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互動式永續交通資訊量化評估與溝通方法 - 以大學學生為案例

**Interactive Communication & Assessment of Information on
Sustainable Transportation:
Case Study on Commuting of University Students**

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Abstract

Though a large number of studies, data, and sustainability schemes in daily lives can be found in different sources, only a limited portion of them are referred to by consumers for the purpose of putting the recommendations into action, because they are not accessible in systematic and appropriate ways. The lack of measurement correspondence between attitude and behavior on a general level has already been pointed out with disregard on consideration of behavior constraints beyond people's control.

Taiwan is known as the highest motorbike-density country in the world. Despite its importance, quantitative research on the extent and magnitude of impacts induced by motorcycles are rarely comprehensive for general public. Problems of motorcycle-commuting has been individually discussed in pollution, congestion, and energy consumption aspects, while other correlative information including safety and economy aspects are less analyzed. This flaw results in ineffective on communication of sustainable transportation, because consumer's primary objective is the safe, flexible, and cheap mobility service. Aiming at more effective communication of sustainability aspects of motorcycles, this research presents a method to collect and quantify information on expense, travel time, safety, and health/environment aspects. Through CAPI (computer-assisted personal interview), we design a easily understanding interface which fulfills real-time customized information feedback based on personalized input of respondents. The study adopts a streamlined approach to estimate DALYs (disability-adjusted life years) loss due to downtown traffic accidents. And find out students commute by motorcycle on average suffer 5.23 times DALYs loss as much as students commute by bicycle. On the other hand, we develop a user-personalized model to calculate environmental external cost derived from motorcycle using by an impact assessment system (Life Cycle Impact Assessment Method based on Endpoint Modeling, LIME) from Japan. Moreover, customized assessment system on travel time and operation expense is also constructed.

With the interactive communication structure developed in the research, students of National Cheng Kung University (NCKU) are selected as target of case study. It's observed that 52.4% of the motorcycle commuting students increased their intensity level of willingness to adopt sustainable commuting mode and, 27.6 % of motorcycle commuting students agree to alternate to adopt sustainable commuting mode or use

sustainable commuting mode more frequently after they received customized commuting information. It's expected to reduce 4.656E+05 kilograms of CO₂ emission, 1.14E+06 NTD on external health damage cost, and 9.44 years of DALYs loss due to traffic accident if we can apply our communication method to all NCKU students.

Interactive communication for sustainability is not only works in transportation issues but also expected to contain potential for applying to other sustainable lifestyle initiatives. Our study demonstrates a methodology on how to construct a interactive communication structure which can induce people to reconsider shifting their current behavior to more sustainable way.

Chinese Abstract

永續生活之相關資訊，雖可經眾多來源取得，然其中基於消費者面向之研究仍屬罕見，其主因乃不易透過系統方法，來瞭解資訊如何在居家行為中付諸行動。私人機動運具如機車等，在帶來交通便利之同時造成多種負面沖擊；有鑑於台灣為全球機車密度最高之國家，且機車使用趨勢於大學校區已成普遍，研擬抑制機車使用趨勢之策略，對於我國邁向建立永續發展社會之願景，實為不容輕忽之重大課題。

關於機車使用所致之衝擊研究，常著眼於污染、交通擁塞、能源耗用等方面；然其資料屬性多需具專業背景之研究人員方能解讀，以公眾易於理解之量化資訊加以評估之研究甚少，故宣導環境友善交通模式時，常欠缺說服力；另一方面，與使用者切身相關之時間、安全、經濟資訊未能同時分析並傳遞至使用者，由於使用者之主要考量點為方便、安全與經濟性，以致在導向公眾永續運輸之溝通效果上發生落差。為著眼於更有效之永續資訊溝通模式，本研究嘗試以成功大學為個案調查研究對象，量化機車使用行為之通勤時間、安全性、使用成本、以及環境衝擊等資訊，並透過電腦輔助問卷調查，設計易理解之訊息介面，即時根據受訪者的通勤條件，進行個人化衡量，再將結果回報受訪者，調查不同資訊對於受訪者在選擇通勤行為時的影響效果。研究中以簡約方法分析市區交通意外導致之失能調整人年(DALYs, disability-adjusted life years)，結果顯示機車通勤學生所遭受之失能調整人年為單車通勤學生之 5.23 倍；而透過日本 Life Cycle Impact Assessment Method based on Endpoint Modeling (LIME) 衝擊評估系統，建立使用者個人化推估模式，以計算機車產生之環境外部成本。另在通勤時間及使用成本方面，亦完成可同時比較不同通勤行為之個人化衡量系統。

透過本研究發展之互動資訊溝通系統，以成功大學學生為個案調查對象，結果發現 52.4% 以機車通勤的受訪學生，觀看個人化通勤資訊分析後，提高改用永續通勤模式之意願；且以機車通勤的受訪學生中，願意改用永續通勤模式之比例提高 27.6 %。若成功大學減少 27.6% 機車通勤學生，其效益相當於每年減少 465.6 噸二氧化碳排放、114.0 萬新台幣之公眾健康損害外部成本、以及 9.44 年因交通意外而損失的失能調整人年。

互動式訊息溝通除用於交通層面之外，亦有應用於其他層面之永續生活型態議題之潛力；本研究中展示如何轉譯公眾易理解之資訊，進而建立互動式溝通架構，以導向更趨永續性之生活型態。

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歷經兩個寒暑，體驗充滿無盡喜樂哀愁的點點滴滴，終於能順利完成本篇論文。儘管內心充滿著喜悅，卻又不免傷感斑斕燦爛的求學生涯即將告一段落。百感交集的當口，已分不清潸潸而下的淚水是苦是甘...

本論文得以完成，首賴恩師 福島康裕先生細膩卓越而不失興味的諄諄教誨，面對玩世不恭、桀驁不馴的學生，適時悉心指導並匡正研究觀念上的缺失，並奠定學生對於系統分析領域應具有之素養與理念，課餘時間恩師予我的關懷、教誨，點滴盡在心頭，沒齒難忘。

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投身 ESA 研究室的兩年過程，記憶片段是一道道耀眼光芒，連接成一串無形卻著實存在的寶石項鍊，緊緊環在胸前不能割捨。峰旗學弟那 OFFICE 快捷鍵指導與泉湧不絕的惡趣味連發，憶難忘；身邊的為凱學弟則有如李麥克的最佳拍檔霹靂車般，和我共同完成一件件胡搞瞎搞的任務；俊騰學弟在論文水深火熱的決勝時刻，屢屢在皮卡丘打排球遊戲中，勇敢犧牲小我，讓學長慘絕人寰地屠殺，排山倒海的壓力頓時無影無蹤；另外，哲源學弟和學長快樂的無腦無責任對話，也將會是未來茶餘飯後可以不斷回味的輕狂記憶；而怡靜學妹為研究室帶來清新脫俗的氣質，宛若無盡荒漠中的點滴甘泉，適時滋潤學長枯槁的心靈之窗，自然是功不可沒；穎安學妹遠在太平洋彼岸傾聽學長的沉鬱心聲，縱然隻字片語卻也字字感心。還有不能不提今生最 match 的好友本原，在共居的關鍵一年間，陪我窮盡天下所有低能之能事；以及高中同窗炮灰、衝哥、建宜、珠珠等人，無時無刻一起在 MSN 不著邊際閒扯風花雪月...

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Chapter 1 Introduction

1.1 Background

Though a large number of studies, data, and sustainability schemes in daily lives can be found in different sources, only a limited portion of information are referred to by consumers for putting those recommendations into action, because they are not accessible in systematic and appropriate ways. The lack of measurement correspondence between attitude and behavior on a general level has already been pointed out with disregard on consideration of behavior constraints beyond people's control^[1]. For instance, daily commuting is deemed to better consider safety and environment aspect, yet we barely find the key driving force for improving present condition.

Motorized private transportation, such as motorcycles in Taiwan, provides versatile mobility service especially in the places where public transportation is less developed. Negative impacts associated with such convenient functions are more and more serious in these areas. Taiwan is known as the highest motorcycle-density region in the world^[2]. The per square kilometer motorcycle density is 366.78. Ministry of transportation of Taiwan predicts that without effective motorcycle restriction policy, the average motorcycle number growing rate would remain +3.8% till the year 2012^[3].

The relationship between commuting mode choices and sustainability comprises energy depletion, global warming, air pollution, noise pollution, and traffic accident. According to Taiwanese EPA's report^[4], about 20% of major air pollutants (NMHC, TOC, CO) in Tainan city are derived from motorcycles. Transportation in a sustainable society should avoid or reduce negative effects, including fuel consumption, global warming, pollution, congestion, and traffic accident, while considering economy and equality aspects^[5]. To this end, slowing down the steep upward trend of motorcycle using is imperative. Notwithstanding, negative impact trade-off of using motorbikes are not well informed to commuter, and thus they don't fully aware of the potential improvement associated with alternative commuting behavior. These observations open the question on how we could raise awareness of consumers in sustainability context, and provide them with triggers to change their consumption patterns.

The alternatives for motorcycle include public transportation, private car, bicycle and others (in-line skate, walking...etc.). The most preferred alternative for motorcycle for the general public is private car^[6], which is even inferior in terms of fuel consumption^[7] and thus global warming points of view. However, the situation for students would be different because the use of private car is usually not economically feasible and unpopular. Therefore, there is relatively greater chance to make a modal shift in the students' transportation.

To realize a shift in the users' behavior, effective risk communication is indispensable. We assume that multiple sustainability aspects should be communicated in the context of people's primary reasons of the current wide use of motorcycles, and merely providing individual information on negative aspects will not produce enough driving force for a voluntary shift.

For example, we have lots of publicly available information on downside of motorcycles; road traffic injuries rank the top in the leading causes of "Burden of Disease from injuries" among the age group of 15-29 years in high-income countries of western pacific region^[8]. Statistics from Department of Health, Taiwan also shows that deaths due to accident ranks 1st in the leading causes of death among the age group of 15-24 years. Traffic accident occupied 81% of deaths due to accident^[9]. Those figures reveal traffic safety issue being a major threat to youth's life. However, those information is not making a shift in the youth's reliance on motorcycles.

On other side, although bicycle is efficient in short distance commuting; is it superior than motorcycle in safety aspect? Slower speed of bicycle might not sufficient lead to this conclusion. Statistical research is needed to provide sufficient evident for justification. MOTC Taiwan published Bicycle Accidents Analysis and Countermeasures^[10] in year 2004. This report even shows that bicycle riders suffer much higher mortal accidents rate per travel distance. The contradictory crux would be further verified.

Economic aspects are said to be important for students, however, calculation of expenses on motorcycle based transportation is not widely practiced even if the economic assessment of motorcycle using is not complex. Institute of transportation, MOTC of Taiwan made "Census of Road Vehicle Operating Cost^[11]" in 1999. In this report, annual total expanse of using motorcycle (including maintenance, repairment ...and etc.) is estimated by both survey and accounting. However, those information is not referred when they decide to use motorcycles for commuting.

Various methods and models have been developed to assess economic, social and environmental consequences of transport plans. However, at present, only a few social indicators are being considered, because of the lack of knowledge and valid methods, tools and techniques for assessing relevant social impacts^[12]. Linda Steg and Robert Gifford^[12] suggest using QoL (quality-of-life) assessments which comprise indicators of 22 aspects for assessing the sustainability of transportation. However, such integrated indicators do not allow general public to see the concrete item inside that can be instinctively understood.

The following psychological barriers and communication gaps could be the important factors for students' decision on choosing motorcycles.

- 1) Traditional viewpoint "The heavier the safer" is commonly ingrained in certain Taiwanese's public's mind. Thus bicycle seems inferior to motorcycle in safety aspect without scientific evaluation.
- 2) Owning a motorcycle has even considered as a matter of course for students. Once they own a motorcycle, it makes them indefinitely feel that they should pay back their initial investment by using it more.
- 3) It is considered motorcycles will be faster than bicycle, but this difference might be less than it is considered in the students' ordinary field of activities; if they live close to the university and if it is in downtown, where parking is not convenient and traffic jam prohibits smooth transportation.
- 4) People knows motorcycle does make air pollution but few knows the how serious and how much damage is resulted from one's motorcycle usage. Without information relevant to users they can not even try to gauge if their behavior already harmful or not.

Those barriers and gaps in the decision context of the students have to be overcome in order to actually shift their behavior.

1.2 Research Objective

The study tries to achieve interactive information exchange, which consists high potential on promoting the driving force induces people toward sustainable lifestyle. We quantify the difference between commuting mode of students on impact of four aspects: Safety, Environment & Health, Monetary expense, and Time. Meanwhile, develop a user-oriented survey structure which could present customized data of the four aspects for respondents basing on individual data input. Therefore, with the improved interactive communication survey tool, researchers were allowed to not only assess respondents' attribute and behavior, but to communicate and educate them simultaneously. This prospect will be accomplished with advanced CAPI (computer-assisted personal interview) interface developed in the study.

The study takes the area around National Cheng Kung University (NCKU, Taiwan) in Tainan city and students of NCKU as the target for the case study. Through highly customized data input function and flexibility of the assessment model, it's expected the whole methodology could be adopt for other university and even for general publics.

Safety aspect is assessed by performing a pioneering-survey on downtown traffic accidents of student and then combing with traffic accident data from NCKU school guard office. Disability-adjusted life years (DALYs) were calculated for quantification of life damage of daily commuting.

Environment and health aspect is assessed via collecting local air pollution emission factor from academic source and computing with an end-point impact assessment model (Life Cycle Impact Assessment Method based on Endpoint Modeling, LIME^[13]) from Japan. So that health impact information could be presented in a comparable unit. We also try to analyze CO₂ reduction potential of changing commuting mode, comparing to other sustainable life-style initiatives.

Break down of operation cost on different commuting modes is also accounted. We quote government reports and develop typical using scenario to estimate fix costs (such as maintenance cost, tax, imperative insurance) of transportation media. Other variable cost such as fuel expense is calculated based on a user-oriented conversion method in order to fit individual's commuting attributes.

Commuting time usage comparison is based on local travel speed data from real on-road travel speed test around NCKU. And the data is verified by taking official travel speed survey from Tainan city government as reference. Thus it's able to provide time usage data comparison on different commuting mode according to individual's estimated travel distance.

The study would contribute a step forward to a comprehensive and effective communication of environmental information to make a shift in the consumer's behavior.

Reference

1. Kaiser, F., Wolfing, S., Fuhrer, U., *Environmental attitude and ecological behaviour*: Journal of Environmental Psychology Volume: 19, Issue: 1, March, 1999, pp. 1-19
 2. Department of Statistics, Ministry of Transportation and Communication (Taiwan), Statistical Abstract of Transportation & Communications (交通統計要覽): annually report of year 2005
 3. Institute of Transportation, Ministry of Transportation and Communication (Taiwan), *Patterns of Motorcycle Ownership and Usage in Taiwan Area (我國機車持有與使用特性之研究)*: Taiwan (2002)
 4. Environmental Protection Administration – Executive Yuan, R.O.C, *Taiwan Emission Data System version 5.1 (空氣污染排放清冊資料庫 TEDS5.1)*: Taiwan (2000)
 5. Liou, Cin-Yu, *永續運輸目標下都會區最適運具比例研究*: Dissertation for Master, Department of Civil Engineering, National Taiwan University, Taipei (1992)
 6. Yang, Chia-Ming, *The Study for the Involvement of Motorcycle Usage Decision and its Affecting Variables - A Case Study for Taipei City (機車使用者涉入程度與運具選擇過程 影響因素之關聯性研究 — 以台北市為例)*: Dissertation for Master, Department of Transportation Technology & Management, National Chiao Tung University, Hsinchu (2003)
 7. Bureau of Energy, Ministry of Economic Affairs (Taiwan), *車輛油耗指南*: Taiwan (2004)
 8. World Health Organization, *Injury: a leading cause of the global burden of disease, 2000*: Department of Injuries and Violence Prevention, Noncommunicable Diseases and Mental Health Cluster, World Health Organization, Geneva (2002)
 9. Department of Statistics, Department of Health, Executive Yuan, ROC, *Main Cause of Death Statistics 2004 (中華民國九十三年臺灣地區死因統計結果摘要)*: Taiwan (2004)
-

10. Institute of Transportation, Ministry of Transportation and Communication (Taiwan), *Bicycle Accidents Analysis and Countermeasures* (腳踏車肇事特性分析及因應措施): Taiwan (2004)
 11. Institute of Transportation, Ministry of Transportation and Communication (Taiwan), *Census of Road Vehicle Operating Cost* (公路車輛行車成本調查): Taiwan (2000)
 12. Linda Steg and Robert Gifford, *Sustainable transportation and quality of life*: Journal of Transport Geography 13 (2005) 59–69
 13. Japan Environmental Management association For Industry, 製品等ライフサイクル環境影響評価技術開発成果報告書: Japan (2002)
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Chapter 2

Analysis on condition of transportation

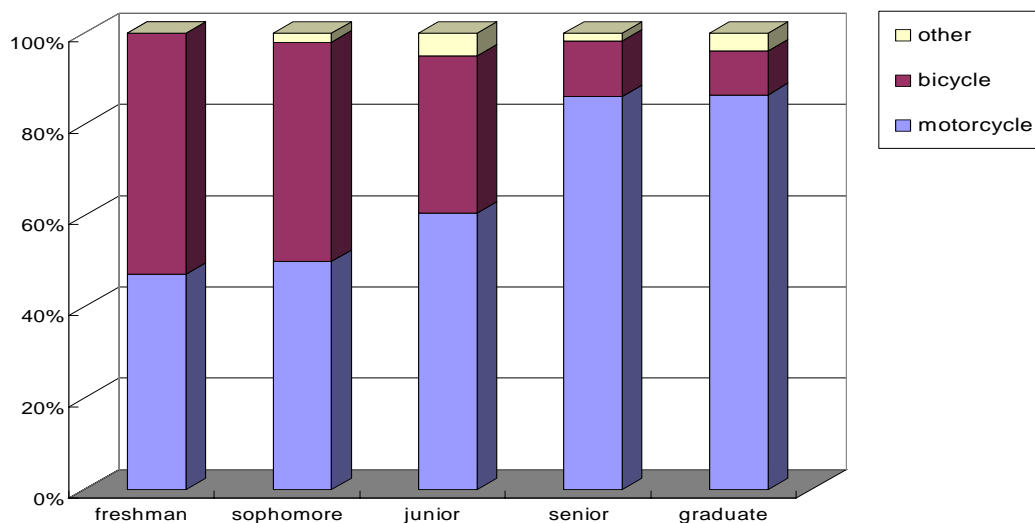
2.1 Transportation in NCKU

2.1.1 Measuring commuting activity of college student

Massive shift of NCKU students commuting style is easily aware by local people who live around campus for years. Elder would suggest that “you need a bicycle if you study in NCKU” before. But actually the situation has changed. Since no statistic data on the how students commute, yet the delicate accident data analysis, a pioneering survey is needed for gathering overview information on students’ commuting behavior.

The pioneering survey was performed from April to June, 2005, at the library and computer center of NCKU, with the face-to-face interview approach. The reason to perform survey in the two spots is because those spots are consider to have more uniform students distribution, without lacking of specific population (whether students belong to which department, and, whether they live in anywhere, and, whichever commuting modes they take, would not limited them from going to those two spots.). Students passed through the gate of library or computer center were randomly asked for filling a short questionnaire which is designed as shown in the Appendix 1. Total 276 effective samples are collected. Each respondents’ main commuting mode and accident record in the recent year in Tainan downtown area (type of ride, injured type, injury duration, have informed school guard office or not, and repairment cost on each accident) was asked.

As shown in Fig. 2-1, 66.3% of surveyed students use motorcycles and 31.2% use bicycles as their main commuting mode, respectively. Motorcycle commuting rate increases as students stay longer in the university. 2.5% of respondents neither commute by motorcycle nor bicycle (5 cases by walking and 2 cases by car). Only 4 out of 62 cases of downtown traffic accidents in our survey were registered on the accident record from school administration.



**Fig. 2-1 Motorcycle commuter rate among NCKU students
(sorted by student status)**

Average motorcycle commuting rate is 66.3%, with 95% confidence level, error within 5.6%.

