The Urban Transport Institute

TUTI Report 1-2000

Seasonal and Weather Impacts on Urban Cycling Trips

A.J. Richardson

July 2000

Seasonal and Weather Impacts on Urban Cycling Trips

A.J. Richardson

The Urban Transport Institute, PO Box 363, Alexandra 3714, Victoria, Australia

---

Abstract

Despite the common perception that bicycle trips are probably the most influenced by inclement weather, there is relatively little empirical evidence to support this claim. This paper attempts to quantify the effect of temperature variations and rainfall on the propensity of cyclists to make trips in the metropolitan area of Melbourne, Australia. The travel data used in the analysis comes from an ongoing household travel survey in Melbourne, while the weather data comes from the Bureau of Meteorology. Using data for the full year of 1994, the analysis shows that cyclists are less likely to ride in very cold or very hot weather, while increasing daily rainfall also reduces the propensity to cycle. Recreational trips are more influenced by inclement weather than other trips made for utilitarian purposes such as commuting to work or school or going shopping. The results of the analysis are used to derive seasonal adjustment factors that can be applied to the results of cycle surveys conducted under varying weather conditions.

Keywords: cycling, weather, temperature, rainfall, seasonal factors, surveys

---

Acknowledgement:

The analysis underpinning this paper was conducted while the author was Director of the Transport Research Centre at RMIT University, Melbourne, Australia.

Contact Author: Phone: (613) 5774 7617 Email: ajr-tuti@virtual.net.au

1. Background

A recent article on the forecasting of bicycle travel (Porter et al., 1999) identified a number of factors as influencing the demand for non-motorised travel, as shown in Figure 1. Amongst these factors, particularly for bicycle travel, was the effect of climate and weather.

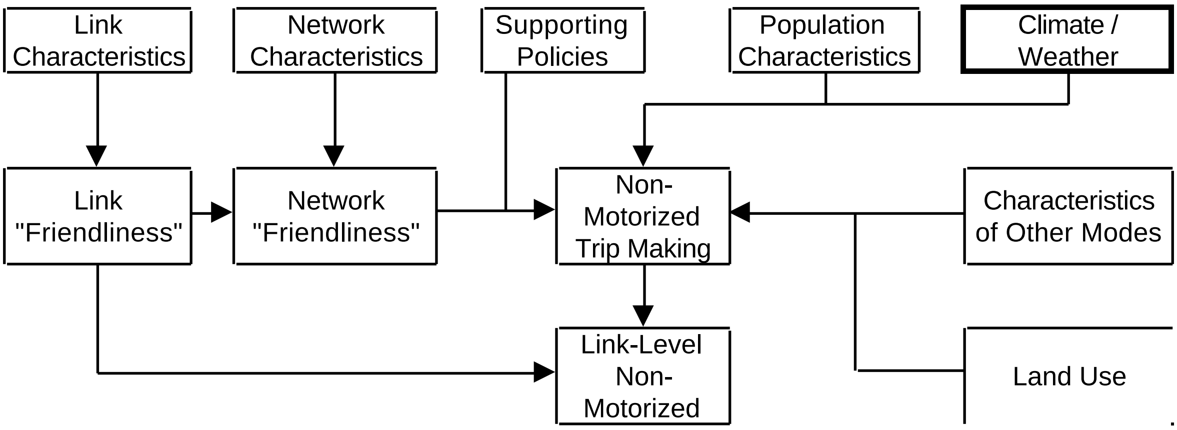

Figure 1 Relationship of Factors influencing Non-motorized Travel

Despite the fact that it appears obvious that bad weather will affect cyclists' behaviour, little investigation of this aspect of the demand for cycling appears to have been undertaken. A review of the literature reveals only a handful of studies which have addressed this problem (Hansen and Hansen, 1977; Hepkinson et al, 1989; Municipality of Copenhagen, 1989; Goldsmith, 1992; Keay, 1992; Niemeier, 1996; Nankervis, 1999), and none of them have produced conclusive results. The most common conclusion has been that recreational cycling is affected by weather variations more than commuter cycling, and that rainfall has a more significant effect than temperature. There has been little data, however, to quantify the magnitude of these effects. Nankervis (1999), in a study of student cyclists in Melbourne, found that neither long-term climate nor short-term weather variations were a strong barrier to student cycle commuting. The Municipality of Copenhagen (1989) estimates that weather conditions in winter can reduce commuter cycling between 30% and 66%, but few other quantitative estimates are available.

One of the major problems with previously reported studies of the relationship between weather and cycling has been that the underlying data bases have not been particularly strong. With the exception of the Hanson and Hanson study (1977), that used data from a travel survey in Uppsala, Sweden, the cycling data has often related to a specific sub-group of the population (such as in Nankervis, 1999) or else the cycling data has been specific to one site (Keay, 1992). In no known study has the cycling data been obtained from a comprehensive travel survey which measures cycle usage across a broad population and across all seasons of the year. The current study seeks to remedy this deficiency by using cycling data from an ongoing household travel survey, and matching this to comprehensive weather data from the Australian Bureau of Meteorology.

2. The Victorian Activity & Travel Survey (VATS)

The Victorian Activity & Travel Survey (VATS) is a household-based travel survey conducted by the Transport Research Centre (TRC) at RMIT University in Melbourne, Australia. VATS began in late-1993 and has been conducted on an ongoing basis since that time. The VATS survey uses a mail-out/mail-back self-completion questionnaire technique, with six discrete stages (Richardson and Ampt, 1995):

1. **Initial contact letter**
2. **First mailing, including:**
   - A follow-up covering letter
   - A household and person form
   - 6 trip forms (to cover the maximum expected number of persons in the household)
   - A trip form with a pre-printed completed example
   - A postage-paid return envelope
3. **First reminder.**
4. **Second reminder.**
5. **Third reminder, including:**
   - all the items sent in the first mailing
   - a cover letter from the Survey Director stressing the importance of cooperation by respondents
6. **Fourth reminder.**

In addition to the postal reminders, a number of other techniques are used to improve response rates and the quality of the reported data. Firstly, for responding households in which there is some question over the quality or completeness of the reported data, telephone interviews are conducted by the data-enterers to clarify any points of uncertainty. Secondly, a sample of responding households is selected for validation interviews, conducted by personal interview. The purpose of these interviews is to check on the manner in which the questionnaires have been completed, and to assess the quality of the reported data (especially relating to the identification of non-reported trips). Thirdly, a sample of households that have not responded after the fourth reminder is contacted personally to ascertain the reasons for their non-response.

The VATS survey records all travel by all modes by all people in responding households in the survey sample. Each household is asked to provide this information for a specified travel day. However, the survey is a continuous process, covering all 365 days of the year, thus enabling seasonal variations in travel and activity patterns to be observed. These seasonal variations extend from variations by time of day, to day of week (including weekends), to month of year.

The data set used in this paper is from the 1994 calendar year. This data was obtained from 7,278 households (with a response rate of 54%), and included data on 19,686 people who made a total of 74,056 trip stages across 64,021 trips. The sample survey data was expanded up to population control totals obtained from the Australian Bureau of Statistics, thereby eliminating sample biases caused by differential sampling rates over space and time.

The overall mode of travel for various trip stage purposes is shown in Table 1. It can be seen that cycling was used for 1.5% of all trip stages. It was above average for pickup/delivery trips (because of the heavy use of bicycle couriers in the CBD), for education trips, for recreational trips (including trips to recreational destinations) and for the small number of trips for "other" purposes. Cycling was not used very much as a feeder mode to public transport, as indicated by the very low proportion of "change mode" trip stages that were made by cycle.

In considering the effect of weather on cycling trips, it is useful to distinguish between those trips which must generally be made, despite the weather, and those which can more easily be postponed to a later date. In line with previous studies of cycling and weather, the trip purposes listed above in Table 1 have been compressed into just two categories; Recreational trips, that include the social and recreational trips listed in Table 1, and Utilitarian trips, that include all other trip purposes (except change mode, which are excluded from the analysis).

