QUANTIFICATION OF THE NATURAL VARIATION IN TRAFFIC FLOW ON SELECTED NATIONAL ROADS IN SOUTH AFRICA

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ABSTRACT

Transport and traffic movement is complex and ever-changing. The movement of people and the means by which they travel are directly influenced by the transportation systems available to them. Engineers have the responsibility to provide safe, efficient and economical transportation services, and in order to do this, have to understand the variable nature of traffic.

Numerous variations in traffic patterns exist due to the continuously changing movements of people. This study aims to quantify these variations to provide engineers with the tools to understand existing traffic conditions and to allow effective future planning and design.

Various types of traffic variations exist, including: variation of traffic over a single day (hourly variation), a week (daily variation), between months of the year (monthly variation), and the annual growth of traffic (annual variation). These variations are analysed using data from 18 counting stations across South Africa.

Modification Factors are introduced to quantify the traffic variations. Modification Factors are generated for each type of traffic pattern, providing a tool to understand the variable nature of traffic. This research was conducted at Stellenbosch University as the final year research dissertation of the main author towards the degree BEng (Civil).

1 INTRODUCTION

1.1 Background

The primary purpose of transportation development is to enable people to travel safely, comfortably, effectively and economically. In order for engineers to develop and improve the existing transportation services, they need to fully understand the status quo of traffic patterns and accurately forecast future traffic conditions.

Evaluating existing traffic conditions can be extremely complex due to the constant change in the movement patterns of people. It is this continuous variation that causes the natural patterns observed in traffic flow over time. Understanding the patterns of the movement of people is crucial for the effective quantification of the variation in traffic flow, as well as for forecasting representative traffic volumes for facility design purposes. Traffic variation patterns include: variation of traffic over a day (hourly variation), a week (daily variation), months of the year (monthly variation), and annual growth (annual variation).

1.2 Purpose of Study

There is significant hourly, daily, monthly and annual variation in traffic flow. This study aims to quantify these traffic variations in order to develop a tool to effectively analyse and understand the patterns of existing traffic flow. Unique *Modification Factors* were developed in this research to describe the traffic patterns.

1.3 Assumptions and Limitations

For the purpose of this study, some assumptions and limitations are applicable to the analysis of data and traffic conditions in general. Firstly, the study does not differentiate between urban and rural areas within a region. The majority of the data analysed was obtained along National Routes clustered around urban areas and therefore the results of this research are applicable to higher order roads in urban and peri-urban areas. Further studies are required to analyse the difference of traffic patterns observed in rural areas and various road classes. The source data used in this study comes from the CTO (Comprehensive Traffic Observation) Stations on the national road network.

Secondly, traffic data was grouped into regions and it is therefore assumed that traffic observed around Pretoria, for example, could be aggregated to provide a representative traffic pattern for that region. Aggregation was weighted according to traffic volume. Thirdly, The CTOSs record mixed traffic data and this study considered all vehicle classifications simultaneously. No differentiation was made with regard to traffic volume of passenger vehicles, public transport or heavy vehicles. The variations quantified in this report might not be applicable to all transport modes.

Lastly, limited count stations were analysed per region (one to three count stations per region). The accuracy of the representative traffic variations of a region is limited by the number of counting stations available in that region. This research provides a proof of concept of a new method to define traffic variation using Modification Factors. Further research to refine the Modification Factors in particular regions may still be required.

2 TRAFFIC VARIATION

2.1 Observed Traffic Variation

Traffic variations over a day, week and year are well documented. A study conducted in 1991 by Jordaan and Van As investigated the hourly variation of traffic throughout a day. They plotted 15 minute traffic counts throughout the day as a proportion of the total daily traffic volume in one direction of travel for each day of the week using data collected over a three year period (Jordaan & As, 1991). This study indicated that while daily flows (veh/day) vary between days of the week, the traffic flow pattern indicated by the proportion of traffic during any particular 15 minute interval, remained consistent over the study period at any particular location. Additionally, the hourly variation traffic pattern also remained relatively constant between days of the week, with slight variation of the afternoon peak on a Friday which started earlier.

Monthly variation over a year that was investigated by researchers in Turkey, which indicated monthly traffic variations affected by season, climate of the area under investigation, as well as proximity to tourist attractions. Traffic volume was found to increase during the summer, particularly at sites with high tourist numbers, however this effect was less significant in areas with a very hot climate (Karacasu, et al., 2011).

2.2   Adjustment of Traffic Counts

Seasonality can be factored out of traffic data to prepare a traffic model for a neutral day, representative of general traffic conditions, by adjusting collected traffic volumes using seasonal factors (Chauke, 2015). These factors can be prepared from continuous traffic counts at permanent count stations. It is considered the global best practice to prepare a representative transport model using traffic from a neutral month with no seasonal influence (Chauke, 2015).

The design of transport infrastructure is usually based on the 30th highest hourly traffic volume (Van As & Joubert, 1989). If the highest recorded hourly traffic volume was to be used, the road would be overdesigned, while using the average hourly volume will result in a road that is oversaturated for much of the time. The K-Factor is used to relate Annual Average Daily Traffic (AADT) to the 30th highest hourly traffic volume. On roads with high recreational traffic (high peaking), a K-Factor of 0.25 is recommended, indicating that 25% of the AADT represents the hourly traffic volume to be used in road design. A K-Factor of 0.12 is recommended on roads with low peaking (Van As & Joubert, 1989).

