Sustainable Urban Development:
Implementation of Public Bike Sharing System - NZ Case Studies

Chan Kim / MSc, PhD
Introduction

- Research Background:
  - Sustainable Urban Design
  - Travel behaviour and mode of transport
  - Public Bicycle Sharing Scheme (PBSS)
- Case Study: Hamilton and Christchurch
  - Survey method and sample
  - Multinomial Logit Model
  - Analysis and implication
- Conclusion & Research Direction
Increasing traffic volume in urban (and CBD) area causes
- Traffic congestion
- Car-related accident rate
- Environmental problems

Increasing connectivity from/to Public Transport

Increasing interest on shared mobility options (e.g. car, bike, e-scooter etc.)
Background: PBSS
What is a Public Bicycle Sharing Scheme

- A mobility service
- Allows citizens to rent and return bicycles
- With no responsibilities of bicycle ownership

Key Components of a PBSS

- Public bicycles
- Docks & stations
- Operation plans
- Accessibility
- Maintenance, Advertisement, and Manual
Background: PBSS
Literature Review

Research question:
How to come up with the suitable operational plans for a Public Bicycle Sharing Scheme

Literature review:
Look into the geographical features and characteristics of PBSS plans in other cities which were similar to Hamilton and Christchurch

<table>
<thead>
<tr>
<th>City</th>
<th>Country</th>
<th>Population</th>
<th>Area (km²)</th>
<th>Pop. Density (hab/km²)</th>
<th>GDP (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hamilton</td>
<td>New Zealand</td>
<td>165,400</td>
<td>110.80</td>
<td>1,500.00</td>
<td>33,912</td>
</tr>
<tr>
<td>Besançon</td>
<td>France</td>
<td>116,914</td>
<td>65.05</td>
<td>1,811.47</td>
<td>30,625</td>
</tr>
<tr>
<td>Kassel</td>
<td>Germany</td>
<td>190,765</td>
<td>107.00</td>
<td>1,864.00</td>
<td>53,133</td>
</tr>
</tbody>
</table>
Background: PBSS

Literature Review – Finding and Implication

- To come up with a suitable number of public bicycles, docks and stations
- Compared to 40 overseas cities
  - The distance between stations from 200m to 500m
  - PBSS in CBD: Mainly for leisure
  - PBSS throughout a city: Mainly for commuting
Background: PBSS

Literature Review – Finding and Implication

- Number of Bicycles: 337
- Number of Stations: 39
- Number of Docks: 538
- Ave. Number of Bicycles per Station: 9
- Ave. Number of Docks per Station: 14
Case Study: User Behaviour
RP survey on Auckland Bike share user

Regional Proportion

- Central: 10%
- North: 9%
- South: 6%
- East: 11%
- West: 64%

Revealed Preference Survey with 625 responses from Auckland
Case Study: User Behaviour
RP survey on Auckland Bike share user

**Gender**
- Male: 57%
- Female: 43%

**Age Bracket**
- Under 20: 25%
- 20 to 30: 49%
- 30 to 40: 15%
- 40 to 50: 8%
- 50 to 60: 2%
- Over 60: 1%

**Marital Status**
- Single with no child: 74%
- Single with a child: 9%
- Married with no child: 9%
- Married with a child: 15%
Sociodemographics

**EDUCATION**
- Bachelor's degree/Postgraduate diploma: 53%
- Diploma/Certificate: 13%
- Secondary: 22%
- None: 3%
- Master's degree: 8%
- Doctoral degree: 1%

**INCOME**
- Less than $20,000: 46%
- $20,000 to $40,000: 18%
- $40,000 to $60,000: 17%
- $60,000 to $80,000: 9%
- More than $80,000: 18%

**OCCUPATION**
- Full-time employed: 45%
- Tertiary student: 32%
- Primary/secondary student: 8%
- Other: 4%
- Part-time employed: 10%
- Retired: 1%

**Case Study: User Behaviour**
RP survey on Auckland Bike share user
Case Study: User Behaviour
RP survey on Auckland Bike share user

Mode Use: Using the PBSS

**Main Purpose**
- For commuting: 38%
- For exercise/leisure: 45%
- For shopping/errand: 12%
- For business purpose (e.g. visiting a client or other company in CBD): 5%

