Transferability of trip generation equations between Queensland provincial cities

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Abstract:

Queensland has many provincial cities with high growth rates for which there is a need to provide regularly updated strategic transport planning. Due to the number and frequency of such planning studies, it is desirable to minimise the resource requirements of each study.

The transferable nature of trip generation equations used in strategic transport planning studies is investigated. Trip attraction and trip production equations for each of six trip purposes from two recent strategic studies are compared. Conclusions are drawn as to their compatibility and any factors to be considered in the transferring of these equations to other provincial cities.

The successful use of transferred equations in two other studies is detailed along with a discussion on the applicability of using transferred equations.

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Introduction

Queensland has many provincial cities with populations in the order of 20 000 to 100 000 which are recording high growths in population, employment, and tourism. Consequently, there exists a real need to provide comprehensive transportation planning to ensure those cities' future requirements are catered for.

The Queensland Department of Transport, Transport Technology Division, in close cooperation with other Divisions and local authorities conducts strategic transport studies in major Queensland cities and has the aim of maintaining, for each major city, a current transport planning report. For many of these strategic studies, a traditional transport model utilising the well known four steps of Trip Generation, Trip Distribution, Mode Split, and Assignment is employed. It is the first of these steps, Trip Generation, which this paper addresses.

To develop trip generation equations at a detailed level is a process requiring significant resources. As there are many provincial cities requiring transport models, any procedure which reduces the resource requirements of each study without unduly compromising its accuracy will be of significant benifit. Hence it would be desirable if the trip generation equations derived for one provincial city could be applied with confidence to another.

This paper examines this issue of trip generation equation spatial transferability and inspects the associated accuracies and problems encountered with the application of such equations.

The Development of Trip Generation Equations

In 1986, the Department of Transport (then the Main Roads Department) conducted large travel data collection exercises in Cairns, Townsville, and Brisbane as part of the Cairns Area Transport Study Update (CATSUP), the Townsville and Thuringowa Road Network Study (TTRNS), and the Brisbane Traffic Study (BTS) respectively. A large part of each of these data collection exercises was Household Interview Surveys (HIS).

In Brisbane, 2000 households were personally interviewed and the occupants asked to complete a travel diary for the nominated travel day. The Cairns and Townsville surveys were conducted as mailback surveys to collect similar household and person travel information.

The mailback survey technique resulted in considerable cost savings allowing acceptable samples to be collected in both Cairns and Townsville for around the same cost as the 2000 Brisbane households.

The household interview data has been utilised in each city to :

- Derive trip generation equations by purpose;
- Determine trip length distributions;
- Give the modal share.

A trip generation equation relates the number of person trips which start or finish in an area to parameters such as the population, employment, school enrollments, etc in the area. Trip generation equations were developed for each city for each of the following trip purposes :

- HBW : Home Based Work;
- HBE : Home Based Education;
- HBS : Home Based Shopping;
- HBR : Home Based Recreation;
- HBO : Home Based Other; and,
- NHB : Non Home Based.

Each trip actually consists of two ends, a trip production, and a trip attraction. Simply put, the trip production is the 'home' end of the trip and the trip attraction is the 'business' end.

The three strategic transport studies, CATSUP, TTRNS, and BTS, used the equations developed from the Cairns, Townsville, and Brisbane household interview surveys respectively. These three studies have since been finalised with final reports for CATSUP (Main Roads (1989a)) and TTRNS (Main Roads (1989b)) being released in early 1989. A report on the BTS was prepared by the Brisbane City Council also in 1989.

It is worth noting that the CATSUP and TTRNS equations have been developed using dummy variables for such parameters as significant shopping centres, primary schools, and secondary/tertiary schools. The BTS equations require more disaggregated data such as the number of retail employment opportunities, the primary and secondary school enrolments, and the tertiary enrolments.

Statistical Comparison of Trip Generation Equations

To highlight the similarities and differences between trip generation equations of different provincial cities, the CATSUP and TTRNS trip generation equations were applied to a common set of input data.

The Brisbane Region Transport Planning (BRTP) data was adopted as the input data set as it consists of a large number (242) of diverse zones which together make up the Brisbane Statistical Division. As the BTS equations were derived in part from this data, it was not considered appropriate to include the BTS equations in this comparison. The BRTP demographic data used is principally from the Australian Bureau of Statistics' 1986 Census of Population and Housing.