3   METHODOLOGY

3.1   Introduction

Typically, traffic engineering analyses and planning exercises use manually counted traffic volumes surveyed on one day during an assumed peak period. This traffic volume is then assumed to be representative of the peak traffic flow for that specific road and is used for traffic design purposes. This method could potentially result in inaccuracies in terms of variations in traffic patterns that are unaccounted for.

The purpose of this study is to quantify the four identified traffic variation patterns that exist in traffic flow. To account for these variations (hourly, daily, monthly, annual), this study proposes Modification Factors for each type of variation. The Modification Factors can also be used to modify observed hourly volumes or Average Daily Traffic (ADT) volumes on similar roads to obtain typical maximum traffic volume values which can be used for design purposes in traffic engineering.

3.2 Source Data

The source data that was used for the development of the Modification Factors was collected at Comprehensive Traffic Observation Stations (CTOSs) on national routes around South Africa located in the vicinity of urban centres. The observed CTOSs are located outside the city centres on the national roads providing access to cities. Figure 1 presents a map of the eighteen CTOSs that were analysed for this research. The stations were classified into ten selected regions, namely: Bloemfontein, Cape Town, Durban, Emahleni, Kimberley, Polokwane, Port Elizabeth, Potchefstroom, Pretoria and Vryburg.

The data used in this research was recorded from 1 January 2007 to 31 October 2015. It is important to note that some days were not recorded, which could be due to system failure or down time for maintenance. Due to these gaps in the data, total volume cannot be used to determine traffic flow patterns. Therefore, average traffic flows were used to compare the variation between different hours, days and months. By using averages, the blank data is omitted from the analysis, i.e. zero counts were excluded by dividing the total volume by the number of hours or days of data that was available.
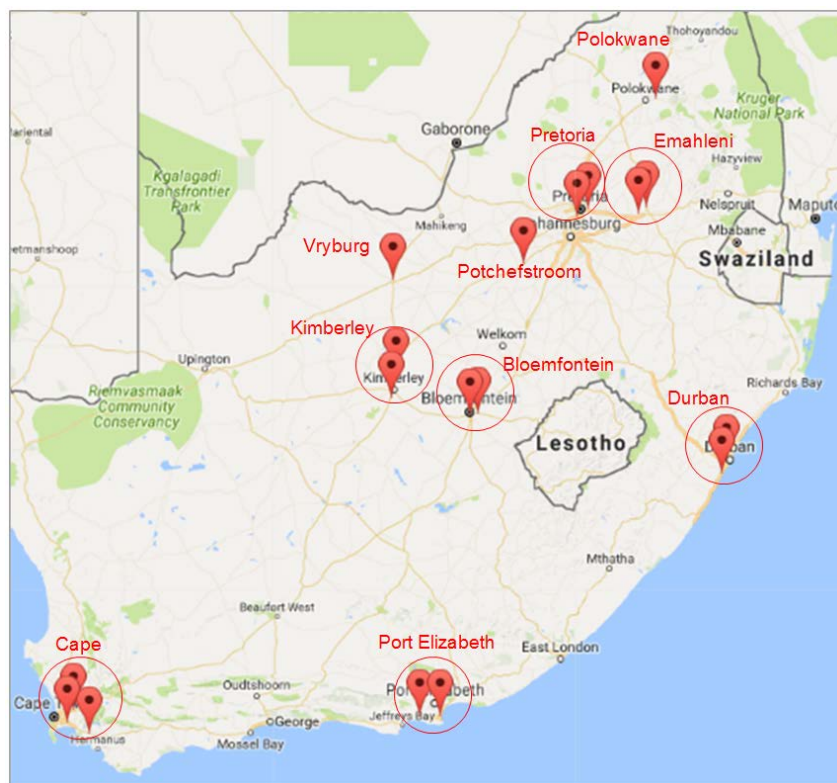

Figure 1: Syntell Counting Stations

3.3 Calculation of Modification Factors

A unique set of *Modification Factors* were developed during this research to quantify traffic pattern variation. Hourly Modification Factors identify the peak hour in a specific day. Daily Modification Factors indicate the day of the week with the highest daily volume. Monthly Modification Factors provide the peak traffic month. Annual variations can be reduced to a growth factor, with traffic volume increasing annually.

The Modification Factors indicate relative traffic volume as ratios from 0 to 1, with 1 representing the time frame with the maximum hourly, daily or monthly volume. The Modification Factors are calculated by dividing the specific average volume at a count station (hour, day or ADT of a specific month) by the maximum corresponding volume of the study period. By calculating a factor, traffic volumes of different days and months can be compared. Additionally, factors allow traffic patterns at different locations with significantly different daily and hourly traffic volumes to be compared.

The Modification Factors were calculated for every counting station within the region. A weighted average of traffic volumes were then determined for the region and used to calculate the Modification Factors of each region. The Modification Factors of every region were then also used to calculate a single, average factor for South Africa.