**Key Factors**
- User cost: 21%
- Cycling environment: 12%
- Service accessibility: 59%
- Service maintenance: 8%

**Restriction**
- Inconvenience (e.g. the number of the bikes and the range of the service area): 57%
- Cycling environment (e.g. conditions of bike lanes/path for safety concern): 22%
- Mandatory helmet laws: 15%
- Registration process or payment method: 6%
Case Study: User Behaviour
RP survey on Auckland Bike share user

PBSS Key Factors

Service Accessibility

- Increasing the number of the available bikes: 71.04%
- Expanding the service area: 10.72%
- Providing docking stations at specific locations: 12.00%
- Providing different types of the bikes: 6.24%

User Cost or Expense

- Lowering the hourly fee: 46.88%
- Lowering the penalty fee: 6.08%
- Improving the membership benefits: 39.04%
- Providing various payment methods: 8.00%

Cycling Environment

- Continuity and connectivity of bike lanes: 46.88%
- Condition of bike lanes: 6.08%
- Comfort of bike lanes: 39.04%
- Safety of bike lanes: 8.00%
Preliminary Study Findings

- **Operation Plan for Hamilton**
  - Location and spacing of the station: 200-500m near the PT stops
  - Number of bicycle, docks and station: 337 bicycles with 538 docks and 39 public stations

- **Use behaviour from Auckland PBSS user survey**
  - Mainly young students and full-time employed with short work experience
  - Increasing the number of available bicycles would be most beneficial in terms of service accessibility and maintenance.
  - The connection and segregating or securing enough space of cycle lane/path should be provided.
  - Lower the hourly fee and providing the membership benefits would encourage more users.
Research Questions & Methodology

- Research Question: how to design PBSS in the urban CBD area in particular
  - How to facilitate modal connectivity by introducing a micro mobility
  - How to improve the flexibility of public transport users
- Apply the key design requirements to two cities, Hamilton and Christchurch
- Stated Preference survey and Econometric Modelling
Methodology
Multinomial Logit Regression Model (MNL)

- The Multinomial Logit Regression Model (MNL) is the most widely used modelling methodology to measure transport users’ mode choice behaviour.

\[ P(y_i = j) = P_{ij} = \frac{\exp (x_i \beta_j)}{\sum_{k=0}^{J} \exp (x_i \beta_k)} \text{ for } j = 0, ..., J \]

\[ \Omega_{ij|iq} = \exp(x_i[\beta_j - \beta_q]) \]

- Abolhassani et al., (2019) – Iran
- Schneider et al., (2019) – U.S.A.

also, Romero et al., (2012), Faghih-Imani and Eluru (2015), etc
Description of Stated Preference Survey (September, 2018)

Section Two – Public Bike Sharing System

**INSTRUCTION**

The following survey will provide vital information to help to determine if a "Public Bike Sharing" system in the Christchurch and Hamilton CBD is viable. This section of questions asks you to compare possible transport options for accessing the Christchurch/Hamilton main CBD area. Each question provides three alternative options. Please choose which type of transport option you would prefer by ticking a box to indicate your choice.

The first column in each question represents ‘current’ (status quo) access pattern to the Christchurch/Hamilton CBD. Assume that you are accessing the CBD by bus and need to walk a moderate distance, approximate 1000 meters (15 minutes) from Bus stop to your final destination.

The second column in each question represents ‘alternative’ CBD transit option under the Public Bike Sharing system. Assume that you are accessing the CBD by bus and you will need to walk from a bus stop to the nearest bike station, then using a traditional bicycle to travel approximate 1000 meters (5 minutes) to the nearest bike station from your final destination.

Finally, the last column in each question represents ‘alternative’ CBD transit option under the Public Bike Sharing system. Assume that you are accessing the CBD by bus and you will need to walk from a bus stop to the nearest bike station, then using an electric bicycle to travel approximate 1000 meters (5 minutes) to the nearest bike station from your final destination.

There are 8 of these questions. There are no right or wrong answers. But if you are unsure or have problems answering these questions, please do feel free to ask your surveyor for help with the questionnaire. Please try to answer all questions.

