Management of Bus Operations and Technology

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OUTLINE

- **Applications of Automated Data Collection Systems**
  - **Scheduling**
  - **Connection Protection**
  - **Service Quality Monitoring**
  - **Travel Pattern Inference**
  - **Travel Behavior**
- **Ongoing Bus Operations Research**
  - **Scheduling**
  - **Limited Stop / X Service Design**
  - **Operations Management and Control**
  - **Interchange Analysis**

MIT Research Focus

- **Get better information from Automated Data Collection Systems**
  - **AFC: Automatic Fare Collection Systems**
  - **AVL: Automatic Vehicle Location Systems**
  - **APC: Automatic Passenger Counting Systems**
- **To support key agency functions:**
  - **Service and Operations Planning**
  - **Operations Management and Control**
  - **Customer Information**
  - **Performance Measurement and Monitoring**

Scheduling Application

Context: Rail scheduling and operations control

Data: Train tracking data

Focus: Analysis of train dwell times, headways, schedule adherence, time-space diagrams, animation playback capability

Application: MBTA Red Line

Recommendations:

Schedule adjustments, branch offsets adjustments,

tighter terminal departure discipline

Key researchers: Haris Koutsopoulos, Matt Dixon, Zhigao Wang (2006)

Connection Protection Application

Context: Transfers from rail to bus

Data: Train tracking data

Focus: Develop improved but simple dispatching strategy for buses based on bus holding lights linked to impending train arrival after long gap

Application: MBTA Red Line Alewife Station

Recommendations:

Implementation would reduce transfer wait time by 25% and greatly reduce "near misses"

Key researchers: Drew Desautels (2006)

Service Quality Monitoring Application

Context: Rail operations

Data: Smart card station entry and exit times

Focus: Develop measures of service reliability from customer's perspective

Application: London Underground service times using Oyster time data

Recommendations:

Use of reliability buffer as an additional measure of service delivery alongside mean measure (Journey Time Metric)

Key researchers: Joanne Chan (2007), David Uniman (in progress)

Travel Pattern Inference Application

Context: Any public transport network -- bus, rail, or combined

Data: AFC transactions (smart card or magnetic stripe) and AVL data

Focus: Estimation of customer origin-destination travel patterns

Application: CTA Rail network
London Underground network
CTA Bus network

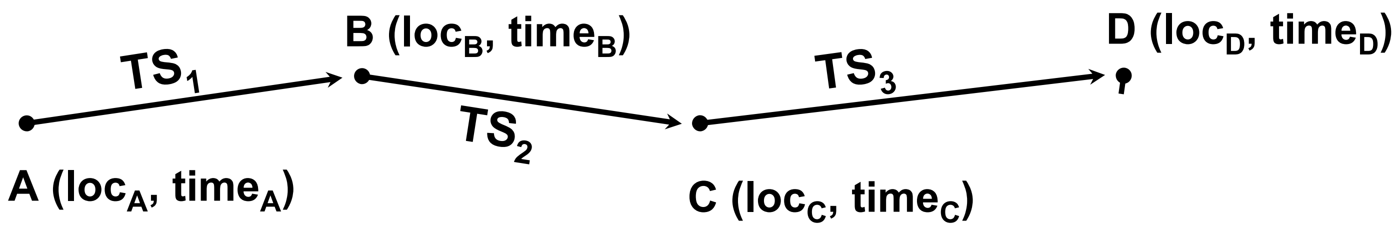
Recommendations:
A practical method for estimating travel patterns with virtually no additional cost beyond existing ADCs

Key researchers: Jinhua Zhao (2004), Alex Cui (2006), Fabio Gordillo (2006), Joanne Chan (2007)

Basic Idea

Each AFC record includes:

- AFC card ID
- transaction type
- transaction time
- transaction location: rail station or bus route



The destination of many trip segments (TS) is also the origin of the following trip segment.

Note: 1) each bus boarding requires a new AFC transaction:
TS_{bus} represents an unlinked bus trip

2) rail-rail transfers do not require a new AFC transaction:
TS_{rail} represents a path on the rail network

Travel Behavior Application

Context: Any public transport network -- bus, rail, or combined

Data: Registered smart card address (exact or approximate), smart card transactions, and AVL data

Focus: Infer public transport access behavior and modal preferences

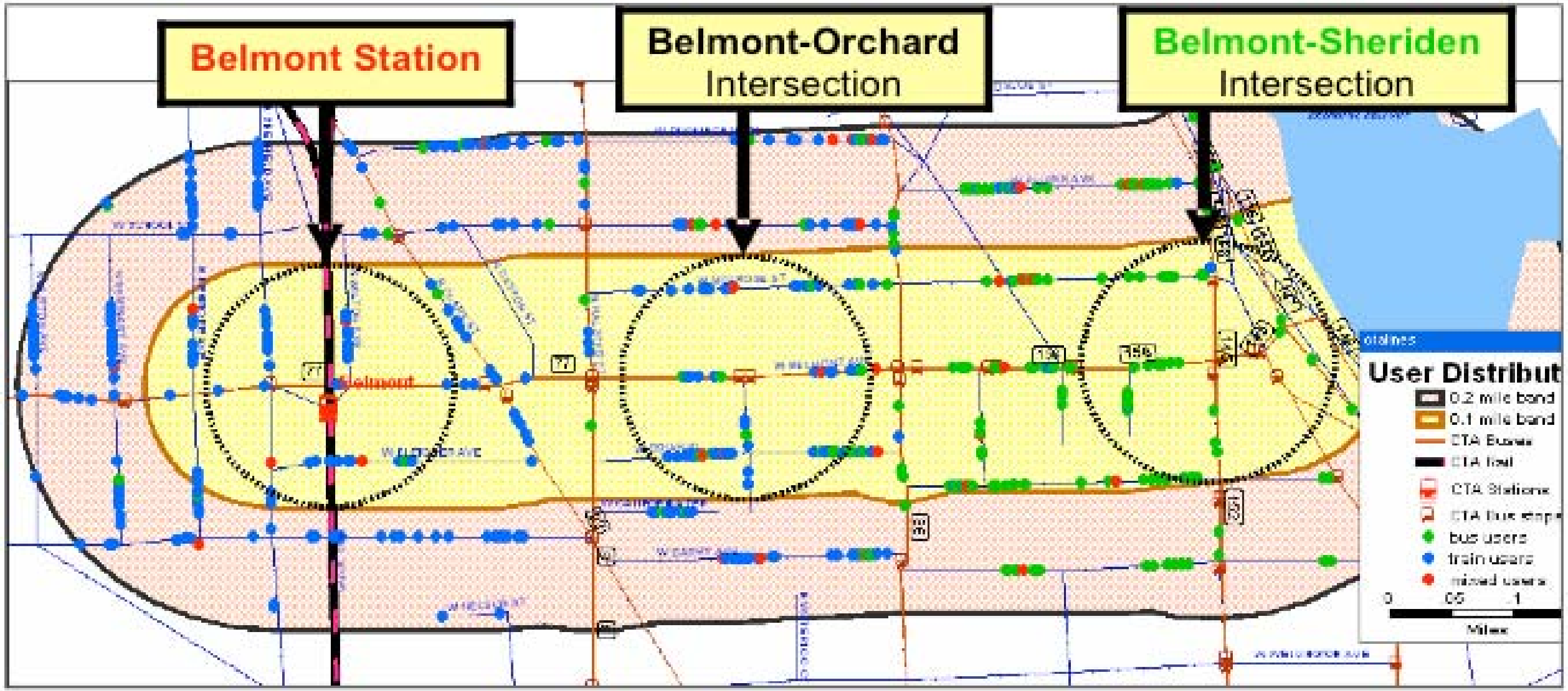
Application: CTA bus and rail network

Recommendations:

This represents a valuable way to monitor behavior and modal preferences as the system changes over time

Key researchers: Mariko Utsunomiya (2005), Saumya Gupta (2006)

Path Choice Analysis: Sample Users



- **Multiple rail and bus routes serving the loop**
- **High quality express bus service and rail service**

Ongoing Bus Operations Research

- Scheduling
- Limited Stop / X Service Design
- Operations Management and Control
- Interchange Analysis
- Bus Route Simulation Model Development
- Chicago Loop Congestion Analysis

Bus Scheduling

- Bus service reliability is a chronic concern of customers and agencies
- Traditionally schedules are developed using rules of thumb -- not a real problem because data has been very poor on actual running times
- Now with AVL data we can evaluate alternative scheduling methods
- Goal is to develop schedules which:
  - result in reliable service
  - don't increase running time too much
  - don't cost too much

Key researchers: Grace Fattouche (2007), Clara Yuan (in progress)

Problem Statement

On high-frequency service, i.e. headways ≤ 10-12 minutes:

- **Develop a timepoint level schedule which minimizes the total weighted time cost to customers**

Subject to:

- **At least 90% of buses should be ready to start their next trip on time**
- **Operators should have at least 5 minutes of recovery time at one end of the route**

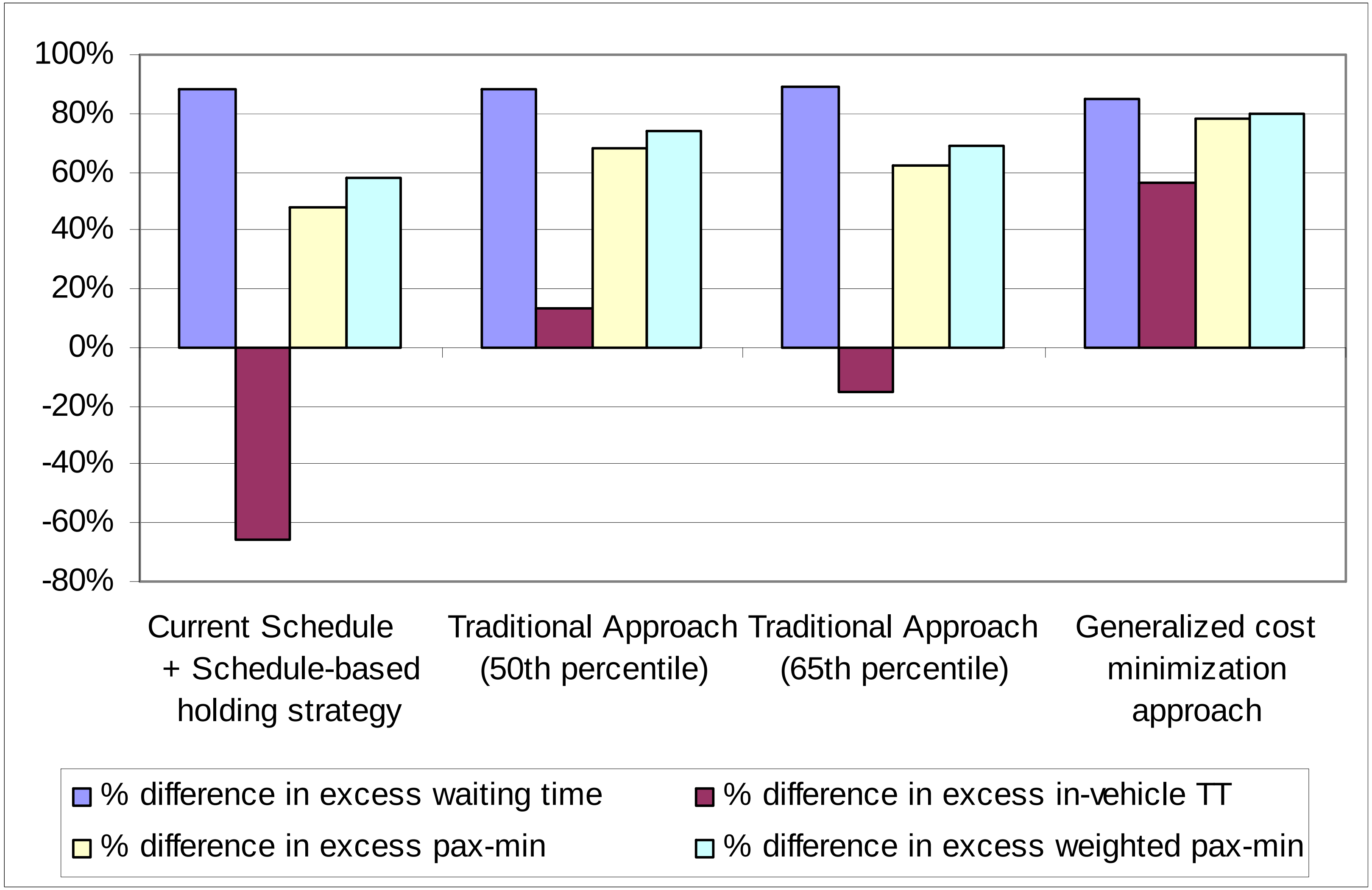
Model

- Evaluates the cost for the waiting passengers, onboard passengers and CTA of a proposed schedule
- Assumes schedule-based holding strategy (i.e. operators do not depart time point early)
- Inputs: AVL and APC data, headway, segment running times and number of buses in operations
- Outputs: costs for the waiting passengers, onboard passengers and CTA

Application to CTA Route 95E

- CTA Key route
- Runs 5 miles East-West on 93rd St. and 95th St.
- Five time points
- Connects with the southern Red Line terminal, and two Metra stations
- High frequency: every 10 mins between 6:00 and 18:00

Percentage Change in Passenger Excess Time



Sensitivity Analysis

The generalized cost minimization schedule is sensitive to:

- **Ratio of waiting passengers to through passengers**
- **Location of the segment on the route**
- **Ratio of waiting passengers on later segments to through passengers**
- **Route Length**

Limited Stop / X Service Design

- **Many high-frequency bus routes in major metropolitan areas are long and have many stops, resulting in:**
  - **long travel times**
  - **poor reliability**
  - **unattractive for long journeys**
- **Limited Stop / X Services are overlay routes with far fewer stops, which:**
  - **provide alternative service mix, which attracts different markets, e.g. longer journeys**
  - **reduce the interaction between buses, i.e., less bunching**
- **One step towards BRT**

Key researchers: Stacey Schwarcz (2004), Harvey Scorcia (in progress)

Problem Statement

- Establish guidelines for the addition of limited stop service
- Develop a model to help in design and evaluation of these services

Key elements in limited stop service design:

- Reduction in # of stops
- Running time savings
- Headway split between local and limited stop service
- Resources: unchanged or increased

Model Components

- Key inputs:
  - Demand by stop
  - Bus running times
  - Limited stops
  - Frequency split
- Key processes:
  - Stop choice for customers closest to local only stop
  - Route choice for customers at combined stops
- Key outputs:
  - Travel times
  - Productivity
  - Market Share
  - Use of stops

