出國報告（出國類別：進修）

系統性探討環境與動機等因素對公共運輸運具選擇之影響

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目錄

第1章　緣起

1.1 研究緣起

因為氣候變遷所造成潛在災難衝擊，激烈的氣候變化已受到國際高度的關注。國際氣候變化委員會得出的結論認為，氣候變化幾乎可以肯定是人為的，石化燃料燃燒的碳排放量為主要元兇之一。為了減少碳排放，促進符合土地利用和交通規劃公共交通的使用已成為政策制定者緩解氣候變遷的重要策略。

公共交通服務是工作、教育、休閒及出行的關鍵交通工具，特別是針對那些沒有車或不能開車、低收入家庭、身心障礙人士、學生或老年人。公共交通也是降低量依賴的重要替代工具，對於車輛使用的依賴，已造成許多城市的交通擁堵及空氣品質不佳的問題。在許多情況下，公共交通均是處於財務虧損的營運狀況，而有許多研究提出，改善以公車為基礎的公共交通，相較於投資於軌道公共交通，是一個更具成本效益和靈活的選擇。

要構建良好的公共運輸服務需要先分析的是哪些關鍵因素影響交通工具的選擇行為。以往研究運具選擇行為的因素包括：社會人口特徵(socio-demographic characteristics)、公共交通提供和服務屬性(public transport provision and service attributes)、建築環境(built environment)、適宜步行（walkability）、態度和意圖(attitudes and intentions)。

個人的運具選擇行為可以由個人的能力(capability)、動機(motivation)及機會(opportunity)（外在條件）共同決定的。能力是指個體的心理和生理能力，使用公共交通工具。機遇是指所有外在的條件影響公共交通選擇的因素，如土地使用，公共交通供給和步行環境等個體之外的因素。動機是指那些大腦的過程，以動機和引導使用公共交通工具，如個人的態度，使用公共交通工具的社會壓力，使用公共交通工具的困難度的看法。

許多研究都集中在北美地區、西歐及澳洲地區作為個案研究基地；然而，只有少數的研究報告對東南亞國家的公共交通的使用。Nijkamp 和 Pepping（1998 年），研究顯示不同的研究地區顯著的影響了研究的結果。因為在東南亞的交工條件是那些在西方世界的許多地方顯著不同，這表明從這些方面的研究的結果可能並不適用於東南亞國家。

東南亞城市的特點是高密度，土地混合使用，以快速機動化。在亞洲大陸的人口密度是每平方公里 135 人(2012 年);這是近五倍於整個歐洲人口密度（每平方公里 32 人），約 10 倍於北美的人口密度(每平方公里 16 人，2012 年)。聯合國預測，在 2025 年 38 個 Mega-city(人口數大於 1000 萬人)中有 22 個預計將存在於亞太地區。此外，到 2050 年，城市化在東南亞的平均水平有望從目前的低水平上升到接近美國和歐洲水平（分別為

目前 89%和 82%）。例如:中國的都市化預計從 2011 年的 51%上升 2050 年的至 77%。該報告還預計，到 2050 年，亞洲人口將上升到超過 50 億，或佔全球近 55%的人口比例。由於這種快速的城市化和機動化，亞洲城市已經面臨著-the paradox of intensification 的現象:增加城市密度可能會導致平均車輛行駛里程降低及促進公共交通與步行的使用，但另一方面，環境條件也可能因為交通的過度擁塞與繁忙的而變得更糟。

機車擁有和高比例使用是東南亞國家的另一個重要特徵。機車在一些東南亞國家的公路交通方面佔有非常重要的功能。例如，在台灣，馬來西亞，泰國，印度尼西亞和越南等國家，機車市佔率大於 50%。騎機車很容易從事單人、短距離及多目的之旅次。在機車研究方面，以往大多數研究都關注安全問題，而較少研究機車和公眾的出行運具選擇。更少的研究在於納入都市個性、公共運輸服務屬性、動機和態度。因此，有需要進行更多此類研究，探索社會人口特徵、建築環境、公共交通的服務屬性及態度與動機等對東南亞國家的出行運具選擇行為影響。本研究以台灣為基地，探索複雜因素包括汽車，機車和公車之間的運具選擇的生理和心理方面的問題。這項研究不僅為台灣公共交通的發展，而且也為其他東南亞國家的一些有用的信息。

1.2 研究問題

本研究採用全國 2011 方式選擇行為調查，土地利用數據和其他有關國家的統計數據。此外，本研究進行了兩項調查，定量調查部分主要在於了解民眾使用公共交通之動機及對於步行環境之認知；定性訪談部分則針對公路公共運輸發展計畫的政策執行部分進行訪談。本研究之研究問題如下：

研究問題 1：探討公共政策執行因素對於公共運輸使用之影響。

研究目標

1. 探討哪些公共政策執行的影響因素。
2. 探討公共運輸政策執行對於公共運輸使用之影響計畫的主要目標尚未實現的原因。
3. 提出公路公共運輸發展計畫(公路公共運輸提升計畫)未來推動之建議。

研究問題 2：考量個體的社經背景因素後，了解土地利用的因素，在不同的地理範圍對於運具選擇行為。

研究目標

1. 探討土地利用的因素在對運具選擇行為的影響程度，並納入不同地理範圍的影響。

2. 探討在旅次起點和終點的土地利用因素對於出行運具選擇行為的影響。

研究問題 3：探討個人的主觀與客觀步行環境評價之間的關係及對於步行行為的影響。

研究目標：

1. 客觀的步行環境因素對於感知的步行環境因素的影響程度;
2. 主觀步行環境因素影響對整體步行感受及步行行為的影響。

研究問題 4：探討心理層面因素，包括能力（Capability），機會(Opportunity)和動機(Motivation)對運具選擇行為的影響。

研究目標：

1. 探討潛在的動機因素之間的關係：對於環保關心(Pro-environment value)、態度(Attitudes)、主觀規範(Subjective norms)，感知道德義務（Perceived moral obligation, PMO）和感知行為控制（Perceived behaviour control, PBC），以及它們對意圖使用公共運輸(Intentions to use public transport)之間的互動影響關係;
2. 探討能力(capability)及機會(opportunity)的因素對於動機(motivation)的影響;
3. 探討能力(capability)、機會(opportunity)和動機(motivation)對交通出行運具選擇的影響。

1.3 章節架構

本報告共計 7 章，第 2 章探討公路公共運輸發展計畫(2010-2012)及公路公共運輸提升計畫(2013-2016)執行面之課題，第 3 章探討土地使用對於運具選擇行為之影響，第 4 章探討客觀及主觀步行環境衡量因素對於步行行為的影響，第 5 章探討心理層面因素對於運具選擇行為之影響，第 6 章綜整過去四年來參加國際研討會及歐洲主要城市觀摩考察，第 7 章提出本報告之結論與建議。

另囿於報告撰寫時間因素，本報告第 3 章及第 5 章中文內容未盡流暢，故將該 2 章報告之英文內容置於附錄 1 及附錄 2 以供參閱。

第2章　影響公路公共運輸發展計畫政策執行因素分析

2.1 引言

公共運輸服務是工作、教育、休閒和出行的命脈，對那些不開車、不能開車、低收入家庭、殘疾人士、學生或老年人更是不可或缺。公共運輸也是用來探討都市擁擠、空氣品質和車輛使用依賴性的重要工具。在許多情況下，公共運輸均是處於財務虧損的營運狀況。許多研究已顯示，提高以公車為主的公共運輸比鐵路投資更靈活、更具成本效益。

在台灣，公共運輸特別是公車，和私人運具（汽車和摩托車）相比，已經逐漸喪失競爭優勢。公車乘客從 1991 年 16.38 億人，到 2009 年已下降至 10.38 億人左右，降幅約 37%（圖 2.1），導致 2009 年公共運輸的市場佔有率僅有 13.4%。同期，汽車和摩托車持有率則從 1991 年每千人 140 輛和 368 輛，穩步上升至 2009 年每千人 247 輛和 632 輛（圖 2.1）。

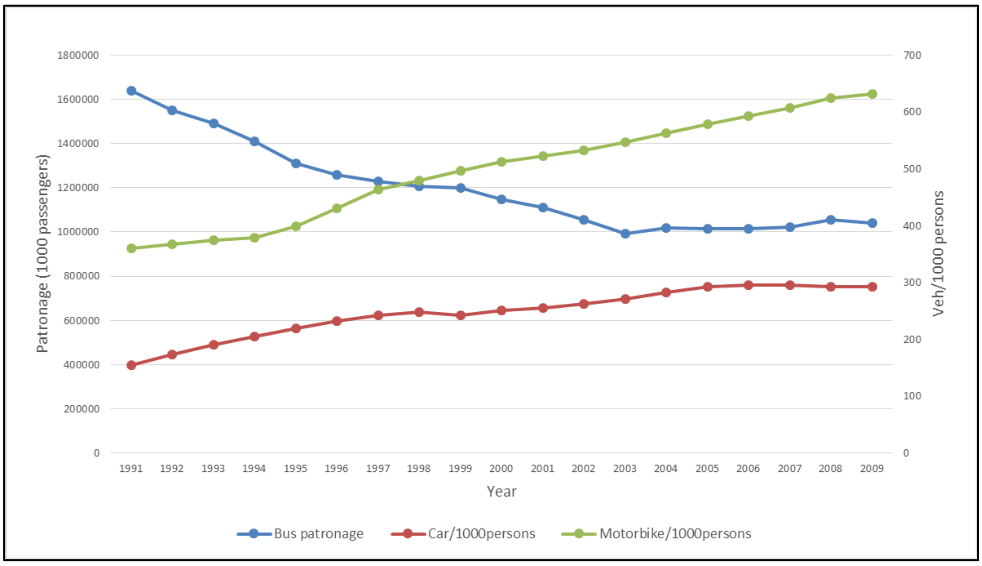


圖 2.1 公車載客人次和私人運具持有率（至 2009 年）

公共運輸載客量和市場佔有率下降以及私人運具使用率增加，已經造成嚴重交通和環境問題。道路運輸二氧化碳排放量從 1991 年 19.8 百萬公噸增加到 2009 年的 32.70 百萬公噸，增幅約 44%，其中約 86%係來自於私人運具。

2010 年，交通部提出「公路公共運輸發展計畫 (2010-2012)」及「公路公共運輸提升計畫(2013-2016)」（NRPTP），引導民眾改變運具使用習慣以期增加公路公共運輸載客量。NRPTP 設置了兩個關鍵目標：公路公共運輸載客量每年成長 5%； 2016 年公共運輸市場佔有率達 18%，中期 2020 年提升至 20%，並以 2025 年提升至 30%作為長期目標。

6 年來，施行成果不如預期（見表 2.1），只有 2010 年也就是 NRPTP 實施的第一年達成公路公共運輸載客量每年成長 5%的目標，隨後四年載客量每年遞減，2011 年僅成長 4.91％，至 2014 年僅成長 1.57，到 2015 年載客量甚至呈現負成長。

2009 年到 2014 年間公共運輸市場佔有率穩步增長，但每年增長幅度不到 1％（表 2.1），至 2014 年臺灣地區公共運輸市占率已達 16％，也因此，2015~2016 這 2 年，市占率能再提升 2％的可能性相當低。

表 2.1 公路公共運輸載客量和公共運輸市場佔有率變化趨勢

	Bus patronage (1000 passengers)	% of bus patronage increase	Bus market share (%)	Public transport market share (%)
2009	1,038,779	--	8.1	13.4
2010	1,109,829	6.84	8.2	13.9
2011	1,164,297	4.91	8.2	14.3
2012	1,191,741	2.36	9.0	15.0
2013	1,220,056	2.38	8.6	15.2
2014	1,239,178	1.57	8.6	16.0
2015	1,220,590	-1.50	N/A	N/A

本文主要目的是找出 NRPTP 所訂定的公路公共運輸載客量每年成長 5%，以及公共運輸市場佔有率達 18%的目標無法實現的關鍵因素？本篇論文採質性研究方法來探討分析 NRPTP 這 6 年政策的執行。

2.2 政策實施影響因素

政策執行的研究重點在探究政府政策規劃與執行結果之間的差距，它是一項將政策付諸實施的傳遞過程。Sabatier and Mazmanian 指出「執行係將一項基本政策決定予以貫徹」。政策執行是影響政策成功與否的關鍵性角色，它可以被視為目標制定和執行之間互動的過程，也就是當政策制定後，匯集執行所需要的各種資源，去達成既定的目標。政策決策無法從政策執行分離出來，同樣，沒有適當的政策執行設計，政策也無法完成。因此，政策的貫徹執行是影響政策能否成功的重要因素。

目前在政策執行的文獻中已歸納出三大課題：執行途徑、影響結果的因素，以及所有利害關係人和他們之間的重要關係。茲分述如下。

2.2.1 執行方法

政策執行研究途徑主要包括三種：一為「由上而下」執行途徑 top-down approaches（又稱「向前推進的策略」forward mapping），二為「由下而上」執行途徑 bottom-up approaches （又稱「由後推進的策略」backward mapping），三為「整合型」執行途徑（synthesis approaches）。

「由上而下」執行途徑多由中央政府或政策決策者開始啟動，政策執行是上令下行、層級結構的指揮命令系統，強調法規的制定和中央政府的指揮與監督。

「由下而上」執行途徑與「由上而下」執行途徑恰好相反，強調決策的分散與下放、靈活性與自由裁量權，以及執行過程中基層人員的意見。政策的制定者與執行者之間界線並不明確，策略推動者為基層人員並以其所認知的目標、策略與利害關係人為基礎，基層官僚由政策執行者轉變為政策制定者。

以上兩種執行途徑都面臨一些批評。「由上而下」執行途徑忽略基層官僚的知識專長並欠缺多樣性，「由下而上」執行途徑則過分重視基層人員，缺乏問責架構，耗費冗長的時間與成本去型塑問題、評估效果、取得共識。

「整合型」執行途徑結合由上而下執行途徑與由下而上執行途徑。對於政策目標衝突性高，或者採取的行動策略與其執行成效不確定性高的政策，採取「由上而下」執行途徑難以有效管控，採取「由下而上」執行途徑風險太高亦無法聚焦，那麼，「整合型」執行途徑將是一個解決方案，如何精確組合由上而下和由下而上執行途徑將取決於政策設計者希望如何處理潛在的策略衝突和不確定性。

2.2.2 政策執行的因素

一些研究聲稱，執行結果是受政策目標、政策資源、組織溝通過程、執行機關的特性、經濟社會與政治條件、執行者和官僚對自由裁量權的態度..等影響。圖 2.2 總結了這些因素之間的關係，茲將各因素詳述如下：

- 政策標準和目標：政策目標是分析執行過程的起點。Pressman & Wildavsky 說：『沒有目標便無法評斷執行的成功或失敗』。對政策執行而言，清晰、明確、擁有共識的政策目標是相當重要的。

- 政策資源：資金或其他動機措施，資源投入不足將難以達到預期的政策目標。

- 組織間的溝通和行為：與該政策有關的組織間和組織內各單位不同程度的承諾和協調。傳統認為，組織之間對政策達成共識有助於政策執行成功。

- 執行機關的特性：政策執行機關正式與非正式特性。Van Meter & Van Horn 認為這些特性包括執行機關人員的知識、技能和人數多寡，執行機構層級控制程度等。

- 經濟社會與政治條件：包括輿論、社經支持和政治條件。

- 執行者的態度：包括負責執行政策者的意向和利益。經驗顯示，組織中的關鍵人物對改革的成敗具有舉足輕重的影響力。執行者的態度受政策資源、經濟社會與政治條件、組織間的溝通和行為、以及執行機構的特性所影響。

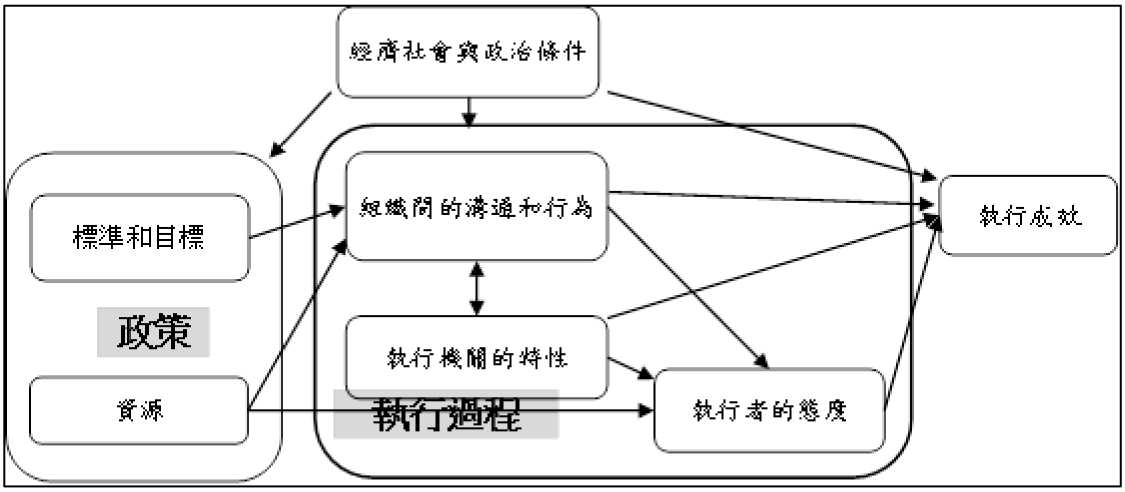


圖 2.2 政策執行模式

2.2.3 利害關係人(stakeholders)

在政策執行文獻中第三個重要議題為與執行機關相關之內部及外部利害關係人的參與，了解利害關係人及其之間的關係是成功政策執行的關鍵因素。O'Toole Jr 將政府關係分為四種類型：政府間的縱向關係、政府間的橫向關係、政府和私營部門之間的監管關係以及承包關係。政府間的縱向關係指的是上下層級之間指揮與控制、法規遵從的程度。政府間的橫向關係是指政府各部門間合作關係的程度。監管關係是指政府通過法令，有權許可、監督、暫停或取消特定服務。承包關係的權利義務建立在政府和私營部門之間的合同。

2.2.4 交通政策的實施

目前已有一些探討交通政策執行情況的相關研究。Fraser, Dougill 指出，在決策過程早期階段，目標群體通過社區參與，能有效制訂永續發展的指標；Lutsey & Sperling & Schreurs 發現，就氣候變遷政策而言，分權管理的模式較佳；Lumsdon & Tolley & Gaffron 研究英國地方當局『參與中央步行和自行車騎乘政策』，亦強調地方政府的態度及承諾將影響政策執行的連貫與可持續性。May, Jopson 總結，有關城市土地可持續利用的決策要求相關研究，公眾的接受度、政治上的可接受性、資金壁壘、技術可行性是推動交通運輸政策執行成功或失敗的關鍵因素。綜言之，回顧以往對交通政策執行的研究，發現少有針對公路公共運輸發展政策之質性研究。

2.3 分析

總體而言，受訪者認為「公路公共運輸發展計畫」實施六年以來有兩項重大貢獻。首先，該政策的實施引發了一些地方政府對市區公車服務的重視；其次，該政策的實施

讓一般民眾和汽車客運業者相信公共運輸已成為台灣交通的主流政策。然而，政策執行上的一些問題也使得該政策無法達到其預期的目標。

2.3.1 政策目標的共識

大多數地方政府和汽車客運業者對公路公共運輸發展計畫的目標認識不夠全面、不夠清楚。

有些知道政策目標是提高公共運輸載客量，卻不知道預期的目標每年需成長多少；有些只能列舉出部分政策目標，如改善偏鄉公車服務、引進低地板公車、加快老車換新速度等。執行者對政策目標並未擁有共識，大多數地方政府不認為他們的公路公共運輸載客量每年可以成長 5%。受訪者提到，無法達成該目標最主要的原因是地方政府沒有自己的公路公共運輸計劃；一些地方當局也說，他們每年提出的公路公共運輸計畫並沒有評估本身的運輸需求也不管提出的方案能否增加載客量。

受訪者 LA1：公路公共運輸發展計畫的目標是改善偏鄉公車服務，引進低汙染公車......”

受訪者 LA6：公路公共運輸發展計畫的目標是補貼中央政府計畫書中特定類型的公共運輸項目...... 鼓勵地方政府將資源集中於公共運輸。

受訪者 LA2：公路公共運輸載客量每年成長 5%到目前為止並非我們的目標，我們（市政府）沒有地方交通政策和公共運輸規劃... 每年的地方公路公共運輸提案是隨意提出、沒有計劃或願景。

2.3.2 執行方法

受訪者認為，實施「由下而上」執行途徑能有效增加公車載客量。

多數受訪者表示，新闢公車路線、規劃快速公車、提供公車票價折扣、增加公車班次頻率等方案能有效增加公車載客量，由於這些方案皆需要深入了解當地公共運輸需求，採取「由下而上」執行途徑更能切合地方實際需要。這也顯示中央政府可能需要鬆綁公路公共運輸發展計畫，允許地方政府更彈性的執行公共運輸方案以提高公車乘客數。

受訪者 LA3：免費公車服務、公車路網調整、規劃幹線公車、新增快速公車路線皆能有效增加搭乘人數。

受訪者 LA4：應採用由下而上執行途徑，但中央政府對於計畫和成果必須善盡監督之責。

2.3.3 監督機制

一些擁有中央政府工作經驗的地方政府受訪者表示，重點是目前缺乏一個監督機制去檢查地方政府是否達成當年度預期目標，地方政府每年提出的年度公路公共運輸政策並未延續前一年的執行成果。

一些受訪者談到公路公共運輸發展計畫執行機制必須改變，建議應要求地方政府提交長期（三到四年）的公路公共運輸計畫並加強績效管理。計畫書應包括年度行動計劃和目標，若中央政府批准該計畫，將保證給予為期三到四年的補助，惟每年的執行成果將影響次一年之經費補助。中央政府每年必須查核地方政府是否達成該年度目標，若否，隔年補助可能會減少甚至暫時停止該計畫。

受訪者 LA3：目前的執行機制有一個很大的問題......如果改變執行機制，要求地方政府提出一個為期四年的方案且每年應有明確的計劃和目標，那麼中央政府即能追蹤執行成效。

2.3.4 執行機關的特性

基層官僚沒有足夠的能力和技術去規劃和執行地方年度公路公共運輸計畫被認為是執行公路公共運輸發展計畫(NRPTP)的主要障礙。

一些地方政府並無交通專責單位，這被視為導致運輸專業知識不足的原因；還有許多地方政府的承辦人員不足（只有一個或兩個），無法應付監管地方公車服務。

受訪者 LA6：......人手不足（只有一名承辦人員），執行公路公共運輸發展計畫(NRPTP) 受限於人力......

受訪者 AU2：......該縣缺乏提出計畫(年度公路公共運輸計畫)的能力，另一個縣市不願接受我們的幫助來擬定他們的計畫，因為他們缺乏人手去執行...

2.3.5 執行者的態度

一些受訪者表示，某些縣市政府對於提出地方年度公路公共運輸計畫的意願相當低，獲得 NRPTP 的預算補助意味政策執行者(基層官僚)的工作負擔將增加。

受訪者 LA6：......考慮到我們的執行能力，即便中央政府願意分配更多的預算給我們，我們也無法執行它（NRPTP 預算）。

受訪者 AU1：...... 只有一個承辦人員負責此項目（NRPTP）......不願做，所以計畫（地方年度公路公共運輸計畫）的品質很差。

2.3.6 首長承諾

缺乏首長對公路公共運輸的關注和承諾也成為一些地方政府執行 NRPTP 的阻礙。

NRPTP 經過六年的執行，雖然大部分地方首長已意識到發展地方公車服務的重要性，但是地方首長對 NRPTP 投入更多的資源（人力和財務）的承諾和支持還需要再提高。

一些受訪者建議，應對地方領導人（市長和地方交通運輸主管部門的主管）施加更大壓力，例如向大眾公布各個地方政府公共運輸服務評價，以期在公車服務上投入更多當地資源。

*受訪者 CG2：......譬如**縣......，並未重視公共運輸。*

受訪者 LA6：我們需要市長強有力的支撐，然後我們可以從我們的政府獲得更多的資源來推動公車服務......

受訪者 AU1：我們希望中央政府可以建立地方公共運輸指標，調查地方公共運輸發展，並將此列入每年城市居民幸福感的評估指標，給地方政府一些壓力。

2.3.7 資源

NRPTP 預算支出僵化與資源問題息息相關。

有關預算支出僵化可分為兩個部分來談，首先，中央政府的補助款要求地方提供一定的自有資金加以配合，對一些財務狀況不良的地方政府根本負擔不起。其次，在 NRPTP 預算中，資本支出和經常性開支的比例被限制為 2 比 1，這意味著經常性開支如票價折扣優惠，不能超過 NRPTP 總預算的三分之一。

受訪者 LA5：我請我們的縣政府提供資金補貼虧損公車路線，但縣政府沒有同意。

受訪者 LA3：...有需要放寬資本支出和經常性開支的比例限制。

2.4 結論和建議

1. 建議建立個利害關係人對於公路公共運輸發展計畫（公路公共運輸提升計畫）目標之共識。
2. 建議提升地方政府首長對於推動公共運輸之承諾，並提供足夠的資源予地方政府。
3. 公路公共運輸發展計畫（公路公共運輸提升計畫）之執行方式建議改變為地方政府應提出 4 年期之計畫爭取中央補助，中央應建立每年績效評估機制。若計劃通過，則中央政府承諾該 4 年期之補助預算，及監督地方政府之執行成效。
4. 建議於公路公共運輸發展計畫（公路公共運輸提升計畫）補助說明書建立明確列示計畫目標，並要求地方政府於提出計畫時提出明確之績效指標，該指標應與整體計劃目標建立連結性。
5. 建議中央給予地方政府充分之資源，尤其在於執行人力部分，以提升地方政府之執行態度。

There are six important conclusions from this study. Firstly, building a consensus on the NRPTP objectives among central government and local authorities should be an imperative task. Some local authorities not only did not clearly understand the NRPTP key objective of raising bus patronage numbers but also did not believe they can achieve the objective – raising bus patronage by 5% annually. Central government should improve intergovernmental communication with local authorities and bus companies to make sure that they all keep the objectives in mind and desire to achieve them.

Secondly, there is a need to study what works in terms of public transport provision, land use and psychological effects in switching private vehicle users to public transport. Local authorities' road public transport proposals should adapt to local land use and public transport development. A better understanding the effects of land use and public transport provision on travel mode choice behaviour provide information for local authorities to initiate road public transport proposal which is fitted to their needs.

Thirdly, mayoral commitment and provision of supporting resources to local transport authorities are critical for the NRPTP implementation. Evaluating local public transport services and disclosing the results to the public could be an approach to increase mayoral commitment to public transport.

Fourthly, the implementation mechanism should be reformed so that the local public transport proposal and bidding process is done once every four years and covers a four year period (for example 2017-2020). In addition, a performance monitoring mechanism should be built in. Once the 4-year proposal is approved, a 4-year subsidy should be simultaneously promised to the local authority. This can help local authorities to make longer-term public transport plans and would ensure continuity in consecutive years. In addition, the central government can then effectively monitor the progress of the NRPTP implementation.

Fifthly, the NRPTP guidance should clearly disclose the objectives of the NRPTP and ask local authorities to propose clear performance indicators which link to the NRPTP objectives. The content of NRPTP guidance now only describes how to initiate the annual local road public transport proposal and lists the projects included in the NRPTP subsidy. The NRPTP guidance may need to be revised to introduce the objectives of NRPTP, announce the criteria for approving local proposals, and require local authorities to set up performance indicators.

Finally, adequate and supporting resources for local authorities are important. Lack of manpower is the most frequent problem faced by local authorities, affecting the attitudes of the NRPTP implementers. There is a disparate capacity within local authorities to deal with transport business. Most of the high-density cities/counties have local transport authorities while most low-density cities/counties do not (see Table 2). DGH could allocate some of the NRPTP budget to help local authorities, especially those who do not have a local transport authority, to set up a local NRPTP implementation office by recruiting some transport expertise. Providing sufficient manpower to local authorities may improve their attitudes towards NRPTP implementation. In terms of subsidy, the match funding requirement and the spending limitation with regards to the ratio of capital expenditure to current expenditure should not be obstacles for NRPTP implementation. Central government should remove these obstacles and help local authorities to implement all the measures which can raise bus patronage.

第3章　土地使用對公共運輸使用之影響

本章探討研究問題 2，其目的是了解土地利用的因素，在不同的地理規模對運具選擇行為的影響。

本章採用多層次 MNL 分析土地使用對於運具選擇行為之影響。在對出行行為對運具選擇影響分析方面，個體的數據和分區的區域數據，如土地使用的影響的分析，總是有層級聚合結構或交叉聚合結構 (hierarchical clustering or cross-classified) 的特點。此外，如果考慮空間背景因素在旅次的起點和終點的作用，聚集的關係則成為交叉分類 (Cross-classified)。傳統的多項 Logit 模型忽略了集群內的變化，並可能導致較差的數據擬合。多層模型可容納空間自相關，空間異質性，更高層次的背景，以及個人的微觀和宏觀尺度的地方，同時處理。一些研究表明，多層次的建模方法滿足土地利用和出行行為的研究，而目前只有少數研究已採用多層級建模方法。因此，本章中使用多層次多項模型、多層次交叉分類模型來研究土地利用變量在鄉鎮市，對市/縣級的影響，並在旅行出發地和目的地的方式選擇行為。

3.1 Multilevel multinomial logit model

本章研究採用了 2 種多層次多項式 Logit（MNL）模型:包括簡單多層次 MNL (Multilevel multinomial logit) 模型和交叉分類 MNL (Multilevel cross-classified multinomial logit)模型分析了土地使用變量對運具選擇行為的影響。

第一個模型，我們預計有可能是個體之間的異質性，旅次起點 i 及迄點 j，這是純粹的聚集區之間。因此，一個三級的多層級多項式 logit 模型，用以捕獲聚集變異(cluster variations)(如圖 3.1)。

從圖 3.1 可以看出，社會人口特徵和交通相關的變量包括在個人層面。社會人口學特徵包括年齡，收入，汽車和機車駕照，家用汽車和機車的所有權。與出行相關的因素包括旅行費用和 OD 距離。在第二層級，鄉鎮市區部分，土地利用變量包括：人口密度、及業密度、混合土地利用熵，四路交叉口和死巷數量比例。在市/縣層級土地使用變量包括:密度和混和土地利用。

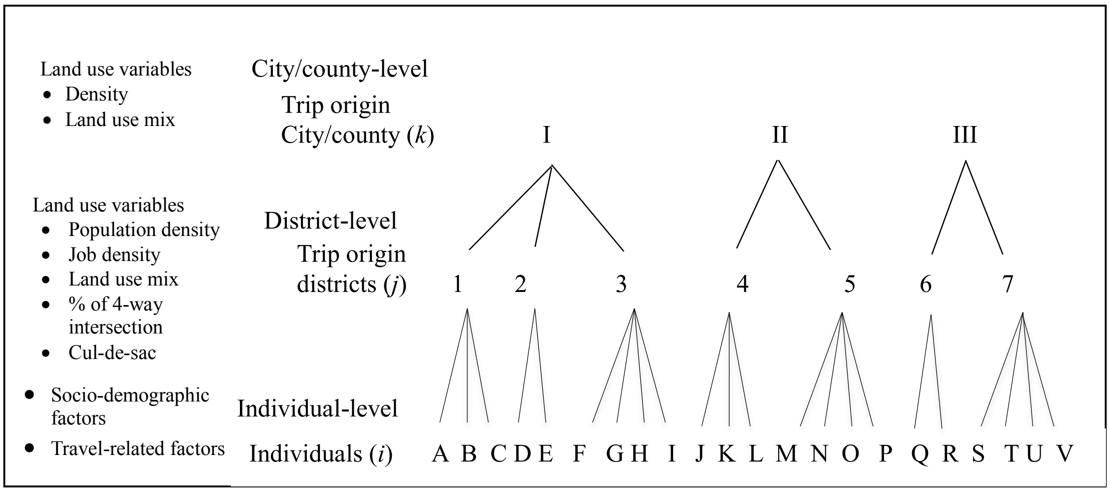


圖 3.1 三層次概念模型

圖 3.2 顯示了多層級交叉分類 MNL 模型的概念模型。分析的基本單位是個體行為的旅次。為了提取土地利用對模式選擇行為的真實空間效果，這項研究包括上班上學的出行目的，社會經變數:個人月收入、汽車和機車駕照，以及交通服務水準變量相關的級別許可證： OD 距離和旅次成本。

這種多層次的交叉分類 MNL 模型是研究整個行程出發地和目的地的空間異質性。鄉鎮市作為空間單元，以適應整個行程的起點和終點的空間異質性。個別旅客嵌套於鄉鎮市內，行為者的旅次特性變數是交叉類聚於旅次起點位置（行程起點）和迄點位置(旅次目的)。

該模型包括五個變量 - 人口密度，密度工作，土地利用結構熵，四路交叉口和死巷比例-代表土地使用變量。在模式選擇行為，這些土地利用的影響，估計在兩個行程起點水平和旅行目的地的水平，因為這些土地使用變量可能會從遊目的地之旅的起源為模式選擇扮演不同的角色。對於人口密度和就業密度，皮沃（1994）發現在行程起源和就業密度在旅行目的地的人口密度上發揮影響方式選擇的作用。張（2004）也發現，在遊目的地的人口密度與模式選擇工作和非工作出行顯著的關係。為了了解人口密度和就業密度的影響在兩個行程的起點和終點的模式選擇和比較研究的結果與之前的結果，估計在兩個行程起源和旅行目的地的人口密度和就業密度的影響。多層級交叉分類模型結構如圖 3.2。

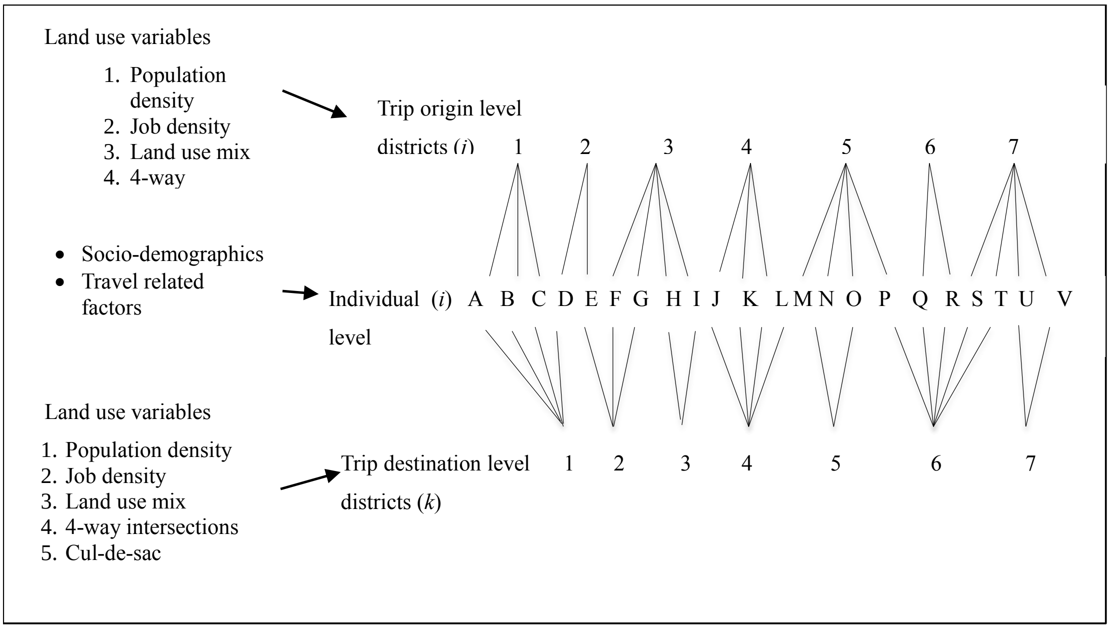


圖 3.2 交叉類聚多層次模型

這項研究的離散因變量是運具選擇（包括汽車，機車和公共交通）。增加公共交通的使用是我國公路公共運輸發展計畫及公路公共運輸提昇計畫重要的政策目標。更好地了解土地利用特徵影響運具選擇的行為，可以幫助決策者更好地規劃土地使用和交通整體策略，以實現這一政策目標。因此，公車、地鐵和火車合併為公共交通，並作為模式校估時的參考類別。

3.2 推估結果

本節介紹模型估計的結果。總計估計六個模型。 A 模型和 C 模型是多層次 MNL 模型; D 模型和 F 模型是多層級交叉分類 MNL 模型。 B 模型和 E 模型為 MNL，其中包括鄉鎮市，市/縣的土地利用變量。估計空模型的目的 – A 模型和 D 模型(多層級 MNL 模型和多層級交叉分類 MNL 模型)- 是理解的 ICC（類內相關性）值。估計 MNL – B 模型和 E 模型 - 是比較 MNL 模型和多層級交叉分類 MNL 模型的結果。該模型的估計是使用 MLwiN 軟體內 MCMC（馬爾科夫鏈蒙特卡羅）程序進行的。這些模型是使用 RIGLS 建立一個先驗分布，利用 Gibbs 抽樣 MCMC 所遵循的估計，在 2000 迭代和 30 次迭代得到後驗分佈第一次運行。