Table 1 Mode of Travel by Trip Stage Purpose

	Mode of Travel						
Trip Stage Purpose	**Walk**	**Cycle**	**Car**	**Taxi**	**Transit**	**Other**	**TOTAL**
Change Mode	44%	0.2%	8%	0%	48%	0%	13%
To accompany someone	21%	1.0%	77%	0%	0%	1%	6%
To buy something	33%	1.4%	65%	0%	0%	0%	12%
Pickup/delivery	18%	2.7%	76%	0%	0%	3%	3%
Chauffeuring	7%	0.3%	93%	0%	0%	0%	6%
For education	40%	3.4%	50%	0%	6%	0%	3%
For work purposes	22%	1.0%	72%	1%	1%	4%	10%
To go home	20%	2.0%	76%	1%	0%	0%	29%
Personal business	26%	1.4%	71%	1%	0%	1%	4%
Social	24%	1.4%	74%	1%	0%	0%	8%
Recreational	28%	5.3%	65%	0%	1%	1%	4%
Other	33%	3.3%	61%	1%	0%	1%	2%
TOTAL	26%	1.5%	65%	0%	7%	1%	100%

Recreational cycle trips tend to be slightly longer both in distance and in time, as shown in Figures 2 and 3. Recreational trips are, on average, 2.4km in length compared to 2.1km for utilitarian trips. They average 19 minutes duration, compared to 15 minutes for utilitarian cycle trips.

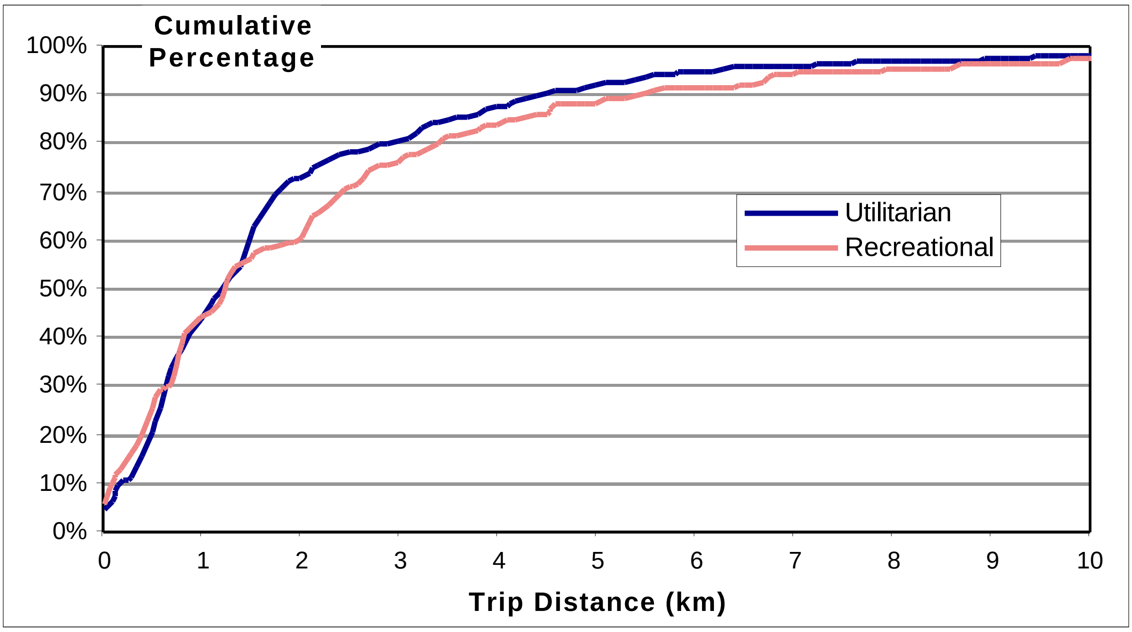

Figure 2 Trip Length Distributions for Cycle Trips

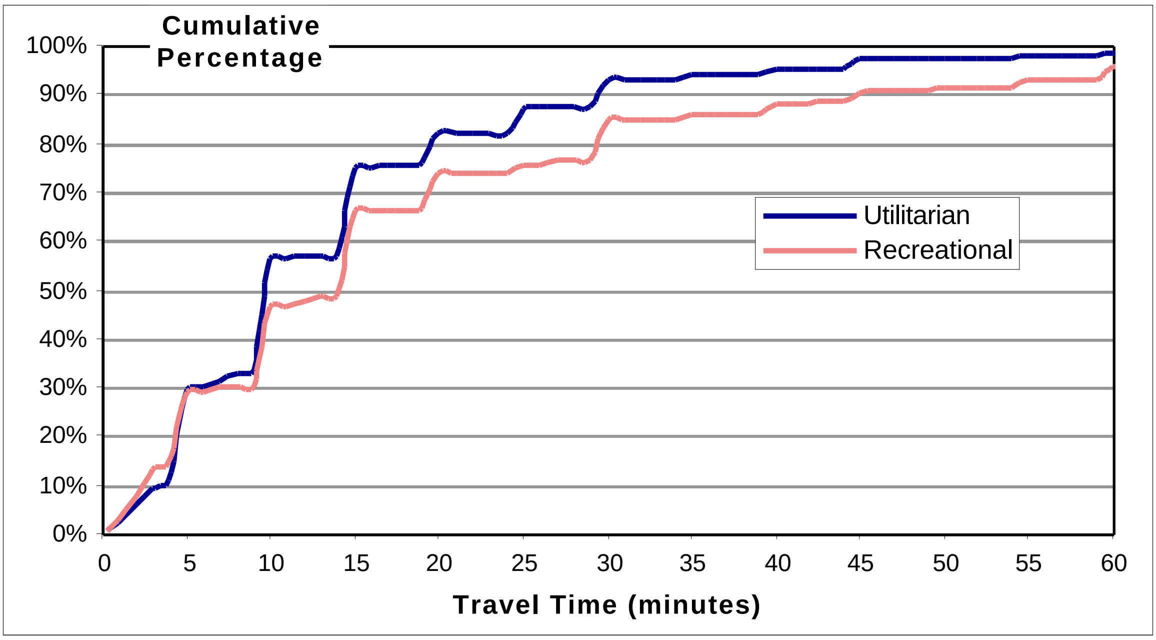

Figure 3 Travel Time Distributions for Cycle Trips

Cycling trips tend to be concentrated among the young. Figure 4 shows that those between 10 and 20 years of age have the highest proportions of their trips made by cycling, both for utilitarian and recreational purposes. Those in their twenties tend to use cycling equally for utilitarian and recreational trips, while all other age groups tend to use cycling more for recreational trips than for utilitarian trips.

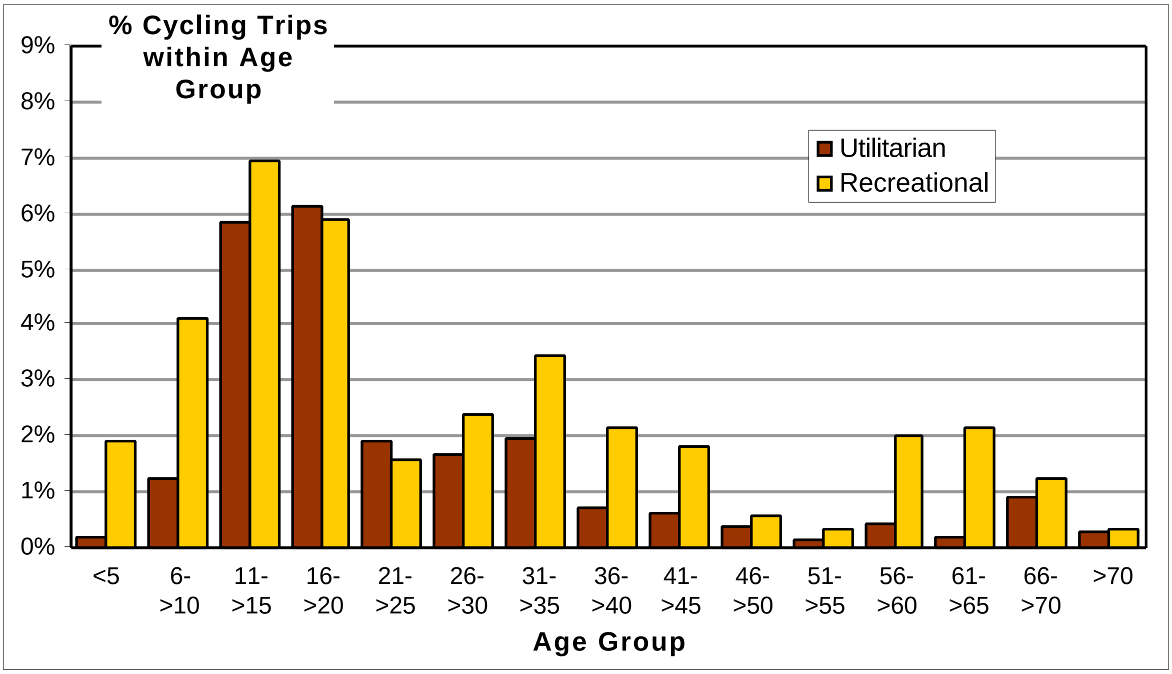

Figure 4 Proportions of Cycle Trips within each Age Group

Cycling also tends to be more prevalent amongst males. Across all ages, males tend to use cycling more than females for both utilitarian and recreational trips. The difference is more pronounced for utilitarian trips, where 78% of these trips are made by males compared to 71% of recreational trips being made by males.