4   QUANTIFICATION OF VARIATION IN TRAFFIC FLOW

4.1   Hourly Variation

Hourly variations are observed over a full day. The hourly variation pattern is subject to many factors such as work hours, school hours, traffic congestion and road category. In most cases, a large difference exists between weekday and weekend traffic patterns. Therefore, weekday and weekend traffic volumes were analysed separately to produce two sets of Hourly Modification Factors.

The Hourly Modification Factors are the ratio of the traffic volume during a particular hour of the day to the maximum hourly traffic volume of the same day. The Hourly Modification Factor is therefore equal to 1.00 in the peak hour and will decrease as the difference in hourly volume from the peak hour increases. The Modification Factor graph therefore has the same shape as the corresponding hourly traffic volumes. The weekday hourly Modification Factors for the selected regions are shown in Figure 2, with the red dashed line indicating average factors for all observed data sets in South Africa.

	00:00-01:00	01:00-02:00	02:00-03:00	03:00-04:00	04:00-05:00	05:00-06:00	06:00-07:00	07:00-08:00	08:00-09:00	09:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19:00	19:00-20:00	20:00-21:00	21:00-22:00	22:00-23:00	23:00-00:00
Cape Town	0.070	0.048	0.042	0.050	0.100	0.297	0.702	0.954	0.814	0.780	0.769	0.770	0.771	0.770	0.778	0.842	0.972	1.000	0.732	0.439	0.299	0.228	0.164	0.100
Port Elizabeth	0.040	0.026	0.021	0.021	0.038	0.118	0.391	1.000	0.691	0.548	0.544	0.551	0.565	0.583	0.607	0.637	0.878	0.702	0.368	0.246	0.170	0.133	0.096	0.057
Bloemfontein	0.068	0.051	0.043	0.047	0.077	0.193	0.624	1.000	0.577	0.559	0.561	0.563	0.578	0.599	0.613	0.664	0.849	0.858	0.562	0.369	0.260	0.196	0.145	0.106
Durban	0.044	0.039	0.032	0.036	0.087	0.304	0.831	1.000	0.693	0.600	0.601	0.611	0.614	0.627	0.654	0.741	0.976	0.832	0.534	0.346	0.235	0.167	0.109	0.058
Kimberley	0.092	0.074	0.074	0.079	0.140	0.289	0.818	0.932	0.829	0.856	0.853	0.856	0.860	0.904	0.939	0.945	1.000	0.991	0.694	0.464	0.335	0.247	0.179	0.125
Pretoria	0.031	0.019	0.017	0.027	0.085	0.313	0.880	1.000	0.783	0.574	0.507	0.502	0.512	0.530	0.559	0.691	0.941	0.905	0.523	0.271	0.169	0.114	0.075	0.040
Emalahleni	0.051	0.032	0.031	0.048	0.152	0.412	0.817	0.904	0.689	0.681	0.687	0.706	0.729	0.746	0.776	0.826	1.000	0.953	0.627	0.402	0.268	0.178	0.113	0.066
Potchefstroom	0.083	0.062	0.069	0.132	0.293	0.476	0.784	0.922	0.778	0.790	0.827	0.834	0.854	0.891	0.937	0.948	1.000	0.850	0.607	0.458	0.334	0.234	0.168	0.115
Polokwane	0.057	0.041	0.038	0.044	0.078	0.261	0.616	0.772	1.000	0.677	0.629	0.616	0.618	0.634	0.667	0.717	0.761	0.884	0.931	0.664	0.386	0.225	0.141	0.091	0.057
Vryburg	0.056	0.035	0.028	0.049	0.077	0.197	0.613	0.958	0.796	0.845	0.859	0.852	0.873	0.901	0.958	0.979	1.000	0.993	0.655	0.415	0.268	0.176	0.113	0.070
RSA	0.059	0.043	0.040	0.053	0.113	0.286	0.723	0.967	0.733	0.686	0.682	0.686	0.699	0.722	0.754	0.803	0.950	0.902	0.597	0.380	0.256	0.181	0.125	0.079

Figure 2: Weekday Hourly Modification Factors

The hourly traffic pattern over a typical weekday is very consistent at all observed CTOSs. Traffic between midnight and 5:00 AM is typically less than 10% of the peak hour traffic. A well-defined, condensed peak is observed between 7:00 and 8:00 AM daily, with lower midday volumes and a more extended peak period in the afternoon between 16:00 and 18:00 PM. Some regions are observed to have a maximum hourly traffic volume (indicated with a Modification Factor of 1) in the morning peak, while other regions have maximum peaks in the afternoon.

The different regions are observed to have high variations of traffic proportion in the inter-peak period. Pretoria, Port Elizabeth and Bloemfontein have the lowest inter-peak values of between 50% and 60% of peak traffic during the midday period. The three regions that indicate very high inter-peak values: Kimberley, Potchefstroom and Vryburg have approximately 85% of peak hourly volume during the same midday time interval, increasing steadily towards the afternoon peak hour. This could be due to the nature of the regions, with these smaller cities exhibiting traffic patterns that are similar to rural areas, where morning and afternoon peaks are usually found to be less pronounced.