Survey conducted in April, 2005

The growing trend of motorcycle commuting rate with students' grade is significant. What are reasons lead them away from more environmental friendly, healthy, and less costly non-motorized transportation? Is it because they tend to leave far away from school? Do they become busier and hustle to study? Do they want to enjoy more outdoor activity and entertainments? Or they even consider riding motorcycle is a symbol of priority and social esteem? Those intriguing question should be known if we do want to induce them toward more sustainable commuting mode.

2.1.2 Travel time comparison between commuting modes

Commuting time is might be a crucial factor when choosing commuting mode. Motorcycles can easily reach higher maximum speed than bicycle, and to maintain high speed on bicycle is rather more difficult. The campus of NCKU is located in downtown area next to Tainan railroad station; traffic sign and rush hour traffic jam make traveling speed of nearby roads slower. In other word, the traveling time difference between commuting media is less significant than theoretical speed.

台灣省市區道路交通特性分析^[1] (Taiwanese Construction & Planning Administration, 2001) used a standardized method to measure average travel speed in several main arteries of Tainan (Table 2-1). However, the speed is measured by automobile, yet lacks of motorcycle and bicycle data. Moreover, some of the arteries measured are not close to NCKU therefore fewer students commute through those arteries is expected. Consequently, our study sets up a real road driving scenario to measure the travel speed by motorcycle and bicycle on roads around NCKU.

Table 2-1 Tainan city travel speed in 8 main arteries

(data from台灣省市區道路交通特性分析^[1])

Artery	morning rush hour		afternoon rush hour		Average
	south→north	north→south	south→north	north→south	
Jhonghua W. Rd.	21.1	24.9	13.5	14.9	18.6
Jhonghua E. Rd.	23.7	23	22.6	22.8	23.0
Dongmen Rd.	21.4	16.4	19.8	18.9	19.1
Guomin Rd.	20.3	22	23.7	28.1	23.5
Gongyuan Rd.	20	19.2	16.4	17.9	18.4
Jinhua Rd.	22	20.2	19	18.6	20.0
Beimen Rd.	20	23.1	17	19.3	19.9
Jiankang Rd.	18.9	19.1	20.6	21.3	20.0
Overall Average (km/h)					20.3

To estimate the traveling time difference between motorcycle and bicycle, three typical routines around NCKU which students would usually take are selected as “reference routine”. The length of each routine is about 2km. We referenced the travel speed measuring method (Box 2-1) from台灣省市區道路交通特性分析^[1] to test the speed of bicycle and motorcycle. The tests are performed at both morning rush hour and afternoon rush hour. The definition of “travel speed” is shown in Box 2-1.

Box 2-1 Definition of “Travel Speed” in 台灣省市區道路交通特性分析^[1]

Travel Speed = (length of route) / (travel time)

Travel Time: time span of vehicle traveling on the routine, including all necessary delay by traffic sign, traffic rule and traffic jam

Table 2-2 shows the travel speed ratio between bicycle and motorcycle in the three tested routes. The average travel speed of motorcycle is 19.14 km/h, which is quite accordant with the data from台灣省市區道路交通特性分析^[1]. Bicycle travel speed is 12.79 km/h. Motorcycle travel speed is on the average 1.49 times faster than bicycle.

Table 2-2 Travel speed comparison between motorcycle and bicycle in three tested routes around NCKU

	Average travel speed			
	morning rush hour		afternoon rush hour	
	motorcycle	bicycle	motorcycle	bicycle
route 1	21.4	13.7	28.7	15.2
route 2	18.7	14.0	13.7	10.5
route 3	18.6	12.1	13.7	11.8

Average motorcycle travel speed: 19.14 km/h

Average bicycle travel speed: 12.89 km/h

Average motorcycle / bicycle travel speed ratio between = 1.49

(Standard deviation = 0.32, with 95% confidential level, error within ± 12.2%)

Since driving bicycle inside NCKU campus is allowed. Bicycle-commuting students benefits from less time consumption walking from parking space to their classroom. While comparing commuting time of individual respondents, “walk through” time is added to motorcycle commuting time. For bicycle and walking commuter, 2 minutes “walk through” time is preset based on experienced assumption. (After completing the main survey later, the result reveals that average walk through time is 2.2 minutes, which does really matches our assumption here.)

Although pioneering-survey shows only 2.5% of NCKU students commute by walking, we do not intend to exclude those cases while preparing customized information. Walking speed is case dependent and hard to decide a adequate rigid value. Tarawneh^[2] analyze pedestrian walking speed in Jordan by collecting 3,500 pedestrian crossing operations in 27 crosswalks, and found out pedestrian speed is on average 1.49 m/s for 21-30 years old age group. Murtagh...^[3] measured walking speed in Northern Ireland public park by both observation and treadmill test. They found out the average observed walking speed is 1.56 m/s and the “brisk” walking speed in treadmill test is 1.79. Therefore, in the study we simply set up a general scenario for student who commutes on foot: 1.5 m/s walking speed is given with the assumption that one will be stopped by traffic sign for 1 minute after every 5 minutes walking. In this case, average walking speed would become 1.25 m/s (4.5 km/h).

Box 2-2 illustrate how can we use the data upon to provide customized travel time information for respondents.

Box 2-2 The method for providing customized travel time information

For a bicycle commuter who needs T_0 (minute) travel from dormitory to school, if he alternate to use motorcycle, his overall travel time (including “walk through” time) will become T_1

$$T_1 = T_0 / r + t^*$$

$$r = (\text{average motorcycle travel speed} / \text{average bicycle travel speed}) = 19.14 / 12.89 = 1.49$$

$$t^* = \text{estimated walk through time} = 2\text{minute}$$

For a motorcycle commuter who need T_2 (minute) overall travel time and t (minute) walk through time , according to his walk through time, if he alternate to use bicycle, his overall travel time become T_3

$$T_3 = (T_2 - t) * r$$

$$t = \text{walk through time needed when using motorcycle}$$

For one who walks to school and needs T_4 travel time from dormitory to school, if he alternate to use motorcycle, his overall travel time (including “walk through” time) will become T_5 ; if alternate to use bicycle, his overall travel time will become T_6

$$T_5 = T_4 / r_1 + t^*$$

$$T_6 = T_4 / r_2$$

$$r_1 = (\text{average motorcycle travel speed} / \text{estimated walking speed}) = 19.14 / 4.5 = 4.25$$

$$r_2 = \text{average bicycle travel speed} / \text{estimated walking speed} = 12.89 / 4.5 = 2.86$$

2.2 Analysis on safety risk from daily commuting

2.2.1 Accident record from school guard

NCKU school guard office has yearly traffic accident record for NCKU students (Table 2-3), but due to the data completeness, data before year 2002 are not used in the survey. However, only those serious accident cases would be reported to school guard office. Adopting those injury data will result in lots of missing value from those frequency dominant moderate and light accident cases. The situation will be elucidated in part 2.2.3. Therefore only the fatal cases record will be used in this study.

Table 2-3 NCKU guard office accident record from year 2002 to 2004

Year 2004	Heavy Injury							Light injury (open wound)		
	death	brain concussion		fracture		internal injury		serious	moderate	minor
AccidentType		serious	moderate	serious	moderate	serious	moderate			
riding motorcycle	1	1	0	3	6	0	0	12	11	30
riding bicycle	0	0	0	0	2	0	0	4	1	4

Year 2003	Heavy Injury							Light injury (open wound)		
	death	brain concussion		fracture		internal injury		serious	moderate	minor
AccidentType		serious	moderate	serious	moderate	serious	moderate			
riding motorcycle	1	0	2	2	5	0	0	7	3	15
riding bicycle	0	0	0	0	1	0	0	5	1	2

Year 2002	Heavy Injury							Light injury (open wound)		
	death	brain concussion		fracture		internal injury		serious	moderate	minor
AccidentType		serious	moderate	serious	moderate	serious	moderate			
riding motorcycle	0	0	1	5	10	1	0	6	7	13
riding bicycle	0	0	0	0	0	0	0	4	0	2

2.2.2 Streamline DALYs estimation for student's traffic accidents

DALYs, developed in the Global Burden of Disease Study (GBD)^[4], is used as a comprehensive indicator to present the various risks of different commuting options. Despite its usefulness, extensive application of DALYs is not an easy task, because it requires detailed general injury records for DALYs calculation (Box 2-3).

Box 2-3 Calculation of DALYs

$$YLD = D \left\{ \frac{KCe^{ra}}{(r + \beta)^2} \right. \\ \times [e^{-(r+\beta)(L+a)}[-(r + \beta)(L + a) - 1] \\ \left. - e^{-(r+\beta)a}[-(r + \beta)a - 1] \right. \\ \left. + \frac{1 - K}{r}(1 - e^{-rL}) \right\}$$

$$YLL = \frac{KCe^{ra}}{r + \beta^2} [e^{-(r+\beta)(L+a)}[-(r + \beta)(L + a) - 1] \\ - e^{-(r+\beta)a}[-(r + \beta)a - 1]] \\ + \frac{1 - K}{r}(1 - e^{-rL})$$

$$DALYs = YLD + YLL$$

D: disability weight

K: the age-weighting factor (1 or 0)

C: a constant (0.1658)

a: age at death

L: in YLD → duration of disability

in YLL → the remaining standard life expectancy at death

r: the discount rate(0.03)

β: the age-weighting factor(0.04)

As mentioned in subsection 2.2.1, not every downtown traffic accident by students would be registered on the accident record of school guard office. On the other hands, students who died from traffic accidents during our survey period should not able to be our respondents. To solve the dilemma, this study combines direct survey result (namely the past year students' accident injury data from pioneering survey) and traffic accident record from school guard office to estimate DALYs due to daily commuting behavior. With this streamlined method, we are able to used both of the data to complement each other, namely by adding per-person Years Lived with Disability (YLD) from direct survey and YLL (Years of Life Lost) from registered data of school guard office together to estimate total DALYs.

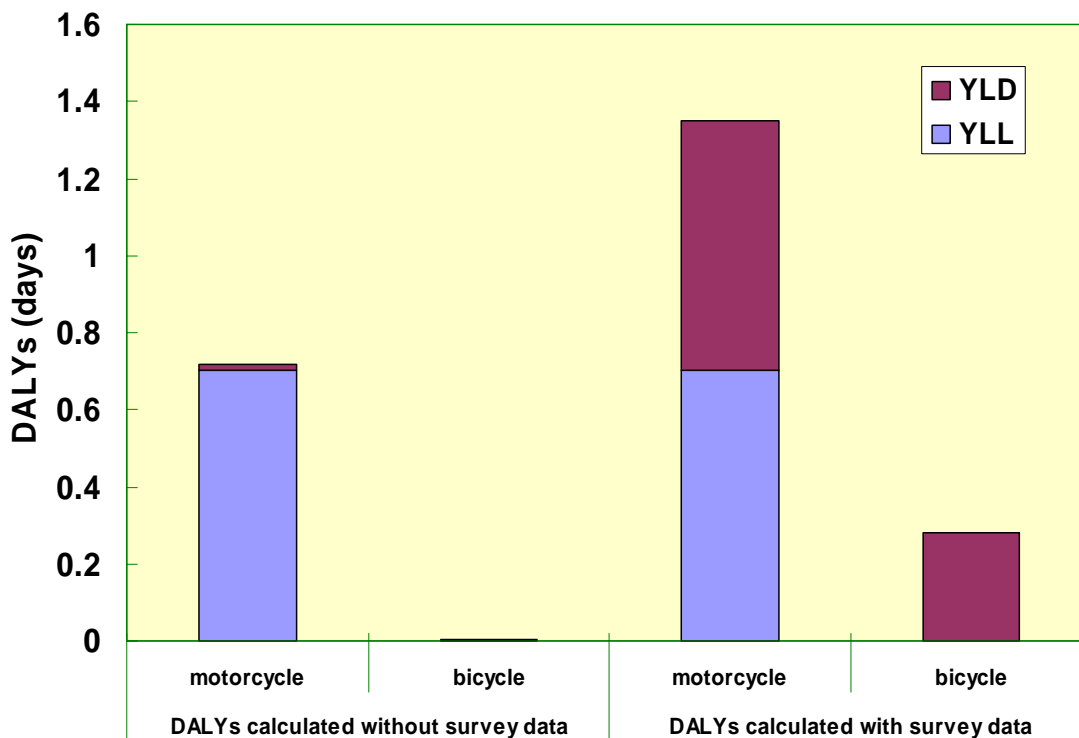


Fig. 2-2 Annually average per-person DALYs due to commuting behavior of NCKU students

The results in Fig. 2-2 show differences in motorcycle and bicycle commuting clearly. Left part of the figure represents the DALYs value calculated only based in school guard office record. As we see, the YLD value is extremely underestimated. The YLD value from registered accident record is 39 times smaller than YLD value from direct survey in motorcycle cases (0.649 versus 0.019) and 48 times smaller in bicycle cases (0.2800 versus 0.0058). The result unquestionably proves the effectiveness of direct survey for estimating the actual injury damage from traffic accident.

Motorcycle-commuting students suffer about 132% (0.65 day over 0.28 day) more per-person accumulated YLD as students who are bicycle commuter. Furthermore, the DALYs (YLL + YLD) for motorcycle-commuting students are 4.82 times (1.35 day over 0.28 day) as much as bicycle commuting student. The result reveals the risk of motorcycle commuting needs to be re-recognized by students.

Figure 2-3 shows the 90% confidence levels of DALYs, and tells us that the safety risk of motorcycle dominates that of bicycle.

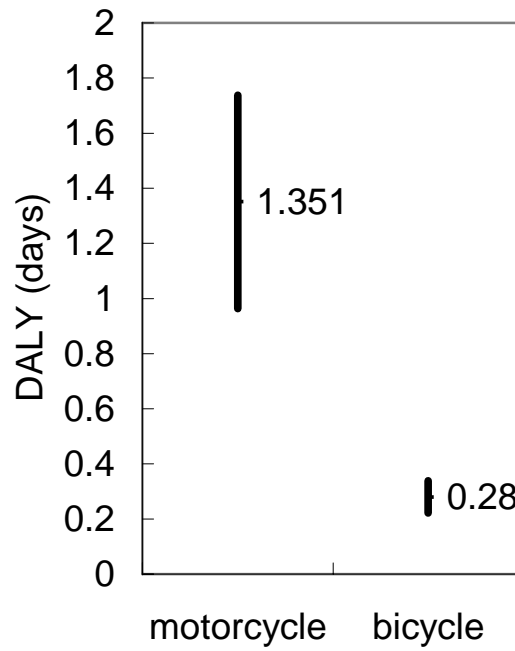


Fig. 2-3 DALYs for different commuting modes (value range shows 90% confidence level)

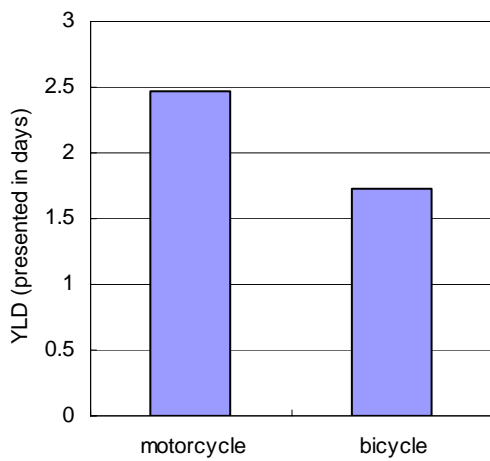


Fig. 2-4 YLDs for each accidents

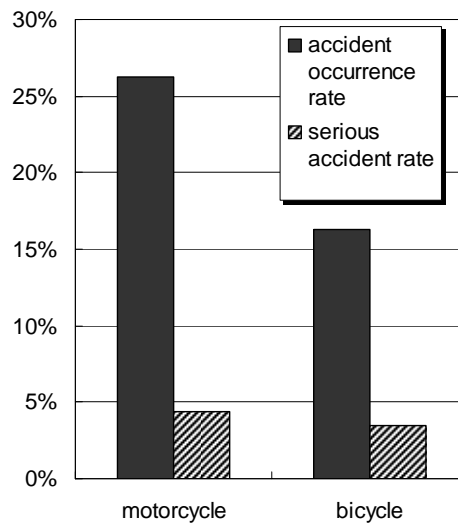


Fig. 2-5 Accident occurrence rate for each commuting mode

Figure 2-4 shows average YLD per each accident of respondents in our survey. We found the tendency that accident happened on motorcycle commuter is severer than bicycle commuter. Figure 2-5 indicates motorcycle commuters suffer either higher (26% versus 16%) general accident occurrence rate (the rate of students who were subjected downtown traffic accident in the recent year) or serious accident (disability duration longer than 2 week) occurrence rate (4% versus 3%) over bicycle commuter by focusing on serious accidents defined as cases with disability duration longer than 2 weeks.

This result for students in Tainan differs from the research in Toronto city^[5], which reported that absolute event rate per bicycle kilometer were found to be between 26 to 68 times higher than rate for mobile travel. Variations in local situations can lead to completely opposite results, therefore it is important to conduct localized researches.

In addition, higher YLD per accident is expected to result in higher medical treatment cost, which is beyond the scope of our study.

2.2.3 Sensitivity analysis on DALYs value

Calculation of DALYs brings in lots of variables. Knowing how influential that our data source quality could cause is crucial to the reliability of survey. We have performed a sensitivity analysis to look at the fluctuation under different variable settings.

DALYs might contain some variables inside its formula that have high sensitivity to the result. For example, Arnesen and Kapiriri pointed out variables such as discount rate have quite critical sensitivity for DALYs^[6]. To verify our result, the sensitivities of discount rate, injury duration, standard life expectancy, disability weight, and death number per year are presented with a tornado graph in Fig. 2-6. 30% variation range was set for injury duration obtained from survey, disability weights given by Global Burden of Disease, and death number per year obtained from guard office. 10% variation was set on Taiwanese standard life expectancy because less fluctuation is expected for this variable. Discount rate ranges from 0 (no discounting) to 0.03 (standard discount rate is taken from GBD). Figure 4 indicates discount rate being the most sensitive parameter of all variables under our variation setting. This finding corresponds with the result by Arnesen and Kapiriri.

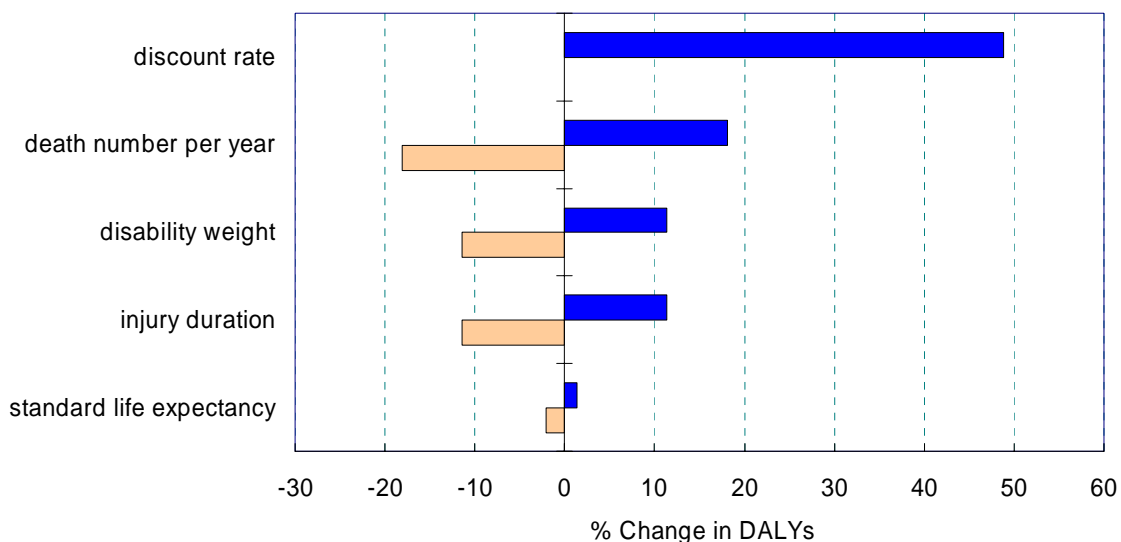


Fig. 2-6 Tornado graph of DALYs for commuting accidents

Reference

1. Taiwanese Construction & Planning Administration, *台灣省市區道路交通特性分析 第十三冊 台南市*: Taiwan (2001)
2. Mohammed S. Tarawneh, *Evaluation of pedestrian speed in Jordan with investigation of some contributing factors*: Journal of Safety Research 32 (2001) 229–23
3. Elaine M. Murtagh, B.A., Colin A. G. Boreham, Ph.D., and Marie H. Murphy, Ph.D., *Speed and Exercise Intensity of Recreational Walkers*, Preventive Medicine 35, 397–400 (2002)
4. Murray, C.L.L., Lopez, A. D., *The Global Burden of Disease*: World Health Organization (1996)
5. Aultman-Hall, L., Kaltenecker, M. G., *Toronto bicycle commuter safety rates: Accident Analysis and Prevention* 31, pp.675-686 (1999)
6. Arnesen, T., Kipiriri, L., *Can the value choices in DALYs influence global priority-setting?*: Health Policy 70, pp.137–149 (2004)

Chapter 3 Assessment on daily commuting of student

3.1 Annual expense on motorcycle and bicycle

3.1.1 Fuel usage

People use motorcycle for numerous purposes (e.g. commuting, shopping, recreation, traveling). The fact makes it difficult to identify the exactly fuel cost of daily commuting. 車輛油耗指南^[1] surveyed by Bureau of Energy, Ministry of Economic Affairs (Taiwan) reveals mileage data for all kinds of motorcycle available on Taiwan market. The mileage data provided already considered different driving condition (simulated city driving mode, fixed speed mode, and average) Table 3-1 shows average mileage of motorcycle in different engine displacement. The mileage difference between engine displacements is within 10.7%, which is not significant.