The trip generations produced by each set of equations were compared using a regression analysis.

Regression Analysis

Results from the regression analysis are presented firstly for the comparison of trip productions by trip purpose, and then for the comparison of trip attractions by trip purpose.

Trip Productions

The goodness of fit of the CATSUP equation versus the TTRNS equation was identified for each of the five trip purposes (HBW, HBE, HBS, HBR, and HBO) for person trip productions by all travel modes (car drivers, car passengers, bus, walk, cycle, etc). A trip production is the 'home' end of a trip. Table 1 summarises the results of the regression analysis.

Home Based Work Trip Productions : These were found to compare well as is shown in the scatter plot (Figure 1). A good correlation between the CATSUP and TTRNS HBW production equations was obtained. A result such as this is expected as the need for people to travel to work is considered to be independent of geographical location given a similar set of conditions. As the slope of the line is close to unity it can be deduced that the home based work trip production rates

Table 1 : Regression Results of Trip Production Equations from the Cairns Area Transport Study Update and the Townsville and Thuringowa Road Network Study.

Trip Purpose	R^2	Slope	Y Axis Intercept (trips)
Home Based Work	0.999	0.951	-14
Home Based Education	0.958	0.700	-76
Home Based Shopping	0.997	1.087	32
Home Based Recreation	0.997	1.010	31
Home Based Other	0.969	0.936	-65
HBW+HBE+HBS+HBR+HBO	0.997	0.932	-76

are similar for both the CATSUP and TTRNS equations with the overall CATSUP generation rate 5% greater than the TTRNS equation.

Home Based Education Trip Productions : A comparison of the HBE trip productions is shown as a scatter plot, Figure 2. While there is a reasonable correlation between the two equations the slope of the line indicates that the CATSUP equations result in a home based education trip production rate nearly 43% more than that produced by the TTRNS equation.

When considering this difference, there are several factors which may be relevant. Firstly, Townsville has a University and a College of Advanced Education while Cairns does not. This would indicate that TTRNS equation should generate more trips than the CATSUP equation due to the higher age group with increased mobility attending the tertiary institutions. However, this is not reflected in the data.

The age distributions for the Cairns and Townsville areas show similar proportions of population in the primary and secondary school age groups (5-9, 10-14, 15-19 years). However, as might be expected, Townsville has a greater percentage of population in the main tertiary education age bracket (20-24 years) than does Cairns. This would suggest that the two cities would have similar HBE trip production rates, and that any differences would reflect a higher number of trips attributable to the tertiary students in Townsville. Contrary to such expectations, more trips seem to be made in Cairns, and the difference is significant. Hence, there are no apparent reasons why the CATSUP HBE trip production equation produces a much higher estimate than its TTRNS counterpart. This will be considered further in future research.

