Appraisal of Factors Influencing Public Transport Patronage in New Zealand

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1. Introduction

2. The Model

3. Data Analysis and Forecast Models
   - Auckland
   - Wellington
   - Christchurch

4. Elasticity Estimates and Discussion
1. **Introduction**

2. The Model

3. Data Analysis and Forecast Models
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4. Elasticity Estimates and Discussion
The overall objective of the study was to undertake an in-depth analysis of factors influencing public transport patronage in NZ

1. Identification of the key factors affecting public transport patronage
2. Estimation of the elasticities with respect to each of the key factors identified
3. Development of forecasting models for use by transport operators and transport funding agencies
Econometric analyses were applied to annual and quarterly national and regional aggregate data for three major regions:

1. Auckland - (Quarterly, 1996Q1 – 2008Q2)
2. Wellington - (Annually, FY99/00 – FY07/08)
3. Canterbury - (Quarterly, 1997Q1 – 2008Q2)
We considered a set of economic and structural determinants that might have contributed to the changes in trends of PT patronage

- **Dependent variable**
  - Patronage (in trips per capita)

- **Economic determinants**
  1. Service level (in bus/train kilometre per capita)
  2. Real fare (in real revenue per passenger)
  3. Real income (in real disposable income per capita)

- **Structural determinants**
  1. Car ownership (in cars per capita by region)
  2. Real fuel price
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4. Elasticity Estimates and Discussion
A dynamic model is specified for each city by mode - relating per capita patronage to fares, service level, car ownership, income and fuel price

- We assume that the long-run equilibrium demand, in passenger trips per capita, can be expressed as a function of service, fare, car ownership, income and petrol price

\[ Q_t^{X M} * = f \left( S_t^{X M}, F_t^{X M}, C_t^{X M}, I_t, O_t \right) + \theta^{X M} Q_{t-1}^{X M} \]

Assumption:
To a certain extent, travel behaviour is a habit

- Assuming that the function is in linear form, if all variables are transformed in logarithmic forms

\[ \ln Q_t^{X M} = \alpha^{X M} + \beta_{S}^{X M} \ln S_t^{X M} + \beta_{F}^{X M} \ln F_t^{X M} + \beta_{C}^{X M} \ln C_t^{X M} \]
\[ + \beta_{I}^{X M} \ln I_t + \beta_{O}^{X M} \ln O_t + \theta^{X M} \ln Q_{t-1}^{X M} \]

where
\[ X = A, W, C \] for Auckland, Wellington and Christchurch respectively
\[ M = B, R \] for Bus and Rail respectively
With a dynamic model, we can estimate both the short-run and long-run elasticities at the same time.

<table>
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<tr>
<th>Elasticity</th>
<th>Definition</th>
<th>Estimation Coefficients</th>
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<tr>
<td>Service elasticity of demand</td>
<td>Percentage change in Patronage per capita / Percentage change in Service</td>
<td>$\beta_S^{X \to M}$ / $\beta_S^{X \to M} / (1 - \theta^{X \to M})$</td>
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<td>Fare elasticity of demand</td>
<td>Percentage change in Patronage per capita / Percentage change in Fare</td>
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<td>Car ownership elasticity of demand</td>
<td>Percentage change in Patronage per capita / Percentage change in Car ownership per capita</td>
<td>$\beta_C^{X \to M}$ / $\beta_C^{X \to M} / (1 - \theta^{X \to M})$</td>
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<td>Income elasticity of demand</td>
<td>Percentage change in Patronage per capita / Percentage change in Real income per capita</td>
<td>$\beta_I^{X \to M}$ / $\beta_I^{X \to M} / (1 - \theta^{X \to M})$</td>
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<tr>
<td>Fuel price elasticity of demand</td>
<td>Percentage change in Patronage per capita / Percentage change in Fuel price</td>
<td>$\beta_O^{X \to M}$ / $\beta_O^{X \to M} / (1 - \theta^{X \to M})$</td>
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</table>
The significance of an influencing factor was determined by hypothesis testing