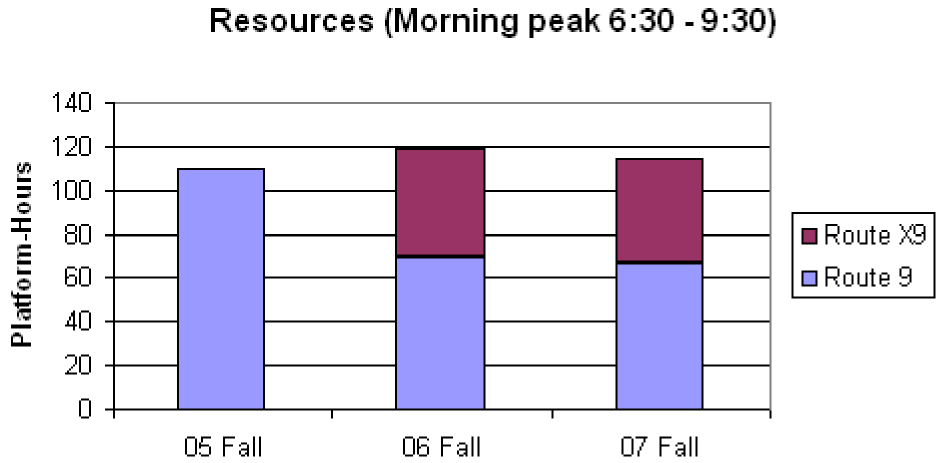
CTA Route 9/X9 Description

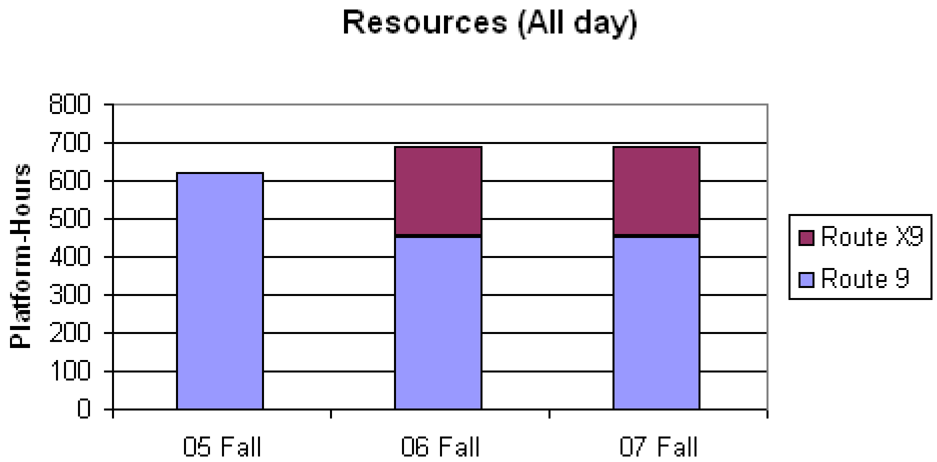
X9 Implemented in Summer 2006

	9	X9
Length	20 miles	
Average Daily Ridership	35,000	
Combined Headway	5 min. Split 50%	
Number of Stops	149	39
Travel Time (mins):		
NB	111	93
SB	106	87

Change in Platform Hours

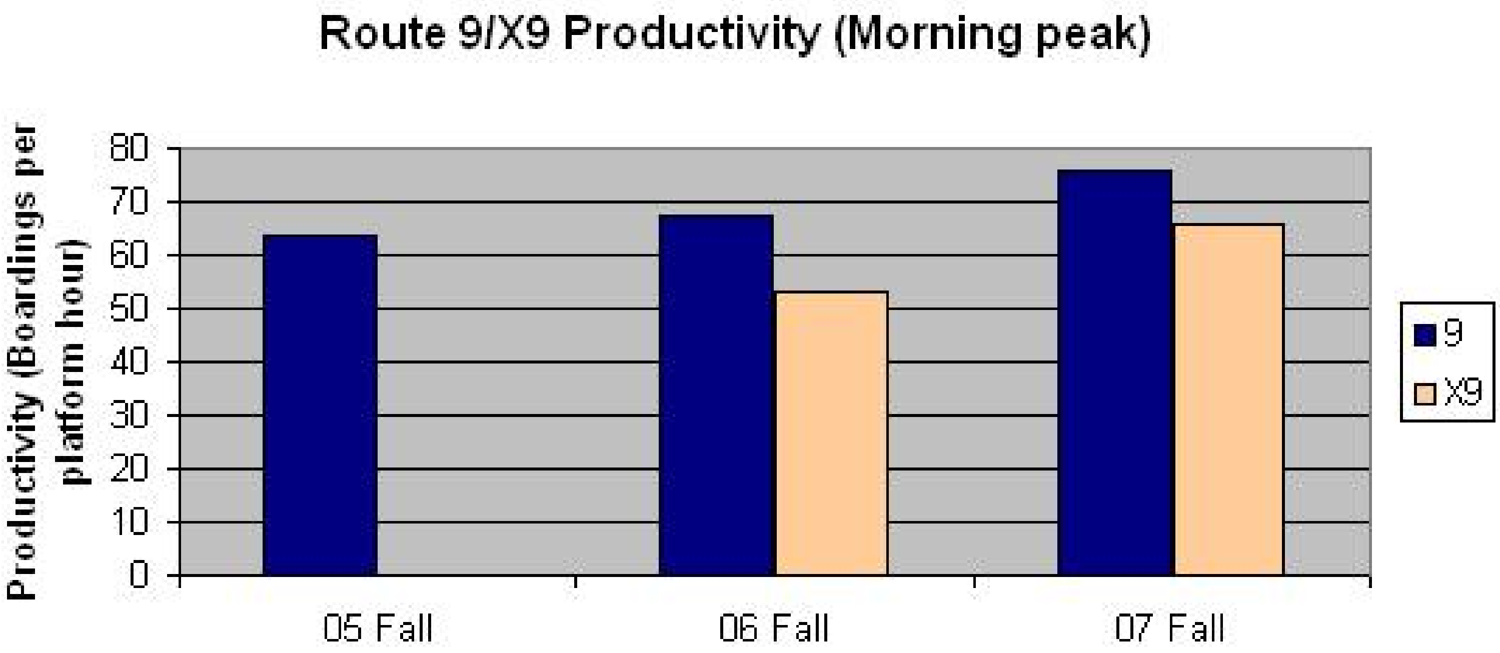
- **Route X9 required a modest increase in resources**





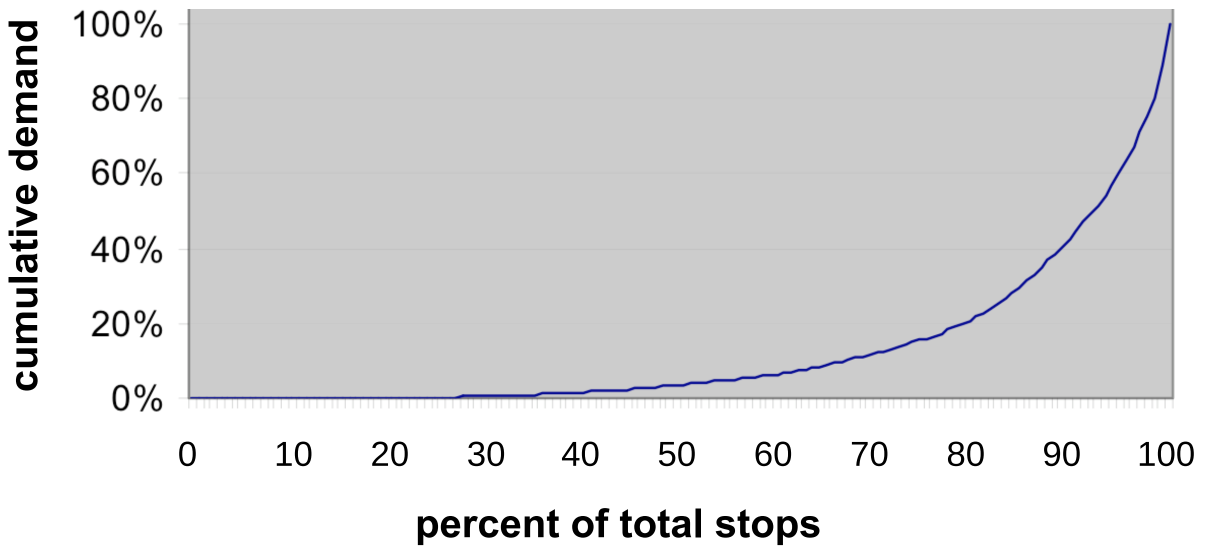
Productivity

- **Overall increase in productivity**



Limited Stop Design Guidelines

- **Stop spacing:**
  - **CTA X services typically serve 25-30% of local stops**
  - **Stop spacing is 0.3-1 mile between X service stops**
  - **Based on cumulative demand by stop function**