**Table 3-1 Official motorcycle mileage test data
(provided by MOTC, Taiwan)**

Engine displacement	50cc	80cc	100cc	125cc	150cc
Mileage (km/L gasoline)	42.4	39.5	39.1	38.4	38.3
Average	39.5				

The 車輛油耗指南^[1] only tests brand new motorcycles on market, and might not able to give the realistic mileage data for those veteran motorcycle commuters. Hence we decide to refer to the dynamometric tests data from "Motorcycles emission factors determined by dynamometric tests using real road driving cycles^[2]" as our basis of mileage calculation. The paper collected regional driving pattern in four main cities in Taiwan (Taipei · Taichung · Kaohsiung · Pingtung), and then used dynamometer to get air pollutant emission factor and mileage data (table 3-2) on the driving pattern inputted. The following study will use the average value "34.09 kilometer travel per liter" as the mileage basis.

Table 3-2 Dynamometric mileage test result according to local driving pattern of motorcycle

Dynamometric Mileage Tests				
City	Taipei	Taichung	Kaohsiung	Pingtung
Mileage (km/L gasoline)	30.54	31.53	34.02	40.25
Average	34.09			

The price of

gasoline varies with time. Owing to steep raise of international oil price in recent year, we decide not to use the average gasoline price of past few years but use price to date for accounting fuel cost. At the time we began the main survey (May, 2006), the gasoline price (average price of three kinds of gasoline – 92, 95, 98 octane value) is 28.01 NTD^[3] per liter. Thus the method to estimate annual individual fuel expense of commuting is as follow.

Box 3-1 Estimate annual fuel consumption during daily commuting

$$C = T / 60 * S / M * n * 365 * P$$

C: Annual individual fuel expense of commuting (NTD)

T: Travel time needed from respondents dwelling to school (minute)

S: Average travel speed around NCKU

motorcycle 19.14km/h

bicycle 12.89km/h

walking 4.5km/h (assumption)

M: Average mileage of motorcycle (34.09 km/L)

P: Price of gasoline (28.01 NTD/L)

n: Number of trips per day (2)

According to the method shown in Box 3-1, if one needs five minutes riding motorcycle from his dormitory to school, his annual commuting fuel expenditure would be 958 NTD. For a bicycle user who plan to alternate his commuting mode to motorcycle, if he needs five minutes riding bicycle from his dormitory to school originally, he would have to pay extra 644 NTD buying fuel for motorcycle.

3.1.2 Maintenance and repair cost

Economic savings could be a major incentive or constraint for students choosing their commuting mode. Primary investment is usually the first considered aspect because of its accessibility. But people barely evaluate operation and maintenance cost, even when they are already in use of their transportation media.

The “Vehicle Operation Cost Survey”^[4] conducted by Taiwanese MOTC estimated the approximate expenses of motorcycle via account tracing on selected respondents and direct survey using questionnaire. Due to the effective measured samples of the former method is less than 10, our research chooses to quote data from the latter method (which collected 224 effective samples). Break down of maintenance cost is presented in Table 3-3.

Statistical research on local bicycle maintenance cost is not available in Taiwan. To deal with lack of information, we consulted with local bicycle shop and inquired for experienced data on bicycle maintenance to estimate the annual maintenance cost (shown in the upper half of Table 3-3). The bicycle maintenance scenario assumed here is under the premise of maintaining bicycle in fine condition. In real situation, riding bicycles in fairly usable condition are also commonly seen in campus.

Table 3-3 Break down of maintenance cost (motorcycle & bicycle)

		Duration (years)	Cost (NT\$)	expected cost per year
Bicycle	brake pad (rear & front)	1	100	100
	brake line (rear & front)	0.5	100	200
	internal tire (rear & front)	2	300	150
	external tire (rear & front)	3	600	200
	patching flat tire	0.5	50	100
	seat cushion	3	150	50
	gear	3	300	100
	total			900
Motorcycle	engine oil			1,847
	tire			632
	engine repairment			239
	bike body repairment			119
	other repairment			774
	regular maintenance			261
	total			3872.4

Averaged repair costs per accident data is collected in the pre-survey. For motorcycle cases, average repairment cost per traffic accident is 1572 NTD (total 75450 NTD lost in 48 accidents), and for bicycle cases, average repair per traffic accident is 107 NTD. (total 1500 NTD lost in 14 accident cases). (Fig. 3-1)

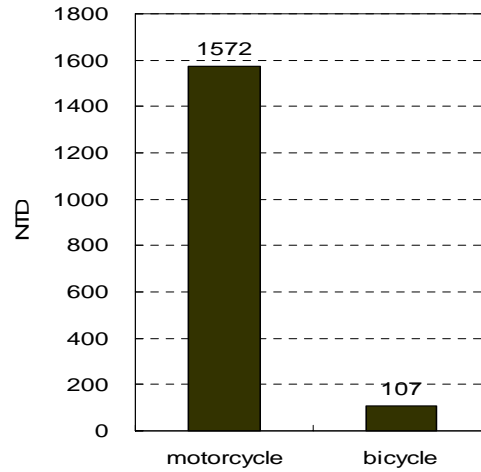


Fig. 3-1 Repairment costs per accident

By adding both repairment cost and maintenance cost, the difference between the two commuting modes is already noticeable. (Fig 3-2)

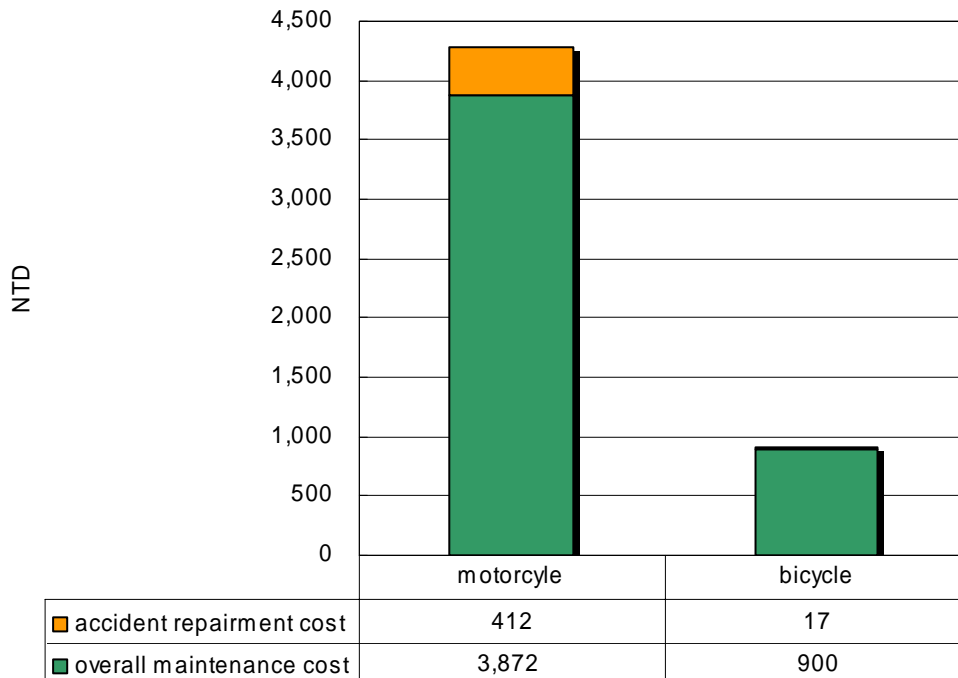


Fig. 3-2 Repairment and maintenance costs per year (NTD)

Note that the annual maintenance cost presented here is not only for daily commuting usage but an overall ordinary usage pattern. If one merely uses his motorcycle for daily commuting, the maintenance cost would probably drop down. The problem could be adjusted if one should provide operation cost survey based on the travel mileage data. However, which commuting media that one uses could affect one's life style and behavior. If one chooses motorcycle as most used commuting media, it could result in that one would prefer to go to shops or restaurants located further more frequently, thus causes higher mileage and maintenance cost comparing to using bicycle. In other word, on the understanding that choosing commuting mode is also as choosing life style, providing general average maintenance cost to people would be more meaningful than providing mileage based maintenance cost.

3.1.3 Tax and imperative insurance

All the motorcycle on road in Taiwan should be registered by MOTC, and users should pay for taxes and imperative insurance. The taxes which associate to motorcycle user include fuel tax and license tax. Those charges vary according to engine displacement of motorcycle. (Table 3-4)

Table 3-4 Annual taxes and insurance of motorcycle

(Data from Directorate General of Highways, MOTC and
Financial Supervisory Commission, Executive Yuan^{[5][6]})

Engine displacement (c.c.)	Fuel Tax	License Tax	Imperative Insurance	Total
50	300	0	560	860
51 ~ 125	450	0	767	1217
126 ~ 150	600	0	767	1367
150+	600	1650	767	3017

3.2 External damage from motorcycle

While discussing about environmental load, it often leads to debated issue: how to interpret and what is the best indicator to describe the consequence of the pollution. In this study, our purpose is to find a comprehensive way to present the external damage, thus allow people to evaluate and to take those information as a clue for making decisions.

Monetary unit and life time loss are most generally assessable objects that common people could recognize. To make such conversion from environmental load and indefinite external damage to assessable objects, there exists some method available such as damage function approach, averting behavior method, and contingent valuation method (CVM). Government and academic institute worldwide endeavor to develop appropriate system for better describe domestic values, works like end-point conversion model and Green GDP accounting are getting thriving in recent years.

3.2.1 Localized pollution pattern of motorcycle using

Localized emission profile for motorcycle using is another key component for quantification of pollution derived from motorcycle. In Taiwan, all the motorcycles on market should conform the exhaust gas emission standard, and government implements nonscheduled random on road spot check to ensure specific pollutants (CO and Hydrocarbons) in exhaust gas not exceed the regulated concentration. (Table 3-5)

Table 3-5 On road spot check exhaust gas emission standard

(according to 機車排氣檢驗標準檢測程序^[7] provided by EPA, Taiwan)

Qualified Standard	Yellow Tag Qualification	Blue Tag Qualification
For motorcycle qualified the third period or early emission standard	3.5%<CO ≤ 4.5% & 7,000ppm<HC ≤ 9000ppm	CO ≤ 3.5% & HC ≤ 7,000ppm
For motorcycle qualified the fourth period emission standard	2.5%<CO ≤ 3.5% & 1,500ppm<HC ≤ 2,000ppm	CO ≤ 2.5% & HC ≤ 1,500ppm

However, to get emission factor more close to real on-road riding scenario, simulated test method such as dynamometric tests is better than merely depend on exhaust gas emission standard. In our study, a dynamometric tests conducted by Wang^[2] in year 2002 is taken as the source data for estimating exhaust gas pollutant pattern. Their survey obtained motorcycles emission factors by input real road driving cycles into dynamometer and measure the emission data. At the beginning, they made on road survey to get regional driving pattern in four major cities of Taiwan (Taipei, Taichung, Kaohsiung, Pingtung), then used dynamometer to simulate the driving pattern and, to detect the concentration of CO₂, CO, NO_x, and THC (Table 3-6). Owing to the lack of PM10 (which also an important pollutant) data, to implement with other relative research is needed.

Liu (2004)^[8] conduct another dynamometer survey on pollution from motorcycle, which includes PM10 emission profile of exhaust gas (Table 3-7). They collected emission data in the “Cold Start” condition (detecting pollutant concentration without letting motorcycle operate for certain time to wait for pollutants being stabilized). This testing method could more reflect the ordinary short distance commuting scenario in downtown area (e.g. students’ daily commuting). Due to engine and anti-pollution device (e.g. Catalytic Converter) does not fully function in low temperature while motorcycle just igniting, pollutant concentration would significantly increase until engine and catalytic converter reach optimum working temperature^[9].

Due to lacking of driving pattern in the dynamometer test in Liu’s study, we decide to take Wang’s test result as a basis and implement the lacking of PM10 data by Liu’s study. MOTC Taiwan categorizes motorcycles have engine displacement below 50c.c. as “light bike” and others as “heavy bike”. Since most of the light bikes on market are 2 cycles and most of the heavy bike are 4cycles, we weighted the emission factor of PM10 according to the ratio of light bike/heavy bike ratio (1:1.81) registered by MOTC^[10]. Therefore the weighted PM10 emission factor is 5.73E-03 gram per kilometer traveled (Table 3-6).

**Table 3-6 Major air pollutants emission factor
based on dynamometer test
(gram per kilometer traveled)**

	Pollutants				
	CO ₂	PM ₁₀ [*]	CO	NO _x	HC
Emission factor (gram per kilometer traveled)	4.99E+01	5.73E-03	7.34E+00	1.25E-01	2.02E+00

*Data of PM10 emission factor is from [8], others emission factors are from [2]

**Table 3-7 Major air pollutants emission factor in cold start condition
(milligram per kilometer traveled)**

	CO	HC	NO _x	PM ₁₀
2 cycle engine	4.45	3.94	0.05	10.1
4 cycle engine	3.37	1.16	0.28	3.31

3.2.2 Green GDP accounting

The Green Gross Domestic Product, also called the Green GDP, is based on the System for Integrated Economic and Environmental Accounting (SEEA) which is developed by the United Nations. The Green Account's main function is to show the systemic interaction between the economy and the environment during economic development. It includes the following types of information^[11] :

- (1) Natural resource inventories and utilization.
- (2) Amounts of pollutants emitted into the environment.
- (3) Environment quality and the impact of these emissions.
- (4) Benefits of natural resources for the environment and human life.
- (5) Developmental trends in environmental expenditures and taxes, which are direct investments by the government and industry for maintaining a viable environmental system.

The information above allows people to understand the extent of environmental resource use in economic development, as well as how economical development impacts our environment positively and negatively. The notion of Green GDP is to take account of the “depreciation” problem that is not concerned in traditional gross domestic product system. Therefore, effectiveness of natural resource use and sustainability of resource use and management can be analyzed with concrete measure. We can also think on a broader scale in assessment of industrial development, facilitating balance between environment preservation and economic development.

Directorate-General of Budget, Accounting and Statistics, Executive Yuan (Taiwan) initiated the project of Taiwanese Green GDP accounting in year 2000, and accomplished the accounting from year 2000~2002 in December 2004^[12]. Green GDP itself is varied by the compiling system adopted and geographical parameter or national specific concern^[13]. For example, SEEA endorses two accounting method for pollution - Accounting for defensive expenditure and Accounting for degradation^[14]. Taiwanese Green GDP

accounting system adopts the former method for quantifying pollution into monetary item, that is, based on “pollution reduction cost”. What pollution reduction cost implies is the cost of current BACT (best available control technology) in industrial society (i.e. fixed/point pollution source) for reducing per unit specific pollutant.

While using Green GDP method for quantifying environmental external damage, some suitability issues would arise. The method of pollution reduction cost is less relevant to the actual damage on environment safe guard objects. Furthermore, the cost and facilities/devices for controlling pollution from mobile source are by no mean the same with that for fixed/point source. The reason why Directorate-General of Budget, Accounting and Statistics didn’t adopt the pollution damage cost method is due to lacking of proper data source and fundamental environment research^[12].

So far the Taiwanese Green GDP system doesn’t include the impact of greenhouse gas emission (e.g. carbon dioxide). Directorate-General of Budget, Accounting and Statistics consider monetizing the loss of biodiversity or the impacts of climate change caused by carbon dioxide emissions is highly controversial, and published results differ by orders of magnitude. Therefore greenhouse gas is excluded in current system. Nevertheless, since CO₂ issue already in the spotlight of global environmental initiatives and Kyoto protocol was approbated and come into effect in February, 2005. Omitting the greenhouse gas category would be a critical flaw on quantification of external damage of air pollution.

Since pollution reduction cost is based on the regulation of air quality standard, it turns out to be less meaningful and less informative for environmental management. The “baseline” for pollution reduction is current air quality standard. In Taiwanese cases, the baseline standard is PSI (Pollutant Standard Index) 100 (Table 3-8). That is, if average concentration of certain pollutant doesn’t exceed the PSI 100, then the cost of the environmental depreciation of this pollutant will be set to zero. This would open a debate that how can we indicate the environmental depreciation from a good state (PSI 50 or below) to moderate state (PSI 100). The questionable issue always emerges in air pollution category. Because concentration below the regulation standard wouldn’t assure no environment damage/depreciation generated.

Table 3-8 Pollutant Standard Index provided by Taiwanese EPA
(data source: Taiwanese EPA)

PSI	PM10 (24hours average concentration)	SO ₂ (24hours average concentration)	CO (8 hours maximum average concentration)	O ₃ (maximum hourly concentration)	NO ₂ (maximum hourly concentration)
	unit: $\mu\text{g}/\text{m}^3$	unit: ppb	unit: ppm	unit: ppb	unit: ppb
50	50	30	4.5	60	—
100	150	140	9	120	—
200	350	300	15	200	600
300	420	600	30	400	1200
400	500	800	40	500	1600
500	600	1000	50	600	2000

Table 3-9 sorts the Green GDP depreciation of major air pollutants. Aggregated damage factor per kilometer traveled by motorcycle is 0.0386 NTD.

Table 3-9 Green GDP depreciation of major air pollutants
(data source: [15] [16])

	Pollutants				
	CO ₂	PM ₁₀ [*]	CO	NO _x	THC
Emission factor (gram per kilometer traveled)	4.99E+01	5.73E-03	7.34E+00	1.25E-01	2.02E+00
Damage of Green GDP (NTD per gram pollutant)	-	6.50E-04	-	5.45E-03	1.88E-02
Health damage per kilometer traveled	-	3.72E-06	-	6.81E-04	3.79E-02
Aggregated damage factor = 3.86E-02 (NTD/km)					

Considering the fact that average measured concentration could not reflect the regional or temporary high concentration incident. The situation is more evident on line-source pollution (mobile source). Air pollution concentration would reach harmful level on major arteries during rush hour. Pedestrians, bike rider who tail after mobiles would also suffer discomfort or other negative effect on respiratory system. Therefore, even if all the official air quality monitoring site detects the concentration below PSA 100, it still possible exists some “hot spot” area (for example: cross road of main arteries) reach harmful concentration of air pollutants.

Pollution reduction cost is based on the commercial anti-pollution device for certain factories (i.e. to reduce NO_x from factory and from motorcycle are two DIFFERENT things). On the consequence of possible higher controlling difficulty on small scale pollution source (e.g. motorcycle), we wonder if it tends to over-underestimate the external cost of line-source air pollution.