3.2.1 多層次多項模型結果

如表 3.1 可以看出，A 模型是空模型。 A 模型的目的是測試 ICC 值，看看是否有顯著的空間異質性與否。模型 B 是一個單一層級 MNL 模型，其中包括鄉鎮市和城市/縣級同一級別內的解釋變量。模型 C 是允許節線可以隨機跨鄉鎮市及市/縣級改變的一個三層 MNL 模型。該模型包括在鄉鎮市和市/縣級在個人層面上，土地利用與旅次相關的屬性和公共交通提供變量，考慮社會人口特徵的影響。

估計 A 模型（空模型）原因是確定採用多層級 MNL 模型是否合理。採用多層級 MNL 模型之合理性取決於在效用函數中未觀察到的變異值及 ICC（內部類相關係數）值的大小。表 3.1 顯示了所有汽車和機車的空間異質性參數在模型鄉鎮市，市/縣級是顯著。此外，ICC-Car 和 ICC-Motorbike（內相關係數）在整個鄉鎮市和城市/縣級，是 0.103 和 0.134，分別表示在同一區和城市/縣個人相關性是 10.3％和 13.4 ％。空間異質性的鄉鎮市和城市/縣級意味著空間異質性不能被忽略，並且有必要採用多層級建模技術，以適應本研究的空間問題。

對於模型的複雜性和適合度，DIC（見表 3.1）值表明，C 模型（多層級 MNL 模型）是三款模型中的最佳模式。 DIC 是有效的參數（PD）和 MCMC 的偏差的數量的總和，表示模型的複雜性和貼合度，並且可以用於比較的模型優劣（Spiegelhalter 於等人，2002）。有效參數的數量是指一個模型的複雜性和越軌行為統計是指一個模型的擬合。Spiegelhalter 於等（2002）建議，增加了模型的擬合（MCMC 的偏差）和複雜性（的有效參數的數量），以形成 DIC（越軌信息準則），可用於與相同的結構或不同的結構模型的比較。添加空間異質到模型後，與模型 B 相比，C 模型的 DIC 為減少了約 43。雖然有效參數(pD)，模型 C 的數目比 B 模型高 60 點，C 模型的 MCMC 為 9110.18，約較 B 模型低了 102 點(表 3.1）。

表 3.1 的最後一列是指相減從在模型 B.大多數鄉鎮市，市/縣級絕對的 t 值鄉鎮市，市/縣級變量模型 C 的絕對 t 值絕對的 t 值'B 模型和 C 模型之間的差異是積極的，除了在鄉鎮市汽車和機車，市/縣級為機車的土地利用熵。另外，在鄉鎮市比較的係數顯著級為 4 路交叉點的密度和％，這些係數是在模型 B 的 95％的水平顯著但無關緊要在模型 C.該比較提供，結果顯示高空間自相關的情況下，無視於空間聚合性及組間差異，而使用單一層級離散選擇模型（B 模型）將誇大係數的意義，並導致謬誤的結果。

相對於在模型 C 個體的社會人口因素的因素和旅次目的(表 3.1)，男性往往較女性更傾向於使用機車，學生更傾向於使用公共交通，而不是汽車和機車。個人所得顯示了模式選擇汽車和公共交通和機車和公共交通之間的相反的結果。隨著越來越多的個人收入，人們更傾向於選擇汽車而不選擇公共交通，另一方面，所得增加會增加對公共運輸的選擇，而不選擇機車。至於出行目的，工作和學校旅行更容易選擇公共交通而不選擇汽車，另一方面工作出行更可能用機車而非公共交通工具。汽車和機車駕駛執照也分別於汽車和機車的使用顯著的積極影響。

對於家庭社會人口因素，家戶內有 18 歲以下孩子的家庭往往選擇汽車的概率顯著較公共運輸高。同樣，家戶內有較高的汽車或機車數可能更傾向於使用汽車或機車。

至於模型 C 旅次相關的屬性，如示於表 6.4，隨著旅次起迄距離 OD 的增加，人們往往會選擇公共交通工具，而不是機車。在另一方面，較高的旅行費用將鼓勵汽車和機車的使用，而不是公共交通工具的使用。

考慮控制因素後，C 模型的結果，如表 3.1，顯示土地使用變量對於模式運具選擇行為影響顯著。在鄉鎮市，增加人口密度和就業密度顯著用在汽車和機車選擇公共交通的概率較大有關。在另一方面，4 路交叉口的百分比 - 代表網格狀的街道格局 - 顯示了機車和汽車的使用強關聯，這意味著人們在更多的網格狀的街道格局都市傾向於選擇機車，而不是公共運輸。更均勻分佈的土地利用區 - 較高的土地利用熵值 -相較於公共交通工具，往往有更多的汽車使用。在城市/縣級而言，增加密度與選擇對於汽車和機車與公共交通的選擇有較高相關性，雖然對於汽車的顯著水平僅為 90％。

隨機部分的協方差是指在鄉鎮市和城市/縣級（表 3.1）汽車和機車的使用之間的相關性。在鄉鎮市和市/縣級的積極協方差意味著各區，市/縣在台灣有汽車的使用比例較高鄉鎮區也有校高的機車的使用比例。

相對於空間異質性（隨機計），A 模型，如示於表 3.1，表明在鄉鎮市和城市/縣級空間異質性參數分別在 90％和 95％的顯著的水平。這意味著有市/縣之間顯著的空間異質性（不可觀測的因素）的影響模式選擇行為。

表 3.1 Multilevel MNL model results

	Fixed Part	Model A Null Multilevel MNL model B	S.E.	t-value	Model B Single-level MNL model B	S.E.	t-value	Model C Multilevel MNL model B	S.E.	t-value	Absolute t-value in model B minus absolute t-value in Model C
Car	Individual-level										
	Intercept	0.63	0.10		-2.06	0.97	-2.12	-2.20	1.47	-1.50	
	Gender (Male=1)				0.14	0.09	1.54	0.15	0.09	1.69	
	Age under 14				0.58	0.33	1.78	0.59	0.33	1.75	
	Age between 15-24				**-0.55**	**0.23**	**-2.43**	**-0.57**	**0.23**	**-2.50**	
	Occupancy (Student=1)				**-0.57**	**0.22**	**-2.59**	**-0.60**	**0.23**	**-2.58**	
	Monthly personal income (US$1,000)				**0.30**	**0.06**	**4.70**	**0.30**	**0.06**	**4.81**	
	Car driver's license				**0.82**	**0.11**	**7.33**	**0.82**	**0.12**	**7.17**	
	Children (under 18) in Household				**0.36**	**0.09**	**4.07**	**0.36**	**0.09**	**4.01**	
	Household car ownership				**0.54**	**0.05**	**12.09**	**0.54**	**0.05**	**11.89**	
	Trip purpose (work=1)				-0.14	0.10	-1.35	-0.15	0.10	-1.46	
	Travel cost				**0.59**	**0.04**	**15.03**	**0.60**	**0.04**	**14.90**	
	OD distance				-0.01	0.01	-0.83	-0.01	0.01	-0.83	
	District-level										
	Population Density				-0.14	0.05	-2.80	-0.08	0.06	-1.33	1.47
	Job density				-0.04	0.06	-0.67	-0.03	0.07	0.42	0.25
	Land use mix entropy				-0.06	0.39	0.50	-0.06	0.47	-0.13	0.37
	% of four-way intersection				**3.85**	**0.83**	**4.64**	**2.01**	**1.03**	**1.95**	2.69
	No. of cul-de-sac				0.05	0.05	1.00	0.05	0.09	0.05	0.95
	City/county-level										
	Density				**-0.21**	**0.05**	**-4.20**	**-0.22**	**0.13**	**-1.69**	2.51
	Land use mix entropy				-1.03	1.41	-0.73	-0.24	2.47	-0.01	0.72
Motor-bike	Individual-level										
	Intercept	0.92	0.11		-2.72	0.82	-3.28	-2.88	1.54	-1.87	
	Gender (Male=1)				**0.17**	**0.08**	**2.13**	**0.18**	**0.08**	**2.23**	
	Age under 14				0.13	0.28	0.46	0.13	0.28	0.46	
	Age between 15-24				0.06	0.18	0.33	0.03	0.18	0.15	
	Occupancy (Student=1)				**-0.52**	**0.18**	**-2.89**	**-0.54**	**0.18**	**-3.00**	
	Monthly personal income (US$1,000)				**-0.19**	**0.06**	**-3.11**	**-0.18**	**0.06**	**-2.97**	
	Motorbike driver's license				**1.32**	**0.11**	**12.03**	**1.32**	**0.11**	**11.93**	
	Children (under 18) in Household				0.15	0.08	1.85	0.14	0.08	1.75	
	Household motorbike ownership				**0.35**	**0.03**	**12.93**	**0.35**	**0.03**	**12.32**	
	Trip purpose (work=1)				0.13	0.09	1.44	0.13	0.09	1.44	
	Travel cost				0.05	0.04	1.33	0.05	0.04	1.29	
	OD distance				**-0.04**	**0.01**	**-6.67**	**-0.04**	**0.01**	**-6.67**	
	District-level										
	Population density				-0.11	0.04	-2.75	-0.08	0.05	-1.60	1.15
	Job density				-0.04	0.05	0.80	-0.02	0.06	0.36	0.44
	Land use mix entropy				**0.56**	**0.35**	**1.60**	**0.68**	**0.41**	**1.65**	-0.05
	% of four-way intersection				**4.18**	**0.75**	**5.57**	**2.58**	**0.93**	**2.77**	2.80
	No. of cul-de-sac				0.05	0.05	1.00	0.06	0.08	0.75	0.25
	City/county-level										
	Density				**-0.21**	**0.05**	**-4.33**	**-0.24**	**0.11**	**-2.18**	2.15
	Land use mix entropy				1.38	1.22	1.13	1.92	2.04	0.94	0.19
Random part	City/county-level										
	$\sigma^2_{\psi_{00k}^{car}}$	0.15	0.07	2.25				0.12	0.07	1.77	
	$Cov(\sigma^2_{\psi_{00k}^{car}}, \sigma^2_{\psi_{00k}^{motorbike}})$	0.15	0.08	2.10				0.07	0.05	1.45	
	$\sigma^2_{\psi_{00k}^{motorbike}}$	0.21	0.09	2.33				0.10	0.05	1.80	
	District-level										
	$\sigma^2_{\zeta_{0j}^{car}}$	0.04	0.02	1.64				0.07	0.04	1.92	
	$Cov(\sigma^2_{\zeta_{0j}^{car}}, \sigma^2_{\zeta_{0j}^{motorbike}})$	0.00	0.02	0.13				0.03	0.03	1.30	
	$\sigma^2_{\zeta_{0j}^{motorbike}}$	0.04	0.02	1.91				0.03	0.02	1.53	
DIC (Deviance Information Criterion)		10988.85			9250.35			9207.75			
MCMC deviance		10903.69			9212.22			9110.18			
pD (the effective number of parameters)		83.69			38.13			97.58			

3.2.2 多層級交叉分類模型結果

多交叉分類 MNL 模型的估計結果示於表 3.2。 D 模型是一個空的多層級交叉分類 MNL 模型來檢驗 ICC 值。 E 模型為單一層級 MNL 模型，其中包括鄉鎮市變量同級別中都之旅的起點和終點。 F 型是允許模式節線隨機變異，以捕捉整個行程起點和目的地變量的多層次交叉分類 MNL 模式。該模型包括在兩個行程起點和目的地土地利用變量，並考量社會人口特徵變數。

估計模型 D 目的是確定採用多層級交叉分類建模技術是否合理（見表 3.2）。所有代表的實用功能為汽車和機車未觀察到的變化的空間異質性參數是整個行程的起點和終點統計顯著。跨行程的起點和終點的 ICC-car 和 ICC-motorbike 是 0.170，0.145，分別表明在相同行程的起點和終點為汽車使用者和機車使用者個人的相關性是 17.0％和 14.5％之間。此外，ICC 車和 ICC-D-car，在相同的出發地和目的地為汽車使用者的相關性，分別為 0.055 和 0.114。ICC-機車和 ICCD-機車，在相同的起源和目的地機車使用者的相關性，分別為 0.055 和 0.090。空間相關性的高比例表明有必要採用一個多層次的建模技術，以適應這種研究的空間特性問題。

在表 3.2 中的最後一列是指在模型 E 的絕對值 t 值的模型之間穿過跳閘起源用地變量和目的地差的絕對值 t 值和絕對 t 值在模型 F.大部分之間的減法 B 和 C 模型是積極的。此外，在行程起點為汽車和旅行目的地為 B 模型和 C 模型機車比較係數的顯著級別的人口密度，係數是模型 C.這種比較提供了在 B 模型 95％的水平顯著，但不顯著證據表明，在高空間自相關的情況下，僅使用單一層級離散選擇模型可能誇大係數的意義，並導致虛假的結果。

由模式的複雜性和適合度 DIC（越軌信息準則）值來看（見表 3.2），F 型（多層級交叉分類 MNL 模型）是三款模型中的最佳模式。添加空間異質到模型後，模型 F 的 DIC 模型 E 相比減少了 31（表 3.2）。

相對於社會人口特徵和出行目的的 C 模型的控制因素，如表 3.2，個人所得顯示了模式選擇汽車與公共交通及機車與公共交通之間的相反的結果。隨著個人收入增加，人們更傾向於選擇汽車而非公共交通，但收入增加，人們會選擇使用公共交通而非機車。至於出行目的，就學旅次傾向於選擇公共交通，而不使用機車，而工作旅次則傾向使用機車而非公共交通工具。

相對於在模型 C 級的服務的控制因素，如表 3.2

，旅行費用和 OD 距離對人過來的公車車和機車之間進行選擇相反的跡象。隨著 OD 的距離，人打算選擇公共交通工具，而不是機車。同樣，較高的旅行費用打算鼓勵汽車和機車的使用，而不是公共交通工具的使用。

納入社會人口和級別的服務因素後，C 模型結果（見表 3.2）表明，土地使用變量發揮無論是在旅行的起源或目的地的方式選擇行為顯著的影響。在行程的起源增加的人口密度與在汽車選擇公共交通的概率較大有關。在與更多的網格狀街道模式，即較高的 4 路交叉口百分比之旅的起源各區，顯著增加在台灣的公共交通相比，使用汽車和機車使用的可能性。在遊目的地，結果表明，較高的及業密度和混合用地增加，人們會乘坐公共交通工具，而不是汽車或機車的概率。及業密度展示了針對汽車和公共交通和機車和公車模式之間選擇行為顯著和消極的關係。土地利用結構只顯示車和公共交通之間的意義顯著（負）的關係。的 4 路交叉點百分比的比例示出了機車和同時顯示汽車和公共交通之間微不足道的公共交通之間意義顯著（正）的關係。

表 3.2 Multilevel cross-classified MNL model results

Dependent variable: mode choice of car, motorbike, and public transport (reference category)		Model D - Null model of multilevel cross-classified MNL model			Model E - MNL model			Model F - multilevel cross-classified MNL model			Subtract absolute t-value in Model B from absolute t-value in Model C
Explanatory variables		B	S.E.	t	B	S.E.		B	S.E.	t	
Fixed Part											
Car	**Individual level**										
	Intercept	0.651	0.065	10.010	-2.210	0.388	-5.696	-1.896	0.499	-3.800	
	Gender (male=1)				0.117	0.090	1.300	0.122	0.092	1.326	
	Aged under 14				0.542	0.331	1.637	0.528	0.338	1.562	
	Aged 15-24				**-0.561**	**0.224**	**-2.504**	**-0.626**	**0.231**	**-2.710**	
	Occupancy (student=1)				**-0.560**	**0.226**	**-2.478**	**-0.558**	**0.230**	**-2.426**	
	Personal income				**0.311**	**0.063**	**4.937**	**0.319**	**0.066**	**4.833**	
	Car driver's license				**0.809**	**0.114**	**7.096**	**0.799**	**0.116**	**6.888**	
	Children in household				**0.362**	**0.088**	**4.114**	**0.352**	**0.090**	**3.911**	
	Household car ownership				**0.543**	**0.044**	**12.341**	**0.539**	**0.046**	**11.717**	
	Trip purpose (work=1)				-0.105	0.098	-1.071	-0.126	0.101	-1.248	
	OD distance				-0.006	0.006	-1.000	-0.006	0.006	-1.000	
	Travel cost				**0.598**	**0.039**	**15.333**	**0.621**	**0.040**	**15.525**	
	Trip origin level										
	Population density				-0.061	0.050	-1.220	-0.045	0.062	-0.726	0.494
	Job density				-0.058	0.053	-1.094	-0.049	0.065	-0.754	0.340
	Land use mix entropy				0.331	0.437	0.757	0.329	0.527	0.624	0.133
	% of 4-way intersections				**3.138**	**0.963**	**3.259**	**2.518**	**1.124**	**2.240**	1.019
	No. of cul-de-sac				-0.020	0.078	-0.256	-0.038	0.091	-0.418	-0.162
	Trip destination level										
	Population density				0.012	0.052	0.231	0.019	0.072	0.264	-0.033
	Job density				**-0.193**	**0.044**	**-4.386**	**-0.192**	**0.067**	**-2.866**	1.520
	Land use mix entropy				**-1.034**	**0.445**	**-2.324**	**-1.285**	**0.608**	**-2.113**	0.211
	% of 4-way intersections				0.601	0.894	0.672	0.553	1.081	0.512	0.160
	No. of cul-de-sac				0.099	0.079	1.253	0.146	0.096	1.521	-0.268
Motorbike	**Individual level**										
	Intercept	0.979	0.063	15.540	-2.003	0.365	-5.488	-1.902	0.412	-4.617	
	Gender (male=1)				**0.167**	**0.080**	**2.088**	**0.164**	**0.081**	**2.025**	
	Aged under 14				0.092	0.287	0.321	0.097	0.290	0.334	
	Aged 15-24				0.050	0.176	0.227	0.023	0.178	0.129	
	Occupancy (student=1)				**-0.499**	**0.182**	**-2.742**	**-0.504**	**0.183**	**-2.754**	
	Personal income				**-0.179**	**0.062**	**-2.887**	**-0.175**	**0.064**	**-2.734**	
	Motorbike driver's license				**1.313**	**0.109**	**12.046**	**1.323**	**0.110**	**12.027**	
	Children in household				0.159	0.080	1.988	0.151	0.081	1.864	
	Household motorbike ownership				**0.349**	**0.027**	**12.926**	**0.351**	**0.028**	**12.536**	
	Trip purpose (work=1)				**0.184**	**0.089**	**2.067**	**0.177**	**0.090**	**1.967**	
	OD distance				**-0.038**	**0.006**	**-6.333**	**-0.038**	**0.006**	**-6.333**	
	Travel cost				0.059	0.040	1.475	0.070	0.041	1.707	
	Trip origin level										
	Population density				-0.053	0.042	-1.262	-0.051	0.051	-1.000	0.262
	Job density				-0.049	0.047	-1.043	-0.039	0.054	-0.722	0.321
	Land use mix entropy				0.606	0.401	1.511	0.671	0.455	1.475	0.036
	% of 4-way intersections				**2.752**	**0.862**	**3.193**	**2.408**	**0.985**	**2.445**	0.748
	No. of cul-de-sac				-0.034	0.075	-0.453	-0.055	0.081	-0.679	-0.226
	Trip destination level										
	Population density				0.066	0.044	1.500	0.066	0.054	1.222	0.278
	Job density				**-0.187**	**0.038**	**-4.921**	**-0.185**	**0.049**	**-3.776**	1.145
	Land use mix entropy				-0.071	0.409	-0.174	-0.150	0.454	-0.330	-0.156
	% of 4-way intersections				**2.431**	**0.792**	**3.069**	**2.430**	**0.904**	**2.688**	0.381
	No. of cul-de-sac				**0.122**	**0.075**	**1.627**	**0.151**	**0.083**	**1.819**	-0.192
Random Part	Trip destination level										
	σ^2_{D-car}	0.226	0.063	3.587				0.168	0.062	2.710	
	$cov(\sigma_{D-car}, \sigma_{D-motorbike})$	0.172	0.053	3.245				0.092	0.038	2.421	
	$\sigma^2_{D-motorbike}$	0.200	0.059	3.390				0.061	0.028	2.179	
	Trip origin level										
	σ^2_{O-car}	0.109	0.044	2.477				0.096	0.005	1.920	
	$cov(\sigma_{O-car}, \sigma_{O-motorbike})$	0.045	0.038	1.184				0.048	0.032	1.500	
	$\sigma^2_{O-motorbike}$	0.106	0.044	2.409				0.053	0.028	1.893	
DIC (Deviance Information Criterion)			10987.83			9214.07			9183.11		
MCMC deviance			10764.63			9170.09			9026.40		
pD (the effective number of parameters)			223.21			43.99			156.72		

3.3 結論

本章介紹了多層次 MNL 模型和多層級交叉分類 MNL 模型，探索未觀測到的空間異質性和土地利用變量在鄉鎮區和市/縣層面的影響，並在旅行出發地和目的地的汽車，機車和公車模式之間的選擇。

這項研究發現，未觀察到的空間異質性（空間的組間差異）對運具選擇行為有顯著的影響。 C 模型和 F 模型的模型適合度而言，多層級 MNL 模型的結果比傳統的單一層級 MNL 模型(模型 B 和 E)適合度顯著改進，除了未觀測到的空間異質性提高，並提供了進一步的證據表明，以往的研究採用單一層級 MNL 模型，忽視空間依賴性和空間異質性，分析土地和出行行為之間的關係可能會誇大樣本量，並導致錯誤的結果（Snijders，2012 年，蛾等，2002）。因此，對於相關的分層群集特徵和分層數據結構的研究中，多層級建模技術可能是一個更好的方法，得到一個更準確的結果。

考量鄉鎮市，市/縣的土地利用，與模型 A 相比，市/縣級不可觀測空間異質性大大降低；在旅行出發地和目的地的未觀測到的空間異質性方面，E 模型也大大的降低了，這意味著，在納入旅次起點及旅次迄點的土地使用變數後，未觀測到的空間異質性被有效的解釋了。

總的來說，本次研究發現，社會人口學特徵及出行相關的屬性對於模式運具選擇行為影響顯著。在個人層面，年齡，個人收入，汽車和機車駕照的所有權，旅行費用和出行距離都影響公共交通相比，汽車和機車之間的個人的模式選擇。關於家庭的住戶的影響，家戶有兒童（18 歲以下）更可能選擇開車而非公共交通工具。家戶內有更多的汽車或機車的人往往分別使用更多的汽車或機車，而不選擇公共交通工具。

由於在旅次起點及迄點的土地使用對於運具選擇影響部分，結果顯示，在高的人口密度的鄉鎮市和高的人口密度與就業密度在市/縣，選擇公共運輸的概率較高。而更多網格狀的街道格局則吸引更多的汽車使用，而非公共交通工具。在鄉鎮市和市/縣層級方面，高人口密度與及業密度的鄉鎮市及縣市傾向於運具選擇使用公共交通而非機車。另一方面，更加多樣化的土地用途，更網格狀的街道格局會鼓勵更多機車使用。過去很少有研究關注土地利用方式對機車的使用效果。

至於土地使用變量在旅次起點及迄點對運具選擇(汽車和公共交通之間)的影響，結果顯示，在高人口密度的鄉鎮市及高人口密度與及業密度的縣市，傾向於選擇公共交通，而不選汽車；另一方面網格狀的都市街道將鼓勵汽車使用而不選擇公共交通。就機車和公共交通之間的運具選擇行為，在旅次目的地有較高的及業密度將鼓勵公共交通的使用，而更多網格狀的街道格局或死路將鼓勵機車的使用。

最後，從結果看來，在台灣，機車的使用行為適合於高人口密度，多元化的土地利用和網格狀的都市街道。多元化土地用途為獲取不同的活動提供更多的機會。同樣地，一個網格狀的街道格局提供用於機車的容易操作及更容易抵達目的地的環境。機車的使用特性為短距離與多旅次目的地的行為，因此，研究顯示，機車適合於混合土地使用、網格狀都市街道的土地使用環境；這種現象可能也適用於其他東南亞國家，如越南，菲律賓，馬來西亞和泰國，機車在這些東南亞國家同樣扮演著重要的交通運輸角色。對機車運具選擇行為以前的研究都集中在旅次特性和社會經濟特性的影響，而很少有研究分析了土地利用方式對機車運具選擇行為的影響。

對於東南亞國家與機車使用，如台灣，越南，菲律賓，馬來西亞，泰國和印尼的比例高，也許有必要實施一些策略來增加機車使用成本或使用上的不便性，使公共交通更具有競爭力。雖然有可能是一個論點，認為機車對環境衝擊較汽車少，因此應該以鼓勵機車使用以減少汽車使用；然而機車是人們達到 18 可以擁有駕駛執照時的私人運具，如果人們在年輕的時後習慣於使用的機車作為交通工具，很多人在年長及所得增加後，非常可能轉向使用汽車。因此，實施有效的策略，以確保建築環境有利於公共交通使用而非機車，對於都市永續交通至關重要。

本章內容詳細英文分析請參閱附錄一。

第4章　客觀建成環境和主觀可步行性對步行行為的影響

步行是一種最常見、最自然的身體活動和運輸方式，也是公共運輸中最重要的一環，連接第一和最後一英里。大多數的公共運輸旅程包含步行到、離公車站/地鐵站/火車站/中間轉乘點。一個適合步行的環境可以提高步行可及性並鼓勵公共運輸的使用。因此，了解步行環境和步行行為之間的關聯就更顯重要。

許多步行出行行為的研究已經確定了建成環境特性(如服務接近、街道連接、交通安全及社區景觀)和步行行為(如步行頻率和時間)之間的關係，人們生活在一個適宜步行的街區，會傾向增加步行的距離和頻率。然而，在出行方式選擇行為模型中將步行旅次包括在內的研究卻相對較少。

一些研究發現的證據已表明，不管從客觀或主觀衡量，步行環境對步行行為都有一定的影響；Alfonzo 聲稱，步行環境的客觀認知會間接影響步行行為；Ewing & Handy 也提出，對步行環境的客觀認知會影響對適宜步行的感知和步行行為。另有一些研究在探究對步行環境客觀衡量或主觀衡量之間的關聯性，及其對步行行為的影響，但卻沒有足夠的證據證明彼此相關。

本研究的主要目的是探討

1）客觀步行環境因素，對步行環境感知的影響；

2）主觀步行環境因素，對整體可步行性及步行行為的影響。

4.1 概念模型

本研究中概念模型的基本假設是，步行環境的感受和可步行性的整體感知是客觀步行環境因素和步行行為的中介變項。可步行性的整體感知反映出個人對步行環境的整體評估是由主觀環境因素所決定；同時，可步行性的整體感知再加上個人社經背景和其他因素也都會影響到步行行為及運具的選擇 (圖 4.1)。

本研究模型考量了性別、年齡、收入、家戶汽車擁有數和家戶機車擁有數等社會人口特徵，另外，選擇步行作為運具亦受限於旅次長度，在台灣，僅有 5％以下的步行旅次其步行路程在 45 分鐘以上。

步行包括兩種主要的交通行為：直接步行到目的地，以及步行到公共運輸站點。直接步行到目的地涉及到可接受之步行距離；步行到公共運輸站點則端看站點是否在可及的步行距離內以及環境的可步行性；這兩種交通行為各有其不同特性，應分別探討之。

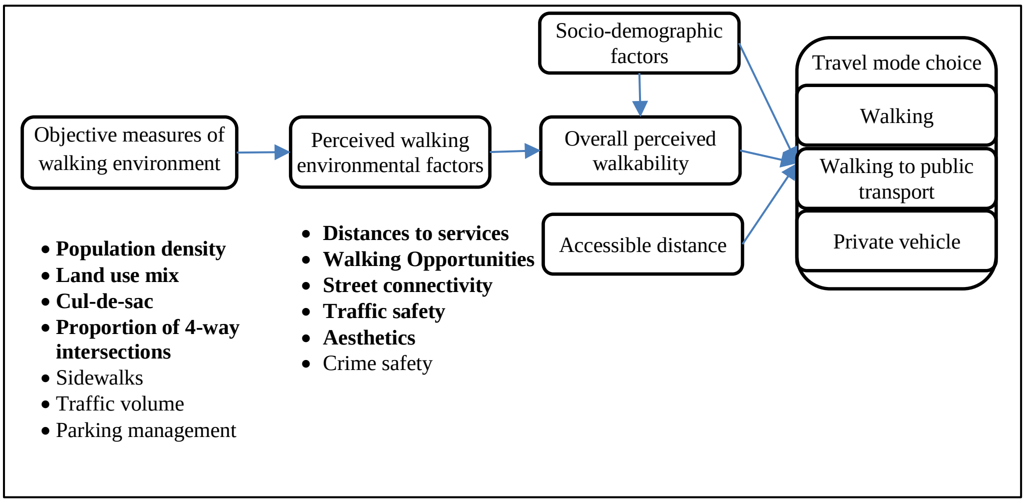


圖 4.1 Conceptual model

4.2 結構模型

基於前述概念模型，本研究結構模型假設主觀步行環境因素和社會人口特徵會影響可步行性的整體感知，而可步行性的整體感知和社經背景會影響選擇直接步行至目的地抑或步行至公共運輸站點/私人運具停車點(圖 4.2)。

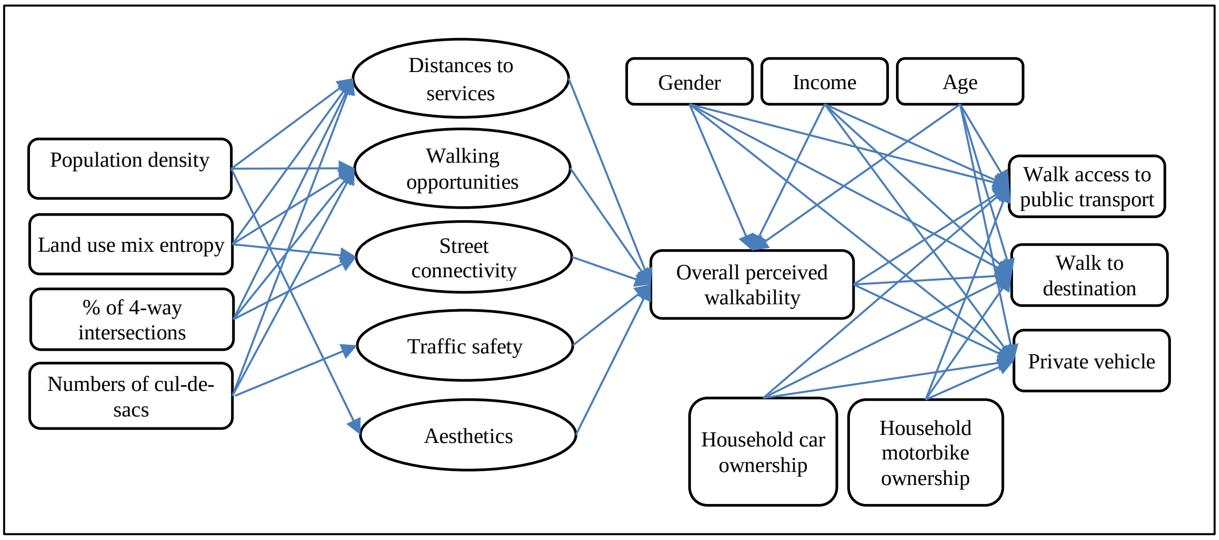


圖 4.2 Model structure

4.3 結果

4.3.1 步行環境指標之主觀衡量的因素分析

由於使用的測量量表不同，因此採取兩次因素分析去探究主觀步行環境因素。

1. 第一次因素分析，選擇問卷中 14 個題項 likert scale 五點尺度量表作因素分析；
2. 第二次因素分析集中於問卷中 7 個指標，研究步行至最近服務據點(如公車站、銀行、郵局、小學、超市…)的距離。

第一次因素分析，使用 likert scale 量表法中常用的信度考驗方法 Cronbach’s Alpha，算出的 Cronbach’s Alpha 值為 0.746，表示這個問卷量表 14 個題項之內部一致性；取樣適

切性量數(KMO, Kaiser-Meyer-Olkin measure of sampling adequacy，KMO-MSA)數值為 0.79，Bartlett's 球形檢定(Bartlett's test of sphericity）之結果 $p<0.000$，代表資料適合進行因素分析。

資料分析利用主軸因素法(Principal axis factoring)及最大變異轉軸法(varimax rotation)，抽取出四項主觀步行環境因素。在表 4.1 中可看出，四個主觀步行環境因素為步行機會與街道連接性、步行障礙、社區景觀和交通安全，這些佔了總變異數的 64.9％，表 4.1 僅顯示負荷量（factor loading）大於 0.30 之因素。

表 4.1 Rotated factor loading matrix

		Factor loading			
		Opportunities & connectivity	On-street barriers	Aesthetics	Traffic safety
WO1	There are many places to go within easy walking distance of my home.	.783			
WO2	Convenient stores are within easy walking distance of my home.	.687			
WO3	It is easy to walk to a public transport stop (bus, metro or train) from my home.	.695			
SC1	Distance between intersections in my neighbourhood is usually short (150 meters or less).	.659			
SC2	There are many alternative routes for getting from place to place in my neighbourhood.	.611			
SC3	There are sidewalks on most of the streets in my neighbourhood.	.615		.336	
TS1	There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighbourhood.	.589			
SC4	**There are motorbike parking on the streets and sidewalks blocking the way.**		.813		
SC5	**There are ‘hawkers’ and shops on the streets and sidewalks blocking the way.**		.788		
TS2	**So much traffic along nearby streets that it makes difficult or unpleasant to walk in my neighbourhood.**		.465		
AE2	There are many attractive natural sights in my neighbourhood			.782	
AE1	There are trees along the streets in my neighbourhood.			.790	
TS4	**Most drivers exceed the speed limits while driving in my neighbourhood.**		.302		.838
TS3	Speed of traffic on most nearby streets is usually slow (40 km/hr or less).				.541

從第二次因素分析抽取出步行至最近服務據點的距離因素，Cronbach’s Alpha 值為 0.87，KMO-MSA 數值為 0.88，Bartlett’s Test of Sphericity 之結果 $p<0.000$，反映內部一致性以及資料適合進行因素分析。

資料分析利用主軸因素法(Principal axis factoring) 萃取出表 4.2 的七項指標佔了總變異數的 58％。

表 4.2Factor loadings of distances to services factor

Code	Indicators	Loading
WT1	Walking time to the nearest convenient store	0.742
WT2	Walking time to the nearest bus stop	0.622
WT3	Walking time to the nearest supermarket	0.782
WT4	Walking time to the nearest primary school	0.700
WT5	Walking time to the nearest post office/ bank	0.796
WT6	Walking time to the nearest breakfast restaurant	0.760
WT7	Walking time to the nearest park	0.580

4.3.2 步行環境因素之主客觀衡量之間的相關性

表 4.3 顯示，相較於客觀的步行環境因素，主觀步行環境因素與可步行性的整體感知關聯性較高；除了交通安全這個因素外，其他的主觀步行環境因素至少與一個客觀的衡量標準具有顯著相關。

表 4.3 Correlations

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Objective measures	Population density (1)	1.00									
	Land use mix (2)	**-0.49**	1.00								
	Percentage of 4-way intersection (3)	**0.22**	-0.06	1.00							
	Numbers of cul-de-sacs (4)	**-0.42**	**0.18**	**-0.23**	1.00						
	Overall perceived walkability (5)	**0.16**	-0.06	0.07	**-0.22**	1.00					
Subjective measures	Opportunities & street connectivity (6)	**0.34**	**-0.11**	**0.19**	**-0.35**	**0.47**	1.00				
	On-street barriers (7)	-0.06	**0.10**	**-0.10**	0.05	**0.13**	-0.03	1.00			
	Aesthetics (8)	**-0.16**	0.09	-0.03	0.04	**0.27**	0.04	0.05	1.00		
	Traffic safety (9)	0.05	-0.06	0.02	-0.04	**0.14**	-0.03	**0.09**	0.06	1.00	
	Distances to services (10)	**-0.39**	**0.11**	**-0.20**	**0.38**	**-0.38**	**-0.65**	**0.13**	0.07	-0.08	1.00

Bold number denote correlation is significant at the 0.01 level (2-tailed)

4.3.3 模型結果

使用 stata 13.1 軟體中結構方程模型（Structural equation modeling, SEM）和廣義結構方程模型（generalized structural equation modelling , GSEM）來推估本研究結構模型各個變數之間的路徑關係。估算分為兩個階段。

第一階段使用結構方程模型 SEM 來估算從客觀步行環境因素到主觀步行環境因素和整體可步行性的路徑。本研究結構模型的適合度檢定（goodness-of-fit）指數分別為：CFI =0.98，TLI=0.94，RMSEA= 0.04，SRMR=0.02。數據顯示假設模型結構適配度良好。

第二階段使用廣義結構方程模型 GSEM，更進一步納入直接步行至目的地抑或步行至公共運輸站點/私人運具停車點之間的個體選擇。Multinomial Logit 模型的 McFadden’s pseudo R-squared 之數值為 0.142。

表 8 顯示結構方程模型 SEM 的結果，從客觀的步行環境因素例如人口密度、土地混合使用、十字路口的比例和死巷子數量，到主觀步行環境因素例如與步行至最近服務據點的距離、步行機會與街道連接性，路徑係數值都達統計上顯著，與研究預期方向相同；從土地混合使用和十字路口的比例到步行阻礙，路徑係數值達統計上顯著，與研究預期方向相同；從人口密度到社區景觀路徑係數值達統計上顯著，與研究預期方向相同。