The weekend Hourly Modification Factors for weekend hourly traffic variation are shown in Figure 3. Unlike the anticipated AM and PM peak pattern of weekday traffic, weekend traffic (Saturdays and Sundays combined) displays a long single peak later in the day. Little variation in the travel patterns is observed in the different regions. The weekend hourly profile has a completely different shape, consisting only of one peak that exists in the middle of the day (around 13:00-16:00).
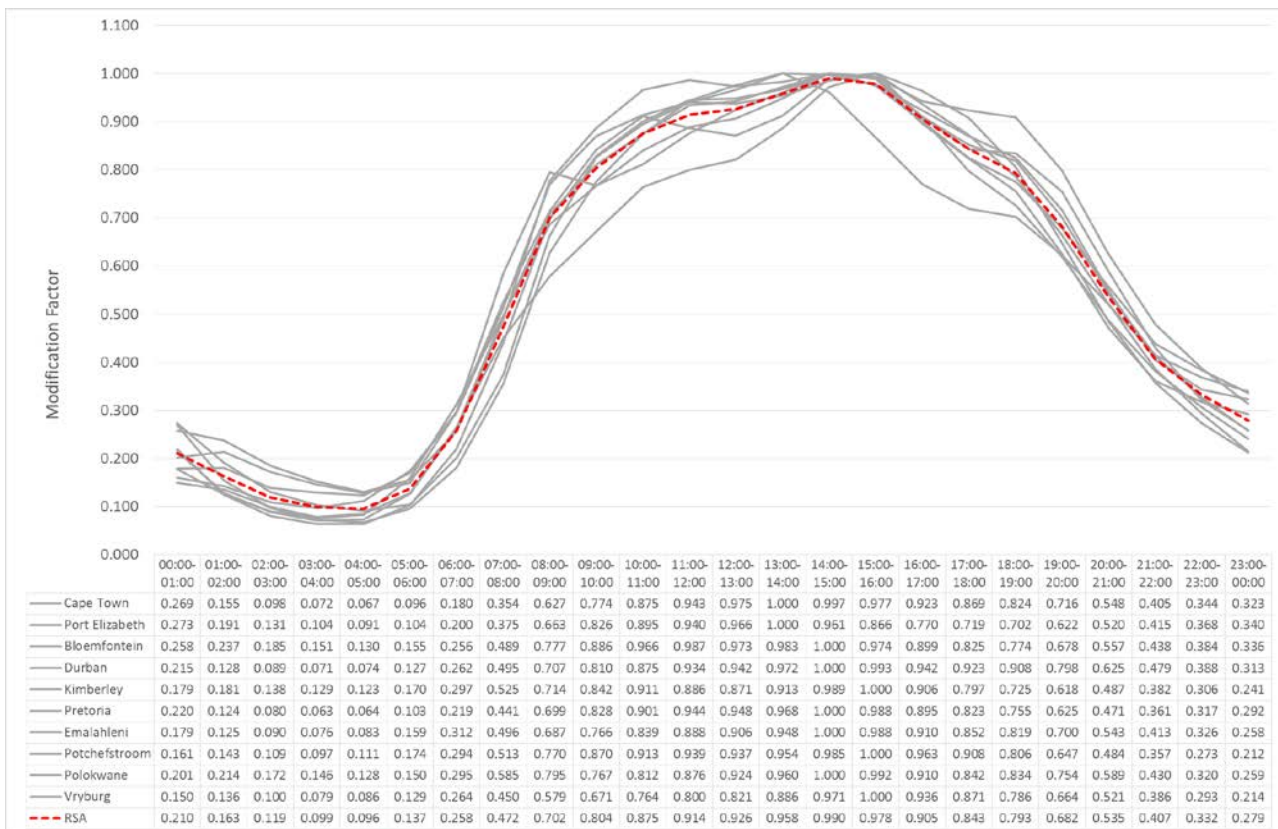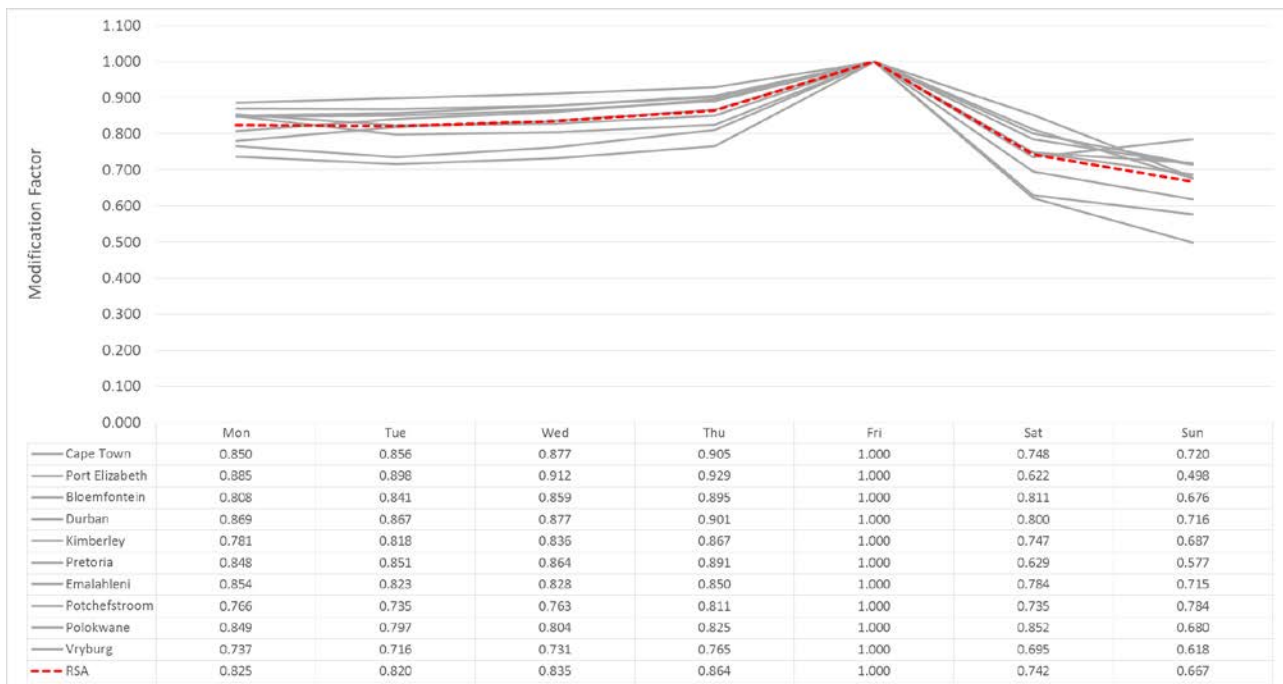
	00:00-01:00	01:00-02:00	02:00-03:00	03:00-04:00	04:00-05:00	05:00-06:00	06:00-07:00	07:00-08:00	08:00-09:00	09:00-10:00	10:00-11:00	11:00-12:00	12:00-13:00	13:00-14:00	14:00-15:00	15:00-16:00	16:00-17:00	17:00-18:00	18:00-19:00	19:00-20:00	20:00-21:00	21:00-22:00	22:00-23:00	23:00-00:00
Cape Town	0.269	0.155	0.098	0.072	0.067	0.096	0.180	0.354	0.627	0.774	0.875	0.943	0.975	1.000	0.997	0.977	0.923	0.869	0.824	0.716	0.548	0.405	0.344	0.323
Port Elizabeth	0.273	0.191	0.131	0.104	0.091	0.104	0.200	0.375	0.663	0.826	0.895	0.940	0.966	1.000	0.961	0.866	0.770	0.719	0.702	0.622	0.520	0.415	0.368	0.340
Bloemfontein	0.258	0.237	0.185	0.151	0.130	0.155	0.256	0.489	0.777	0.886	0.966	0.987	0.973	0.983	1.000	0.974	0.899	0.825	0.774	0.678	0.557	0.438	0.384	0.336
