AN INVESTIGATION INTO TEMPRO GROWTH FACTORS

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1. INTRODUCTION

This research was originally the dissertation element for the Southampton University MSc Transportation Planning and Engineering in September 2015. It investigates the performance of TEMPro growth factors, used to ascertain best-guess estimates of future travel demand. The growth factors reliability is crucial to ensure confidence in the capacity provision and consequent financial investment.

Following a retrospective analysis of the difference in TEMPro growth factors and observed growth, the reliability and realism of the predictions were critically discussed. This project focuses on a case study of three Devon towns; Barnstaple, Newton Abbot and Tiverton. The data analysed covers the period of 2001-2014, with TEMPro forecasts obtained for up to 2030.

The key findings highlighted that the TEMPro growth factors appear to predict continuous growth, despite the flat observed growth profile. The TEMPro overforecasting was such that hypothesis testing indicated the observed growth was significantly less.

Having analysed the historical performance of TEMPro, an attempt to construct a predictive model which generates more realistic growth factors has been undertaken. Using a Generalised Linear Model (GLM) for Gamma and Gaussian distributions, a range of different models were produced and growth factors generated. These growth factors are broadly in line with the observed growth from 2010-2014, with the models demonstrating a much flatter profile than the TEMPro predictions.

Transport planners require growth factors for several decades into the future. To cater for this, growth factors have been generated for long range forecasts up to 2030. These extend the flat profiles previously generated and, should the recent trend of traffic growth continue, it could be assumed that the predictions generated in this project would be more reliable than TEMPro.

This project concludes that TEMPro growth factors are hindered by consistent overforecasting arising from a model assuming constant growth. Strong evidence suggests this is not the trend observed in recent past across the UK. To instil confidence in practitioners who rely on these predictions, it would be prudent for other models to be investigated, such as those explored in this project. The potential for further areas of research is vast; although this project justifies the choice of Devon as a study area representative of elsewhere in the UK, further studies would be needed to fully understand the extent TEMPro is overforecasting on a national scale.

2. TEMPRO

2.1. What is TEMPro?

TEMPro is a program developed by the Department for Transport (DfT) providing traffic growth projections used in transport models and intended to act as a nationwide standardised distribution of growth in trip ends. This allows consistency between different areas of the country when justifying transport proposals (DfT, 2009).

TEMPro relies on datasets, the most recent being 6.2. Also available are 6.1 and the earliest, 5.4. Dataset 6.2 addresses numerous outdated features of 5.4. These changes were prompted by the recession in an attempt to ensure the datasets were producing realistic predictions (WSP, 2011). The DfT advise that the 6.2 dataset should be viewed as definitive, with the 5.4 dataset available only for the purpose of checking historic work (DfT, 2011).

TEMPro presents the output of the data from the National Trip End Model (NTEM) which is the final step in the TEMPro system (DfT, 2009), shown in Figure 1.

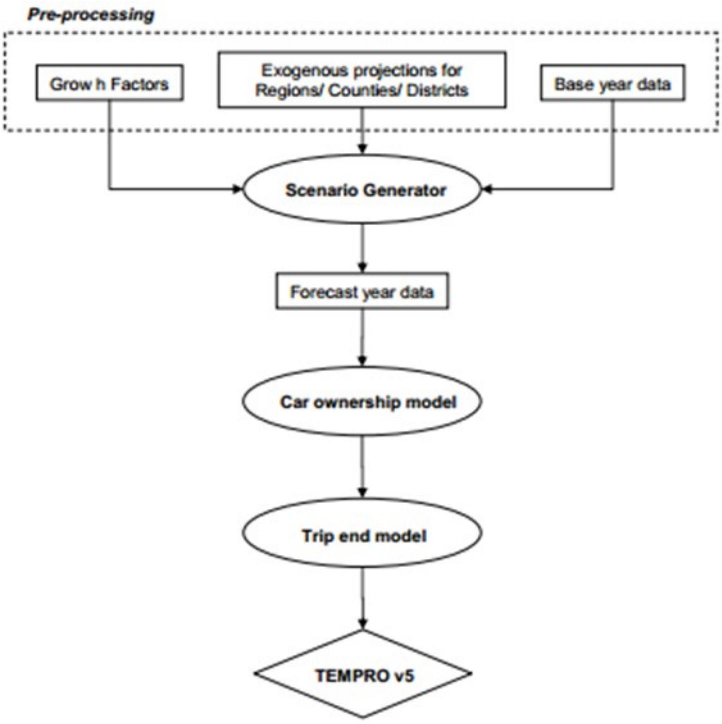

Figure 1: TEMPro Forecasting Process (DfT, 2009a)

The DfT's Road Transport Forecasts 2013 state: '*The NTM Road Traffic Forecasts should not be viewed as what we think will actually happen in the future, or what we want the future to look like. The forecasts are what may happen, based on current understanding of how people make travel choices, the expected path of key drivers of travel demand and assuming no change in government policy beyond that already announced'.* Any TEMPro forecasts should be considered as best-guess predictions of what may happen. It is unrealistic to expect these predictions to show consistently accurate forecasts;

however, this project aims to investigate whether there is scope for improvement.

2.2. Use of TEMPro Data

TEMPro is used in the development of future transport schemes, particularly factoring base year trip matrices to reflect the expected condition of the future. The DfT TEMPro guidance states that 'TEMPro should be used only in three circumstances:

- To derive local adjustment factors which modify National Road Traffic Forecasts (NRTF) growth, for applications where there is no transport model
- To derive trip growth factors for use in highway-only models (either with a fixed matrix, or those where re-distribution and/or fixed-elasticity methods are used to represent responses to congestion)
- As growth factors for trip matrices in strategic multi-modal models' (DfT, 2006)

Highway models are generally created in order to illustrate future constraints and justify transport schemes. After calibrating to base year values, TEMPro growth factors inflate the matrix to reflect what the expected growth might be on the network. The forecast matrix will be used to assess where specific problems arise in the network and advise whether the scheme achieves its objectives or has consequential unacceptable impacts.

The future scenario results can be fed into appraisal software, such as the DfT's TUBA (Transport User Benefit Appraisal) program. The results from TUBA form a critical part of schemes business cases, used to support decision making for major investments (DfT, 2013) and generate the estimation of a scheme's BCR (Benefit Cost Ratio) and 'Value for Money' category. The categories in the DfT's 'Value for Money Advice for Local Decision Makers' document are as follows:

- **Poor** – BCR below 1
- **Low** – between 1 and 1.5
- **Medium** – between 1.5 and 2
- **High** – between 2 and 4
- **Very High** - greater than 4

The amounts of trips in the forecast matrices are a key factor in the estimation of benefits and it is critical that the growth factors applied have a good level of validity to enable the benefits to be considered reliable. Should the growth factors overestimate growth, then an unrealistic amount of trips will be 'benefitting' from an improvement and the BCR will be higher. Conversely, an underestimation will be representing less value for money. TEMPro growth factors need to have a degree of predictive power to avoid critical funding decisions balancing on unrealistic forecast traffic levels. Should TEMPro growth factors be inaccurate then road schemes may need an adjusted BCR to reflect alternative growth scenarios, resulting in less schemes falling into the highest value for money categories.

This chapter demonstrates that TEMPro growth factors have the potential to completely alter the interpretation of a proposed scheme's funding and expected success. Provided TEMPro is inflating all transport scheme BCRs proportionally, the highest BCRs will remain the highest inflated BCRs therefore funding decisions are unlikely to change. The application of TEMPro is only relevant to highway schemes. In the UK, a multi modal approach to transport planning is adopted and a bias in assessment of one mode will skew investment.

3. CASE STUDY: TEMPRO V DEVON

To investigate the performance of TEMPro growth factor predictions over recent years, this project will focus on a case study of the observed traffic trends versus the historic TEMPro growth factors in the county of Devon spanning from 2001-2014.

3.1. Why Devon?

Devon is a county in the south west of England, shown in Figure 2, with over 90% designated as rural (Heart of the South West, 2014).

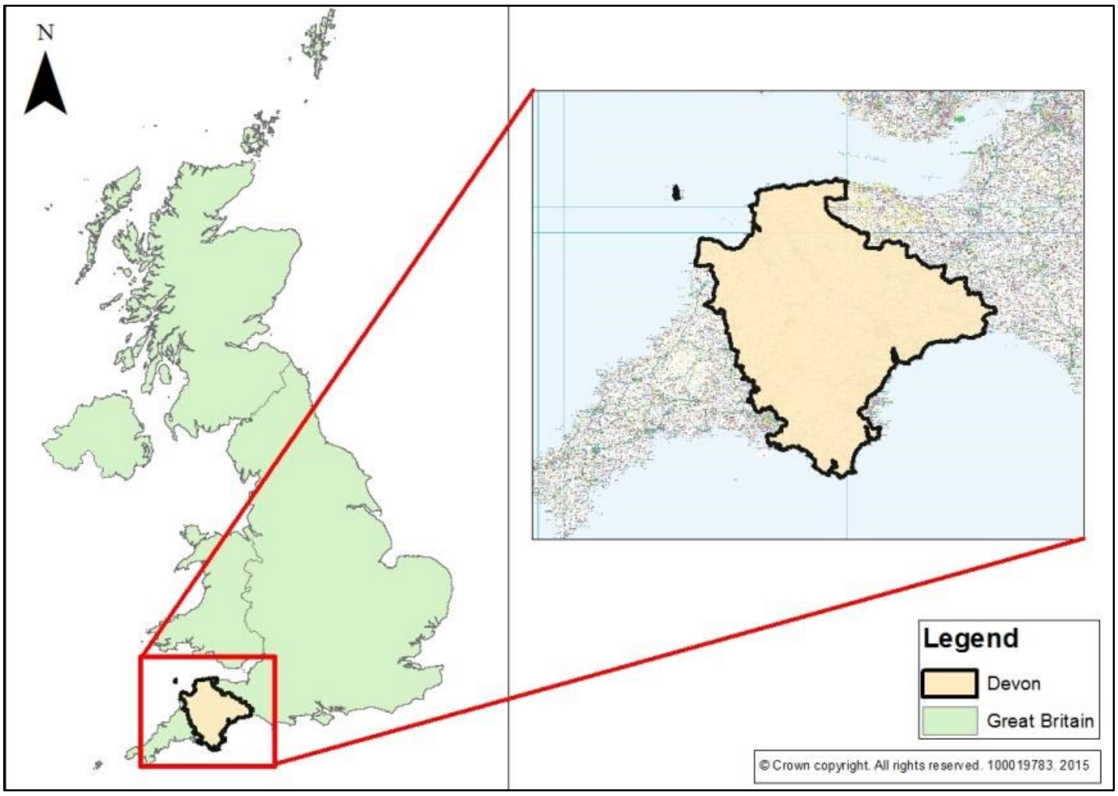

Figure 2: Location of Devon

Devon lies outside the influence of England's capital, whilst remaining accessible to it within five hours on the road. For this report to be applicable to a wider scope of UK locations, it is important that there are unifying features which can be related to. 200 miles from London extends to Leeds, Aberystwyth and Hull. The average journey time to London can be similarly extended and the rail journey time is demonstrated in Figure 3. Devon is a largely rural non-metropolitan county, of which there are several others at a similar distance from London, such as areas of North Wales, Cornwall, Derbyshire and Cumbria. Devon represents similar population density to many of these areas, shown in Figure 4, and the difference to metropolitan areas such as London and Birmingham is also demonstrated.