In conclusion, regulation of air quality is the bottom line that people could bare. Consider the fact of data lack, if reduction cost method will still be applied in following year, change the baseline of quality standard to more strict quality level might be a solution to rectify the defect. Besides, the category of greenhouse gases should be mended for more precisely represent the environmental depreciation.

3.2.3 Ecological Footprint

Since international organizations, such as IUCN, UNEP, WBCSD, and WWF, have promoted the concept of “Sustainable Development” in 1980’s, lots of relevant studies (Haberl H. 2004^[17], Senbel M. 2003^[18], Stoglehner, G. 2003^[19], Wackernagel M. 1997^[20]) have been carried out, including development of sustainability indicators. “Ecological Footprint” proposed in 1994 by Rees and Wackernagel is one of such indicators, which continue on gaining more and more attention nowadays, due to its simplicity in calculation by the users, and the clear and communicative concept of land use area with an explicit unit (ex. hectare of land use).

Ecological Footprint (EF) is an emerging indicator to measure the environmental burden of human activities. Its “land area based” concept can be applied to extensive aspects like transportation^[21], diet^[22], recreation^[23], or daily life. EF is concise and could easily comparable and therefore becomes a popular indicator in sustainable initiatives.

Xu^[21] has made a research on traffic ecological footprint taking two metropolises (Taipei and Kaohsiung) in Taiwan as case study target. Land area for CO₂ assimilation, land requirement for food (for bicycle cases), and road area were taken account of in her study. Notwithstanding, when it comes to assess on choosing commuting mode, one has to recognize that roads have already been “built” at all. This especially hold true is downtown area. In other word, whether user alternate his commuting mode or not, there’s nothing to do with the land depletion of the roads. For this reason, we will only take account of land area for CO₂ assimilation in our study.

Box 3-2 Calculation of ecological footprint on daily commuting

If one need to ride motorcycle 5 minutes from dormitory to school...

$$E_m = R * H * T / 60 * S / M / A * n * 365 = 0.0173 \text{ (hectare)}$$

E_m : Annual Ecological footprint of motorcycle commuting from home to school

R : Correct factor for indirect CO₂ emission in manufacturing and maintenance stage (1.45)

H : Heat content per liter of gasoline (0.035GJ/L)

T : Single-way motorcycle travel time from home to school (5minutes)

S : Average motorcycle travel speed around NCKU (19.14 km/h)

M : Average mileage of motorcycle (34.09 km/L)

A : CO₂ assimilation potential on fossil fuel per 1 hectare of land (100GJ/Ha/ year)

n : Number of trips per day (2)

If substitute to commute by bicycle...

$$E_b = T / 60 * S * F * r / C / P * n * 365 = 0.0062 \text{ (hectare)}$$

E_b : Annual Ecological footprint of bicycle commuting from home to school

F : Food calorie requirement for riding bicycle (90KJ per kilometer travel)

r : Correct factor of land requirement for food processing (2)

C : Calorie per kilogram of food (13000KJ/kg) (assume to eat cereal)

P : Cereal production per 1 hectare of farm (2600kg/ha)

Box 3-2 illustrates annually ecological footprint comparison between bicycle and motorcycle. On the average students commute by motorcycle will require 2.8 times of land usage as commute by bicycle. However, one should keep in mind that the land requirement is of different attribute when comparing motorcycle and bicycle. There always exists question that how to compare agriculture land with forest land. Furthermore, although EF is a simple and easy understanding indicator, but its measuring coverage is just too narrow that ignore other important factors such as air pollution and exhaust in maintenance/disposal stage.

Research taking Ecological Footprint to evaluate environmental burden has been done in Taiwan using city-wide aggregated data. Lee^[24] calculated average per-person ecological footprint of Taiwanese. The result is 4.673 ha/person/year. Therefore the ecological footprint from daily commuting is considered minimal at all.

3.2.4 Life Cycle Impact Assessment Method based on Endpoint Modeling

The Japanese Ministry of Economy, Trade and Industry set up a national project, the “Development of Assessment Technology of Life Cycle Environment Impacts of Products, etc.” (the “LCA Project”) as a five-year plan commencing in fiscal 1998, with the aim of developing LCA methodology and a reliable LCA data base accessible from all parts of Japan. This project convene experts from the fields of industry, the government and academia, and industry groups to establish 3 committees focuses on the realms of Inventory Study, Impact Assessment Study, and Data Base Study under the Administration Committee. The final goal is to develop a quantitative method to evaluate environmental load of products, thus facilitate technologies and design with the vantages of environmental friendly, recyclable, and better eco-efficiency characteristic^{[25][26]}.

The purpose of this project includes the development of (1) LCA methodology, (2) LCA database, for the whole of Japan, and (3) a network system which is easily operable by users, and also the application of the results of developments in the following fields.

Application to industrial production activities

- (1) Popularization of eco-design,
- (2) Construction of eco-process

Application to marketing Persuasive

- (1) Approval of eco-labeling,
- (2) Establishment of environment specification

Reflection in Environmental Administration

- (1) Green Purchasing,
- (2) Coping with COP3 Protocol, etc.

Acceleration of LCA popularization

- (1) Popularization of reliable LCA software,
 - (2) Enrichment of textbooks for education,
 - (3) Training of LCA experts
-

The 'LCA Project' in the end come out with a solid database system called "Life Cycle Impact Assessment Method based on Endpoint Modeling (LIME)".

The research realm of "LCA Project" takes so called "problems comparison" method. It involves characterization of each specific impact (toxicity, global warming...etc.) categories, and single indicator for overall integrated environmental impact. 'Problem comparison' method is popular in recent LCA study worldwide, though it would concern over 10 different environmental impact categories, thus probably conceal the information on actual scale of impacts, and turn out to be less transparent or less reliable. That is to say, adequate data source and comprehensive estimation method are necessary conditions of the studies.

Those kinds of integrated end-point impact assessment model have been thought useful in recent years, for example, Eco-indicator 99, EPS developed from European. LIME adopts similar methodology but use the parameter according to Japanese environmental condition (meteorology, population density, contingent values judgment...). To collect localized data requires relatively detailed study and sufficient budget, so there are few countries have developed its own database, including Taiwan. It's agreeable that Japan and Taiwan have similar environmental condition to certain degree comparing to European countries. But while we apply the end-point impact assessment model from Japan for this study, we should always remember the probably existing across-country difference and suggest government and academic group to construct the localized database for Taiwan.

The LIME database is designed to be generally assessable and available, and in the mean time applies highly-developed LCIA (Life Cycle Impact Assessment) method. Therefore, both the reliability and convenience issues should be considered. The coefficients derived from the model are capable of linear aggregation by LCA practitioner.

The LCIA coefficient lists in LIME system include the following three categories:

1. Characterization Coefficient List
 2. Damage Coefficient (for safe guard object) List
 3. Integrated Coefficient
-

The three different lists allow LCA practitioner could choose the most adequate one for their specific purposes. We adopt integrated coefficient for our case study due to its highly applicability in environmental evaluation and accounting. Besides, integrated coefficient also shows better effectiveness in environmental communication for general public. On the other side, integrated coefficient inevitably involves subjective value judgment and thus results in lower reproductivity. And the weighting method might not been broadly verified by society.

Prevalent air pollutants emitted from motorcycle include CO, NO_x, HC (hydrocarbons), PM (particular matter). Each of them has its consequent environmental / healthy damage. With analysis on dose-response mechanism, DALYs loss can be estimated. And DALYs loss can then be transform to monetary unit by conjoint analysis (1 year of DALYs loss = 9.70E+06 Japanese yen, conversion coefficient is retrieved by survey on Japanese's willingness to pay). And, although not classified as air pollutant, carbon dioxide is also analyzed due to its well-known global warming potential.

Table 3-10 shows the LIME integrated health damage of each motorcycle-oriented pollutant in terms of money. Monetary values in LIME database is presented in Japanese Yen, which we have converted into NTD for the assessability in later survey. The aggregate damage factor calculated by LIME system is 1.40E-01 NTD per kilometer travel by motorcycle, which is 3.63 times over the aggregated damage factor calculated by Taiwanese Green GDP system.

Table 3-10 Aggregate damage factor (external health damage cost) based on LIME (presented in monetary term*)

*original data is presented in Japanese Yen, the currency is 1 NTD = 3.61 Japanese yen at April 19, 2006

	Pollutants				
	CO ₂	PM ₁₀	CO	NO _x	THC
Emission factor (gram per kilometer traveled)	4.99E+01	5.73E-03	7.34E+00	1.25E-01	2.02E+00
LIME health damage (NTD per gram pollutant)	6.14E-04	3.13E+00	-	5.46E-02	4.18E-02
Health damage per kilometer traveled	3.07E-02	1.79E-02	-	6.82E-03	8.42E-02
Aggregated damage factor = 1.40E-01 (NTD/km)					

Box 3-3 Calculation of external health damage from daily commuting

If one need to ride motorcycle 5 minutes from dormitory to school...

$$D = T / 60 * S * n * H * 365 = 163.3 \text{ (NTD)}$$

D: Annual external health damage from daily commuting

T: Single-way motorcycle travel time from home to school (5minutes)

S: Average motorcycle travel speed around NCKU (19.14 km/h)

H: Aggregated health damage factor (0.14 NTD/km)

n: Number of trips per day (2)

Both DALYs and monetary unit could be selected as our indicator for environmental damage. Since we already applied DALYs to represent the safety risk, again using DALYs to quantify environmental risk is an instinctive option. On the other side, environmental risk has more of a non-fatal and indirect effects comparing to safety risk, and it also has the attribute that tends to dispread over wider area and affects more people. It's also more difficult to perceive the negative effect of the environmental issue. (For example, one can express when, how, and to what degree the traffic accident is, but this holds not true for the case of health damage from pollutant)

Estimated annually DALYs loss due to pollutants from motorcycle for the commuting scenario in Box 3-3 is $6.08E-05$ year (equivalent to 0.022 day). It's obvious that DALYs loss due to pollutants is relatively minimal compare to DALYs loss due to traffic accident (1.35 day). Consider the intrinsic difference between the two aspects, the study decide to use monetary unit as the indicator to quantify the effect of air pollution from motorcycle using activity.

To sum up at all, ecological footprint behaves narrow-sighted point of view on pollution problem, Green GDP consists some critical flaws (e.g. accounting for defensive expenditure, based on PSA 100 pollution standard, emission of global warming gases are excluded in current system) when applying to line-source pollution as mentioned previously. Consider the damage factor derived from LIME (based on health damage) is more relevant to people and appropriate to our case study, we will use the damage factor derived from LIME system for communicating environment/public health damage issue to our survey target (NCKU students).

3.2.5 Quantification of greenhouse gas emission

Motorcycle generates power by combusting gasoline; thereby inevitably result in CO₂ emission, and, different from other air pollutants, no controlling device is available on motorcycle to reduce CO₂ emission. The fact that CO₂ is a gas with no odor and color, one can't easily detect how much CO₂ is emitted from tailpipe. Not to mention the negative of global warming is a chronic and less conscious problem. The nature of greenhouse gas issue results in generally unawareness of motorcycle/mobile users. Thus, providing gaugeable indicator to better describe the CO₂ emitted quantity would help people more aware of the problem. For example, equivalent quantity comparing to other daily life activities could give a clearer image on it.

Since people would have clearer image on their travel time during commuting (comparing to fuel usage or travel distance), basing on data available, we could develop an emission factor on CO₂ emission versus time traveled by motorcycle. (Box 3-4)

Box 3-4 CO₂ emission from riding motorcycle

We can simply calculate CO₂ emission per minutes traveled by motorcycle...

$$G = T / 60 * S * E$$

G: CO₂ emission from riding motorcycle (gram)

T: Time traveled by motorcycle (minute)

S: Average travel speed in Tainan city (km/h)

E: CO₂ emission per kilometer traveled by motorcycle (gram)

In Tainan city commuting cases, S = 19.14 E=57.18

Therefore, CO₂ emission per minutes traveled by motorcycle would be

18.27 (grams/minute).

While the original motive to quantify CO₂ emission from commuting behavior is to know if its magnitude worth noting or not, we could develop a common scenario basing on the formula in Box 3-5. Considering the present situation that about 74% of electricity is generated by firepower plant^[27] - which is a major source of greenhouse gas emission -, provide electricity equivalent comparison between commuting and daily life activities could be a comprehensive idea. Among all the daily life activities, air conditioner using is more of higher demand elasticity, that is, people would have more flexibility deciding whether to use it or not. Therefore, we simply take it as our comparison target.

Box 3-5 quantification of CO₂ emission from commuting behavior

If one need to ride motorcycle 5 minutes from dormitory to school...

Annual CO₂ emission from daily commuting:

$$5 / 60 * 19.14 * 57.18 * 2 * 365 = 66681.89 \text{ (gram CO}_2\text{)}$$

(Two trip per day, 365 days per year)

Although the power demand varies according to type and brand, we assume the power demand of a typical air conditioner for single room is 1 kilowatt. And according to data provided by Taiwanese EPA, CO₂ emission per 1 kilowatt electricity is 660 grams^[28] (with the present electric power supply structure in Taiwan)

Therefore, annual electricity equivalent CO₂ emission in this scenario is:

$$66681.89 / 660 = 101.03 \text{ (hours / year)}$$

That is, for a motorcycle commuter, the annual CO₂ emission derived during daily commuting is equal to turn on a typical air conditioner for single room for about 101 hours continuously.

Air conditioner (cooler) is deemed to be the most energy drained household appliance which is the cause of summer electricity peak demand. So, it's amazing that merely 10 minutes riding time a day result in over 100 hours equivalent air conditioner usage a year in CO₂ emission. If we consider the 5 months from May to September is the period that air conditioner (cooler) is needed, than saving motorcycle usage 10 minutes a day could achieve equal CO₂ reduction effect to curtail about 40.4 minutes air conditioner usage per day.

As the growing concern global warming issue, governments, organizations, and individual researchers over the world keep on initiatives that focus on green house gas reduction. For example, Japanese government proposed the "COOL BIZ" action aims at greenhouse gas reduction. The action encourage people to wear light suit in summer and set the temperature on air conditioner to Celsius 28 degrees According to the survey from Japanese Ministry of the Environment, 95.8% of Japanese know the action and estimated 0.46 million tons of CO₂ reduction per year is achieved^[29]. That is equal to 3.75 kg of CO₂ reduction per one Japanese who knows the COOL BIZ action. But looking back at daily commuting, we have demonstrated that urging one who commutes 5 minutes by motorcycle twice a day to commute by bicycle would contribute 66.7 kg of CO₂ reduction per year - the magnitude is over 17 times higher than COOL BIZ action. Even though not all Japanese who know the COOL BIZ initiative do practice it at all, COOL BIZ action still hard to reaches the overwhelmingly CO₂ reduction effect from changing commuting mode.

Reference

1. Bureau of Energy, Ministry of Economic Affairs (Taiwan), *車輛油耗指南*: Taiwan (2004)
 2. Wang, Wen-Jeng, *Motorcycles emission factors determined by dynamometric tests using real road driving cycles (以實際道路行車型態作動力計測試之機車排放係數研究)*: Dissertation for Master, Department of Environmental Engineering, National Sun Yat-San University, Kaohsiung (2002)
 3. Bureau of Energy, Ministry of Economic Affairs (Taiwan), *油價分析與管理系統*: <http://www.moeaboe.gov.tw/oil102/>
 4. Institute of Transportation, Ministry of Transportation and Communication (Taiwan), *Census of Road Vehicle Operating Cost (公路車輛行車成本調查)*: Taiwan (2000)
 5. Directorate General of Highways, MOTC (Taiwan), *燃料使用費、使用牌照稅作業相關規定*: <http://www.thb.gov.tw/hw/look2-2.html#a3>
 6. Financial Supervisory Commission, Executive Yuan, R.O.C., *強制汽、機車責任保險費率表修正案總說明*: <http://www.ib.gov.tw/public/Attachment/6121733971.doc>
 7. Environmental Protection Administration – Executive Yuan, R.O.C., *機車排氣檢驗標準檢測程序*: <http://210.243.193.33/epa/%E6%B3%95%E8%A6%8F/%E9%99%84%E9%8C%84%E4%B8%89.doc>
 8. Yang, Hsi-Hsien, *Polycyclic aromatic hydrocarbons emission from 2-stroke, 4-stroke carburetor and 4-stroke injection motorcycles (二行程、四行程化油器與四行程噴射引擎機車多環芳香烴化合物排放特徵之研究)*: Dissertation for Master, Department of Environmental Engineering and Management, Chaoyang University of Technology, Taichung (2004)
-

9. Yah, Gou-Lin, *Effect of Engine Speed and the Catalytic Converter on Aldehydes Emission in Automobile Exhaust* (觸媒轉換器對汽車廢氣中醛類之影響): Dissertation for Master, Department of Environmental Engineering, National Cheng Kung University, Tainan (1997)
 10. Ministry of Transportation and Communication (Taiwan), Number of Registered Motor Vehicles in Taiwan - Fuchien Area (台閩地區機動車量登記數): Taiwan (2004)
 11. Taiwan Area Green National Income Account Website, http://www129.tpg.gov.tw/mbas/eng_green/index.html
 12. Department of statistics, Environmental Protection Administration – Executive Yuan, R.O.C, 行政院環保署統計室 第 672 次主管會報: Taiwan (2004)
 13. Liao, Chao-Ning, 世界各國綠色國民所得帳之編製情況與趨勢
 14. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank, *Handbook of National Accounting – Integrated Environmental and Economic Accounting*: UN (2003)
 15. Directorate General of Budget Accounting and Statistics, Executive Yuan, R.O.C, 臺灣地區綠色國民所得帳試編結果報告「摘要分析」: Taiwan (2004)
 16. Environmental Protection Administration – Executive Yuan, R.O.C, *Taiwan Emission Data System version 5.1* (空氣污染排放清冊資料庫 TEDS5.1): Taiwan (2000)
 17. Haberl H., Wackernagel M., Krausmann F., Erb K.H., Monfreda C., *Ecological footprints and human appropriation of net primary production: a comparison*: Land Use Policy 21 279–288 (2004)
 18. Senbel, M., McDaniels, T., Dowlatabadi, H., *The ecological footprint: a non-monetary metric of human consumption applied to North America*: Global Environmental Change 13, 83–100 (2003)
-

19. Stoglehner, G., *Ecological footprint – a tool for assessing sustainable energy supplies*: Journal of Cleaner Production 11, 267-277 (2003)
 20. Wackernagel M., Rees W.E., *Perceptual and conceptual barriers to invest in natural capital: Economics from an ecological footprint perspective*: Ecological Economics 3-24 (1997)
 21. Hsu, Hu-Mei, *A Study of Development Traffic Ecological Footprint (交通生態足跡分析法之研究)*: Department of Civil Engineering. National Taiwan University, Taipei (2003)
 22. P.W. Gerbens-Leenes, S. Nonhebel, *Consumption patterns and their effects on land required for food*: Ecological Economics 42 185–199 (2002)
 23. Gossling, S., Hansson, C.B., Horstmeier, O., Saggel, S., *Ecological footprint analysis as a tool to assess tourism sustainability*: Ecological Economics 43, 199-211 (2002)
 24. Lee Yung-Jaan, Chen, An-Chyi, *從生態足跡的觀點探討台灣的永續發展: 經社法制論叢 第 22 期 437~465*, Taiwan (1998)
 25. Website of Japanese Environmental Management Association For Industry (JEMAI): <http://www.jemai.or.jp/english/lca/project.cfm>
 26. Japan Environmental Management association For Industry, *製品等ライフサイクル環境影響評価技術開発成果報告書*: Japan (2002)
 27. Website of Taiwan power company – annual report – 5 year operation statistics (updated 2006/4/19) :
http://www.taipower.com.tw/left_bar/jing_ying_ji_xiao/statistical_data/installment_capacity.htm
 28. Website of greenmark information (Environmental Protection Administration – Executive Yuan, R.O.C):
<http://greenmark.epa.gov.tw/declare/inform.asp>
-

29. Press release of Japanese Ministry of the Environment 05.10.28:
<http://www.env.go.jp/en/press/2005/1028a.html>

Chapter 4 Interactive survey based on computer-assisted personal interview

4.1 Information interchanging pathway

The study tries to develop an “Interactive survey mode”. That is, respondents do not just provide answers for questions; they can also get relative information from the questionnaire system. The built-in model in the system can even provide customized information based on the input of respondent. Interactive survey mode allows us to compare and analysis the attitude change before and after respondent get the information (Fig 4-1).