Table 2 % Trips by Cycle by Gender of Cyclists by Trip Type

	% Cycle Trips		
	Male	Female	% Male
Utilitarian	2.4%	0.7%	78%
Recreational	3.9%	1.5%	71%

The overall seasonal trends in cycling are shown in Figure 5. It can be seen that there is relatively little systematic variation in the proportion of utilitarian cycle trips within each month, with the proportion of annual trips in each month hovering around 8%. However, the recreational trips tend to peak in the summer months at around 10% of annual trips each month, and decrease in the winter months to about 6% of annual trips each month.

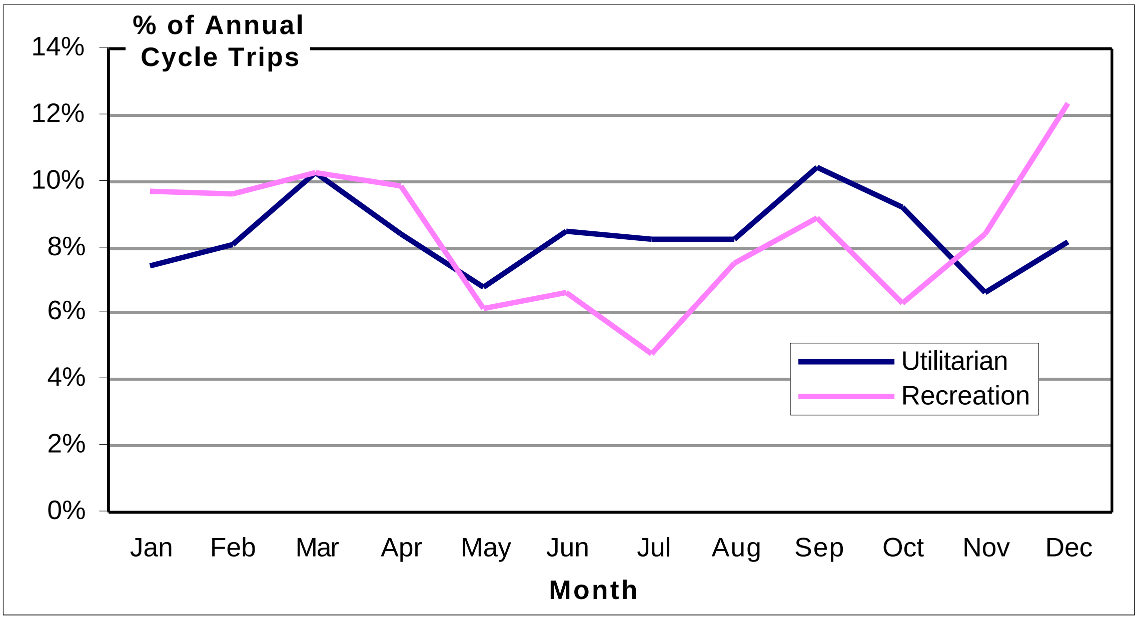

Figure 5 Proportions of Cycle Trips within each Month

3. The Weather Data

The weather data used in this project was obtained from the Australian Bureau of Meteorology. A data file was obtained containing the following information for every day between October 1980 and August 1995 at one weather station site in the Melbourne inner suburbs:

- Maximum daily temperature
- Minimum daily temperature
- Maximum wind speed and direction
- Daily rainfall
- Hours of sunshine
- % cloud cover

A summary of the principal weather features by month of year, for 1994 and for the 14 years from 1981 through 1994 are shown in the following diagrams. Figure 6 shows the average maximum daily temperature in each month of 1994, plus the corresponding 14-year average. It can be seen that over the 14-year period, the maximum daily temperature falls from a high of about 25°c in summer down to about 15°c in winter. The 1994 temperatures were very similar to the 14-year average, except for December which was about three degrees higher than normal.

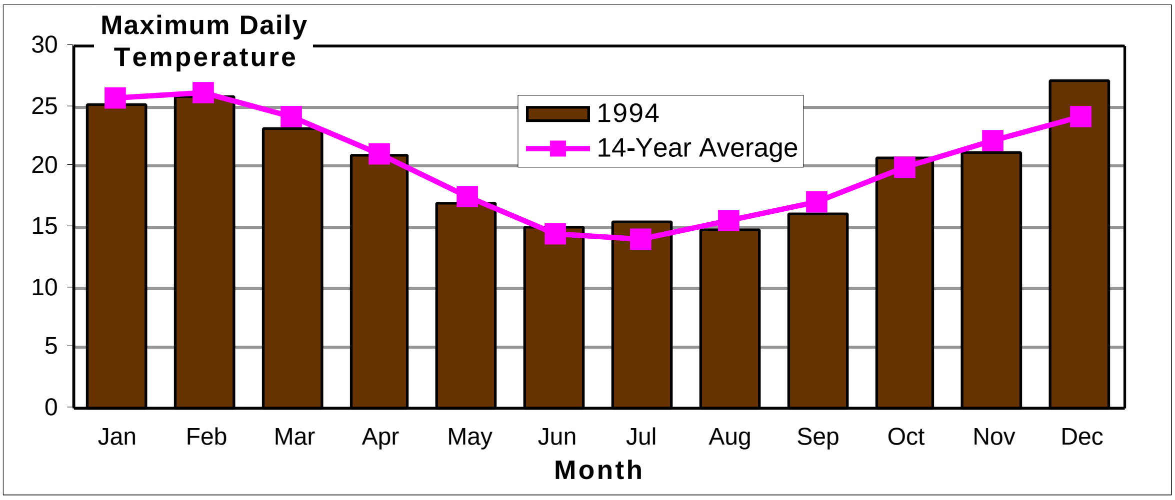

Figure 6 Maximum Daily Temperature by Month of Year

Figure 7 shows the average daily maximum wind speed in each month of 1994, plus the corresponding 14-year average. It can be seen that over the 14-year period, the maximum wind speed falls from a high of about 12 kph in summer down to about 10 kph in autumn. The 1994 values show a similar trend to the 14-year average, except for May which was much windier than normal.

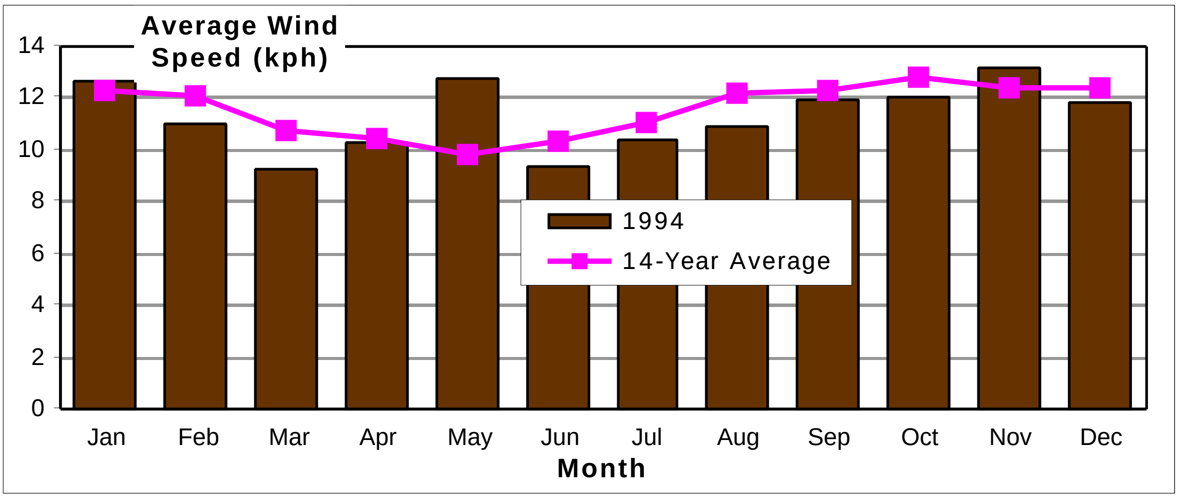

Figure 7 Average Maximum Wind Speed by Month of Year

Figure 8 shows the average daily rainfall in each month of 1994, plus the corresponding 14-year average. It can be seen that over the 14-year period, the average daily rainfall gradually increases over the year, after an initial drop from January to February, which is the driest month. Unlike the results for temperature and wind speed, the 1994 values for average rainfall show several differences to the 14-year average. February was the wettest month in 1994, while December was the driest. The winter months were also relatively dry in 1994.

