Effect of Weather Conditions and Weather Forecast on Cycling Travel Behavior in Singapore

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Abstract

Weather conditions have considerable influence on cycling travel behaviour, especially in tropical countries such as Singapore which has a hot, humid and rainy climate. This study examined the effects of weather conditions and weather forecasts on cycling travel behaviour in

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Singapore. Cyclists (n = 553) answered a questionnaire on their perceptions of weather conditions, travel accident risk, pre-trip and during trip acquisition of weather information, possible travel plan changes, trip duration, trip purpose, trip frequency and respondents' social demography. The questionnaires were administrated directly on sites around mass rapid transit (MRT) stations and bike parking areas during day-light hours (08:00h-18:00h) and in dry as well as wet weather conditions. Concurrently, real time weather information from the nearest weather measurement station and weather forecast information were collected from smart phone application furnished by the National Environment Agency. Cyclists were found to prefer relatively lower temperature (29.5°C - 31.5°C) and humidity (52.3% - 62.7%) and no rainfall (in past 60 minutes). Higher temperature (>30.9°C), humidity (>55.8%) and rainfall (>0.28mm in past 60 minutes) tended to elevate cyclists' self-estimated level of traffic accident risk. Nearly 30% of participating cyclists checked the weather forecast information before the onset of the trip, in which internet, radio and smart phone applications were the main media sources. Social/leisure trip was the main purpose for cyclists during wet weather. Irregular trips were clearly under-represented during wet weather conditions, suggesting that some trips were postponed or cancelled. Cyclists with before-trip information of wet weather forecast were more likely to change their travel mode, but such influence was weaker for adverse weather forecast acquired during the trip. Research results suggested that the authorities could provide real time

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and predicted weather information, especially during wet weather conditions, to help travellers adjust their travel plan in time and improve the level of travel safety.

Key words

weather; cycling travel behaviour; travel safety; accident risk; field survey

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1 Introduction

Adverse weather conditions, e.g. rainfall, temperature fluctuations and extreme humidity, affect cycling travel behaviour. Research studies on weather effect have been undertaken such as in Austria, USA, Canada and the Netherlands (Brandenburg et al., 2007; Thomas et al., 2009; Miranda-Moreno and Nosal, 2011; Nosal and Miranda-Moreno, 2012). Nankervis (1999) investigated the effect of weather on commuter cycling in Melbourne (Australia). Survey data confirmed that bad weather conditions had an adverse effect on commuting in Melbourne. The number of cyclists was lower in winter than the number in summer due to the cold weather. Similar result was found in Auckland city (in neighbouring New Zealand) by Tin et al. (2012). The hourly volume of cyclists was 26.2% higher during sunshine condition as compared to without sunshine. Rose et al. (2011) examined the relationship between weather and cycling travel behaviour through comparing data from Portland (USA) and Melbourne (Australia). The study revealed that warmer temperatures and less rainfall led to increased bicycle traffic in both cities. However, the coefficients of the temperature variable were 0.3 to 0.6 in one city, and 0.2 in the other, showing that the extent of the effect temperature has on cycling travel may differ in each city. Flynn et al. (2012) combined location- and time-specific weather data from rural north eastern State of Vermont (USA) to model the weather impact on the travel behaviour of commuter cyclists. Precipitation, temperature, wind and snow conditions had significant and substantial independent effects on the odds of travel to work by bicycle among a diverse panel of

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adult bicycle commuters. In Canada, Winters et al. (2007) found that more days of precipitation per year and more days of freezing temperatures per year were both associated with lower levels of utilitarian cycling in 53 selected cities. Besides that, Amiri and Sadeghpour (2013) investigated the cycling characteristics in Calgary (Canada) under close-to-freezing temperatures. They found 96% of frequent winter cyclists will continue to cycle for commuting to work and 71% of the participants did not mind cycling in temperatures up to -20°C or colder. Furthermore, Helbich et al. (2014)'s study results showed that leisure trips appear to be more weather sensitive than commuter trips. Thomas et al. (2013) explored daily cycling demand changes according to the daily temporal fluctuations in the Netherlands. The most significant variables that affected the cycling demand are average 24-hour temperature, duration of sunshine, duration of precipitation, and the average wind velocity. Recently, Motoaki and Daziano (2015) showed that cyclists with higher skills and greater experiences are less affected by adverse weather than those cyclists with lower skills and lesser experiences.

Although research results may be city-dependent, the general finding is clear: weather conditions have noteworthy effects on cycling travel behaviour. Existing literature is mainly from 4-season western cities where cyclists have distinct perception of the cycling conditions across different seasons. Cities close to the equator, such as Singapore, have a hot and humid climate throughout the year. It is generally assumed that this kind of weather is not suitable for cycling, and there is little research into how the tropical climate affects cycling travel behaviour.

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However, as cycling demand has continued to grow in recent years in Singapore, there are plans and concerns on the range of usage for cycling facility in promoting sustainable transport (Koh et al., 2011).