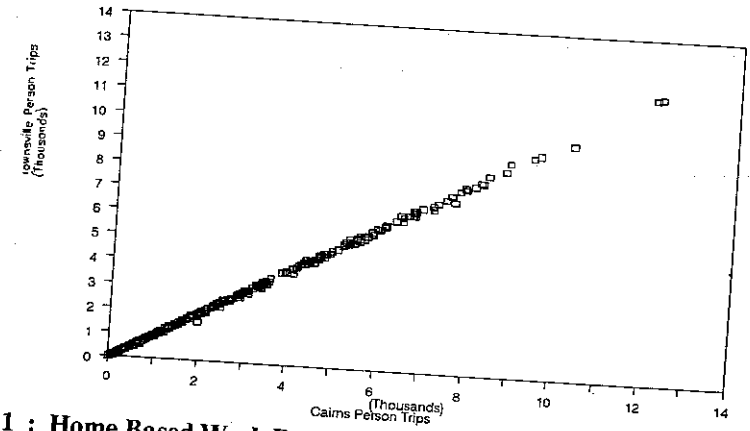

Figure 1 : Home Based Work Person Trip Productions

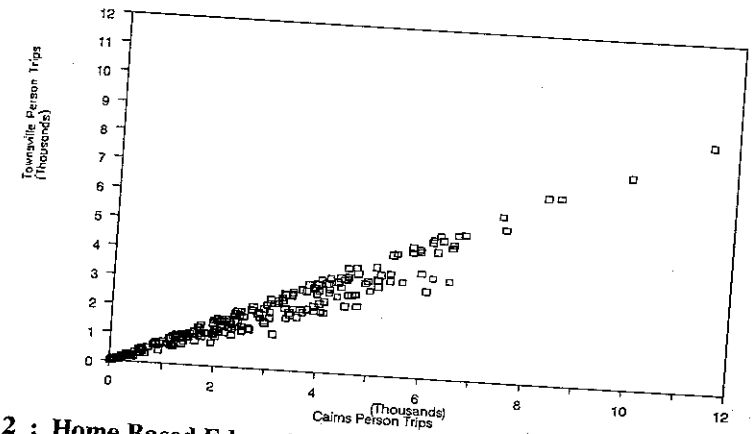

Figure 2 : Home Based Education Person Trip Productions

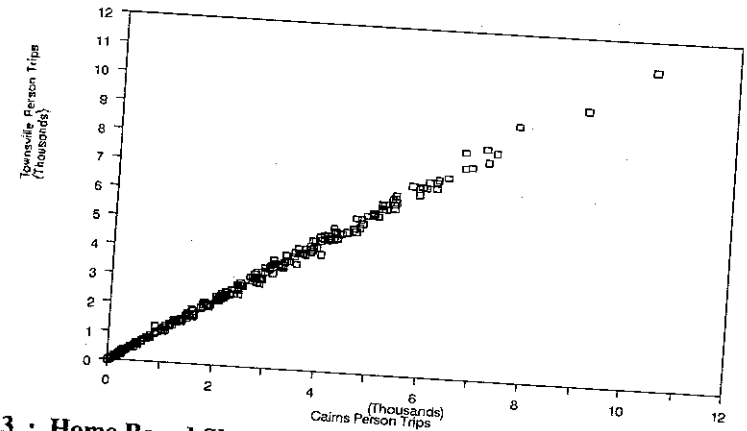

Figure 3 : Home Based Shopping Person Trip Productions

Home Based Shopping Trip Productions : Figure 3 is a scatter plot showing the comparison between the HBS person trip productions. It was deduced that there is good similarity between the two equations with the TTRNS equation producing 9% more shopping trips per person than the CATSUP equation. The difference in generation rates may be related to the longer average trip length for shopping trips in Cairns than those in Townsville (due to Cairns' linear shape as opposed to Townsville's square shape) and hence the greater impedance to making a shopping trip. The number and sizes of each city's shopping centres may also influence trip rates, as large centres are believed to generate fewer trips during which more purchases are made.

Home Based Recreation Trip Productions : A scatter plot of the HBR comparison is shown in Figure 4. The good fit between the two equations suggests that recreation trip productions are basically a function of person characteristics and are not influenced by geographical location. The CATSUP equation is shown to produce only 1% more trip ends than the TTRNS equation.

Home Based Other Trip Productions : The scatter plot of the HBO trip production comparison is shown in Figure 5. This indicates a reasonable fit between the two equations with the CATSUP equation producing 7% more trips than the TTRNS equation. There are no significant factors to be taken into consideration when comparing the two estimates of home based other trip productions. Home based other travel is a diverse group of trip purposes which apparently are slightly less transferable (in terms of a rate) between cities than other production equations such as home based work.

Combined Home Based Trip Productions : If all the preceding trip purposes are summed for both the CATSUP and TTRNS methods, the combined trip productions can be utilised to compare the similarity between the two sets of trip production equations. A scatter plot of such a comparison is given as Figure 6. It can be concluded that at a combined trip production level, there is good similarity between the CATSUP and TTRNS equations with the CATSUP equations generating 7% more trip ends than the TTRNS equations.