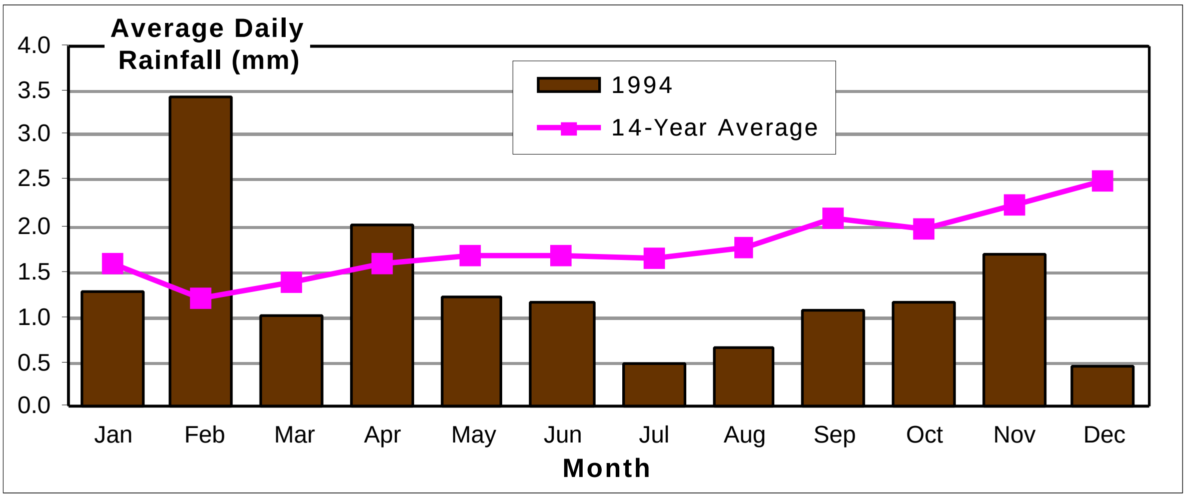

Figure 8 Average Daily Rainfall by Month of Year

This variability in rainfall from year to year suggests that rainfall is more likely to be associated with short-term changes in weather conditions, whereas temperature is more likely to be associated with long-term seasonal variations in climate (using the distinction between weather and climate as noted by Nankervis (1999)).

Figure 9 shows the average cloud cover (as a percentage of daylight hours) in each month of 1994, plus the corresponding 14-year average. It can be seen that over the 14-year period, the average cloud cover falls from a high of about 55% in winter down to about 35% in summer. The 1994 values show a similar trend to the 14-year average, although the winter months were less cloudy than normal. This corresponds to the lower winds and rainfall in winter 1994, as shown in Figures 7 and 8.

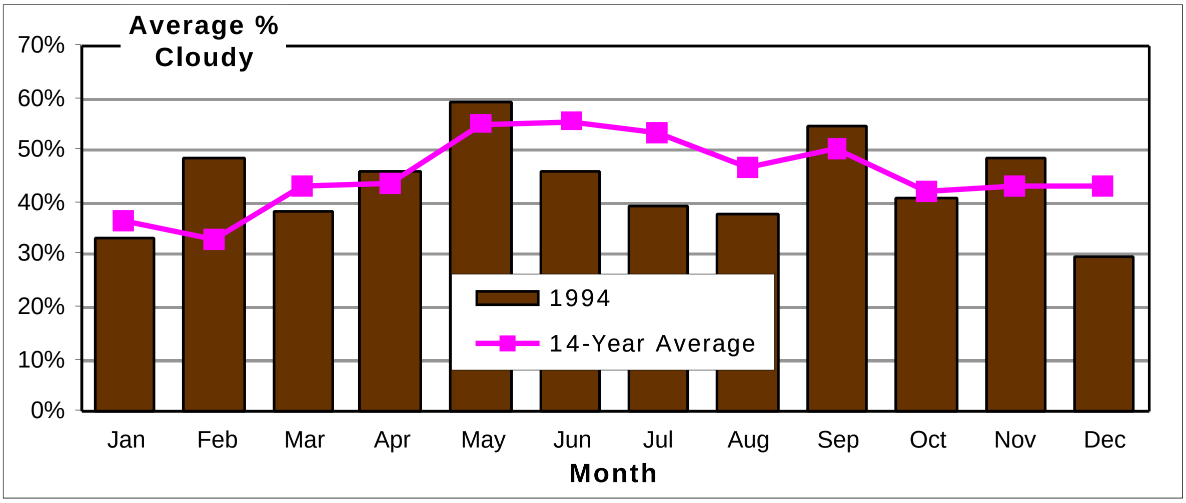

Figure 9 Average Cloud Cover by Month of Year

4. The Effect on Weather on Cycling

Figure 5 has shown that, for recreational cycle trips at least, there is a decrease during the winter months. The previous section has shown predictable deterioration in weather conditions during the winter months. This section of the paper will determine whether there are any specific relationships between the propensity to cycle and the weather conditions. In particular, the effect of temperature variations and rainfall will be investigated, since these two variables represent the extremes of day-to-day variability within a month, as shown in Figure 10. As such, maximum daily temperature is probably a good indicator of relatively predictable seasonal climate variations, while daily rainfall is a good indicator of day-to-day weather variations within a month.

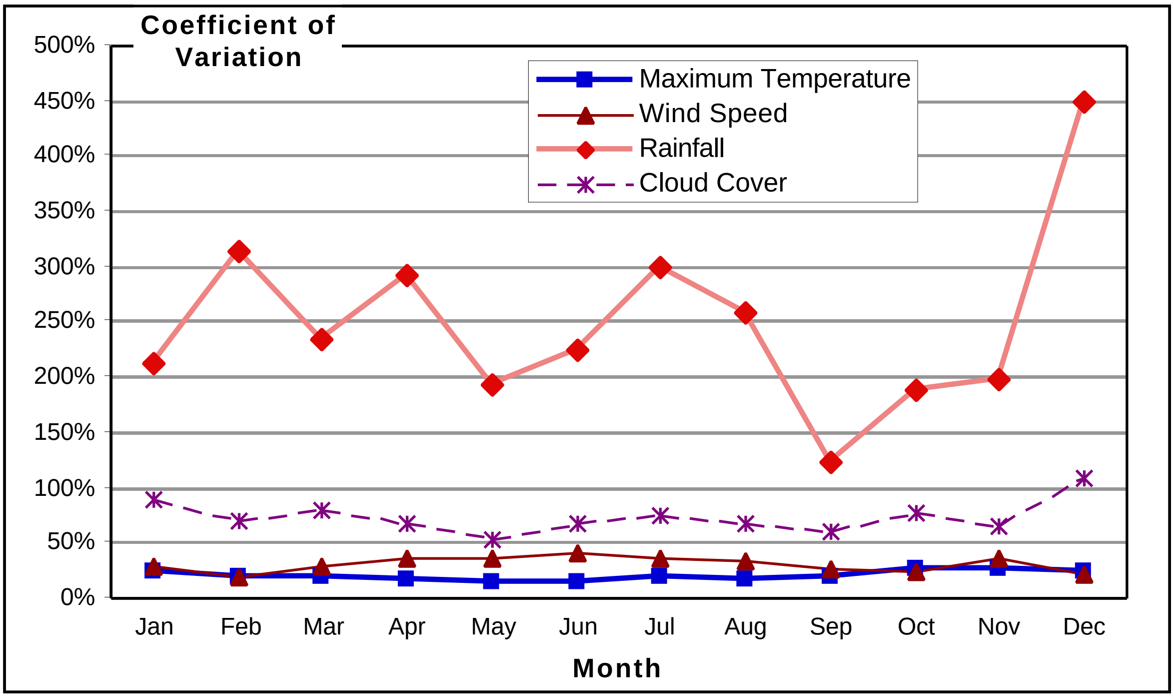

Figure 10 Day-to-Day Variability in Weather Parameters

For each day of the year, the number of cycle trips and the weather conditions on that day were tabulated. Figure 11 shows the average number of cycle trips on days with different maximum temperatures (where the days have been aggregated into groups with the same temperature to the nearest degree). The quadratic of best fit (fitted to the disaggregated data points) is also shown, and indicates that daily cycle flows are lower at both low and high temperatures.