Adverse weather does not only make cycling less enjoyable, but it is also associated with an elevated risk of traffic accidents. Effect on motorised traffic has been well studied: snow, heavy rain and fog greatly elevate traffic accident rate in most cities (Híjar et al., 2000; Keay and Simmonds, 2005; Qiu and Nixon, 2008). Several researchers have started to focus on effect of adverse weather on cycling accident situations in the last ten years. Kim et al. (2007) found that adverse weather conditions increased the likelihood of fatal injury in an accident by 128.8% on average, as compared to clear and cloudy weather. Mislan et al. (2009) found that May is the month with the greatest frequency of cyclist risky days in San Francisco (USA), because of the high temperature (≥30°C). de Geus (2012) suggested to inform cyclists of the increased risk of accidents during winter months and bad weather conditions based on the analysis of cyclist accidents data in Belgium. Notably, such kind of studies has seldom been conducted in tropical cities.

The weather information acquisition and effect from weather forecast information are also examined in this study to provide useful results for further Intelligent Transportation System (ITS) development. Weather forecast has been provided to motorised drivers through ITS in some cities in Europe, America and China (Rämä and Kulmala, 2000; Zhang et al., 2006;

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Kilpelainen and Summala, 2007; Böcker et al., 2013). Results showed some percentage of drivers would follow the indication and thereby reduced the travel risks caused by adverse weather at a certain level. Comparing with drivers, cyclists may require the weather information with different emphasis, such as cyclists focus more on the temperature value than drivers. However, little specific attention has been paid on cyclists on such application anywhere in the world, though cyclist is also a major user of the road network system. Will cyclist check the forecast weather information before or during their trip? Will they be influenced by forecast weather information if such kind of service is available? Is it necessary for traffic authorities to provide such information to cyclists on a large scale? This study examines these pressing problems. Such research findings can be helpful in understanding cycling usage, and providing guidance in planning cycling facilities in tropical countries.

Based on the afore-mentioned policy issues, the key objective of this study is to investigate the influence of weather condition and weather forecast on cycling travel behaviour in Singapore. To achieve this objective, four research questions need to be discussed through the analysis from field survey, which are: firstly, what is the general perception of cyclists on prevailing weather conditions on the basis of temperature, humidity and railfall; secondly, how is the cyclists' perception on risk of cyclists under different weather condition, especially the adverse weather; thirdly, do the cyclists need the weather information before the onset of trip; lastly, if weather information is provided, what is the influence of the weather information on the

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cyclist behaviour. Having established the study's motivation, the remaining paper is organised as follows: Section 2 gives a brief overview of Singapore weather conditions and cycling characteristics. The study methodology pertaining to the field survey is described in Section 3. Section 4 analyses the findings from the survey data. Conclusions and discussions are drawn in Section 5.

2 Weather conditions and cycling characteristics in Singapore

Singapore being one of the tropical countries (1°17′0″ N, 103°50′0″ E), has a typical wet equatorial climate with fairly constant temperature (mean daily maximum of 30.0°C - 31.7°C), relative humidity (24-hour mean of 82.7% - 86.9%), rainfall (24-hour mean of 5.1mm - 9.3mm) and wind speed (24-hour mean of 1.3m/s- 2.8m/s) across the months of the year (see Figure 1). Compared with temperate climate, temperature, humidity and wind speed in Singapore are more stable. Although there is no distinct wet or dry season in Singapore, rainfall is slightly higher in November to January than other months. Such tropical climate makes cycling activity unattractive, because high temperature and humidity result in excessive sweat, and frequent rainfall also elevates cycling traffic risk. However, cycling complements mass rapid transit (MRT) trips well as it is effective and convenient for the first/last mile connection. With the rapid improvement and expansion of MRT network in Singapore, cycling has been revitalised and becoming popular in Singapore in recent years. The Government has put forth many plans to promote Singapore as a bicycle-friendly city, such as the National Cycling Plan (Urban

Redevelopment Authority, 2013) to expand bicycling infrastructure more than three folds, to 750km. Here in, transport policy needs to take into account the weather effect on cycling travel behaviour, which is a key concern for traffic planners in Singapore.

3 Data collection

A field survey was conducted on cyclists aimed at exploring the cyclists' perception on prevailing weather and safety conditions, as well as the estimation of the effect of adverse weather on level of cycling and perceived accident risk. A binary logistic regression model of acquisition of weather forecast information was calibrated to investigate how essential weather forecast is to the cyclists. Moreover, the effect of acquired weather information was examined using the data collected during dry weather, yet the weather forecast at that time was reported as rainy. A questionnaire form was prepared to acquire data of the weather information, cyclists' demographic variables, cyclist travel characteristics, weather condition assessment and self-estimated risk perceptions. The questionnaires included up to 18 questions, where 14 questions were to be answered by cyclists; quantitative aspects about the weather information (current temperature, humidity, wind speed and direction, rainfall in past 60 minutes) were filled by the interviewers.