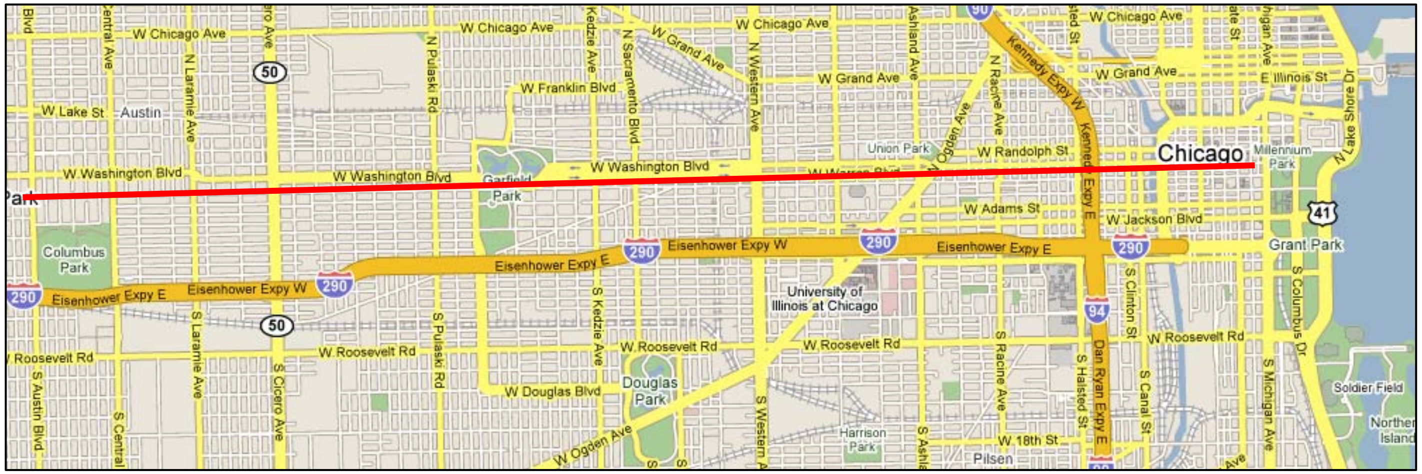


Limited Stop Design Guidelines

- **Running time reduction:**
  - **Savings of at least 15% should be achievable**
- **Limited stop frequency share:**
  - **Frequency on X routes must be greater than on local service**
  - **Typically 60% of service should be on the X route**

Operations Management and Control

- **<u>Objectives</u>:**
  - **Examine how real-time AVL system can support improved service reliability**
- **<u>Application</u>:**
  - **CTA Route 20**
  - **AM peak period headway: 5 minutes**
  - **Average weekday boardings: 24,700**
  - **8.5 mile, 60 minute eastbound trip**
  - **Capacity and bus bunching issues**

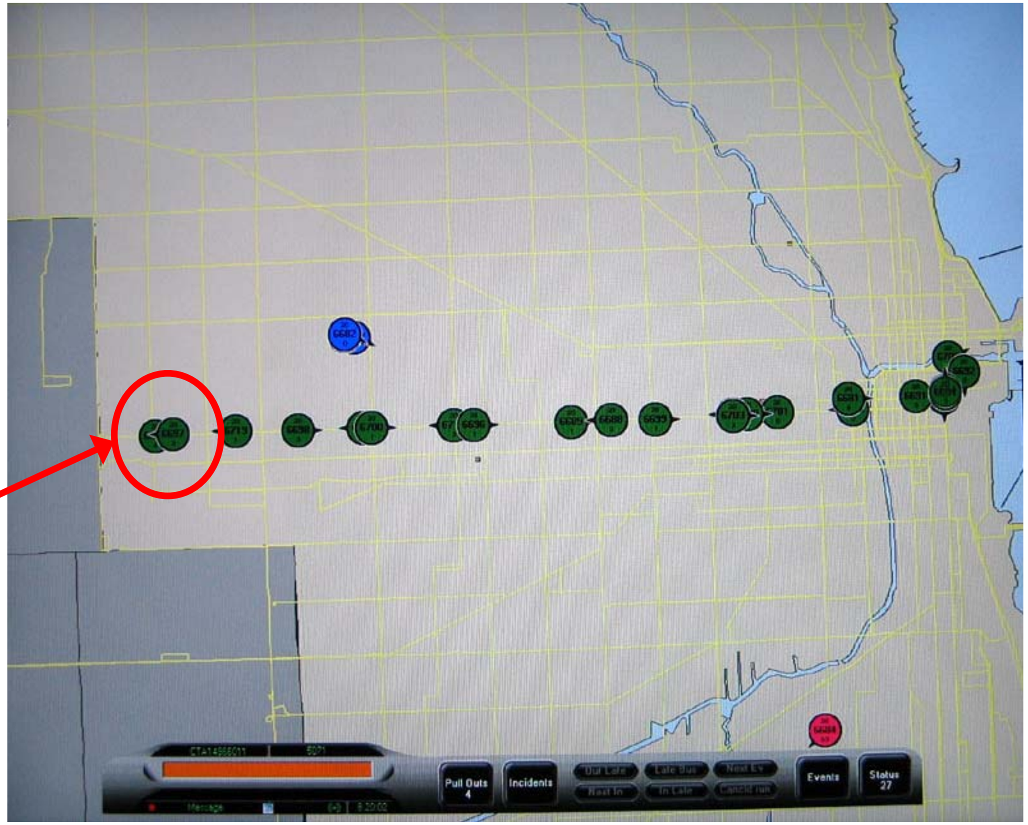


Key researchers: Chris Pangilinan (2006)

Operations Management and Control

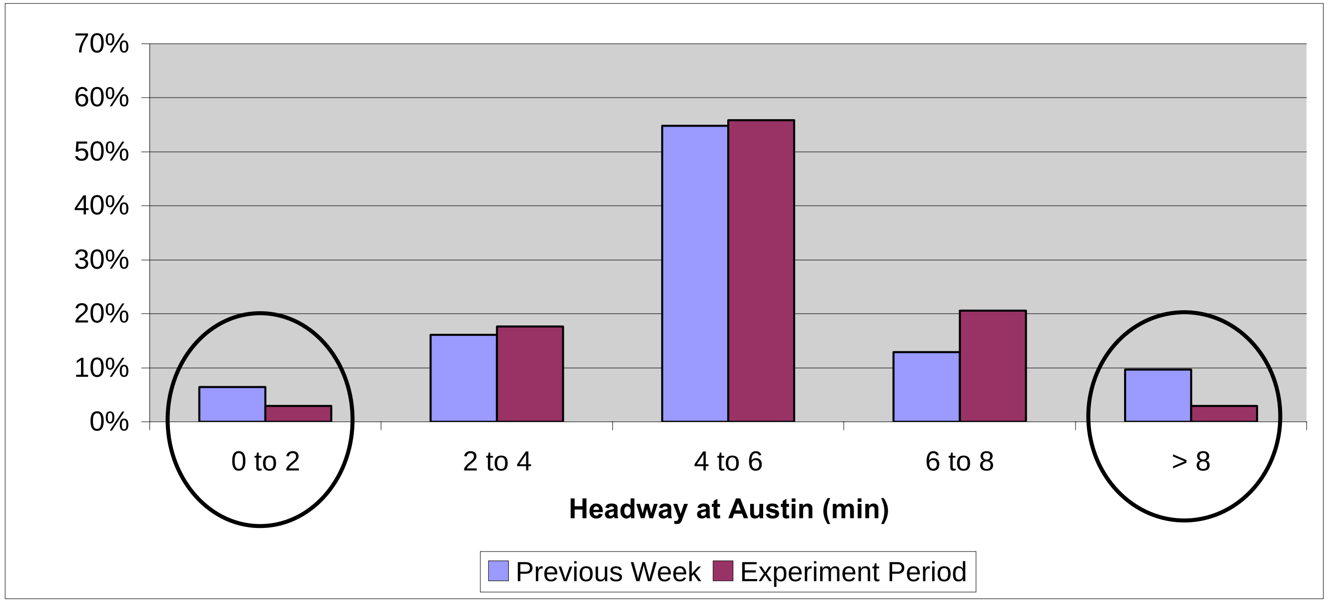
- **Application**:
  - CTA Bus Tracker System
  - MIT Student acted as controller for one week using Bus Tracker information