Durban	0.215	0.128	0.089	0.071	0.074	0.127	0.262	0.495	0.707	0.810	0.875	0.934	0.942	0.972	1.000	0.993	0.942	0.923	0.908	0.798	0.625	0.479	0.388	0.313
Kimberley	0.179	0.181	0.138	0.129	0.123	0.170	0.297	0.525	0.714	0.842	0.911	0.886	0.871	0.913	0.989	1.000	0.906	0.797	0.725	0.618	0.487	0.382	0.306	0.241
Pretoria	0.220	0.124	0.080	0.063	0.064	0.103	0.219	0.441	0.699	0.828	0.901	0.944	0.948	0.968	1.000	0.988	0.895	0.823	0.755	0.625	0.471	0.361	0.317	0.292
Emalahleni	0.179	0.125	0.090	0.076	0.083	0.159	0.312	0.496	0.687	0.766	0.839	0.888	0.906	0.948	1.000	0.988	0.910	0.852	0.819	0.700	0.543	0.413	0.326	0.258
Potchefstroom	0.161	0.143	0.109	0.097	0.111	0.174	0.294	0.513	0.770	0.870	0.913	0.939	0.937	0.954	0.985	1.000	0.963	0.908	0.806	0.647	0.484	0.357	0.273	0.212
Polokwane	0.201	0.214	0.172	0.146	0.128	0.150	0.295	0.585	0.795	0.767	0.812	0.876	0.924	0.960	1.000	0.992	0.910	0.842	0.834	0.754	0.589	0.430	0.320	0.259
Vryburg	0.150	0.136	0.100	0.079	0.086	0.129	0.264	0.450	0.579	0.671	0.764	0.800	0.821	0.886	0.971	1.000	0.936	0.871	0.786	0.664	0.521	0.386	0.293	0.214
RSA	0.210	0.163	0.119	0.099	0.096	0.137	0.258	0.472	0.702	0.804	0.875	0.914	0.926	0.958	0.990	0.978	0.905	0.843	0.793	0.682	0.535	0.407	0.332	0.279