In recent years, cycling as principal transport mode accounts for about 1% of all trips in Singapore (LTA Academy, 2011) and most cyclists use cycling as the travel mode for first/last mile. Also, cyclists in Singapore prefer to store their bicycles within their residences when not in

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use as the cycling parking infrastructure is not sufficient around residential buildings. Nevertheless, most MRT stations provide parking spaces for bicycles. Therefore, surveys were conducted at 8 MRT stations (see Figure 2) to interview cyclist respondents during daytime (08:00h -18:00h) over May 28, 2014 to July 14, 2014 period. Cyclists were invited to participate in a survey conducted by Nanyang Technological University, as concerning current cycling conditions. A total of 553 survey questionnaires were collected, in which 223 cyclists were interviewed during wet weather (rainfall>0mm in past 60 minutes) and 330 cyclists were interviewed in good weather (rainfall = 0mm in past 60 minutes).

Interviewers were fully trained before field survey. They would guide the cyclists to fill the questionnaire and concurrently retrieve and record the prevailing weather information from the nearest weather measurement station which was obtained from the smart phone application developed by National Environment Agency. As mentioned earlier, the temperature, humidity and wind speed are generally stable year round in Singapore, and the cyclists were asked to rate the prevailing weather conditions on a five-level scale (very good, good, normal, poor, very poor) instead of detailed numbers, and classify their perceived accident risk on a three-level scale (normal, elevated, very elevated). They were asked whether they had acquired weather-related information for the trip; if affirmative, how they had acquired this information (through internet, TV, smart phone applications, etc.). They were also asked to report their decisions whether they would change their travel plan if they got the adverse information that the weather would not be

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good for their trip, for both the cases of before the onset of trip and during the trip. Demographic variables collected included age, gender, employment and nationality. Travel characteristics included trip duration and trip purpose, and trip frequency.

Research results from Zhang et al. (2014) showed that rainfall is the most significant weather variable in Singapore that affects cyclists' decision whether to cycle or not. An important issue is to ‘quantify’ the cyclists' perception of the weather conditions by comparing their perceived weather conditions in dry weather condition (rainfall = 0 in past 60 minutes) and wet weather conditions (rainfall>0 in past 60 minutes) with actual weather records.

4 Results

4.1 Cyclists' perceptions of weather conditions

To analyse how the weather variables (temperature, humidity, rainfall, wind speed) affect the cyclists' weather perception rating, a generalised linear model was developed based on the corresponding weather record, where cyclists' weather perception rating was the dependent variable and the four weather variables were the independent variables. Results showed that rainfall was the most significant variable in this model (Coef = -3.17, P = 0.00), followed by humidity (Coef = -1.03, P = 0.03) and temperature (Coef = 0.03, P = 0.04), while wind speed was not significant and was excluded from further analysis (Coef = 0.02, P = 0.61).

Since rainfall, humidity and temperature were found to be significant in cyclists' weather perception, the average value of each variable with 95% error bands at different rating levels were analysed as shown in Figure 3 for both dry weather condition and wet weather condition. Comparing the results, it can be observed that cyclists prefer lower temperature (29.5°C-31.5°C, very good to normal level) and lower humidity (52.3%-62.7%, very good to normal level) in dry weather conditions; cyclists tended to rate weather conditions more favourably with decreasing temperature and humidity.

A 2-dimensional perception matrix in dry weather condition can be deduced based on the collected data as shown in Figure 4. Lower temperature and humidity were preferred while higher temperature and humidity were associated with poor ratings. Generally, there is correlation of higher humidity with higher temperature, and likewise lower humidity with lower temperature.

However, findings were different in wet weather conditions. A heavy rainfall would cause poor rating by cyclists which is not surprising. For humidity, cyclists preferred lower humidity (57.6% - 66.8%) in wet weather condition, but the tolerance range was higher than dry weather condition; 65% humidity in wet weather condition would be considered as normal level, but was regarded as poor level if it was dry weather. However, cyclists perceived lower temperature as poor conditions, which does not correspond with the common sense in Singapore that lower temperature is welcome. According to the Singapore’s weather record (National Environment

Agency, 2014), 24-hour mean temperature was correlated reciprocally with the rainfalls in rainy days. A generalised linear model was done to examine the interrelationship between temperature and rainfall using Singapore's weather record of rainy days, where temperature was the dependent variable and rainfall was the independent variable. Result showed that rainfall in rainy days has significant effect on corresponding temperature (Coef = -0.32, P←0.01). Relationship between temperature and rainfall in wet weather condition in this survey is shown in Figure 5. Therefore, the relatively lower temperature being associated with poor weather rating in wet days is rationalised to be mainly due to the more dominant rainfall variable. Meanwhile, there is no significant correlation between temperature and humidity in cyclists' perception matrix in wet weather condition, which also indicated that rainfall was the more important variable that affected the cyclists' perception.