Individual Buses



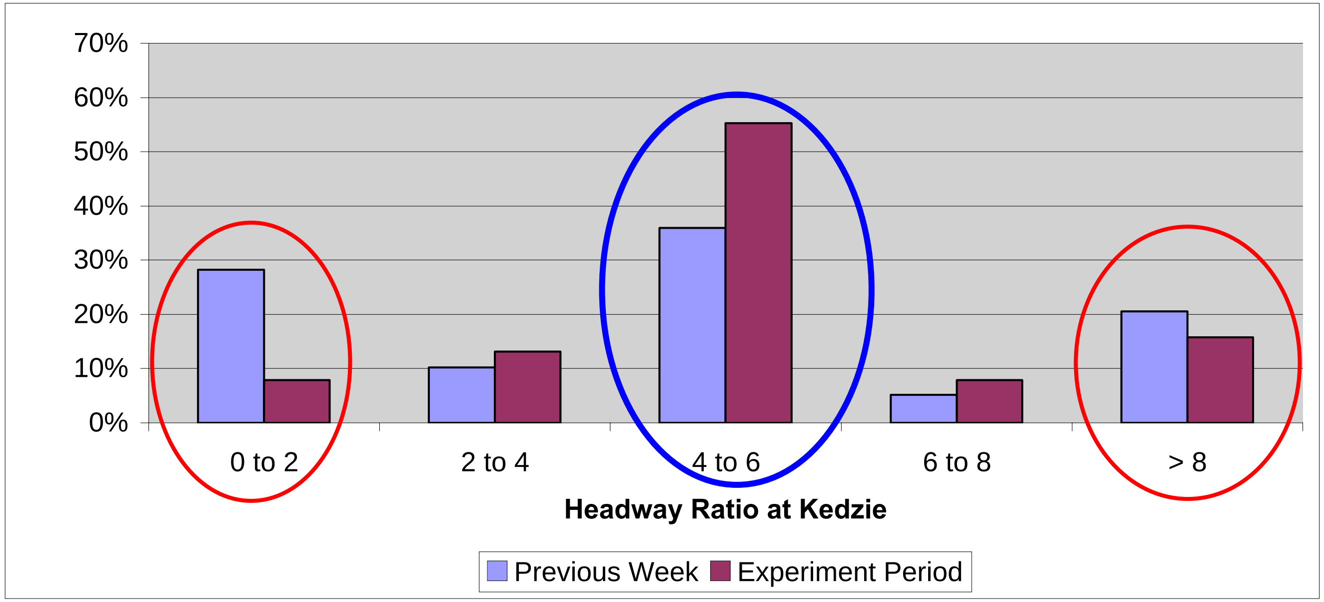
Results

- **Headways leaving Austin (Terminal)**

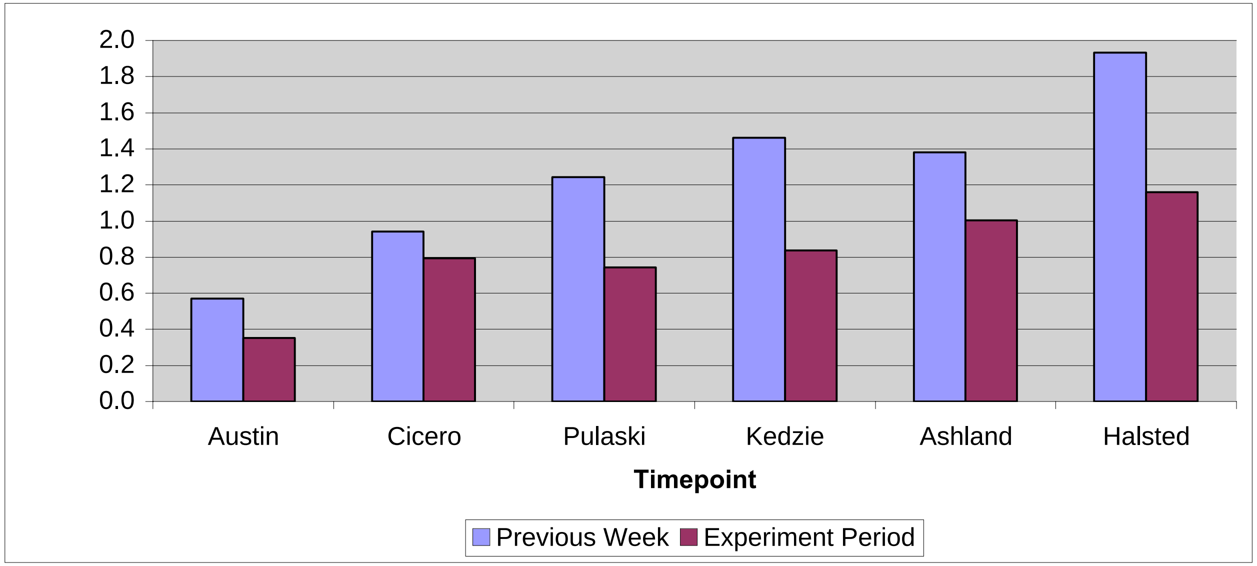


Results

- **Headways 3.5 miles east of terminal**



Results: Excess Wait Time



% of Scheduled Wait Time	Austin	Cicero	Pulaski	Kedzie	Ashland	Halsted
Previous Week	23%	38%	50%	58%	55%	77%
Experiment Period	9%	15%	20%	23%	22%	31%

Results in Perspective

- **To achieve the same reduction in excess passenger waiting time <u>without</u> improving reliability:**

  6 more buses would have to be added to the current 24 during the AM peak

Summary of Results

- Real-time AVL and supervision strategies contributed to:
  - Lower rate of bus bunching
  - Lower rate of long headways
- Downstream headways benefited from terminal control
- Reduction in excess wait time
- Dwell time, traffic, and other factors will take its toll on reliability, regardless of supervision