Below are three different options for your trip to CBD. These options include information on Parking and Transport Cost, Walking Distance, and Service Frequency. If the options below are the only options available for your trip, which would you prefer?

<table>
<thead>
<tr>
<th>CHOICE SET</th>
<th>OPTIONS</th>
<th>Current (Bus + Walk)</th>
<th>Traditional Bike</th>
<th>Electric Bike</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Service Cost ($/hour)</strong></td>
<td>$2.40</td>
<td>$2.40</td>
<td>$2.90</td>
</tr>
<tr>
<td></td>
<td><strong>Bicycle Accessibility (metres)</strong></td>
<td>&lt; 25 m</td>
<td>&lt; 25 m</td>
<td>&lt; 25 m</td>
</tr>
<tr>
<td></td>
<td><strong>Bicycle Availability (%)</strong></td>
<td>50 %</td>
<td>100 %</td>
<td></td>
</tr>
</tbody>
</table>

**YOUR SELECTION:**

- 3 options: current, traditional bike, E-bike
- 3 attributes: Cost, Bike Accessibility, Availability
- 8 hypothetical choice sets
- 2 Cities: Hamilton and Christchurch
- Total of 486 survey samples
  - 185 Sample from Christchurch
  - 301 Sample from Hamilton
Sample Analysis
Sociodemographics

**Hamilton**

- **Gender**
  - Male: 54%
  - Female: 46%

- **Age**
  - Under 18: 13%
  - 19-29: 42%
  - 30-39: 23%
  - 40-49: 11%
  - 50-59: 6%
  - 60-69: 3%
  - Over 70: 2%

**Christchurch**

- **Gender**
  - Male: 53%
  - Female: 47%

- **Age**
  - Under 18: 10%
  - 19-29: 41%
  - 30-39: 21%
  - 40-49: 11%
  - 50-59: 11%
  - 60-69: 4%
  - 70+: 2%

**Mode of Transport to CBD**

- **Bus**
  - Hamilton: 48.2
  - Christchurch: 46.2

- **Car**
  - Hamilton: 43.2
  - Christchurch: 31.0

- **Bike**
  - Hamilton: 2.0
  - Christchurch: 11.4

- **Walk**
  - Hamilton: 6.6
  - Christchurch: 11.4
Sample Analysis
Sociodemographics

Trip Purpose to CBD

Hamilton
(301 responses)

Christchurch
(184 responses)
The MNL modelling results use to calculate the likelihood probability by using a utility function for each option.

\[ U = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \varepsilon \]

Where

- \( a_0 \) is the ASC coefficients
- \( X_1 \) is the cost of service,
- \( X_2 \) is accessibility for the distance to access the bikes (or E-bikes),
- \( X_3 \) is the availability, \( a_3 \) is the availability for the percentage chance that there will be a bike or E-bike available

The model share for the utility function of three options is given by the proportion function.

\[ P_m = \frac{e^{U_1}}{e^{U_1} + e^{U_2} + e^{U_3}} \]
Both E-bike and Trad-bike is more attractive than Bus only service

E-bike is more attractive than Bus only service but Trad-bike is less attractive

All of the coefficients of the generic attributes have the expected sign and are statistically significant in the MNL model

The coefficients of the cost and accessibility variables are negative, indicating that alternatives with a higher cost or longer walking distance are less likely to be chosen.

The coefficients of the availability variable are positive, as CBD users are expected to favour choosing modes with higher bike availability.
**MNL Modelling**

**Modal Share**

- Utility Function: $U_n = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \varepsilon$
- Modal Share: $P_m = \frac{e^{U_1}}{e^{U_1} + e^{U_2} + e^{U_3}}$
- Base Scenario:

<table>
<thead>
<tr>
<th></th>
<th>SQ (Bus Only)</th>
<th>ALT 1 (Bus + Trad- Bike)</th>
<th>ALT 2 (Bus + E- Bike)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost ($/trip)</td>
<td>$2.40</td>
<td>$2.40</td>
<td>$2.40</td>
</tr>
<tr>
<td>Availability (%)</td>
<td>50 %</td>
<td>50 %</td>
<td>50 %</td>
</tr>
<tr>
<td>Accessibility (metre)</td>
<td>50 m</td>
<td>50 m</td>
<td>50 m</td>
</tr>
</tbody>
</table>