從主觀因素（步行至最近服務據點的距離、步行機會與街道連接性、社區景觀、步行阻礙和交通安全）到整體可步行性，路徑係數值都是統計上顯著，與研究預期方向相同。（表 4.4）。結果顯示，個人整體可步行性的感知取決於他/她對與步行至服務據點的距離、步行機會與街道連接性、步行阻礙和交通安全的主觀看法，影響最大的是步行機會與街道連接性（0.381），接著是與服務據點的距離（-0.272），再來是社區景觀（0.264）、步行阻礙（0.197），最後是交通安全（0.176）。

表 4.4 的方向係數解釋了步行環境因素之主客觀衡量之間的相關性。假如環境中有較高的人口密度、土地混合使用和十字路口的比例，以及較少的死巷子，則人們主觀上會覺得步行至服務據點的距離較短、較大的步行機會與街道連接性。居住在人口密度較低的社區，如農村地區，則較重視更好的社區景觀。步行阻礙的感知與土地混合使用呈正相關與十字路口的比例呈負相關，這可能因為土地混合使用高的地區意味著許多活動可以通過步行到達，從而潛在地減少私人運具的使用，也因此降低穿越馬路的困難和違規停車的數量。另一方面，更高比例的十字路口意味著更多有利機車進入的方格狀街道格局。人們對機車的使用率愈高可能造成愈嚴重的步行障礙，特別是當機車停放在人行道上時。

這些結果支持研究的假設，即客觀的步行環境因素間接影響可步行性和步行行為。

在這項研究中使用的社會人口特徵沒有任何一項對可步行性的整體感知具有顯著影響，亦即可步行性的整體感知並沒有因為社會人口特徵而有所差異。

表 4.4 Structure model for objective and subjective walking environmental factors and walkability

	Coefficient	Std. dev.	t-value	Sig.
Distances to services <-				
Population density	**-0.373**	**0.034**	**-11.140**	**0.000**
Land use mix entropy	**-0.106**	**0.031**	**-3.460**	**0.001**
Percentage of 4-way intersections	**-0.103**	**0.027**	**-3.810**	**0.000**
Numbers of cul-de-sacs	**0.187**	**0.026**	**7.320**	**0.000**
Constant	-0.002	0.026	-0.090	0.927
Opportunities & street connectivity <-				
Population density	**0.358**	**0.035**	**10.380**	**0.000**
Land use mix entropy	**0.083**	**0.031**	**2.630**	**0.009**
Percentage of 4-way intersections	**0.107**	**0.028**	**3.860**	**0.000**
Numbers of cul-de-sacs	**-0.120**	**0.026**	**-4.550**	**0.000**
Constant	-0.031	0.027	-1.140	0.254
Aesthetics				
Population density	**-0.167**	**0.032**	**-5.280**	**0.000**
Land use mix entropy	0.003	0.032	0.090	0.931
Constant	0.016	0.027	0.580	0.559
On-street barriers <-				
Land use mix entropy	**0.074**	**0.028**	**2.690**	**0.007**
Percentage of 4-way intersections	**-0.074**	**0.026**	**-2.850**	**0.004**
Constant	0.011	0.026	0.430	0.671
Traffic safety<-				
Numbers of cul-de-sacs	-0.026	0.022	-1.150	0.249
Constant	-0.004	0.025	-0.150	0.879
Perceived overall walkability <-				
Distances to services	**-0.272**	**0.054**	**-4.990**	**0.000**
Opportunities & street connectivity	**0.381**	**0.047**	**8.170**	**0.000**
Aesthetics	**0.264**	**0.035**	**7.600**	**0.000**
On-street barriers	**0.197**	**0.036**	**5.510**	**0.000**
Traffic safety	**0.176**	**0.038**	**4.660**	**0.000**
Gender (female=0)	-0.094	0.061	-1.550	0.121
Aged 55 and over	0.169	0.128	1.320	0.186
Monthly income >= US$ 2,667	0.161	0.087	1.860	0.063
Constant	-0.051	0.048	-1.050	0.295

表 4.5 顯示運具選擇的影響。可步行性的整體感知和大部分的社會人口特徵對於選擇步行至公共運輸站點/私人運具停車點抑或直接步行至目的地具有統計上顯著影響。可步行性的整體感知對這兩種選擇的影響類似。社會人口特徵部分，55 歲及以上年齡層比其他年齡組更可能選擇步行至目的地或至公共運輸站點；相較其他收入群體，高收入組（月收入> US $2,667）具有較高的可步行性感知，但他們選擇步行至公共運輸站點

的機率較低；在台灣，家戶自用小客車和機車的擁有者選擇步行的可能性極低，家中機車愈多，家庭成員不管是選擇直接步行至目的地抑或步行至公共運輸站點的可能性就愈小。一些研究已經發現，機車的特徵是短途及多旅次，因此，比汽車能提供更多的替代步行的選擇。

表 4.5 **Walkability and -demographic characteristics influence walking behaviour**

		Coefficient	Std. dev.	t-value	Sig.
Walking to access public transport	Overall walkability	**0.414**	**0.098**	**4.210**	**0.000**
	Gender (female =0)	**-0.372**	**0.182**	**-2.050**	**0.041**
	Aged 55 and over	**0.937**	**0.371**	**2.530**	**0.012**
	Monthly income >= 2,667	-0.368	0.264	-1.400	0.163
	Household car ownership	**-0.716**	**0.140**	**-5.100**	**0.000**
	Household motorbike ownership	**-0.707**	**0.096**	**-7.390**	**0.000**
	Constant	**0.985**	**0.223**	**4.430**	**0.000**
Walking to destinations	Overall walkability	**0.401**	**0.179**	**2.240**	**0.025**
	Gender (female =0)	-0.370	0.327	-1.130	0.257
	Aged 55 and over	**1.623**	**0.555**	**2.920**	**0.003**
	Monthly income >= 2,667	**-1.341**	**0.598**	**-2.240**	**0.025**
	Household car ownership	**-0.720**	**0.254**	**-2.830**	**0.005**
	Household motorbike ownership	**-0.642**	**0.173**	**-3.720**	**0.000**
	Constant	-0.619	0.371	-1.670	0.095

第5章　動機對公共運輸使用之影響

本章包含第四個研究問題（RQ4），其目的是了解的能力(capability)，機會(opportunity)和動機(motivation)對運具選擇行為的影響。

運具選擇行為是由動機，能力和機會所影響。本章主要有兩個目標。首先是分析哪些動基因素會影響民眾使用公共運輸的動機；影響使用公共交通動機的因素可能包括：親環境的價值(pro-environment value)，態度(attitudes)，主觀規範(subjective norm)，感知道德義務（perceived moral obligation, PMO），感知行為控制（perceived behavioural control, PBC）和意圖(intentions)。第二個目的是動機對公共交通影響擴展到包括能力和機會等。能力和機會對運具選擇的影響包括直接的和間接的，間接的影響是由動機作為中介的。

5.1 模式構想

從圖 8.1 可以看出，這一章假定在運具選擇個人決策是由個人特徵（動機和能力）和外在條件（行動的機會）決定。此外，能力和機會的因素施加動機因素產生一些影響（圖 5.1）。

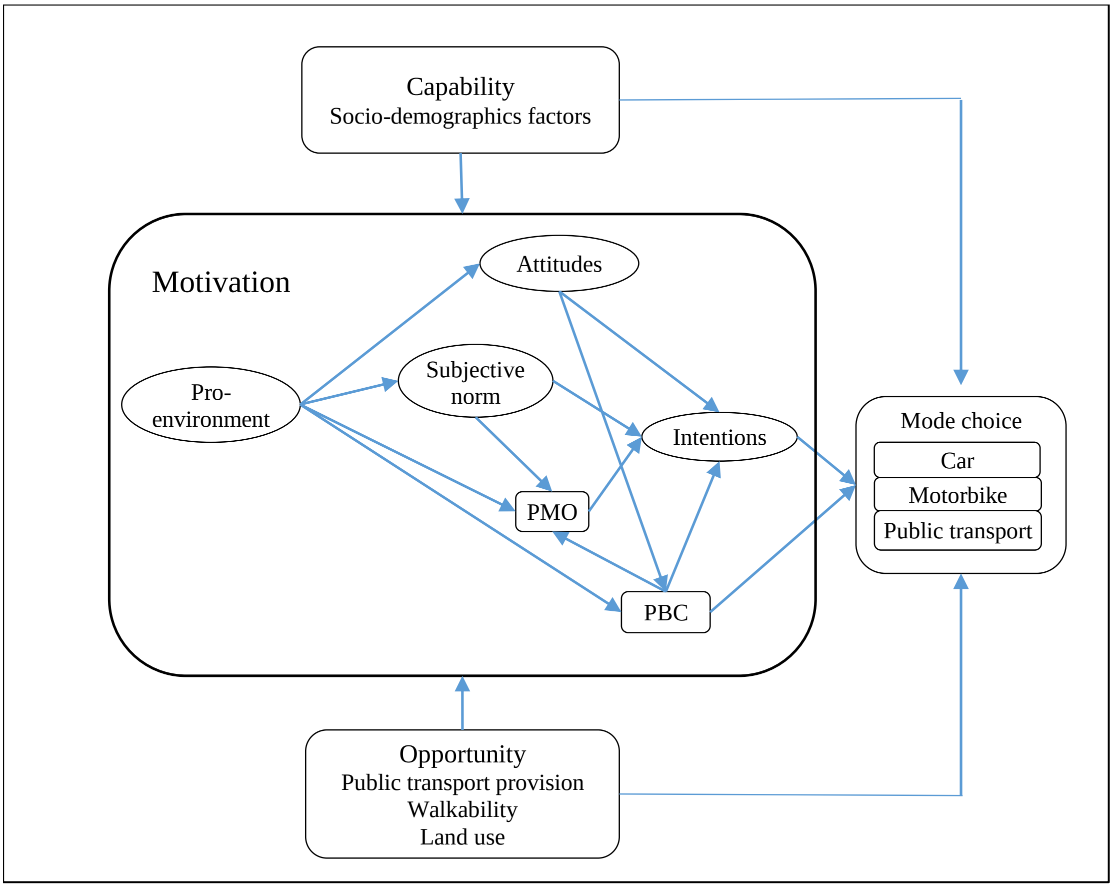


圖 5.1 模式構想

5.1.1 對公共交通動機(motivation)

探討公共交通的動機模型是為了了解影響動機的各項因素(motivational factors)、意圖(intentions)及使用公共運具選擇行為的關係。動機是指"大腦過程動機或直接行為"（米基等，2011），這表明為什麼個人將有動作的原因。例如，旅運者可能會認為他/她想要使用公共運輸，因為大多數的他/她的朋友已經使用這種形式的交通工具。在"要使用公共交通工具"是表明他的意圖，"因為大多數的他/她的朋友已經使用公共交通工具了"，則表達他的動機。

動機因素包括：親環境的價值，態度，主觀規範，個人道德義務，感知行為控制和意圖，是由計劃行為理論（TPB）及其擴展模型的理論，計畫行為理論是常用的基本框架來解釋出行行為的意圖和出行行為。陳和東（2014 年）Heath 和吉福德（2002）採用感知道德義務（PMO）、環境問題和價值，以豐富的解釋力意圖擴展 TPB 模型。親環境的價值，態度，主觀規範，個人道德義務，感知行為控制將被視為意圖使用公共交通先行，如圖 5.1。在感知行為控制來說，它指的是一個人的難易程度判斷使用公共交通和假設，以反映過去使用公共交通的經驗，以及預期的阻礙和障礙。 PBC 也可以作為實際行為控制的代理，並有助於模式的選擇行為的預測，如圖 5.1。

假設親環境值可能間接地影響使用公共交通工具的意圖，其間接影響性，是透過態度、主觀規範、個人道德義務及感知行為控制等因素作為中介的，如圖 5.1。親環境價值對於行為的影響，大多數以往的研究結果令人失望，其結果顯示親環境價值對行為的影響僅低度到中度。班貝格（2003）回顧了以前的一些研究，並假設親環境的價值，這是對環境的關注和值的一般態度，對特定環境行為的意圖和具體的環境行為的影響是間接的。Chen（2014 年）和班貝格（2003 年）給出了證據表明，親環境的價值並沒有對行為的意圖和行為本身顯著的直接影響，但作用在特定情況下，對信念和態度有很強的直接影響。該研究還假定，態度，主觀規範，個人道德義務和中國感知行為控制（圖 5.1）之間的一些互動影響關係。

5.1.2 機會(opportunity)

機會變數類似於可及性，是探討供給面公共交通服務水準、需求面土地利用狀況和步行環境。公共交通提供涉及使用公共交通工具的機會，而土地用途涉及訪問活動的機會。在本章中，機會變量包括公車站的密度、公車營運長度、地鐵站、混合土地利用熵、街道格局和整體感知適宜步行。

5.1.3 能力(capability)

森（1993）定義的能力為'在人所能達到的各種選擇的組合中，個人可以選擇的一個集合’。能力涉及身體、心理和精神方面的問題。在這項研究中，性別，年齡，孩子在家庭，駕駛執照和家庭車輛擁有被採納為能力的因素。例如，一個人逐漸變老，身體約束使他/她更願意使用公共交通，而不是私家車。此外，擁有汽車或機車（工具）使一個人更有能力用汽車或機車。心理方面的能力涉及教育和職業。財務方面的能力涉及收入。例如，收入較高的人更能夠擁有一輛汽車，並使用汽車作為交通工具的。

在圖 5.1 這個模型出行選擇行為模型，本章的目標是：1）確定潛在因素：親環境的價值，態度，主觀規範，個人道德義務，感知行為控制和意圖及各因素間的關係; 2）研究能力和機會對動機因素的影響; 3）這些動機因素對於意圖使用公共交通工具的影響，以及 4）能力、機會和動機對於運具選擇行為的影響。

5.2 推估結果

根據圖 8.1 所提出的概念模型，這一節探討動機變量：親環境價值，態度，主觀規範，個人道德義務，感知行為控制，對意圖及公共交通運具選擇行為的影響。方法上採用結構方程模型（SEM）和廣義結構方程模型（GSEM）進行模式校估。

5.2.1 因素的相關性

如表 5.1 所示，就所有因素間相關性加以比較，PBC 與意圖的之間的相關性最高，親環境價值與意圖相關性最低。主觀規範和個人道德義務，感知行為控制有高相關性，這意味著態度，主觀規範和個人道德義務和意圖之間有相互作用影響。同樣，態度和主觀規範及個人道德義務之間存在潛在的相互作用。

表 5.1 Correlations between motivational factors

	Pro-environment	Attitudes	Subjective norms	PMO	PBC	Intentions
Pro-environment	1.00					
Attitudes	0.22	1.00				
Subjective norms	0.25	0.12	1.00			
PMO	0.41	0.41	0.47	1.00		
PBC	0.15	0.51	0.44	0.51	1.00	
Intentions	0.27	0.44	0.46	0.63	0.77	1.00

本研究校估有三種 SEM 模型。在第一個模型，該研究估計全樣本模型來測試概念模型的假設。第二和第三 SEM 模型採用了汽車使用者和機車使用者，以了解汽車和機車使用者對使用公共交通工具意圖的影響。

模型適合度（GOF）顯示，該模型擬合數據良好，RMSEA <0.06，CFI 和 TLI> 0.9，SRMR <0.08。

就整體樣本模型而言，如表 5.2 和圖 5.2，結果證實對環境的關切和價值（親環境價值）是意圖使用公共交通工具的先驗因素。所有四個路徑顯示，從親環境因素直接顯著影響對公共交通的態度，主觀規範，個人道德義務和感知行為控制。換句話說，個人對公共交通主觀規範，感知道德義務和感知行為控制的態度受他/她的親環境價值的影響。此外，與態度，主觀規範和 PBC 比較，親環境價值對道德義務影響最大（PMO）。這意味著個人對於氣候變化和環境問題的認知度較高，具有較高的認知道德義務使用公共交通工具。

如表 5.2 和圖 5.2 的動機因素的路徑可以看出：主觀規範，個人道德義務和感知行為控制對意圖使用公共交通工具有統計上顯著的影響，且在符號上也是符合預期的方向。結果表明，一個人的意圖使用公共交通工具是通過在公共交通工具面，個人的主觀規範，感知道德義務和感知行為控制來決定。意圖中使用公共交通工具的總變異中約 80％已被這些動機因素所解釋，這表明，該模型在預測意圖使用公共交通工具有良好的解釋能力。

感知行為控制(PBC)是所有的動機因素中，對意圖使用公共交通（表 5.2）影響最大的因素，這意味著個人的感知容易或難以利用公共交通在模型中，是影響個人意圖使用公共交通工具最重要的因素。 個人道德義務(PMO)也是解釋使用公共交通工具（表 5.2）意圖不可或缺的重要因素。

如在表 5.2 中可以看出，圖 5.3 和圖 5.4，向公共交通的態度是在整個樣本模型微不足道;並顯示了汽車和機車使用者的意圖相反的影響，使用公共交通工具。對公共交通的態度是機車使用者只統計顯著。這可能是因為運具選擇行為更像是一種習慣性的行為和汽車使用者有心理矛盾。

有兩個原因來解釋為什麼態度對於意圖使用公共交通的影響是不顯著的。首先，運具選擇行為已成為自動行為，這意味著運具選擇已是習慣自動觸發模式選擇（耶林等，2001 年，RONIS 等人，1989 年，AARTS 等，1998）。在這種情況下，當運具選擇已經發展成為一個習慣，對公共交通的態度可能選擇行為無關（耶林等，2001 年，RONIS 等人，1989 年，AARTS 等，1998）。

其次，矛盾(ambivalence)，這是指對一個對象持有矛盾的感情和信仰（GERD Bohner，2002）也許能夠解釋，為什麼汽車使用者對公共交通的態度在統計上不顯著。汽車使

用者的社會地位（收入）比機車和公共交通使用者高。社會地位，使汽車使用者更關注氣候變化和環境問題。因此，他們往往會給公共交通用更積極的態度。然而，汽車使用者仍可以享受駕駛。所以，他們的意圖使用公共交通工具可能會低於預期。如表 8.18 和圖 8.5 中可以看出，對公共交通的意圖與態度之間的負相關提供心理矛盾的佐證。

有關意圖使用公共交通的變異，在整體樣本模式、汽車使用者的模式和機車使用者模型（表 5.2）中，分別有 72.7%，69.3%和 75%被動機因素解釋，這表明在這個分析中以這些動機因素來預測意圖使用公共交通得到很好的結果。

表 5.2 Structural model estimated results for intentions to use PT

Path	Model 1: Whole sample			Model 2: car users			Model 3: motorbike users		
	B	SD	Sig	B	SD	Sig	B	SD	Sig
PE → AT	0.22	0.026	***	0.18	0.051	***	0.25	0.041	***
PE → SN	0.25	0.025	***	0.25	0.044	***	0.21	0.038	***
PE → PMO	0.33	0.023	***	0.28	0.042	***	0.29	0.037	***
PE → PBC	0.05	0.025	*	0.02	0.004		0.09	0.029	**
AT → PBC	0.52	0.023	***	0.36	0.036	***	0.34	0.029	***
PBC → PMO	0.25	0.026	***	0.21	0.053	***	0.30	0.053	***
SN → PMO	0.30	0.026	***	0.36	0.047	***	0.34	0.042	***
AT → IN	0.01	0.018		-0.02	0.034		0.07	0.026	*
SN → IN	0.06	0.018	**	0.12	0.039	**	0.05	0.028	
PMO → IN	0.28	0.018	***	0.27	0.037	***	0.25	0.025	***
PBC → IN	0.52	0.018	***	0.46	0.041	***	0.42	0.034	***
Constant									
Total IN variance explained	72.7%			69.3%			75.0%		
Goodness of fit (GOF)	RMSEA=0.063, CFI=0.997, TLI=0.974, SRMR=0.018			RMSEA=0.069, CFI=0.994, TLI=0.956, SRMR=0.015			RMSEA=0.000, CFI=1.0, TLI=0.999, SRMR=0.006		
Sample size	1427			413			565		

PE: pro-environment value, AT: attitudes towards public transport, SN: subjective norms over public transport, IN: intentions to use public transport

Level of significance: p<0.000 '***', p<0.01 '**', p<0.05 '*'

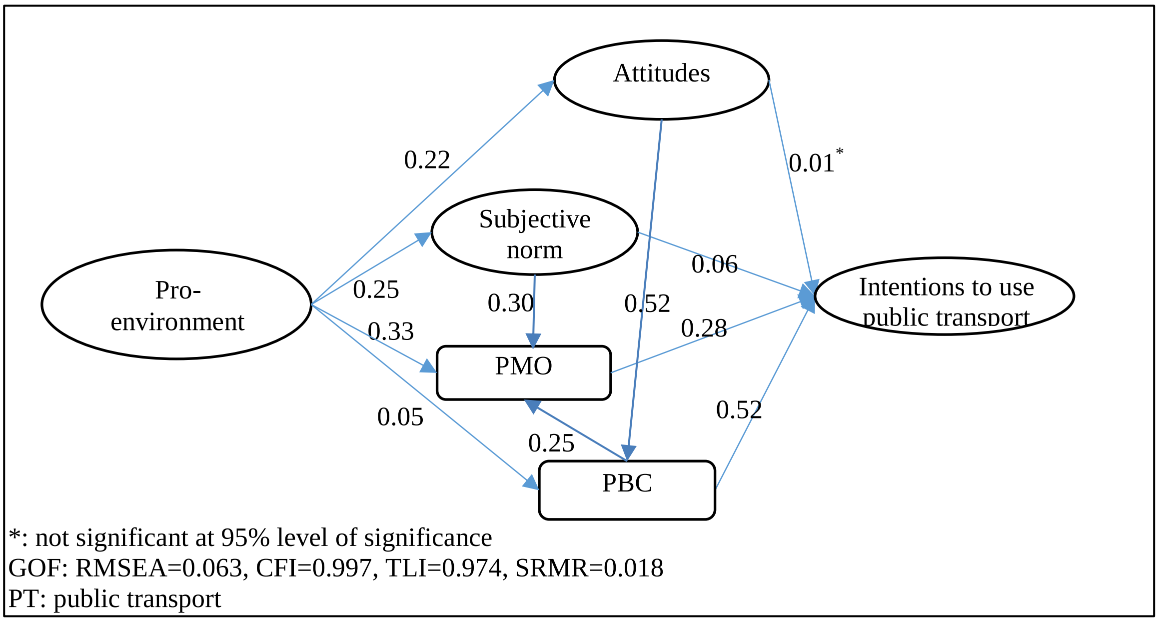


圖 5.2 Intentions to use public transport estimated results: whole samples

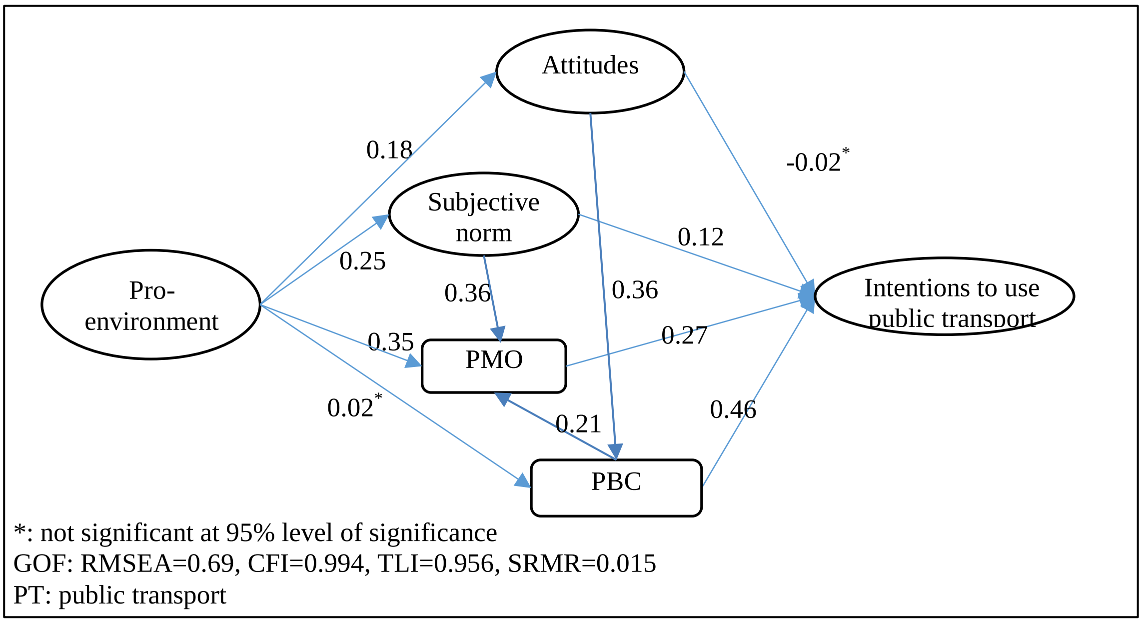
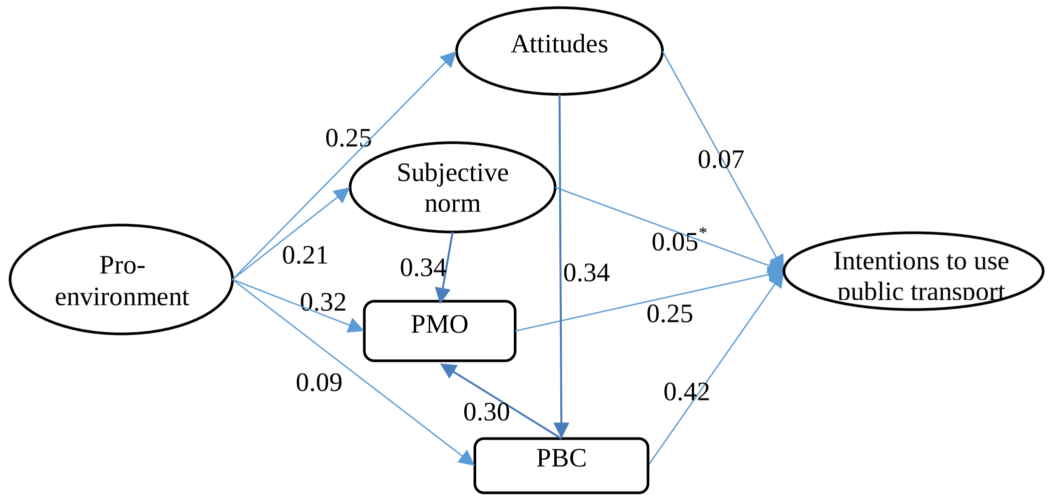


圖 5.3 Intentions to use public transport estimated results: car users



*: not significant at 95% level of significance
GOF: RMSEA=0.000, CFI=1.000, TLI=0.999, SRMR=0.006
PT: public transport

圖 5.4 Intentions to use public transport estimated results: motorbike users

5.3 結論

1. 模式結果表明，包括動機因素的運具選擇模型很好地解釋意圖使用公共交通工具選擇行為。
2. 根據估計模型的結果，感知行為控制對公共交通的方式選擇行為的影響力最強，無論是經由對意圖使用公共運輸的影響或直接使用公共交通工具的影響。因此，在策略面如何提高民眾對於公共運輸的使用，宜從感知行為控制及意圖著手，感知行為控制為民眾感受使用公共運輸的難易度，例如，增加公共運輸場站的可及性及時間的可及性，可提高民眾對公共運輸使用的感知行為控制。在意圖面，可朝提高民眾對環境議題的認知及對於公共運輸使用的道德義務，以促進個人對於公共運輸使用的意圖。
3. 對公共交通的態度並沒有表現出對意向顯著影響使用公共交通工具。這可能是因為出行模式的選擇已經成為一種習慣性行為，也或許是汽車使用者在心理上的矛盾性，即認為公共運輸的服務是滿意的，但是卻不使用公共運輸。
4. 親環境價值是對公共交通模式的動機不可或缺的因素;然而，其對意圖使用公共交通工具等影響是間接的。親環境的值對意圖和行為的影響是經由對態度，主觀規範，個人道德義務和感知行為控制等之影響。
5. 本章內容詳細英文分析請參閱附錄二。

第6章　參加國際研討會暨都市觀摩考察

6.1 參加公共交通國際聯會(UITP)會議

6.1.1 60 屆公共交通國際聯會世界大會

1. 公共交通國際聯會 (International Association of Public Transport, UITP)為全球最大的公共交通組織，於 1885 年成立迄今已 128 年，會員包括大眾運輸業者、政府部門、學術機構以及公共運輸供應商等，會員多達 3,400 單位，分佈於 92 個國家，涵蓋地鐵、公車、輕軌、城際與郊區鐵路及水上運輸等各種公共交通系統。
2. 公共交通國際聯會(UITP)每兩年召開一次全球聯會(World Congress)，該聯會近年積極推動之目標為希望在 2025 年全球公共運輸使用率成長一倍(Doubling public transport market by 2025, PTX2 by 2025)。
3. 為達到公共運輸使用率倍增之目標，該聯會自 2011 年起舉辦 Growth with Public Transport International Awards, 透過獎項競賽，選拔全球最佳的公共運輸案例，並於兩年一度全球聯會進行頒獎，並分享公共運輸推動經驗。
4. 102 年 2 月將 2010 年起臺灣推動「公路公共運輸發展計畫」成果撰寫「Surface Public Transport Reconstruction Campaign in Taiwan, Towards PTX2 by 2025」計劃書提送參加”Growth with Public Transport 2013 International Awards”獎項之政治承諾(Political Commitment)項目評比。2013 年全球總計有 43 個國家，超過 240 個計畫參加該獎項評比。
5. 該計畫經亞太區(Asia-Pacific)初評為亞太區政治承諾獎項參賽單位中最優計畫，超越新加坡、馬來西亞、澳洲及日本等參賽單位，並進入全球前 20 名之最後入選名單(finalists)。
6. 交通部入選 Global Award Finalist，於 5 月 26 日大會開幕逐一唱名，讓全球代表看見臺灣在公共運輸發展成果，並獲贈獎牌一面。
7. 5 月 29 日在該會議的亞太區會議(Asia-Pacific Session)中發表「Attempt to Change Mobility Behavior － Holistic Public Transport Planning, the case of Taiwan」，報告臺灣 3 年來推動公路公共運輸的成果及未來挑戰。
8. 5 月 29 日會亞太區會議簡報結束後，並接受公共交通國際聯會(UITP) 秘書長 Alain Flausch 親自頒發 Growth with Public Transport 2013 International Awards 亞太區政治承諾獎(Political Commitment)獎牌。
9. 臺北捷運公司報名參加”Growth with Public Transport 2013 International Awards“ 的顧客服務獎項(Customer Service Awards)，亦進入最後入選 20 個名單(Finalists)及獲頒亞太區顧客服務獎最優獎項。

圖 6.1 開幕大會-交通部與捷運公司入選 Finalists

圖 6.2 UITP 秘書長頒亞太區政治承諾獎

圖 6.3 簡報臺灣公共運輸發展成果

圖 6.4 獲獎合影

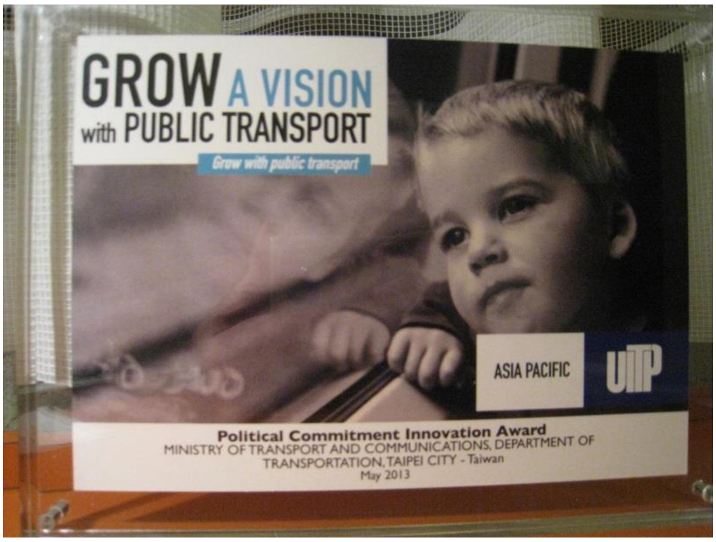


圖 6.5 Asia-Pacific Political Commitment Innovatio 獲獎獎牌

圖 6.6 Political Commitment Global Award Finalist 獎牌

圖 6.7 展覽會

6.1.2 參加第 61 屆公共交通國際聯會(UITP)世界大會

1. 公共交通國際聯會 (International Association of Public Transport, UITP) 是目前全球最大的公共交通組織，會員遍布全球 92 個國家。該組織每兩年舉辦一次 World Congress。此次會議臺灣總計有 5 位人員與會，包括:臺北捷運公司 董事長 賀陳旦、臺北捷運公司 主任 林榮輝、臺北市政府捷運局 總工程司 張台光、臺北市政府交通局 股長 黃于嘉及本人。
2. 7 月 10 日上午 11am-12.30pm 於 Parallel Session 20 – Open, big and smart data 簡報「公車動資訊系統如何改變臺北都會區公車服務」‘How Bus Information System Transform Bus Service in Taipei’，簡報分享臺北都會區引入公車動態資訊系統後在資訊整合、民眾服務、資訊共享及公私部門在公車管理變革等四項重要課題，最後並談到正在執行中的如何運用悠遊卡刷卡資料及公車動態資訊建立公共運輸乘客旅次起訖資訊(Origin and destination matrix)，該資訊對未來臺北市將推動公車路線調整及票價變革的重要性，簡報內容如附件一。
3. 同一場會議也包含倫敦交通局 Mr Vernon EVERITT, Managing Director Customer Experience, 簡報倫敦對於交通大數據資料應用’Innovation in London’s Transport: Big Data as Game Changer’，其中相當多的大數據資料應用可作為參考。倫敦預估至 2030 年都市人口數將達 1000 萬人(maega city)，目前每周公車旅次有 4600 萬旅次，地鐵旅次有 2500 萬旅次。簡報重要內容及案例如下:
   1) 倫敦大數據交通資料來源包括: Oyster card (倫敦交通票證)刷卡數據、公車動態資訊、地鐵列車資訊、道路交通資訊、乘客回饋資訊及社會媒體資訊(such as twitter)。
   2) 倫敦交通局目前蒐集有超過 400 萬位乘客的電子郵件信箱，因此，及時交通資訊可透過該管道傳送給乘客。

3) 倫敦交通局也透過大數據資料進行公車乘客旅次起訖資料(Origin and destination matrix)推估，並利用該資料了解公車路線在不同時段及路段的載客量，也運用該資料進行公車路線調整。

4) 倫敦交通局在 2014 年運用公車乘客刷卡及公車動態資訊，分析橋梁進行施工封閉時，受影響的公車乘客數量及型態，以評估如何減輕應橋梁封閉對公車乘客的影響。

5) 倫敦公共交通票證(Oyster card)如有誤扣款情況，經乘客上網申訴同意後，目前提供在地鐵刷卡時，刷卡機辨識確認後，自動將誤扣款返還乘客之作法。

6) 此外，倫敦交通局也透過公車票證刷卡資料分析地鐵站旅客型態，例如: regular frequent user, occasional user (residents), irregular frequent user and occasional user (visitor)。並利用 traveller's pattern 來進行管理措施已影響交通需求型態。

4. 同場會議另有資訊產業界新創公司(Starup) Moovit 簡報該如何整合數據資料，簡報主題' The power of crowdsourced technology to change the transit experience'。Moovit 使用資訊包括官方資訊及網路上群眾資訊(crowdsourced live updates)來提供精確的城市公共交通資訊，目前提供全球 600 多個城市的公共交通資訊。目前 Moovit app 全球已有超過 2000 萬使用者，幾乎每日均有新的都市加入該 app 服務。該公司網站 http://moovitapp.com/。

   Moovit app 重要資訊如下

   ● 20M+ users

   ● 10M+ user-generated reports each day

   ● Growing 1M+ users/month

   ● 600 cities -> 55 countries -> 36 languages

   ● 60+ U.S. cities with more than 1.5M users

   ● 60 employees in 6 countries

   ● Product, Operations, R&D HQ in Israel

   ● Global Marketing and Partnerships HQ in San Francisco

5. 本場會議'Open, Big and Smart Data' 吸引滿場聽眾，誠如該場次主持人，公共交通國際聯會資訊技術委員會主席，公開資料及大數據應用在交通方便日益受到重視，臺北市在公車動態資訊建立完成即公開資料與民間介接，衍生開發出許多手機軟體，資訊開放使用之作法及成果，使臺北能有此次機會與倫敦交通局及資訊業界一起在這個公共交通全球最大的會議中一起分享成果。

6.1.3 參加 16th FETRANSPOR Bus Conference

1. 16th FETRANSPOR Bus Conference

1) 本次研討會選址於巴西里約舉辦，主要著眼於 2016 年奧運會將於里約舉辦，透過研討會了解巴西如何因應 2016 年奧運的交通疏運。

2) 簡報主題「**Bus System Reform in Taiwan**」，介紹台灣近年來推動的公路公共運輸發展計畫，讓國際的公共交通專業人員了解，如何透過有限的預算，大幅改善公車與公共運輸服務品質，提升公共運輸的 accessibility and mobility。