4.2 Estimates of adverse weather on cyclists' usage and perceived accident risk

Of cyclist respondents in wet weather, nearly 70% were men. Young adults (18-30 years old) (30.9%) were the major cycling group in wet weather sample, followed by the elderly group (>50 years old) (27.7%). These findings are consistent with the results in dry weather, as well as the survey results from another case study of Jurong Lake District (JLD) in Singapore undertaken during dry weather condition (Zhang et al., 2014). In effect, being wet weather condition does not affect the gender and age composition of cyclists. About three in five (58.5%) cyclist respondents were employed. This is somewhat less than the proportion in dry weather condition (64.4%). The proportion of trips for leisure/social purposes increased (45.7% in wet weather vs. 37.6% in dry weather) while the work/school trip decreased (36.7% in wet weather vs. 44.8% in dry weather). One possible explanation is that wet weather would affect the cycling travel duration, which would not be conducive for commuting trips due to the punctuality requirement of work/school trip. Irregular trips (less than 3 times/month) were distinctively under-represented (0%) during wet weather (9% in good weather), suggesting that some trips were postponed or cancelled.

Wet days make pavement surface slippery which would elevate traffic accident risk. Hot and humid environment may also slow down the response time of the cyclists. A global cycling condition measure is difficult to define as risk perception covers many factors, including adverse weather. Therefore, a 3-level self-estimated risk was rated by cyclists as being of normal risk, elevated and very elevated, as based on the prevailing weather conditions. A generalised linear model was developed to testify the significant weather variables on risk evaluation, where cyclists' risk perception was the dependent variable and four weather variables were the independent variables. Results showed that except for wind speed (Coef = 0.76, P = 0.45), the other variables of temperature (Z = 3.82, P = 0.00), humidity (Z = 4.83, P = 0.00) and rainfall (Z = 5.82, P = 0.00) all had significant impact on cyclists' risk evaluation. Figure 6 shows the average values of each variable at different risk perception level. Results showed that cyclists' risk perception would be elevated along with the increase of temperature, humidity and rainfall.

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The upper threshold for acceptable and safe weather condition was around 30.4°C temperature, 55.8% humidity and 0.28mm rainfall. However, it should be noted it is not feasible to isolate the individual effects of these inter-correlated weather variables.

4.3 Acquisition of forecast traffic weather information

Among participating cyclists, 28.2% of them reported having acquired weather information before the onset of current trip through some media. Of the cyclists who checked weather information before the onset of trip, 28.3% reported having acquired information from internet, 18.9% from radio and 15.0% from smart phone applications. It is worth noting that there were nearly 20% cyclists who did not check the weather information before the onset of trip but claimed that they looked at the sky and watched the clouds to make a judgment.

To get an understanding on what type of cyclists currently acquire weather information and when they are most likely to do so, acquisition of weather information before the onset of trip was examined with a logistic regression model. The model is presented in Table 1. The pseudo R^2 (0.49) suggests that the overall model explains the data well.

From the results in Table 1, juveniles and young adult, male, and employed cyclist were the most likely to check weather information before the onset of trip compared with other groups. Short-distance cycling trips had significant influence on the active acquisition of weather information. It was because nearly 85% of one-way cycling trips in Singapore were less than 20

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minutes. Cyclists seek information more actively when they are not certain about the forthcoming weather condition, such as they preferred to acquire the weather forecast information under wet weather conditions, while they made travel decisions by themselves without weather information if the current weather was very poor; cyclists who rated the current travel safety condition as being poor tended to check the weather information before the onset of trip, while they would not check the information at all if they thought the current travel safety condition was very poor.

4.4 Effects of acquired weather information

The aim of studying the weather forecast information is not only about whether such information is received or not, but to examine the effect on cyclist behaviour. In this study, 66.5% of all the cyclists reported they would change their travel plan if they know in advance it would rain before the onset of trip. Cyclists who checked weather information before the onset of trip changed their travel plan considerably more often than those who did not check (69.3% vs. 34.1%). Most of the cyclists for work/school purpose would transfer to other traffic modes while cyclists for leisure purpose would postpone their trips.

Only 17.6% of cyclist checked weather forecast during their trips. Among them, nearly half obtained the information from smart phone applications, the rest were from radio and internet information. The effect of weather forecast obtained during the trip was weaker compared to the information obtained before the onset of trip. But it still had 57.4% of cyclists switching traffic

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mode if they knew it would rain during their trip, and nearly 80% of them would take a bus at the nearest bus stop and parking the bicycles nearby.

Moreover, data that were collected during dry weather, but the weather forecast at that time reported rain in the day, were analysed. For cyclists who checked the weather forecast, the trust degree was different among the cyclists. Figure 7 showed the mode shift rate for different cyclists. For cyclists who considered the current weather condition as being normal, they were less dependent on the weather forecast, whereas 41.3% of them would change travel mode before the trip, while the rate decreased to 30.3% if the information was acquired during the trip. For cyclists who thought the current weather condition was poor, 67.5% would shift travel mode before the trip, while half would change mode if the information was acquired during the trip. For cyclists who considered the current weather condition as being very poor, the shift rate was much higher than others; more than 90% would change to other travel modes before the trip, while 70% would give up cycling during the trip.