We construct a model to calculate environment impact from use phase of motorcycle that works behind computer GUI. Environmental impacts are derived from green house gas emission and toxic substance (NO_x, HC, PM) is interpreted as integrated external cost by LIME system. Those personalized analysis (environmental impact, time and expense comparison) will be presented to respondents together with pre-collected traffic accident damage data (in terms of DALY loss). We expect those customized data could support their decisions on choice of commuting manners.

That is, we will ask respondents’ attitude on information before and after we provide them pre-collected statistics data for respondents. Knowing if those information have the influence to activate respondent and change their concept and even their action. While respondent input their commuting variables (commuting styles, time...etc), data based on each respondent’s commuting manner are calculated instantly.

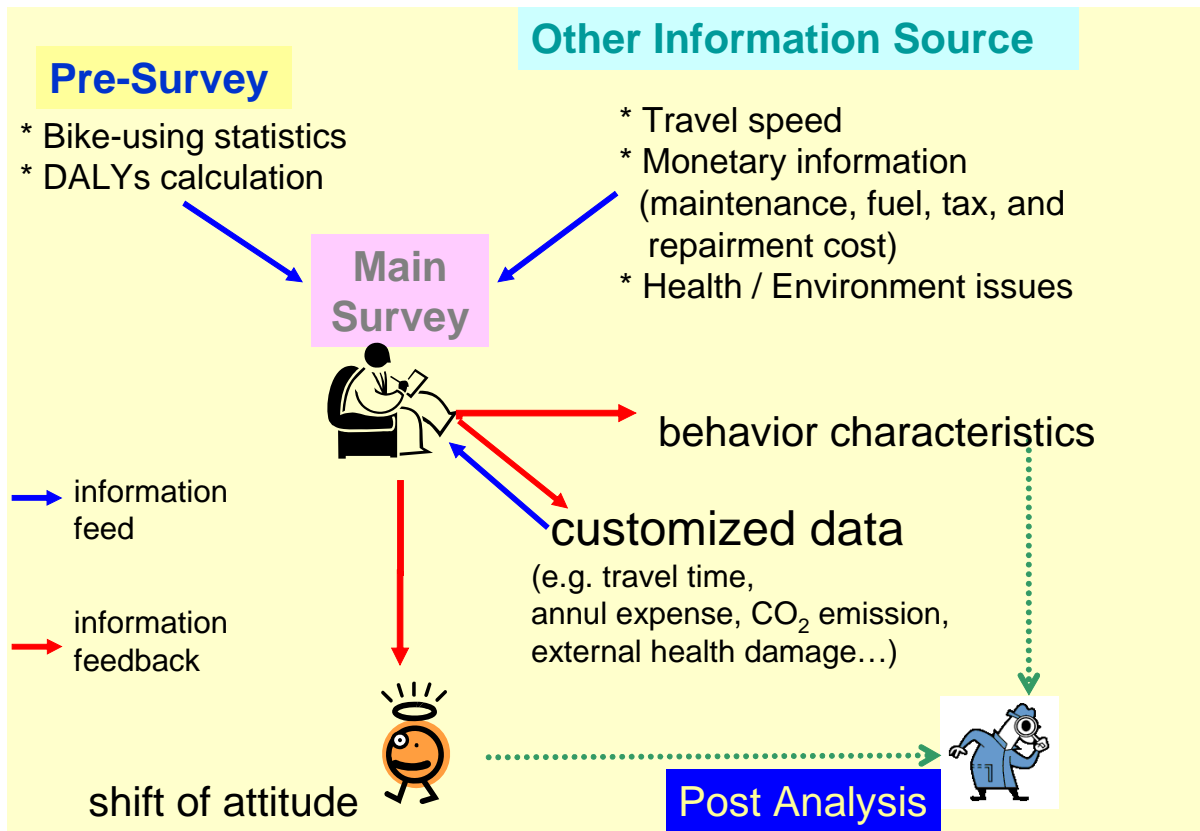


Fig. 4-1 The diagram of the interactive survey structure

Respondents not only act as information provider but simultaneously received customized information that can be easily assessed by them

4.2 Interface design

To facilitate the survey efficiency, we attempted to design questionnaire software that connected to a internal database which could automatically record all the answer replied. A tablet PC is used for interview survey, letting respondents could easily choose their answer on the touch sensitive LCD screen.

The software consists of three parts: web-server system (constructed by Appserv) , interface layout (constructed by DreamweaverMX), and database (constructed by PHP code). Therefore it's capable of being an on-line questionnaire system with automatic recording database.

The questions in the questionnaire can be classified to 4 groups:

1. *Personal attribute (Fig. 4-2)*

This category includes:

- Sexuality
- Live in school dormitory or not
- Grade of student
- Knowledge reconization on transportation
(three questions:
 1. Do you know Taiwan ranks top 1 among the world in motorcycle density?
 2. Do you know traffic accident rate of motorcycle commuting students is higher than bicycle commuting students in NCKU?
 3. Do you know traffic accident rate of motorcycle commuting students is higher than bicycle commuting students in NCKU?)
- Transportation pattern
(two questions:
 1. What kinds of transportation media do you usually use for commuting between dormitory to school?
 2. What kinds of transportation media do you own in Tainan city?

(complete questions set are listed in Appendix 2)

Microsoft Internet Explorer window titled "問卷調查 - Microsoft Internet Explorer".

請問您上下學通常使用何種交通工具？
 機車 腳踏車 步行 其他

您目前在台南擁有那些交通工具？(可複選)
 機車 腳踏車 其他

請問您的年級是？
 大一 大二 大三 大四 研究所



[下一頁](#)

Fig. 4-2 Layout of questionnaire software (personal attribute)

2. Attitude scale on the consequence of commuting modes (Fig. 4-3)

Apply five levels attitude scale for knowing respondents recognition and preference on commuting modes.

(complete questions set are listed in Appendix 2)

The screenshot shows a web browser window titled "問卷調查 - Microsoft Internet Explorer". The main content area contains a questionnaire with the following structure:

請根據您自身的想法，選擇您對下列觀點的同意程度

	非常同意	同意	差不多	不同意	非常不同意
我使用機車的原因 是因為比起腳踏車或走路， 可以省下很多上下學交通時間	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得用腳踏車或走路來上下學很累	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
使用機車的金錢開銷對我造成負擔	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得使用機車比起騎腳踏車或步行更有優越感	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我使用機車是為了方便和異性朋友共乘車	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

**Fig. 4-3 Layout of questionnaire software
(Attitude scale on the consequence of using motorcycle)**

3. Input of data for calculating customized information (Fig. 4-4)

The data input here will be used for calculating customized information which will be shown to respondent later, includes questions as below:

- One-way travel time for commuting between dormitory and school
- Engine displacement of motorcycle (for motorcycle commuter only)
- How long does it take for walking from your regular parking space to the building you take class? (for motorcycle commuter only)

您的機車排氣量? 50 51~125 126~150 150以上

以機車從您目前的住處，前往上課處
約需花費幾分鐘的行駛時間
(不含停車)? 分鐘

從您平常停車的地點，走到上課地點
平均需要幾分鐘?
(不含進入建築物後的上下樓時間) 分

下一頁

**Fig. 4-4 Layout of questionnaire software
(Input of data for calculating customized information)**

4. Importance level of factors on deciding commuting mode (Fig. 4-5)

Apply 5 level attitude scale for knowing the importance level of the four factors (time, environmental & healthy issue, safety, monetary expense) on their thought of deciding which commuting mode to choose.

	非常重要	重要	差不多	不重要	毫不重要
交通工具的使用開銷資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
交通工具的環境、健康損害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
交通工具的意外傷害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
交通工具的時間、速度資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

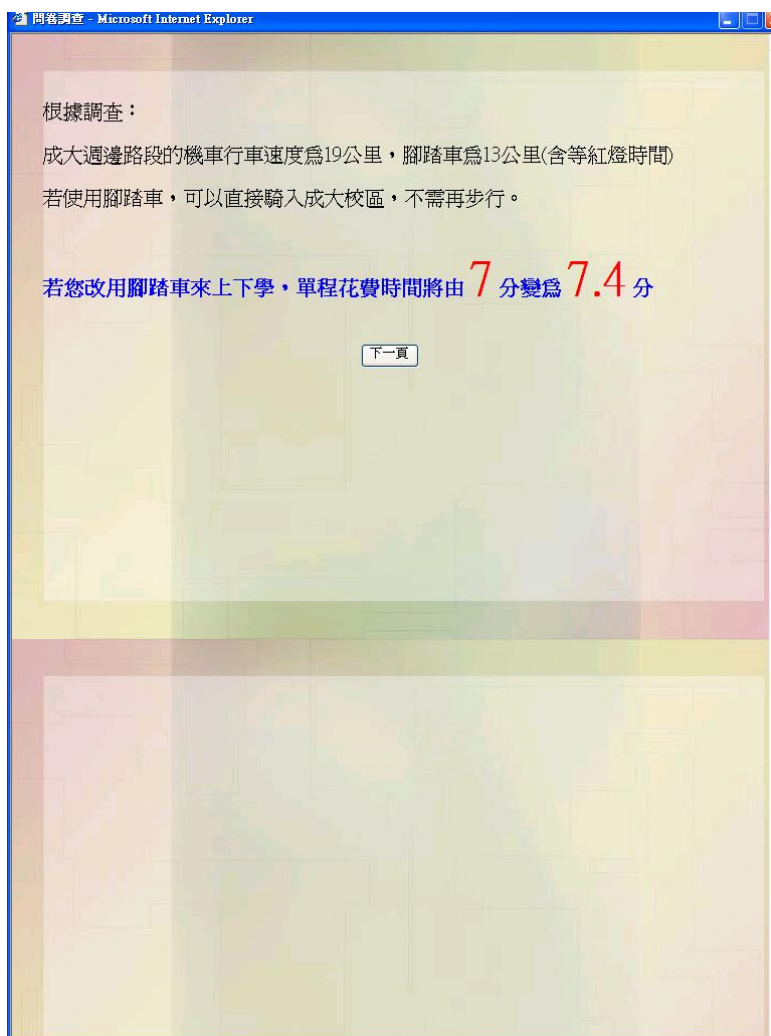
**Fig. 4-5 Layout of questionnaire software
(Importance level of factors on deciding commuting mode)**

5. Presentation of customized information for respondent

In this section, customized information will be shown in both numerical and graphical ways. Because what respondent see in this part is calculated based on individual's input result, interactive communication will be achieved.

The information shown here includes:

- Travel time comparison between different commuting modes according to respondent's current commuting pattern. (Fig. 4-6)



**Fig. 4-6 Layout of questionnaire software
(Travel time comparison information page)**

- Comparison between motorcycle commuter and bicycle commuter in annual average per person DALYs from downtown traffic accident. (Fig. 4-7)



Fig. 4-7 Layout of questionnaire software
(DALYs comparison information page)

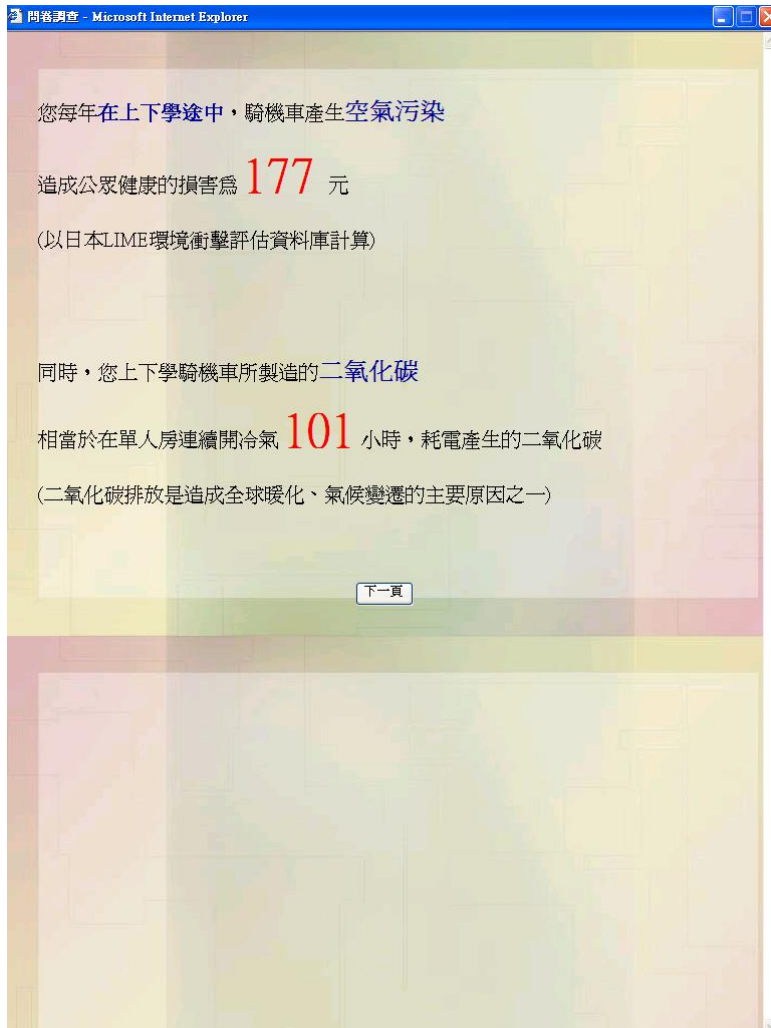
)

- Expected annual overall commuting expenditure in different commuting modes (motorcycle only, bicycle only, and commute by bicycle but keep motorcycle available) according to respondent's current commuting pattern. The expenditure includes fuel, accident repairment, maintenance, tax and imperative insurance.



Fig. 4-8 Layout of questionnaire software (DALYs comparison information page)

- Expected annual public health damage of air pollution derived motorcycle in case of respondent choosing motorcycle for daily commuting from home to school. Expected annual CO₂ emission from motorcycle in case of respondent choosing motorcycle for daily commuting from home to school. (presented as equivalent CO₂ emission comparing to operate an air conditioner in single room) (Fig. 4-9)



**Fig. 4-9 Layout of questionnaire software
(Health/Environment aspects comparison information page)**

6. Measuring shift of respondent's point of view after receiving customized information.

After providing customized information, again apply 5 level attitude scale for knowing the importance level of the four factors (time, environmental & healthy issue, safety, monetary expense) on their thought of deciding which commuting mode to choose. Therefore, shift of respondent's point of view due to customized information could be analyzed.

In the same page, for emphasizing the information to respondents, we make a check list to provide the information of four aspects together in clear, explicit way.

金錢開銷 (每年)	環境、健康損害 (每年)
用機車 6018 元	您在上下學途中，騎機車產生污染造成的民眾的健康損失為 177 元
用腳踏車 917 元	並製造相當於在單人房開冷氣 101 小時所產生的二氧化碳
用腳踏車保留機車 5649 元	
意外傷害 (每年)	時間比較 (單程上下學時間)
您用機車上下學會比用腳踏車多 1.07 天的生命機能喪失	用機車 7.0 分 用腳踏車 7.4 分

• 看完以上提供的數據後，現在這四個方面的資訊對您選擇上下學交通工具的重要程度為...

	非常重要	重要	差不多	不重要	毫不重要
金錢開銷資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
環境、健康損害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
意外傷害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
時間比較	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 4-10 Layout of questionnaire software (Importance level of factors on deciding commuting mode after receiving customized data)

4.3 Survey plan

The goal of this survey is to communicate environmental (local and global), social (safety), economical (internal and external cost), and time usage information in comprehensive way, and thus psychological aspects that are highly connected to students' commuting manners could be identify and analyzed.

The crucial obstruction of statistical surveys is the limited patience of respondents. When content of a questionnaire raises beyond one's tolerance, response rate will tend to drop down and data collected will become less reliable. Since maintaining positive attitude of respondents and communicating information effectively is crucial for the research, we decide to apply computer-assisted personal interview (CAPI) in our survey together with graphical data presentation.

The survey adopts random sampling. For getting unbiased sample that could represent the mother body, we select the library of NCKU as the survey spot. Binding by limited time and budge constraint, we took 175 effective samples. According to the statistic formula (Box 4-1) for minimum samples needed, the error is within 7.4% at 95% confidential level.

Box 4-1 calculation of minimum samples needed for survey

$$n = \frac{Z^2 \times \sigma(1 - \sigma)}{e^2} \quad Z=1.96 \quad \sigma=0.5$$

Each information page provides corresponding interpretation to briefly explain what it means and how it was calculated. Therefore inquirer does not need to explain while respondent answering questions, thus it reduces the interference to respondents.

Chapter 5 Result

5.1 Effectiveness of information conveying

We got total 175 effective respondents by personal interview during May to June in year 2005. With our unique questionnaire interface, 90.3% response rate is reached. (Box 5-1)

Box 5-1 Statistics of the interactive survey

Total effective samples: 175

Response rate: 90.3%

Male/female ratio of respondents: 90/85

Grade of respondents:	Freshman	33
	Sophomore	27
	Junior	44
	Senior	38
	Graduate	33

Rate of respondents who live in school dormitory: 32.0%

About the general knowledge about commuting, we found out 56.0% of students do not know that Taiwan has highest motorcycle density in the world. 43.3% of respondents do not aware that NCKU students who commute by motorcycle suffer higher accident rate than those commute by bicycle. And, merely 18.9% of respondents have the idea of how far a motorcycle could travel by 1 liter of gasoline.

And from Fig. 5-1 we can also understand the awareness of the environmental issue on motorcycle. 72% and 45% of students consider motorcycle result in serious problem on air and noise pollution respectively. While providing preferable environment suits for research and study is one of the key concerns to raise competitiveness of university, there should be enough motives for school administrator to consider policies aims at motorcycle issues.

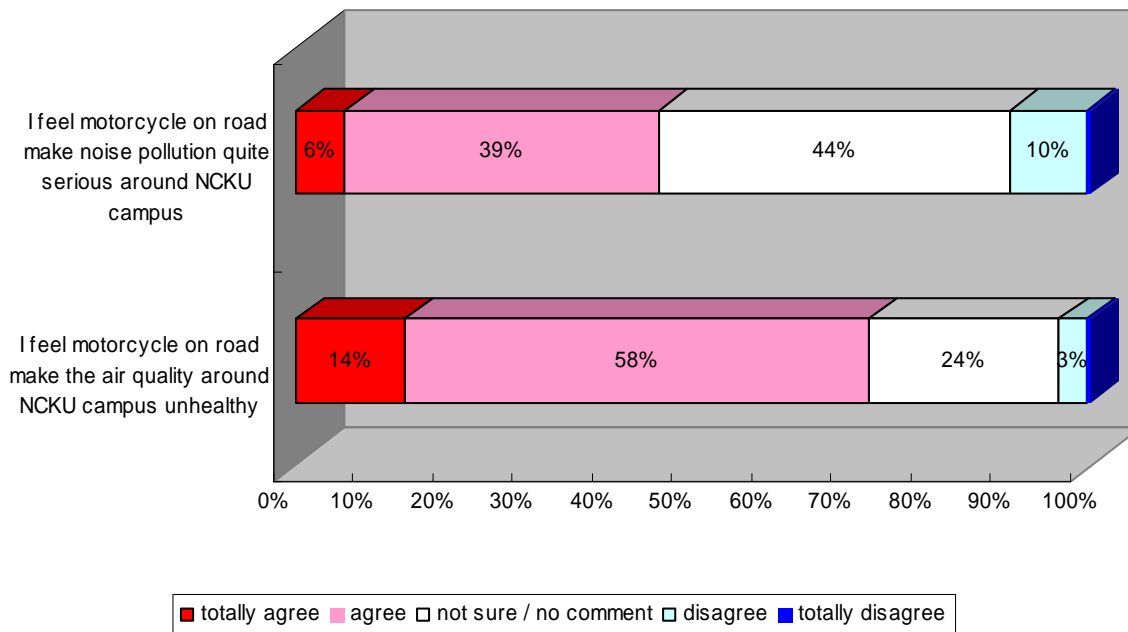


Fig. 5-1 Awareness of the environmental issue of students

Box 5-2 shows average time usage for respondents travel from their dormitory to school. Motorcycle commuting students on average travel 1.92 times (3.45km) longer distance than bicycle commuting students, that is, if motorcycle commuting students shift to commute by bicycle, they might need 16.1 minutes traveling from home time. Khisty.C.J. and Kolbuszewski made a survey on the maximum tolerance on travel distance for both pedestrian and bicycle user, and develop an equation to describe maximum acceptable travel distance (Box 5-3). Basing on the equation the maximum acceptable travel distance for bicycle user would be 9.7 kilometers (equivalent travel time is 45.2 minute). However, looking at the travel time distribution pattern (Fig. 5-2), we can find only 5% of bicycle commuting students travel more than 15 minutes. This reveals the general time constraint of NCKU students in choosing commuting modes.