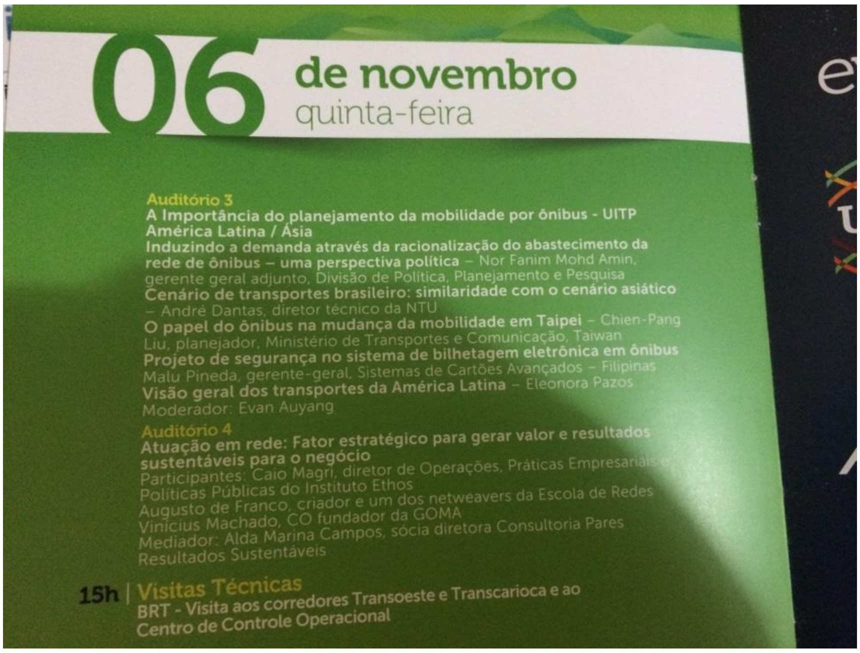


圖 6.8 會議議程

圖 6.9 演講者合影

2. 參觀里約 BRT (Bus rapid transit) 建設

1) 里約 BRT 路網圖

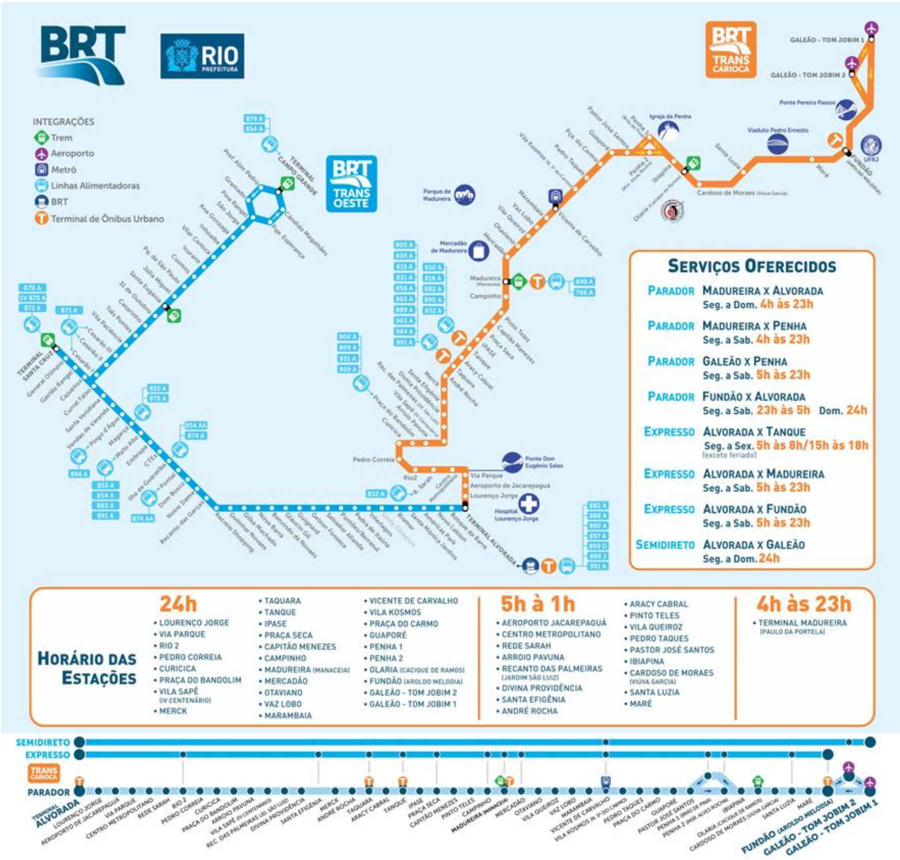


圖 6.10 已營運之 BRT 路線圖

2) Alvorada Bus Terminal

a. Alvorada 公車站為兩線 BRT 公車路線交會點，也是許多其他公車路線匯集站。為 BRT 營運，而增設 BRT 車輛調度站。

3) BRT 車輛與車站設施

a. BRT 車輛採用雙節公車，車身長度 18 公尺，每輛車座位 58 位，站位 120 人。
b. 專用月台，月台高度與車輛地板高度相同，無高差，提供無障礙服務。
c. 採進站刷卡付費方式，以加快乘客乘車及下車速度。
d. BRT 車道在車站區增設超車道，提供不停靠站之 BRT 車輛可以不需停等，快速通過站區。
e. 一律使用電子票證搭車。

圖 6.11 BRT 車輛採用雙節公車

圖 6.12 BRT 調度場站

圖 6.13 提升 BRT 車站月台

圖 6.14 BRT 營運採用進站刷卡付費

圖 6.15 BRT 車站入口

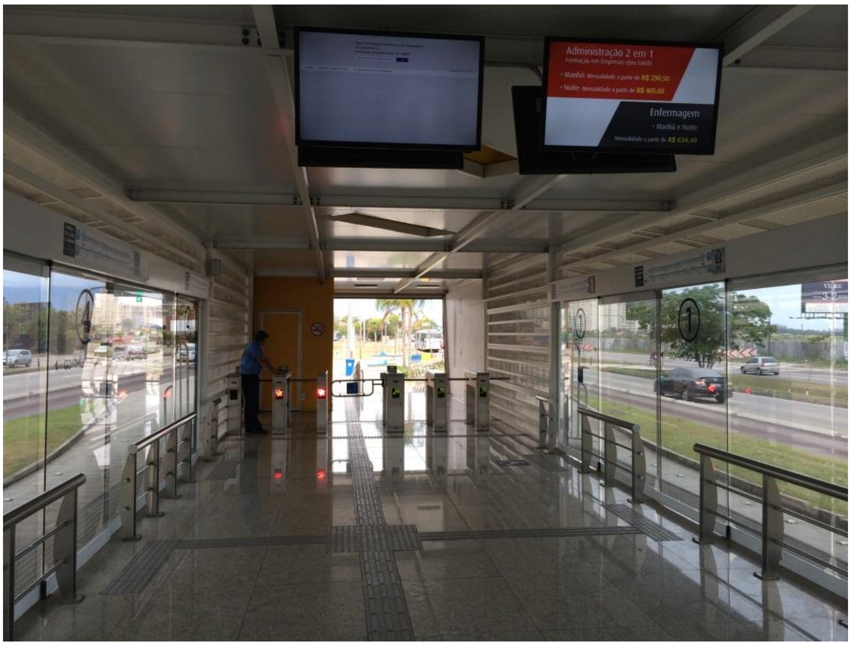


圖 6.16 BRT 站內設施

圖 6.17 Platform-level boarding

圖 6.18 車站區設置超車道

圖 6.19 不停站車輛行駛超車道穿越站區

圖 6.20 公車與 BRT 電子票證

4) BRT 營運控制中心: 為監控及調度 BRT 車輛，由 BRT 得標之營運業者於 Alvorada Bus Terminal 處設置 BRT 控制中心。

圖 6.21 BRT 控制中心入口

圖 6.22 BRT 控制中心

圖 6.23 下午尖峰 BRT 搭乘人潮

3. 里約公車營運觀察

1)巴西物價相對而言挺貴的，巴西人均ＧＤＰ約 11,000 美金（台灣 20,000 美金)，但是，巴西物價並非台灣的一半，跟台灣差不多，比如餐廳的玻璃罐裝啤酒約 110 台幣。這或許也是台灣的所得以購買力平價(Purchasing Power Parity, PPP)換算已達 41,000 美金，而巴西僅約 15,000 美金。當然，如果以歐洲的所得而言，這兒物價就不算貴，所以，或許物價是被觀光客炒高的。

2) 再看看公共運輸票價，里約的公車及地鐵均以計次收費，每次搭乘 公車 3 Reals(約台幣 36 元)，地鐵 3.5 Reals（約台幣 42 元），如果再加計所得水準，可以想見票價之貴，世足賽前就曾為了公共運輸運價太高而發生過罷工抗議事件。

3) 公共運輸票價不僅高，也反映其不合理，無論里程長短都一樣票價，但是里約真的很大，而且市區交通管理感覺很糟，塞車狀況非常嚴重，週三及週五分別搭公車從里約市中心往返里約會展中心，公車單程搭了快 2 小時(塞車塞了很久)票價也是 3 元，星期六搭公車到 sugerloaf,搭了約 10-20 分鐘，票價也是 3 元。

4) 公車及地鐵票價不合理，部分反映在票價結構及政府補貼，據開會期間與巴西公車公會高層人員聊天，他提到，老人及學生免費，但是政府並沒有給公車公司票價補貼，該票價則分攤到其他一般使用者身上。

5) 票價不合理外，或許為降低失業率，或者是避免逃票，巴西公車上還有配置車掌小姐（先生），負責收錢找錢。

圖 6.24 里約公車配置車掌小姐

6) 里約已使用電子票證，每台公車都配置驗票機，但是，電子票證使用率不高，且驗票機驗票速度異常緩慢，我感覺約要 2 秒，跟另一位德國人談到這件事，他認為驗票時間約 5 秒，超級慢。

7) 談到安全問題，該公會高層人員提到巴西人喜歡燒公車，最近 18 個月有 500 輛公車被蓄意縱火燒掉（沒有人員傷亡，縱火的人會要求車上人員均離開），燒車在沒有人員傷亡的情況下，只是輕微犯罪，拘禁一天就放出來了。

8) 再來公車服務，如此高的公車票價，但是，多數（應該一半以上）里約的公車沒有冷氣，看出來已經逐步在汰換，但是，汰換速度似乎太慢，這兒濕熱氣候，搭公車宛若 20-30 年前台灣搭公車。

9) 里約公車司機開車速度驚人，猛起步、急煞車是公車司機常態，公車司機經常超車，接近公車站也不會減速，過站不停是常有的事，所以我學習當地人，當看到你要搭的公車時，一定要站出來猛力給他揮手。公車站沒有公車路線圖或資訊，搭公車全憑經驗及其他方法取得資訊。

6.1.4 參加 2nd UITP MENA Public Transport for Large Events Summit & Showcase

1. 受邀簡報「How Taipei Manages 2010 Flora Exposition and Future Universiade 2017」，報告臺北市 2010 年國際花卉博覽會在妥善的公共運輸規劃與配置，有效降低民眾使用私人運具參觀花博，超過 70%參觀者使用公共運輸工具參觀花博。對未來

2017 世大運(Universiade)已進行先期交通規劃，對於參賽者、裁判及貴賓，將提供及戶(door to door)的交通服務，對於觀眾則規劃以公共運輸為主之交通策略。

圖 6.25 演講者合影

2. Qatar 為主要產油國，因此該國油價相對而言非常便宜，每公升汽油約 1 Riyal (約台幣 8.6 元)，交通工具主要以汽車為主，公共運輸並不發達。目前在 Doha 市中心區由於都市發展集中，並以小汽車為主要運輸工具，因此道路車流狀況相當擁塞。
3. 該國爭取到 2022 年世界杯足球賽(FIFA)主辦權，為使世足賽順利舉辦，故召開本次研討會，參考國際都市如何運用公共運輸以因應大型活動期間交通維持。
4. Qatar 以預計在 2022 年世足賽前引進 2000 輛新公車，同時投資 1590 億 Riyals(約 441 億美金)發展軌道運輸系統，包括市區輕軌系統(light rail)、捷運系統(metro)及鐵路運輸(rail)系統。高速公路系統將由目前的 2500 公里擴展至 8500 公里。

6.2 參加學術研討會

6.2.1 參加香港運輸學會研討會(HKSTS)

1. 於 2015 香港運輸學會國際研討會(HKSTS-2015)簡報「土地使用在不同地理範圍對於運具選擇之影響」'Analysis Of Land Use Effects At Different Geographical Scale On Mode Choice Behaviour in Taiwan'。

圖 6.26 HKSTS 簡報

2. 與臺灣、香港及大陸三地交通運輸學界進行學術交流，瞭解目前關切之研究課題與方法。

6.2.2 參加 95th Transport Research Board Annual Conference

海報簡報研究成果「Applying multilevel MNL model to analyse land use influence mode choice behaviour in Taiwan」，如附照片。

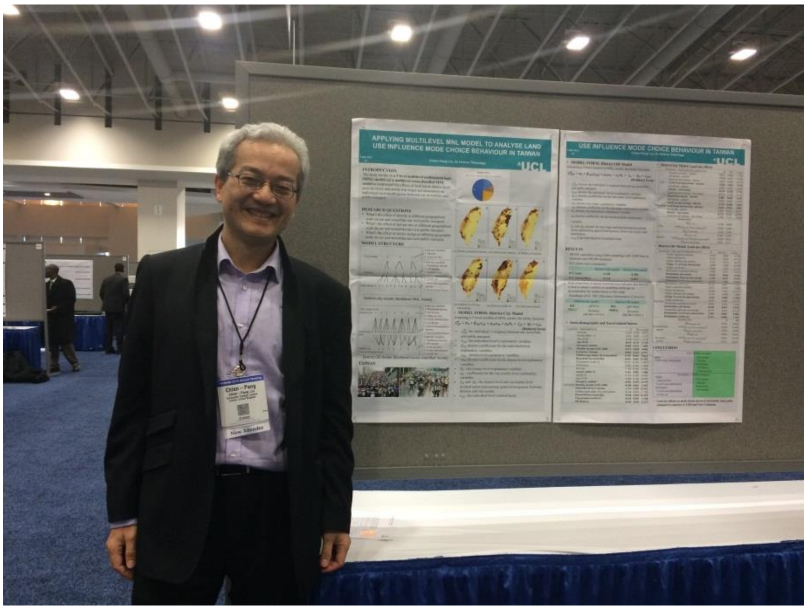


圖 6.27 海報簡報

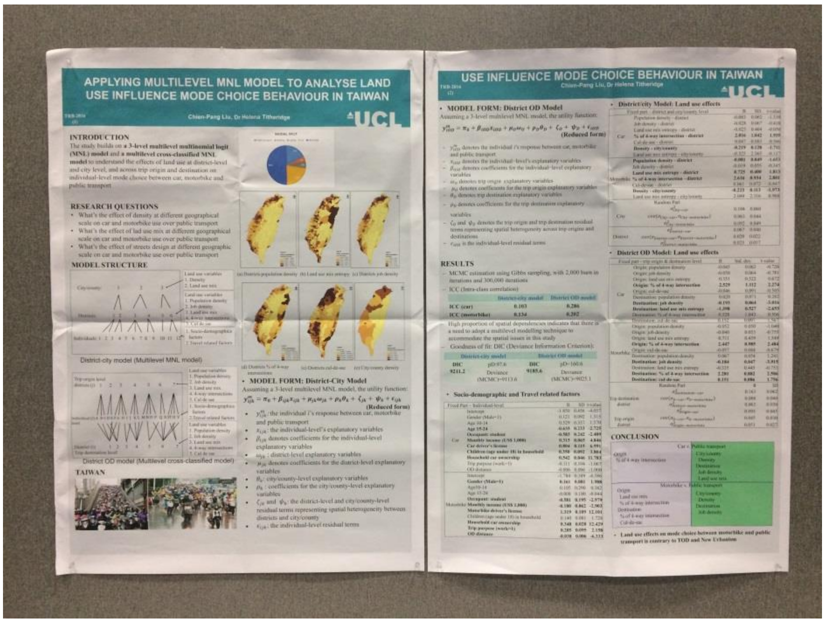


圖 6.28 展示海報

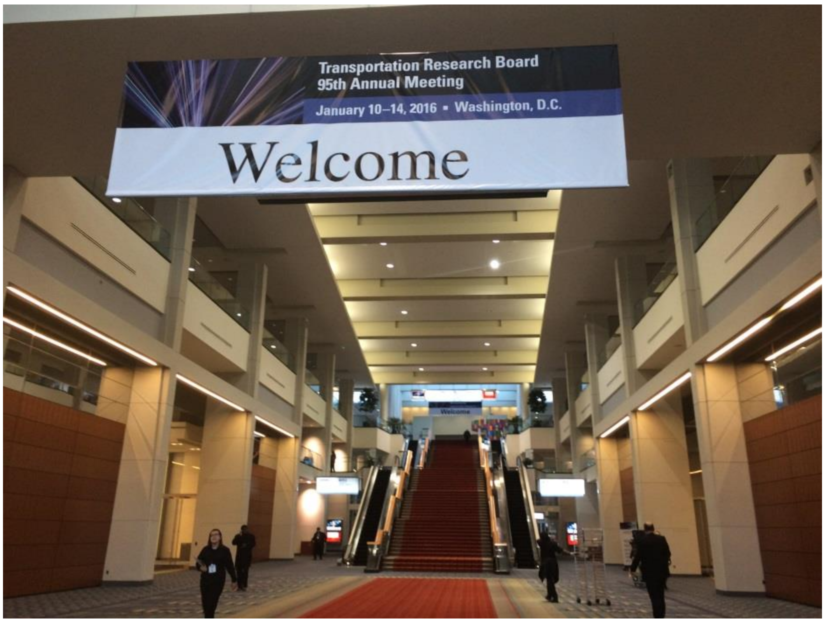


圖 6.29 會場入口

6.3 都市公共交通及自行車與步行環境觀摩考察

6.3.1 法國巴黎

1. 公共自行車（Vélib）

 1)法國巴黎公共自行車 Vélib'從 2007 年正式營運，使用電子無人自動化管理系統，依照電腦螢幕指示操作可輕鬆租借自行車，且 24 小時不打烊，提供巴黎市民和遊客更便捷的短距離交通服務。

圖 6.30　巴黎公共腳踏車(1)

2) Vélib'為 3 段變速，具防滑把手，防盜裝置，自動開啟的前後燈裝置，可調式坐墊，輪子和踏板具反光片，車體前方設有購物籃方便使用者置放物品，適合 14 歲以上的使用者。

圖 6.31　巴黎公共腳踏車(2)

3) Vélib'目前已有超過 20,000 台公共自行車，1800 個租賃站，約每 300M 即設有一租賃站。

4) Vélib’ 租借費率如下表所示。

項目	1 年 Vélib' Classic	1 年 Vélib' Passion	7 天 7-day ticket	1 天 1-day ticket
註冊費	€29	€39	€8	€1.7
優惠	前 30 分鐘免費	前 45 分鐘免費	前 30 分鐘免費	前 30 分鐘免費
優惠時間後的第一個半小時 1st additional half-hour	€1	€1	€1	€1
優惠時間後的第二個半小時 2nd additional half-hour	€2	€2	€2	€2
之後每半小時 Any further time, per half hour	€4	€4	€4	€4

備註:

- 針對 14~26 歲族群另有較優惠的租借費率。
- 公共自行車若還車至較冷門的 Bonus V+ 租賃站，可於下次使用時獲得額外的 15 分鐘免費。

5)巴黎市區自行車道的配置相當多樣，或採用自行車專用道、或與行人共用車道，或與其他運輸工具混合使用車道。

圖 6.32 市區車道配置

圖 6.33 行人及腳踏車標示

6) 為使自行車的騎乘更安全，巴黎市區在路口會特別搭配標誌及標線的配置，提醒使用者多加注意。

圖 6.34 市區路口警示標示

2. 汽車共享(Autolib)

1) 法國的 Autolib 計畫為全球第一個都市建置電動汽車共享的案例，該計畫推動進程如下:

a. 2010 年 9 月 Autolib 計畫推動委員會同意委託 Bollore 集團執行這項計畫，為期 12 年。

b. 2011 年 1 月 25 日正式簽約

c. 2011 年夏天開始進行設備建置，成立客服中心。

d. 2011 年 10 月 2 日 33 座公共車輛租借站及 66 輛電動車啟用營運。

e. 2011 年 12 月 5 日完成 250 座公共車輛租借站及提供 250 輛電動車。

f. 2012 年 6 月完成 1100 座公共車輛租借站及 1740 輛電動車設置(如下圖)。預計至 2014 年將完成 6600 座租借站及提供 3000 輛電動車。

g. 該計畫一項特色為，車輛租借站之充電設備不僅提供汽車共享之電動車輛充電使用，也提供給私人電動車輛(相同充電設備者)付費充電。

h. 參考網站：https://www.autolib.eu/en/our-commitment/urban-revolution/

2) 租借流程

a. 汽車共享之車輛租借必須先登入會員，可於線上、在租借站 Kiosk 或服務據點加入會員，登入會員必須準備駕照、身分證明文件及信用卡。

b. 加入會員可取得一個 RFID 徽章(RFID badge)，憑此徽章即可進行車輛租借。

3) 費用

a. 登記一年會員，會員費每年 120 歐元，租用車輛每 30 分鐘 5.5 歐元

b. 登記一個月會員，會員費每月 25 歐元，租用車輛每 30 分鐘 6.5 歐元

c. 登記一周會員，會員費每周 10 歐元，租用車輛每 30 分鐘 7 歐元

d. 臨時會員，租用車輛每 30 分鐘 9 歐元。

e. 該租借站亦提供私人電動車充電服務，會員費用每年 15 歐元，充電每小時 1 歐元

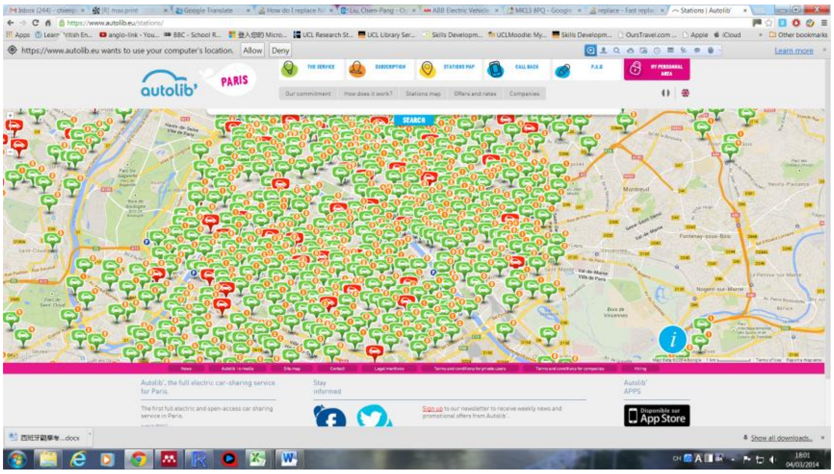


圖 6.35 租借格位散布

圖 6.36 汽車共享設施

圖 6.37 路側汽車共享租車流程說明

圖 6.38 汽車共享租車 KIOSK

圖 6.39 私人車輛共用充電柱

6.3.2 德國鐵公路交通網路

1. 德國慕尼黑除了鐵路系統外，還包括 S-Bahn、U-Bahn、Tram 和 Bus，共同交織出綿密且便利的大眾運輸系統。

2. 慕尼黑大眾運輸系統票種相當多元，有 Single Ticket、Stripe Ticket、Single Day Ticket、Partner Day Ticket、CityTourCard、Weekly and Monthly Tickets 等，依不同費率圈(Inner District, Munich XXL, Outer District or the Entire Network)而有不同的票價，多元的票種及票價滿足不同民眾的需求。

3. 慕尼黑大眾運輸系統票證與票價高度整合，在票種許可的範圍內，購票一次即可搭乘多種大眾運輸系統，不同運具的轉乘及銜接都也都相當方便，提高民眾使用大眾運輸系統的意願。

4. 德國車站入口無驗票閘門，完全採信任制度。在慕尼黑如購買 Single Trip Tickets, Stripe Tickets and Day Tickets 使用前必須先在驗票機(ticket machines)上打印日期，否則即視為無效票。

5. 民眾可以在特定時段攜帶自行車搭乘慕尼黑的 S-Bahn 、U-Bahn 和區域鐵路(不得攜帶自行車搭乘的時段為周一到周五上午 6 時到 9 時及周一到周五下午 4 時到 6 時)，但必須另行付費，Bycycle Day Ticket 的費率為 2,50 €，車廂內設有彈性空間方便自行車停放。

6. 慕尼黑建有自行車專用道，騎乘時不會與車爭道、與人爭道。

7. 慕尼黑部分 Tram 使用獨立路權，設於道路中間，軌道兩旁鋪設突起的地磚，將 Tram 的行駛空間與其他車輛隔離，Tram 的兩側設有汽車道，車道最外側另設有自行車專用道及人行道。

8. 慕尼黑部分 Tram 的軌道以平面方式鋪設，與一般車道並無高差，可與 Bus 共用路權。

9. 慕尼黑 Tram 的候車亭標示、路線圖以及到站資訊系統都非常清楚詳細，提供民眾完整的交通資訊。提供夜間服務的 Tram 及公車，在站牌上路線名稱前方會標註貓頭鷹圖樣，以供民眾識別。

10. Wurzburg 中央車站前的交通場站配置，正前方是 Tram 車站，右側為公車站，為公共運輸轉乘規劃做了很好的示範，由於 Tram 與公車可以非常方便的與鐵路車站銜接，因此，自用車完全不能進入車站區域，車站前保留了很大的廣場。

11. Wurzburg 的 Tram 軌道以平面方式鋪設，允許 Tram 以外的車輛行駛在 Tram 的軌道上，行人亦可穿越軌道，充分呈現街道的活潑性，為生活化街道非常好的典範。

6.3.3 盧森堡、比利時綠色運輸系統觀摩考察

1. 盧森堡

1) 盧森堡大公國擁有一個規劃完整的全國自行車道騎乘路網，縱橫交錯穿越各個主要城市、出行地點和歷史遺跡，這個全國性的自行車路網乃由 23 條主要騎乘路徑所組成，總長度約 950 公里，目前已有 600 公里投入公眾使用。

2)盧森堡市公共自行車稱 vel'oh，3 段變速，可調式坐墊，適合 14 歲以上的使用者，車體具備寬大擋泥板可避免褲腳或裙襬捲入受傷，前方設有購物籃方便使用者置放物品。

3) 盧森堡市公共自行車 vel'oh 使用電子無人自動化管理系統，依照電腦螢幕指示操作可輕鬆租借自行車，可查詢其他租借站可供租借的車輛數，並可使用交互式地圖查詢附近街道和車站。

4) 盧森堡市公共自行車 vel'oh 於 2008 年設有 25 個租借站，擴建至目前共設有 72 個租賃站，約每 300M~400M 即設有一租賃站。vel'oh 租賃站歷年擴建情形如下表所示：

時 間	站 數
2008 年 3 月	25
2008 年 8 月	28
2008 年 11 月	32
2009 年 3 月	43
2009 年 7 月	47
2010 年 3 月	54
2011 年 5 月	64
2011 年 7 月	72

5) 盧森堡市公共自行車 vel'oh 的租借費率如下表所示。

項目	**1 年**	**7 天**

註冊費	€ 15	€ 1
前半小時	免費	免費
前半小時以後每小時	€ 1	€ 1
24 小時最多€5	€ 5	€ 5

6) 盧森堡市四處可見專用自行車道，騎乘自行車時不會與車爭道、與人爭道。

2. 比利時

1) 比利時布魯塞爾擁有 Train、Streetcar、Metro 和 Bus，共同交織出綿密且便利的大眾運輸系統。

2) Streetcar 軌道以平面方式鋪設，允許以外的其他車輛行駛在 Streetcar 的軌道上，行人亦可穿越軌道。

3) 布魯塞爾在自行車的政策規畫非常全面，不管是自行車專用道的建置、路標號誌的設置、騎乘路線的規劃及自行車停放等相關設施都相當完善，希望自行車成為居民每天的交通方式，並承諾在 2020 年將自行車在各交通工具中所佔比例提升至 15%、事故死亡率減少 50%。此外，將每週五訂為「Friday Bikeday」，鼓勵人們每週少開一天車，改騎自行車上班；同時，為鼓勵公務員使用自行車，每年編列預算購買 30 個新自行車供公務使用。

4) 布魯塞爾公共自行車稱 Villo，7 段變速，可調式坐墊，車體具備寬大擋泥板可避免褲腳或裙襬捲入受傷，前方設有購物籃方便使用者置放物品。

5) 布魯塞爾公共自行車 Villo 使用電子無人自動化管理系統，先用信用卡做押金的設定，帳戶內至少要有足夠餘額(€150)，接著依照電腦螢幕指示操作可輕鬆租借自行車，約每 450M 即設有一租賃站。

6) 布魯塞爾公共自行車 Villo 的租借費率如下表所示。

項目	1 年	1 週	1 天
基本費	€32	€7.5	€1.6
0-30 分鐘	免費	免費	免費
30 分鐘-1 小時	+ €0.5	+ €0.5	+ €0.5
1 小時-1.5 小時	+ €1	+ €1	+ €1
1.5 小時-2 小時	+ €2	+ €2	+ €2
大於 2 小時後每 30 分鐘	+ €2	+ €2	+ €2

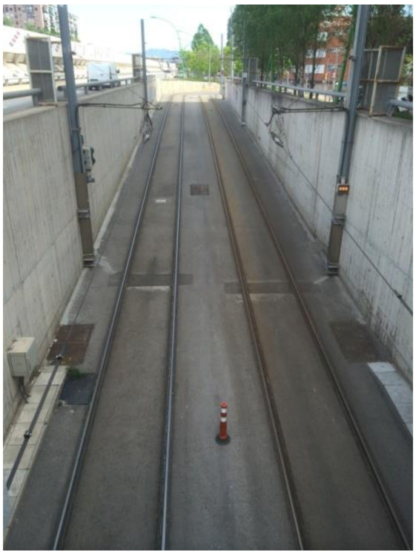
6.3.4 西班牙觀摩考察

1. 西班牙巴塞隆納輕軌 Tram

1)巴塞隆納的輕軌包含兩個路網: Trambaix 和 Trambesós，共有 6 條路線(T1~T6)，56 個車站，軌道總長 29.2 公里。車輛長 32 公尺，寬 2.65 公尺，最高時速可達 70 公里/時。

2) 輕軌同時包含兩種票證系統，若搭乘開放式票證系統，旅客必須在上車前持有有效車票，並在車上驗票機上自行打票。若搭乘 T5 輕軌，在 Espronceda, Sant Martí de Provençals 和 Besòs 這三個車站入口設有驗票閘門，上車後即無須再打票。車上常見稽查人員，一旦被查到未持有有效票，罰款 100 歐元。

3) T5、T6 線輕軌的 Besòs 車站設於平面下，軌道以類似隧道方式設計，從地面上緩坡往下至月臺，月臺上方地面可見微微隆起，坡度平緩。本車站為雙軌路段，入口設有驗票閘門，軌道兩側設有月臺，軌道上方開有天窗引進自然光源節省電力，一旁即為地鐵 Metro，方便旅客轉乘。

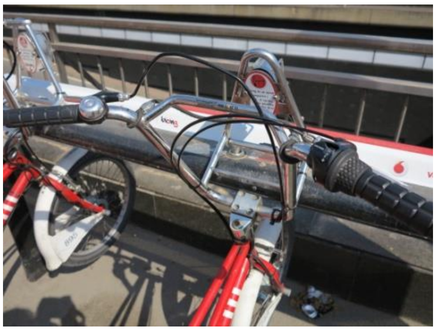



4) T4、T5、T6 線輕軌 Glòries 車站位於平面，無月臺門系統，軌道設置於道路中央，車站以中央側式站臺的方式設於軌道兩側，往外兩側設有自行車專用道並以高起的路緣石將自行車騎乘空間與其他車輛分隔，最外側是公車專用道、車道跟人行道，由於乘客搭車必須穿越車道，設有行人穿越道以維安全。


5) T4 線輕軌的端點站 Ciutadella/Vila Olímpica 車站採用側式月臺，軌道設置於道路中央，旁邊並無一般車道，月臺與原有的人行道空間結合，搭乘輕軌時無須穿越車道，並於部分軌道區域植入草坪，增加美觀。


6) 為維護行人穿越輕軌軌道的安全，在輕軌行駛的軌道上設有行人穿越號誌，或在行人穿越道上以彩色鋪面警示穿越區域，提醒輕軌駕駛及行人多加留意。

2. 西班牙巴塞隆納公共自行車系統 Bicing 自 2007 年營運至今，目前共有 6,000 臺 Bicing，420 個租賃站，該服務僅供西班牙居民使用。使用前必須上網註冊，年費€47.16，使用前 30 分鐘免費，之後每半小時€0.74，每次最多使用 2 小時，超過 2 小時，每小時將罰款€4.49，一再違約者將被停止使用該服務。目前已有超過 99400 註冊人數，平均每次使用時間約 13 分鐘。遊客若想騎單車漫遊巴塞隆納，有許多其他自行車出租系統可選擇，惟費率較高。



3. 西班牙市區具有相當多樣化的自行車專用道: 或設置單邊雙向自行車專用道、單邊單向自行車專用道；或將自行車專用道劃設在道路中央、車道外側、人行道上；或鋪上彩色鋪面、或以明顯標線、標誌標示其範圍、或以高起的路緣石、抑是釘上反光條確實區分自行車道，在在顯示對自行車路權的重視。











4. 西班牙無障礙環境的設計也令人印象深刻。平整寬闊的人行道、人行道及道路路面高低差小、路緣斜坡設計平順，採用低底盤公車，輕軌及地鐵車廂與月臺間隙小、高差不大，在公車停靠站及地鐵無障礙車廂停靠處加設可移動式無障礙斜坡，讓車廂底盤與月臺齊平，真正讓身障人士在無障礙的環境中行動自如。



5. 巴塞隆納的夏天跟台灣一樣炎熱，因此人行道兩側多有植栽，加上寬敞的人行道，提高民眾步行意願。

6.3.5 挪威及丹麥觀摩考察報告

1. 丹麥：

   1) 哥本哈根公共運輸相當發達，市內 buses、 trains 和 Metro 的路網規劃完善，欲知不同運具間轉乘時間、地點、價格及方式，可透過丹麥國鐵 http://www.dsb.dk/路程規劃系統來查詢，並可將規劃結果傳送到 E-mail 或手機，節省紙張印出，該系統亦將每個旅程選擇搭乘公共運輸或自行開車所製造的 CO_2 排放量清楚列出，讓我們知道每趟旅程若使用大眾運輸工具能減少多少 CO_2 排放量，能為環境盡多少心力。

   2) 哥本哈根車站入口無驗票閘門，採信任制度，上車前自行在月台的車票打印機打印，若車上查票無法出示有效車票，罰款高達 750 克朗。

3)哥本哈根交通採分區計費，且票種相當多元，有 Discount cards、24-hour ticket、City Pass 等等，可依自己的規劃購買適合的交通票證，並在票種許可的範圍內，任意搭乘公車、地鐵或火車，不同運具的轉乘及銜接都相當方便。

4) 哥本哈根為促進觀光，發行結合交通與門票的 CPH Card，擁有該卡，可免費進入 60 個以上的博物館及景點，並無限次搭乘大根本哈根區所有的公車、地鐵或火車，在費用高昂的丹麥，〝CPH Card〞是個很划算的選擇。

5) 丹麥國鐵 DSB 提供早鳥票，稱為 Orange Tickets，可在出發前 2 個月開始訂購，只要做好規劃，即可享有高達 60%折扣。

6) 丹麥不論是 bus、 train 或 Metro 的無障礙設施都相當完善，部分列車設有專門無障礙車廂，並在車廂外觀清楚標示，方便身心障礙人士、攜帶娃娃車或自行車民眾辨識及上車。

7) 丹麥 Odense 是安徒生的故鄉，該地區行人專用號誌的圖形竟是將安徒生人像剪影取代制式圓形圖案，觀光與文化的結合，頗具創意與巧思。

2. 挪威：

1) 挪威國鐵 NSB 亦提供早鳥票，稱為 Minipris Tickets，無論旅程的長度，票價從 NOK 249, NOK299, NOK 399,到 NOK499 不等，越早訂購，價格越低。

2) 公車停靠站提供公車到站時間顯示，相當準確。

3) 挪威國土狹長，全境高原、山地、冰川、湖泊、峽灣自然景觀豐富，若欲拜訪挪威但時間有限的情況下，可規劃 1 到數日搭乘各種交通工具走完 Oslo-Myrdal-Flåm-Gudvangen-Voss-Bergen 這段行程，一般稱之為「Norway in a nutshell」，即可在短時間體驗挪威峽灣及不同自然景觀之美。以下是「Norway in a nutshell」的觀光規劃：

地點及交通工具	**時　間**
Train from Oslo s	08:05
To Myrdal	12:44
Train from Myrdal	13:00
To Flåm	13:50
Boat from Flåm	15:10
To Gudvangen	17:20
Bus from Gudvangen	17:25
To Voss	18:20
Train from Voss	18:35
To Bergen	19:53

上述運具種類看似繁複，事實上從火車到渡輪到公車等等的轉乘都相當方便，搭乘的時間及地點銜接地恰到好處，標示十分清楚，一點都不怕迷路。

4) 「Norway in a nutshell」其中一段從 Myrdal 到 Flåm 的 Flåm Railway 是世界上最陡的鐵路之一，1923 年開始建造，接近 20 年完工，總長 20.20 km 公里，接近 80%的路線坡度為 55‰，傾斜度 1：18，不得不讓人讚嘆 Flåm Railway 的鬼斧神工。要了解更多關於 Flåm Railway 的歷史及其技術發展，可利用在 Flåm 短暫停留時間，到距離 Flåm 車站 100 公尺遠的 Flåm Railway Documentation Centre