- We determine the level of significance of a variable by testing the null hypothesis of the coefficient of the variable being zero

\[
\ln Q_t^{X \ M} = \alpha^{X \ M} + \beta_S^{X \ M} \ln S_t^{X \ M} + \beta_F^{X \ M} \ln F_t^{X \ M} + \beta_C^{X \ M} \ln C_t^{X}
+ \beta_I^{X \ M} \ln I_t + \beta_O^{X \ M} \ln O_t + \theta^{X \ M} \ln Q_{t-1}^{X \ M}
\]

- For example, to determine the significance of fares

Null hypothesis

\[ H_0 : \beta_F^{X \ M} = 0 \]

Fare did not have significant influence on patronage

Alternative hypothesis

\[ H_a : \beta_F^{X \ M} \neq 0 \]

Fare did have significant influence

- If we can reject the null hypothesis, that means there was no evidence that this factor did not have significant influence
A forecast model is satisfactory only if all the influencing factors are statistically significant.

- Include all factors
- Test significance
- All factors are NOT significant
- Include only Service + Fare
- Test significance
- Include other factors
- All factors are significant
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4. Elasticity Estimates and Discussion
Bus patronage in Auckland has been increasing since 1999 while rail patronage has been increasing only since 2003

Bus and Rail Patronage per Capita in Auckland 1996-2008

Bus Patronage per Capita in Auckland
Rail Patronage per Capita in Auckland
Bus services has been significantly improved in response to the increase in demand since 1999

![Bus Patronage and Bus-kilometres per Capita in Auckland 1996-2008](image_url)
Deregulation of bus services induced a significant increase in fare but bus patronage continued to climb despite the fare increase.

Bus Patronage per Capita and Revenue per Bus Passenger in Auckland 1996-2008

- Bus Patronage per Capita in Auckland
- Real Revenue per Bus Passenger in Auckland
Rail patronage has been on a steep climb since the opening of Britomart in 2003 and rail service has been tremendously improved.

[Graph showing Rail Patronage and train-kilometres per Capita in Auckland 1996-2008]

Rail Patronage and train-kilometres per Capita in Auckland 1996-2008

- Rail Patronage per Capita in Auckland
- Rail-km per Capita in Auckland

Rail patronage has been on a steep climb since the opening of Britomart in 2003 and rail service has been tremendously improved.
Despite significant increase in rail fare, rail patronage has been climbing steeply
Car ownership has been on the rise with increase in income

Real Disposable Income and Car Ownership per Capita in Auckland 1996-2008

- Real Disposable Income per Capita
- Car Ownership per Capita in Auckland

Car ownership has been on the rise with increase in income.
Car ownership’s increasing trend has flattened while fuel price has been volatile and rapidly increasing in recent years.
The increase and fluctuations in fuel price in recent years did have a positive impact on PT patronage.

Fuel Price and PT Patronage per Capita in Auckland 1996-2008
Two models were identified for Auckland Bus Patronage Forecast

- Auckland Bus Patronage Model (1999Q3-2008Q2)
  - Service + Car ownership + Q4 Seasonal dummy

\[
\ln Q_t^{AB} = -0.8046 + 0.4977 \ln S_t^{AB} - 1.3239 \ln C_t^A \\
+ 0.5071 \ln Q_{t-1}^{AB} - 0.0661 D_{4t}
\]

- Auckland Bus Patronage Model (2003Q3-2008Q2)
  - Service + Car ownership + Fuel price + Q4 Seasonal dummy

\[
\ln Q_t^{AB} = -1.9306 + 0.4603 \ln S_t^{AB} - 1.9618 \ln C_t^A + 0.2040 \ln O_t \\
+ 0.3677 \ln Q_{t-1}^{AB} - 0.0478 D_{4t}
\]
Two models were identified for Auckland Bus Patronage Forecast

Bus Pax Per Capita

This period is not considered because it has a different trend. Possible reasons are:
1. In 1990’s Car prices fell by 50% as Japanese second hand imports entered the market. In 1998 Tarrifs removed from cars
2. Deregulation of bus services in 1989

The opening of the CBD railway station Britomart in 2003 and subsequent improvement of rail services has induced modal shifts and marked the beginning of a changed trend
Two models were identified for Auckland Rail Patronage Forecast