**Box 5-2 Average travel time usage
for respondents traveling from their dormitory to school**

Average single-way time usage for students commute by bicycle 8.4 minutes
(with 95% confidence level, error within 1.5 minute)

→ estimate travel distance: 1.80km

Average single-way time usage for students commute by motorcycle 10.8 minutes
(with 95% confidence level, error within 1.5 minute)

→ (estimate travel distance: 3.45km)

Average “walk through” time for students commute by motorcycle 2.2 minutes
(with 95% confidence level, error within 0.3 minute)

Average single-way time usage for students commute by walking 7.6minutes
(with 95% confidence level, error within 2.7 minute)

→ (estimate travel distance: 0.57km)

Box 5-3 Maximum acceptable travel distance for bicycle user and pedestrian

$$d = 0.22V^{1.48}$$

d: maxim acceptable travel distance

v: travel speed

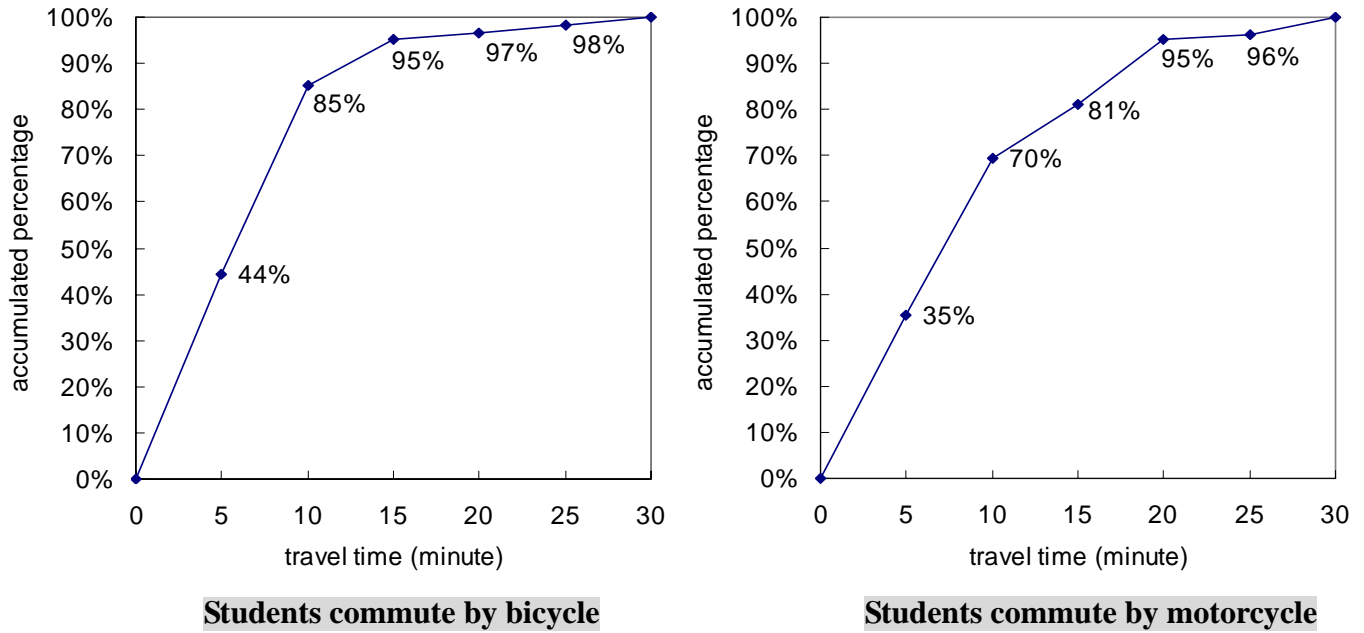


Fig. 5-2 Accumulated percentage of respondents versus single-way travel time from home to school

With the available travel time data, overall travel distance pattern of NCKU students can also be done by simple conversion. (Fig 5-3) Note that the critical difference between motorcycle and bicycle user emerges at 2.5 kilometer travel distance, where 85% of bicycle user travel less than 2.5 kilometer but only 39% motorcycle user travel less than the distance.

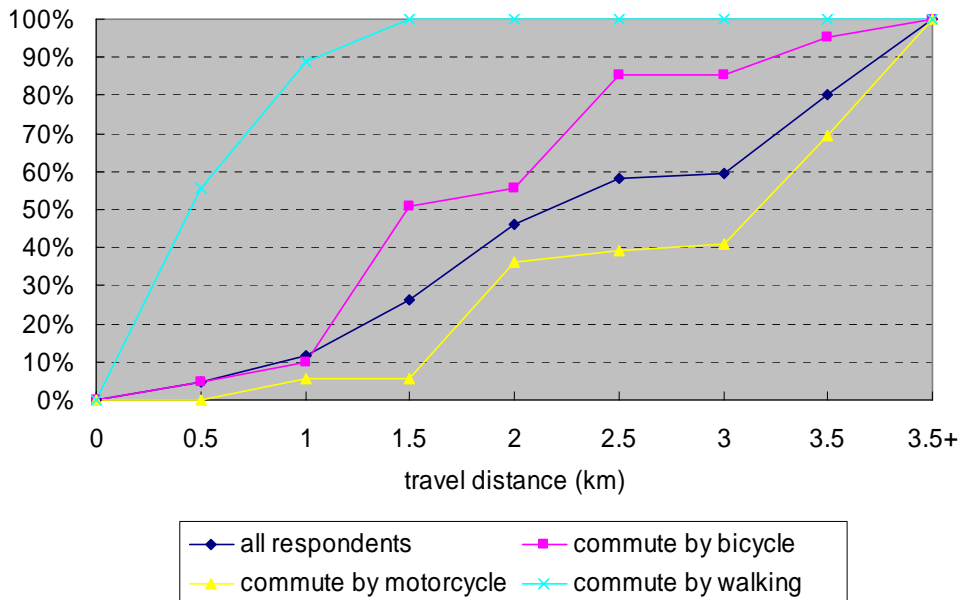


Fig. 5-3 Travel distance pattern of NCKU student

Only 28.6% of students who live in school dormitory use motorcycle for commuting, whereas 74.8% of student who do not live in school dormitory use motorcycle for commuting. And 75% (12/16) of those students who live in dormitory and commute by motorcycle totally agree to adopt substitute commuting mode after responded our questionnaire. The rate is higher than those who not live in school dormitory (56.2%, 50/89). And of all 105 students who use motorcycle for commuting, 44.8% of them also owns bicycle in Tainan city.

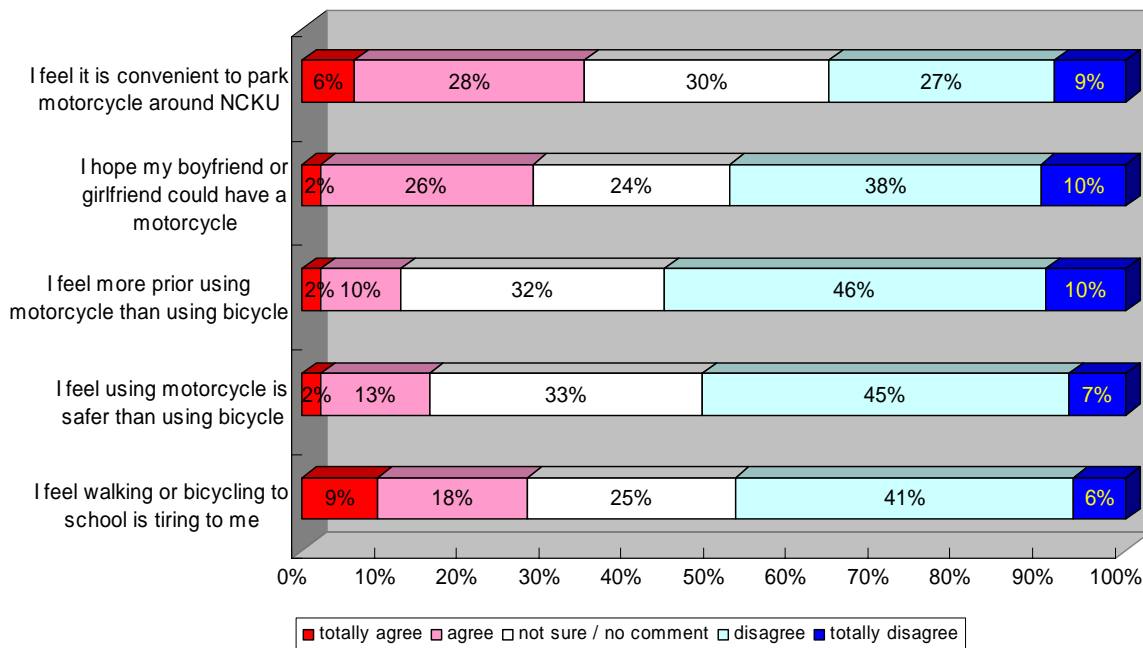


Fig. 5-4 Respondents' attitude on daily commuting behavior

Respondents' attitude on daily commuting behavior was shown in Fig. 5-4. Those attitudes had been measured before we provided them their customized commuting information. Since only 12% of students feel more prior using motorcycle than bicycle, the previous assumption that most students would consider motorcycle is a necessary item showing superior self-esteem might not be correct. Only 52% of respondents consider using motorcycle is not safer than motorcycle. The rate is lower for motorcycle commuting students (42.8%). Nevertheless, our previous research already proved bicycle is by far safer than motorcycle in downtown commuting. That is, without providing statistical data, about half of students didn't not aware the notable higher risk of using motorcycle.

About the importance level of factors (time, accident, health/environment, expense) on deciding commuting modes, Fig. 5-5 and Fig. 5-6 show our survey result respectively before/after the respondents received their customized data. If we deem the combination of level of “very important” and “important” represent the “influential degree”, than it’s interesting that the order of “influential degree” on the four aspects is accident, time, environmental/health, and expense. However, after respondents received customized commuting information, Health/Environment aspect become most influential, and tailed by accident, expense, and time.

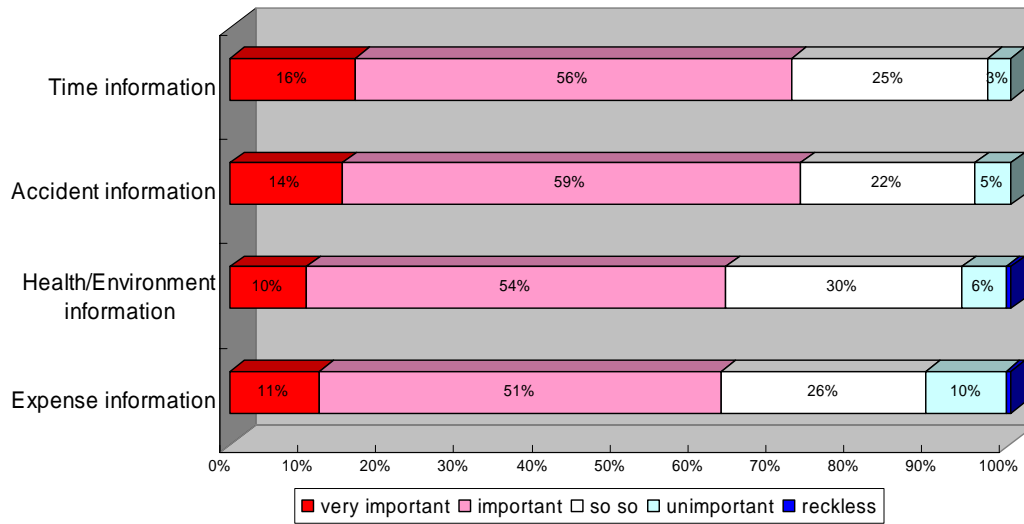


Fig. 5-5 Importance level of factors on deciding commuting mode (before receiving customized commuting information)

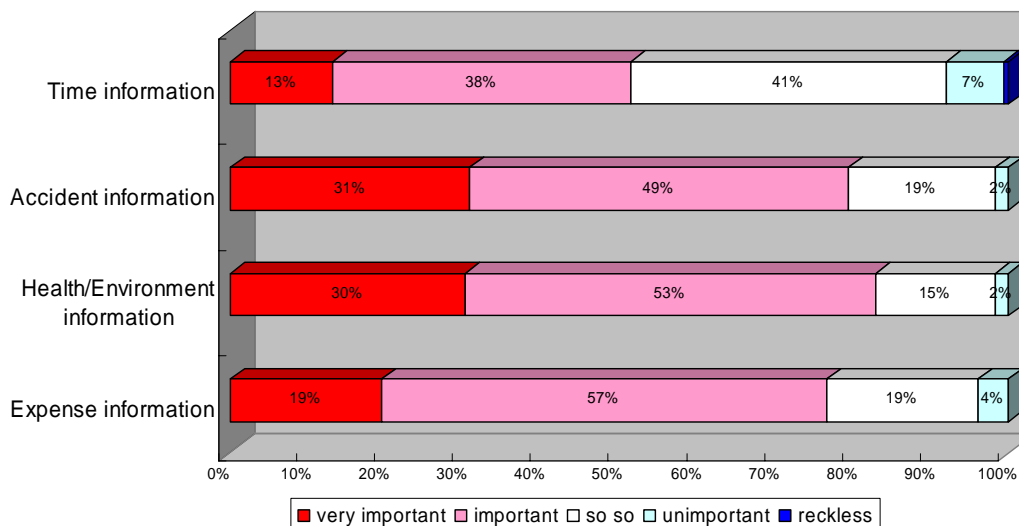


Fig. 5-6 Importance level of factors on deciding commuting mode (after receiving customized commuting information)

We can clearly compare the respondents' attitude shift before/after receiving customized data by Fig. 5-7. Over 40% of students raised their importance concern (red area) on Health/Environment aspect, whereas, only 14% of respondents raised their importance concern on travel time aspect. Moreover, 33% of respondents lower their importance concern (blue area) on travel time aspect. The might owing to students not really had done comparative test on travel time but just gauge it by their subjective impression. In this case, they can't make a full assessment including the impact of traffic jam and "walk through" time which limited the speed gained from motorcycle. And since 80% of respondents travel less than 3.5 kilometers in a single-way trip to school, travel time difference between motorcycle and bicycle become less significant. This could explain why students lowered their importance concern on time aspect after receiving our customized information.

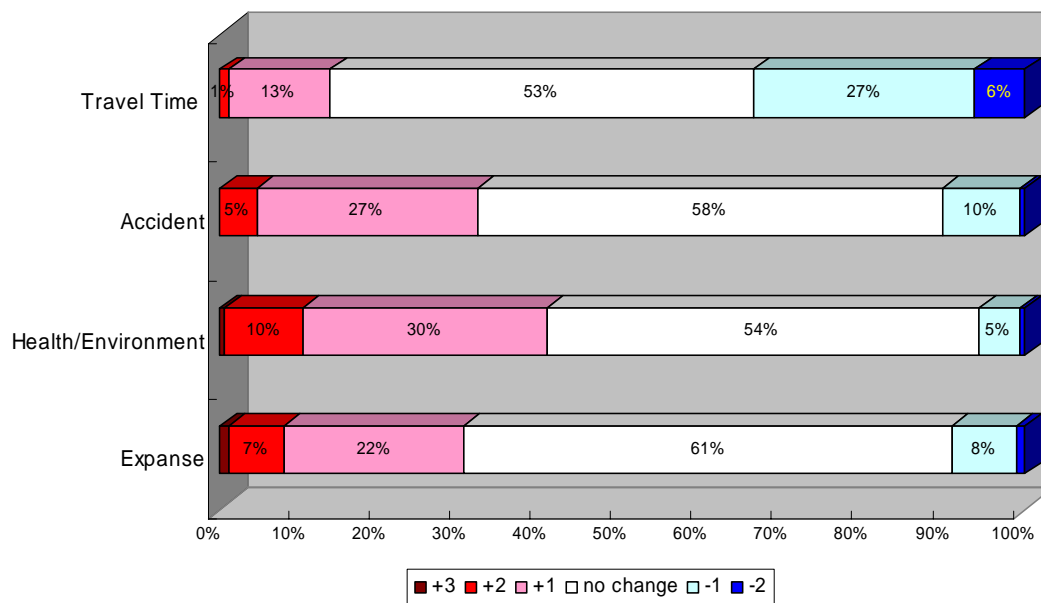


Fig. 5-7 Attitude shift of the importance level on choosing commuting mode

Obviously, even students raise their concern of the health/environment and accident aspects, none can conclude that this will direct contribute to higher motive to use other sustainable commuting modes. With those questions on the willingness of adopting more sustainable commuting mode before/after receiving customized information, it is possible to observe the "effectiveness of information conveying". Fig. 5-8 and Fig. 5-9 use a comprehensive way to represent this issue, namely "Greenness shift pattern". For motorcycle commuting students, the raise of willingness level to "alternate to adopt sustainable commuting mode or use sustainable commuting mode more frequently" that

is presented as green color with different color saturation in Fig. 5-9. As we can see, 52.4% of the respondents increased their intensity level of willingness to adopt sustainable commuting mode. And Fig. 5-10 shows that additional 27.6 % (95% confidence level ranges from 28.6% to 26.6%) of motorcycle commuting students agree to alternate to adopt sustainable commuting mode or use sustainable commuting mode more frequently after they received customized commuting information.

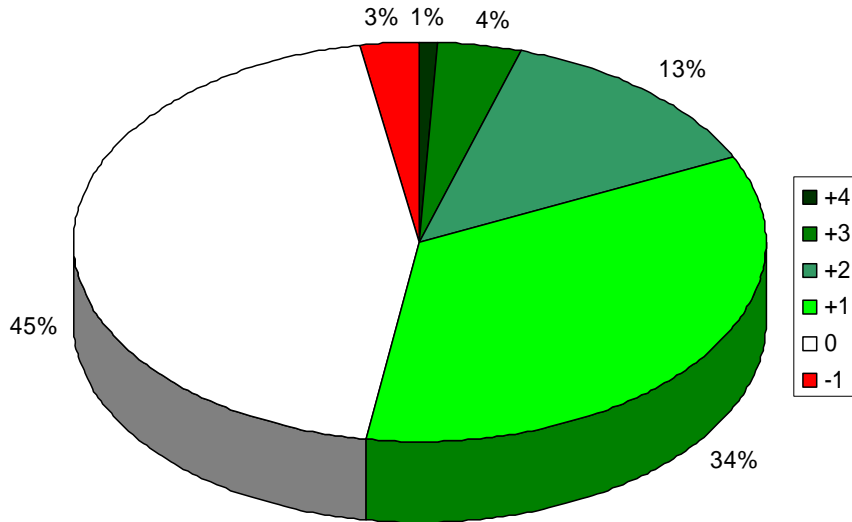


Fig. 5-8 “Greenness shift pattern” of motorcycle commuting students

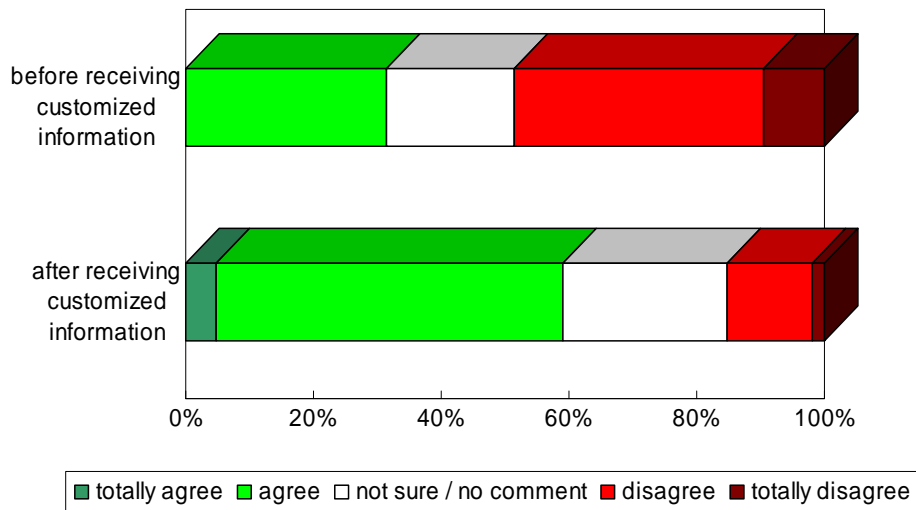


Fig. 5-9 Distribution of the answer of attitude scale on the question “I would consider to use bicycle, bus or walking for commuting” for motorcycle commuting students

Fig. 5-10 presents the data with the similar way as Fig. 5-9. For bicycle commuting students, the decrease of willingness level to “substitute to use motorcycle for commuting” is presented as green color. However, 75% of bicycle commuting did not change their attitude here. It seems like the information we presented to bicycle commuting students are not as effective as to motorcycle commuting students. From Fig. 5-11 we can find customized information barely have effect to make bicycle commuting students not to use motorcycle in the future. The phenomena might due to the rate of their “greenness” (rate of disagree and totally disagree to use motorcycle before graduate) already high (44%) originally comparing to motorcycle commuting students (31%).