免費參觀，且 Flåm Railway Documentation Centre 會配合火車班次開放，觀光規劃之完整可見一般。

5) 奧斯陸公共運輸工具以 electrical tram 和 bus 為主，票種相當多元，可依需要自行在自動售票機購買 Single ticket pre-bought、24-hour ticket、7-day ticket 或 30-day ticket 等，也可購買結合交通和觀光的 Oslo Pass，若上車後向司機只能購買 Single ticket，且票價較 Single ticket pre-bought 高。

6) 奧斯陸 Single ticket 票價相當昂貴(成人票價 50 挪威克朗)，不過還是相當人性提供一小時內轉乘免費。

7) 奧斯陸車站入口亦無驗票閘門，採信任制度，若車上查票無法出示有效車票，罰款高達 900 挪威克朗。

6.3.6 捷克觀摩考察

1. 布拉格地區及其週邊城市的公共運輸路網是由地鐵(Metro)、輕軌(Tram)、公車(Bus)、火車(Train)、渡輪(Ferry)及纜車(Funicular)所構成，包含 17 家運輸公司，其中最重要的運輸公司是 Prague Public Transport Company (DPP)。整個交通路網由 Regional Organiser of the Prague Integrated Transport (ROPID)負責整合，使用單一票證讓民眾使用大眾運輸更為便利。

2. 布拉格市中心之公共運輸以地鐵與輕軌為交通骨幹，縱橫交錯四通八達，幾乎覆蓋整個市區，兩者運量占布拉格大眾運輸(不含火車)總運量 75%以上。而公車及火車主要在連結郊區與市中心的往來，互補有無。下表為 2013 年布拉格公共運輸載客量統計:

運具	%	載客量
地鐵	47.86%	583 867 000
輕軌+纜車	27.36%	333 778 000
公車	24.78%	315 039 000
總計	**100%**	**1 232 684 000**

*資料來源: Prague Public Transport Company

3. 布拉格地鐵系統 :自 1974 年 5 月 9 日地鐵 C 線正式開通營運，目前計有 A、B、C 三線，57 座地鐵站，總長約 60 公里，營運時間從上午 5 時至午夜 12 時，尖峰時

段 2-3 分鐘一班車，第 4 條地鐵 D 線預計於 2022 年開通。就無障礙設施而言，雖已逐步改善車站無障礙空間，但因早期系統規劃興建時未考量無障礙環境，施工困難度高，目前僅約 2/3 的地鐵站設有無障礙電梯，地鐵車廂與月台略有高差，不利輪椅上下車。


4. 布拉格輕軌系統: 可追溯自 1875 年，當時首部輕軌乃由馬匹拉行，1891 年開始電氣化並逐漸擴展規模，1996 年試運行 4 輛低地板輕軌 RT6N1，3 年後因車輛瑕疵停駛，2005 年重新引進低地板輕軌Škoda14T，隨後陸續購入 KT8D5.RN2P、T3R.PLF、Škoda 15T 等低地板車型，目前低地板輕軌車廂為總車輛數的 20%，預計 2017 年增加至 40%。布拉格輕軌系統包含 25 條日間行駛路線(營運時間 04:30-24:00)及 9 條夜間行駛路線(營運時間 24:00-04:30)，600 座輕軌站，營運路線總長 547 公里。為方便旅客辨識無障礙車廂，在輕軌車體上、到站資訊系統或時刻表上均標識輪椅符號，儘管布拉格近年來已陸續進行無障礙設施站台的改善，但多數車廂與月台仍存有明顯間隙及高差。


8492
9255


8277


7 Radlická
9275

5. 布拉格輕軌車站因地制宜有採用中央側式月台，輕軌軌道設在道路中央，軌道兩側設以側式月台，更外側則為一般車道，常見乘客未依規定行走行人穿越道，直接違規穿越外側車道或跨越軌道。


6. 布拉格輕軌車站亦常見採用車道外緣側式月台，道路一側是單向車道或雙向車道，另一側是輕軌軌道，中央以單側輕軌月台做為分隔，另一側月台則與原有的人行道空間結合。

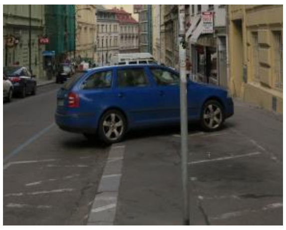
7. 布拉格另一種形式的輕軌車站，未設置島式月台，直接在停靠站前方車道上繪製黃色標線，道路配置如下:輕軌軌道設在道路中央，軌道兩側為一般車道，於人行道上置放輕軌站牌，站牌前方一般車道上繪製黃色標線，當輕軌到站時，一般車輛必須停止於標線後方，空出黃色標線處讓搭乘輕軌的民眾經由此處穿越一般車道。如此車道配置，搭乘輕軌的民眾安全有賴汽車駕駛人的守法行為。

8. 布拉格公車系統:包含日、夜間公車。自 1994 年~1995 年 3 輛低地板公車投入營運，至今約有 66.5%以上為低地板公車，部分公車亦配有輪椅專用斜坡板，便利輪椅上下車，此外，公車站牌上亦提供低地板公車路線及時刻表(標以輪椅符號)，以方便殘疾乘客妥善規劃自己的旅程。近年來，為增進公車營運效率，在交通量較高路線增加雙節公車數量，交通量較低路線則改行駛中型公車。

9. 布拉格車站入口無驗票閘門，車票使用前須先於地鐵入口、輕軌或公車上的驗票機自行打印時間日期，未持有有效票罰款為 1000 捷克克朗。

10. 布拉格市中心道路狹窄停車不易，大部分路邊停車位是為居民保留，停車標線為藍色實線，停車標誌下方註記「RESERVE」字樣。在某些車道較為狹窄的路段，停車格位會劃設於部分人行道上，停車時須依規定將車開上人行道，惟仍需保留人行空間。相關路邊停車停放時間及停車費率如下:

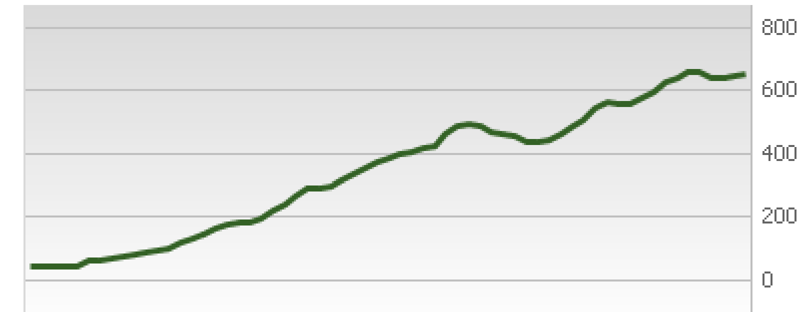
停車區域	停放時間	停車費率
Orange Zone	限停 2 小時	每小時 40 捷克克朗
Green Zone	限停 6 小時	每小時 30 捷克克朗
Blue Zone	不限時	只供當區居民及公司停放(必須持有社區停車證)



11. 布拉格 P+R (park+ride) 停車轉乘制度：轉乘停車場主要設在地鐵站或鄰近公共運輸，方便駕駛人停車轉乘，並提供每日 20 捷克克朗的優惠停車費率及公共運輸轉乘優惠，鼓勵民眾轉乘公共運輸工具，減少小客車進入布拉格市中心。

6.3.7 冰島觀摩考察

1. 冰島人口總數 329100 人，土地面積 103,000 平方公里，人口密度僅 3.1 人/平方公里，是歐洲人口密度最低的國家。60%以上人口居住在首都雷克雅維克及附近，主要交通方式為航運、海運和公路運輸。
2. 冰島地廣人稀，大眾運輸發展受到地形、天候、人口及城市密度等影響發展不易，早期交通政策重點在公路建設，小客車成為主要運輸方式，大眾運輸使用率偏低。根據一項 2002 年針對「雷克雅維克市民對 5 公里以下短程旅次的運具選擇」的調查，結果顯示高達 76%民眾使用私人汽車，19%步行或騎自行車，只有 4% 的民眾選擇搭乘公車。儘管 85%左右雷克雅維克市民居住在公車站牌 300 公尺範圍內，但使用大眾運輸的比率仍然偏低。
3. 歷史和地理因素也造成冰島平均每人小客車擁有率相當高。根據統計，冰島 2002 年平均每千人持有之小客車數 561 輛，至 2013 年每千人持有之小客車數上升至 658 輛，平均每人擁有 1.5 輛小客車。



*每千人持有之小客車數（*source: Statice.is*）

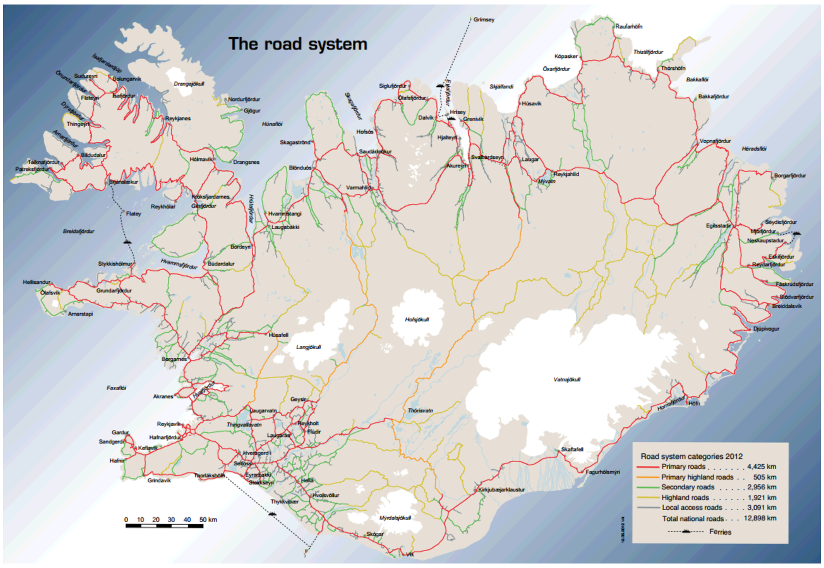
4. 冰島公共道路不收費，路線總長 12,898 km，公路系統分類如下:

(1) 主要公路(primary roads): 為冰島公路骨幹，包含 1 號環形公路(ring-road)、聯繫主要城市與城市之間、聯繫人口超過 100 人以上村莊以及聯繫主要港口和機場間的道路，總長 4,425 km，多已鋪設柏油路面。

(2) 高地主要公路和高地公路(primary highland roads and highland roads):穿越高山和荒原，兩者總長 2,426 km，為自然砂石路面，冬季封閉。

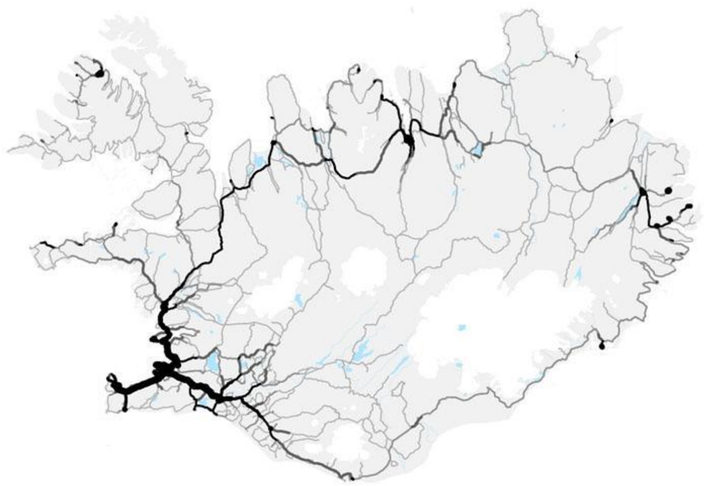
(3) 次要公路(secondary roads):用於聯繫主要公路或人口小於 100 人以下村莊，路線總長 2,956 km，僅 26%的次要公路鋪設柏油路面。

(4) 地方道路(local access roads): 路線總長 3,091 km，主要為通往農場、工廠、教堂或公立學校等的道路。



*2012 年冰島公路系統（*Source: The Icelandic Road Administration*）

5. 冰島的公路運輸足以容納現有的交通量，交通壅塞在冰島並不是問題，事實上，影響交通中斷或延遲的最主要因素是天候。下圖可看出冰島交通流量分佈，車流主要集中在西南部首都雷克雅維克附近，為減低尖峰時間車流量，雷克雅維克政府實行彈性工作時間，鼓勵員工避開上下班尖峰時刻以減少車流。



*2012 年冰島公路交通流量（*Source: Icelandic Road and Coastal Administration)*

6. 冰島政府積極推動綠色城市、永續運輸，以首都雷克雅維克「2010-2030 年市政計畫」為例，市政規劃重點在推動大眾運輸為導向的都市發展。期許在 2030 年所有公車及多數私人運具能使用低汙染環保節能車輛，私人運具使用率從 75% 降低至

58%，大眾運輸使用率從 4% 提高至 12%，步行和自行車的使用率從 21% 至少提高至 30%。在運輸政策上主要有以下幾個重點:

(1) 透過土地使用政策改變居民的旅運行為，推動大眾運輸，發展緊密都市型態，減少小汽車旅次，打造一小時經濟圈。

(2) 建構友善的人行步道系統及自行車騎乘空間: 雷克雅維克在 2005 年完成第一條長度 100 公尺的自行車專用道，2015 年長度將達 50 公里，預計 2020 年增建至 100 公里。目前首都自行車專用道加上人行道總長約 74 公里，平均每位居民享有的長度為 0.63 公尺。

(3) 推動氫燃料公車和環保節能車輛並積極增設充電站，獎勵每公里二氧化碳排放率低於 120 克、百公里耗油量低於 5 升、使用甲烷燃油的車輛、氫燃料車輛、以及電動車都可享有在市區免費路邊停車 90 分鐘。

(4) 特定路推行汽車共乘之高乘載車輛政策，減少小汽車的使用，達到節能減碳之目的。

7. 冰島的公共運輸系統:

(1) 冰島無軌道運輸系統，主要公共運輸工具為公車。

(2) 公共運輸的發展歷史可追溯到 1931 年 Buses Reykjavík Ltd 公司成立，初期為私人經營，1944 年由雷克雅維克地方政府買下，目前由包含首都在內的七個城市地方政府共同擁有經營，名為 Strætó (Strætó 在冰島語中的意思為**公車**)。

(3) Strætó 公車除運行首都市區及周圍城鎮，路線也延伸至冰島南部、西部、西北部、北部以及東北部的主要城市和景點。市區單程票價 400 冰島克朗，可於 75 分鐘內免費轉乘。

8. 冰島 BSI 公車總站(BSI bus terminal)

BSI 是冰島主要的公車站，位於首都雷克雅維克中心，是進出市區的主要樞紐。冰島最大客運公司之一 Reykjavík Excursions 即以此處為主要據點，由此出發前往冰島各景點；Keflavik 國際機場到雷克雅維克市區的接駁公車「FlyBus」亦停靠於此。客運公司亦提供 BSI 公車總站與市區旅館間的小型車無縫隙接駁服務，方便旅客搭乘公共運輸工具。

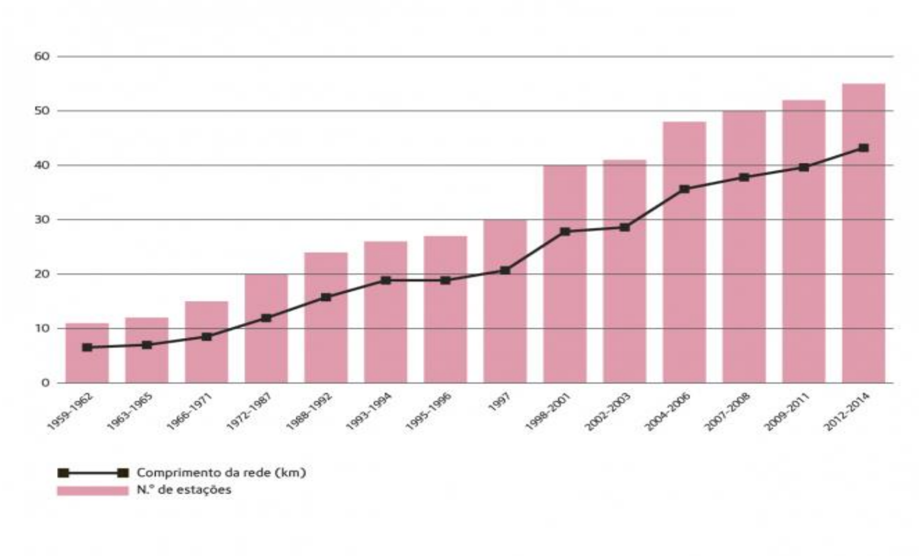
6.3.8 葡萄牙里斯本觀摩考察

1. 葡萄牙里斯本的公共運輸路網是由地鐵(Metro)、輕軌(Tram)、公車(Bus)、火車(Train)、渡輪(Transtejo/Soflusa)、纜車(Funicular)及電梯(Lift)所構成。

2. 里斯本地鐵(Metro)系統：

   (1) 由 Metropolitano de Lisboa E.P 公司負責經營。自 1955 年 8 月 7 日開始建造，1959 年 12 月 29 日正式營運。

   (2) 目前共計有 56 座地鐵站，軌道總長 44.2 公里，包含四條路線：Green Line（長 8.9 公里，13 座地鐵站）、Yellow Line（長 11.1 公里，13 座地鐵站）、Blue Line（長 13.7 公里，18 座地鐵站）、Red line（長 10.5 公里，12 座地鐵站）。營運時間從上午 6 時 30 分至隔天凌晨 1 時。

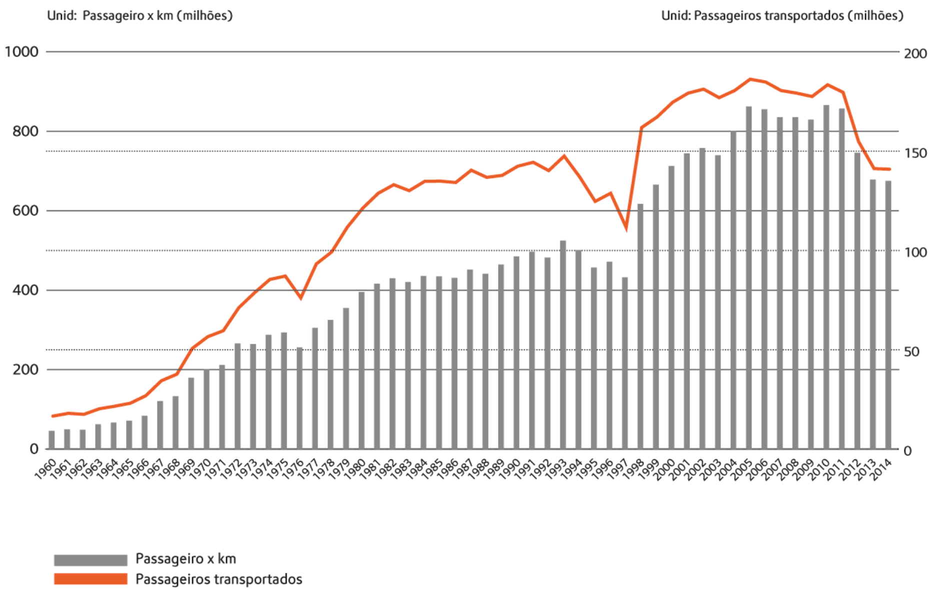


*1960~2015 里斯本地鐵長度變化表 (source: Metropolitano de Lisboa)

*2016 里斯本地鐵路網圖 (source: Metropolitano de Lisboa)

(3) 就無障礙環境而言，目前地鐵站共配置 209 座自動手扶梯 escalators， 95 座無障礙電梯 lifts，和 10 座自動行人通道 travelators，其中 31 個地鐵站提供完全無障礙設施，其他無障礙設施也逐步改善中。

(4) 每年運量從營運第一年計有 15.3 million 旅客旅次，增加至現在每年運量 139million 旅客旅次以上（每日運量約 50 萬旅客旅次）。



*1960~2015 里斯本地鐵每年運量統計（單位 million） (source: Metropolitano de Lisboa)

3. 里斯本輕軌(Tram)、公車(Bus)、纜車(Funicular)及電梯(Lift)系統，由 CARRIS 公司負責經營，共擁有 57 輛輕軌，752 輛公車， 3 台纜車和 1 部電梯。

(1) 輕軌(Tram) 系統 : CARRIS 公司成立於 1872 年，1873 年引進由馬匹拉行之輕軌； 1901 年 8 月 31 日，首輛電氣化（power-driven）輕軌正式投入營運，1905 年全面電氣化。目前計有 5 條日間行駛路線，軌道總長 48 公里。包含 Articulated Trams 和 Historical Trams 兩款車型：Articulated Trams 車輛長 24.02 公尺，寬 2.4 公尺，最高時速可達 70 公里/時；Historical Trams 車輛長 8.385 公尺，寬 2.378 公尺，最高時速可達 50 公里/時。


*Articulated Tram


*Historical Tram

(2) 公車(Bus) : 1944 年 4 月 9 日，公車服務正式啟用。1960 年代，CARRIS 公司決定以公車系統取代輕軌，有計畫地削減輕軌路線與車輛，自此公車成為里斯本最重要的大眾運輸系統。目前計有 78 條日間行駛路線，6 條夜間行駛路線，營運路線總長 667 公里。就無障礙設施而言，88%以上為低地板公車，50%以上公車設有輪椅停放空間，亦配有輪椅專用斜坡板，便利輪椅上下車。另提供小型復康公車，提供點對點預約運輸服務。

(3) 纜車（Funicular）及電梯（Lift）系統：里斯本市區為丘陵組成，地勢高低起伏，為了解決地形崎嶇造成的人員和貨物流動上的阻礙，電梯和纜車即因此應運而生，並在 2002 年 2 月列為國家古蹟。Elevador de Santa Justa 落成於 1902 年 7 月 10 日，它是里斯本唯一一部用於公共服務的垂直電梯；另外 3 部纜車為 Gloria funicular、Bica Funicular、Lavra Funicular，分別於 1885 年 10 月 24 日開放、1892 年 6 月 28 日和 1884 年 4 月 19 日向公眾開放營運迄今。


4. 里斯本大眾運輸系統票種相當多元，簡單說明如下：

票種	交通工具	費率€	說明
Single Ticket 上車才買票	Bus	1.80	單程票
	Tram	2.85	單程票
	Bica, Glória and Lavra Funiculars(2 trips)	3.60	來回票
	Sta. Justa Lift(2 trips)	5.00	來回票
Pre-buy Ticket 先購買 7 Colinas 或 Viva Viagem 儲值卡，工本費€0.50，有效期為一年。再儲值需要的票種。	單程票 Carris/Metro	1.40	1. 儲值單程票到儲值卡內。 2. 1 小時內可轉乘地鐵、輕軌及公車。
	一日票(24h) Carris/Metro network	6.00	1. 儲值一日票到儲值卡內。 2. 啟用後 24 小時內免費無限次搭乘地鐵、輕軌、公車、電梯及纜車。
	使用 Zapping 方式，pay as you go	1.25	1. 先儲值一定的金額到儲值卡，使用時再從裡面扣除金額。 2. 沒有轉乘優惠。 3. Zapping 第一次儲值最少€2 最多€15，接下來儲值金額從€0.01 ~ €15 ，每張儲值卡最高可儲值到€20。
Lisboa Card	Metro, Carris, Buses, Trams, Funiculars and CP trains (to Cascais and Sintra)	24hr € 18.50 48hr € 31.50 72hr € 39.00	1. 結合交通與門票的觀光卡。 2. 可無限次搭乘公車、地鐵、輕軌、纜車、電梯或往 Sintra Cascais 火車。 3. 享有進入博物館及景點免費或折扣的優惠。

5. 里斯本廣場眾多，開放的公共空間設計巧妙的置放著許多公共藝術，充分感受到文化與休閒功能；寬闊的人行道以石材鋪設，拼湊成各式圖案，創造專有的步行與社交空間，都讓人印象深刻。

6.4 觀摩考察心得

1. 臺灣近年來推動公路公共運輸發展計畫，在公共運輸票證電子化及公車動態資訊系統建置皆已完成，下一階段在公開數據資料(open data) 及大數據資料(big data)應用方面，或可參考倫敦之應用經驗。

2. 交通資料來源部分，Moovit app 應用會員使用者提供即時資料(Crowdsourced data)來輔助官方公共運輸資料之作法，亦可參考借鏡。

3. 巴黎汽車共享為全球首個案例，由該城市推動公共腳踏車及汽車共享之案例顯示，其成功條件如下:

    a. 委託具有聲望之大企業參與

    b. 良好的財務計畫

    c. 大規模建置，以高覆蓋率提高租借設備租與還可及性

    d. 簡便的租還車流程

e. 良好的車輛調度服務

4. 考察德國公共運輸場站的規劃設計，非常重視不同運具的轉乘需求，除了在硬體設施上能彼此整合，不同運具之時刻表亦互相調整配合，以利乘客轉乘，真正做到運具「無縫接點」。國內目前公共運輸建設及交通資訊整合可以做為參考借鏡。

5. 德國交通票證高度整合，再配合實施多元的票種、票價及配套的軟硬體設施，來提高民眾使用大眾運輸系統的意願，值得參考。

6. 里約已完成及營運之 BRT 路線係銜接新開發區之住宅區至 Alvorado 公車場站，沿線原本道路空間即相當寬廣，因此，引進 BRT 後不致產生有限道路空間競合問題，或可供後續台灣在推動 BRT 路線選擇之參考。

7. 西班牙不管在人行道的設計、自行車專用道的設置、無障礙空間的規劃都可充分感受到對人、對弱勢交通族群在道路空間使用上的尊重。我國目前已積極打造交通無障礙空間，推動人行環境改善計畫 ，但仍有許多努力的空間，西班牙處處可見具體落實以人為本的都市空間與運輸環境，值得參考。

8. 巴塞隆納的車道配置與號誌設計充分發揮因地制宜的特性，因應道路空間設置自行車專用車道、汽車車道、輕軌軌道、公車與計程車專用道等等，並透過專用道的設置鼓勵民眾使用綠色運具及大眾運輸工具。臺灣既有市區道路空間有限，加上民眾使用交通運具的習慣不同，巴塞隆納的車道配置也許不完全適用，但其具備足夠人行、綠帶空間配置仍可做為我國將來土地重劃或道路規畫之參考。

9. 丹麥及挪威交通資訊整合的相當完善，透過大眾運輸查詢系統平台，即可透過單一窗口查詢到最佳旅行路徑、最佳運具組合、各運具轉乘時間及交通即時資訊，真正做到無縫運具整合。國內目前在各種運具及各城市間交通資訊的整合還有待努力，應儘速建立交通資訊平台，整合各項交通資訊，並提供單一窗口方便民眾查詢。

10. 實際觀察哥本哈根及奧斯陸，公車候車亭所提供的公車到站資訊都相當準確。國內這幾年在公車動態資訊系統上的建置成果與先進國家不相上下，值得讚賞。

11. 挪威為行銷觀光，陸續建置 18 條國家級出行路線(National Tourist Routes in Norway) ，這些路線不但能代表挪威自然景觀之精粹且各具其歷史及人文特色，重要的是，更在這些出行路線中設計了各種觀景平臺、休憩區及服務設施，讓遊客在讚嘆大自然的美景時同時能體驗各種巧思與便利。此一統合作法，可供國內推動深度出行之參考。

第7章　結論與建議

1. 推動「公路公共運輸發展計畫」及「公路公共運輸提昇計畫」政策執行時，建議應強化各利害關係人對於計畫目標之共識、修改計畫申請機制(應提出 3 至 4 年期之計畫)、計畫申請單位應提出明確之計畫目標(與整體計畫目標建立連結性)、加強執行單位之績效考核、提升地方首長對於公共運輸發展之承諾及提供充足之執行資源等。
2. 研擬推動公路公共運輸計畫時，建議應針對土地使用，包括鄉鎮區的人口密度、就業人口密度、混合土地使用及都市街道設計等對公共運輸運具選擇之影響納入參考。
3. 在推動公共運輸時，建議應重視心理層面部分，民眾對於公共運輸使用容易與否的感知行為控制(Perceived behavior control) 及使用公共運輸的意圖(intentions to use public transport)對於是否使用公共運輸的影響最為重要。

附錄 1: Land Use Variables at Different Geographic Scales Influence on Travel Mode Choice Behaviour

本報告第 3 章整體分析及結果

Introduction

This chapter addresses the third research question (RQ3) which aims to understand how land-use factors, at different geographic scales influence travel mode choice behaviour after accounting for socio-economic characteristics. If refers to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.10, this chapter is to examine the relationships between Block C – land use factors, Block A – socio-demographic characteristics, and travel mode choice behaviour (see Figure 2.10).

Multilevel MNL models are adopted in this chapter. In the analysis of the effects of land-use on travel behaviour, individuals' travel behaviour data and zonal area data, such as land-use, always have the features of hierarchical clustering or cross-classified structures. For example, in a travel mode choice context, individuals are clustered in households and households in home zones. In addition, if consider the effects of spatial contexts at trip origins and destinations, the clustered relationships become cross-classified, which means that individuals are both clustered in districts of trip origins and in districts of trip destinations. Traditional single level multinomial logit model neglects the within cluster variation and may lead to an inferior data fit. Multilevel models can accommodate spatial autocorrelation, spatial heterogeneity, higher-level context, and simultaneous handling of the micro-scale of individuals and the macro-scale of places. Several studies have suggested that multilevel modelling method satisfies the requirements of land-use and travel behaviour study, which places difference and data at different geographic scales should be accounted for (Overmars and Verburg, 2006, Jones and Duncan, 1996), while only few studies have adopted multilevel modelling method (Antipova et al., 2011, Li et al., 2005, Schwanen et al., 2004, Snellen et al., 2002, Bhat, 2000). Hence, this chapter used multilevel multinomial model and multilevel cross-classified model to examine the impacts of land-use variables at district-level and city/county level, and across trip origins and destinations on mode choice behaviour.

There are six sections in this chapter. The following section introduces the conceptual models of multilevel multinomial (MNL) model and multilevel cross-classified multinomial (MNL) model. The third section presents both of the model forms. This is followed by descriptive statistics of the data used in this chapter. The fifth section delivers the models' estimated results. The final section discusses the results and draws conclusions of this chapter.

Multilevel conceptual model

This study estimates two multilevel multinomial logit (MNL) models, which are multilevel MNL model and multilevel cross-classified MNL model to analyse the land-use variables' influence on mode choice behaviour.

The first model, which we expect there may be unobserved heterogeneity between individuals *i* and between districts *j* of trip origins, which are purely clustered. Therefore, a three-level multilevel multinomial logit model is adopted to capture the clustered variations, as shown in Figure 0.1.

As can be seen in Figure 0.1, socio-demographic characteristics and travel-related variables were included in the individual level. Socio-demographic characteristics included age, income, car and motorbike driver license, household car and motorbike ownership. Travel-related factors included travel cost and OD distance. At the second level, district-level, land use variables: population density, job density, mix land use entropy, percentage of four-way intersections and numbers of cul-de-sac were adopted. At the city/county-level, density and land use mix entropy were adopted.

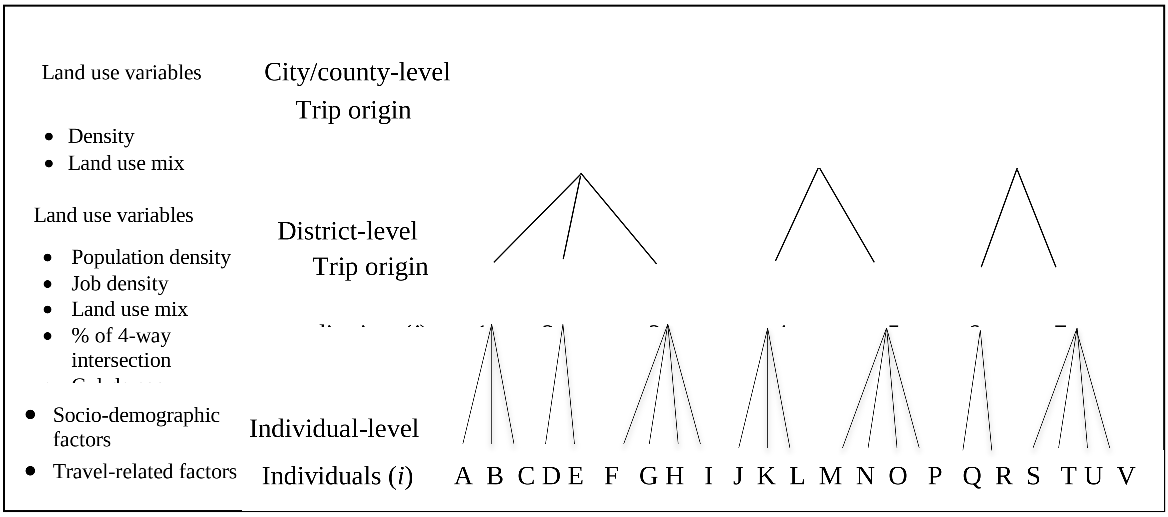


Figure 0.1 Three-level multilevel conceptual model

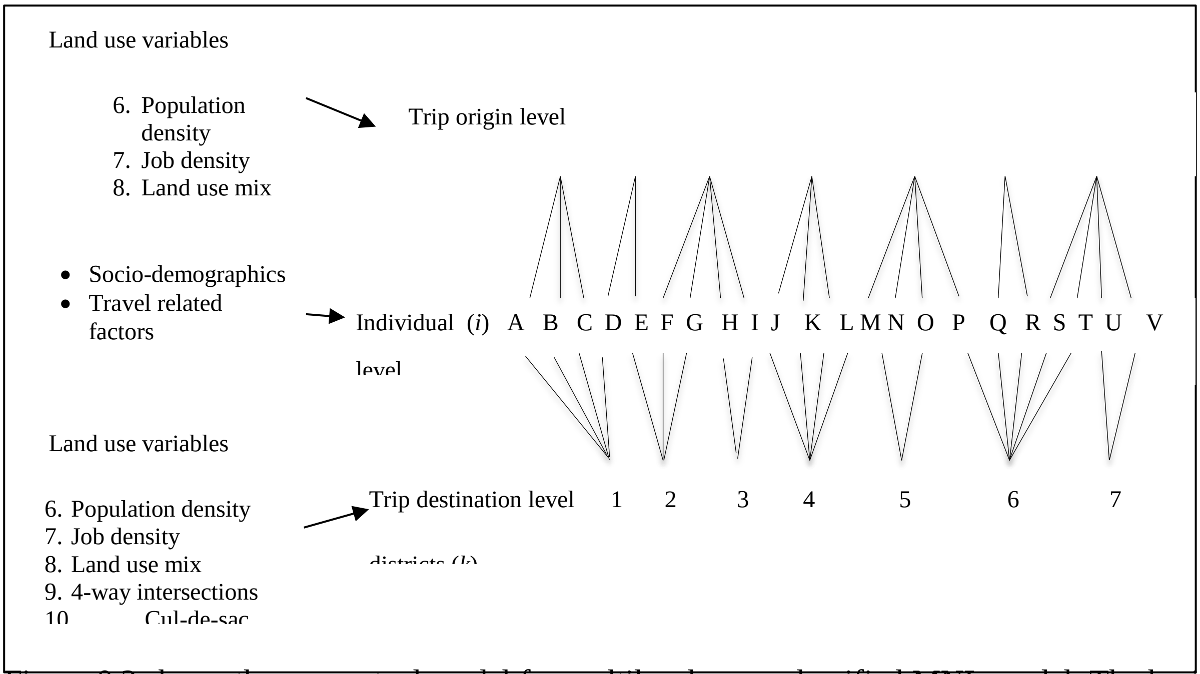


Figure 0.2 shows the conceptual model for multilevel cross-classified MNL model. The basic unit of analysis is the trip, as made by individuals. In order to extract the true spatial effects of land use on mode choice behaviour, this study includes trip purpose of work and school, socio-demographic: personal monthly income, driver's license for car and motorbike, and travel-related level of service variables: OD distance and travel cost, at the individual level as controlling factors.

This multilevel cross-classified MNL model is to examine the spatial heterogeneity across the trip origins and destinations. Districts are used as the spatial unit to accommodate the spatial heterogeneity across trip origins and destinations. Individual travellers are nested within districts. Travellers are cross-classified by home location (trip origin) and the district within which their trip ends (trip destination).

Household-level and neighbourhood-level are not included in this study because, for Taiwan's 2011 Mode Choice Behaviour Survey data, there were only two samples for each household, which were a vehicle-owner and a non-vehicle-owner. This sample size for each household is not enough to estimate the household heterogeneity. In addition, analysing the spatial heterogeneity at neighbourhood level and at district level (neighbourhoods clustered in districts) would involve examining the spatial heterogeneity of different geographical scale. This will add complexity to the model structure and will substantially increase the number of variables incorporated in the model. This study concentrates on the cross-classified relation across trip origins and destinations.