5 Conclusions and discussion

Weather information system should not only be for drivers, but also cyclists for equity and safety concern. The accessibility and acceptability would contribute to the cyclist travel behaviour decisions. Therefore, to promote the cycling usage in a sustainable transport system, studies about how cyclist perceives the current weather information, how cyclist responds to the weather forecast information and how cyclist rates the travel accident risk are discussed in this paper through a cycling survey in Singapore. The survey is conducted around MRT stations to capture the cyclists. Although this method leads to a selective group, it is the most typical and common group of cyclists in Singapore. Presently, cycling only constitutes a very small proportion (1%) in Singapore and most cycling is for access to the MRT/bus stations, that is, the first/last mile. Meanwhile, cycling infrastructure and facility are not sufficient in the residential areas. Therefore, the selected cyclists near MRT stations are representative of the mass cyclist group in Singapore.

Results for two kinds of weather conditions, dry weather condition (rainfall = 0 in preceding 60 minutes) and wet weather condition (rainfall>0 in preceding 60 minutes), were compared to analyse the cyclists' perception of weather conditions. Lower temperature and lower humidity were preferred in dry weather conditions, while rainfall made cyclists feel the weather is not good in wet weather conditions. Moreover, high temperature, high humidity and heavy rainfall increased the level of perceived risk.

Almost three in ten cyclists checked the weather forecast before the onset of trip through media, in which internet, radio and smart phone applications were the main sources. Nearly two in three cyclists would change their travel plan if they knew it would rain before the onset of trip. Cyclists who had different weather perception had different trust degree of weather forecast information. Cyclists who thought the current weather condition was very poor were more likely to change travel mode before and during the trip if the weather forecast conforms with their perception.

Timely and accurate weather information is important for the cyclists to make their travel plan. Good preparation for the weather changes can reduce traffic accidents and promote cycling usage. As cycling activities continue to grow, agencies in Singapore are paying more attention to the cyclists' safety and satisfaction. Currently, specific traffic information is not available for cyclists. This research provides a basic understanding of the need of weather forecast information for cyclists. Moreover, covered shelters from the rain should be considered for the future cycling path planning.

Compared with the results from other cities (e.g. Canada, USA, Australia), the present findings are inherent to cycling travel behaviour in a tropical weather environment like Singapore with a moist humidity. In this regard, humidity condition is found to be an influencing variable, in addition to the commonly-found effects of temperature and rainfall (snow) on the usage of cycling and cyclist’s risk perception. This finding is different with the results from the Netherlands (Thomas et al., 2013) where the (moderate) humidity was explicitly rejected as a relevant weather variable. It is to be noted that the present findings are based on a selective sample of subjects who have decided to cycle at that time; also, the method of self-reporting is reliant upon the honesty of participants. Herein, future study shall extend the survey to day-to-day travel behaviour of participants drawn from generalised cycling population, and leveraging on computer-aided survey methodology.

To the credit of the efficient and well-managed transport infrastructure in Singapore, the operating environment is relatively safe and is un-polluted; hence safety and environmental pollution variables studied in this study in view of insufficient contrast. Nevertheless, it is prudent that future studies should also focus on these effects as safety and the environment are pertinent issues in many burgeoning cities.

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Acknowledgements

The authors would like to thank the student helpers who assisted in data collection. This study is part of a research project, which is jointly led by Dr Y. D. Wong, Dr M. Meng, and Dr P. H. Au, funded by the NTU Sustainable Earth Office (project title: Modelling multimodal travel behaviour linking non-motorised transport with public transport), and also funded by Singapore National Research Foundation under its Campus for Research Excellence And Technological Enterprise (CREATE) programme.

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Table 1 A binary logistic regression model of active acquisition on weather information

Variable	95%Confidence interval				
	Odds ratio	Lower	Upper	P	Z
Age(ref. <18)				**0.02**	-2.42
18-30	2.27	0.57	8.96	**0.04**	2.17
31-40	2.53	0.61	10.43	0.20	1.28
41-50	2.04	0.44	9.44	0.36	0.91
>50	1.32	0.33	5.30	0.70	0.39
Gender (ref. male)				**0.00**	-4.84
Female	1.05	0.53	2.07	0.90	0.13
Employment (ref. employment)				**0.00**	-4.07
Non-employment	0.80	0.42	1.54	0.51	-0.65
Nationality (ref. Singaporean)				0.59	0.54
Foreigner	1.02	0.19	5.47	0.99	0.02
Travel time (ref. <10)				0.05	-5.93
10-20	1.32	0.56	3.11	0.53	0.63
>20	1.97	0.73	5.33	0.18	1.34
Travel purpose (ref. work/school				**0.00**	-3.10