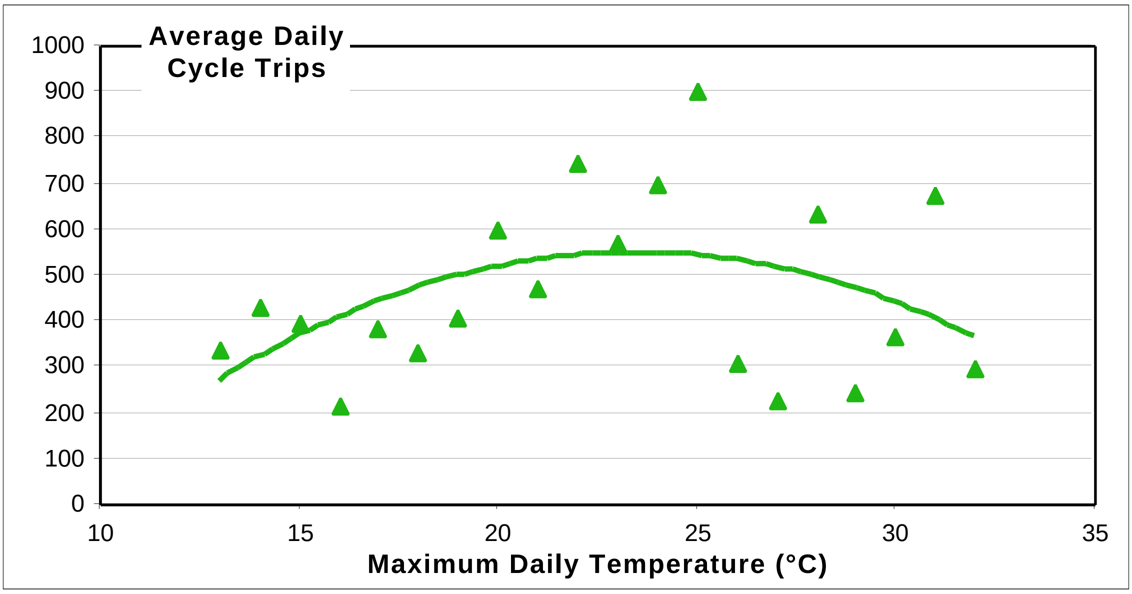

Figure 11 The Effect of Temperature Variations on Cycle Flows

A similar analysis was performed for the effect of daily rainfall on cycle flows, and the results are shown in Figure 12. It can be seen that increasing daily rainfall results in lower daily cycle trips, although the effect is not linear. Up till about 5mm per day, there seems to be no discernible effect on cycle flows, but further rainfall has a significant effect in reducing cycle flows.

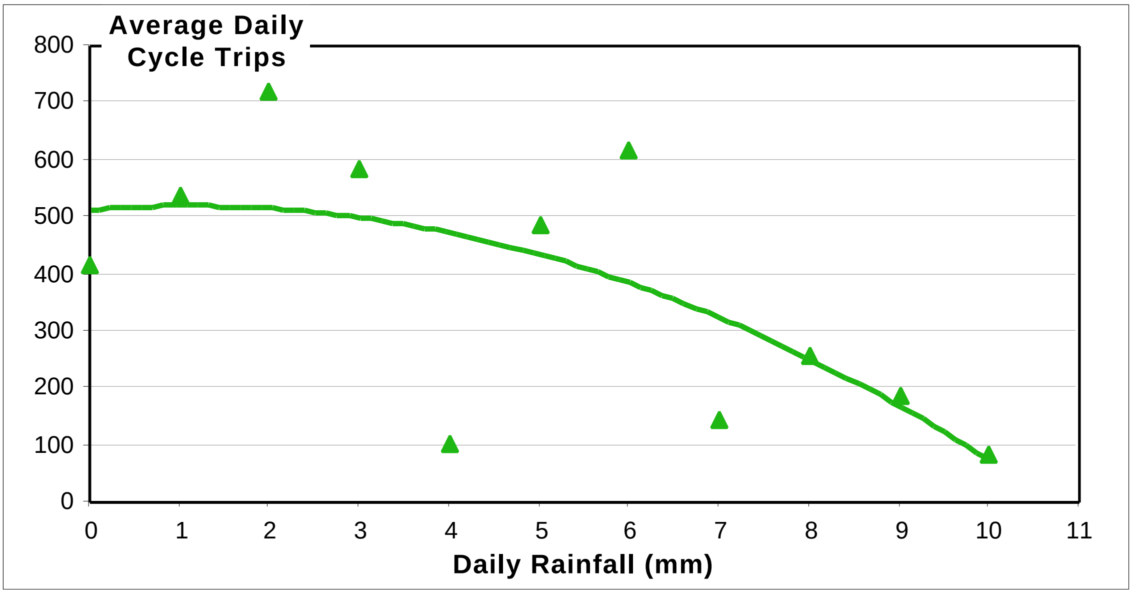

Figure 12 The Effect of Rainfall on Cycle Flows

According to previous research, the effect of climate and weather is different for different types of cycle trips. Therefore, the cycle trips were separated into utilitarian and recreational trips and the above analyses repeated. The effect of temperature variations on the different types of cycle trips are shown in Figure 13. It can be seen that both types of trips are affected by high and low temperatures, but the overall number of recreational trips is lower at each temperature. The effect of rainfall on the different types of cycle trips are shown in Figure 14. It can be seen that both types of trips are affected by rainfall, but in different ways. Utilitarian trips are unaffected by low amounts of rainfall and only decrease as the rainfall increases. Recreational trips, on the other hand, are affected by any amount of rainfall. It seems that recreational trips, which are more easily postponed than utilitarian trips, are deterred by any rainfall, while utilitarian trips continue to be made until the rainfall increases substantially.

