The consumer value of frequency changes in transport services

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Structure

• Background and objectives
• Theoretical approaches
• Aggregate specifications of disutility
• Some discrete choice literature
• Other issues
• Conclusions
Background

• Many transport services not available continuously in time (timetable)
  – same issues may apply in other contexts

• Service frequencies range from (very) low (ferry, air connection) to (very) high (train, bus, metro)

• Impact of changes in service frequency for travelling population can be substantial
Objectives

• How can consumer effects of changes in service frequency be estimated using discrete choice models?

• Or: investigate how frequency effects can be incorporated in utility functions of discrete choice models
A bit of theory

• Low frequency services:
  – Most passengers plan their journey
  – Schedule delay is key idea
  – Waiting (short buffer)
  – Need to consult timetable

• High frequency services:
  – Most or all passengers turn up randomly
  – Waiting time is key idea
Percentage random by frequency
suburban railway stations in Paris

y = -3.1 x + 56.66
R² = 0.842

y = -5.92 x + 102.38
R² = 0.7624

Pourcentage visant l'horaire (%)

Laplace PM
Laplace AM
Rueil
Joinville
Torcy
Joinville
Villepreux
Etampes
Versailles
Lagny
Colombes
Epinay
Bry sur Marne
Louvres
Louveciennes
Haussmann
Ivry
Aubervilliers
Passenger arrival time pattern
suburban railway stations in Paris

High frequency (I=5min)
Medium frequency (I=10min)
Low frequency (I=15min)

Distribution of waiting time (%)

Min before departure of the train

RAND Europe and Stratec 2006
Formulation of model

• Schedule delay and waiting time both proportional to service interval
  – suggests utility should be modelled by inverse of frequency

• Frequency can also be seen as indicating a number of alternatives
  – suggests utility should be modelled as log function
  – i.e. a sort of logsum over the alternatives
  – used in some practical studies
  – more suited to lower frequency contexts
Impact of irregularity

• Reduces benefit of learning timetable
• Can have dominant impact on high-frequency services
• Less important in low-frequency context

• Note: if there is severe irregularity, we may need to consider issues of risk aversion
Aggregate approaches

• Passenger Demand Forecasting Handbook
  – used in the UK railway industry
  – based on literature review

• Abrahams approach
  – drawn from airline analyses
The impact of frequency according to the PDFH (rail)

• Two types of passenger arrivals: random and planned
  
  • Random: high freq or constrained arrival time
    – Average waiting time = half interval (assumes regular service!)
    – Disutility of waiting > disutility of journey time
  
  • Planned: low freq
    – Schedule delay + a bit of waiting time + cost of looking up timetable
    – Disutility of schedule delay < disutility of waiting

• Service interval multiplier $p \rightarrow$ converts interval into equiv journey time: $F = p.I$
Disutility of frequency PDFH

![Graph showing the relationship between frequency and disutility]
Marginal disutility of frequency PDFH

Change in equivalent journey time

Frequency

Full fare
Reduced fare
Cost of frequency according to Abrahams (2006)


Expression [1]: \[95.8-21\ln(freq)\]
Expression [2]: \[(1-(1-.171)^{freq})\times8\times70/freq\]
The impact of utility specification (1)

- Abrahams (2006):
  - \( \log(\text{freq}), \frac{1}{\text{freq}} \)
  - Conclusion: little difference (except extremes)
Some discrete choice literature

Note: not exhaustive, illustrative only

- Skinner (1976)
- Furuichi and Koppelman (1994)
- Basar and Bhat (2003)
The impact of utility specification (2)

- Furuichi and Koppelman (1994) and Basar and Bhat (2003)
  - Used linear frequency specification
  - Used log(freq) referring to analogy to size effect
  - Used log(freq) in more recent publications
The impact of utility specification (3)

- Skinner (1976)
  - Linear freq, linear within period, 0.5/freq
  - Conclusion: no preferred specification

  - Linear freq, (freq-0.5)/freq \( (\text{Brooke et al. 1984}) \)
  - Conclusion: non-linear specification better
The impact of model structure

  - Multi Nomial Logit
  - Nested Logit
  - Nested structure preferred

  - Multi Nomial Logit
  - Nested Logit
  - Cross Nested Logit
  - Mixed Logit
  - (C)NL structure preferred, mixed logit preferred
Other issues

- Heterogeneity
- Preferences for time-of-day
- Complex and non-uniform services
- Paradox in estimating coefficients
- Irregular services
Heterogeneity

• Different passengers value frequency differently
• VTTS of different passengers are different
• Observed
  – e.g. business vs. leisure
• Unobserved
  – mixed logit model with spread in log frequency coefficient
  – or latent class model?
Preferences for time of day

- Desired departure time distribution not uniform → value differs by TOD

Grammig et al. 2005
Complex service patterns

• In complex situations, travellers may be able to choose among overlapping sets of lines
  – actual choice may depend on street geometry

• Assessing benefit of frequency may require complicated simulations

• Even a simple service with unequal headways or service speed may present difficulties
Paradox in model estimation

- Number of passengers using a departure is generally proportional to service interval
  - simply because their random or planned departures are distributed more-or-less uniformly

- This can easily lead to an apparently positive interval coefficient

- Aggregating over departures will not solve the problem!
Irregular services

• Can have dominant impact on high frequency services
• Can lead to increased buffer (waiting) time
• May be difficult to separate frequency effect from irregularity effect
Conclusions (1)

• Changes in the frequency of transport services may result in significant changes in consumer value, and need to be taken into account in Cost Benefit Analyses

• The magnitude of the effect varies with the frequency in the reference situation: large effect for low reference frequencies, and vice versa
Conclusions (2)

• Consumer value of frequency is frequency dependent
  – % passengers arriving at random (waiting)
  – % passengers aiming at specific departure time (schedule delay+waiting+consulting timetable)
  – Punctuality effect needs to be added

• Several other reasons for variations in value of frequency:
  – Heterogeneity in values (observed, non-observed)
  – Non-homogenous Preferred Departure Time distribution
  – Unequal headways, specific timing of services
Conclusions (3)

• In discrete choice models: use decreasing marginal utility specification

• Can use either log freq or 1/freq specification → differences at frequency extremes

• Consider use of mixed logit or latent class model to capture unobserved heterogeneity
More research is needed

• Level of understanding is inadequate for this key variable
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