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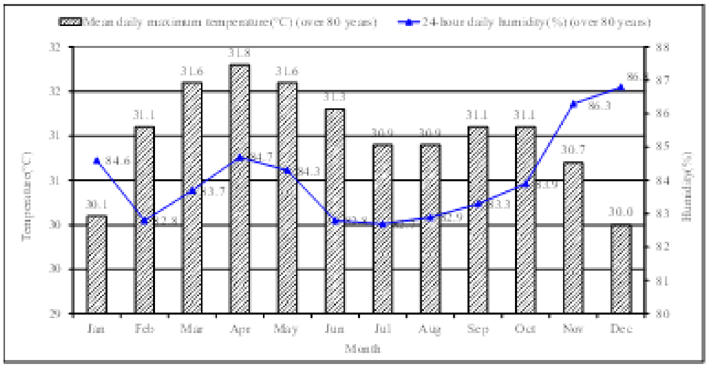
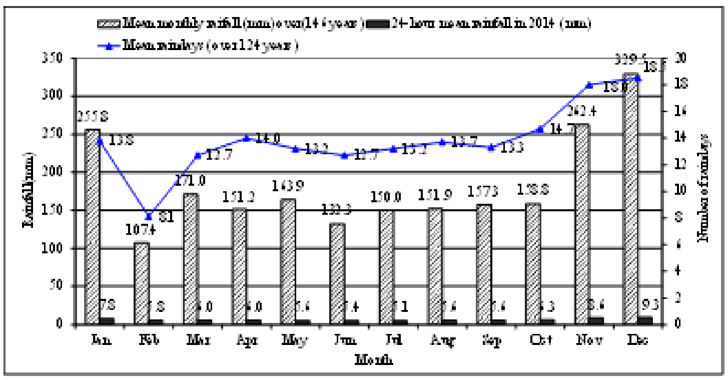
trip)					
Work errand	0.55	0.18	1.73	0.31	-1.02
Leisure trip	0.43	0.18	1.02	**0.05**	-1.92
Other errand	0.26	0.55	1.28	0.10	-1.65
Trip frequency (ref. daily)				**0.00**	-5.30
Few time/week or weekly	1.09	0.50	2.34	0.84	0.21
Fortnightly or <3 times/year	0.28	0.03	2.31	0.24	-1.18
Weather conditions rating (ref. normal, good and very good)				0.26	-1.13
Poor	0.24	0.65	0.91	**0.04**	-2.09
Very Poor	0.94	0.24	3.61	0.93	-0.09
Cyclists' safety conditions rating (ref. normal)				**0.00**	-3.86
Poor	0.34	0.11	1.03	**0.05**	-1.92
Very poor	0.83	0.36	1.92	0.67	-0.43

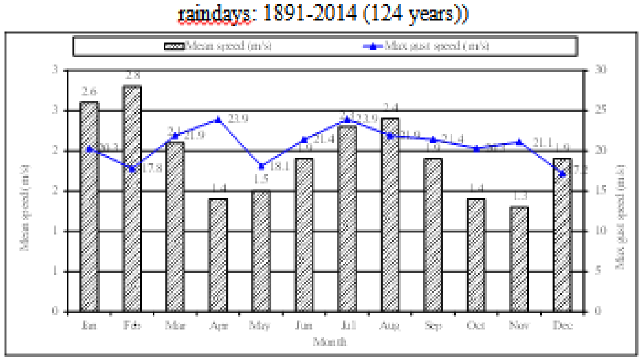
Statistically significant findings are shown in bold.



(a) Daily temperature and humidity information (period of record for temperature and humidity: 1929-1941, 1948-2014)



b) Rainfall information (period of record for mean monthly rainfall: 1869-2014(146 years), for mean raindays: 1891-2014 (124 years))



(c) Surface wind information in 2008

Figure 1 Weather in Singapore (Source: National Environment Agency, 2014)

Figure 1 Weather in Singapore (Source: National Environment Agency, 2014)

Figure 2 Map showing the study locations (Source: One Map Singapore, 2014)