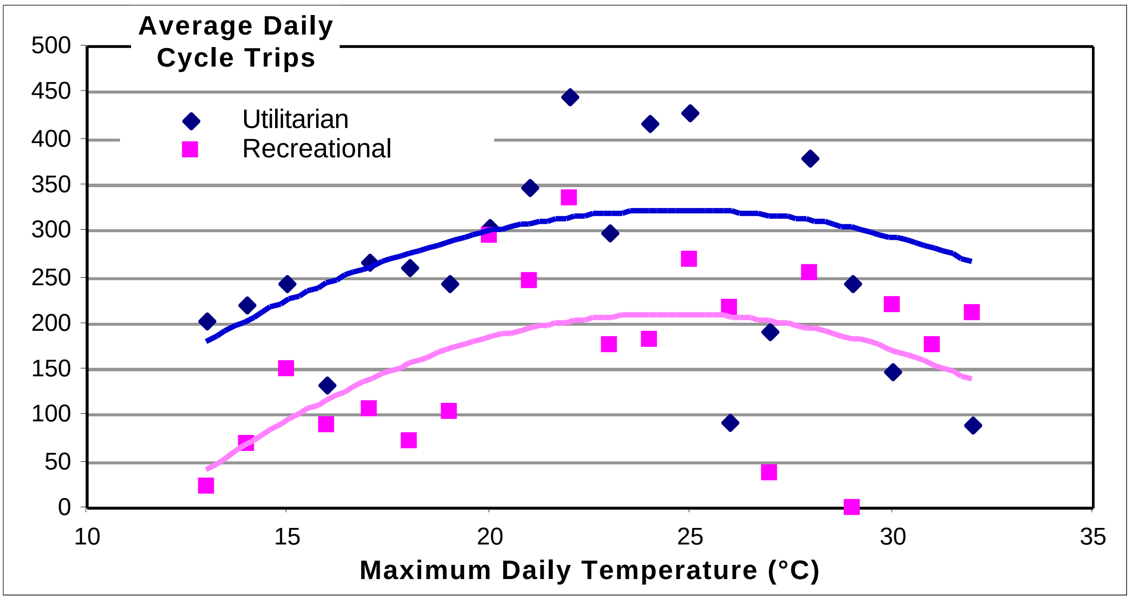

Figure 13 The Effect of Temperature Variations on Different Cycle Trips

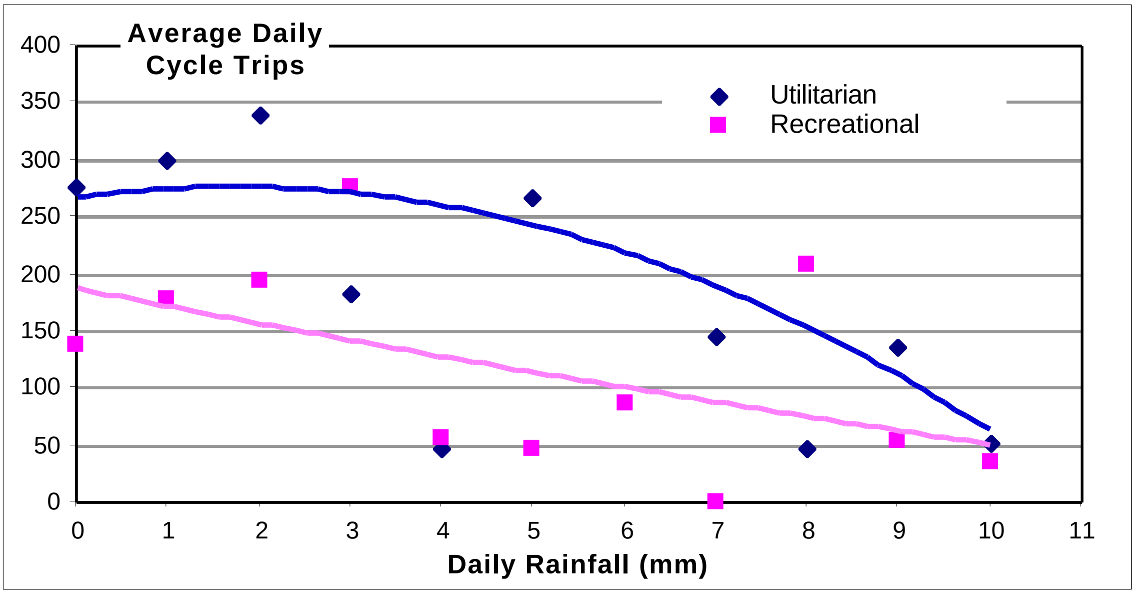

Figure 14 The Effect of Rainfall on Different Cycle Trips

The relationship shown in Figures 13 and 14 can be converted to standardised probability graphs by scaling each quadratic of best fit, such that the maximum point on each curve is equal to 100%, as shown in Figures 15 and 16. After doing this standardisation, several points emerge. Firstly, the maximum probability of making either type of cycle trip occurs at 25°C. On either side of this "ideal cycling temperature", recreational trips are more deterred by temperature variations. For example, at 15°C, 70% of utilitarian cycle trips continue to be made, compared to only 45% of recreational trips.

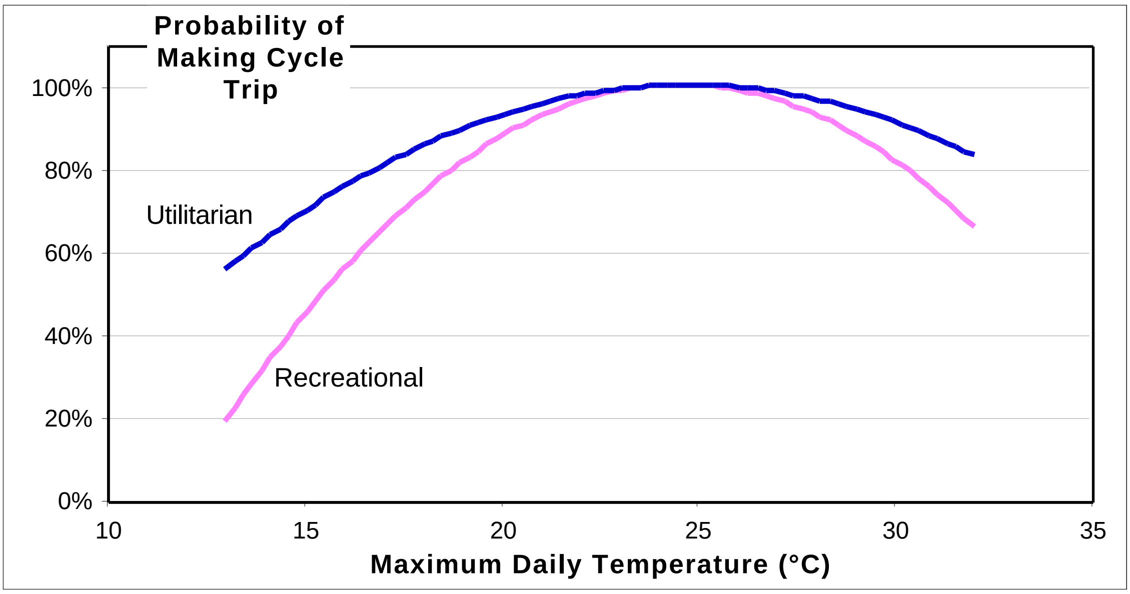

Figure 15 The Propensity to Make Cycle Trips as a Function of Temperature

The ideal rainfall for cycling is zero rainfall. As rainfall increases, both types of trip decrease (if one ignores the slight rise in the quadratic curve for the utilitarian trips at low rainfalls), but while they decrease almost linearly for recreational trips, they only start to decrease significantly for utilitarian trips above a daily rainfall of 4mm. For example, at 5mm per day, 90% of utilitarian trips are still being made, compared to only 60% of recreational trips. However, by the time the rainfall has increased to 10mm per day, only 25% of either utilitarian or recreational trips are still being made.

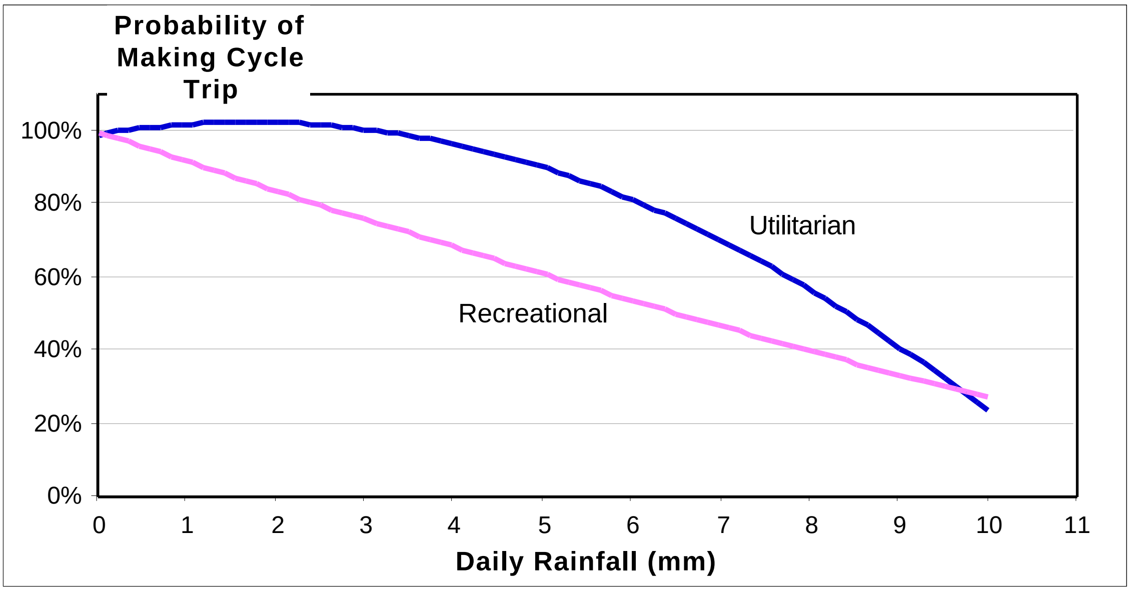

Figure 16 The Propensity to Make Cycle Trips as a Function of Rainfall

5. Testing of the Model

The implicit assumption that has been made in the analysis so far is that daily variations in cycle flows are caused solely by variations in weather conditions, in particular by variations in temperature and rainfall. It is assumed that other weather features, such as wind speed and cloud cover, do not have additional effects on cycle flows. Also, it is assumed that there are no other seasonal effects not related to weather variations. While none of these assumptions are absolutely correct, a first test of the model is whether the use of the temperature and rainfall factors alone can reproduce the variations in cycle flow observed in 1994.

To test the ability of the model to predict the observed variations during the year, a small simulation model was constructed where, given the weather conditions on each day of the year, the proportion of utilitarian and recreational trips being made (compared to the ideal day) are calculated using the results from Figures 15 and 16. The average proportion for each month has then been calculated for utilitarian and recreational trips, and compared with the observed flows for 1994, as shown in Figure 17 for utilitarian trips and Figure 18 for recreational trips.