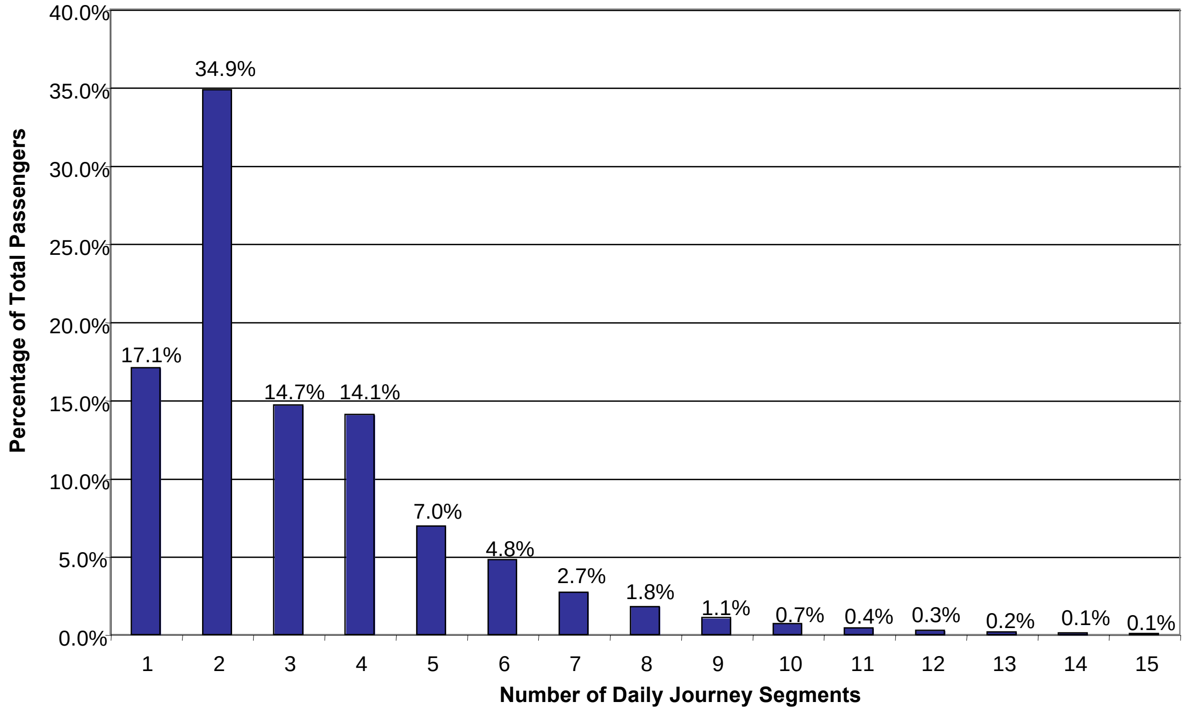
Interchange Analysis

Research Questions:

- **Can Oyster data be used to help improve the public transport network in London by focusing on bus passenger interchange behaviour?**
- **Key contribution:**
  - **Methodology for exploring passenger interchange behaviour in London using Oyster card data**

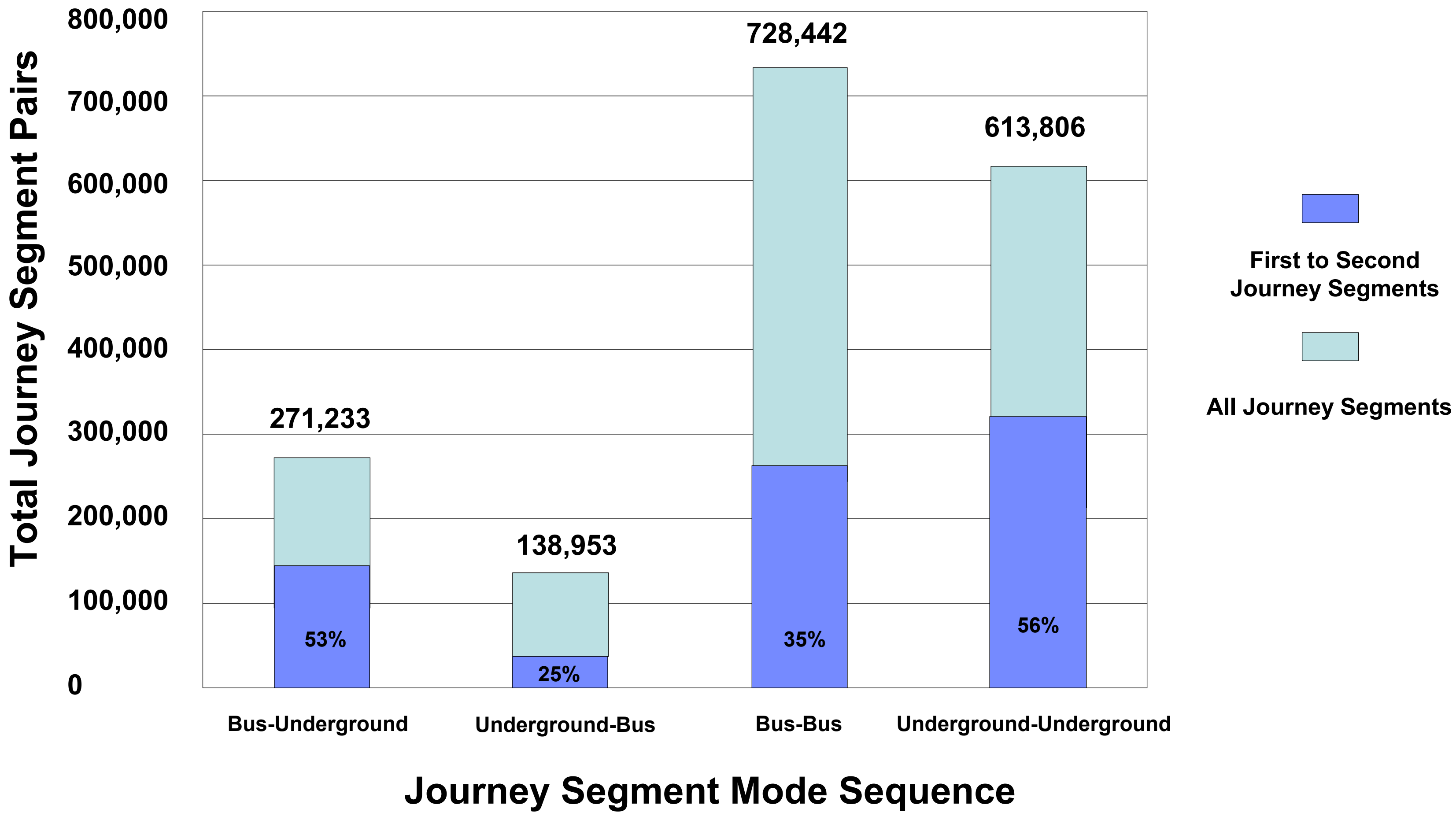
Key researchers: Catherine Seaborn (in progress)

Journey Segments Per Passenger



Source: 5% Oyster data for 2007 Period 2 (April 29 – May 26)