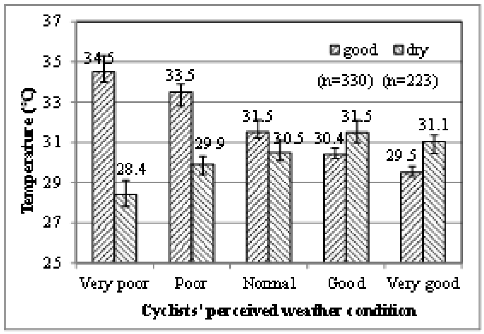


Figure 3(a) Average temperature at each rating level by cyclists

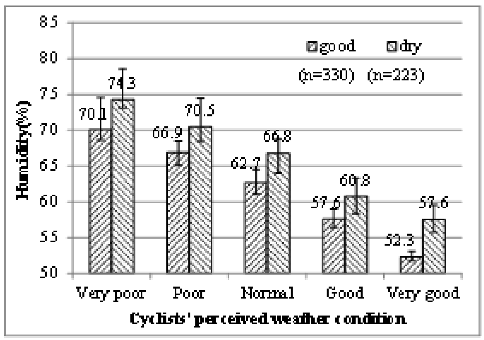


Figure 3(b) Average humidity at each rating level by cyclists

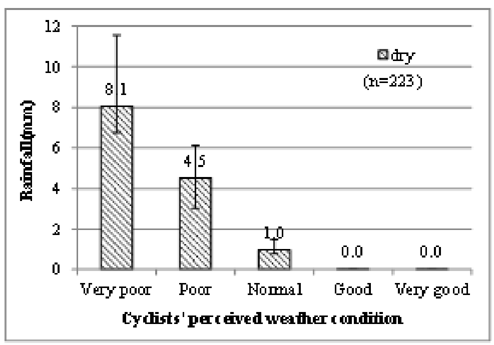


Figure 3(c) Average daily rainfall at each rating level by cyclists

Figure 3. (a) Average temperature at each rating level by cyclists, Figure 3(b) Average humidity at each rating level by cyclists, Figure 3(c) Average daily rainfall at each rating level by cyclists

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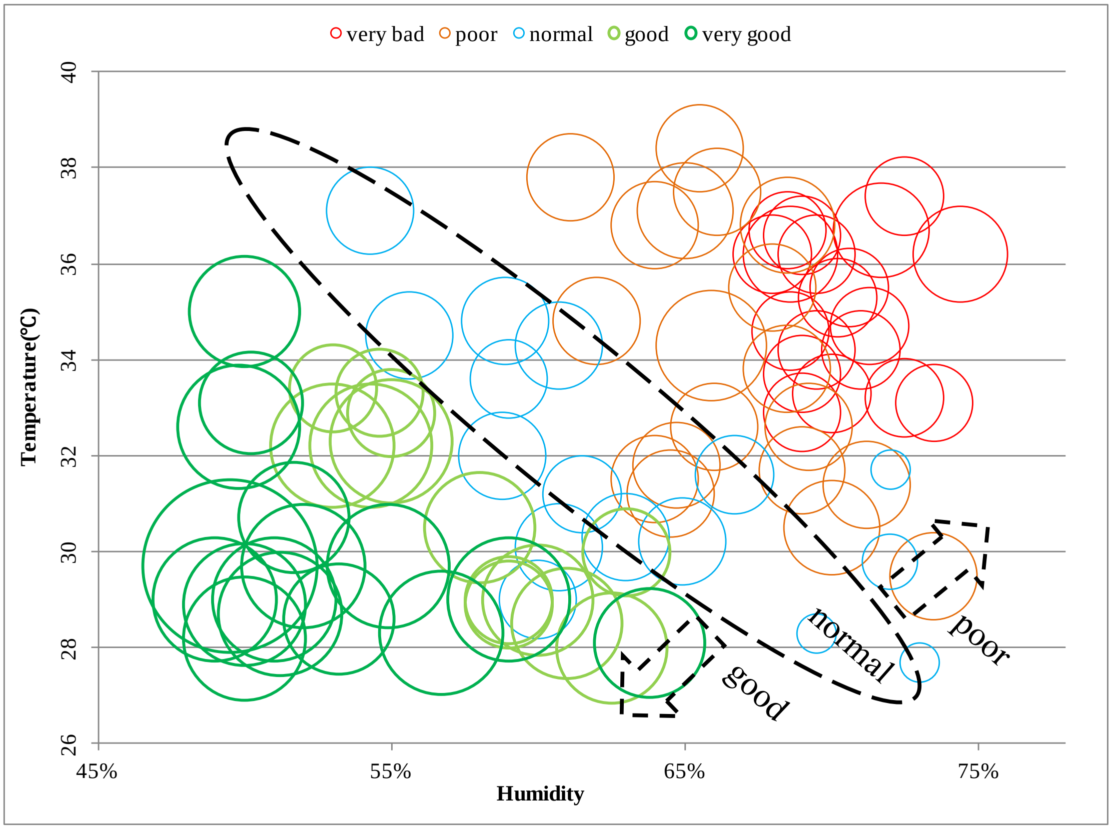