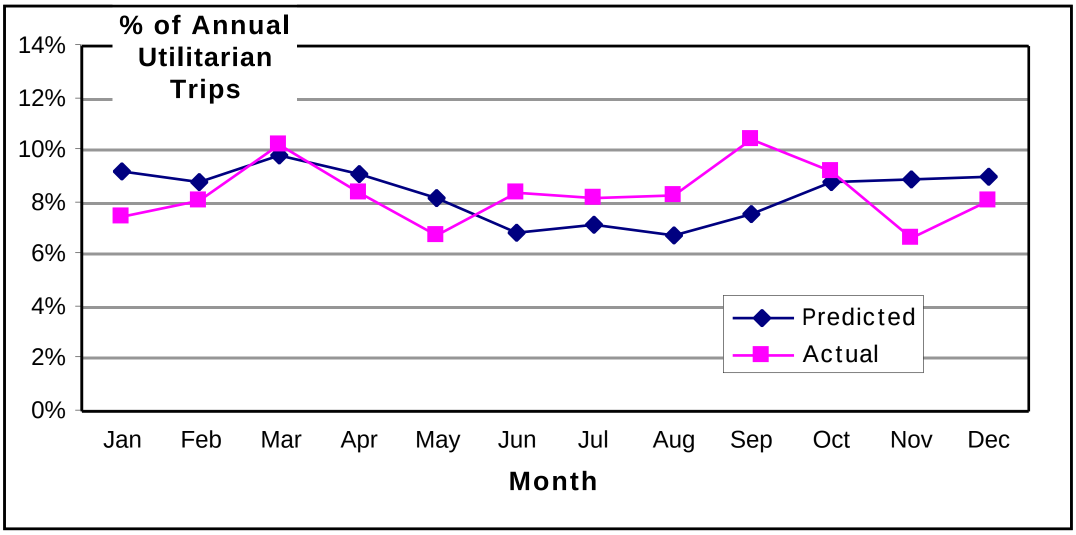

Figure 17 Predicted and Actual Utilitarian Cycle Flows by Month in 1994

It can be seen that neither the predicted nor the actual utilitarian cycle flows show great seasonality. There is a peak in March, and a slight fall in the cooler months, but generally the monthly figure hovers around 8% of the annual total.

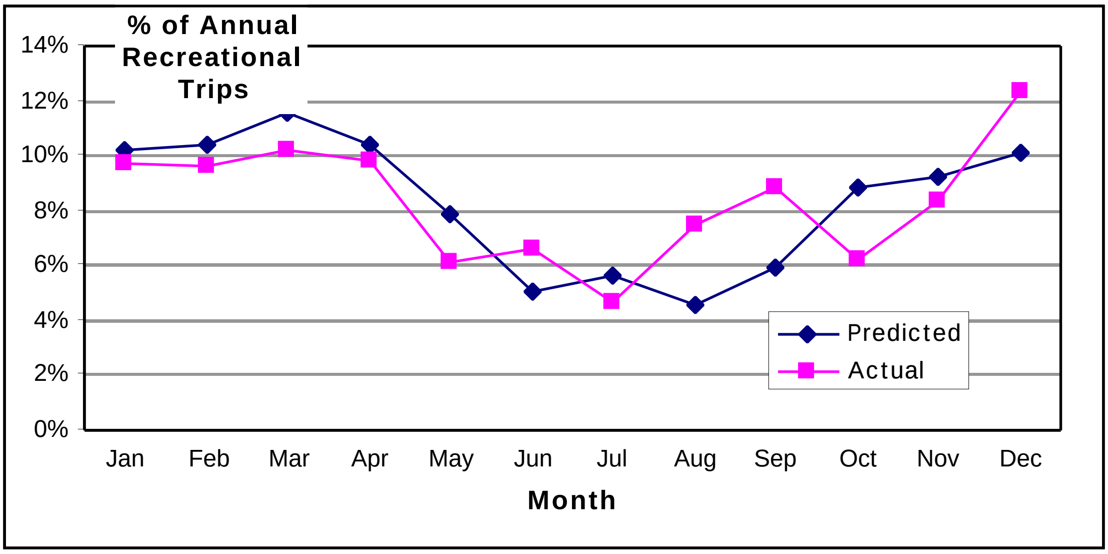

Figure 18 Predicted and Actual Recreational Cycle Flows by Month in 1994

The seasonal variations are much more pronounced for recreational cycle flows. Both the predicted and actual values are high at about 10% of the annual total for each of the first four months of the year, followed by a sharp drop in the winter months to about 5% per month, and then a gradual climb over the rest of the year.

It therefore appears that a seasonal model, based only on temperature and rainfall, can reproduce actual seasonal cycle flow patterns reasonably well. It should be realised, however, that this test is not particularly strong since the prediction of the 1994 cycle flows is based on a model that is also estimated from the 1994 data. A better test would be to use the model to predict cycle flows in a different year for which weather and cycle flow data were also available.

6. Generation of Seasonal Factors

One of the reasons for studying the impacts of climate and weather on cycle flows is to better account for seasonal variations when conducting surveys of cycle facility usage. Unlike the VATS survey, where cycle trips were recorded across the entire year, many surveys of cycle flows (especially observational surveys) are conducted at limited times during the year (sometimes only on one occasion during the year). Nevertheless, some estimate of annual usage is often required from such a survey. For this reason, an annual expansion factor that takes due account of weather conditions on the day of the survey would be useful.

For example, if a survey was conducted on a weekday on which the weather was 15°C and 5mm of rain, then, assuming independence between the temperature and rainfall effects, one could estimate that only 63% of utilitarian trips would be made (=70% x 90%) and 27% of recreational trips (=45% x 60%), compared to a dry day with a temperature of 25°C (the "ideal" cycling weather). Therefore, if a flow of U utilitarian trips were observed on the survey day and R recreational trips, then the estimated total number of trips on an "ideal" day would be U/0.63 + R/0.27. However, not all days in the year are ideal for cycling (as shown in the weather diagrams earlier in this paper). Indeed, most days are less than ideal. Instead of having 260 ideal weekdays and 104 ideal weekend days, we have 260 "less than ideal" weekdays and 104 "less than ideal" weekend days. Just how "less than ideal" these days are will depend on the weather patterns over the course of the year.

To determine the proportion of effective "ideal days" during the year, a small simulation model was constructed where, given the weather conditions on each day of the year, the proportion of utilitarian and recreational trips being made (compared to the ideal day) are calculated using the results from Figures 15 and 16. The average proportion for each month has then been calculated for utilitarian and recreational trips. Because of different weather patterns each year, the monthly proportions will vary across the years. The analysis was therefore repeated for all 14 years of weather data (1981-1994), and the mean and individual yearly results are shown in Figure 19 for utilitarian trips and Figure 20 for recreational trips.

It can be seen that, even in the best of months, only 90% of utilitarian cycle trips are made, compared to the number that would be made under ideal weather conditions, while about 80% of recreational cycle trips would be made. Across the year, only 75% of utilitarian and 59% of recreational cycle trips are made, compared to the number that would be made under ideal weather conditions.

Therefore in expanding a single survey's results to an annual total, they should be expanded to a year of "average" days, rather than a year of "ideal" days. Using the previous example of a survey conducted on a weekday with a temperature of 15°C and a rainfall of 5mm, the estimated total number of trips on an "average" weekday would be 0.75*U/0.63 + 0.59*R/0.27.

