generation information

The average rate method is traditionally used for determining generated trips and is the method employed by *South African Trip Generation Rates* (Stander, Kruger, Coetzee, & Lamprecht, 1995). The rate (R) is defined as the number of trip ends (Q) per unit of independent variable (C) as indicated by Equation 2. The standard deviation of a set of data should also be provided with this average rate to indicate the confidence level or how widely dispersed the actual data points are.

$$R = \frac{\sum_{i=1}^{n} \frac{Q_i}{C_i}}{n} \quad \textbf{(2)}$$

It is beneficial to consider alternative methods of presenting trip generation rates, including the graphic plot method and the regression model. A graphic plot is a graph with the site specific characteristic (C) as the independent variable and the number of trips (Q) entered as the dependant variable. The plot graphically presents the relationship between actual traffic volumes and the independent characteristic. The average trip generation rate can be added to the plot as a straight line with a gradient equal to the rate. A graphic plot can often indicate the type of regression function that will best fit the traffic volume data.

Calculation of trip generation information

Trip generation rates were calculated for each peak hour on both Friday and Saturday. The peak hours that were considered are the morning adjacent street traffic peak hour (between 7:00 and 9:00), the afternoon adjacent street traffic peak hour (between 16:00 and 18:00) and the peak hour of the generator. The rates were determined for each of the four trip generation characteristics, which allowed the rate that provided the best correlation to traffic to be identified. These rates for the Saturday morning adjacent street traffic peak hour are summarised in Table 2 with the standard deviation associated with each characteristic. For each peak hour it was consistently determined that the starting period of the session provided the best correlation to golf course traffic.

Table 2: Trip generation rates for Saturday morning peak hour for each characteristic

	Trip generation characteristic			
	Area of course (ha)	Number of employees	Number of members	Starting period of session (min)
Trip generation rate	2.0308	1.8875	0.0601	0.2927
Standard deviation	1.5315	0.7141	0.0117	0.0095

DATA ANALSIS OF RESIDENTIAL GOLF ESATE TRAFFIC

Residential golf estates are multi-use developments, as stated in Chapter 3.1. The traffic generated by the golf course at a residential estate is entirely separate from that traffic produced for residential purposes, which is supported by the results of the traffic surveys. The traffic distributions show that residential traffic is unaffected by golf traffic and that golf traffic patterns are typical of those produced by recreational golf clubs. In this chapter, the applicability for the use of recreational golf course trip generation rates at residential golf estates is determined and any adaptation to the rates that are required is identified.

Comparative traffic volume – player correlations

The applicability of the determined recreational golf course trip generation rates to describe the golf related traffic at a residential golf course was established by examining the correlation between the number of players and the produced traffic volume. A particular correlation and regression equation was not determined as for recreational golf courses because the sample size of only two residential golf courses was not adequate for this purpose. Rather a general connection between residential golf traffic and the previously determined traffic – player correlations for recreational golf courses has been examined. An evident correlation would allow the rates defined in Chapter 6 to be applied to residential golf estates.

The method followed to determine the anticipated correlation is similar to the method used in Chapter 6.1. An example of the result of this analysis is presented in Figure 4. It is clear that traffic volumes increase as the number of players increases. The data points representing golf orientated traffic reflect this trend. The green points represent private golf traffic at residential golf estates, and the pink points indicate total golf orientated traffic, including that produced by employees of the golf club at the estate. These data points are relatively close to the linear regression curves that indicate the relationship of recreational golf traffic to number of players. The data points representing residential golf course traffic are all within the region described by recreational golf course traffic. This correlation was considered adequate enough to allow recreational golf course trip generation rates to be used to describe expected traffic volumes at residential golf estates.