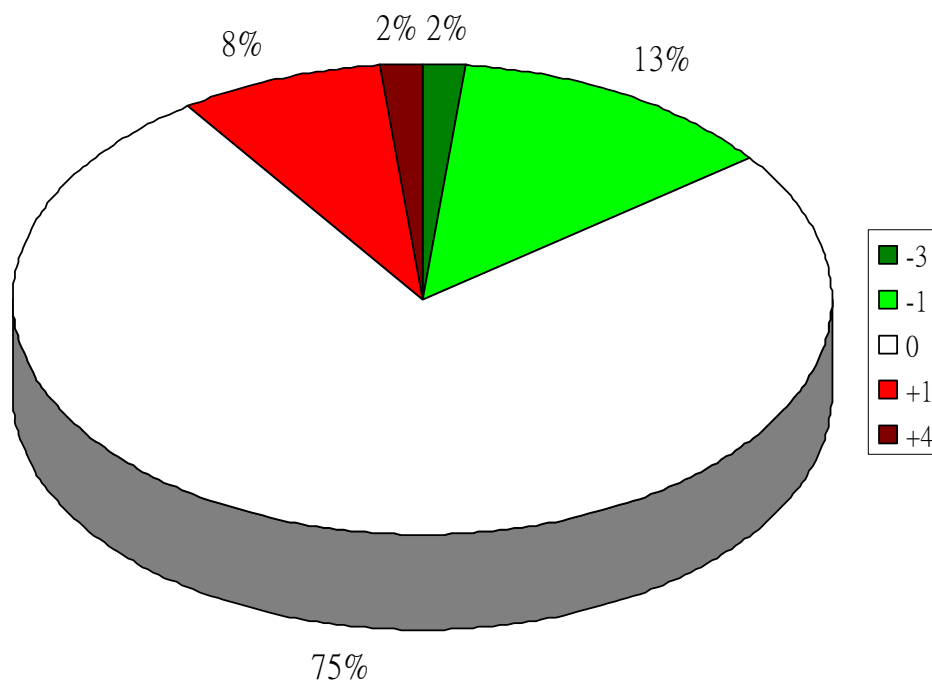


Fig. 5-10 “Greenness shift pattern” of bicycle commuting students

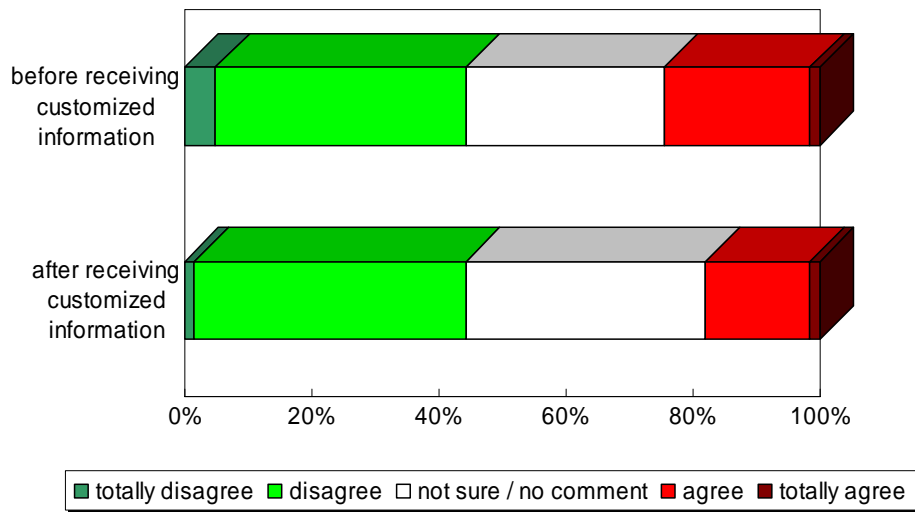


Fig. 5-11 Distribution of the answer of attitude scale on the question “I would consider to substitute to using motorcycle for commuting before graduate from NCKU” for bicycle commuting students



It's also intriguing to know the "greenness shift pattern" of different student status. Fig. 5-12 presents greenness pattern of all student grades. The difference between each status is not significant at all, though the biggest difference is lie between freshman and graduate student. The percentage of students who raise their willingness to use non-motorized commuting after receiving customized information in freshman group is 27.5% (18.0%~37.1% with 95% confidence level) higher than graduate student group.

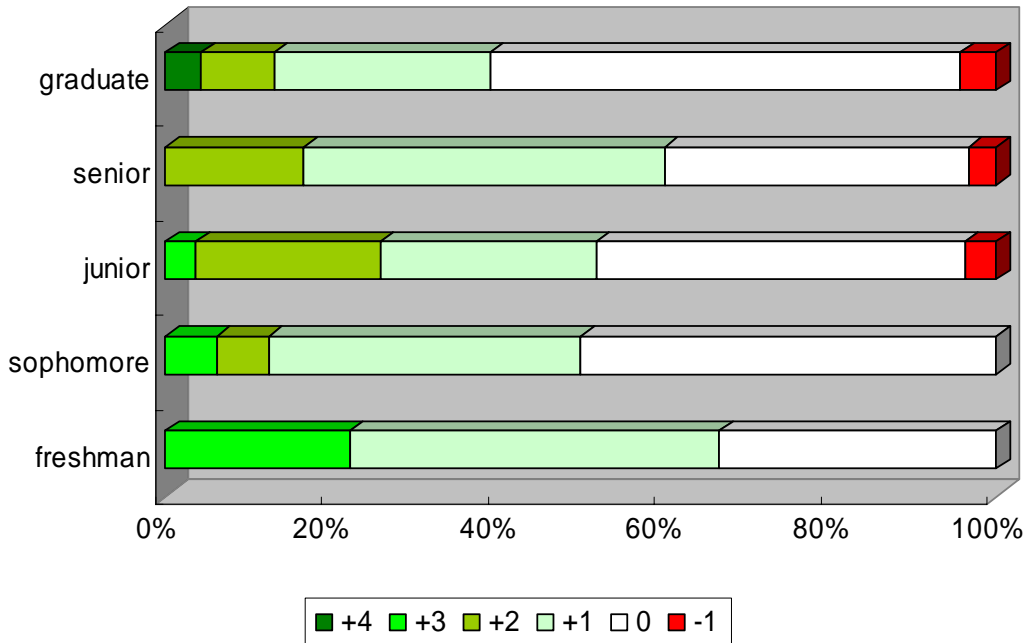


Fig. 5-12 Greenness shift pattern of students in different student status (for motorcycle commuting students)

5.2 Expected benefit of inducing students toward sustainable commuting mode

5.2.1 CO₂ reduction, pollution reduction, DALYs, and fuel saving

Motorcycle commuting students travel average 10.84 minutes for a single-way trip from home to school. So we could calculate the projected negative impact (pollution and accident damage) of whole NCKU. (Box 5-4)

According to the method demonstrate in Box. 5-4, the motorcycle commuting students in NCKU derived about 1.687E+06 kilogram of carbon dioxide. The amount is equivalent to CO₂ emission from 2.56E+06 kW of electricity power generated from Taiwan. External cost of health damage from air pollution is 4.130E+06 NTD. And excessive DALYs loss comparing to commute by bicycle is 12485.6 days annually. That is equal to 34.2 life years.

In previous section, we already elucidate how much we have increased the students' willingness level to using bicycle for commuting in our interactive survey. Therefore, it's also possible to quantify the essential benefit from our study. We've let extra 27.6% of motorcycle commuting student intend to adopt sustainable commuting mode. If we assume the optimum situation could happen (those respondents actually do what they responded to do), the positive benefit could be derived from our survey is estimated in Box 5-5.

Box 5-4 Assessment of the impact of motorcycle commuting in NCKU (annually data)

CO₂ emission:

$$G = N * R * T / 60 * S * n * E * 365 = 1.687E+09 \text{ (gram)} = 1.687E+06 \text{ (kg)}$$

G: CO₂ emission from NCKU students' commuting (gram)

N: Number of NCKU students (17600 up to year 2005)

R: Rate of motorcycle commuting students (66.3%)

T: Average single-way travel time of motorcycle commuting students (10.84 minute)

n: Number of trips per day (2)

S: Average motorcycle travel speed around NCKU (19.14 km/h)

E: CO₂ emission per kilometer traveled by motorcycle (57.18 gram)

External cost of health damage from air pollution:

$$H = N * R * C * T / 60 * S * n * 365 = 4.130E+06 \text{ (NTD)}$$

H: External cost of health damage from air pollution calculated by LIME system (NTD)

C: External cost of health damage per kilometer motorcycle travel (0.14)

Excessive DALYs loss (comparing to commute by bicycle):

$$D = N * R * (d_1 - d_2) = 12485.6 \text{ (days)}$$

D = Excessive DALYs loss comparing to commute by bicycle (day)

d₁ = average per person DALYs loss due to downtown traffic accident
(For motorcycle commuting student)

d₂ = average per person DALYs loss due to downtown traffic accident
(For bicycle commuting student)

Fuel useage

$$F = N * R * T / 60 * S * n / M * 365 = 8.65E+07 \text{ (liters)}$$

F = gasoline used per year (liter)

M = mileage data of motorcycle (34.09 km per kilometer travel)

Box 5-5 Benefit from our interactive survey (annually data)

If the extra 28% of motorcycle commuting student intend to adopt sustainable commuting mode really shift their commuting mode...

CO₂ reduction:

$$G_r = N * R * T / 60 * S * n * E * 365 = 4.192E+06 \text{ (gram)} = 4192 \text{ (kg)}$$

G_r : Reduction of CO₂ emission from NCKU students' commuting (gram)

N = number of respondents commute by motorcycle (105)

R : Rate of extra motorcycle commuting student intend to adopt sustainable commuting mode (27.6%)

T : Average single-way travel time of motorcycle commuting students (10.84 minute)

n : Number of trips per day (2)

S : Average motorcycle travel speed around NCKU (19.14 km/h)

E : CO₂ emission per kilometer traveled by motorcycle (57.18 gram)

External cost of health damage from air pollution:

$$H_r = N * R * C * T / 60 * S * n * 365 = 10264 \text{ (NTD)}$$

H_r : Reduction of external cost of health damage from air pollution calculated by LIME system (NTD)

C : External cost of health damage per kilometer motorcycle travel (0.14NTD)

Excessive DALYs loss (comparing to commute by bicycle):

$$D_r = N * R * (d_1 - d_2) = 31.03 \text{ (days)}$$

D_r = Reduction of excessive DALYs loss comparing to commute by bicycle

d_1 = average per person DALYs loss due to downtown traffic accident (1.35 days)
(for motorcycle commuting student)

d_2 = average per person DALYs loss due to downtown traffic accident (0.28 day)
(For bicycle commuting student)

5.2.2 Net time usage comparison

Although motorcycle commuting students suffer higher DALYs loss from traffic accident, some might argue that those students can get compensated by shorter travel time due to higher travel speed. By doing net time usage comparison we can verify if this plausible viewpoint true or not. From Box 5-6, we found commuting by motorcycle saves more time than the life time loss (DALYs) due to traffic accident comparing to commuting by bicycle. Nevertheless, the life time loss due to accident is mean by injure or death, which is consider far more painful than cycling. Not to mention that cycling is usually taken as a kind of exercise and is proved to be beneficial for health. (reference???) Therefore, it's kind of assertive to judge bicycle commuting is inferior in time usage aspect.

Box 5-6 Net time comparison between commuting modes (annually data)

$$T_r = (T * S / S_b - W - T) * n * 365 = 2249.3 \text{ (minute)} = 1.56 \text{ (days)}$$

T_r : Average travel time saved per year comparing to commute by bicycle for motorcycle commuting students in NCKU

T : Average single-way travel time of motorcycle commuting students (10.84 minute)

S : Average motorcycle travel speed around NCKU (19.14 km/h)

S_b : Average motorcycle travel speed around NCKU (12.89 km/h)

W : Average "Walk Through" time for motorcycle commuting students (2.2 minutes)

n : Number of trips per day (2)

Since the gain of reduction of DALYs loss from motorcycle to bicycle is 1.07 days per year, commute by motorcycle is superior in net time comparison than bicycle.

5.3 Scenario Analysis

5.3.1 Apply the information conveyance to whole university

While we have already clarified the negative aspects of motorcycle using and known how many percentage students shifted their attitude after they had responded our interactive survey, our concern how much impact could achieved by broaden the scope of our communication strategy. Assume 27.6% curtailment of motorcycle commuting students in our survey group could be projected to whole NCKU. That means to reduce 4.656E+05 kilograms of CO₂ emission, 1.14E+06 NTD on external health damage cost, and 9.44 years of DALYs loss due to traffic accident.

5.3.2 Apply charge of parking fee

Consider the noise, the pollution, the excessive traffic accidents, and the illegal occupation of sidewalk resulted from motorcycle, it's not justifiable to let user exempt the duty of externality. At the present situation, NCKU administration only charges the parking fee for basement parking space. But the charge is not imperative and most students can still park their motorcycle elsewhere.

Parking motorcycle is not charged in roads and most parking lots around NCKU. In our survey, all respondents who commute by motorcycle were asked their critical amount of parking fee. Fig. 5-13 shows the relation curve on imperative parking charge versus motorcycle commuting rate. Since the objective of charging parking fee itself is to induce student using non-motorized transportation and to rectify the externality. What we seek is a effective charge without overly aggravating students economic burden. From the information shown in Fig. 5-13, we analyze the benefit from charging parking fee at three different level (5, 10, 20 NTD per day) and present the result in in Fig. 5-14.

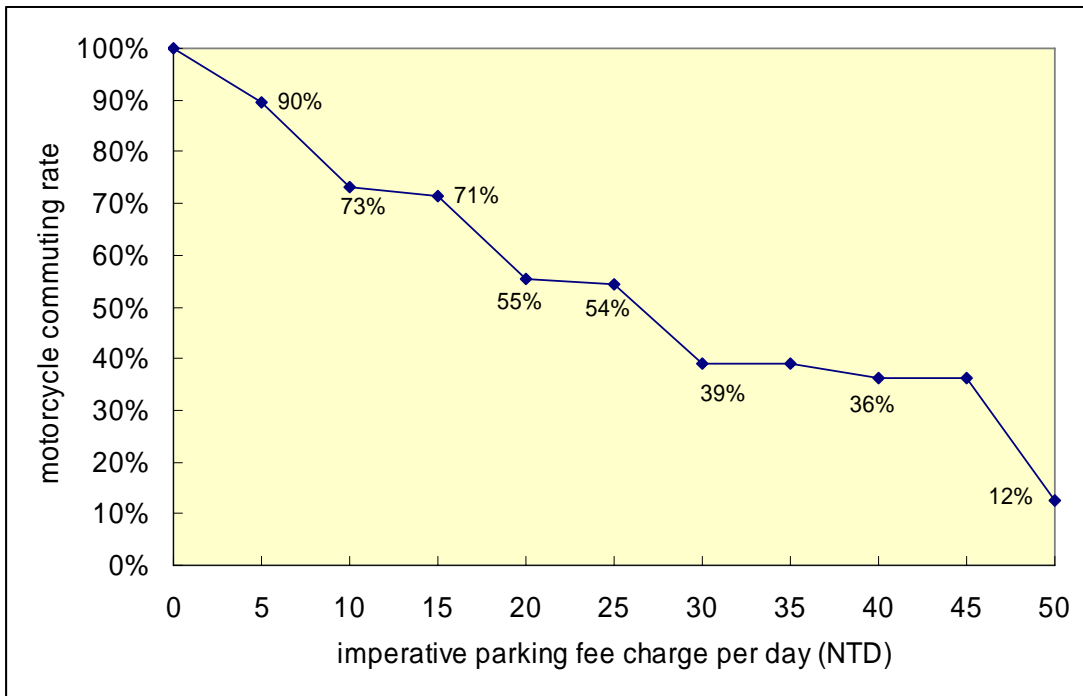


Fig. 5-13 Imperative parking charge versus motorcycle commuting rate (For motorcycle commuting students)

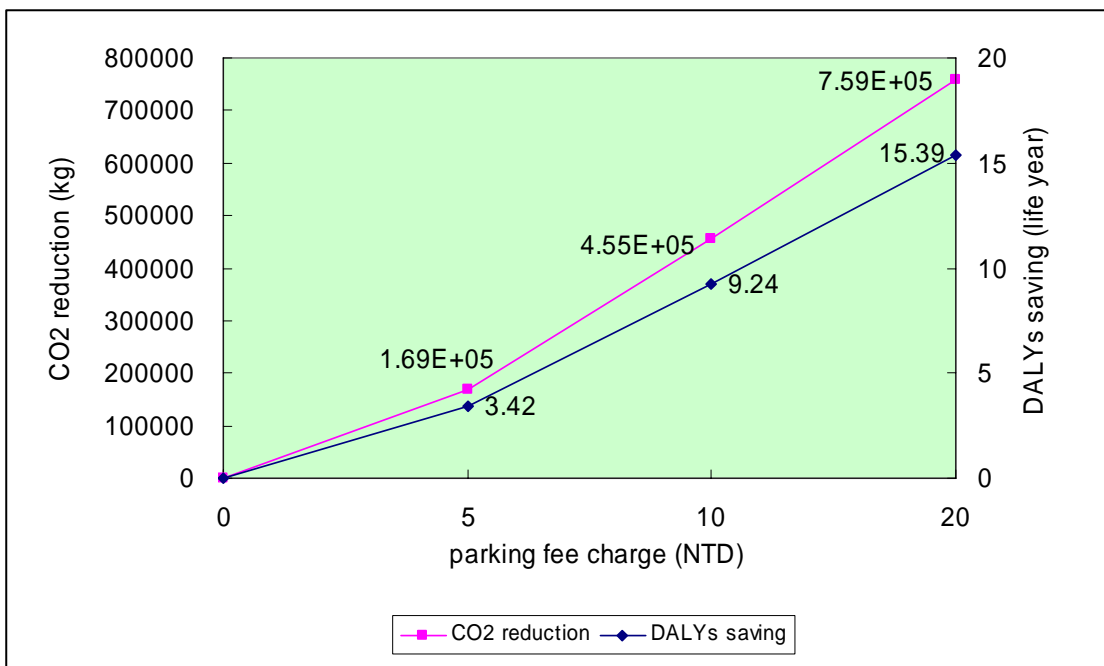


Fig. 5-14 Benefit from charging parking fee

However, because only 30.9% of respondents agree school to charge parking fee for restrain motorcycle commuting. Policy without sufficient general comprehension and consensus often turn out to be fail.