The model includes five variables - population density, job density, land use mix entropy, percentage of four-way intersections and numbers of cul-de-sac- to represent land use effects. These land use effects on mode choice behaviour were estimated at both trip origin level and trip destination level because these land use variables may play different roles for mode choice at trip origins from trip destinations. For population density and job density, Pivo (1994) found that population density at the trip origins and job density at the trip destinations played a role on influencing mode choice. Zhang (2004) also found that population density at the trip destinations had significant relationships with mode choice for both work and non-work trips. In order to understand the impacts of population density and job density at both trip origins and destinations on mode choice and to compare this study's results to previous results, the effects of population density and job density were estimated at both trip origins and trip destinations. The multilevel cross-classified model structure is shown as

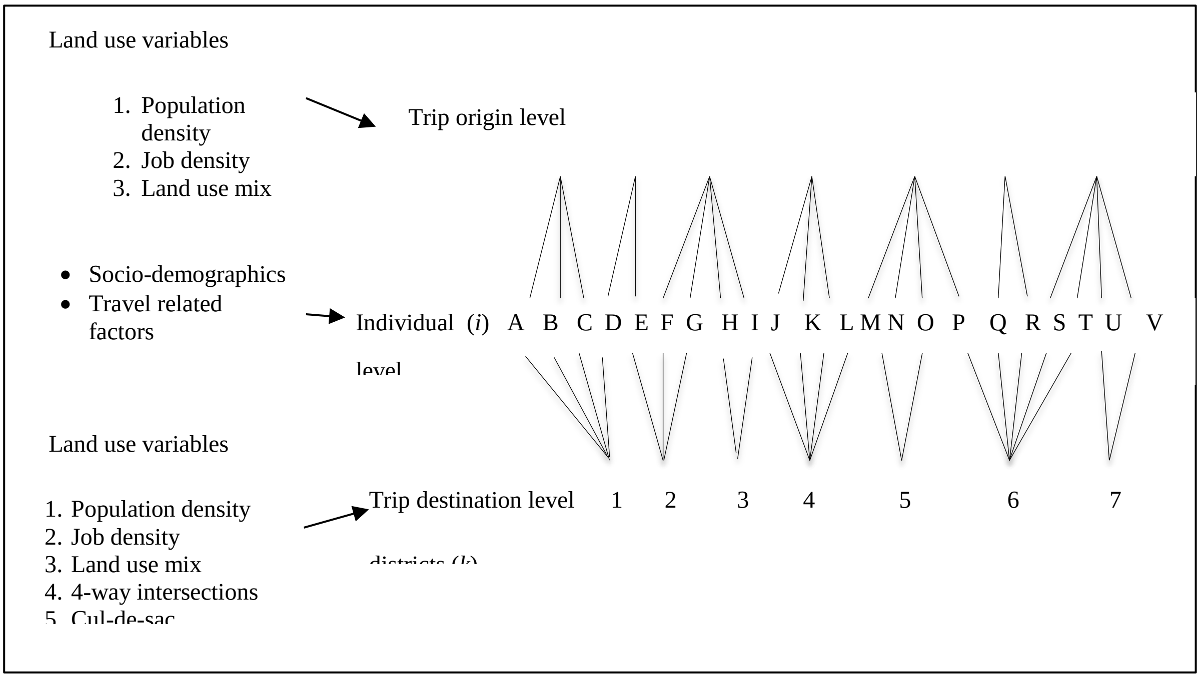


Figure 0.2 Multilevel cross-classified conceptual model

The discrete dependent variable of this study is mode choice (from car, motorbike and public transport). Increasing public transport use is an important policy goal within Taiwan's National Road Public Transport Plan (Executive Yuan, 2012). Gaining a better understanding of the extent to which land use characteristics influence mode choice between car and public transport, and between motorbike and public transport can help decision-makers plan better land use and transport integration strategies to fulfil this policy goal. Hence, bus, metro and train were combined as public transport, and public transport was set as the of interest (reference) category.

Descriptive statistics

Travel behaviour data

The travel behaviour data used in this study is drawn from Taiwan's 2011 Mode Choice Behaviour Survey (Institute of Transportation, 2011). Respondents were asked to report the features of their most frequent trip during a week. Trip features asked about included mode choice (among bus, metro, train, car and motorbike), trip purpose, trip frequency, trip origin and destination, travel cost, travel time, and service satisfaction. Travel cost refers to the out-of-pocket monetary cost of the trip. For car and motorbike users, this includes parking costs and fuel costs but nothing towards the cost of vehicle purchase, tax, insurance and maintenance. For public transport users, this cost equals the fare paid if respondents hold seasonal tickets such as monthly tickets, are asked to convert to single trip cost according to their monthly trips.

A number of socio-demographic characteristics (gender, age, education, job and wage, and whether they had a car and/or motorbike driver's licence) were also collected for each respondent. At the household level, data was collected on the number of cars, motorbikes and bicycles within the household, household size, the total number of driver's licences held, and household income.

After removing incomplete responses, this gave a valid sample size of 5,356 individuals. Among all the trips, the trip origins covered 289 districts of all 348 districts and covered all 19 cities/counties in Taiwan. Within the sample, 20.5% of trips were made by public transport, 47.0% by motorbike, and 32.5% were by car.

It should be noted that the trip data used in this study only covers frequent trips reported by respondents and does not include all trips made by them. This means that commuting trips and school trips are likely to be over represented in the data set, and social and leisure trips are likely to be underrepresented. Some of the tour features, such as stops or transfers within the trips are not reported in the survey.

Table 0.1 show the relationships between sociodemographic characteristics and mode choices. In Taiwan, a greater proportion of males use the car, whilst a higher proportion of females use public transport. Use of the motorbike is evenly split between males and females. The samples' gender ratio of female to male is 50.6% to 49.4%. The chi-square test shows that we cannot reject the hypothesis that the samples' gender ratio is the same as Taiwan's population gender ratio of 49.9% to 50.1% (Taiwan Ministry of the Interior, 2015). Table 0.1 also shows that the groups of people aged under 14 and 15-24 have higher proportion to use public transport over car and motorbike. This maybe because people cannot have a car and motorbike driver's license until the age of 18 in Taiwan due to the regulation. Car and motorbike users under age 18 are passengers driving by their parents or someone else. Aged 15 - 34 have the highest percentage of motorbike use, and aged 35 - 54 have the highest percentage of car use. This may reflect to people's mode shift from motorbike to car along with their age increase and social status changes. In addition, for occupancy, students have the highest percentage of choosing public transport compared to other occupancy.

The driver's license ownership and children in household associate with mode choice, as shown in Table 0.1. The percentage of respondents who own car driver's license and use car is more than twice as the percentage of respondents who do not own car driver's license and use car as passengers. Likewise, the percentage of respondents who own motorbike driver's license and use motorbike is about twice as the percentage of respondents who do not own motorbike driver's license and use motorbike as passengers. Respondents with children (under 18) in households have much higher percentage of using car than respondents without children in household because the responsibility of transport their children.

Table 0.1 socio-demographics and mode choice

Gender	Mode choice	Frequency	Percent
Female	Car	841	30.7
	Motorbike	1294	47.2
	Public transport	606	22.1
	Total	2741	100.0
Male	Car	901	34.5
	Motorbike	1220	46.7
	Public transport	493	18.9
	Total	2614	100.0
Aged			
Under 14	Car	33	27.0
	Motorbike	49	40.2
	Public transport	40	32.8
	Total	122	100.0
15-24	Car	90	13.8
	Motorbike	329	50.4
	Public transport	234	35.8
	Total	653	100.0
25-34	Car	341	26.3
	Motorbike	712	54.9
	Public transport	244	18.8
	Total	1297	100.0
35-44	Car	520	40.8
	Motorbike	554	43.4
	Public transport	202	15.8
	Total	1276	100.0
45-54	Car	445	39.0
	Motorbike	493	43.2
	Public transport	203	17.8
	Total	1141	100.0
55-64	Car	245	38.4
	Motorbike	268	42.0
	Public transport	125	19.6
	Total	638	100.0
65 and over	Car	68	29.8
	Motorbike	109	47.8
	Public transport	51	22.4
	Total	228	100.0
Occupancy			
Student	Car	121	16.8
	Motorbike	327	45.3
	Public transport	274	38.0
	Total	722	100.0
Public servant	Car	281	43.8
	Motorbike	254	39.6

		Public transport	107	16.7
		Total	642	100.0
Technology industry		Car	199	37.5
		Motorbike	251	47.4
		Public transport	80	15.1
		Total	530	100.0
Financial industry		Car	68	34.5
		Motorbike	74	37.6
		Public transport	55	27.9
		Total	197	100.0
Business and service industry		Car	346	35.6
		Motorbike	463	47.6
		Public transport	163	16.8
		Total	972	100.0
Other service industry		Car	365	32.9
		Motorbike	564	50.8
		Public transport	181	16.3
		Total	1110	100.0
Housekeeper		Car	181	28.5
		Motorbike	325	51.3
		Public transport	128	20.2
		Total	634	100.0
Others		Car	181	33.0
		Motorbike	256	46.7
		Public transport	111	20.3
		Total	548	100.0
Car driver's license owned or not	Yes=1	Car	1563	37.1%
		Motorbike	1971	46.8%
		Public transport	678	16.1%
		Total	4212	100.0%
	No=0	Car	179	15.6%
		Motorbike	544	47.6%
		Public transport	421	36.8%
		Total	1144	100.0%
Motorbike driver's license owned or not	Yes=1	Car	1502	32.5%
		Motorbike	2333	50.4%
		Public transport	790	17.1%
		Total	4625	100.0%
	No=0	Car	240	32.8%
		Motorbike	182	24.9%
		Public transport	309	42.3%
		Total	731	100.0%
Children (age under 18) in household or not	Yes=1	Car	915	36.0%
		Motorbike	1130	44.4%
		Public transport	499	19.6%
		Total	2544	100.0%
	No=0	Car	827	29.4%
		Motorbike	1385	49.3%
		Public transport	600	21.3%
		Total	2812	100.0%

Table 0.2 shows the descriptive of income, household car ownership, household motorbike ownership, travel cost and OD distance compared with different mode choice groups. For personal income and household income per month, car users have the highest average income level (US$1,400 and US$2,900 for personal income and household income respectively) than motorbike (US$1,000 and US$2,400 for personal income and household income respectively) and public transport users (US$1,000 and US$2,700 for personal and household income respectively). For household car ownership and household motorbike ownership, car users have the highest average household car ownership (average 1.6 cars per household) than

motorbike and public transport users. Also, motorbike users have the highest average household motorbike ownership (average 2.4 motorbikes per household) than other mode groups.

In terms of travel cost, car users have the highest average travel cost, US$2.3 compared with motorbike and public transport users. Travel cost refers to out of pocket cost, which includes fuel cost and parking cost for car and motorbike, and fare cost for public transport. The respondents who hold season tickets such as monthly tickets were asked to convert to single trip costs according to their monthly trips.

OD distance is included in this study is to examine the impacts of spatial distance between trip origins and destinations on mode choice behaviour. As precise origins and destinations were not known, it was calculated using the Euclidean distance between the trip origin district and trip destination district centroids. The district centroids were found by calculating the median centres, which minimize the overall Euclidean distance to the points of interests (POI) in each district. The POI data was supplied by Taiwanese Institute of Transportation, and included government offices, education facilities and public services. Trips that originated and ended within the same district were assigned an OD distance of 3 km. This distance (3km) is approximately half the average radius of the districts. Table 0.2 shows that car users have the longest average OD distance (8.8 km) ranging from about 1.2km to 166.8km and motorbike users have the shortest OD distance (6.3km) ranging from about 1.2km to 53.9km.

The distribution of OD distance for each mode reflects the service ranges for those modes. Table 0.2 shows that car enjoys the widest service range between the minimum of 1.2 km and maximum of 166.8 km than motorbike and public transport. Although there is some short trip use for cars, the average OD distance for car is the longest compared to motorbike and public transport. It seems that the car serves mainly for middle to long range trips. On the other hand, motorbike has the shortest average OD distance and smallest OD distance standard deviation, which means that motorbike may mainly serve for the shortest range trips due to the features of easy to use and free charging of parking in most cities in Taiwan. With trip distance increasing, travellers tend to use public transport and car instead of motorbike, possibly due to the increasing risks and discomfort for motorbike. In terms of public transport, the minimum OD distance is longer than that for motorbike and car, which may mean that for some short distance trips public transport users tend to walk or cycle rather than use public transport. The average OD distance for public transport is in between car and motorbike, which means that public transport may mainly cover the middle range trips in Taiwan. As trip distance increases, travellers would tend to use the car rather than public transport, possibly due the increasing in-vehicle time, transfers and waiting time. Although travel time was not included in this study, the OD distance this study adopted can reflect the some of the features of car, motorbike and public transport.

Table 0.2 Income, motorised vehicle ownership and mode choice

	Items	Min.	Max.	Mean	Std. Deviation
Car	Personal income per month (US$ 1,000[1])	.3	3.3	1.4	.85
	Household income per month(US$ 1,000[1])	.7	7.50	2.9	1.79
	Household car ownership	0.0	6.0	1.6	.82
	Household motorbike ownership	0.0	8.0	1.7	1.19
	Travel cost (US$[1])	0	14	2.3	2.05
	OD distance	1.2	166.8	8.8	8.81
Motorbike	Personal income per month (US$ 1,000[1])	.3	3.3	1.0	.67
	Household income per month(US$ 1,000[1])	.7	7.5	2.4	1.58
	Household car ownership	0.0	6.0	1.2	.79
	Household motorbike ownership	0.0	8.0	2.4	1.20
	Travel cost (US$[1])	0	12.7	1.0	1.20
	OD distance	1.2	53.9	6.3	5.59
Public transport	Personal income per month (US$ 1,000[1])	.3	3.3	1.0	.76
	Household income per month(US$ 1,000[1])	.7	7.5	2.7	1.71
	Household car ownership	0.0	5.0	1.2	.75
	Household motorbike ownership	0.0	6.0	1.9	1.18
	Travel cost (US$[1])	0	6.7	1.0	0.98
	OD distance	1.7	50.9	7.7	6.77

Land use data

In this chapter, the impacts of land use factors on individuals' mode choice behaviour are examined at the district and city/county scale. There are 348 districts clustered in 19 cities/counties in Taiwan. The average area and population of the districts and cities/counties are 102 km2 and 66,000 residents for each district and about 1,800 km2 and 1,210,000 residents for each city/county respectively.

The trip origins of 5,356 samples used in this analysis were clustered in 285 districts of 348 districts and in all 19 cities/counties, and the trip destinations covered 293 districts in Taiwan. About 65% of all the trips had their origin and destination located in different districts.

The data from the Mode Choice Behaviour Survey is supplemented with land use data. The land use data is drawn from the Taiwanese National Land Surveying and Mapping Centre and the Traffic Network Digital Map database under Taiwanese National Geographic Information System (TNGIS), at a resolution of 1/25,000. A number of land use variables are estimated at the district level: population density, job density, land use mix entropy, and the percentage of 4-way intersections and the numbers of cul-de-sac. Figure 0.3 shows the land use measurements at district-level and city/county-level in Taiwan.

Table 0.3 gives the mean, standard deviation for the land use variables across the respondents' trip origin and destination districts, and cities/counties included in the model. For land use mix entropy, which indicates the extent of land use diversity, was calculated as Eq. (1) based on six land use categories: residential, commercial, industrial, government offices, educations,

[1] Exchange rate: US$:NT$(New Taiwan Dollar)=1:30

and hospital and social care buildings. Land use entropy ranges from 0 to 1 in which higher entropy value indicates that a more evenly distributed mix of land uses.

$$\boldsymbol{Land\ use\ mix\ entropy} = -\sum_j \boldsymbol{P_j} \times \frac{\ln(\boldsymbol{P_j})}{\ln(\boldsymbol{J})} \qquad \textbf{(Equation 0.1)}$$

Where P_j is the proportion of land use type j in the area, and J is the total number of land use types, which equals to 6.

The percentage of four-way intersections indicates the extent of grid-like street pattern (Cervero and Kockelman, 1997). The numbers of cul-de-sac in the district represents the street connectivity. These were extracted from the mapping data of Taiwanese Traffic Network Digital Map using ArcGIS 10.2 package. The road network included all the road types, such as provincial road, city/county road, and load road, except highways.

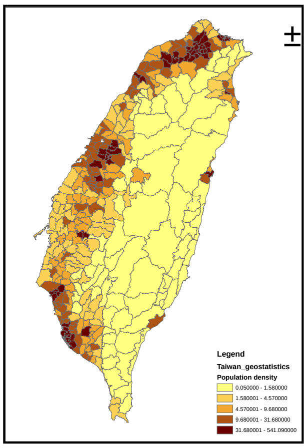
Population density and job density are adopted as explanatory variable at district-level either at trip origin or trip destination. At the city/county-level factor analysis was adopted to combine city/county's population density and job density into density variable. Most trips (81%) have their trip origins and destinations within the same city or county, and there is a high correlation between population density and job density (0.99) at this level. Thus it made sense to have a combined density measure at the city/county level.

The trip-related and socio-demographic variables adopted in this study were determined using a stepwise test to check if there were significant relations between the chosen variables and mode choice behaviour. The resulting variables selected to be included in the models were: trip purpose of work and school, and individual socio-demographic characteristics – age, gender, personal income, car driver's license and motorbike driver's license, children in household, and household car and motorbike ownerships as controlling factors. From the literature, these have been shown to be important determinants of mode choice.

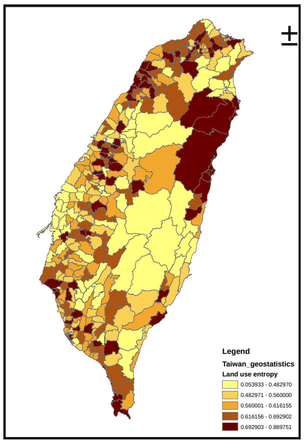
Table 0.3 Land use statistics for Taiwanese districts and city/county

Variables	Definition at district level	Trip origin districts		Trip destination districts		Cities/counties	
		Mean	SD	Mean	SD	Mean	SD
Population density	Population/area size(persons/ha)	83.77	96.62	86.64	97.07	22.59	28.39
Job density	Employment/area size(jobs /ha)	34.12	50.23	44.91	65.37	11.10	19.14
Land use mix entropy	Mixture of residential, commercial, industrial, government offices, educations, and hospital, social care buildings	0.65	0.11	0.65	0.11	0.66	0.04
% of 4-way intersections	Percentage of four-way intersections	0.22	0.07	0.23	0.09	--	--
Cul-de-sac	Numbers of cul-de-sacs	542.59	536.74	531.58	555.04	--	--
Density (city/county-level)	Factor analysis combines population density and job density at city/county level	--	--			0.00	1.00

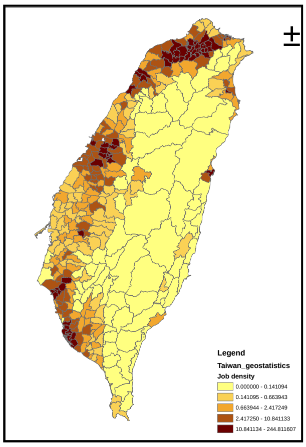
It should be noted that the population density, job density and numbers of cul-de-sac were standardised into z-scores for the purposes of the model estimation in order to obtain consistent results with other variables.



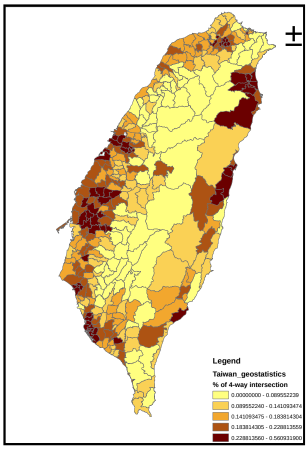
(a) Districts population density



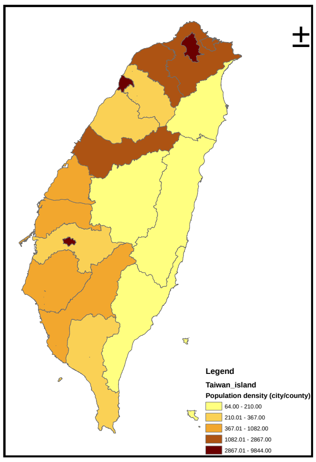
(b) Districts land use mix entropy



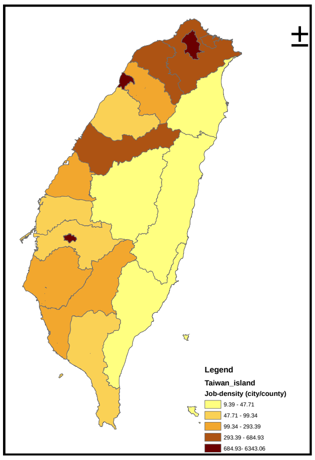
(c) Districts job density



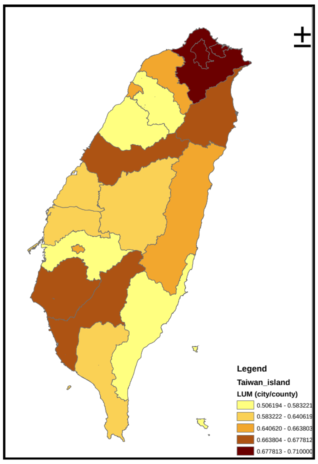
(d) District % of 4-way intersection



(e) City/county population density



(f) City/county job density



(g) City/county land use mix entropy

Figure 0.3 District and city/county land use features in Taiwan

Model form

Multilevel MNL model and multilevel cross-classified MNL model

Multilevel multinomial model and multilevel cross-classified MNL model is to capture the spatial heterogeneity at different geographical scales of district and city/county, and examine the impacts of land use variables at these geographical scales on travel mode choice behaviour. The multilevel MNL model allows the intercept of the utility functions to vary randomly over clusters. The utility function of the multilevel MNL model includes two parts, a fixed part and a random part. In order to capture the spatial heterogeneity, two random terms (combined as the random part) are included in the utility functions. The fixed part of the model includes individual level variables (trip-related, socio-demographic, and travel-related level of service variables), and land use variables at district-level and city/county-level.

Assuming a three-level multilevel MNL model (individual-level denotes *i*, district-level denotes *j*, and city/county-level denotes *k*), the utility function can be expressed as

$$\boldsymbol{U_{ijk} = \pi_{000} + \beta \quad x_{ijk} + \gamma_{01k}\omega_{jk} + \pi_{001}\theta_k + \zeta_{0j} + \psi_k + \epsilon_{ijk}} \qquad \textbf{(Equation 0.2)}$$

Where, π_{000} is constant of the function, $\beta \quad x_{ijk} + \gamma_{01k}\omega_{jk} + \pi_{001}\theta_k$ is fixed part of the function. And $\zeta_{0j} + \psi_k + \epsilon_{ijk}$ is random part of the function. ω_{jk} is district-level explanatory variables, and γ_{01k} is coefficients for the district-level explanatory variables. ζ_{0j} is the district-level random terms representing spatial heterogeneity between districts. θ_k is city/county-level explanatory variables, and π_{001} is coefficients for the city/county-level explanatory variables. ψ_k is the city/county-level random terms representing spatial heterogeneity between city/county. Random terms at different levels are independent. Random terms at district-level and city/county-level are assumed to be normally and identically distributed, and random terms at different levels are independent.

$$\boldsymbol{\zeta_{0j}^m \sim N\left(0, \sigma^2_{\zeta_{0j}^m}\right), \psi_{00k}^m \sim N\left(0, \sigma^2_{\psi_{00k}^m}\right)} \qquad \textbf{(Equation 0.3)}$$

The random terms at individual-level, ϵ_{ijk}, are independent and identically distributed with Gumbel (type 1 extreme value) distribution with a variance (σ_ϵ^2) of $\pi^2/6$ (Train, 2009).

Then a multinomial logit model form can be denoted as

$$\mathbf{Pr}(\boldsymbol{Y_{ijk}} = \boldsymbol{m}) = \frac{\mathbf{exp}(\boldsymbol{u_{ijk}^{m}})}{\sum_{s=1}^{M} \mathbf{exp}(\boldsymbol{u_{ijk}^{s}})} \qquad \textbf{(Equation 0.4)}$$

The multilevel cross-classified MNL model allows the intercept of the utility functions to vary randomly across trip origins and trip destinations. The utility function of the multilevel cross-classified MNL model includes two parts, a fixed part and a random part. In order to capture the spatial heterogeneity across trip origins and trip destinations, three random terms – individual residuals, trip origin residuals and trip destination residuals - (combined as the random part) are included in the utility functions. The fixed part of the model includes individual level variables (trip-related, socio-demographic, and travel-related level of service variables), and land use variables at trip origin level and at trip destination level.

Assuming a three-level multilevel MNL model (individual level, trip origin level and trip destination level), the utility function can be expressed as

$$\boldsymbol{u_{ijk}^{m}} = \boldsymbol{\pi_{000}^{m}} + \boldsymbol{\beta_{1jk} x_{ijk}^{m}} + \boldsymbol{\gamma_{01k}^{m} \omega_{jk}} + \boldsymbol{\pi_{001}^{m} \theta_{k}} + \boldsymbol{\mu_{0jk}^{m}} + \boldsymbol{r_{00k}^{m}} + \boldsymbol{\epsilon_{ijk}^{m}} \quad \textbf{(Equation 0.5)}$$

Where, m is the set of alternatives (car, motorbike, public transport), and *i (i=1, 2, ...,I)* denotes individuals, which is nested in trip origin districts *j (j=1, 2, ...,J)* and in trip destination districts *k (k=1, 2, ..., K)*. $\pi_{000}^{m}$is constant of the function. $\beta_{1jk} x_{ijk}^{m} + \gamma_{01k}^{m} \omega_{jk} + \pi_{001}^{m} \theta_{k}$ is fixed part of the function. And $\mu_{0jk}^{m} + r_{00k}^{m} + \epsilon_{ijk}^{m}$ is random part of the function. x_{ijk}^{m} denotes the individual-level explanatory variables, ω_{jk} denotes level-2 (trip origin districts) explanatory variables, and θ_{k} denotes level-3 (trip destinations districts) explanatory variables. μ_{0j}^{m} and r_{00k}^{m} are random terms representing spatial heterogeneity parameters, which capture unobserved variations at trip origins and trip destinations, respectively. ϵ_{ijk}^{m} is a random term for the individual-level. Then a multinomial logit model form can be denoted as Equation 6.7.

However, the three-level multilevel multinomial model is not completely fit for this study in which data are impurely clustered between individuals and trip origin districts, and individuals and trip destination districts. Thus, a multilevel cross-classified multinomial model, which is a modified three-level multilevel multinomial model, is used.

The classification notation recognizes that cross-classified factors appear at the same level and thus has the same letter for the subscript representing them but is distinguished by numerical sub-subscripts ( ) as *(j1)* refers to the level of trip origin districts and *(j2)* refers to the level of trip destination districts (Browne et al., 2001). Therefore, the reduced form of the utility function for multilevel cross-classified multinomial models can be expressed as

$$\boldsymbol{u_{ijk}^{m} = \gamma_{000}^{m} + \beta_{1(j1,j2)} x_{i(j1,j2)}^{m} + \gamma_{0(j1)}^{m} \omega_{0(j1)}^{(2)} + \pi_{0(j2)}^{m} \theta_{0(j2)}^{(3)} + \mu_{00(j1)}^{m(2)} + \mu_{00(j2)}^{m(3)} + \epsilon_{i(j1,j2)}^{m}}$$
(Equation 0.6)

Where, $\gamma_{000}^{m} + \beta_{1(j1,j2)} x_{i(j1,j2)}^{m} + \gamma_{0(j1)}^{m} \omega_{0(j1)} + \pi_{0(j2)}^{m} \theta_{0(j2)}$ is termed the fixed part of the model and $\mu_{00(j2)}^{m(3)} + \mu_{00(j1)}^{m(2)} + \epsilon_{i(j1,j2)}^{m}$ is termed the random part of the model.

In the fixed part of the model, $x_{i(j1,j2)}^{m}$ is an individual variable with slope coefficient $\beta_{1(j1,j2)}$, $\omega_{0(j1)}^{(2)}$ is a classification 2 variable with slope coefficient $\gamma_{0(j1)}^{m}$, and $\theta_{0(j2)}^{(3)}$ is a classification 3 variable with slope coefficient $\pi_{0(j2)}^{m}$. For random part of the model, $\mu_{00(j2)}^{m}$ and $\mu_{00(j1)}^{m}$ are random terms that capture unobserved variations at trip origins and trip destinations, respectively, and $\epsilon_{i(j1,j2)}^{m}$ is random term for individual-level, where $\mu_{00(j1)}^{m} \sim N\left(0, \sigma_{\mu_{00(j1)}^{m}}^{2}\right), \mu_{00(j2)}^{m} \sim N\left(0, \sigma_{\mu_{00(j2)}^{m}}^{2}\right)$.

The random terms at individual-level, ϵ_{ijk}, are independent and identically distributed with Gumbel (type 1 extreme value) distribution with a variance (σ_{ϵ}^{2}) of $\pi^2/6$ (Train, 2009).

ICC (Intra-class correlation)

The intra-class correlation coefficient (ICC) refers to the proportion of between group variance to total variance (Snijders, 2012). The index can represent the spatial heterogeneity of mode choice behaviour across districts (either trip origin district or trip destination district) and cities/counties, and can capture spatial autocorrelations among individuals within the same districts and cities/counties and recognise spatial heteroscedasticity (Ding et al., 2014). The ICC values for empty models (a model only adopts random effects without any explanatory variable) of linear regression models often range between 0.10 and 0.25 (Snijders, 2012). A greater ICC value for empty model indicates that adoption of the multilevel model is meaningful. Using the notation of this study, the ICC for mode choice of car for multilevel MNL model can be expressed as

$$\boldsymbol{ICC^{car} = \frac{\sigma_{\zeta_{district}^{car}}^{2} + \sigma_{\psi_{city/county}^{car}}^{2}}{\sigma_{\zeta_{district}^{car}}^{2} + \sigma_{\psi_{city/county}^{car}}^{2} + \sigma_{\epsilon^{Car}}^{2}}}$$ **(Equation 0.7)**

Estimation software

MLwiN (version 2.30), which was created by the Centre for Multilevel Modelling based in Bristol University, was used to estimate the results of all the models in this chapter. Only multinomial logit model can be estimated by MLwiN so far, which means that alternative specific variable is not allowed to be included in the model. Hence, travel time was not included in the models and travel cost was treated as individual-specific variable, which value did not vary across alternatives.

Results

This section presents the results of the model estimation. Six models were estimated. Model A and C are multilevel MNL models; Model D and F are multilevel cross-classified MNL models. Model B and Model E are single-level MNL models, which include district and city/county land use variables. The purposes of estimating the empty models – Model A and Model D – are to understand the ICC (Intra-class correlation) values for multilevel MNL model and multilevel cross-classified MNL model. Estimating single-level MNL models - Model B and Model E - are to compare the results with multilevel MNL model and multilevel cross-classified MNL model. The models' estimation was conducted using MCMC (Markov Chain Monte Carlo) procedures within the MLwiN package. These models were first run using restricted iterative generalized least square (RIGLS) to establish a prior distribution, follow by MCMC estimation using Gibbs sampling, with 2,000 burn in iterations and 300,000 iterations to get the posterior distribution.

Multilevel multinomial model results

As can be seen in Table 0.4, Model A is null-models for multilevel MNL model with only intercept in the model. The purpose of Model A is to test the ICC values to see whether there is significant spatial heterogeneity or not. Model B is a single-level MNL model, which includes district-level and city/county-level explanatory variables within the same level. Model C is a 3-level multilevel MNL model which allowed intercepts to be varied randomly across district-level and city/county-level. This model includes travel-related attributes at the individual level, land use and public transport provision variables at district-level and city/county-level, and accounted for socio-demographic characteristics.

The reason for estimating Model A (null model) is to determine whether the adoption of a multilevel MNL model was justified. It depends on the significance of the spatial heterogeneity parameters representing the unobserved variations in utility functions and the level of ICC (intra-class correlation coefficients) values. Table 0.4 shows that all the spatial heterogeneity parameters for car and motorbike at district-level and city/county-level in Model A are significant. In addition, the ICC^{Car} and $ICC^{Motorbike}$ (intra-class correlation coefficient) across district-level and city/county-level, are 0.103 and 0.134, respectively, indicating that correlations for individuals at the same district and city/county are 10.3% and 13.4%, respectively. The high level of spatial heterogeneity at district-level and city/county-level implies that the spatial heterogeneity cannot be ignored and there is a need to adopt multilevel modelling technique to accommodate spatial issues of this study.

With respect to the models' complexity and fit, the DIC (Deviance Information Criterion) (see Table 0.4) values suggest that Model C (Multilevel MNL model) is the best model among the three models. The DIC, which is the sum of the number of effective parameters (pD) and the deviance of MCMC, represents the model's complexity and fit, and may be used for comparing models(Spiegelhalter et al., 2002). The number of effective parameters refers to the complexity of a model and the deviance statistic refers to a model's fit. Since increasing complexity is trade-off by a better model's fit. Spiegelhalter et al. (2002) suggested that adds the model's fit (deviance of MCMC) and complexity (the number of effective parameters) to form the DIC (Deviance Information Criterion) for comparing models with the same structure or different structure. After adding spatial heterogeneity into the model, the DIC for model C reduced by around 43 compared with Model B. Although the number of effective parameters for Model C is 60 points higher than Model B, the deviance of MCMC for Model C, 9110.18, is about 102 points lower than Model B (Table 0.4).

The last column in Table 0.4 refers to the subtraction the absolute t-value for district-level and city/county-level variables in Model C from the absolute t-value for district-level and city/county-level in Model B. Most of the absolute t-values' difference between Model B and Model C are positive, except land use entropy at district-level for car and motorbike, and city/county-level for motorbike. In addition, comparing the coefficients' significant-level for density and % of 4-way intersection at district-level, these coefficients are significant at the 95% level in Model B but insignificant in Model C. This comparison provides evidence that, under the circumstances of high spatial autocorrelation, ignoring the spatial between-group difference by using a single-level discrete choice model (Model B) may exaggerate the coefficients' significance and lead to spurious results (Snijders, 2012, Snellen et al., 2002).

With respect to controlling factors of individual's socio-demographic factors and trip purpose in Model C, as shown in Table 0.4, Males tend to use motorbike more than public transport compared with females. Students are more likely to use public transport rather than car and motorbike compared to other occupation groups. Personal income shows opposite results between the mode choice of car and public transport, and motorbike and public transport. With increasing personal income, people are more likely to choose car over the public transport but would choose public transport over the motorbike. As for trip purpose, work and school trips are more likely to be made by public transport than by car while work trips are more likely to be made by motorbike than by public transport. Car and motorbike driver's licenses also have significantly positive effects on car and motorbike use respectively.

With respect to household socio-demographic factors, households with children aged under 18 in the household tend to have a higher probability of car use than public transport use. Likewise, households with higher car or motorbike ownership are more likely to use the car or motorbike respectively Table 0.4.

As for travel related attributes in Model C, as shown in Table 0.4, OD distance and travel cost have the opposite signs for people choosing between car and motorbike over public transport. With increasing OD distance, people tend to choose public transport rather than motorbike. On the other hand, higher travel costs intend to encourage car and motorbike use rather than public transport use.

After accounting for the controlling factors, the Model C results, as shown in Table 0.4, indicate that land use variables exert significant influence on mode choice behaviour. At the district-level, increasing population density and job density is significantly associated with a greater probability of choosing public transport over the car and the motorbike. On the other hand, the percentage of 4-way intersections – representing grid-like street pattern – shows strong association with motorbike and car use, which means that people in the districts with more gird-like street pattern tend to choose motorbike rather than public transport. Districts with more evenly distributed land uses – higher land use entropy values – tend to have more car use than public transport but tend to have more car and motorbike use than public transport (though not significant at the 95% level). In terms of the city/county-level, increasing density is associated with a higher probability of choosing public transport over the car and the motorbike, although the significant level for car is only at 90%.

The covariance of the random part refers to the correlation between car and motorbike use at district-level and city/county-level (Table 0.4). The positive covariance at district-level and city/county-level means that districts and city/ county in Taiwan have higher proportion of car use also have high proportion of motorbike use.

With respect to spatial heterogeneity (random terms), Model A, as shown in Table 0.4, shows that spatial heterogeneity parameters at district-level and city/county-level are at the level of significance of 90% and 95% respectively. It means that there is significant spatial heterogeneity (unobserved factors) influence mode choice behaviour between districts and cities/counties.