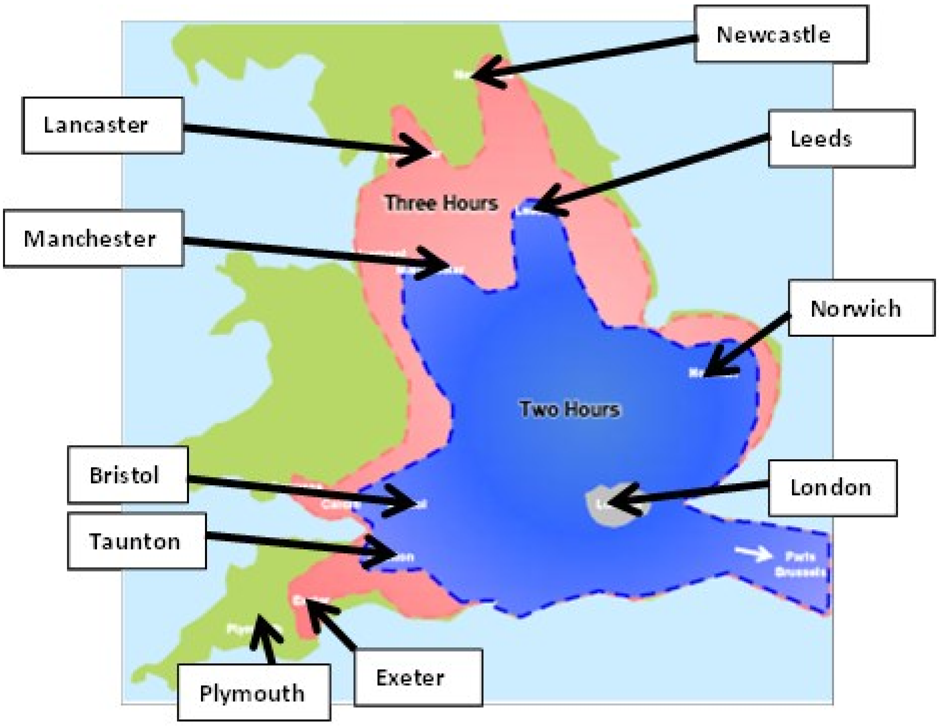

Figure 3: Average Rail Journey Time Isochrones from London (DCC, 2013)

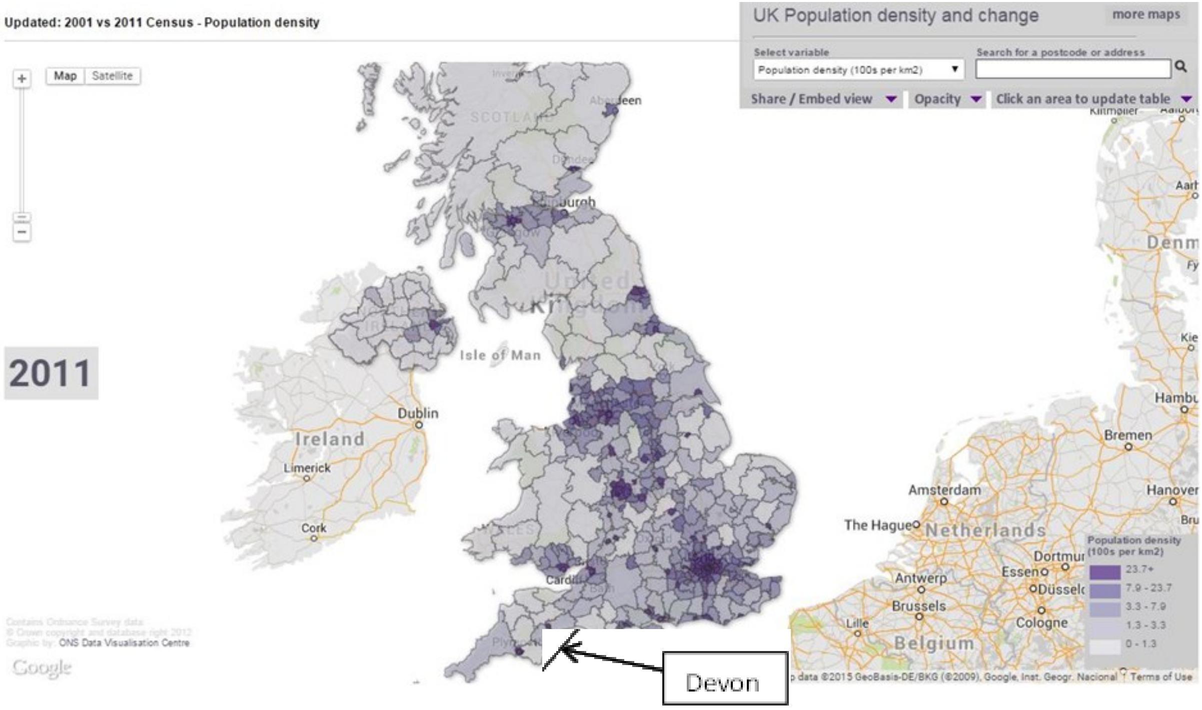

Figure 4: UK 2011 Census Population Density Map (Office for National Statistics, 2011)

Devon has undergone growth in line with the national average (2.654%), over the past few decades, with an aspiration driven by the Heart of the South West Local Enterprise Partnership to exceed this by 2030 (Heart of the South West, 2014). It is an underlying assumption within TEMPro that the level of development in an area is linked to the level of traffic growth. This makes Devon a good candidate for observed traffic growth and should provide a good opportunity for relationships between historic trends and TEMPro predictions to be expressed.

The '*Research into Changing Trip Rates over Time and Implications for the National Trip End Model'* report by WSP concludes with the observation that the NTEM model, and therefore the TEMPro growth factors it produces, could be improved by the inclusion of income variables (WSP, 2009). Average income in the UK is higher than incomes in Devon, shown in Figure 5, enabling potential for any inaccuracies of the NTEM growth factors to be highlighted. The distribution of incomes in Devon shows that there is a strong skew towards the lower incomes bracket, as demonstrated in Figure 6. Though this is likely to be replicated across the UK, the performance compared to the national average combined with the lower income skew could be considered key factors in Devon's overall relatively poor economic performance compared to the rest of the country, shown in Figure 7.

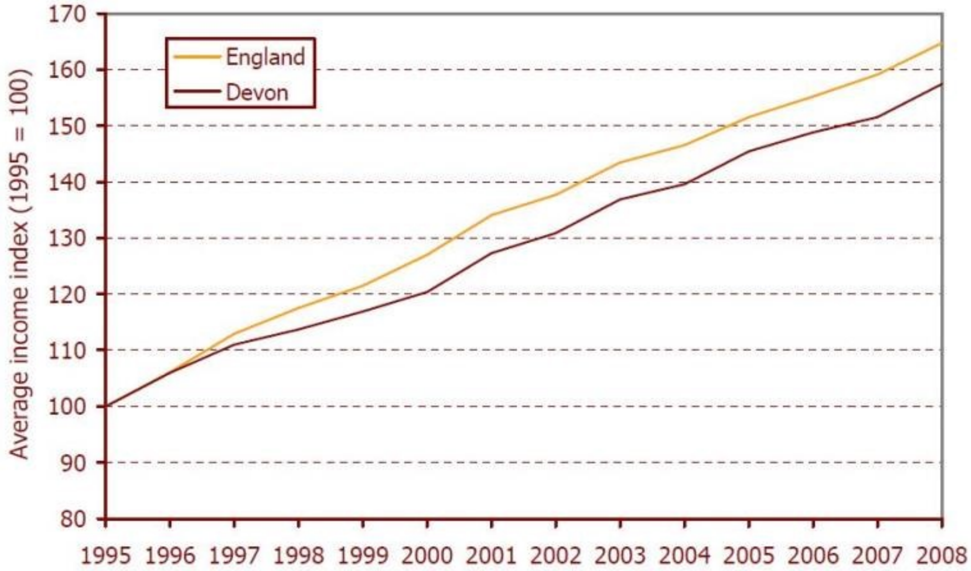

Figure 5: Devon average incomes compared to the national average (Devon County Council, 2008)