Trip Production Summary : From the proceeding analysis comparing person trip productions for a common data set and utilising equations from the Cairns Area Transport Study Update and the Townsville and Thuringowa Road Network Study, the following conclusions can be drawn :

- Home based work trip productions are very similar and can be transferred for use in other provincial cities;

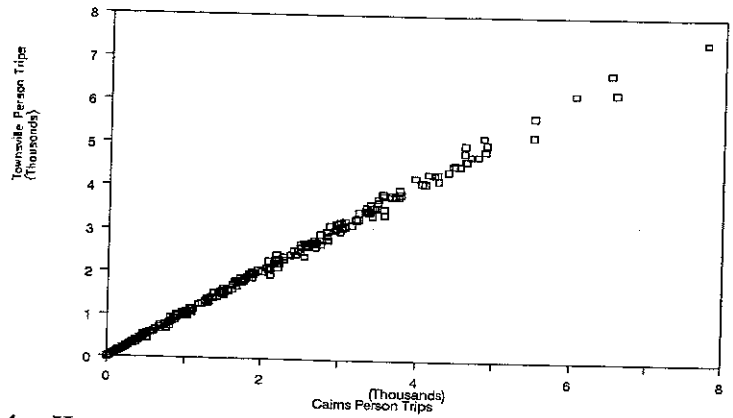

Figure 4 : Home Based Recreation Person Trip Productions

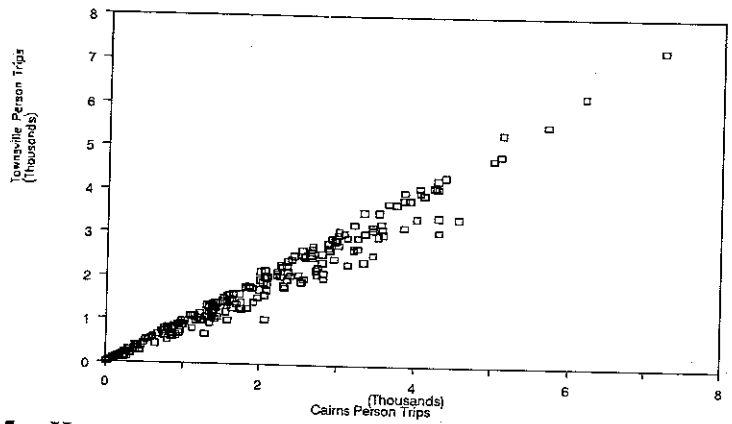

Figure 5 : Home Based Other Person Trip Productions

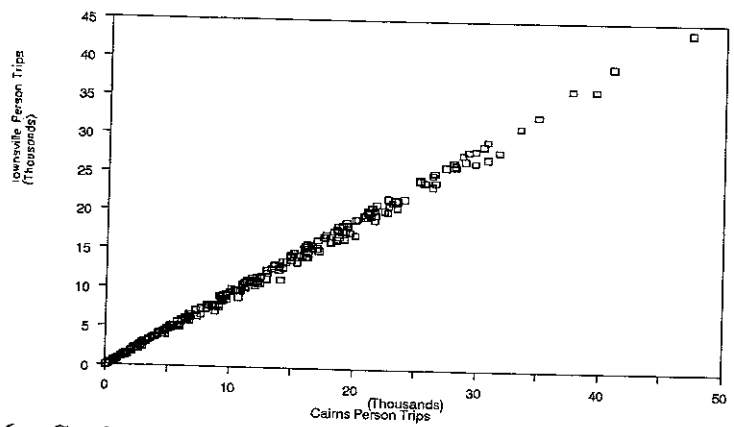

Figure 6 : Combined Home Based Person Trip Productions

- Home based education trip productions have good correlation but the CATSUP equation generates far more trips than does the TTRNS equation. Care should be used in transferring these equations with consideration given to the size and type of educational facilities in the city concerned.
- Home based shopping trip productions compare well and may be used for other provincial cities.
- Home based recreation trip productions also compare well and may be transferred for use elsewhere.
- Home based other trip productions have reasonable correlation between the two methods and may be used in other provincial cities.
- Combined home based trip productions compare well and demonstrate that at the combined level, the individual variations between trip purposes are masked.

It has been shown that the CATSUP trip production estimates range between one and forty-three percent more than the TTRNS estimates across the five trip purposes. At the combined trip level, the CATSUP equations generate only 7% more trip ends than the TTRNS equations.