Consecutive Journey Segments



Source: 100% Oyster data for Wednesday, November 14, 2007

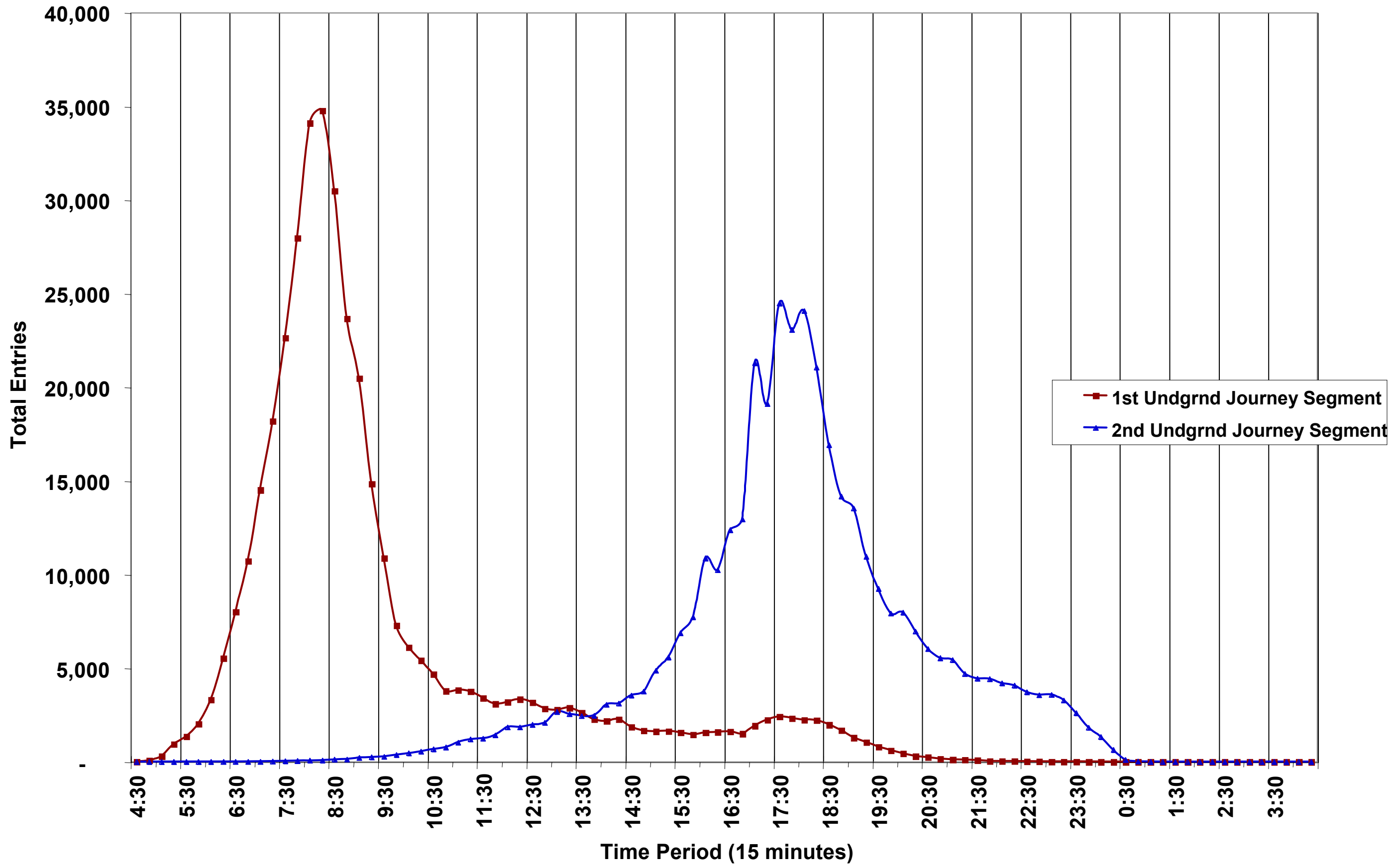
Weekday Journey Segment Patterns

- **Top 10 patterns shown** **Total patterns: 15,802**

Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Passengers	Share	Cumulative Share
U	U					416,082	16.3%	16.3%
B	B					401,356	15.7%	32.0%
B						266,561	10.4%	42.4%
B	B	B				150,781	5.9%	48.3%
B	B	B	B			144,275	5.6%	54.0%
U						125,528	4.9%	58.9%
B	U	U	B			77,353	3.0%	61.9%
B	B	B	B	B		72,943	2.9%	64.8%
U	U	U				65,190	2.6%	67.3%
B	B	B	B	B	B	50,485	2.0%	69.3%

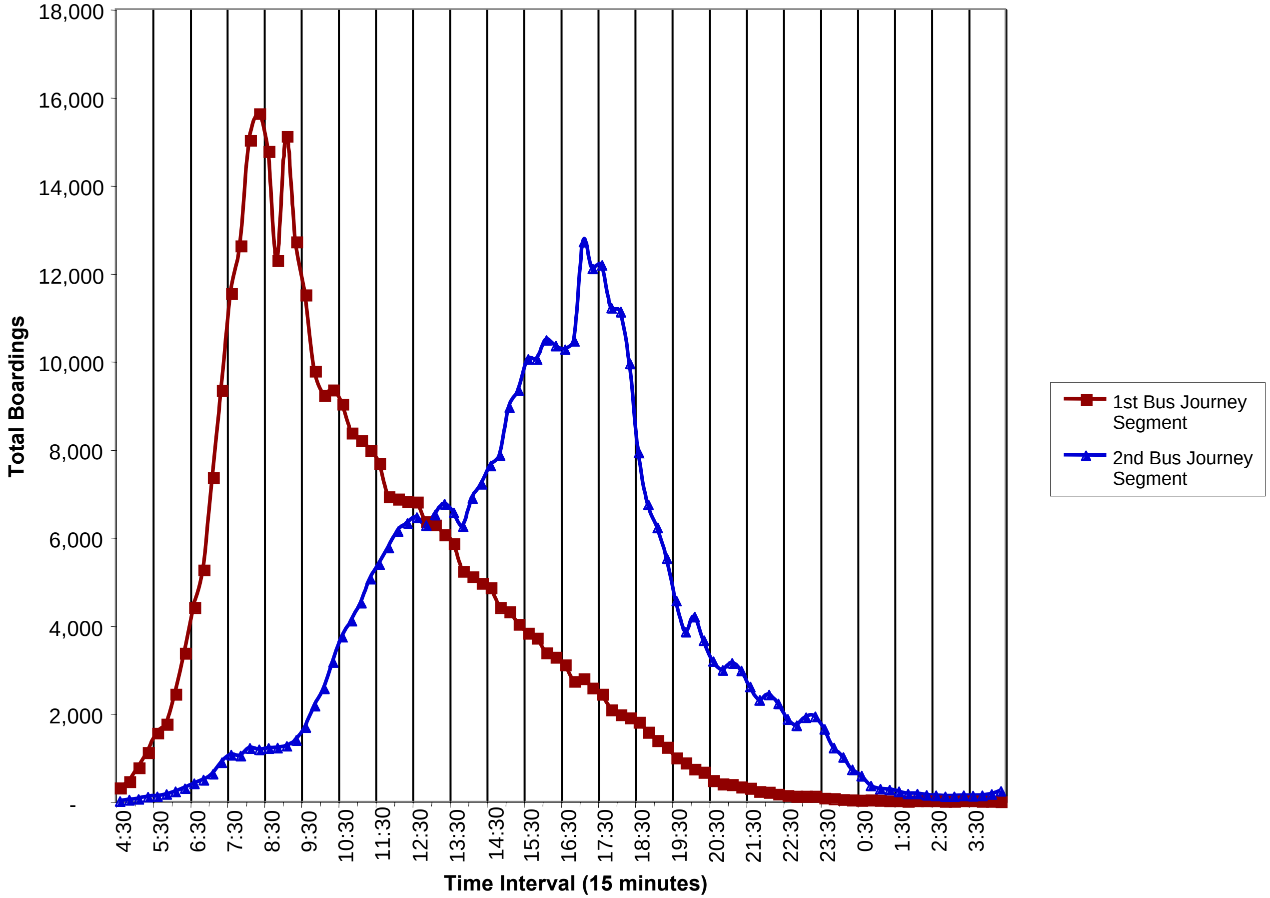
Source: 100% Oyster data for Wednesday, November 14, 2007