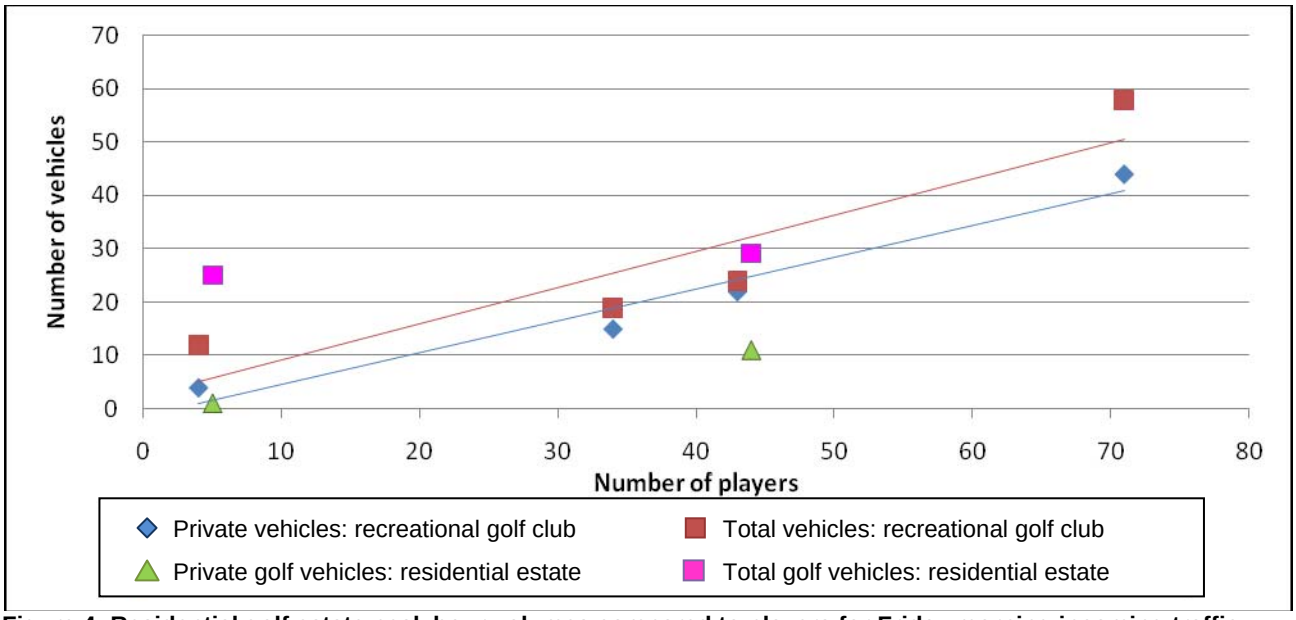

Figure 4: Residential golf estate peak hour volumes compared to players for Friday morning incoming traffic

Recommendations for golf purpose trip generation rates

Because of the multi-use nature of residential golf estates, internal trips can be expected. These internal golf purpose orientated trips are described by the trip generation rate for the golf land use of the estate. For traffic that is applied to the external highway system, these internal trips must be removed from the total trips estimated by the trip generation rate of the land use. *Trip Generation* (ITE, 1991) provides a method of removing internal or "captured" trips from the total generated traffic by applying a "capture rate". This capture rate is defined as a percentage reduction of forecasted trips.

The percentage of golf playing non-members compared to total players at a residential golf estate was considered as an appropriate capture rate. The number of non-members and members playing golf was determined by examining the time sheets that were obtained on the days that traffic surveys were conducted as well as for 1 and 2 February 2008. From this analysis it was found that on average 33% of the players were residents of the golf estate. The capture rate was therefore defined as 0.67. The peak traffic volume determined using the recreational golf course trip generation rate should be multiplied with the capture rate to estimate the number of vehicles added to adjacent street traffic.

SUMMARY OF TRIP GENERATION RATES

NO	LAND USE	CODE	UNIT	RECOMMENDED TRIP GENERATION RATES		
				PERIOD	RATE	SPLIT IN:OUT
21	Golf Course Recreational golf course to use rates as is Residential golf estate to multiply resulting traffic by 0.67	430	Starting period of session *	Friday A.M. Peak	0.36	80:20
				Friday P.M. Peak	0.25	30:70
				Friday Generator	0.355	65:35
				Saturday A.M. Peak	0.29	95:5
				Saturday P.M. Peak	0.14	10:90
				Saturday Generator	0.350	80:20

* The starting period of the session is the time allowed for all golfers in a session to begin their game and is defined by golf course management. For a two-tee start format double this time.

Figure 5: Trip generation rates summarized in the format of South African rates

CONCLUSION

It was determined that identifiable and predictable traffic patterns are produced at all recreational and residential golf estates from traffic counts conducted during winter. It was found that these patterns could be explicitly described in terms of a relationship between peak hour traffic volumes and the number of golfers playing in an associated session. This relationship was found to be time and direction related, allowing summer traffic volumes to be estimated with a high level of confidence.

The estimated summer traffic volumes were used to determine the required peak hour trip generation rates. These peaks occur during the adjacent street peak hours in the early morning and late afternoon, as well as late in the morning which constitutes the generator peak hour. The best correlation between a characteristic and traffic was consistently found to be described by the starting period of a session. It was determined that the same trip generation information used to describe recreational golf course traffic, could be used to estimate the golf related traffic at residential golf estates. A capture rate was defined with a value of 0.67, to reduce the golf orientated traffic volumes determined with the trip generation rates for residential golf estates.

This study was undertaken so that trip generation information regarding golf courses in South Africa could be found and used by traffic engineers. The results can be used when conducting traffic impact assessments of proposed golf estates and can aid in the correct design of entrances, internal roads and parking facilities on the golf course site. It is recommended that the determined summer trip generation rates be used for this purpose.

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