Table 0.4 Multilevel MNL model results

		Model A Null Multilevel MNL model			Model B Single-level MNL model			Model C Multilevel MNL model			Absolute t-value in model B minus absolute t-value in Model C
	Fixed Part	B	S.E.	t-value	B	S.E.	t-value	B	S.E.	t-value	
Car	Individual-level										
	Intercept	0.63	0.10		-2.06	0.97	-2.12	-2.20	1.47	-1.50	
	Gender (Male=1)				0.14	0.09	1.54	0.15	0.09	1.69	
	Age under 14				0.58	0.33	1.78	0.59	0.33	1.75	
	Age between 15-24				**-0.55**	**0.23**	**-2.43**	**-0.57**	**0.23**	**-2.50**	
	Occupancy (Student=1)				**-0.57**	**0.22**	**-2.59**	**-0.60**	**0.23**	**-2.58**	
	Monthly personal income (US$1,000)				**0.30**	**0.06**	**4.70**	**0.30**	**0.06**	**4.81**	
	Car driver's license				**0.82**	**0.11**	**7.33**	**0.82**	**0.12**	**7.17**	
	Children (under 18) in Household				**0.36**	**0.09**	**4.07**	**0.36**	**0.09**	**4.01**	
	Household car ownership				**0.54**	**0.05**	**12.09**	**0.54**	**0.05**	**11.89**	
	Trip purpose (work=1)				-0.14	0.10	-1.35	-0.15	0.10	-1.46	
	Travel cost				**0.59**	**0.04**	**15.03**	**0.60**	**0.04**	**14.90**	
	OD distance				-0.01	0.01	-0.83	-0.01	0.01	-0.83	
	District-level										
	Population Density				-0.14	0.05	-2.80	-0.08	0.06	-1.33	1.47
	Job density				-0.04	0.06	-0.67	-0.03	0.07	0.42	0.25
	Land use mix entropy				-0.06	0.39	0.50	-0.06	0.47	-0.13	0.37
	% of four-way intersection				**3.85**	**0.83**	**4.64**	**2.01**	**1.03**	**1.95**	2.69
	No. of cul-de-sac				0.05	0.05	1.00	0.05	0.09	0.05	0.95
	City/county-level										
	Density				**-0.21**	**0.05**	**-4.20**	**-0.22**	**0.13**	**-1.69**	2.51
	Land use mix entropy				-1.03	1.41	-0.73	-0.24	2.47	-0.01	0.72
Motor-bike	Individual-level										
	Intercept	0.92	0.11		-2.72	0.82	-3.28	-2.88	1.54	-1.87	
	Gender (Male=1)				**0.17**	**0.08**	**2.13**	**0.18**	**0.08**	**2.23**	
	Age under 14				0.13	0.28	0.46	0.13	0.28	0.46	
	Age between 15-24				0.06	0.18	0.33	0.03	0.18	0.15	
	Occupancy (Student=1)				**-0.52**	**0.18**	**-2.89**	**-0.54**	**0.18**	**-3.00**	
	Monthly personal income (US$1,000)				**-0.19**	**0.06**	**-3.11**	**-0.18**	**0.06**	**-2.97**	
	Motorbike driver's license				**1.32**	**0.11**	**12.03**	**1.32**	**0.11**	**11.93**	
	Children (under 18) in Household				0.15	0.08	1.85	0.14	0.08	1.75	
	Household motorbike ownership				**0.35**	**0.03**	**12.93**	**0.35**	**0.03**	**12.32**	
	Trip purpose (work=1)				0.13	0.09	1.44	0.13	0.09	1.44	
	Travel cost				0.05	0.04	1.33	0.05	0.04	1.29	
	OD distance				**-0.04**	**0.01**	**-6.67**	**-0.04**	**0.01**	**-6.67**	
	District-level										
	Population density				-0.11	0.04	-2.75	-0.08	0.05	-1.60	1.15
	Job density				-0.04	0.05	0.80	-0.02	0.06	0.36	0.44
	Land use mix entropy				**0.56**	**0.35**	**1.60**	**0.68**	**0.41**	**1.65**	-0.05
	% of four-way intersection				**4.18**	**0.75**	**5.57**	**2.58**	**0.93**	**2.77**	2.80
	No. of cul-de-sac				0.05	0.05	1.00	0.06	0.08	0.75	0.25
	City/county-level										
	Density				**-0.21**	**0.05**	**-4.33**	**-0.24**	**0.11**	**-2.18**	2.15
	Land use mix entropy				1.38	1.22	1.13	1.92	2.04	0.94	0.19
Random part	City/county-level										
	$\sigma^2_{\psi^{car}_{00k}}$	0.15	0.07	2.25				0.12	0.07	1.77	
	$Cov(\sigma^2_{\psi^{car}_{00k}}, \sigma^2_{\psi^{motorbike}_{00k}})$	0.15	0.08	2.10				0.07	0.05	1.45	
	$\sigma^2_{\psi^{motorbike}_{00k}}$	0.21	0.09	2.33				0.10	0.05	1.80	
	District-level										
	$\sigma^2_{\zeta^{car}_{0j}}$	0.04	0.02	1.64				0.07	0.04	1.92	
	$Cov(\sigma^2_{\zeta^{car}_{0j}}, \sigma^2_{\zeta^{motorbike}_{0j}})$	0.00	0.02	0.13				0.03	0.03	1.30	
	$\sigma^2_{\zeta^{motorbike}_{0j}}$	0.04	0.02	1.91				0.03	0.02	1.53	
DIC (Deviance Information Criterion)		10988.85			9250.35			9207.75			
MCMC deviance		10903.69			9212.22			9110.18			
pD (the effective number of parameters)		83.69			38.13			97.58			

Multilevel cross-classified model results

The estimated results of multilevel cross-classified MNL models are shown in Table 0.5. Model D is an empty multilevel cross-classified MNL model to test the ICC values. Model E is a single-level MNL model, which includes district-level variables for both trip origins and destinations within the same level. Model F is a multilevel cross-classified MNL model which allowed intercepts to be varied randomly across trip origins and trip destinations. This model includes land use variables at both trip origin level and trip destination level and accounted for socio-demographic characteristics.

The reason for estimating Model D was to determine whether the adoption of a multilevel cross-classified modelling technique was justified (Table 0.5). Of all the spatial heterogeneity parameters representing the unobserved variations in utility functions for car and motorbike are statistically significant across trip origins and destinations. The ICC_{car} and $ICC_{motorbike}$ across trip origins and destinations are 0.170, and 0.145, respectively, indicating that the correlations for individuals at the same trip origins and destinations for car users and motorbike users are 17.0% and 14.5%, respectively. In addition, the $ICC_{O\text{-}car}$ and $ICC_{D\text{-}car}$, the correlations for car users at the same origins and destinations, are 0.055 and 0.114, respectively. The $ICC_{O\text{-}motorbike}$ and $ICC_{D\text{-}motorbike}$, the correlations for motorbike users at the same origins and destinations, are 0.055 and 0.090, respectively. The high proportion of spatial dependencies indicates that there is a need to adopt a multilevel modelling technique to accommodate the spatial issues of this study.

The last column in Table 0.5 refers to the subtraction between the absolute t-values in Model E and the absolute t-values in Model F. Most of the absolute t-values' difference for the land use variables across trip origins and destinations between Model B and Model C are positive. Also, comparing the coefficient's significant-level for population density at trip origin for car and at trip destination for motorbike in Model B and Model C, the coefficient is significant at the 95% level in Model B but insignificant in Model C. This comparison provides evidence that, under the circumstances of high spatial autocorrelations, ignoring the spatial between-group difference by only using a single-level discrete choice model may exaggerate the coefficients' significance and lead to spurious results (Snijders, 2012; Snellen et al., 2002).

With respect to the models' complexity and fit, the DIC (Deviance Information Criterion) (see Table 0.5) values suggest that Model F (multilevel cross-classified MNL model) is the best model among the three models. After adding spatial heterogeneity into the model, the DIC for model F reduced by around 31 compared with Model E. Although the number of effective parameters for Model F is about 113 points higher than Model B, the deviance of MCMC for Model F, 9026.4, is about 144 points lower than Model B (Table 0.5).

With respect to the controlling factors of socio-demographic characteristics and trip purpose in Model C, as shown in Table 0.5, personal income shows opposite results between the mode choice of car and public transport, compared with between motorbike and public transport. With increasing personal income, people are more likely to choose the car over public transport but would choose public transport over the motorbike. As for trip purpose, school trips are more likely to be made by public transport than by car, while work trips are more likely to be made by motorbike than by public transport.

With respect to the controlling factors of level-of-service in Model C, as shown Table 0.5

, travel cost and OD distance have opposite signs for people choosing between car and motorbike over public transport. With increasing OD distance, people intend to choose public transport rather than the motorbike. Likewise, higher travel costs intend to encourage car and motorbike use rather than public transport use.

After accounting for socio-demographic and level-of-service factors, the Model C results (Table 0.5) indicate that land use variables exert significant influence on mode choice behaviour either on trip origins or on destinations. Increasing population density at trip origins is associated with a greater probability of choosing public transport over the car. The districts at trip origins with more grid-like street patterns, i.e. a higher percentage of 4-way intersections, significantly increase the probability of car and motorbike use compared with public transport use in Taiwan. At trip destinations, the results suggest that higher job density and mix land use increase the probability that people will take public transport rather than the car or motorbike. Job density shows significant and negative relationships for mode choice behaviour between car and public transport, and motorbike and public transport. Land use mix only shows significance significant (negative) relationship between car and public transport. The proportion of percentage of 4-way intersections shows significance significant (positive) relation between motorbike and public transport while shows insignificant between car and public transport.

Table 0.5 Multilevel cross-classified MNL model results

Dependent variable: mode choice of car, motorbike, and public transport (reference category)		Model D - Null model of multilevel cross-classified MNL model			Model E - MNL model			Model F - multilevel cross-classified MNL model			Subtract absolute t-value in Model B from absolute t-value in Model C
Explanatory variables		B	S.E.	t	B	S.E.		B	S.E.	t	
Fixed Part											
Car	**Individual level**										
	Intercept	0.651	0.065	10.010	-2.210	0.388	-5.696	-1.896	0.499	-3.800	
	Gender (male=1)				0.117	0.090	1.300	0.122	0.092	1.326	
	Aged under 14				0.542	0.331	1.637	0.528	0.338	1.562	
	Aged 15-24				**-0.561**	**0.224**	**-2.504**	**-0.626**	**0.231**	**-2.710**	
	Occupancy (student=1)				**-0.560**	**0.226**	**-2.478**	**-0.558**	**0.230**	**-2.426**	
	Personal income				**0.311**	**0.063**	**4.937**	**0.319**	**0.066**	**4.833**	
	Car driver’s license				**0.809**	**0.114**	**7.096**	**0.799**	**0.116**	**6.888**	
	Children in household				**0.362**	**0.088**	**4.114**	**0.352**	**0.090**	**3.911**	
	Household car ownership				**0.543**	**0.044**	**12.341**	**0.539**	**0.046**	**11.717**	
	Trip purpose (work=1)				-0.105	0.098	-1.071	-0.126	0.101	-1.248	
	OD distance				-0.006	0.006	-1.000	-0.006	0.006	-1.000	
	Travel cost				**0.598**	**0.039**	**15.333**	**0.621**	**0.040**	**15.525**	
	Trip origin level										
	Population density				-0.061	0.050	-1.220	-0.045	0.062	-0.726	0.494
	Job density				-0.058	0.053	-1.094	-0.049	0.065	-0.754	0.340
	Land use mix entropy				0.331	0.437	0.757	0.329	0.527	0.624	0.133
	% of 4-way intersections				**3.138**	**0.963**	**3.259**	**2.518**	**1.124**	**2.240**	1.019
	No. of cul-de-sac				-0.020	0.078	-0.256	-0.038	0.091	-0.418	-0.162
	Trip destination level										
	Population density				0.012	0.052	0.231	0.019	0.072	0.264	-0.033
	Job density				**-0.193**	**0.044**	**-4.386**	**-0.192**	**0.067**	**-2.866**	1.520
	Land use mix entropy				**-1.034**	**0.445**	**-2.324**	**-1.285**	**0.608**	**-2.113**	0.211
	% of 4-way intersections				0.601	0.894	0.672	0.553	1.081	0.512	0.160
	No. of cul-de-sac				0.099	0.079	1.253	0.146	0.096	1.521	-0.268
Motorbike	**Individual level**										
	Intercept	0.979	0.063	15.540	-2.003	0.365	-5.488	-1.902	0.412	-4.617	
	Gender (male=1)				**0.167**	**0.080**	**2.088**	**0.164**	**0.081**	**2.025**	
	Aged under 14				0.092	0.287	0.321	0.097	0.290	0.334	
	Aged 15-24				0.050	0.176	0.227	0.023	0.178	0.129	
	Occupancy (student=1)				**-0.499**	**0.182**	**-2.742**	**-0.504**	**0.183**	**-2.754**	
	Personal income				**-0.179**	**0.062**	**-2.887**	**-0.175**	**0.064**	**-2.734**	
	Motorbike driver’s license				**1.313**	**0.109**	**12.046**	**1.323**	**0.110**	**12.027**	
	Children in household				0.159	0.080	1.988	0.151	0.081	1.864	
	Household motorbike ownership				**0.349**	**0.027**	**12.926**	**0.351**	**0.028**	**12.536**	
	Trip purpose (work=1)				**0.184**	**0.089**	**2.067**	**0.177**	**0.090**	**1.967**	
	OD distance				**-0.038**	**0.006**	**-6.333**	**-0.038**	**0.006**	**-6.333**	
	Travel cost				0.059	0.040	1.475	0.070	0.041	1.707	
	Trip origin level										
	Population density				-0.053	0.042	-1.262	-0.051	0.051	-1.000	0.262
	Job density				-0.049	0.047	-1.043	-0.039	0.054	-0.722	0.321
	Land use mix entropy				0.606	0.401	1.511	0.671	0.455	1.475	0.036
	% of 4-way intersections				**2.752**	**0.862**	**3.193**	**2.408**	**0.985**	**2.445**	0.748
	No. of cul-de-sac				-0.034	0.075	-0.453	-0.055	0.081	-0.679	-0.226
	Trip destination level										
	Population density				0.066	0.044	1.500	0.066	0.054	1.222	0.278
	Job density				**-0.187**	**0.038**	**-4.921**	**-0.185**	**0.049**	**-3.776**	1.145
	Land use mix entropy				-0.071	0.409	-0.174	-0.150	0.454	-0.330	-0.156
	% of 4-way intersections				**2.431**	**0.792**	**3.069**	**2.430**	**0.904**	**2.688**	0.381
	No. of cul-de-sac				**0.122**	**0.075**	**1.627**	**0.151**	**0.083**	**1.819**	-0.192
Random Part	Trip destination level										
	σ^2_{D-car}	0.226	0.063	3.587				0.168	0.062	2.710	
	$cov(\sigma_{D-car}, \sigma_{D-motorbike})$	0.172	0.053	3.245				0.092	0.038	2.421	
	$\sigma^2_{D-motorbike}$	0.200	0.059	3.390				0.061	0.028	2.179	
	Trip origin level										
	σ^2_{O-car}	0.109	0.044	2.477				0.096	0.005	1.920	
	$cov(\sigma_{O-car}, \sigma_{O-motorbike})$	0.045	0.038	1.184				0.048	0.032	1.500	
	$\sigma^2_{O-motorbike}$	0.106	0.044	2.409				0.053	0.028	1.893	
DIC (Deviance Information Criterion)			10987.83			9214.07			9183.11		
MCMC deviance			10764.63			9170.09			9026.40		
pD (the effective number of parameters)			223.21			43.99			156.72		

Discussion and conclusion

This chapter introduced a multilevel MNL model and multilevel cross-classified MNL model to explore unobserved spatial heterogeneity and the impact of land use variables at district and city/county level, and across trip origins and destinations on mode choice between car, motorbike and public transport.

The results of this study add to the growing body of evidence that land use variables: density, mixed land use, and street design, apply influence on mode choice behaviour, after accounting for socio-demographic characteristics, trip purpose of work and school, travel distance, and travel cost. In addition, the model's fit for the multilevel MNL model and multilevel cross-classified MNL model are greatly improved compared to the traditional MNL model.

This study found that the unobserved spatial heterogeneity (spatial between-group variations) do exert significant influence on mode choice behaviour. The model's fit of Model C and Model F improved by adopting unobserved spatial heterogeneity compared to Model B and Model E. In addition, by comparing the results of traditional single-level MNL model and multilevel MNL model, it provides further evidence that previous studies by adopting single-level MNL model, which neglected spatial dependency and spatial heterogeneity, to analyse the relationships between land and travel behaviour could exaggerate the sample size and cause misleading results (Snijders, 2012, Snellen et al., 2002). Therefore, for the studies related to hierarchical clustered features and hierarchical data structure, multilevel modelling techniques may be a better method leading to a more accurate results.

After accounting for the land use of district-level and city/county-level, the unobserved spatial heterogeneity at city/county-level was reduced greatly compared to the random term in Model A. Likewise, the unobserved spatial heterogeneity at trip origins and destinations in Model E were reduced sharply compared to the random terms in Model A (null-model) after accounting for the land use variables across trip origins and destinations. This means that the unobserved spatial heterogeneity was effectively explained by the land use variables at city/county-level, and at trip origin-level and destination-level adopted in this study.

By and large, this study found that socio-demographic characteristics and travel-related attributes exert significant influence on mode choice behaviour. At the individual-level, age, personal income, car and motorbike driver's license ownerships, travel cost and trip distance all affect individuals' mode choice between car and motorbike compared with public transport. With regard to the impact of household to individual, individuals with children (aged under 18) in households are more likely to choose car than public transport. Individuals with more cars or motorbikes in household tend to use more car or motorbike than public transport respectively.

As for the influence of land use variables at trip origins on travel mode choice between car and public transport, the results show that higher population density at district-level and higher population density and job density at city/county level associate to higher probability of choosing public transport over the car while more grid-like street pattern intends to attract more car use rather than public transport. In terms of travel mode choice between motorbike and public transport, on the one hand, higher population density at district-level and city/county-level and job density at city/county-level also associate with choosing public transport over the motorbike. On the other hand, more diversified land uses and more grid-like street pattern associate to higher probability of motorbike use. Few studies have paid attention to the effects of land use on motorbike use.

As for the influence of land use variables at trip destinations on travel mode choice between car and public transport, the results show that higher job density and land use mix associate with higher probability of choosing public transport over the car. In terms of travel mode choice between motorbike and public transport, higher job density at trip destination will encourage public transport use while more grid-like street pattern or cul-de-sac intends to attract more motorbike use rather than public transport.

Finally, from the results it seems that, in Taiwan, motorbike use fits better with high density, diversified land use and grid-like street patterns than the car. Diversified land uses provide more opportunities for access to different activities. Likewise, a grid-like street pattern provides an easy access environment for the motorbike. Chang & Wu(Chang and Wu, 2008) characterised motorbike by shorter trip distances and a greater number of multi-stop trips compared to car use. This phenomenon may also apply to other countries in Southeast Asia, such as Vietnam, the Philippines, Malaysia and Thailand, where the motorbike plays an important role in road transport. Most previous studies on motorbike mode choice behaviour (Chen and Lai, 2011, AK et al., 2006) have focused on the influence of trip features and socioeconomics characteristics while few studies have analysed the influence of land use on motorbike mode choice behaviour.

For Southeast Asian countries with a high proportion of motorbike use such as Taiwan, Vietnam, the Philippines, Malaysia, Thailand and Indonesia, maybe there is a need to implement some strategies to increase the inconvenience or the costs for motorbike use in urban area in order to make public transport more competitive compared to the motorbike. Although there may be an argument that the is preferable to the car in terms of environmental impact, and should therefore be encouraged in order to discourage growth in car use, the motorbike is a step into private motorised transport for people reaching the age of 18 enjoying the right to have driver’s license. If people get used to using the motorbike as daily transport mode at the young age, many of them may well shift to car ownership as their income increases and they get older. Therefore, implementing effective strategies to ensure the built environment favours public transport over motorbike use is critical for a sustainable future.

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附錄 2: The Influence of Capability, Opportunity and Motivation on Travel Mode Choice

本報告第 5 章整體分析及結果

Introduction

This chapter addresses the fifth research question (RQ5) which aims to understand how capability, opportunity and motivation influence on travel mode choice behaviour. If refers to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.10, this chapter is to examine the relationships between Block E, intention to use public transport, and travel mode choice behaviour, and also the interactions with Block A, B, C and D (see Figure 2.10).

Based on travel mode choice model built in Figure 2.9 (chapter 2), travel mode choice behaviour are influenced by motivation, capability and opportunity (Michie et al., 2011). There are two aims in this chapter. The first is to analyse passengers' motivation towards public transport and to disentangle the influence of motivation on the travel mode choice behaviour. Motivation towards public transport involves the understanding of the motivational factors: pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO), perceived behavioural control (PBC) and intentions, which are related to public transport use. The second aim is to extend the motivation towards public transport to include capability and opportunity. Capability and opportunity influence travel mode choice directly and directly. Indirectly, the impacts of capability and opportunity on travel mode choice are mediated by motivation.

Increasing public transport market share has been an important transport policy in Taiwan, while there is still lack of knowledge in the psychological factors that can motivate mode choice behaviour towards public transport (Lan et al., 2006). The Ministry of Transport and Communications (MOTC) in Taiwan launched the National Road Public Transport Plan (NRPTP), which has invested a further budget of about $166 million annually since 2010. The key objectives of the NRPTP are to raise the bus patronage number by 5% per year and double the public transport market share reaching 30% (about 15% in 2009) by 2025 (Ministry Of Transportation and Communications, 2010, Ministry Of Transportation and Communications, 2012). Marketing strategies have been included in the project, however, it is still unclear what the impact the motives have on switching travel mode choice towards public transport.

There are eight sections in this chapter. The following section proposes a conceptual model; the third section describes the descriptive statistics of the indicators; the fourth section uses factor analysis to extract the latent factors of the motivation towards public transport model; the fifth section analysis the association of the factors in the motivation model with socio-demographic characteristics and different places. The sixth section presents the impacts of motivational factors on intentions to use public transport by structure equation model (SEM). The seventh section examines the influence of motivational factors on travel mode choice behaviour. The final section delivers the conclusion of this chapter.

Travel mode choice conceptual model

As can be seen in Figure 0.1, this chapter assumes that individual decision-making on travel mode choice is determined by personal characteristics (motivation and capability) and extrinsic conditions (opportunity for action) (Michie et al., 2011, Thøgersen, 2009). In addition, factors of capability and opportunity exert some impacts on motivational factors (Figure 0.1).

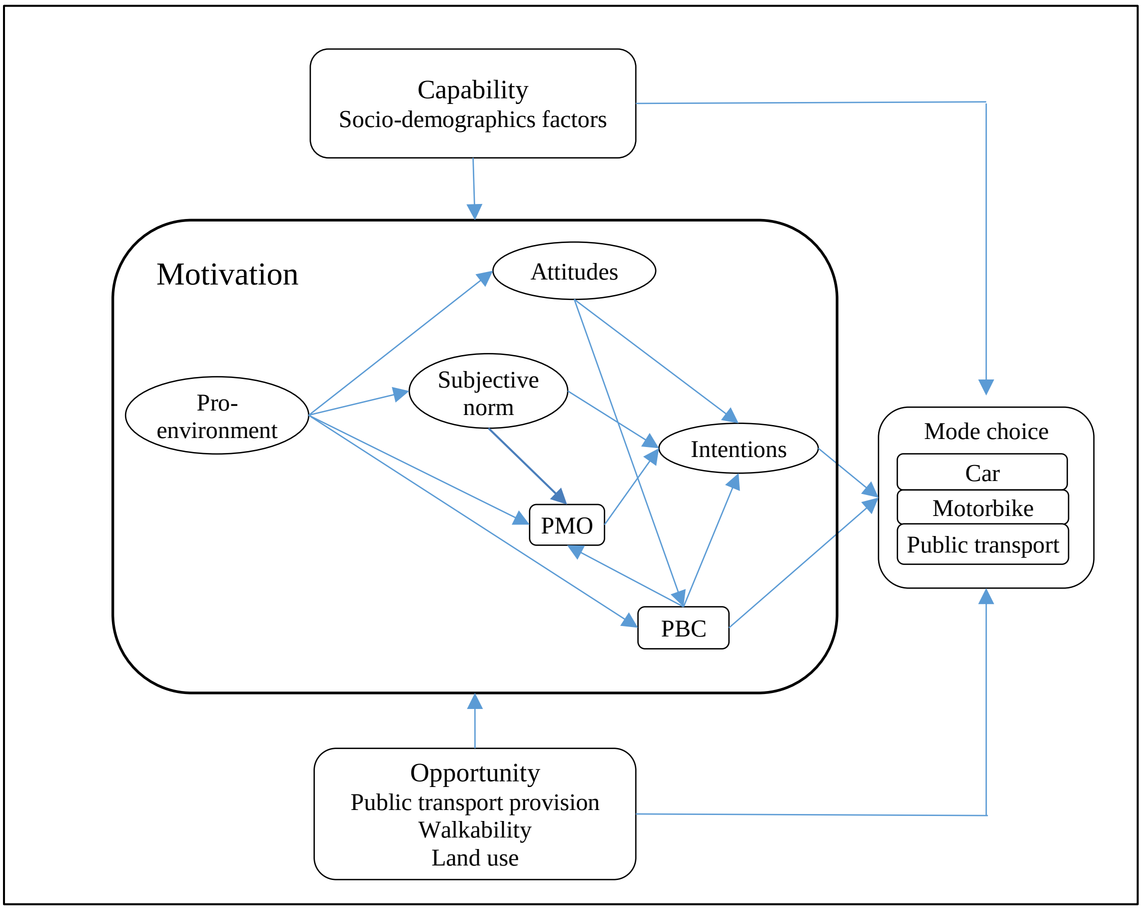


Figure 0.1 Travel mode choice behaviour model

Motivation towards public transport

Motivation towards the public transport is to bridge the relations between motivational factors, intentions to use public transport and travel mode choice behaviour. Motivation refers to 'brain processes to energize or direct behaviour' (Michie et al., 2011), which indicate the reasons why the individual intends to have the action. For example, the individual traveller may think he/she wants to use public transport because most of his/her friends have already been using this form of transport. The 'want to use public transport' is the intentions and the 'because most of his/her friends have already been using public transport' is the motivation.

The motivational factors: pro-environment value, attitudes, subjective norms, PMO, PBC and intentions, were developed by the theory of planned behaviour (TPB) (Ajzen, 1991) and its extended model (Chen and Tung, 2014, Heath and Gifford, 2002). The theory of planned behaviour (TPB) model and its extended model are the commonly used basic frameworks to explain travel behaviour intentions and travel behaviour (Chen and Chao, 2011, Chen and Lai, 2011, Thøgersen, 2009, Bamberg et al., 2003, Heath and Gifford, 2002). Chen and Tung (2014) & Heath and Gifford (2002) extended TPB model by adopting perceived moral obligation (PMO), and environmental concerns and value to enrich the explanatory power for intentions. Pro-environment value, attitudes, subjective norms, PMO, PBC are treated as antecedent of intentions to use public transport, as shown in Figure 0.1. In terms of PBC, it refers to an individual's judgement about ease or difficulty in using public transport and it is assumed to reflect past experience as well as expected impediments and obstacles for using public transport. PBC can also serve as a proxy for actual behaviour control and contribute to the prediction of mode choice behaviour, as shown in Figure 0.1 (Ajzen, 1991).

Pro-environment value is assumed to be related to the intentions of using public transport indirectly, which is mediated by attitudes, subject norm and PMO in the motivation towards public transport model, as shown in Figure 0.1. Most of the previous studies reported disappointing results, which showed low to moderate relationships between environmental concerns and behaviour. Bamberg (2003) reviewed some previous studies and assumed that pro-environment value, which is a general attitudes on environment concerns and value, had an indirect influence on specific environmental behaviour intentions and specific environmental behaviour. Chen and Tung (2014) & Bamberg (2003) gave the evidence that pro-environment value did not have significant direct impact on behaviour intentions and behaviour itself but exerted strong direct impacts on situation-specific beliefs and attitudes.

For example, imagine two people A and B in which A has higher environmental concerns and values than B. With all other conditions the same, person A may report higher evaluation on attitudes towards public transport and perceived moral obligation of using public transport than person B under the same public transport service level due to person A's higher pro-environmental value. In terms of subjective norms, person A may report higher evaluation on subjective norms over public transport than person B because his/her pro-environment value let him/her have more sensitivity on the social pressure to use public transport than person B. Likewise, person A may report easier to use public transport than person B because his/her pro-environmental value let him/her have higher tolerance on using public transport.

This study also assumes that there are some interactions between attitudes, subjective norms, PMO and PBC (Figure 0.1). Individual's attitudes may exert some impact on perceptions of behavioural control over public transport (PBC). Perceptions of moral obligation (PMO) may be affected by social pressure (subjective norms) and perceptions of behavioural control (PBC).

Opportunity

Opportunity is similar to accessibility which is affected by the supply side of public transport service quality, the demand side the situation of land use and walking environment. Public transport provision relates to the opportunity of using public transport, and land use relates to the opportunity of access to activities. In this chapter, opportunity variables include bus stops density, bus operation length, metro station, mixed land use entropy, street patterns and overall perceived walkability.

Capability

Sen (1993) defined capability as 'the alternative combinations of functions a person can achieve and from which he or she can choose one collection.' Capability relates to physical, psychological and mental aspects. In this study, gender, age, children in household, drivers' licence and household vehicle ownership were adopted as proxies of physical aspect of capability. For instance, as a person grows older, the physical constrains make him/her more willing to use public transport rather than private vehicle. In addition, a person who owns car or motorbike (tools) is more capable to use car or motorbike. Mental aspect of capability relates to education and occupation. Financial aspect of capability relates to income. For example, higher income people are more capable of owning a car and using car as transport mode.

Building on this travel model choice behaviour model in Figure 0.1, the aims of this chapter are to: 1) identify the latent factors: pro-environment value, attitudes, subjective norms, PMO, PBC and intentions; 2) examine the influence of capability and opportunity on motivational factors; 3) to what extent these motivation factors influence intentions to use public transport, and 4) to what extent the capability, opportunity and motivation influence travel mode choice behaviour.

Descriptive statistics

Data on perceptions of the walking environment, attitudes towards public transport, mode choice for commuting trips, and socio-demographic characteristics was drawn from an online survey of travel behaviour. An unrestricted self-selection survey method was used, in other words the survey was open to the public for participation. A snowball sampling method was used; the questionnaire web link was sent to contacts in Taiwan *via* email, Facebook and online chat apps; these contacts were asked both to complete the questionnaire and to forward the web link to their friends in Taiwan. The survey took place between July and August, 2015. There are 1,619 valid samples in this survey. Of all the effective samples, 1,427 samples was used in this analysis because 192 samples did not report commuting trips. This section describes the descriptive statistics of capability variables, opportunity variables and the indicators for motivational factors.

Descriptive statistics of capability and opportunity variables

The descriptive statistics for capability variables can be seen in Table 0.1. Of all the 1,427 samples, about 40% respondents reported using motorbike as commuting mode of transport, about 30% used car and public transport respectively (Table 0.1). If compare the samples' modal split with the modal split of Taiwanese National Travel Survey 2014 for commuting trips (car : motorbike : public transport = 23.6% : 53.9% : 25.7%) (Department Of Statistics, 2015), motorbike users were underrepresented in the sample while car and public transport users were overrepresented. This may be caused by the proportion of samples from metropolises such as Taipei City and New Taipei City were larger than the proportion of the population. These cities have higher public transport use rate and lower car use rate. However, as the focus of this study is on understanding individual behaviour rather than predicting behaviour for the population this is not of major concern.

Overall, female, aged 24 and under, aged 55 and over, lower education level, lower monthly income level, and without children in household tended to have higher possibility of using public transport (Table 0.1). Female had higher possibility (35.5%) of using public transport compared with male and male had higher possibility (44%) of using motorbike (Table 0.1). In terms of age, aged 24 and under 25, and aged 54 and over tended to use public transport more compared with other aged 25-54 (Table 0.1). Lower education level (high school and under) had the highest possibility to use public transport (40.2%) among all the education groups, and higher education level (master's and doctoral degree) had the greatest proportion (34.6%) of car use (Table 0.1). Lower income group (Monthly income <US$ 667) had the highest possibility (42.5%) of using public transport and higher income group (monthly income >= US$ 2,667) had the highest possibility (56.7%) of using car compared with other income groups (Table 0.1). Whether there are children (aged under 18) in household seems related to travel mode choice. Household without children tended to have higher possibility of using public transport (36.6%) and motorbike (43.2%) than household with children (Table 0.1).

By and large, car and motorbike driver's license and household car and motorbike ownerships, which represent the capability of using car and motorbike, associated with travel mode choice (Table 0.1). The public transport usage rate for respondents without car driver's license (57.8%) and without motorbike driver's license (73.0%) were about double and triple to the respondents with car driver's license (26.9%) and with motorbike driver's license (25.1%) (Table 0.1). In terms of household car and motorbike ownerships, the proportion of public transport use decreased along with the increasing of household car and motorbike ownerships (Table 0.1).

Table 0.1 Modal split and socio-demographic characteristics

	Car (%)	Motorbike (%)	Public transport (%)
Total	28.9	39.6	31.5
Male	27.6	44.0	28.4
Female	30.7	33.8	35.5
Aged 14-24	5.3	50.6	44.1
Aged 25-54	31.7	39.5	28.8
Aged 55 and over	37.8	18.3	43.9
Education: high school and under	22.7	37.1	40.2
Education: bachelor's degree	25.7	47.1	27.2
Education: master's and doctoral degree	34.6	29.7	35.7
Monthly income < US$ 667	5.23	52.3	42.5
US$[1] 667<=Monthly income<US$ 2,667	27.4	44.0	28.6
Monthly income>=US$2,667	56.7	9.1	34.2
Children(aged under 18) in household: no	20.3	43.2	36.6
Children(aged under 18) in household: yes	38.7	35.6	25.7
Car driver's license: no	5.6	36.6	57.8
Car driver's license: yes	33.0	40.1	26.9
Motorbike driver's license: no	24.9	2.1	73.0
Motorbike driver's license: yes	29.6	45.3	25.1
Household car ownership: 0	1.2	50.0	48.8
Household car ownership: 1	25.2	40.8	34.0
Household car ownership: 2	55.0	27.8	17.2
Household car ownership: 3	49.3	40.3	10.4
Household car ownership: 4	60.0	40.0	0.0
Household motorbike ownership: 0	44.5	2.3	53.2
Household motorbike ownership: 1	32.2	31.6	36.2
Household motorbike ownership: 2	23.7	49.9	26.4
Household motorbike ownership: 3	24.1	57.6	18.3
Household motorbike ownership: 4	14.9	71.6	13.5

1. Exchange rate: US$: NTD (New Taiwan Dollar) = 1:30

Table 0.2, show descriptive statistics of the opportunity variables: land use mix entropy, percentage of 4-way intersections, walking time to public transport stop/station, bus operation, bus stop density and overall perceived walkability for car, motorbike and public transport users.

Table 0.2 Descriptive statistics of opportunity variables

Variables		Mean	Std. dev.	Min.	Max.
Land use mix entropy (district)	Car	0.647	0.117	0.205	0.890
	Motorbike	0.644	0.113	0.054	0.853
	PT	0.650	0.092	0.228	0.890
% of 4-way intersections (district)	Car	0.214	0.075	0.034	0.561
	Motorbike	0.234	0.088	0.055	0.561
	PT	0.225	0.073	0.034	0.561
Bus operation length (district)	Car	2.16e+07	1.99e+07	6539	7.06e+07
	Motorbike	2.38e+07	1.99e+07	0	7.06e+07
	PT	3.60e+07	1.96e+07	0	7.06e+07
Bus stop density (Stops/per km^2, village)	Car	0.850	1.310	0	7.886
	Motorbike	1.086	1.417	0	10.891
	PT	1.912	1.968	0	17.919
Walking time to PT stop/station	Car	8.840	8.138	3	35
	Motorbike	8.277	7.243	3	35
	PT	5.148	3.997	3	35
Overall perceived walkability	Car	4.828	1.498	1	7
	Motorbike	4.703	1.453	1	7
	PT	5.241	1.371	1	7

PT: public transport

Descriptive statistics of motivational indicators

As can be seen in Table 6.1, the constructs of motivation towards public transport contains five components including pro-environment value (PE1-PE7), attitudes towards public transport (AT1-AT5), subjective norms over public transport (SN1-SN3), PMO (perceived moral obligation of using public transport), PBC (perceived behaviour control for public transport) and intentions to use public transport (IN1 and IN2). Table 0.3 shows all the indicators this study adopted to measure the constructs of motivation towards public transport.

A 5-likert scale was used to for the respondents to measure these indicators, and the data are coded as strongly agree: 5, agree: 4, neutral (neither agree nor disagree): 3, disagree: 2, strongly disagree: 1. For questions, PE3 - the effects of climate change are too far in the future to really worry me, PE4 - the so called ‘environmental crisis’ facing humanity has been greatly exaggerated, and PE7 - technological advances will solve many environmental problems - were reversely coded, as strongly agree: 1, agree: 2, neutral: 3, disagree: 4, strongly disagree: 5. The higher the number indicates a more positive pro-environment value, as noted in the last column in Table 0.3.

As can be seen in Table 0.3 and Figure 0.2, generally, most of the respondents agree with the severe climate change and potentially caused environmental problem. All the indicators in the group of pro-environment value indicators except PE7 have a negative skewness. PE2 – we will all need to make sacrifices in our lifestyles to reduce environmental problems - has the highest mean score (4.39) and lowest standard deviation (0.609). PE7 - Technological advances will solve many environmental problems - has the lowest mean score (2.5) and highest standard deviation (0.985) in the group of pro-environment value indicators. From the histogram in Figure 0.2 and the positive skewness in Table 0.3, although most of the respondents agree that the climate change is an important issue, many others believe that technological advances will relieve the problem.

As for AT1-AT5 the indicators for measuring attitudes towards public transport (Table 0.3, Figure 0.2), Question AT1 - for me, (if) I can take public transport for everyday routes would overall be (very bad to very good) - has the highest mean score of 4.20 with a standard deviation of 0.876, which indicate that most of the respondents agree that it is a good thing if they can use public transport as everyday routes. Question AT2 - in the past year, using public transport is a satisfying experience, and AT3 - for me, using public transport for everyday routes is convenient - have the same lowest mean score of 3.57 with standard deviation of 0.937 and 1.046 respectively among the attitudes questions, which indicate that the respondents reported satisfaction and convenience for public transport service were not as well as their willingness to use public transport for a daily mode of transport.

As for the indicators (SN1-SN3) measuring subjective norms over public transport (Table 0.3 and Figure 0.2), SN1 - most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence) has the highest mean score (3.41) and lowest standard deviation (0.958). SN3 - most of my friends and relatives use public transport regularly - has the lowest mean score (3.01) and highest standard deviation (1.026). The skewness for SN2 and SN3 are close to 0, which means that the range of answers for both questions are about balance, as shown in Figure 0.2.