Figure 3: Weekend Hourly Modification Factors

4.2   Daily Variation

Daily variations are observed over the days of the week. These variations are subject to many factors such as work week, weekend days, public holidays and road category. Daily Modification Factors are a ratio of the daily volume of any particular day, to the daily traffic volume of the day of the week with the highest traffic volume. The average daily variation Modification Factor for each region, as well as the average for South Africa (red dashed line) are presented in Figure 4. It is important to note that this information is averaged for every week over a year, and therefore has minimal influence of public holidays and school holiday periods.

Figure 4 indicates very consistent daily variations across all regions with a clear and consistent peak on Friday. Weekday daily traffic volumes from Monday to Thursday are between 7% and 28% lower than the Friday peak. Weekend daily traffic volumes are considerably lower (20 to 50%) than Friday volumes. These variations are expected in the urban areas where the data was collected, as traffic is higher during the week due to commuters travelling to and from work.
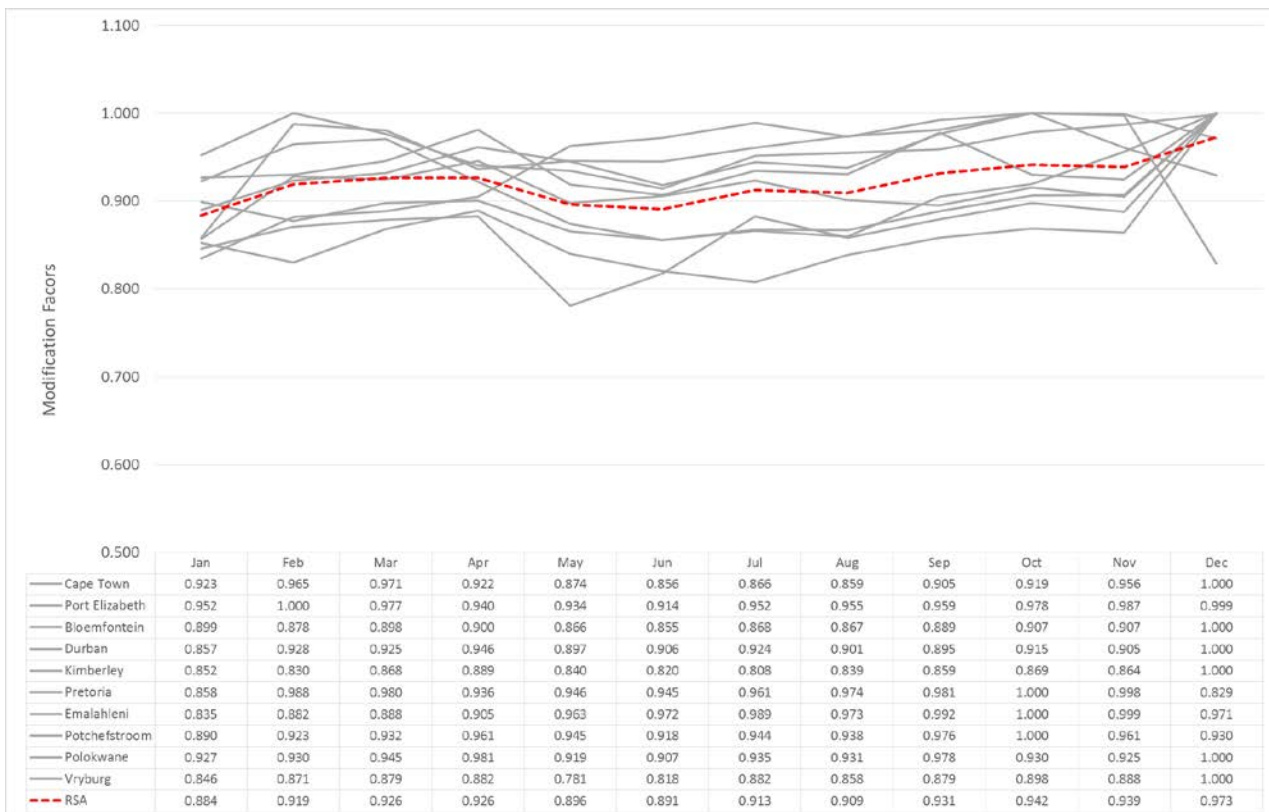
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
—— Cape Town	0.850	0.856	0.877	0.905	1.000	0.748	0.720
—— Port Elizabeth	0.885	0.898	0.912	0.929	1.000	0.622	0.498
—— Bloemfontein	0.808	0.841	0.859	0.895	1.000	0.811	0.676
—— Durban	0.869	0.867	0.877	0.901	1.000	0.800	0.716
—— Kimberley	0.781	0.818	0.836	0.867	1.000	0.747	0.687
—— Pretoria	0.848	0.851	0.864	0.891	1.000	0.629	0.577
—— Emalahleni	0.854	0.823	0.828	0.850	1.000	0.784	0.715
—— Potchefstroom	0.766	0.735	0.763	0.811	1.000	0.735	0.784
—— Polokwane	0.849	0.797	0.804	0.825	1.000	0.852	0.680
—— Vryburg	0.737	0.716	0.731	0.765	1.000	0.695	0.618
- - - RSA	0.825	0.820	0.835	0.864	1.000	0.742	0.667