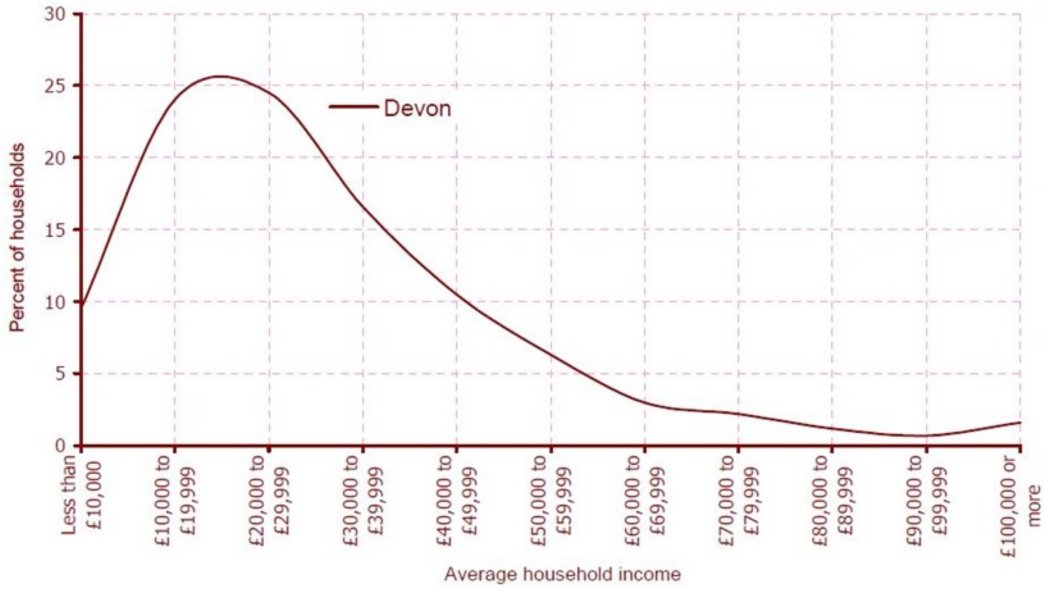

Figure 6: Devon income distribution (Devon County Council, 2008)

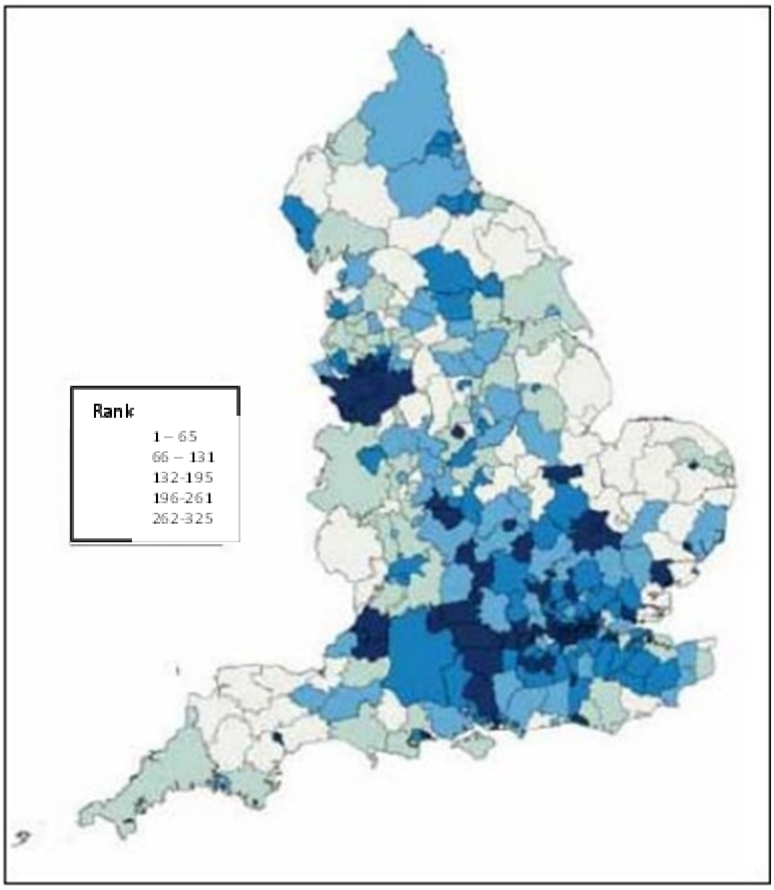

Figure 7: Overall economic performance of local authorities (Local Futures, 2013)

The choice of Devon as a case study can be justified. It should produce results which are applicable across more than the study area and can provide an indication of the reliability of the TEMPro growth projections. However, these results will not be representative of the whole of the UK.

3.2. Study Towns

Three medium sized Devonian towns will be used (Barnstaple, Tiverton and Newton Abbot), shown in Figure 8. It is envisioned that any conclusions and trends observed will not be specific to the towns themselves but can also be applied across the county and potentially other counties of a similar location and demographic.

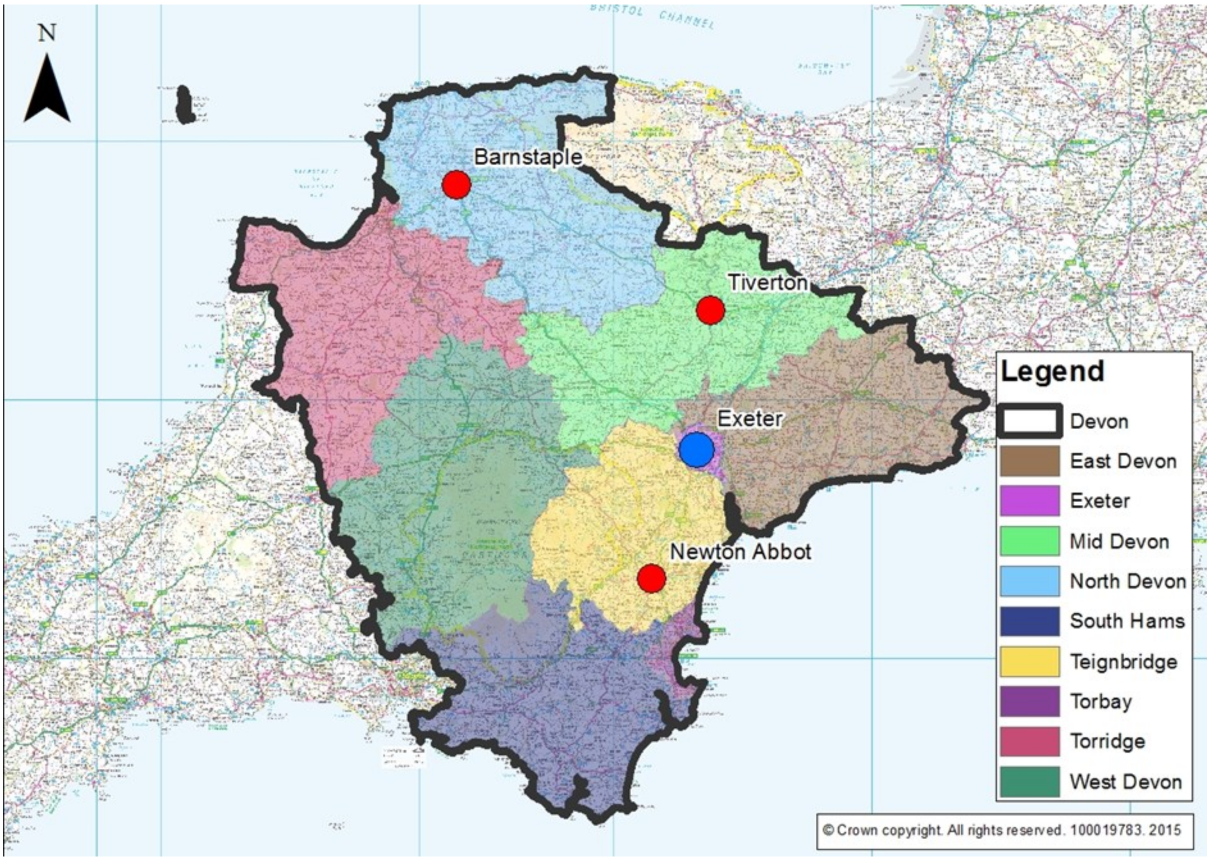

Figure 8: Location of study towns

3.3. Data

TEMPro growth rates will be obtained for between the years of 2001-2014. The base years will be 2001, 2005 and 2010 to allow the observation of whether this affects the total traffic expected per forecast year. Additionally, TEMPro datasets of 6.2, 6.1 and 5.4 will be used to see whether the models have been adapted to reflect trends in observed traffic growth.

The ATC data will be selected based on a 'cordon' around the town centres, as shown in Figure 9, Figure 10 and Figure 11. This should ensure that any developments delivered during the observed years should not affect the trip distribution greatly, as it can be assumed that attraction levels to a town centre will remain relatively consistent.