Underground-Underground Journey Segment Entry Times



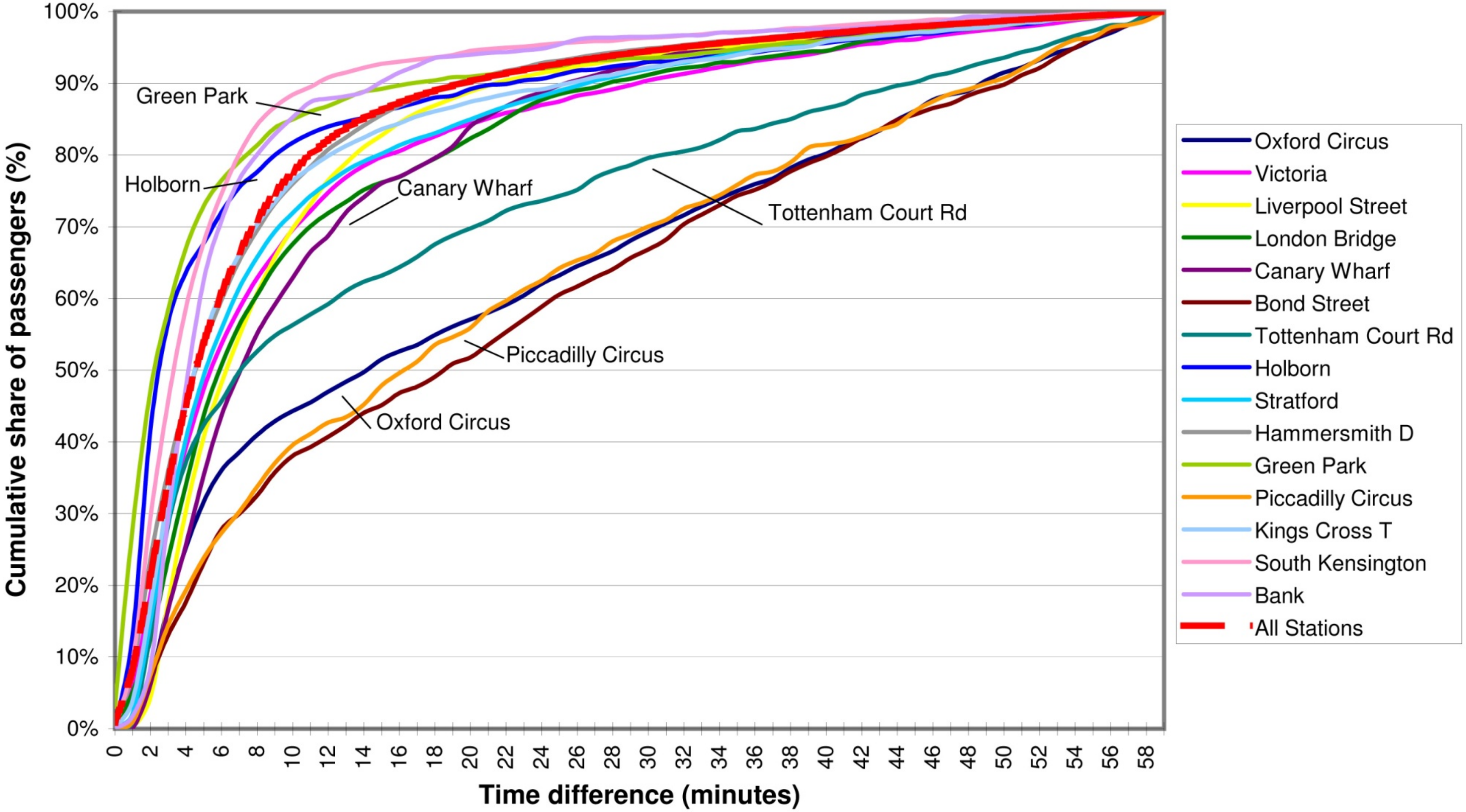
Source: 100% Oyster data for Wednesday, November 14, 2007

Bus-Bus Journey Segment Boarding Times



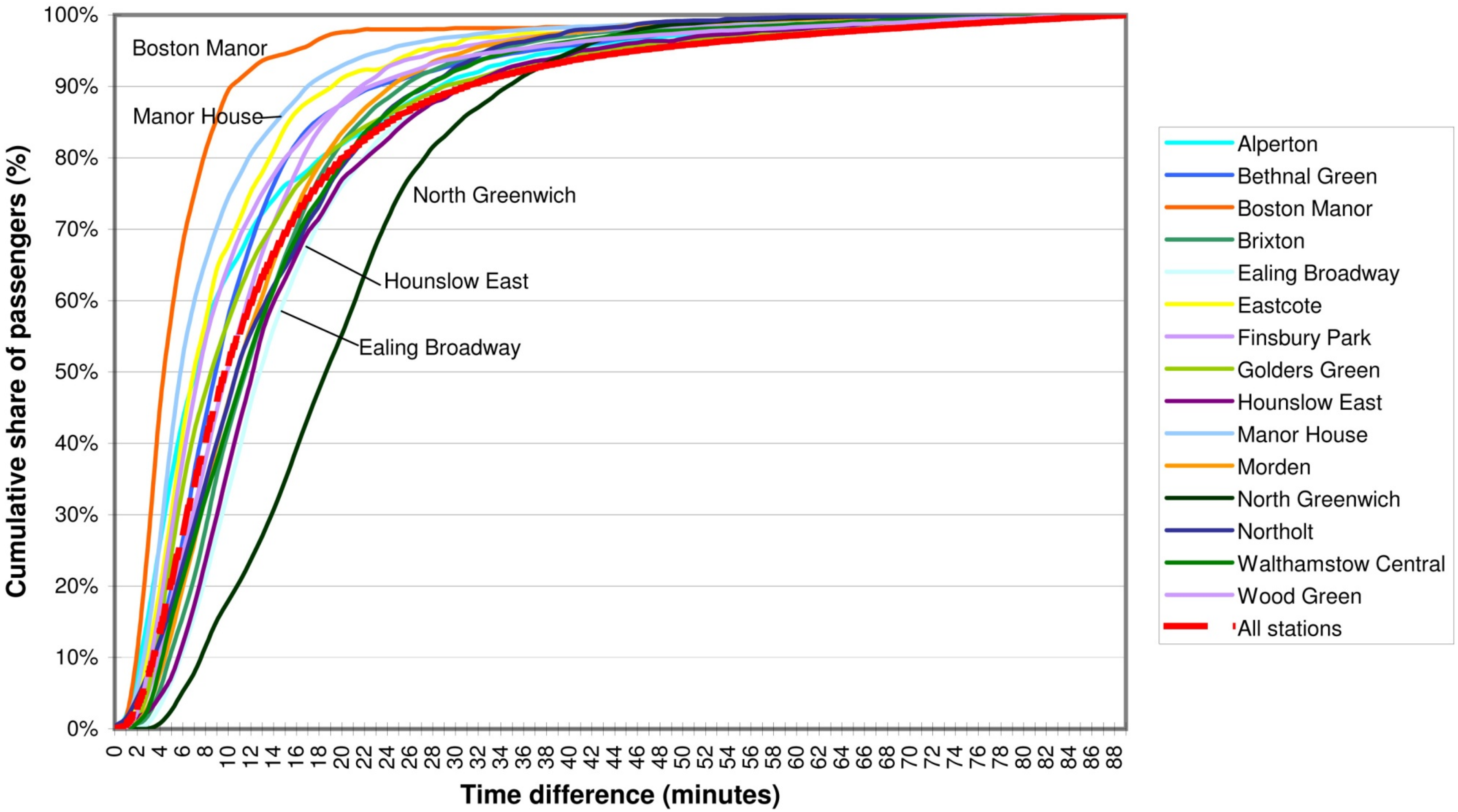
Source: 100% Oyster data for Wednesday, November 14, 2007

Underground Station Exit to Bus Boarding: Time Difference at Highest Exit Volume Stations



Data source: Transport for London. All Oyster Card journey segments on Wednesday, November 14, 2007.

Bus Boarding to Underground Station Entry: Potential Transfers are Large Share of Entries



Data source: Transport for London. All Oyster Card journey segments on Wednesday, November 14, 2007.