Figure 4: Daily Modification Factors

4.3   Monthly Variation

Monthly variations occur over the months of the year. Monthly variations are subject to factors such as school terms and holidays, religious holidays and seasons. Monthly Modification Factors are the ratio of the of the monthly traffic volume to the maximum monthly volume, results are shown in Figure 5. Monthly traffic was evaluated as an Average Daily Traffic (ADT) volume.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cape Town	0.923	0.965	0.971	0.922	0.874	0.856	0.866	0.859	0.905	0.919	0.956	1.000
Port Elizabeth	0.952	1.000	0.977	0.940	0.934	0.914	0.952	0.955	0.959	0.978	0.987	0.999
Bloemfontein	0.899	0.878	0.898	0.900	0.866	0.855	0.868	0.867	0.889	0.907	0.907	1.000
Durban	0.857	0.928	0.925	0.946	0.897	0.906	0.924	0.901	0.895	0.915	0.905	1.000
Kimberley	0.852	0.830	0.868	0.889	0.840	0.820	0.808	0.839	0.859	0.869	0.864	1.000
Pretoria	0.858	0.988	0.980	0.936	0.946	0.945	0.961	0.974	0.981	1.000	0.998	0.829
Emalahleni	0.835	0.882	0.888	0.905	0.963	0.972	0.989	0.973	0.992	1.000	0.999	0.971
Potchefstroom	0.890	0.923	0.932	0.961	0.945	0.918	0.944	0.938	0.976	1.000	0.961	0.930
Polokwane	0.927	0.930	0.945	0.981	0.919	0.907	0.935	0.931	0.978	0.930	0.925	1.000
Vryburg	0.846	0.871	0.879	0.882	0.781	0.818	0.882	0.858	0.879	0.898	0.888	1.000
RSA	0.884	0.919	0.926	0.926	0.896	0.891	0.913	0.909	0.931	0.942	0.939	0.973

Figure 5: Monthly Modification Factors

In most regions, December had the highest traffic, likely due to the annual summer holiday. Only Pretoria, Emalahleni and Potchefstroom do not peak in December (consistent peak in October for all three regions). Throughout the year, regions display very different patterns. Cape Town and Port Elizabeth have clear summer peaks, with between 10 and 15 % lower volumes in winter months. Traffic in Kimberley, Bloemfontein and Vryburg remain consistently low from January to November at between 80 and 90% of December traffic volumes. Pretoria traffic remains in at approximately 95% of peak traffic (October) throughout the year.

The monthly variations are high when considering one region at a time. However, when the average monthly variations are determined for the entire country (red dashed line in Figure 5), the monthly variations are less significant.

4.4   Annual Variations

Figure 6 indicates the progression in the year-on-year traffic growth rate from 2008 to 2014 compared to the growth rate of the South African GDP (Viljoen, 2017). The traffic growth rate in South Africa seems to follow the historic economic growth rate. There was a significant decrease in traffic from 2007 to 2008 (-1.5%) that was observed at the majority of count stations considered in this research, this was followed by a reduction in GDP from 2008 to 2009. Both traffic and SA GDP were likely affected by the global economic recession of 2008. Between 2009 and 2010, both traffic and GDP grew by over 3.5%, with lower growth rates since. Further research is required to quantify the relationship between

GDP and traffic growth. The average compound traffic growth rate over the entire study period from 2007 to 2015 was calculated to be +1.59% per annum.
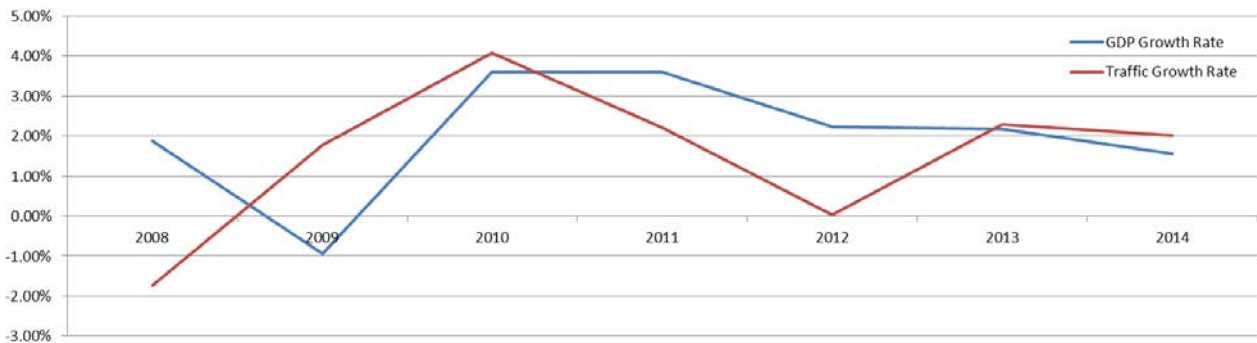
Figure 6: Economic vs. Traffic Growth rate in South Africa

5   APPLICATION OF MODIFICATION FACTORS

The four types of Modification Factors generated in this study to quantify the variation in traffic flow can also be used to calculate typical traffic volumes when used as adjustment factors, discussed below.