Trip Attractions

The trip attraction is the 'business' end of a trip where the work, education, shopping, etc activity takes place. Person trip attractions estimated for a common data set using the Cairns Area Transport Study Update and Townsville and Thuringowa Road Network Study equations were compared for each of the six trip purposes (HBW, HBE, HBS, HBR, HBO, and NHB).

The regression analysis results are summarised in Table 2 and then discussed by purpose.

Home Based Work Trip Attractions : Figure 7 shows the HBW trip attraction comparison. There is an extremely good correlation between the CATSUP and TTRNS home based work trip attraction equations (R^2 of 1.000). However, the CATSUP equation results in a trip attraction estimate that is 27% greater than that of the TTRNS equation.

Home Based Education Trip Attractions : Figure 8 gives a scatter plot showing the comparison of the HBE trip attraction estimates. A good correlation between the two estimates is obvious. Also apparent is that the trip attractions are 35% greater when using the TTRNS equation than using the CATSUP equation. The scatter plot reveals an interesting relationship between the two

Table 2 : Regression Results of Trip Attraction Equations from the Cairns Area Transport Study Update and the Townsville and Thuringowa Road Network Study.

Trip Purpose	R^2	Slope	Y Axis Intercept (trips)
Home Based Work	1.000	0.789	41
Home Based Education	0.994	1.354	-86
Home Based Shopping	0.824	0.527	622
Home Based Recreation	0.900	0.993	-131
Home Based Other	0.940	0.838	216
Non Home Based	0.929	0.409	604
HBW+HBE+HBS+HBR+HBO+NHB	0.962	0.665	2272

estimates. Two separate regimes are revealed by the plot, the slopes being very similar. A cursory investigation of this effect suggests that the 'upper' line in Figure 8 may be produced by zones in which there are no schools, and where presumably there should be few, if any attractions. Further investigation of this effect would be warranted, as it indicates an area where the equations could possibly be significantly improved.

In considering the transferability of the HBE trip attraction equations, the effects of tertiary education facilities requires discussion. The CATSUP equation was developed for the Cairns area which has no significant tertiary institutions. The TTRNS eqaution was developed by excluding the traffic zone which contains the Townsville area's University and College of Advanced Education. These institutions were subsequently treated as special generators in the modelling process.

Hence, the HBE trip attraction equations from CATSUP and TTRNS are transferable provided all major tertiary facilities are treated as special generators.

Home Base Shopping Trip Attractions : This comparison is presented as a scatter plot, Figure 9. The Y Axis Intercept is significant for this trip purpose as it represents about 10% of the highest zone total for shopping attractions. The R^2 value indicates that the HBE trip attraction has by far the least compatibility of any of the production or attraction equations. The total estimated trip attractions using the CATSUP equation are 90% greater than the estimates obtained using the TTRNS equation.