5.3.3 Build student dormitory around university

For those students live in NCKU school dormitory, only 28.6% commute by motorcycle, the rate ratio is much lower than average (66.3%). On the other side, students who do not live in school dormitory have 74.8% motorcycle commuting rate.

So far there are 32% of students live in school dormitory. If it were possible for administration of NCKU to build more school dormitory near the campus, benefit from reduction of motorcycle using can be expected. Once NCKU increases 10% of student lodging rate, $(0.1) \times (0.748 - 0.286) = 4.62\%$ of total students will possibly give up commuting by motorcycle. This means $0.0462 / 0.663 = 7.0\%$ net negative effect (including CO₂ emission, air pollution, and DALYs loss) derived from motorcycle commuting of NCKU is reduced.

As well as higher non-motorized commuting rate, those lodging students who commute by motorcycle even has higher willingness (75%) to use non-motorized commuting modes after receiving customized information comparing to while sampling body (59%). If NCKU can increase 10% lodging rate and in the mean time present customized information to those new lodging student students, in optimum situation, the reduction of net negative effect will rise up to $\{0.1 \times [0.748 - 0.286 \times (1 - 0.75)]\} / 0.663 = 10.2\%$. Fig. 5-15 take CO₂ reduction and DALYs saving for instance to demonstrate the benefit from increase student lodging rate.

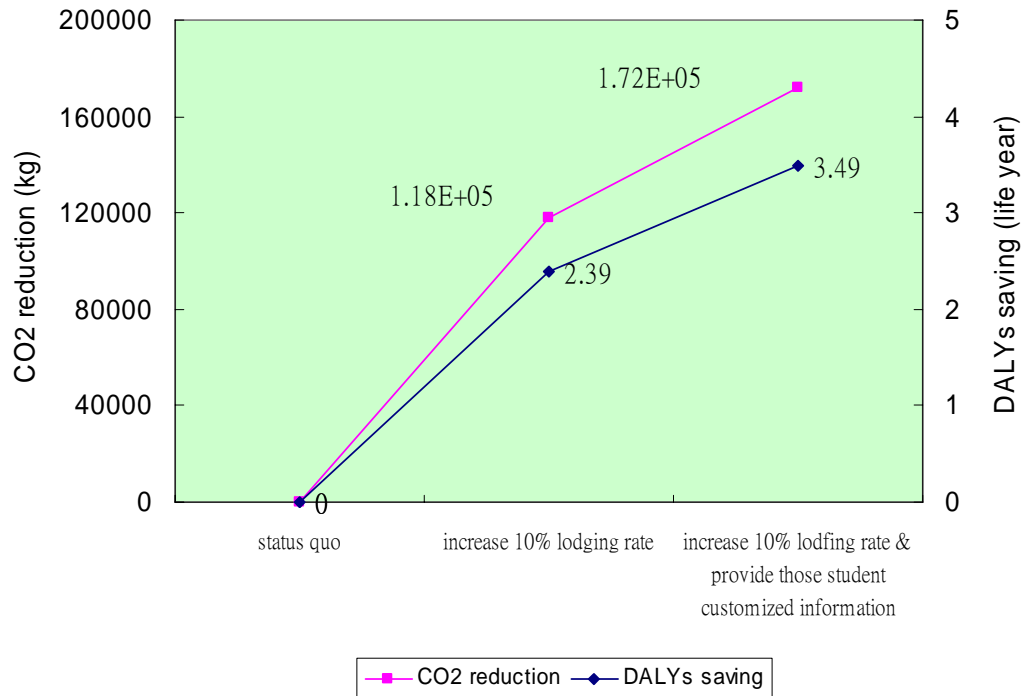


Fig. 5-15 Benefit from increase student lodging rate

However, every 10% of lodging rate increase requires building capable of 1760 students. Construct new dormitory is unavoidable consuming both energy and material, and, bring on CO₂ emission. Without full stage life cycle assessment being done, it's hard to conclude the benefit over constructing dormitory is overwhelmingly a preferable policy.

Chapter 6 Conclusion

In the study, we have clarified and quantified the negative impact of motorcycle commuting. And by the interactive survey, we effectively communicate full assessment on choosing commuting modes. 52.4% of the motorcycle commuting students increased their intensity level of willingness to adopt sustainable commuting mode (bicycle and walking) and, 27.6 % of motorcycle commuting students agree to alternate to adopt sustainable commuting mode or use sustainable commuting mode more frequently after they received customized commuting information on consequences of their choices. This communication could potentially reduce 4.656E+05 kilograms of CO₂ emission, 1.14E+06 NTD on external health damage cost, and 9.44 year of DALYs loss due to traffic accident if we can apply our communication method to all NCKU students, assuming their willingness completely results in their behavior change. Looking at the survey result presented above, “the power of information” is prominent and noticeable.

We can observe the priority shift of students in the four aspects (time, safety, health/environment, expense) on choosing commuting mode. This result implies either people tend to make decision on commuting mode choices without analytical assessment on advantages and disadvantages of different commuting modes or their evaluation tends to underestimate negative aspects, or some aspects we have communicated were not referred when they first made their decisions. Combinations of those reasons could be the reality.

On the other hand, for achieving friendly environment for sustainable commuting, school administration could set up favorable policies for students who would like to adopt non-motorized commuting mode. Survey result shows reduction of motorcycle commuting rate could be achieved by for example building more students dormitory, charge imperative parking fee, or providing customized information to students. The latest solution could be put into practice without much investment or resulting repulsion from students. And since the customized information is most effective to freshman and most ineffective to graduate students, it's recommendable that school administration could propose a project enable every new-coming student to use similar interactive information system in their computer class.

Despite the possible benefit from our interactive survey methodology, we should note that the results from this study could involve bias that could lead to overly optimized result. Although it is not necessary to give advice to the respondents, our CAPI survey method is inevitably requires inquirer to supervise respondent sometimes in order to ensure respondent to operate the computer program correctly. Consequently, respondents might consider to answer those questions not based on their preference but not to “disappoint” inquirer. Moreover, there always exists a gap between people’s recognition and practice. For clarifying the actual impact of the information, survey more in depth tracing on respondents behavior change is necessary.

To prepare an adequate set of information in an adequate form is also the key component of our communication structure. Of all the sustainable indicator/evaluation system, researcher and policy maker need to find out most suitable one. The information for applying to general public should qualify the following three terms: 1.easily Communicable with effective media, 2.Comprehensive meaning for respondents to recognize without difficulty, and 3.Correlative to respondent’s daily life behavior in order to let people assess by themselves. It’s difficult to change people’s daily life behavior which they have already accommodated. But information valid in the “3C” conditions should at least enable people to reconsider their behavior but not just leave the “nomenclature like” sustainable issues behind their mind.

Interactive communication for sustainability may not only work in transportation issues but also contains potential for applying to other sustainable lifestyle initiatives. We suggest for different daily life behaviors, providing relevant information that can arouse people’s association on their safe guard objects. Our case study demonstrate a methodology on how to construct a interactive communication structure which can induce people to reconsider shifting their current behavior to more sustainable way.

Appendix

Appendix 1: Questionnaire form of pioneering survey

您好，本問卷為環境工程所「永續性資訊對公眾教育與行為模式之影響－台南市短距交通個案分析」研究參考所需。您的個人資料與回答將完全保密，不對外公開。謝謝您的協助與合作。

- 請問您的系級？
- 請問您是否擁有機車？
- 請問您平常上下學使用的交通工具為何？
- 請根據您過去一年，在台南市使用該交通工具時，所發生的交通意外次數

與情形填寫以下表格（是：打 O 否：打 X）

	使用交通工具	是否發生在台南市區	您的主要受傷部位、類別(如擦傷、骨折、腦震盪、內傷...)	意外中受傷人數	痊癒時間(天)	車輛修理費用	是否通報學校教官室
第1次							
第2次							
第3次							
第4次							
第5次							

Appendix 2 Screenshot of CAPI interactive survey software

問卷調查 - Microsoft Internet Explorer

請問您上下學通常使用何種交通工具？

機車 腳踏車 步行 其他

您目前在台南擁有那些交通工具？(可複選)

機車 腳踏車 其他

請問您的年級是？

大一 大二 大三 大四 研究所



下一頁

問卷調查 - Microsoft Internet Explorer

您的機車排氣量？ 50 51~125 126~150 150以上

以機車從您目前的住處，前往上課處
約需花費幾分鐘的行駛時間
(不含停車) 分鐘

從您平常停車的地點，走到上課地點
平均需要幾分鐘？
(不含進入建築物後的上下樓時間) 分

下一頁

問卷調查 - Microsoft Internet Explorer

請根據您自身的想法，選擇您對下列觀點的同意程度


	非常同意	同意	差不多	不同意	非常不同意
我使用機車的原因 是因為比起腳踏車或走路， 可以省下很多上下學交通時間	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得用腳踏車或走路來上下學很累	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
使用機車的金錢開銷對我造成負擔	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得使用機車比起騎腳踏車或步行更有優越感	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我使用機車是為了方便和異性朋友共乘車	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

問卷調查 - Microsoft Internet Explorer

	非常同意	同意	差不多	不同意	非常不同意
我擁有機車是為了方便假日出外旅遊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得使用機車比騎腳踏車更安全	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得校區周邊機車停車很方便	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得道路上的機車造成學校周邊的空氣品質不佳	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我覺得校區周邊機車所造成的噪音污染很嚴重	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

問卷調查 - Microsoft Internet Explorer

	非常同意	同意	差不多	不同意	非常不同意
我同意學校提出管制政策(例：提高停車費)來鼓勵學生利用腳踏車、步行、大眾運輸上學	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我偶爾會使用步行、腳踏車或大眾運輸工具來上下學	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我會考慮在畢業之前改用步行、腳踏車或大眾運輸工具來上下學	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



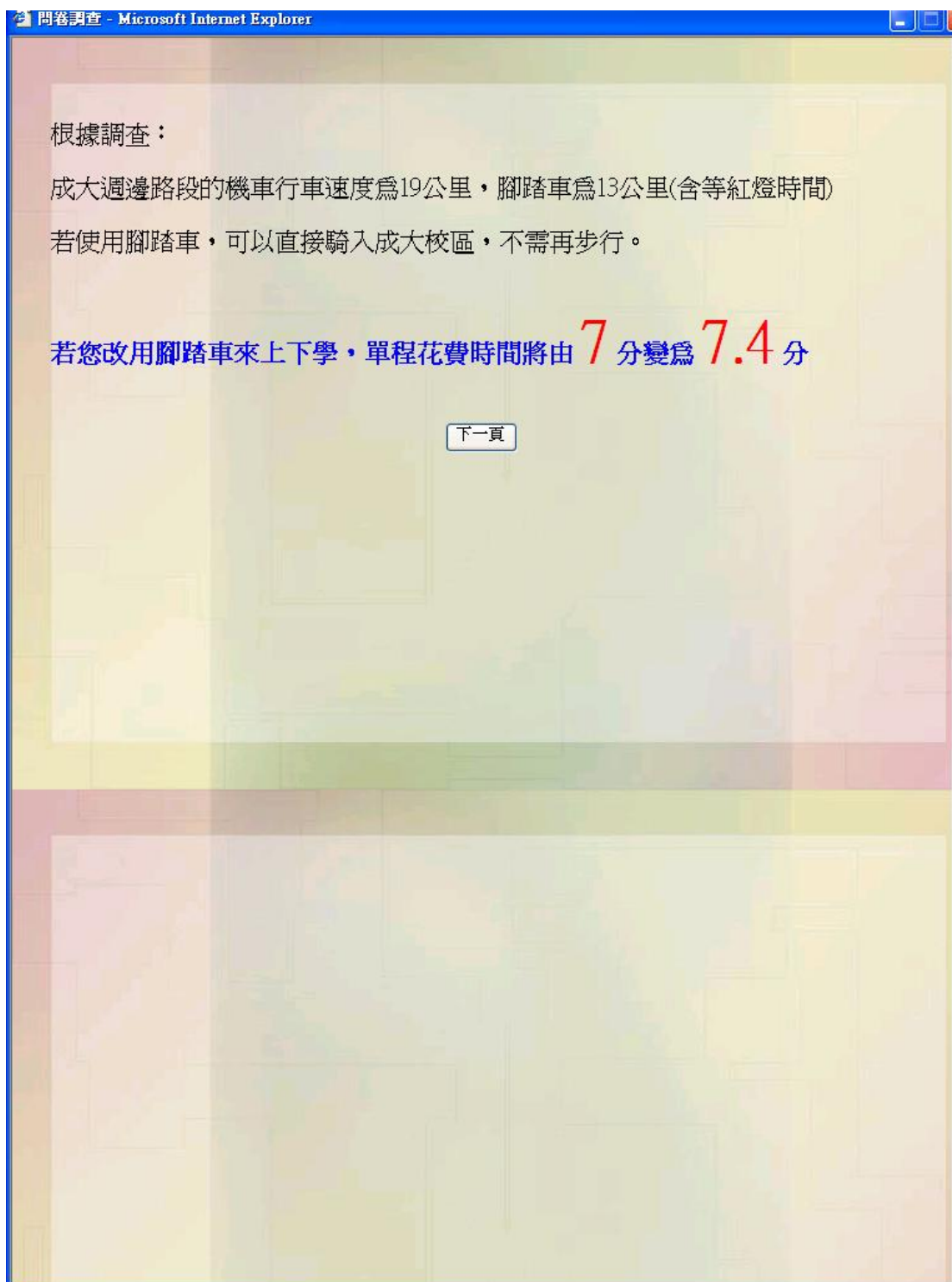
問卷調查 - Microsoft Internet Explorer

如果學校對校區週邊的機車停車位(含地面、地下停車場)全面收費，
當**每天**要額外付出的**停車費**達 元時，我會改用其他替代交通方式

問卷調查 - Microsoft Internet Explorer

在你選擇上學交通方式的過程中，下列資訊對您的重要程度為…

	非常重要	重要	差不多	不重要	毫不重要
交通工具的使用開銷資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
交通工具的環境、健康損害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
交通工具的意外傷害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
交通工具的時間、速度資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



問卷調查 - Microsoft Internet Explorer

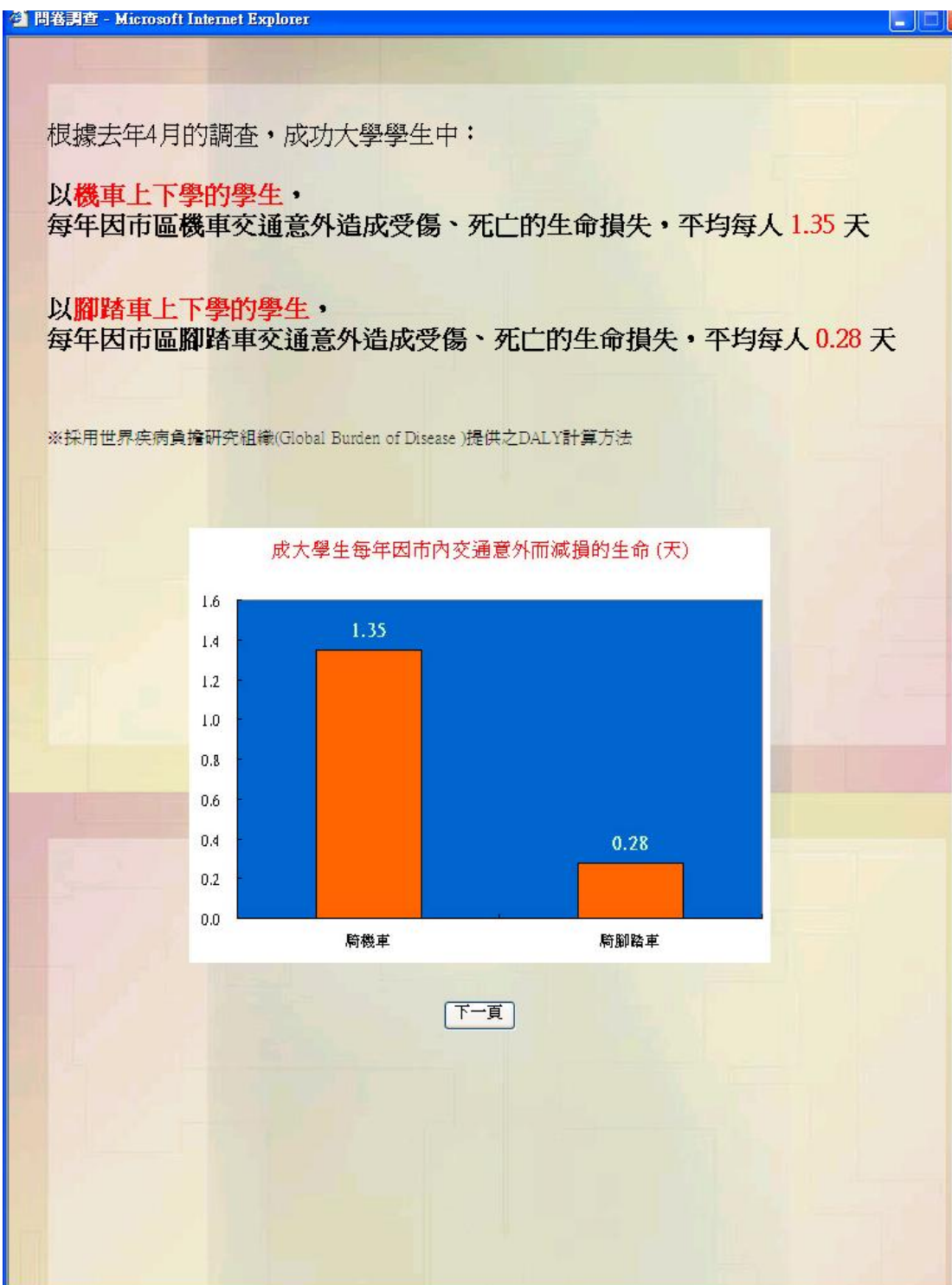
根據調查：

成大週邊路段的機車行車速度為19公里，腳踏車為13公里(含等紅燈時間)

若使用腳踏車，可以直接騎入成大校區，不需再步行。

若您改用腳踏車來上下學，單程花費時間將由 **7** 分變為 **7.4** 分

下一頁





問卷調查 - Microsoft Internet Explorer

您每年在上下學途中，騎機車產生空氣污染

造成公眾健康的損害為 **177** 元

(以日本LIME環境衝擊評估資料庫計算)

同時，您上下學騎機車所製造的二氧化碳

相當於在單人房連續開冷氣 **101** 小時，耗電產生的二氧化碳

(二氧化碳排放是造成全球暖化、氣候變遷的主要原因之一)

下一頁

問卷調查 - Microsoft Internet Explorer

<p>金錢開銷 (每年)</p> <p>用機車 6018 元</p> <p>用腳踏車 917 元</p> <p>用腳踏車保留機車 5649 元</p>	<p>環境、健康損害(每年)</p> <p>您在上下學途中，騎機車產生污染造成的民眾的健康損失為 177元</p> <p>並製造相當於在單人房開冷氣 101小時所產生的二氧化碳</p>
<p>意外傷害 (每年)</p> <p>您用機車上下學會比用腳踏車多1.07天的生命機能喪失</p>	<p>時間比較 (單程上下學時間)</p> <p>用機車 7.0 分</p> <p>用腳踏車 7.4 分</p>

• 看完以上提供的數據後，
現在 這四個方面的資訊
對您選擇上下學交通工具的重要程度為…

	非常 重要	重要	差不多	不重要	毫不 重要
金錢開銷資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
環境、健康損害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
意外傷害資訊	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
時間比較	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

問卷調查 - Microsoft Internet Explorer

請根據您現在自身的想法，選擇您對下列觀點的同意程度

	非常同意	同意	差不多	不同意	非常不同意
我能理解以上提供的資訊所代表的意義	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
我會考慮在畢業之前改用步行或腳踏車通勤 (或增加步行、騎腳踏車的頻率)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>



問卷調查 - Microsoft Internet Explorer

我會把以上得到的資訊向朋友分享，鼓勵他們改用腳踏車或步行來上下學

非常同意 同意 差不多 不同意 非常不同意