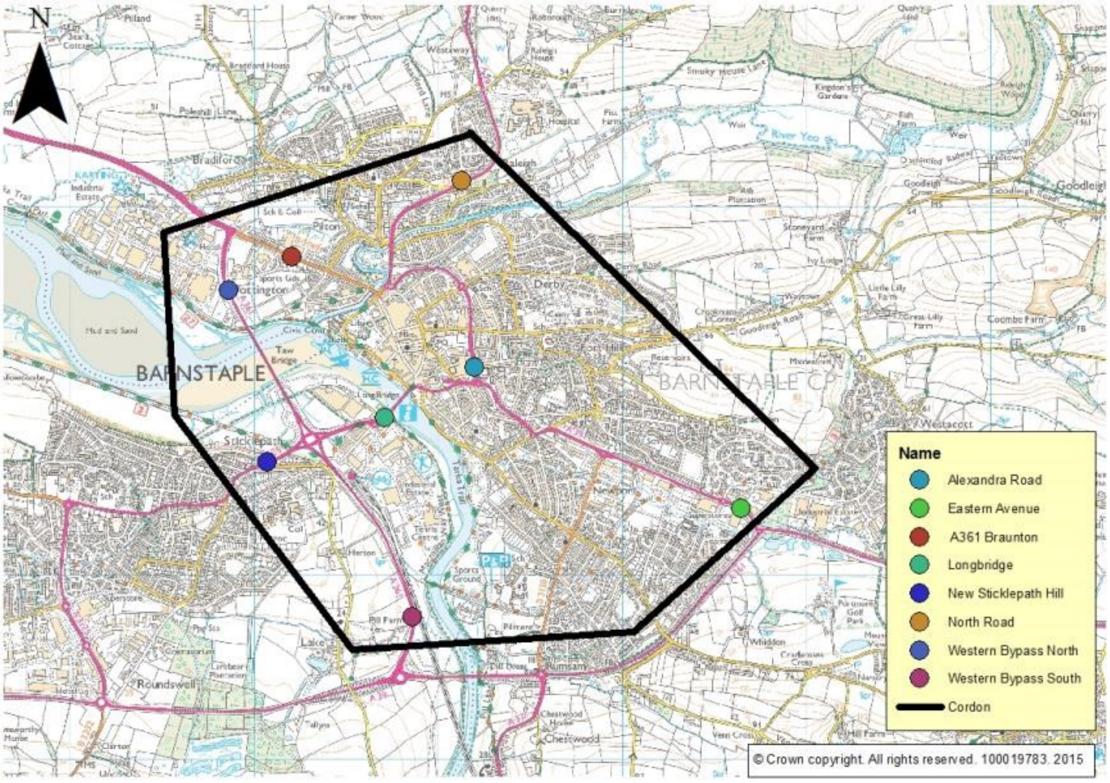

Figure 9: Barnstaple Count Sites

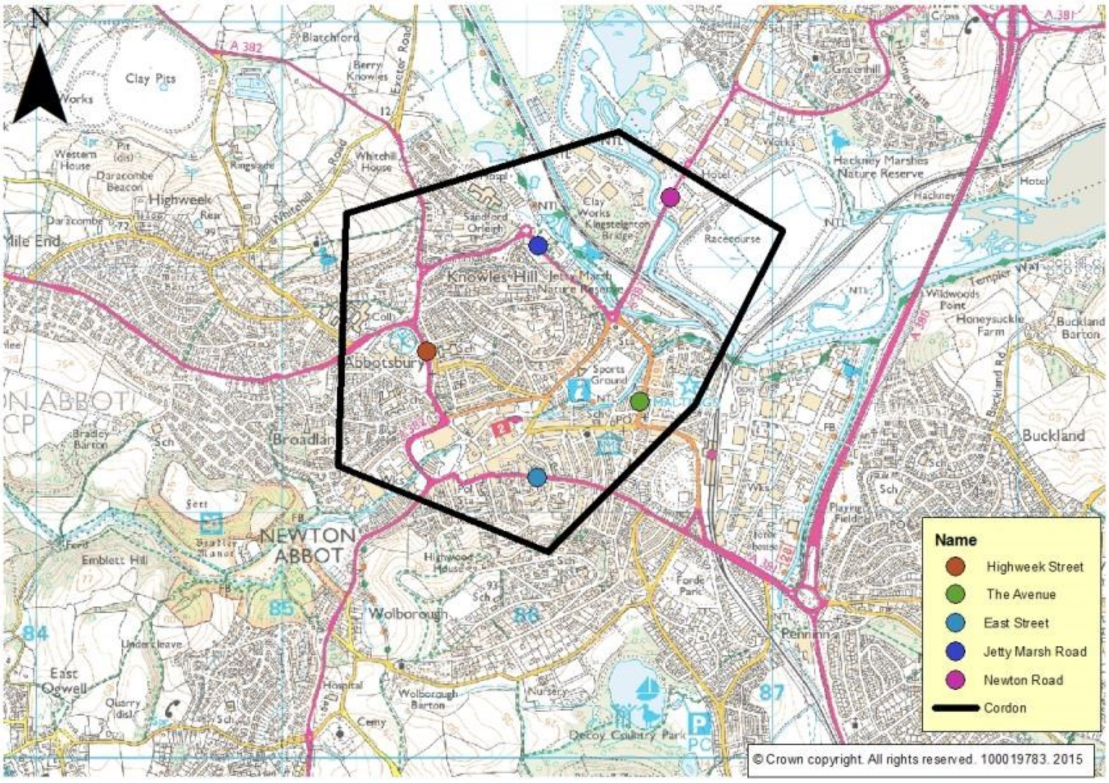

Figure 10: Newton Abbot Count Sites

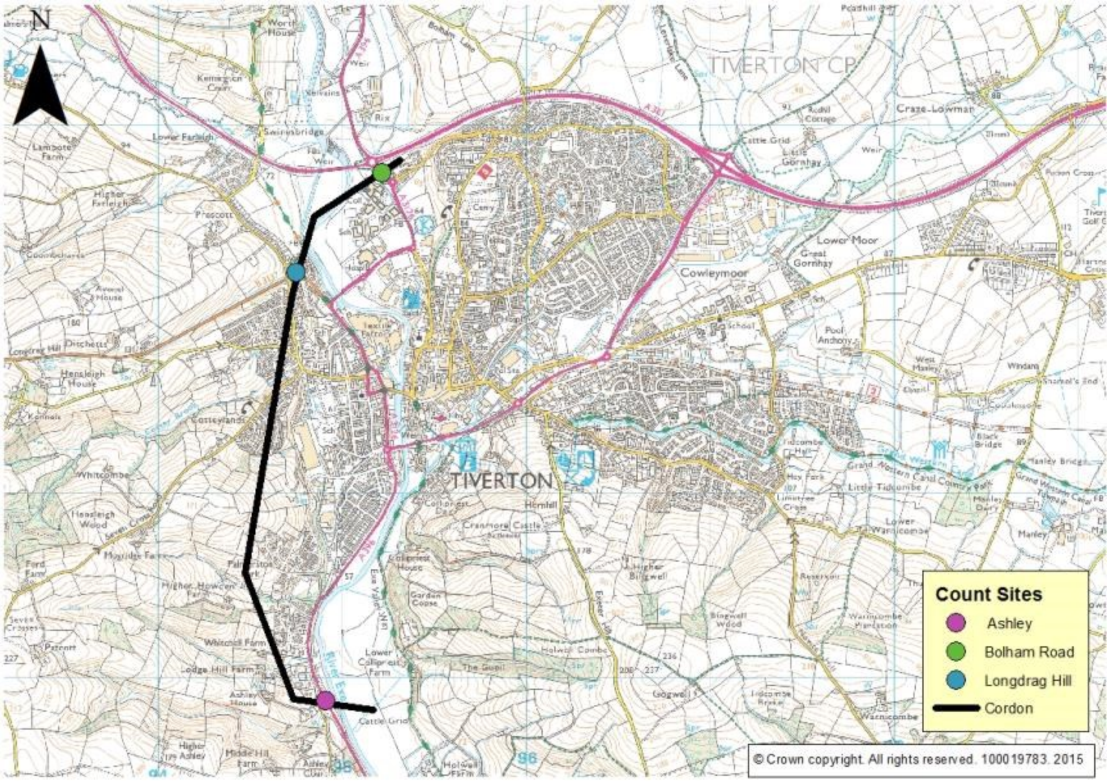

Figure 11: Tiverton Count Sites

3.4. Initial Observations

Figure 12 shows the observed growth rates for each town alongside the predicted growth rates from TEMPro.

Town	Growth Factor	Year													
		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Barnstaple	Observed	1	1.028	1.030	1.029	1.020	1.011	1.024	1.000	1.028	1.030	1.029	1.020	1.011	1.024
	TEMPRo 6.2	1	1.026	1.052	1.078	1.105	1.131	1.142	1.153	1.163	1.174	1.185	1.197	1.208	1.220
	TEMPro 6.1	1	1.017	1.034	1.051	1.068	1.085	1.095	1.104	1.114	1.124	1.134	1.150	1.165	1.181
	TEMPro 5.4	1	1.014	1.029	1.043	1.058	1.072	1.089	1.106	1.124	1.141	1.158	1.171	1.183	1.196
Newton Abbot	Observed	1	1.017	1.017	1.017	1.019	1.023	1.042	1.022	1.014	1.004	0.996	1.000	1.002	1.015
	TEMPRo 6.2	1	1.015	1.029	1.044	1.058	1.073	1.078	1.083	1.089	1.094	1.099	1.109	1.118	1.128
	TEMPro 6.1	1	1.011	1.022	1.034	1.045	1.056	1.060	1.064	1.068	1.072	1.076	1.092	1.108	1.123
	TEMPro 5.4	1	1.015	1.030	1.045	1.060	1.075	1.091	1.107	1.123	1.139	1.154	1.166	1.178	1.190
Tiverton	Observed	-	-	-	-	1.000	1.009	1.023	1.008	1.006	0.963	0.972	0.960	0.970	0.982
	TEMPRo 6.2	-	-	-	-	1.000	1.025	1.040	1.056	1.072	1.087	1.103	1.119	1.135	1.151
	TEMPro 6.1	-	-	-	-	1.000	1.018	1.030	1.042	1.054	1.066	1.078	1.095	1.111	1.128
	TEMPro 5.4	-	-	-	-	1.000	1.016	1.032	1.048	1.064	1.080	1.096	1.108	1.121	1.133

Figure 12: Observed and Predicted Growth Rates

The predicted traffic growth levels are consistently higher, culminating in 2014 factors being up to 20% higher than the observed growth. The observed growth levels generally have remained close to the 2001 levels, with some growth observed up to 2008, before plateauing or declining. This could be linked to the UK's economic climate. From the early 90s, the UK experienced constant economic growth with low inflation and falling unemployment between 2000-2007 (Pettinger, 2013). This is perhaps reflected in the rising traffic levels: a driver's willingness to pay will be higher, leading to more non-essential trips. The economy dramatically changed in 2008 when major economies across the world fell into a recession. The impact was felt across the UK, with a drop in economic growth from 2008 up to 2013. This coincides with the observed turning point of traffic growth. However, even if the observed growth up to 2007 had been extrapolated, it would have remained lower than TEMPro growth. This is illustrated in Figure 13, Figure 14 and Figure 15. To highlight the issue of extrapolating beyond 2014, the TEMPro growth factors up to 2030 have also been plotted.