**Hamilton**

<table>
<thead>
<tr>
<th></th>
<th>SQ (Bus Only)</th>
<th>ALT 1 (Bus + Trad- Bike)</th>
<th>ALT 2 (Bus + E- Bike)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modal Share</td>
<td>22 %</td>
<td>21 %</td>
<td>57 %</td>
</tr>
</tbody>
</table>

**Christchurch**

<table>
<thead>
<tr>
<th></th>
<th>SQ (Bus Only)</th>
<th>ALT 1 (Bus + Trad- Bike)</th>
<th>ALT 2 (Bus + E- Bike)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modal Share</td>
<td>13%</td>
<td>32%</td>
<td>55%</td>
</tr>
</tbody>
</table>
# MNL Modelling

## Policy Application

### Modal Share Scenario: Service Fare

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
<th>Scenario 3</th>
<th>Scenario 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SQ (Status Quo): Bus only</strong></td>
<td>$ 2.5</td>
<td>$ 2.5</td>
<td>$ 2.5</td>
<td>$ 2.5</td>
</tr>
<tr>
<td><strong>Alt1: Bus + Traditional Bike</strong></td>
<td>$ 2.75</td>
<td>$ 2.75</td>
<td>$ 3.0</td>
<td>$ 3.0</td>
</tr>
<tr>
<td><strong>Alt2: Bus + E-Bike</strong></td>
<td>$ 2.75</td>
<td>$ 3.0</td>
<td>$ 3.0</td>
<td>$ 3.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 1</th>
<th>Hamilton</th>
<th>Christchurch</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ($2.5)</td>
<td>31.4%</td>
<td>16.7%</td>
</tr>
<tr>
<td>A1($2.75)</td>
<td>49.9%</td>
<td>52.8%</td>
</tr>
<tr>
<td>A2($2.75)</td>
<td>18.7%</td>
<td>30.5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2</th>
<th>Hamilton</th>
<th>Christchurch</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ($2.5)</td>
<td>38.9%</td>
<td>45.1%</td>
</tr>
<tr>
<td>A1($2.75)</td>
<td>37.9%</td>
<td>35.4%</td>
</tr>
<tr>
<td>A2($2.75)</td>
<td>23.2%</td>
<td>19.4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 3</th>
<th>Hamilton</th>
<th>Christchurch</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ($2.5)</td>
<td>42.7%</td>
<td>21.4%</td>
</tr>
<tr>
<td>A1($2.75)</td>
<td>41.6%</td>
<td>28.7%</td>
</tr>
<tr>
<td>A2($2.75)</td>
<td>15.6%</td>
<td>21.1%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 4</th>
<th>Hamilton</th>
<th>Christchurch</th>
</tr>
</thead>
<tbody>
<tr>
<td>SQ($2.5)</td>
<td>57.8%</td>
<td>49.8%</td>
</tr>
<tr>
<td>A1($2.75)</td>
<td>21.1%</td>
<td>33.1%</td>
</tr>
<tr>
<td>A2($2.75)</td>
<td>11.6%</td>
<td>42.2%</td>
</tr>
</tbody>
</table>
Conclusion

- Preliminary Survey Analysis shows that the majority of people surveyed would consider using a PBSS service.
- There will be a greater need for more E-Bike options in urban CBD.
- Service fare, follow by the Walking distance to access the service and Bicycle availability at the station, is one of the biggest reasons why existing public transport needs to be improved to meet the growing demands for public transport.
- ‘Tailored’ operational plan will be required regarding
  - Location of the docks and station, Bicycle tracking system, booking methods, etc.
Limitation & Research Direction

- Limited **Sample size** and the **location** samples are collected.

- **Advanced econometric models (ML, GMXL etc.)** allow researchers to analyse and predict how people's choices are influenced by personal characteristics and by the alternatives available to them.

- Measure **Willingness-to-pay (WTP)** to evaluate **elasticity** of demand based on new service (Traditional Bike and E-bike).
Thank you

QUESTIONS OR COMMENTS
CHAN.KIM@WINTEC.AC.NZ