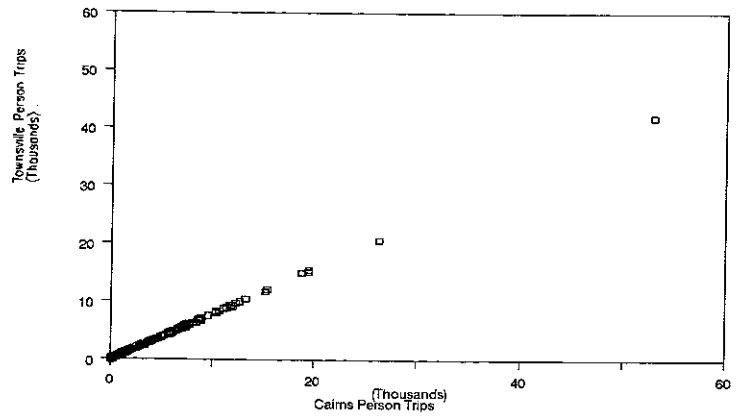

Figure 7 : Home Based Work Person Trip Attractions

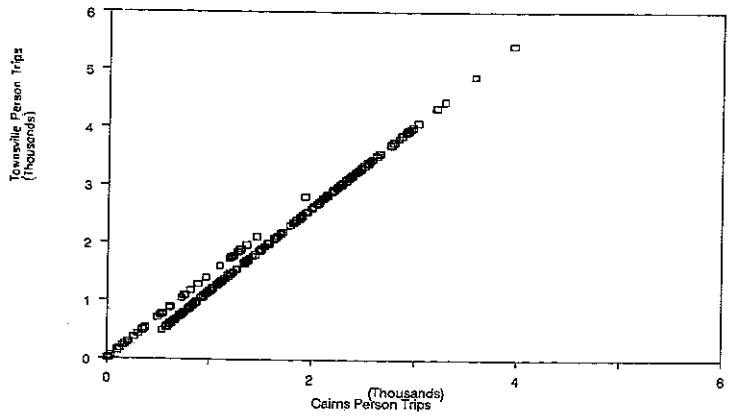

Figure 8 : Home Based Education Person Trip Attractions

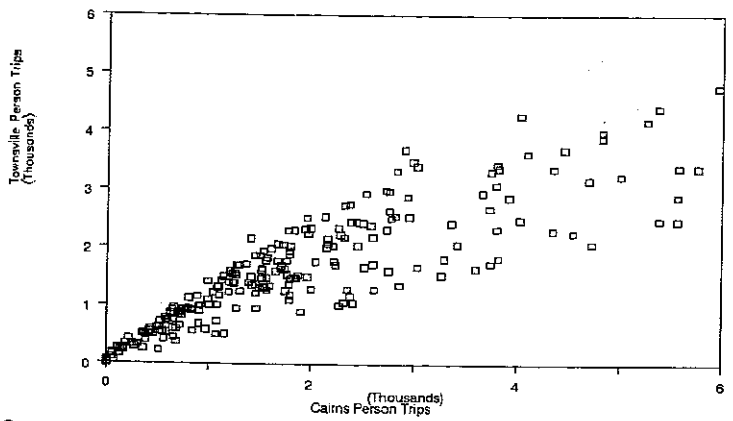

Figure 9 : Home Based Shopping Person Trip Attractions

Because the Y Axis Intercept was so high, a second regression analysis was performed forcing the regression through the origin. The resulting R^2 was lower, as expected, with a value of 0.717. Also as expected, the slope improved to 0.658.

The (relatively) poor correlation between the two home based shopping trip attraction equations is not unexpected. Traffic generation at shopping centres is a function of the individual shopping centre characteristics, particularly gross floor area. As the CATSUP and TTRNS equations were developed from empirical data for provincial cities with only a few shopping centres of significant size, the trip attraction equations are probably influenced strongly by the number and sizes of the shopping centres in the cities for which they were derived.

Hence, the home based shopping trip attraction equations are not truly transferable. Rather, as the equations are a function of the individual shopping centres in the cities from which they were derived, they are only truly transferable to another provincial city with similar shopping centres. This aspect is discussed further under the section "Previous Use of Equations in Other Cities"

Home Based Recreation Trip Attractions : The comparison of HBR trip attractions is shown diagrammatically in Figure 10. This indicates similarity between the two trip attraction equations and would suggest that they are transferable to other provincial cities. It is noted that the HBR trip attractions estimated by the CATSUP equations are less than 1% greater than those produced by the TTRNS equation.

Home Based Other Trip Attractions : A scatter plot showing the comparison between the HBO trip attractions is given as Figure 11.

This indicates good correlation between the two equations. The HBO trip attractions estimated from the CATSUP equation are 19% greater than those estimated by the TTRNS equation. It is however apparent that the home based other trip attraction equations are transferable.

Non Home Based Trip Attractions : Non home based trip attraction equations from the CATSUP and TTRNS were compared. The resulting scatter plot is shown as Figure 12. While there is good correlation between the equations, the trip attractions estimated by the CATSUP equation are 144% greater than that estimated by the TTRNS equation.