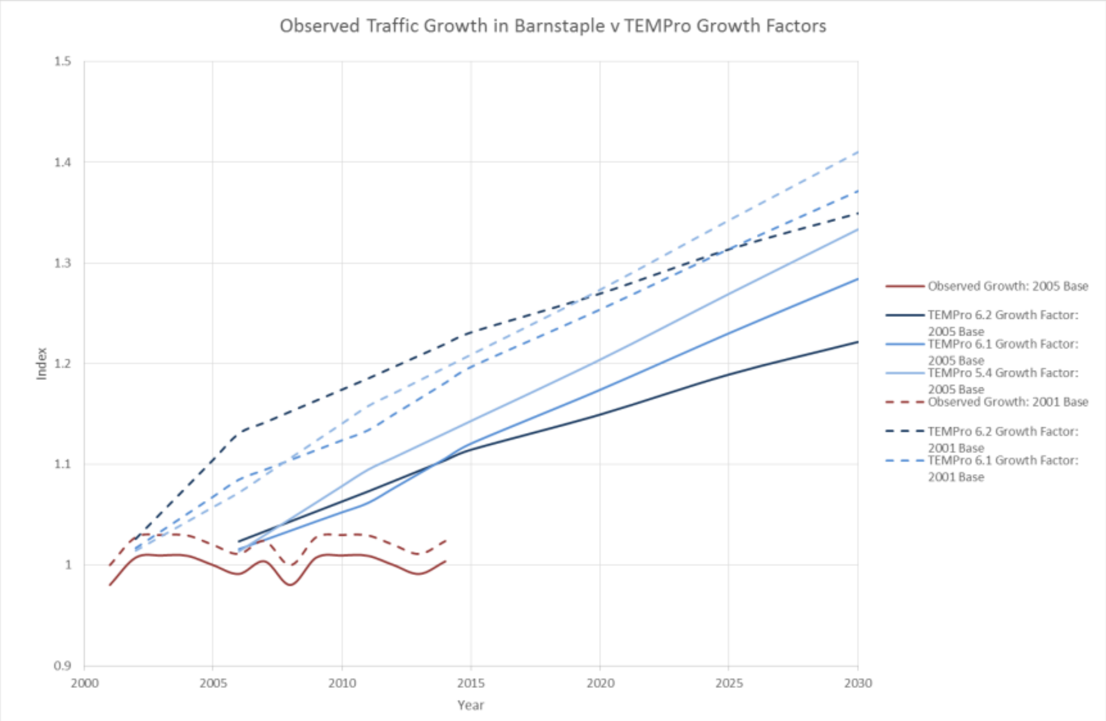

Figure 13: Barnstaple Observed Traffic Growth v TEMPro Growth Factors

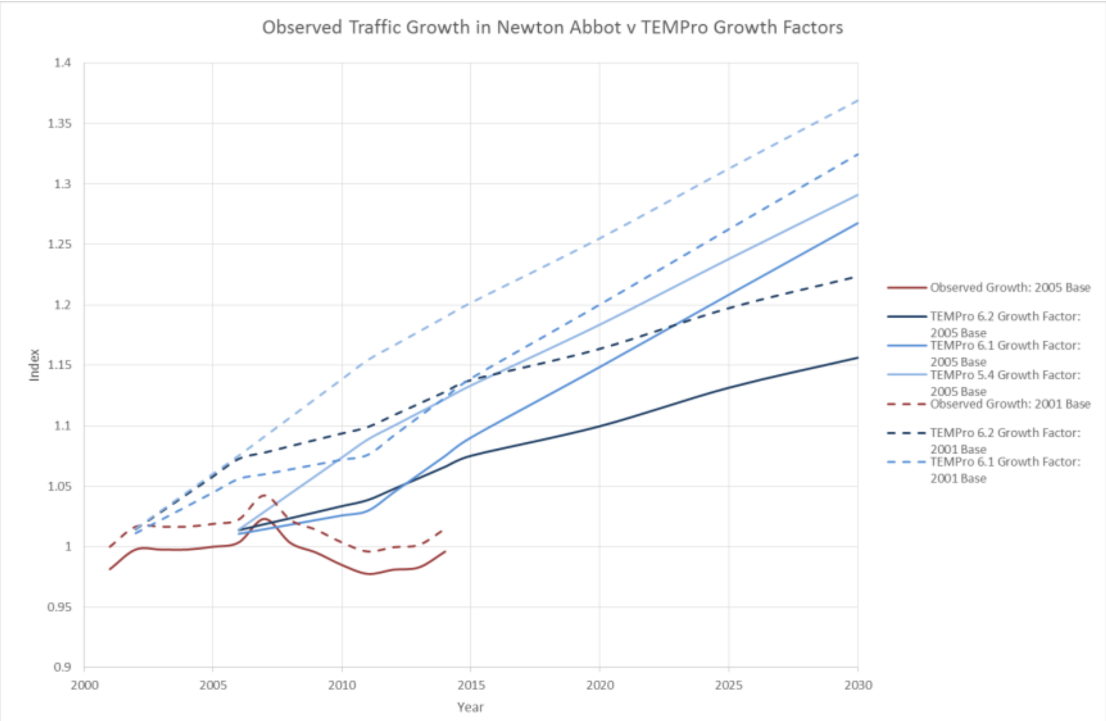

Figure 14: Newton Abbot Observed Traffic Growth v TEMPro Growth Factors

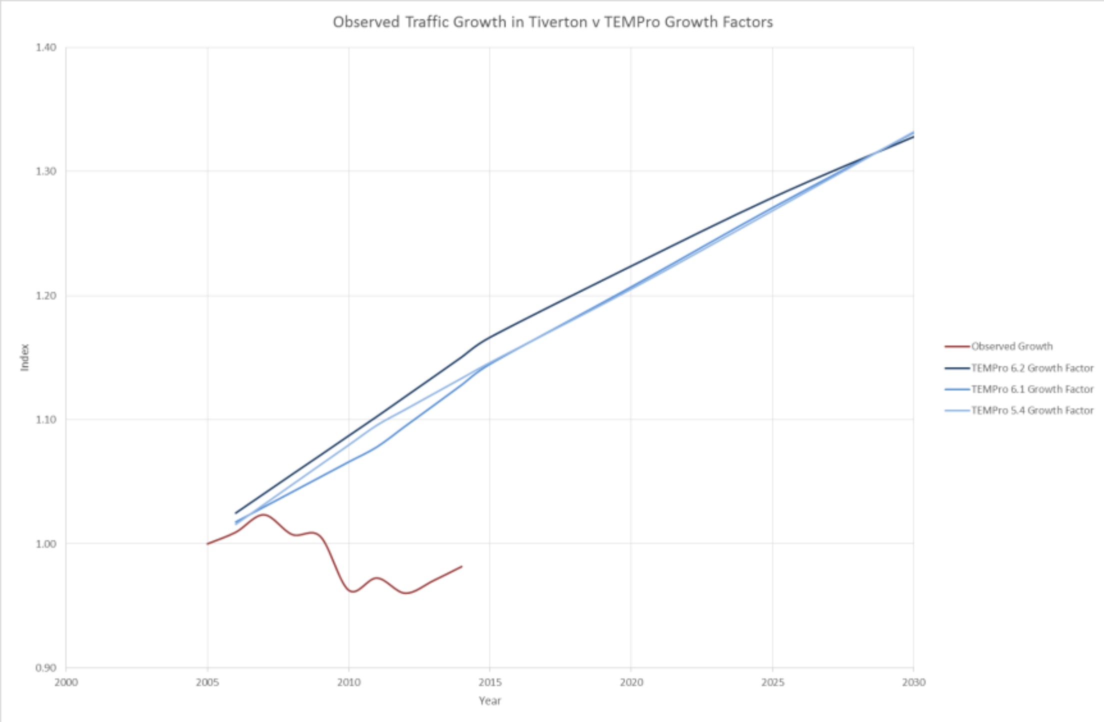

Figure 15: Tiverton Observed Traffic Growth v TEMPro Growth Factors

3.5. Hypothesis Testing

A paired t-test evaluates the significance of the difference between the predicted and observed traffic growth. The proposed hypotheses are given in Equation 1. Should the null hypothesis be rejected, then the evidence would suggest that TEMPro predictions are significantly different to observed growth in the study towns.

$$H_0: \mu_d = 0$$
$$H_1: \mu_d \neq 0$$
$$Where\ H_0 is\ the\ null\ hypothesis, H_1\ is\ the\ alternative\ hypothesis$$
$$and\ \mu_d\ is\ the\ meanof\ the\ differences$$

Equation 1: Paired t-test hypotheses

Table 1 shows the results of the paired t-test. There is only one instance where the null hypothesis is not rejected; TEMPro version 6.1 with a 2010 base year in Tiverton. The 2010 base values should be viewed with caution due to the small dataset giving each data point the potential to significantly alter the results. The difference between the observed and predicted traffic growth values were calculated using Equation 2. All the confidence intervals have an upper and lower limit less than 0, with the exception of the Tiverton 2010 base year. This suggests that the TEMPro predicted traffic growth is consistently significantly higher than the observed growth across each town, version of TEMPro and base year.

$$x_O - x_T = d$$
$$Where\ x_O\ is\ the\ observed\ growth, x_T\ is\ the\ TEMPro\ predicted\ growth$$
$$and\ d\ is\ the\ difference$$

Equation 2: Predicted v Observed Traffic Growth Difference

Town	TEMPro Version	Base Year	p-value	95% Confidence Interval	Significant Difference
Barnstaple	5.4	2001	0.000	[-0.123,-0.046]	
		2005	0.000	[-0.106,-0.046]	
		2010	0.024	[-0.070,-0.010]	
	6.1	2001	0.000	[-0.112,-0.048]	
		2005	0.000	[-0.080,-0.033]	
		2010	0.042	[-0.074,-0.003]	
	6.2	2001	0.000	[-0.158,-0.081]	
		2005	0.000	[-0.085,-0.043]	
		2010	0.033	[-0.060,-0.005]	
Newton Abbot	5.4	2001	0.000	[-0.131,-0.052]	
		2005	0.001	[-0.115,-0.040]	
		2010	0.003	[-0.041,-0.019]	
	6.1	2001	0.001	[-0.073,-0.026]	
		2005	0.005	[-0.063,-0.015]	
		2010	0.022	[-0.045,-0.007]	
	6.2	2001	0.000	[-0.088,-0.039]	
		2005	0.002	[-0.064,-0.020]	
		2010	0.005	[-0.027,-0.010]	
Tiverton	5.4	2001	N/A	N/A	
		2005	0.002	[-0.136,-0.042]	
		2010	0.004	[-0.043,-0.003]	
	6.1	2001	N/A	N/A	
		2005	0.003	[-0.125,-0.037]	
		2010	0.055	[-0.053,0.001]	✓
	6.2	2001	N/A	N/A	
		2005	0.001	[-0.147,-0.051]	
		2010	0.041	[-0.053,-0.002]	

Table 1: Paired t-test results

3.6. Conclusions

Comprehensive analysis of observed and TEMPro predicted traffic growth rates for three towns has been undertaken. The TEMPro predictions have been obtained from several versions of the datasets over a range of base and forecast years. The observed growth values have been derived using AADT values obtained from a cordon of ATCs across the town centres.