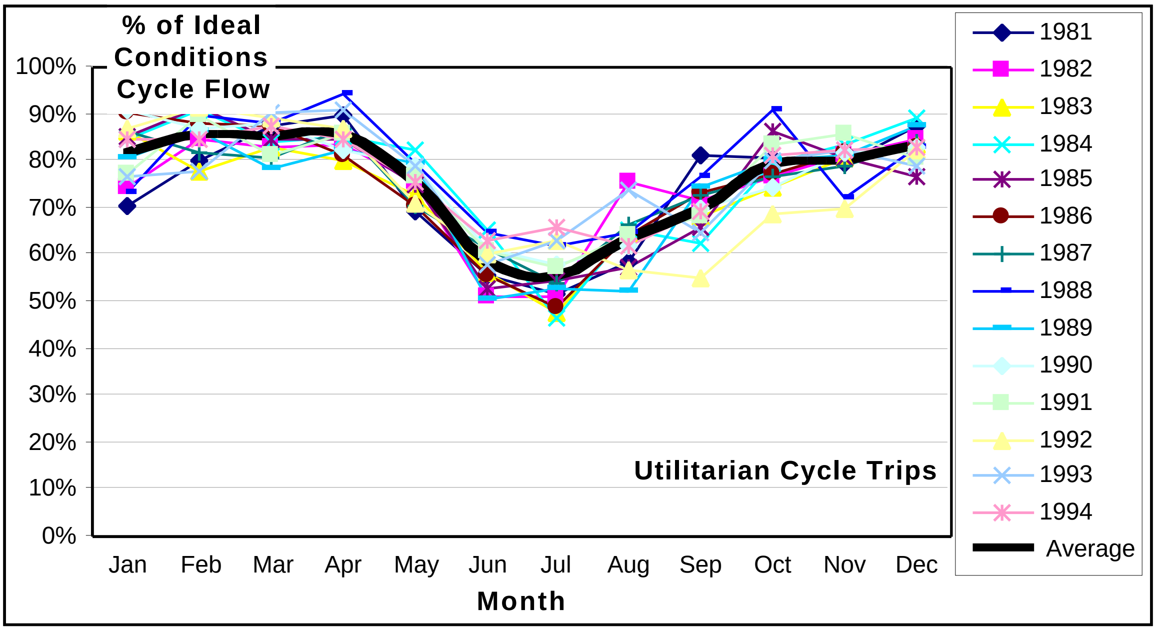

Figure 19 Percentage of Ideal Condition Utilitarian Cycle Flows by Month

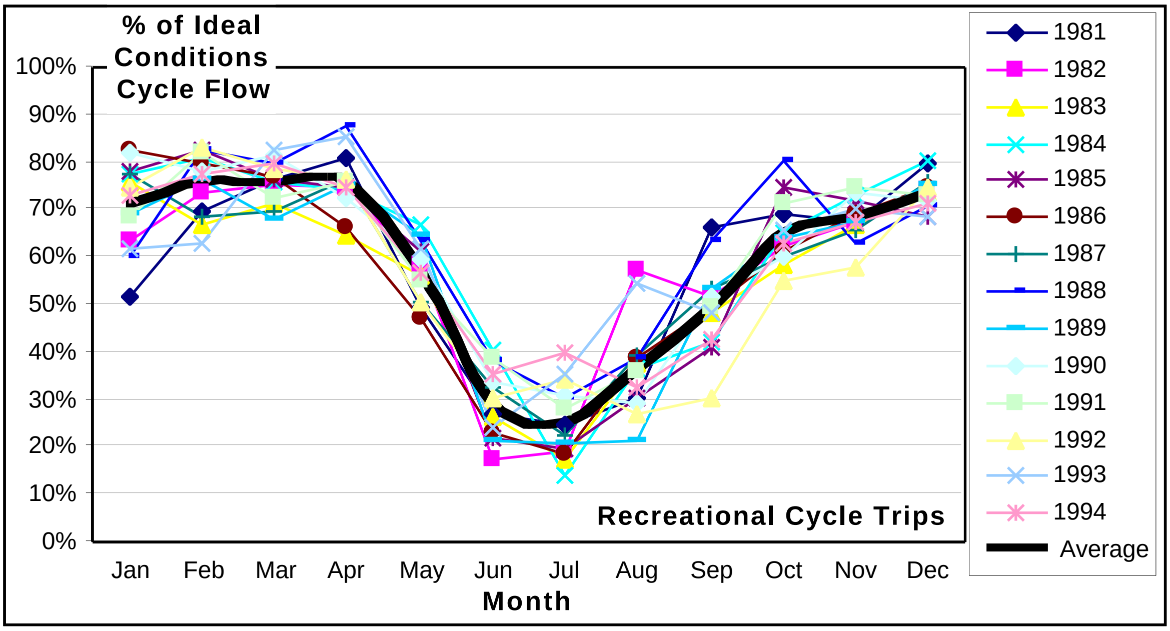

Figure 20 Percentage of Ideal Condition Recreational Cycle Flows by Month

It should be noted that this seasonal adjustment should not be applied only to surveys conducted on days where the weather was less than ideal. The results obtained from a survey conducted on an ideal day should be adjusted downward to account for the fact that the "average" day is not as good as the "ideal" day. Thus, if a survey was conducted on an ideal weekday with a temperature of 25°C and no rainfall, the estimated total number of trips on an "average" weekday would be 0.75*U+ 0.59*R.

The seasonal adjustment factors for cycle surveys conducted on days with any type of specific weather conditions are shown in Table 3. For example, for a survey conducted on a day where the maximum daily temperature was 29°C and the daily rainfall was 3mm, the utilitarian trip count should be expanded by a factor of 0.82 (interpolating between 25°C and 30°C, and between 2mm and 4mm), while the recreational trip count should be expanded by a factor of 0.93.

Table 3 Weather Adjustment Factors for Cycle Survey Counts

Utilitarian	Rainfall (mm)						
Temperature	0	2	4	6	8	10	12
10	2.47	2.47	2.57	3.05	4.36	10.71	####
15	1.07	1.07	1.12	1.33	1.89	4.65	####
20	0.80	0.80	0.84	0.99	1.42	3.49	####
25	0.75	0.75	0.78	0.93	1.32	3.25	####
30	0.82	0.82	0.85	1.01	1.45	3.55	####
35	1.13	1.13	1.18	1.39	1.99	4.90	####
40	2.98	2.98	3.11	3.68	5.27	12.94	####

Recreational	Rainfall (mm)						
Temperature	0	2	4	6	8	10	12
10	####	####	####	####	####	####	####
15	1.31	1.57	1.93	2.46	3.31	4.90	8.86
20	0.67	0.80	0.99	1.26	1.69	2.50	4.52
25	0.59	0.71	0.87	1.10	1.49	2.20	3.98
30	0.72	0.86	1.06	1.34	1.81	2.68	4.84
35	1.77	2.12	2.60	3.31	4.46	6.59	11.93
40	####	####	####	####	####	####	####

Note: #### = unspecified because of insignificant flows

7. Conclusions

This paper has attempted to quantify the relationship between cycle flows and weather conditions. Using cycling data from a comprehensive household travel survey and weather data from the Bureau of Meteorology, it has been shown that cycle trips are decreased in very high or very low temperatures, and in the presence of rainfall. The effect of weather has been shown to be more significant for cycle trips made for recreational purposes than for cycle trips made for utilitarian purposes. Using the relationships derived for temperature and rainfall effects on cycle flows, a series of seasonal adjustment factors have been derived for cycle survey counts obtained on days with any combination of temperature and rainfall.

While the results presented in this paper appear very promising in being able to correct for the effect of weather in cycle flow surveys, there are a number of limitations to the analysis which need to be borne in mind when interpreting the results:

- cycling is a relatively rare travel activity (only 1.5% of all trips in Melbourne) and hence the analysis is based on a relatively small number of observations of cycle trips (about 1000 in the VATS 1994 data);
- the weather data was obtained from only one weather station in central Melbourne. Since the Melbourne metropolitan area is quite large (about 50km square), it is likely that significant variations in weather occurred across the metropolitan area;
- the rainfall data is a daily total. Since most cycle trips are made in daylight hours, it would have been better to use daylight-hour rainfall totals, if that data had been available.

Despite the above limitations, it seems that the relationship between weather and cycling can be quantified. Such quantification allows for the adjustment of cycle survey results, and also casts light on one aspect of the demand for cycling as described by Porter et al., (1999).

References

Goldsmith S (1992). "Reasons why Bicycling and Walking are not being Used more Extensively as Travel Modes". US Department of Transportation, Washington DC.

Hanson, S. and Hanson, P. (1977). "Evaluating the Impact of Weather on Bicycle Use". Transportation Research Record 629, pp 43-48.

Hepkinson P, Casten and Tight M (1989). "Review of Literature on Pedestrian and Cycle Route Choice Criteria". Institute for Transport Studies, University of Leeds, Working Paper 20.

Keay C (1992). "Weather to Cycle". Ausbike 92, Bicycle Federation of Australia, pp152-155.

Municipality of Copenhagen (1989). "Investigation of the Use of Bicycles for Commuting to Office Workplaces in Copenhagen". Cyclen som transportmiddel til arbejde (Kontor)

Nankervis M (1999). "The Effect of Weather and Climate on Bicycle Commuting". Transportation Research A, 33, pp 417-431.

Niemeier, D.A. (1996). "Longitudinal Analysis of Bicycle Count Variability: Results and Modelling Implications". ASCE Journal of Transportation Engineering, 122(3), pp200-206.

Porter C, Suhrbier, J and Schwartz, W.L. (1999). “Forecasting Bicycle and Pedestrian Travel: State of the Practice and Research Needs”. Transportation Research Record 1674, pp 94-101.

Richardson, A.J. and Ampt, E.S. (1995). "The Application of Total Design Principles in Mail-Back Travel Surveys", 7th World Conference of Transport Research, Sydney.