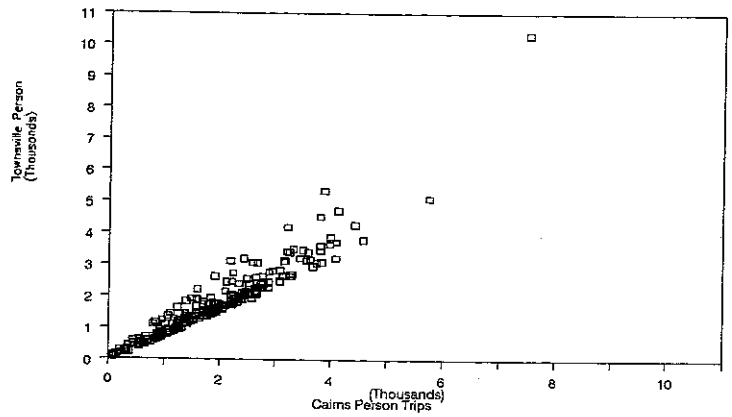

Figure 10 : Home Based Recreation Person Trip Attractions

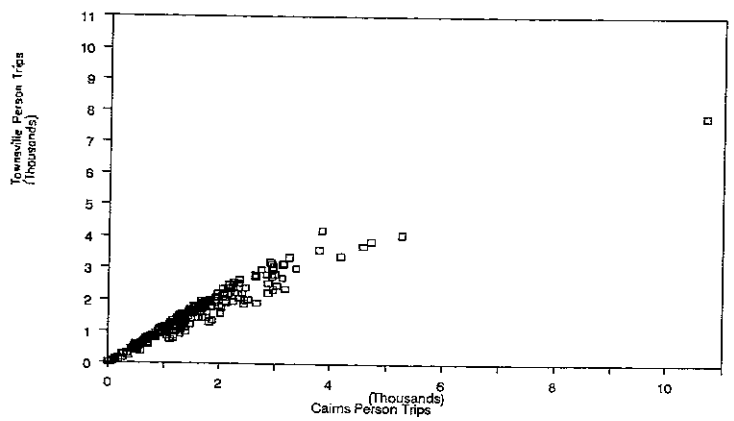

Figure 11 : Home Based Other Person Trip Attractions

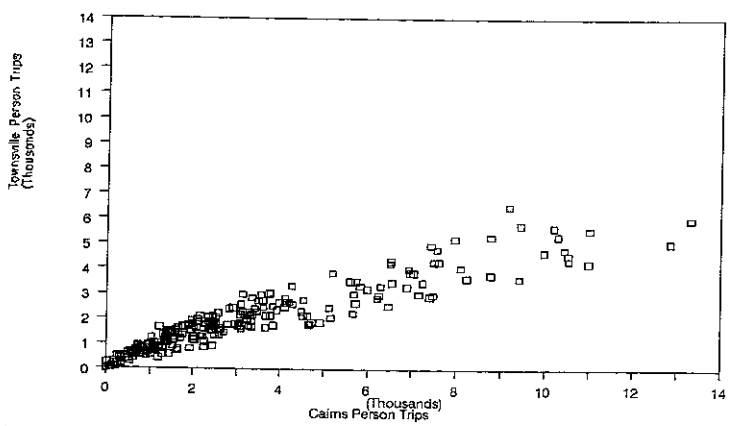

Figure 12 : Non Home Based Person Trip Attractions

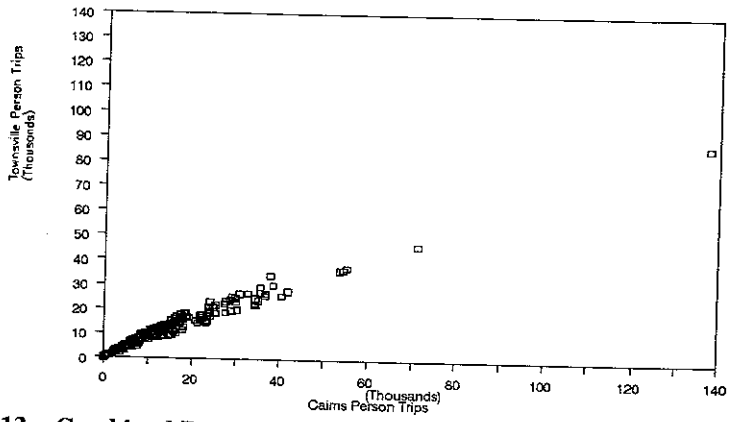

Figure 13 : Combined Person Trip Attractions

Combined Trip Attractions : The scatter plot, Figure 13, shows the comparison between the sum of CATSUP trip attraction estimates and the sum of all TTRNS trip attraction estimates. This comparison is useful as an indication of the overall degree of compatibility between the two sets of trip attraction equations.