Hourly Modification Factors can modify an observed hourly traffic volume of a specific day to any other hourly traffic volume of that same day, according to Equation 1. This is useful if for example, an hourly traffic volume is required that was not included in a traffic survey.

$$AV = CV \left(\frac{MF_{AVH}}{MF_{CVH}} \right) \qquad \textbf{(1)}$$

Where: AV = Adjusted Volume (veh/h)
           CV = Counted Volume (veh/h)
           MF_{AVH} = Hourly Modification Factor for hour required
           MF_{CVH} = Hourly Modification Factor for hour observed

Daily Modification Factors adjust an observed daily volume to an equivalent daily volume for any other day of the week. If Daily Modification Factors are combined with Hourly Modification Factors, an hourly volume on any particular day can be estimated from the observed hourly volume counted on another day and at a different hour, according to Equation 2.

$$AV = CV \left(\frac{MF_{AVH}}{MF_{CVH}} \right) \left(\frac{MF_{AVD}}{MF_{CVD}} \right) \qquad \textbf{(2)}$$

Where: MF_{AVD} = Daily Modification Factor for day required
           MF_{CVD} = Daily Modification Factor for day observed

Similarly, Monthly Modification Factors can also be incorporated to estimate typical hourly traffic volumes in different month from that which was observed, according to Equation 3.

$$AV = CV \left(\frac{MF_{AVH}}{MF_{CVH}}\right)\left(\frac{MF_{AVD}}{MF_{CVD}}\right)\left(\frac{MF_{AVM}}{MF_{CVM}}\right) \quad\quad (3)$$

Where: MF_{AVM} = Monthly Modification Factor for month required

                  MF_{CVM} = Monthly Modification Factor for month when traffic was observed

Finally, the traffic volume at some time in the future can also be predicted by applying a growth rate to the hourly traffic volume, according to Equation 4.

$$AV = CV \left(\frac{MF_{AVH}}{MF_{CVH}}\right)\left(\frac{MF_{AVD}}{MF_{CVD}}\right)\left(\frac{MF_{AVM}}{MF_{CVM}}\right)\left(1 + \frac{i}{100}\right)^n \quad\quad (4)$$

Where: i = The Annual Growth of a Site/Region/Country (in percentage)

                  n = The Difference in Years from Counted Volume to Adjusted Volume

The Modification Factors can be used to determine typical maximum hourly traffic flows. For maximum peak hour flow, MF_{AVH}, MF_{AVD} and MF_{AVM} should be set to 1.00 (to give volume in the peak hour on a Friday and in the month with the highest traffic). The factors for each region should be applied accordingly due to the high variation in Modification Factors between regions. Additionally, the factors indicated should only be applied to traffic on national routes until further research has been conducted into the applicability of these traffic patterns on all road classes. Further applications of the Modification Factors include the estimation of typical Average Daily Traffic (ADT) volumes from hourly volume, and a representative ADT in a particular month of the year.

As previously indicated, road design is usually based on the 30th highest hourly volume (Van As & Joubert, 1989). It is proposed that the above described method for applying Modification Factors can be used to estimate an approximation of the 30th highest hourly volume. The Hourly and Daily Factors allow the peak hour traffic volume on a Friday to be estimated from any hourly traffic count. The Monthly Factor (which is based on ADT for each month of the year), will convert this to an hourly volume typical of the month with the highest traffic. This will consider the highest typical hourly volume without taking into account arbitrary peaks due to incidents or events. Future research should evaluate the use of Modification Factors to estimate a reasonable 30th highest hourly traffic volume.

6   CONCLUSION & RECOMMENDATIONS

6.1   Conclusions

Traffic displays repetitive patterns. Traffic pattern variations can be observed over a day (hourly variation), a week (daily variation), a whole year (monthly variation) and annually. Weekday hourly variations follow a distinct pattern in urban areas, with a typical morning and afternoon peak period. Weekend hourly variation has a long peak traffic period that gradually builds during midday on a Saturday and Sunday. Observed daily traffic patterns indicate that all researched regions experience peak daily traffic flow on a Friday. Mondays to Thursdays experience approximately 7 to 28 % lower daily traffic volumes than Friday and weekends between 20 and 50% lower than peak Friday daily traffic volumes.

Monthly traffic patterns were observed to vary considerably between regions. Most regions peak during December. It was found to be more accurate to evaluate monthly variations according to region, rather than using the average for the country. Annual traffic growth was observed to fluctuate in consecutive years, with an apparent link to economic factors. An average annual compound growth observed over all CTOSs included in this study for the period from January 2007 to October 2015 of 1.59% per annum was obtained.

The accuracy of the Modification Factors are influenced by the number of counting stations that are analysed in each region. Limited CTOSs were evaluated in this research to establish a method of calculating and applying Modification Factors. Modification Factors can be useful when conducting a traffic analysis, especially if insufficient source data is available. Accurate Modification Factors can eliminate the risk of underestimating design traffic flow which could lead to insufficient design standards. Modification Factors vary between regions and it is therefore recommended that they only be applied to traffic in the regions in which the factors were determined.

6.2   Recommendations for Future Research

Only traffic on higher order national routes in the vicinity of large urban centres were analysed in this research. The application of the determined Modification Factors to other road classes should be investigated. Additionally, the Modification Factors should also be evaluated for both rural and urban areas separately to determine if natural traffic variations are consistent on different road categories and how much these traffic patterns differ between rural and urban areas in the same region.

The application of Modification Factors to estimate particular design volumes such as the 30th highest hourly traffic volume is a potential use case for the Modification Factors estimated in this paper, and should be considered in future research.

Finally, this research was conducting using total traffic volumes. It would be valuable to determine similar Modification Factors for various classifications of vehicles (passenger vehicles, light delivery vehicles, heavy vehicles and public transport services).

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