Perceived moral obligation and Perceived behaviour control are only measured by PMO and PBC respectively, as shown in Table 0.3 and Figure 0.2. PMO has the higher mean score (3.39) and lower standard deviation (1.027) compared with PBC (mean=2.94, SD=1.326). The gap between PMO and PBC means that the respondents feel that they are obliged to use public transport, however, some feel that it is difficult for them to use public transport as daily mode of transport.

Intentions to use public transport is measured by IN1 - how likely is it, that in the next 6 months you will use public transport for everyday routes (extremely unlikely to extremely likely), and IN2 - my intentions to use public transport for everyday routes is (extremely weak to extremely strong). The mean score and standard deviation for the indicators IN1 and IN2 are 2.85 and 1.335, and 2.91 and 1.163 respectively.

Table 0.3 Descriptive statistics for motivation towards public transport questions

No.	Items	Mean	Std. Dev.	Skewness	Kurtosis	Reverse code
PE1	I am very concerned about environmental issues.	4.22	.738	-.643	.134	No
PE2	We will all need to make sacrifices in our lifestyles to reduce environmental problems.	4.39	.609	-.840	2.003	No
PE3	**The effects of climate change are too far in the future to really worry me.**	4.09	.843	-1.068	1.390	Yes
PE4	**The so called 'environmental crisis' facing humanity has been greatly exaggerated.**	3.93	.930	-.949	.745	Yes
PE5	I would be prepared to pay more for environmentally-friendly products.	3.98	.722	-.843	1.801	No
PE6	If things continue on their current course, we will soon experience a major environmental disaster.	4.19	.735	-.967	1.763	No
PE7	**Technological advances will solve many environmental problems.**	2.50	.985	.478	-.481	Yes
PE8	There is an urgent need for something to be done about the environmental pollution caused by car and motorbike use.	4.35	.661	-1.135	3.075	No
AT1	For me, (if) I can take public transport for everyday routes would overall be (very bad to very good).	4.20	.876	-1.166	1.373	No
AT2	In the past year, using public transport is a satisfying experience.	3.57	.937	-.760	.436	No
AT3	For me, using public transport for everyday routes is convenient.	3.57	1.046	-.730	-.006	No
AT4	For me, using public transport for everyday routes is reliable.	3.63	.858	-.833	.904	No
AT5	For me, using public transport for everyday routes is cheap.	3.60	.970	-.627	-.040	No
SN1	Most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence.	3.41	.958	-.337	-.283	No
SN2	Most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence.	3.11	.983	-.031	-.471	No
SN3	Most of my friends and relatives use public transport regularly.	3.01	1.026	-.057	-.734	No
PMO	Regardless of what other people do, because of my own values/principles I feel an obligation to use public transport instead of the car and motorbike for everyday trips.	3.39	1.027	-.421	-.289	No
PBC	For me using public transport for everyday routes is (extremely difficult to extremely easy).	2.94	1.326	.079	-1.222	No
IN1	How likely is it that in the next 6 months you will use public transport for everyday routes (extremely unlikely to extremely likely).	2.85	1.335	.086	-1.241	No
IN2	My intentions to use public transport for everyday routes is (extremely weak to extremely strong).	2.91	1.163	-.069	-.808	No

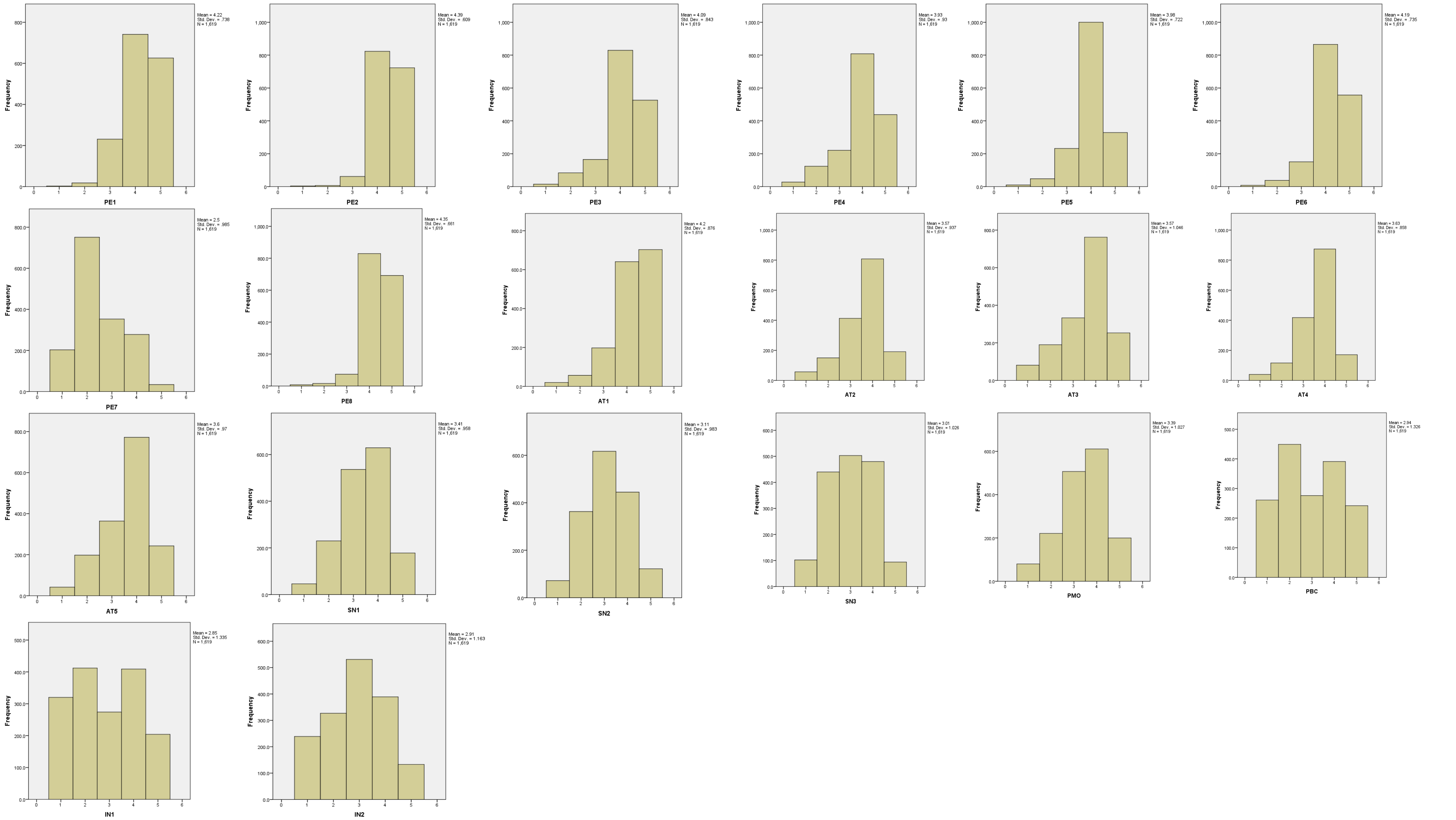


Figure 0.2 Histogram for motivation towards public transport questions

The Cronbach’s α is 0.892, as shown in Table 0.4, which exceed the acceptable level of 0.7 (Nunnally et al., 1978). This value indicates that the dataset of motivation towards public transport indicators is reliable and has adequate internal consistency.

Table 0.4 Reliability statistics

Cronbach's Alpha	N of Items
.892	20

Exploratory factor analysis for motivation model latent factors

Exploratory factor analysis (EFA) rather than confirmative factor analysis (CFA) was used in identify the measurement model of SEM. The questionnaire adopted some related questions as indicators to measure the unobserved motivational factors: pro-environment value, attitudes, subjective norms, perceived moral obligation (PMO), perceived behavioural control (PBC) and intentions. As can be seen in Table 0.5, there are many cross correlations between indicators in different categories, which indicate that if CFA was used and fixing cross-loadings at 0 may cause a worse fit of a measurement model. Then, there is a need to do intensive model modification by using model modification indexes to find a well-fitting model. The process of model modification becomes exploratory rather than confirmatory. Hence, EFA was used to identify the measurement model, which is the latent constructs between motivational latent variables and the indicators (Asparouhov and Muthén, 2009, Marsh et al., 2010, Browne, 2001).

Sample size is the first prior criteria to be checked when doing factor analysis. Williams et al. (2012) suggested that the sample size level for factor analysis is as follows: 100 as poor, 200 as fair, 300 as good, 500 as very good and 1,000 or more as excellent (reference needed). Hair et al. (2009) also suggested that the minimum was to have at least five times as many observations as the number of indicators to be analysed, and a more acceptable sample size is to have an observation to indicator ratio of 10:1 but it would more accurate to have a ratio of 20:1. There are 1,427 samples in this study survey, which is about the ‘excellent’ sample size requirement and the observations to indicators ratio of about 80:1. Therefore, the sample size of this study is enough for carrying out factor analysis.

The second prior task to be checked is the correlation matrix displaying the relationships between the individual observed indicators, as shown in Table 0.5. Hair et al. (2009) suggested that if there were no substantial number of correlations greater than (+/-) 0.3, then factor analysis is probably inappropriate. Table 0.5 shows that there are a substantial number of correlations greater than 0.3. Also, there is no multicollinearity problem (no correlations greater than 0.9), therefore, the data of this study are suitable for factor analysis. Correlation matrix in Table 0.5 also shows that the correlations between indicators PE7 - technological advances will solve many environmental problems - and other indicators are all lower than (+/-) 0.3, which means that PE7 may be irrelevant to other indicators. PE7 seems more likely to assess pro-technology value rather than pro-environment value. Therefore, PE7 is excluded in the factor analysis. Expand on this in meeting

Table 0.5 Correlation matrix for motivation towards public transport indicators

	PE1	PE2	PE3	PE4	PE5	PE6	PE7	PE8	AT1	AT2	AT3	AT5	AT5	SN1	SN2	SN3	PMO	PBC	IN1	IN2
PE1	1.00																			
PE2	.595	1.00																		
PE3	.489	.467	1.00																	
PE4	.412	.409	.605	1.00																
PE5	.382	.437	.360	.360	1.00															
PE6	.425	.474	.458	.500	.441	1.00														
PE7	-.001	.002	.061	.071	-.003	-.007	1.00													
PE8	.380	.458	.382	.343	.402	.430	-.089	1.00												
AT1	.274	.341	.272	.220	.307	.283	-.029	.418	1.00											
AT2	.154	.183	.146	.093	.214	.193	-.013	.184	.349	1.00										
AT3	.136	.198	.119	.116	.219	.182	-.037	.201	.357	.705	1.00									
AT4	.162	.214	.143	.112	.240	.189	-.046	.207	.349	.653	.668	1.00								
AT5	.164	.221	.170	.144	.226	.187	-.011	.248	.338	.418	.426	.438	1.00							
SN1	.172	.233	.136	.126	.235	.189	-.024	.249	.422	.420	.439	.405	.390	1.00						
SN2	.201	.220	.139	.137	.230	.179	-.051	.239	.356	.396	.439	.397	.377	.729	1.00					
SN3	.105	.140	.066	.085	.147	.107	-.035	.141	.265	.396	.460	.392	.318	.530	.546	1.00				
PMO	.340	.351	.288	.240	.353	.315	.022	.374	.546	.415	.439	.391	.388	.456	.486	.342	1.00			
PBC	.102	.149	.118	.082	.162	.102	-.002	.180	.398	.505	.567	.430	.358	.479	.474	.451	.514	1.00		
IN1	.154	.196	.154	.126	.217	.137	.024	.241	.441	.444	.493	.368	.354	.445	.452	.382	.563	.774	1.00	
IN2	.244	.284	.222	.200	.271	.194	.038	.297	.488	.377	.433	.345	.342	.439	.451	.325	.639	.644	.733	1.00

Factor analysis for pro-environment, attitudes towards public transport and subjective norms over public transport

Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO-MSA) and Bartlett's Test of Sphericity confirmed that the dataset of the 15 indicators (PE1-PE8) (exclude PE7), AT1-AT5 and SN1-SN3) are the most suitable for factor analysis. The index of KMO-MSA ranges from 0 to 1 and the measure’s guideline is: 0.8 or above, meritorious; 0.70 or above, middling; 0.60 or above, mediocre; 0.50 or above miserable; and below 0.5, unacceptable (Hair et al., 2009). Table 0.6 shows that the KMO-MSA for motivation towards public transport indicators’ data is 0.887, reaching the meritorious level. Bartlett's Test of Sphericity is to check if the correlation matrix has significant correlations among at least some of the indications (Hair et al., 2009). The significant level of p<0.000 for Bartlett's Test of Sphericity, as shown in Table 0.6, confirmed that the motivation towards public transport indicators do have patterned relationships.

Table 0.6 KMO-MSA and Bartlett's test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.887
Bartlett's Test of Sphericity	10119.826	13839.174
	105	153
	.000	.000

Factor analysis aims to extract the latent factors of pro-environment, attitudes towards public transport and subjective norms over public transport. The indicators for these latent factors include PE1-PE8 (exclude PE7), AT1-AT5 and SN1-SN3.

Principal axing factoring method is used to extract the latent factors from the motivation towards public transport indicators' dataset. There are 3 factors extracted if the extraction rule follows that factors with eigenvalues greater than 1.0 are extracted (Hair et al., 2009). Figure 0.3 shows the scree plot, which plot the latent roots against the first 15 factors extracted in these 15 indicators, in order. Also, Table 0.7 shows that the first three extracted factors accounted for about 60% of total variance.

Table 0.7 Total variance explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factor	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.312	35.412	35.412	4.845	32.303	32.303	3.242	21.610	21.610
2	2.583	17.221	52.633	2.119	14.125	46.427	2.450	16.334	37.944
3	1.051	7.010	59.643	.728	4.851	51.278	2.000	13.333	51.278
4	.829	5.528	65.170						
5	.705	4.702	69.873						
6	.674	4.494	74.367						
7	.641	4.271	78.638						
8	.548	3.652	82.291						
9	.510	3.400	85.691						
10	.482	3.214	88.904						
11	.396	2.638	91.542						
12	.375	2.497	94.040						
13	.350	2.334	96.373						
14	.287	1.911	98.285						
15	.257	1.715	100.000						

Extraction Method: Principal Axis Factoring.

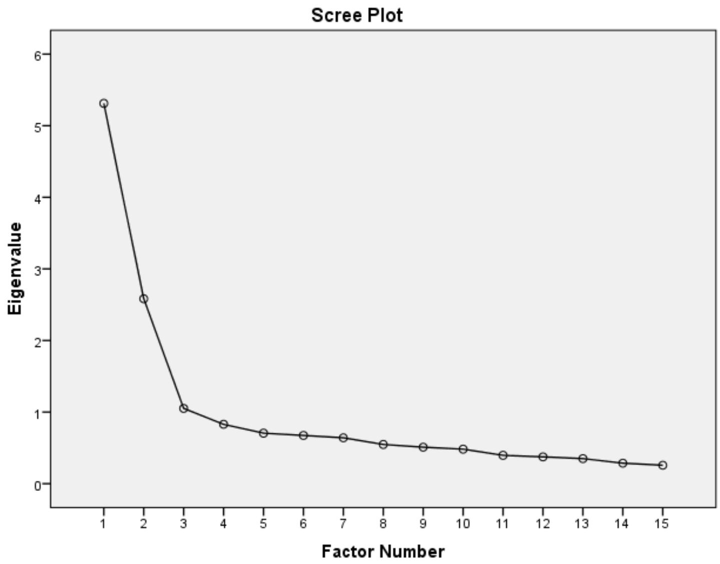


Figure 0.3 Scree plot for the extracted factors

As can be seen in Table 0.8 unrotated factor loadings show the factor loadings prior to rotation with some cross-loadings in them, which indicates that there is a need to introduce factor rotation to simplify the factor loadings. Factor loadings represent the correlations between the observed indicators and the latent factors. So, the squared factor loading is the amount of the indicator's total variance accounted for by the latent factor. In addition, the sum of the squared loadings for each factor is the communalities for each indicator, as shown in the last column in Table 0.8. The factor loadings under 0.30 are suppressed for easier interpretation. Hair et al. (2009) suggested some guidelines for factor loadings. Firstly, factor loadings in the range of ±0.30 to ±0.40 are considered to meet the minimal level for interpretation of structure (that is why Table 6.11 and 6.12 supress factor loadings under ±0.30). Secondly, factor loadings ±0.50 or greater are considered practically significant. However, identifying significant factor loadings also based on sample size. For sample sizes greater than 350, factor loading ±0.30 or greater is significant at the level of 95%. In addition, the sum of loadings exceeding 1.70 are considered indicative of well-defined structure and are the goal of any factor analysis (Hair et al., 2009). Table 0.8 shows that all factor loadings of this study comply with all the requirements. Each factor has more than three indicators which have significant loadings. However, the unrotated factor loading matrix shows complicated relationships between the indicators and latent factors. Some indicators such as PE1, PE2, PE3, PE4, PE6, PE8, AT2, AT3, AT4, SN1 and SN2 were found cross-loadings with two or three factors. Hence, there is a need to introduce factor rotation, which can maximize high indicator loadings and minimize low indicator loadings to reduce, or even eliminate cross-loadings and thus transform a simple structure.

The last column in Table 0.8 shows the communalities of the indicators, which represent the proportion of the variance that is explained by the extracted factors. SN1 - most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence - has the highest proportion of variance, about 74.2%, explained by the extracted latent factors. In addition, AT3 - for me, using public transport for everyday routes is convenient, SN1 - how likely is it, that in the next 6 months you will use public transport for everyday routes (extremely unlikely to extremely likely), and SN2 - my intentions to use public transport for everyday routes is (extremely weak to extremely strong), which relates to the attitudes towards public transport and subjective norms over public transport respectively, have more than 70% of their variances explained by the extracted latent factors.

Table 0.8 unrotated factor loadings

	Factor			Communalities
	1	2	3	
AT3	.659	-.430	-.310	.716
SN1	.659	-.349	.432	.742
SN2	.643	-.338	.432	.714
AT4	.635	-.364	-.316	.635
AT2	.635	-.398	-.342	.678
PE2	.580	.432		.523
AT1	.577			.335
PE8	.534	.305		.379
PE6	.531	.427		.467
AT5	.528			.316
PE5	.522			.356
PE1	.509	.446		.459
SN3	.506	-.360		.418
PE3	.496	.509		.508
PE4	.456	.488		.446

Extraction Method: Principal Axis Factoring.

The cross-loading problem has improved by adopting varimax rotation method, which is the orthogonal transformation in which the transformed factors are mutually uncorrelated. The reason to choose this orthogonal transformation technique is because the following analysis will examine the association of these latent factors with mode choice behaviour by using the extracted factors’ scores. The orthogonal rotation method can avoid the collinearity between the factors. Table 0.9 shows rotated factor loading matrix. Compared to Table 0.8 (unrotated factor loading matrix) the latent factor structure has been simplified if suppress the insignificant factor loadings (factor loading less than 0.30). Therefore, the extracted four latent factors can easier be interpreted.

The factor loadings in Table 0.9 show that each factor has some excellent indicators. Tabachnick and Fidell (2007) suggested that loadings in excess of 0.71 (50% overlapping variance) are considered excellent, 0.63 (40% overlapping variance) very good, 0.55 (30% overlapping variance) good, 0.45 (20% overlapping variance) fair, and 0.32 (10% overlapping variance) poor. The indicators are ranked by their factor loadings in each group of factor.

The first extracted factor is 'Pro-environment value', as shown in Table 0.9, which is mainly measured by PE3 - The effects of climate change are too far in the future to really worry me, PE2 - We will all need to make sacrifices in our lifestyles to reduce environmental problems, PE6 - If things continue on their current course, we will soon experience a major environmental disaster', PE1 - I am very concerned about environmental issues), and PE4 - The so called 'environmental crisis' facing humanity has been greatly exaggerated). More than 40% of these five indicators' (PE3, PE2, PE6, PE1 and PE4) variances are accounted for by the first latent factor. The indicators grouped in the first factor except AT1 are all related to environmental concerns and value, thus named the first latent factor as 'Pro-environment value'.

The second extracted factor is 'Attitudes towards public transport', as shown in Table 0.9, which is mainly measured by AT3 - For me, using public transport for everyday routes is convenient, AT2 - In the past year, using public transport is a satisfying experience, and AT4 - For me, using public transport for everyday routes is reliable. More than 50% of these three indicators' (AT3, AT2 and AT4) variances are accounted for by the second latent factor. All the indicators grouped in the third factor are related to the attitudes towards public transport, thus named the third latent factor as 'Attitudes towards public transport'.

The third extracted factor is 'Subjective norms over public transport', as shown in Table 0.9, which is mainly measured by SN1 - most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence - and SN2 - most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence. More than 50% of these three indicators' (SN1 and SN2) variances are accounted for by the third latent factor. All the indicators grouped in the third factor are related to subjective norms over public transport use, thus named the third latent factor as 'Subjective norms over public transport'.

After factor analysis, this study summarises the 15 motivational variables' indicators into 3 latent factors: pro-environment values, attitudes towards public transport and subjective norms over public transport.

Table 0.9 Rotated factor loadings

		Factor		
		Pro-environment	Attitudes towards PT	Subjective norms over PT
PE3	The effects of climate change are too far in the future to really worry me.	.710		
PE2	We will all need to make sacrifices in our lifestyles to reduce environmental problems.	.703		
PE6	If things continue on their current course, we will soon experience a major environmental disaster.	.669		
PE1	I am very concerned about environmental issues.	.669		
PE4	The so called 'environmental crisis' facing humanity has been greatly exaggerated.	.667		
PE8	There is an urgent need for something to be done about the environmental pollution caused by car and motorbike use.	.576		
PE5	I would be prepared to pay more for environmentally-friendly products.	.557		
AT1	For me, to take public transport for everyday routes would overall be (Very bad to very good)	.372	.305	.321
AT3	For me, using public transport for everyday routes is convenient.		.796	
AT2	In the past year, using public transport is a satisfying experience.		.786	
AT4	For me, using public transport for everyday routes is reliable.		.752	
AT5	For me, using public transport for everyday routes is cheap.		.430	.305
SN1	Most people who are important to me would support my using public transport instead of car and motorbike for daily travel from my current place of residence.			.802
SN2	Most people who are important to me think that I should use public transport instead of car and motorbike for daily travel from my current place of residence.			.790
SN3	Most of my friends and relatives use public transport regularly.		.358	.536

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 4 iterations.

8.1.2 PMO, PBC and intentions to use PT

1. PMO (perceived moral obligation) and PBC (perceived behaviour control)

PMO and PBC are measured by the indicators: regardless of what other people do, because of my own values/principles I feel an obligation to use public transport instead of the car and motorbike for everyday trips, and for me using public transport for everyday routes is (extremely difficult to extremely easy) respectively. In order to pertain consistent result, standardised scores with mean 0 and standard deviation 1 for PMO and PBC are used in the model analysis.

2. Intention to use PT

Intention to use public transport is measured by two indicators: IN1 - how likely is it, that in the next 6 months you will use public transport for everyday routes.(extremely unlikely to extremely likely)- and IN2 -my intention to use public transport for everyday routes is (extremely weak to extremely strong). The Cronbach’s Alpha for the two indicators is 0.841, which suggests its adequate internal consistence. The extracted intention to use public transport factor explained about 87% of total variance and each indicator has 73.2% variance explained by the intention to use public transport factor.

Estimation results

Based on the conceptual model developed in Figure 0.1, this section examines the impact of the motivational variables: pro-environment value, attitudes, subjective norms, PMO, PBC, on intentions to use public transport and travel mode choice behaviour by adopting structural equation model (SEM) and generalized structural equation model (GSEM).

Correlations of the motivational factors

As can be seen in Table 0.10, PBC had the highest correlation with intentions among all the motivational factors, and pro-environment had the lowest correlation with intentions. High correlations occurred between attitudes, subjective norms and PMO, and PBC, which implies that there are interactions between attitudes, subjective norms and PMO, and intentions. Likewise, there are potential interactions between attitudes and subjective norms, and PMO.

Table 0.10 Correlations between motivational factors

	Pro-environment	Attitudes	Subjective norms	PMO	PBC	Intentions
Pro-environment	1.00					
Attitudes	0.22	1.00				
Subjective norms	0.25	0.12	1.00			
PMO	0.41	0.41	0.47	1.00		
PBC	0.15	0.51	0.44	0.51	1.00	
Intentions	0.27	0.44	0.46	0.63	0.77	1.00

Motivational factors influence on intentions

There are three SEM models being estimated with a maximum likelihood estimation method. In the first model, this study estimated a whole sample model to test the hypothesis of the conceptual model. The second and third SEM models adopted car users and motorbike users in order to understand the different effects for car and motorbike users on intentions to use public transport.

Table 0.11, Figure 0.4, Figure 0.5 and Figure 0.6 report the estimated results. The goodness of fit (GOF) indices indicate that the proposed model fits the data well, RMSEA<0.06, CFI and TLI >0.9, SRMR<0.08 (Bartholomew et al., 2008) for both whole samples model and motorbike users except car users model.

For the whole sample model, as shown in Table 0.11 and Figure 0.4, the results confirm that environmental concerns and value (pro-environment) is an important antecedent determining an individual's intentions to use public transport. All the four paths direct from pro-environment factor to attitudes towards public transport, subjective norms over public transport, PMO and PBC are statistically significant. In other words, an individual's attitudes towards public transport, subjective norms over public transport, perceived moral obligation and perceived behaviour control are influenced by his/her environmental concerns and value. In addition, environmental concerns and value (pro-environment) asserts the highest impact on perceived moral obligation to use public transport (PMO) compared with attitudes, subjective norms and PBC. This means that individuals, who enjoy higher awareness of climate change and environmental problem, have higher perceived moral obligations to use public transport.

As can be seen in Table 0.11 and Figure 0.4, the paths of motivational factors: subjective norms, PMO and PBC to intentions to use public transport are statistically significant and in the expected direction. The results indicate that an individual's intentions to use public transport is determined by his/her subjective norms over public transport, perceived moral obligation and perceived behaviour control. About 80% of the total variance in intentions to use public transport factor is explained by the motivational factors, which indicate that this model enjoys a well explanatory power in predicting intentions to use public transport.

PBC is the most influential factor affecting the intentions to use public transport of all the motivational factors (Table 0.11), which implies that the individual's perceived easy or difficult to use public transport is the most important factor in the model influence his/her intentions to use public transport. PMO is also an indispensable factor in explaining intentions to use public transport (Table 0.11).

As can be seen in Table 0.11, Figure 0.5 and Figure 0.6, attitudes towards public transport is insignificant in the whole sample model; and shows opposite impacts on car and motorbike users' intentions to use public transport. Attitudes towards public transport is only statistically significant for motorbike users. This may be because travel mode choice behaviour is more like a habitual behaviour and car users have psychological ambivalence, which explain as the following.

There are two reasons to explain why attitudes was insignificant to intentions. Firstly, mode choice behaviour has become automatic behaviour, which means that habits are automatically triggered the mode choice (Gärling et al., 2001, Ronis et al., 1989, Aarts et al., 1998). Under this situation, attitudes towards public transport may become irrelevant in guiding behaviour when mode choice has developed into a habit (Gärling et al., 2001, Ronis et al., 1989, Aarts et al., 1998).

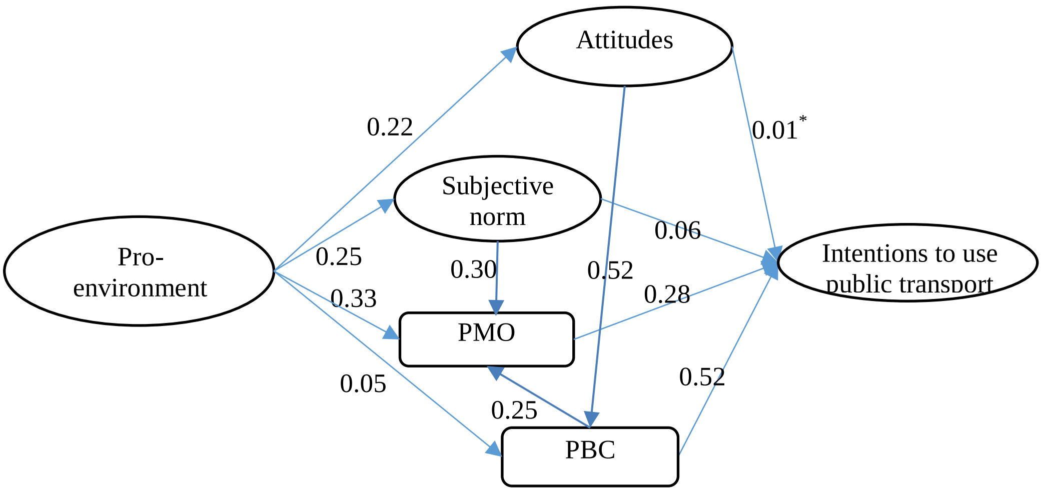
Secondly, ambivalence, which refers to 'holding conflicting feelings or beliefs towards one object (Gerd Bohner, 2002) may be able to explain why the attitudes towards public transport is not statistically significant for car users. The social status (income) for car users is higher than motorbike and public transport users. The social status makes car users pay more attention on climate change and environmental problems. So, they tend to give more positive attitudes for public transport use. However, car users may still enjoy driving. So, their intentions to use public transport could be lower than expected. As can be seen in Table 0.11 and Figure 0.5, the negative coefficient between attitudes towards public transport and intentions to use public transport gives evidence of the psychological ambivalence for car users.

Of all the variance in intentions to use public transport for whole sample model, car users' model and motorbike users' model (Table 0.11), 72.7%, 69.3% and 75% were explained by the motivational factors respectively, which indicates that the motivational factors adopted in this analysis are good predictors for intentions.

Table 0.11 Structural model estimated results for intentions to use PT

Path	Model 1: Whole sample			Model 2: car users			Model 3: motorbike users		
	B	SD	Sig	B	SD	Sig	B	SD	Sig
PE → AT	0.22	0.026	***	0.18	0.051	***	0.25	0.041	***
PE → SN	0.25	0.025	***	0.25	0.044	***	0.21	0.038	***
PE → PMO	0.33	0.023	***	0.28	0.042	***	0.29	0.037	***
PE → PBC	0.05	0.025	*	0.02	0.004		0.09	0.029	**
AT → PBC	0.52	0.023	***	0.36	0.036	***	0.34	0.029	***
PBC → PMO	0.25	0.026	***	0.21	0.053	***	0.30	0.053	***
SN → PMO	0.30	0.026	***	0.36	0.047	***	0.34	0.042	***
AT → IN	0.01	0.018		-0.02	0.034		0.07	0.026	*
SN → IN	0.06	0.018	**	0.12	0.039	**	0.05	0.028	
PMO → IN	0.28	0.018	***	0.27	0.037	***	0.25	0.025	***
PBC → IN	0.52	0.018	***	0.46	0.041	***	0.42	0.034	***
Constant									
Total IN variance explained	72.7%			69.3%			75.0%		
Goodness of fit (GOF)	RMSEA=0.063, CFI=0.997, TLI=0.974, SRMR=0.018			RMSEA=0.069, CFI=0.994, TLI=0.956, SRMR=0.015			RMSEA=0.000, CFI=1.0, TLI=0.999, SRMR=0.006		
Sample size	1427			413			565		

PE: pro-environment value, AT: attitudes towards public transport, SN: subjective norms over public transport, IN: intentions to use public transport
Level of significance: p<0.000 ‘***’, p<0.01 ‘**’, p<0.05 ‘*’



*: not significant at 95% level of significance
GOF: RMSEA=0.063, CFI=0.997, TLI=0.974, SRMR=0.018
PT: public transport

Figure 0.4 Intentions to use public transport estimated results: whole samples

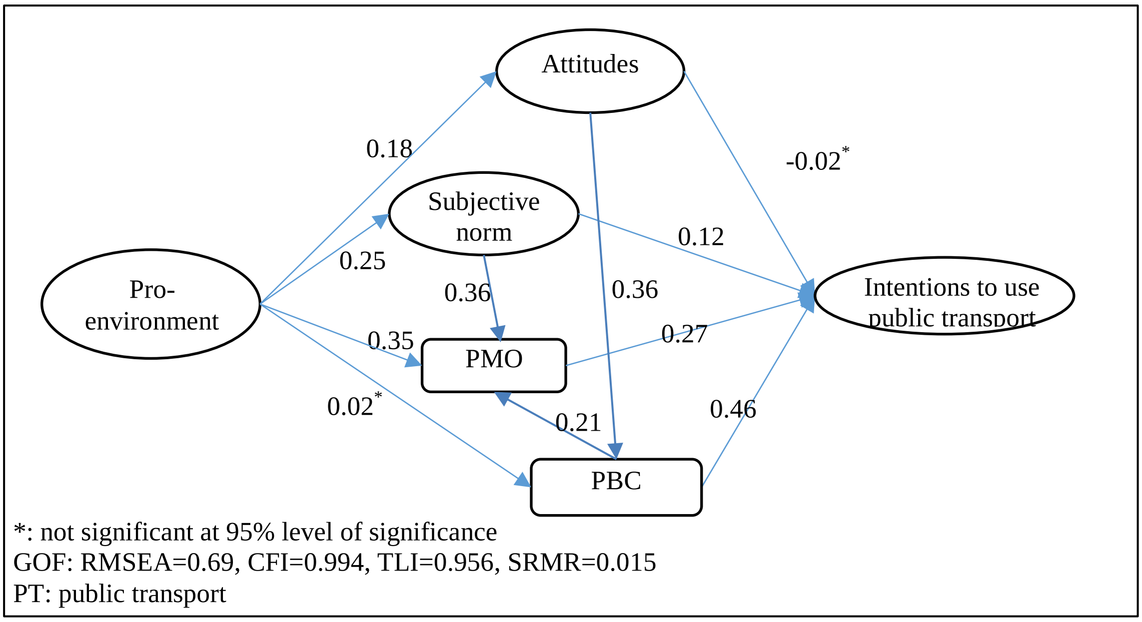


Figure 0.5 Intentions to use public transport estimated results: car users

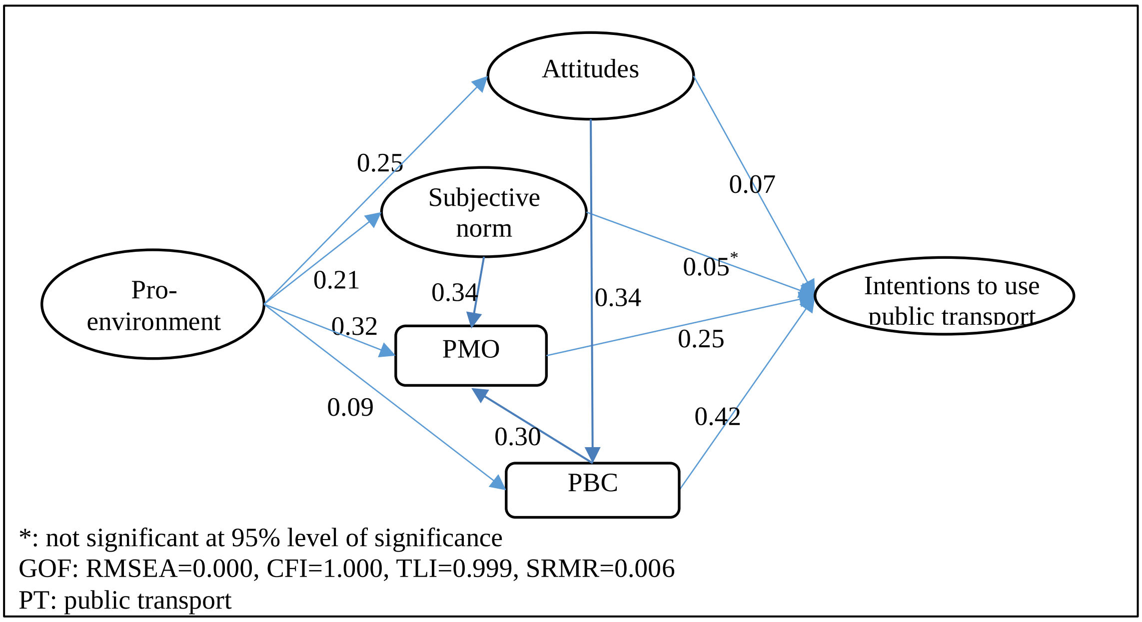


Figure 0.6 Intentions to use public transport estimated results: motorbike users

Conclusion

1. The results of this chapter gives the evidence to the proposed model for travel mode choice behaviour towards use public transport in Figure 2.9 (Chapter 2), which capability, opportunity and motivation exerted effects on travel mode choice and, additionally, there are interactions between capability, opportunity and motivation.

2. The estimation results showed that including the motivation factors into the travel mode choice model well explained the intentions to use public transport and mode choice behaviour in Taiwan.
3. Based on the estimated model results, PBC had the strongest influence on mode choice behaviour towards public transport, either directly or indirectly mediated by intentions to use public transport.
4. Attitudes towards public transport did not show significant impact on intentions to use public transport. This may be because that travel model choice has become a habitual behaviour and also car users had psychological ambivalence.
5. Pro-environment value was indispensable factor in the motivation towards the public transport model; however, its influence on intentions to use public transport and mode choice behaviour was indirect. The influence of pro-environment values on intentions and behaviour was antecedent of attitudes, subject norm, PMO and PBC.