- Auckland Rail Patronage Model (2003Q3-2008Q2)
  - Model 1 - Service + Fare + Income+ Q4 Seasonal dummy
    \[
    \ln Q_{t}^{A R} = -1.1448 + 0.9946 \ln S_{t}^{A R} - 0.9672 \ln F_{t}^{A R} + 1.606 \ln I_{t} \\
    + 0.2957 \ln Q_{t-1}^{A R} - 0.1325 D_{4t}
    \]

- Auckland Rail Patronage Model (2003Q3-2008Q2)
  - Model 2 - Service + Fare+ Q4 Seasonal dummy
    \[
    \ln Q_{t}^{A R} = 1.6913 + 0.8827 \ln S_{t}^{A R} - 0.6755 \ln F_{t}^{A R} \\
    + 0.4584 \ln Q_{t-1}^{A R} - 0.1478 D_{4t}
    \]
Two models were identified for Auckland Rail Patronage Forecast

The opening of the CBD railway station Britomart in 2003 and subsequent improvement of rail services has induced modal shifts and marked the beginning of a changed trend.

The rail market in Auckland had been stagnant for many many years...

1996 Q1 to 2003 Q2
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4. Elasticity Estimates and Discussion
One model was identified for Wellington Bus Patronage Forecast

Bus Pax Per Capita

- Observed Patronage per Capita per Annum
- Best Fitted Model 98-08 R-square = 0.9006

\[
\ln Q^W_B = 2.0590 - 0.2312 \ln F^W_B + 0.4934 \ln Q^W_{t-1}
\]

Fare is a significant factor.
Two models were identified for Wellington Rail Patronage Forecast

- Wellington Rail Patronage Forecast Model
  - Model 1 - Service + Car ownership + Fuel price

\[
\ln Q^W_R = -1.3759 + 0.7424 \ln S^W_R - 0.3246 \ln C^W_t + 0.1303 \ln O_t \\
+ 0.6889 \ln Q^W_{t-1}
\]

- Wellington Rail Patronage Forecast Model
  - Model 2 - Service + Income + Fuel price

\[
\ln Q^W_R = -0.4663 + 0.7847 \ln S^W_R - 0.2176 \ln I_t + 0.1212 \ln O_t \\
+ 0.6900 \ln Q^W_{t-1}
\]
Two models were identified for Wellington Rail Patronage Forecast

![Graph showing Observed Patronage per Capita per Annum compared to Best Fitted Models 1 and 2. The graph illustrates a financial year timeline from 2000 to 2008 with the X-axis representing Financial Year and the Y-axis representing Rail Pax Per Capita.]
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3. **Data Analysis and Forecast Models**
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4. Elasticity Estimates and Discussion
Two models were identified for Christchurch Bus Patronage Forecast

- Christchurch Fitted Bus Patronage Forecast Model (1998Q1-2008Q2)
  - Service only + Q4 Seasonal dummy

\[
\ln Q_t^{CB} = 0.1147 + 0.0708 \ln S_t^{CB} - 0.0898 \ln Q_{t-1}^{CB} + 0.8863 D_{4t}
\]

- Christchurch Fitted Bus Patronage Forecast Model (2004Q1-2008Q2)
  - Fare + Fuel price + Q4 Seasonal dummy

\[
\ln Q_t^{CB} = 0.1731 - 0.2620 \ln F_t^{CB} + 0.2785 \ln O_t \\
+ 0.2373 \ln Q_{t-1}^{CB} - 0.0429 D_{4t}
\]
Two models were identified for Christchurch Bus Patronage Forecast.

Bus Pax Per Capita

- Observed Patronage per Capita per Quarter
- Best Fitted Model 98-08 R-square = 0.9861
- Best Fitted Model 04-08 R-square = 0.8717

- Cash ‘Gold Coin’ fare in 1998 marked the beginning of a new trend
- Metrostar cross-suburban service introduced in Nov 2004
- The introduction of the Metrocard in July 2003 also had significant impact on patronage
- Orbiter ring route introduced in 1999
- Orbiter ring route weekday frequency increased from a 15-min headway to 10-min in 2001
- Norther Star bus service introduced in Nov 2006
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4. Elasticity Estimates and Discussion
The three cities all have different characteristics and the drivers behind the trends were also different.