Initial observations suggest there has been a systematic overestimation of traffic growth rates by TEMPro. It appears TEMPro forecasts almost uniform growth in traffic levels though the observed growth has fluctuated around the same levels throughout the study period.

The hypothesis tests revealed the predicted and observed traffic growth factors are significantly different for almost all scenarios, supporting the assumption that TEMPro traffic growth factors are significantly higher than observed.

There has been consideration to how appropriate it would be to apply any conclusions to other locations locally, regionally and nationally. There are numerous characteristics present in the three towns and Devon which could make the results suitable for use elsewhere. Further study will be needed to determine the extent of the validity of results for other areas.

The causes of the significant difference have also been considered. The recession is likely to have played some part in the fall in traffic growth. However, the evidence seems to indicate traffic growth was low even prior to this, suggesting other factors may be prevalent. Virtual mobility could be nullifying the necessity for many trips to be made. Furthermore, awareness of the importance of sustainable travel has spurred on ambitions to improve the provision of alternative modal options. New developments are being encouraged to minimise their traffic impact and it seems that traffic growth is not in line with development growth, which may have been assumed within TEMPro.

4. ALTERNATIVE PREDICTIVE MODELS

4.1. Generalised Linear Modelling

To create future traffic growth factors, a model will be created that uses a selection of variables to assign a probability of future growth factors. A common statistical approach is to use a Generalised Linear Model (GLM), and this is the methodology which will be used.

The response variable is 'traffic growth factor' and therefore is continuous, positive and likely to be positively skewed around the factor of 1, bounded by 0 with some higher growth factors possible. This can be represented by the Gamma distribution. The Gaussian distribution could also be used as the evidence shown previously demonstrates that the growth factors do not fluctuate much beyond 1.05 or less than 0.95, though it is possible for these values to exist. This suggests the growth factors would be clustered roughly symmetrically around the growth factor of no change (1).

Any models built will have their predictions plotted against not only the observed values, but also the TEMPro predictions. The key objective of this task will be to determine whether the models produce more reliable and accurate predictions than TEMPro for the out of sample data.

4.2. Data

The explanatory variables chosen are year, town, average price of petrol (representing the cost of driving), average income, population and number of new build housing delivered. For each explanatory variable, the data for between 2001 and 2014 were obtained. When building the predictive model, to ensure the model has the best predictive power as opposed to explanatory power, the model will be created using data up to 2010 only. For 2011-2014, the data will be used to validate the performance of the model.

4.3. Short Range Forecasts

Initial models were generated using both the Gamma and Gaussian distribution and all the explanatory variables. These models showed signs of overparameterisation, multicollinearity and poor calibration, though the predictions arising from them did seem to indicate a better performing model than TEMPro. In order to improve the predictive models, the variables included in the model were systematically altered.

A total of 26 models were produced and the five models with the lowest AICs were analysed further, shown in Table 2. The AIC (Akaike Information Criterion) provides a one value assessment of performance. Not only are the best performing models the same, but the AIC values also are very similar. The Gaussian models produce slightly lower AIC values, but only by an insignificant difference of around 0.2. The AIC values of these five models are all significantly different from that of the full model and within a difference of 2 of the lowest value.

Model	Gamma AIC	Gaussian AIC
Year + Petrol	-139.45	-139.69
Year + Petrol + Year:Petrol	-139.19	-139.43
Petrol	-138.96	-139.19
Year + Petrol + Population:New Builds	-137.61	-137.86
Year + New Builds + Petrol	-137.57	-137.81

Table 2: AIC Values of the Top Five Tested Models

The predictions for traffic growth factors in each study town between the years of 2011-2014 arising from the best five performing models are shown in Figure 16, Figure 17 and Figure 18. The predictions generated by the models are closer to the observed traffic growth than the TEMPro predictions. This observation is consistent across all three study towns, which provides some validation to the application of the model. It appears that the predictions are very similar for each study town, though this may be due to their close geographical proximity on a national scale resulting in the values of the explanatory variables, in particular average petrol price, being similar. The Gaussian models overall appear to be a better fit to the observed data than those from the Gamma models. The overall trend also seems to be more reliable, with a gradual increasing trend shown. Should the models be extrapolated over a longer range then it is possible that the trends may diverge from the observed traffic growth values.