It can be concluded that there is good similarity between the two sets of equations at the total attractions level. As is shown by the slope of the line, the CATSUP trip attractions estimate is 50% greater than the TTRNS estimate.

Trip Attraction Summary : The preceding analysis comparing trip attraction estimates by trip purpose from the Cairns Area Transport Study Update and the Townsville and Thuringowa Road Network Study can be summarised as follows :

- Home based work trip attraction equations are extremely similar and can readily be transferred for use in other cities.
- Home based education trip attraction equations are similar and can be transferred between cities provided tertiary facilities are treated separately.
- Home based shopping trip attraction equations are not directly transferable to other cities. Rather, consideration should first be given to the type and form of the actual shopping centres in the city concerned.
- Home based recreation trip attraction equations are similar and could therefore be directly applied to other provincial cities
- Home based other trip attraction equations are transferable between provincial cities.
- Non home based trip attraction equations are also transferable. However, due to the significant variation in totals between the two equations, the total number of such trips may need to be independently estimated.

- The combined trip attractions compare well and consequently as a whole, the equations can be considered transferable.

The CATSUP trip attraction equations produce higher estimates than do the TTRNS equations by between one and 144 percent at the total trip attraction level over the six trip purposes. At the combined trip level, the CATSUP equations generate 50% more trip ends than do the TTRNS equations

At the trip distribution stage of the four step model, the total trip attractions are made to equal the total trip productions. This is due to the greater accuracy inherent in the data input to the production equations over that required for the attraction equations. Thus, the greater discrepancy between the CATSUP and TTRNS trip attraction generation rates is reduced to that of the productions during the Trip Distribution phase.

Previous Use of Equations in Other Provincial Cities

The trip generation equations from the TTRNS have been used in strategic transport planning studies for two other provincial cities over the last two years. TTRNS equations were selected for use in both studies because the two cities concerned were more similar to the Townsville region than to Cairns. In particular, the cities did not have the tourism industry as their base, and had geographical characteristics which more closely resembled those of Townsville.

In calibrating the TTRNS trip generation model for the other cities one principal problem was encountered, viz home based shopping trips. As shown by the trip attraction estimates discussed above, the HBS trip attraction equation is heavily influenced by the individual shopping centres upon which the equation was derived. Because the size and style of the shopping centres in the two cities concerned were not similar to those in Townsville, it was necessary to modify the TTRNS HBS trip attraction equation using trip end information collected for the specific shopping centres concerned. This data is part of a report on provincial city shopping centre generation (Main Roads (1986)).

Once this discrepancy in home based shopping trip attractions was corrected, there were no further significant difficulties in obtaining a reasonable calibration for both strategic planning studies. While there was no observed travel data for the two cities concerned, the calibration was in each case successfully checked against observed traffic counts throughout the region. Hence the equations exhibited a good degree of transferability.

Conclusions

Significant resource savings can be achieved by utilising trip generation equations derived in one city for a strategic transportation planning study in another if no significant loss in accuracy results.

It has been generally shown that trip production and trip attraction equations developed for studies in the Cairns and Townsville Areas are similar and can be considered transferable with a few exceptions.

Tertiary education institutions of significant size must be treated as special generators and their trip attractions added to those produced by the HBE trip attraction equations,

The HBS trip generation equations are heavily influenced by the shopping centres upon which they were derived. Consequently, it may be more accurate to determine the trips generated by shopping centres by alternate procedures.

In general the estimates produced by the CATSUP equations are greater than those produced from TTRNS equations. Some allowances may be required for differences in total trip generation rates between cities when transferring these equations.

As trip production equations are a function of household attributes, they were found to be very similar and hence transferable. Trip attraction equations are based on 'industry' and hence it was not unexpected to find a greater difference in generation rates between the two cities than was shown for trip productions. This is recognised in the trip distribution phase of the modelling process by setting trip attractions equal to trip productions. Consequently the greater differences are compensated for.

This research indicates that while the existing trip generation equations from the Cairns Area Transport Study Update and the Townsville and Thuringowa Road Network Study can be considered transferable within limits, futher research would better explain some of the anomalies identified. Subsequently, it would be possible to redefine the parameters used in the equations showing the greatest discrepancy to maximise their transferability.

Acknowledgements

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