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<th>Auckland Rail</th>
<th>Wellington Bus</th>
<th>Wellington Rail</th>
<th>Christchurch</th>
</tr>
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<tbody>
<tr>
<td>Service</td>
<td>positive</td>
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<td>n/a</td>
<td>positive</td>
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</tr>
<tr>
<td>Fare</td>
<td>n/a</td>
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<tr>
<td>Car Ownership</td>
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</tr>
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A summary of best estimates of elasticities

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Key: Short-run (Long-run)
Service was identified as the key driving factor among all five factors considered

- It had significant influence in all cities and in almost all modes except Wellington bus and the elasticity estimates were all positive

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Key: Short-run (Long-run)
Bus fare was a significant influencing factor in both Wellington and Christchurch but not in Auckland

- Auckland had a higher proportion of public transport dependent population. As a result, it appeared that fare did not have a significant influence on bus patronage in Auckland.

- Despite the increase in fares, the increase in fuel price was more significant. In other words, public transport was still relatively ‘cheap’ as compared to driving. As a result, the increase in patronage was influenced by the increase in fuel price but not influenced by fare for Auckland bus and Wellington rail.

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Key: Short-run (Long-run)
Income was found to have a positive effect on Auckland rail patronage and on the contrary a negative effect on Wellington rail patronage, while international estimates were negative.

- The change in rail market as a result of the tremendous investment in infrastructure and service improvement. A higher proportion of commuters with higher income were attracted to use rail service since the opening of Britomart in 2003.

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Key: Short-run (Long-run)
A higher proportion of commuters with higher income were attracted to use rail service since the opening of Britomart in 2003.
Rail service and fare elasticities were higher than the corresponding estimates for bus in Auckland and in other cities

- Auckland’s public transport system, especially the rail system, had gone through tremendous improvement over the last decade. As a result, the service and fare elasticities were higher (more elastic) than in other cities.

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Key: Short-run (Long-run)
The fluctuations in fuel price in recent years had a positive impact on PT patronage in all three cities, although not on all modes

- The estimated fuel price elasticity in Christchurch was higher than in Auckland and Wellington:
  - Christchurch had the highest car ownership per capita among the three cities but relatively cheaper bus fares and a more convenient ticketing system

- This implied a higher substitution effect between bus and car in Christchurch as compared to other cities

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Key: Short-run (Long-run)
Christchurch has always had the highest car ownership among the three cities.
In the long run, the most effective policy to encourage use of public transport could be by controlling car ownership or its use

- Car ownership was the most elastic among all the factors identified and fuel price was found to have significant influence in Auckland and Christchurch bus patronage but only in the latest four or five years.

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Key: Short-run (Long-run)
The elasticity estimates for Wellington were lower (less elastic) than those for Auckland and Christchurch in general

- The market in Wellington was quite different from Auckland and Christchurch:
  - Wellington has the highest public transport use among the three cities
  - Wellington also had the highest walk modal share as the CBD employment area is more compact and walkable
  - The council also had a committed parking restraint policy in CBD

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<th>Auckland</th>
<th>Wellington</th>
<th>Christchurch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bus</td>
<td>Rail</td>
<td>Bus</td>
</tr>
<tr>
<td>Service</td>
<td>0.46 (0.73)</td>
<td>0.88 (1.63)</td>
<td>n/a</td>
</tr>
<tr>
<td>Fare</td>
<td>n/a</td>
<td>-0.68 (-1.25)</td>
<td>-0.23 (-0.46)</td>
</tr>
<tr>
<td>Car Ownership</td>
<td>-1.96 (-3.10)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Income</td>
<td>n/a</td>
<td>1.61 (2.28)</td>
<td>n/a</td>
</tr>
<tr>
<td>Fuel Price</td>
<td>0.20 (0.32)</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Key: Short-run (Long-run)
Concluding Remarks ...

- Our methodology and analysis in this study was limited by data availability
  - Auckland
    - Bus data: contract services only
    - Rail data: service measured in train-km
  - Wellington
    - Only annual information available
  - Christchurch
    - Service data: approximation from time table
    - Fare data: only available from 2004

- Partial Adjustment Model is the best model given the data limitation

- Econometric analysis can be a powerful tool for forecasting but more effort is required in maintaining a database of good quality information
Thank you!
Any questions?

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