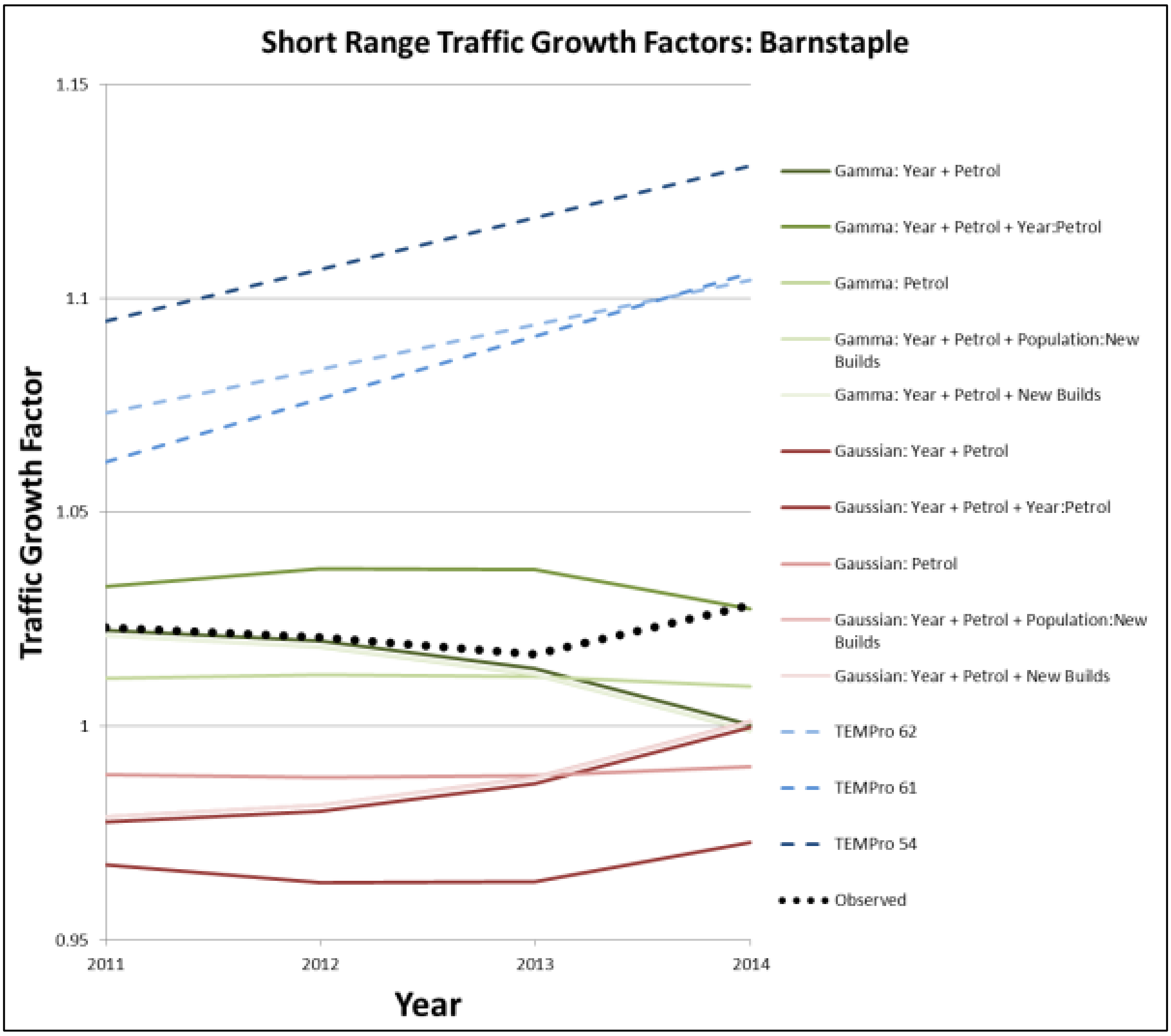

Figure 16: Short Range Model Predictions for Barnstaple

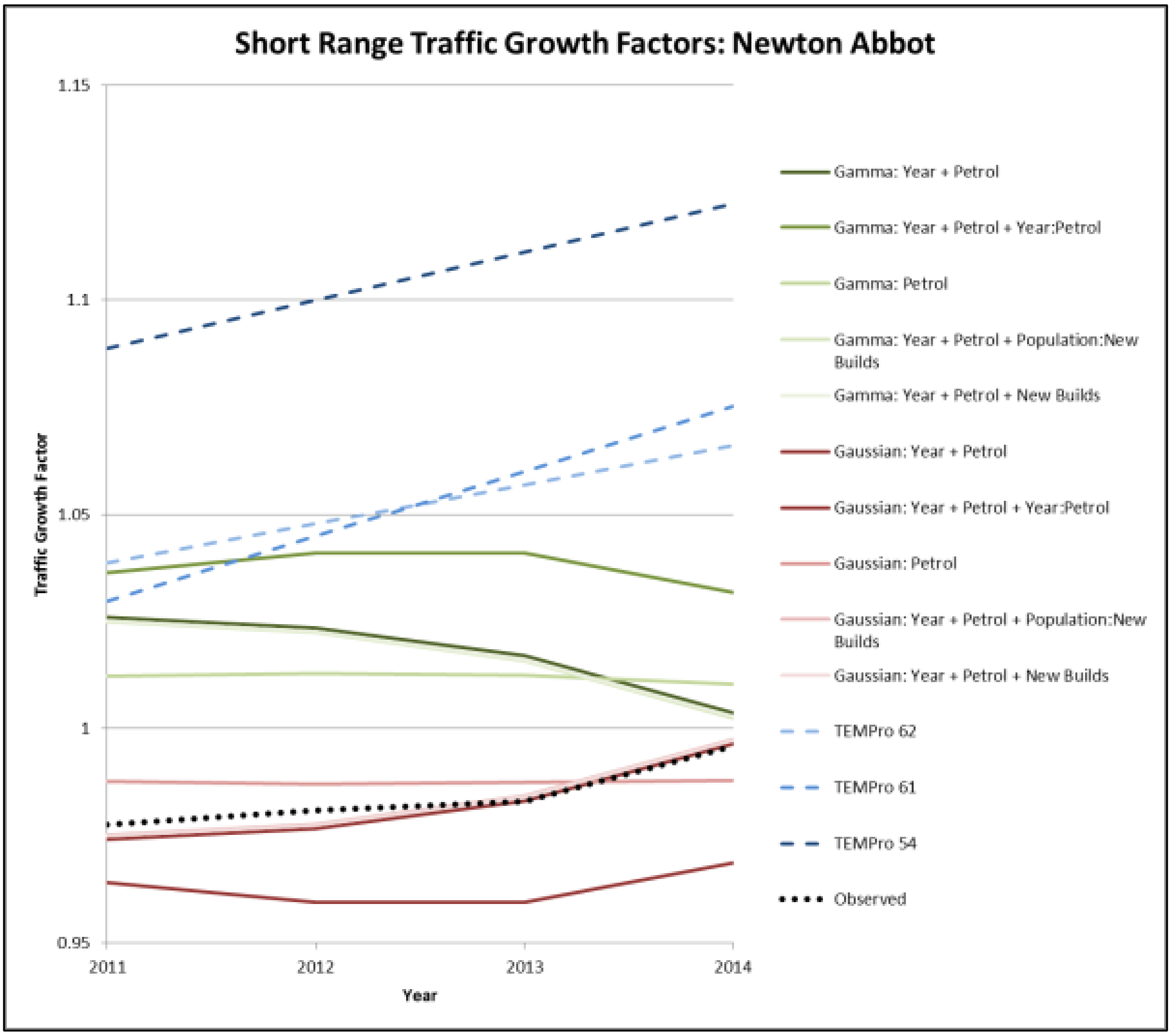

Figure 17: Gamma Model Predictions for Newton Abbot

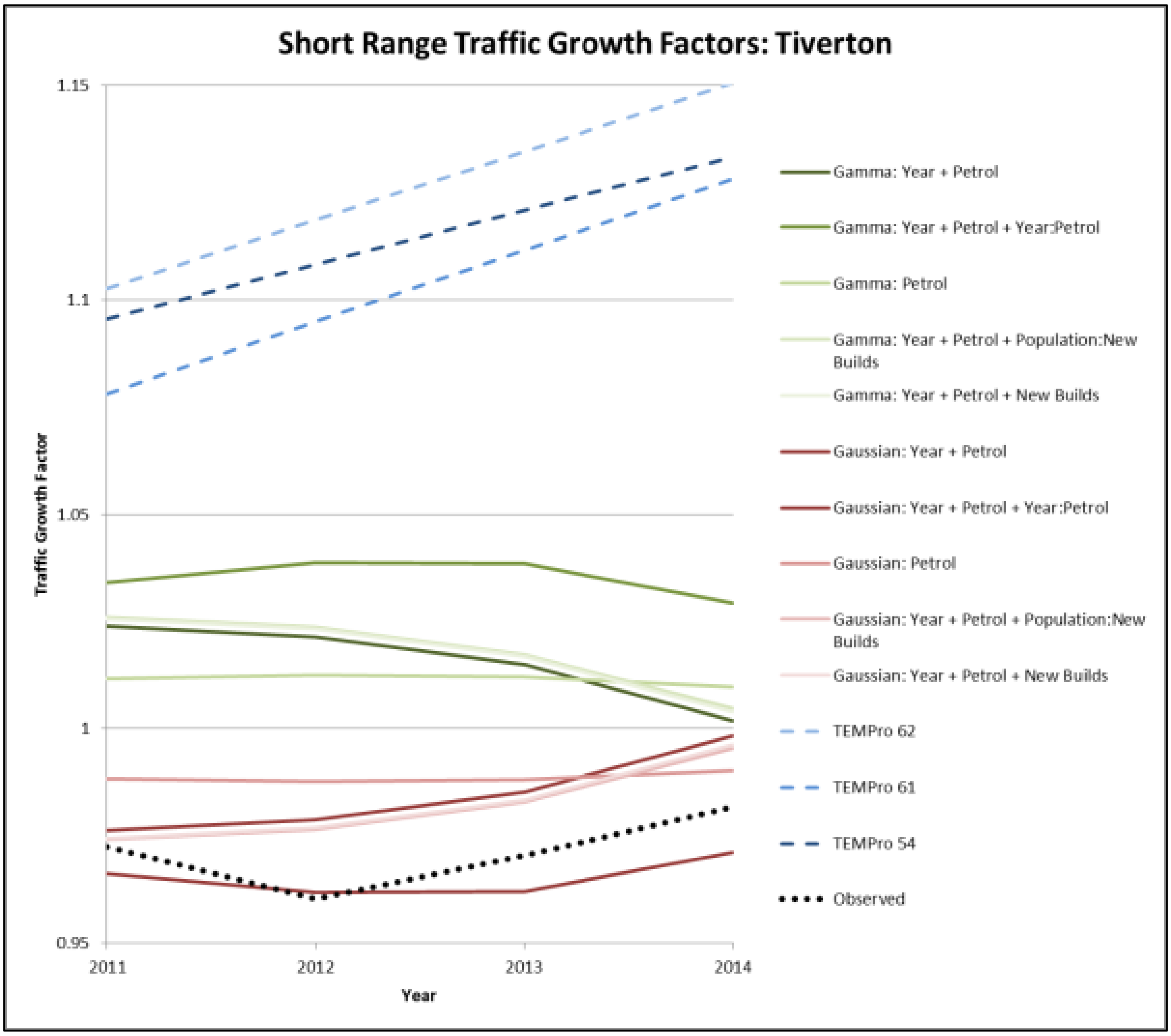

Figure 18: Gamma Model Predictions for Tiverton

The AIC values are all within a difference of 2, suggesting that the complexity of the models needs to be considered rather than simply the lowest scoring, meaning the Gamma model with just one explanatory variable (average petrol price) should be considered the best performing. All the other models produce similar AIC values with the complexity of additional variables without significantly improving the model performance. This assumption is further supported by the plots showing the observed and TEMPro values along with the model outputs. Without the study of further long range forecasts it is reasonable to assume that the flat profile of the average petrol price model is sufficient to predict the growth factors, particularly given their historical trend of remaining close to the no change growth factor of 1.

The performance of Gaussian models indicate an improvement on the TEMPro predicted values and the Gamma models. The recommendation of best model for the Gaussian models is the model containing year and petrol. The outputs of this model are very similar to that of the year, average petrol price and interaction between population and new builds delivered and year, average petrol price and interaction between year and average petrol price models. However, the addition of the interaction term does not alter the outputs of the year and average petrol price model and therefore it is advised to take forward the model of least complexity.

4.4. Long Range Forecasts

Traffic growth factors for many years in the future are used by transport planners. Therefore, although it is useful to be able to determine the predictive power of the models for between 2011-2014, the forecasts of interest are much further in the future.

To generate long range predictions, it is necessary to have values for the explanatory variables for the forecast years. This will involve generating predictions for the individual explanatory variables and having a forecast model for each feeding the outputs of this into the traffic growth factor model, in a similar way to which the various models such as car ownership and income models feed into the NTEM, requiring in depth analysis to determine the reliability of each model. However, in this instance, rough estimations of the explanatory variables for long range forecast years have been derived.

The long range forecasts for both the Gamma and Gaussian models are shown below in Figure 23, Figure 20 and Figure 21.