Figure 4 Cyclists' perception matrix in dry weather condition

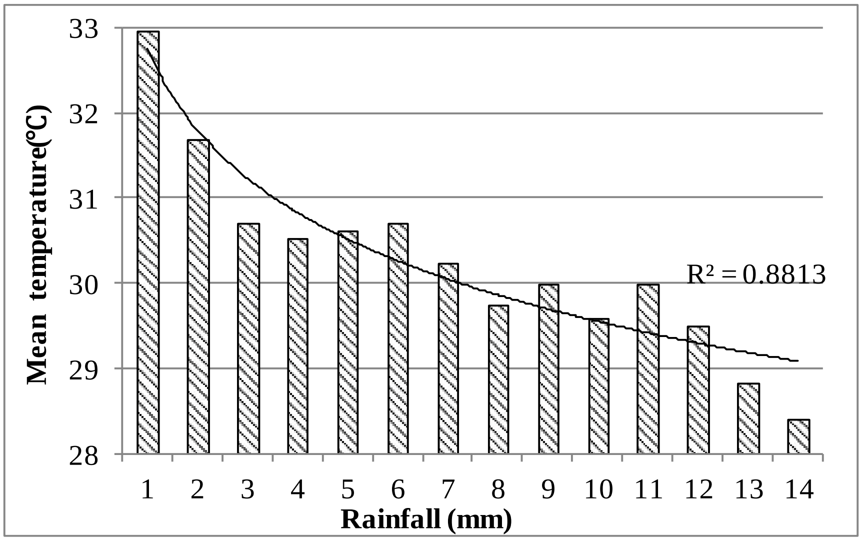

Figure 5 Relationship between 24-hour temperature and rainfall in wet weather condition

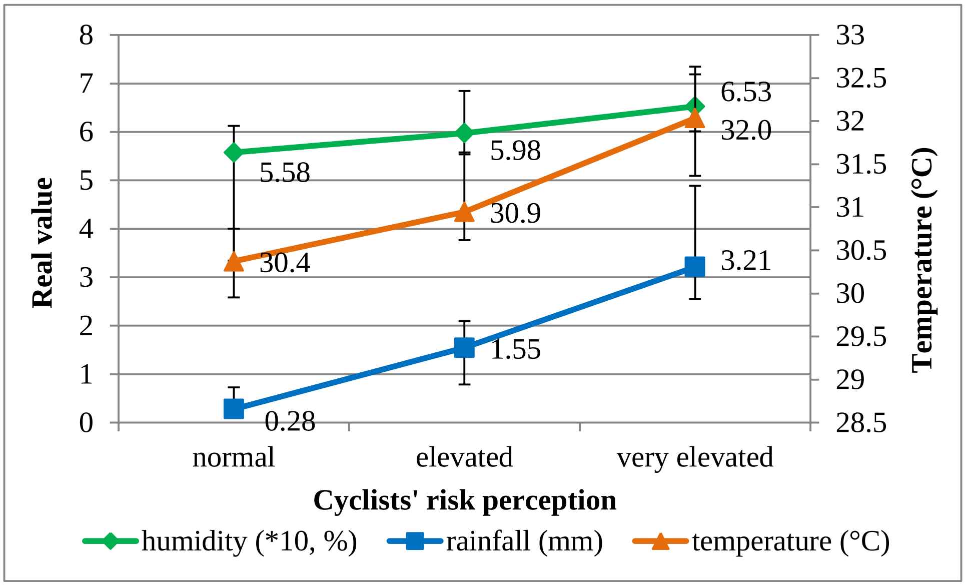

Figure 6 Average values of each variable at different risk perception level

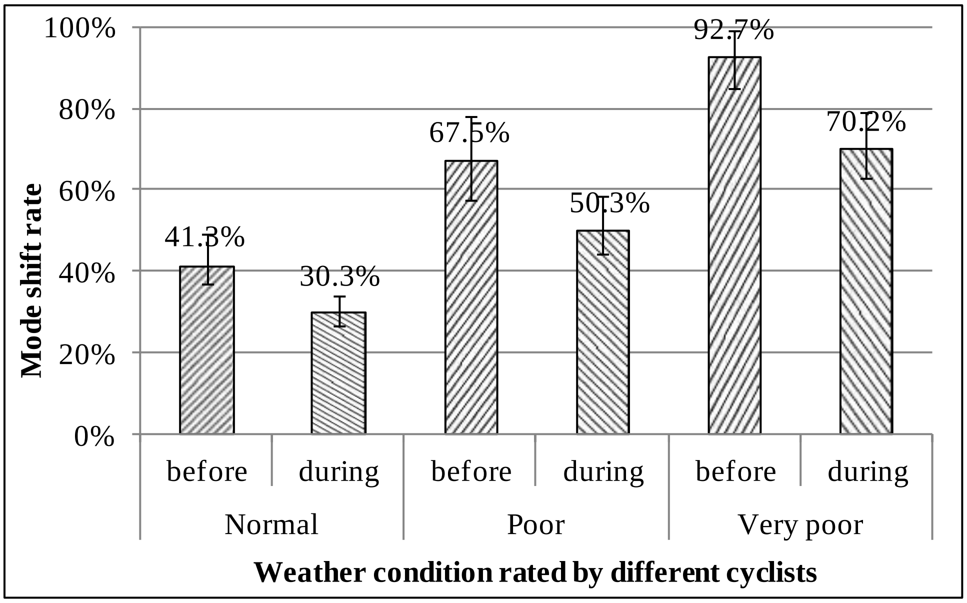

Figure 7 Different cyclists' mode shift rate

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