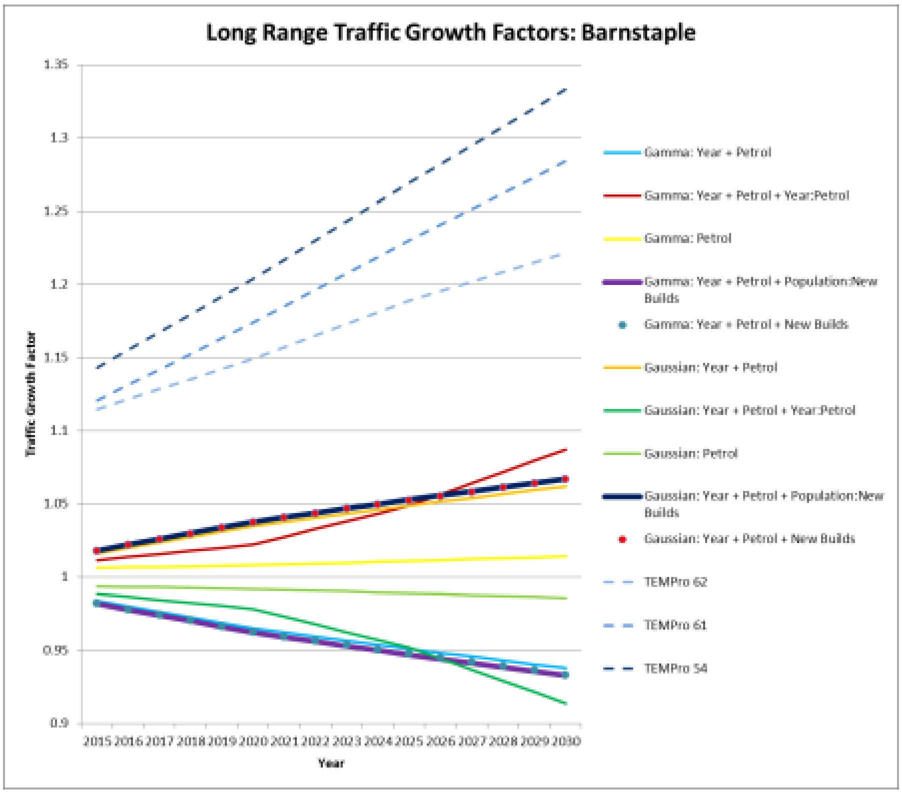

Figure 19: Long Rang Gamma and Gaussian Forecasts for Barnstaple

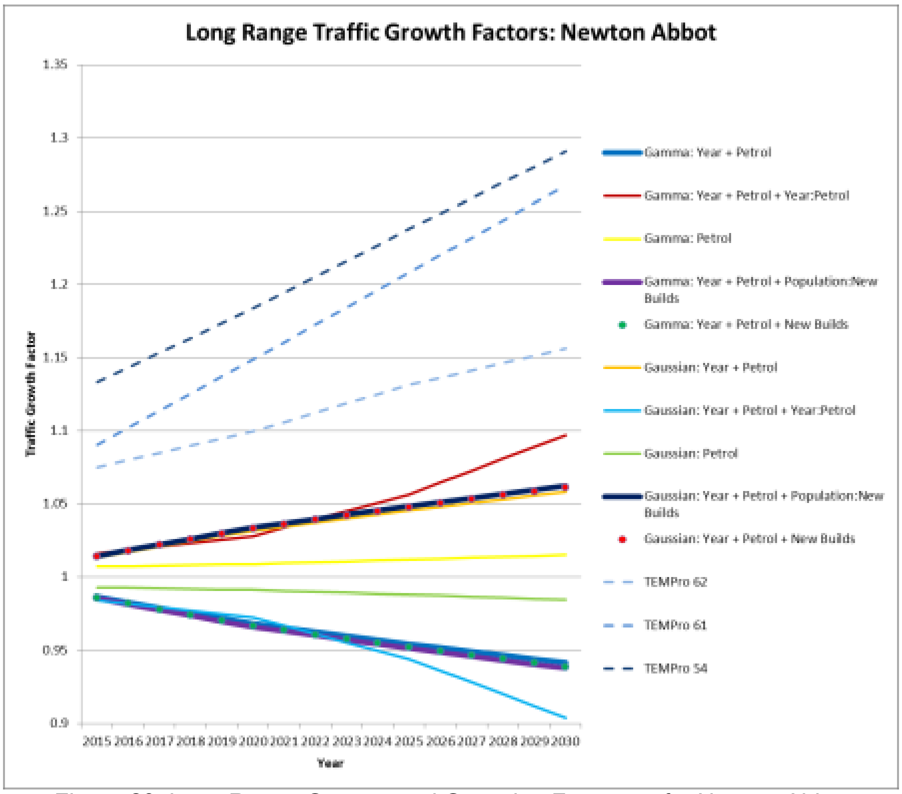

Figure 20: Long Range Gamma and Gaussian Forecasts for Newton Abbot

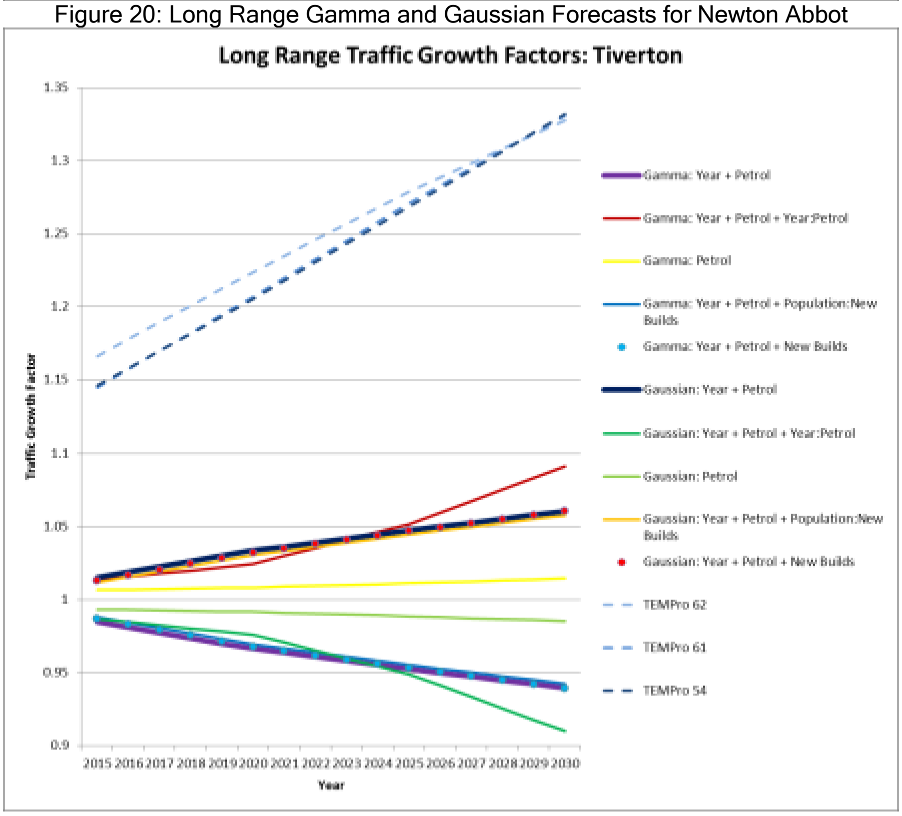

Figure 21: Long Range Gamma and Gaussian Forecasts for Tiverton

All models tested show that the traffic growth predictions up to 2030 are lower than those generated from TEMPro. This is desirable due to TEMPro values historically extrapolating previous growth trends beyond the real life situation suggesting that this could also be the case further in the future, with the difference exponentially increasing.

The observed traffic growth for the towns has been less than 2% for each town compared to the TEMPro values of 11%, 8% and 7%. The models above predict traffic growth levels of between +10% and -10% from 2005 by the year 2030. This seems to indicate that the models are more in line with the known growth trends over the past decade.

It is not possible to determine the predictive accuracy of the models due to the nature of their predictions existing in the future. It is only possible to retrospectively analyse how well their predictions were correlated to the observed values. Although the TEMPro values look unrealistically high given the previous performance of their predictions, it is not possible to dismiss them in the future. We can merely speculate that the predictions from the Gamma and Gaussian models appear to be more realistic.

There could be unexpected events which occur in the future that alter the traffic growth trend. A sudden burst of economic growth may generate an increase in traffic levels or a reoccurrence of recession could prompt traffic levels to fall. Given the apparent significance of petrol price to traffic growth, it is also possible that fluctuation in the oil industry could drive previously unseen trends in traffic growth. August 2015 saw the lowest level of trading crude oil prices since March 2009 (Macalister, 2015). Perhaps a continued fall in supermarket fuel prices, driven by the falling price of crude oil, will spur traffic growth to unprecedented levels. Should this happen, it is likely the price will rise again to manage the demand of petrol, therefore causing a cyclical relationship to develop. This is potentially what has happened in the past and the current slowing of traffic growth levels is simply part of this cycle.

5. SUMMARY

This project has undertaken several tests into the performance of TEMPro growth factors and its use in informing infrastructure investment and capacity provision documented.

Using a 2005 base year, the observed traffic growth factors have been compared to the TEMPro predictions. A graphical representation for 2001-2014 indicates a clear difference between the observations and predictions. A hypothesis test showed that the TEMPro values were significantly greater than the observed values. This could be due to the economic downturn from 2007, however, the years prior to this also show a much flatter traffic growth profile than TEMPro predicts, suggesting something more fundamental is causing the difference, and that it would have been apparent regardless of the recession.

TEMPro is a predictive model intended to be used to forecast several decades into the future and not intended to be fitted to past data. Error in predictive models is unavoidable, though this should be monitored. Given the scale of error apparent in the TEMPro predictions, the root is an important factor to consider. One of the NTEM models could be generating inaccurate outputs which are then fed into TEMPro and their errors are propagated. For instance, it could be that the interaction between population growth and traffic growth are outdated. The apparent effect of population on traffic growth levels explored in this project suggests that it is not as significant as initially thought and the price of petrol is more crucial. There have been concerted efforts from local councils and developers to ensure that new developments are as sustainable as possible, and thus encouraging less car dependence. This could be reflected in TEMPro, with a reviewed relationship between the delivery of new developments and the additional pressure on the highway network.

A further source of error within TEMPro could be that it is not in the form of a time series model. Therefore, the model has been built with interactions between the explanatory and response variable which are not updated until the model is reviewed. However, a time series model would be able to use previous year's patterns and trends to influence future predictions. This would allow trends to be picked up earlier and contribute towards the elimination of an error propagation effect. A time series model would take into account for 2008 that the flows in 2007 showed a decrease from previous observations, which were already a relatively flat growth profile, and incorporate into the model to advise the future growth factors. Currently, this recession stimulated dip in traffic growth would not have advised the growth factors. If TEMPro is truly to provide best-guess estimates of traffic levels in the future, then it would be prudent to include a mechanism which enables it to appropriately consider the most recent trends and use these to inform its view of the future.

Having concluded that the historical performance of TEMPro has resulted in significant overforecasting, an attempt to build a predictive model to challenge TEMPro in its accuracy was undertaken. When observed values were plotted alongside the model outputs and TEMPro predictions, it was evident that TEMPro were the worst performing predictions.

It is important to assess the predictive models' long range forecasting performance. Therefore, predictions for up to 2030 have been plotted and clearly show a trend of the models predicting gradual changes in traffic levels, accumulating to predicted changes of up to 10% difference by 2030. This is far lower than the 35% increase predicted by TEMPro by 2030. This level of growth seems unlikely considering the historic levels of traffic growth. Though the predictions from the models seem to be more realistic, the TEMPro values should not be discarded due to the unknown nature of future forecasts.

Overall, the evidence provided about the performance of TEMPro growth factors when applied in Devon seems conclusive that they are significantly greater than the observed growth factors. The problem of being able to forecast traffic growth accurately is something that should be of concern to any conscientious transport planner when evaluating what is the appropriate action to take to manage the efficient operation of the future road networks. Trends can change quickly in the current unstable economic climate, and this should be the motivation needed to ensure that any predictive models are maintained regularly and assessed according to thorough criteria. In reality, no one can predict the future of travel demand accurately but we must aspire to ensure that all likely scenarios are considered and critique any values arising that seem to be counterintuitive given the historical and recent data available.

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