

The Role of Information Technology in Improving Transit Systems

by

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OUTLINE

- **MIT Transit Research Program**
- **Key Automated Data Collection Systems (ADCS)**
- **Key Transit Agency/Operator Functions**
- **Impact of ADCS on Functions**
- **Traditional Relationships Between Functions**
- **State of Research/Knowledge**
- **Examples of Recent Research**
- **Emerging Possibilities**
- **Remaining Challenges**

MIT Urban Public Transport Research Program

A major focus of MIT transportation research over the past fifteen years

Research projects included:

- **Tren Urbano (Puerto Rico):** 1994 - 2003
- **Chicago Transit Authority:** 2001 - present
- **Massachusetts Bay Transportation Authority:** 2003 - 2005
- **Transport for London:** 2005 - present
- **Diputacion Foral de Gipuzkoa** 2009 – present

Six faculty and research staff

15-20 graduate students

COMMON PHILOSOPHY

Multi-year applied research program conducted in close collaboration with transit operating and planning agencies

- **Focus has often been a major infrastructure project with MIT program helping to develop intellectual capital to match infrastructure investment**
- **Strong support from agency leadership**
- **Professional development within agencies**
- **Inter-disciplinary research: broad range of research questions addressed**
- **Application of research to multiple agencies**
- **Student internships within transit agencies for in-depth immersion**

Faculty and Research Staff

John Attanucci, Research Associate

- Urban public transport planning, operations
- Fare policy and management

George Kocur, Senior Lecturer

- Information Technology
- Ticketing systems and fare policy

Mikel Murga, Research Associate

- Transportation planning and modeling
- Geographic Information System

Fred Salvucci, Senior Lecturer

- Transportation policy and politics

Nigel Wilson, Professor of Civil & Environmental Engineering

- Urban public transport planning, operations, control, and management

Jinhua Zhao, Research Scientist

- Travel preferences and behavior
- Transport policy

Transit Agencies Are at a Critical Transition in Data Collection Technology:

Manual

- low capital cost
- high marginal cost
- small sample sizes
- aggregate
- unreliable

- limited spatially and temporally
- not immediately available



Automatic

- high capital cost
- low marginal cost
- large sample sizes
- more detailed, disaggregate
- errors and biases can be estimated and corrected
- ubiquitous
- available in real-time or quasi real-time

Key Automated Data Collection Systems

- **Automatic Vehicle Location Systems (AVL)**
 - bus location based on GPS
 - train tracking based on track circuit occupancy
 - real-time availability of data
- **Automatic Passenger Counting Systems (APC)**
 - bus systems based on sensors in doors with channelized passenger movements
 - passenger boarding (alighting) counts for stops/stations with fare barriers
 - train weighing systems to estimate number of passengers on board
 - traditionally not available in real-time
- **Automatic Fare Collection Systems (AFC)**
 - increasingly based on contactless smart cards with unique ID
 - provides entry (exit) information (spatially and temporally) at the individual level
 - traditionally not available in real-time

ADCS - Potential and Reality

Potential

- **Integrated ADCS database**
- **Models and software to support many agency decisions using ADCS database**
- **Providing insight into normal operations, special events, unusual weather, etc.**

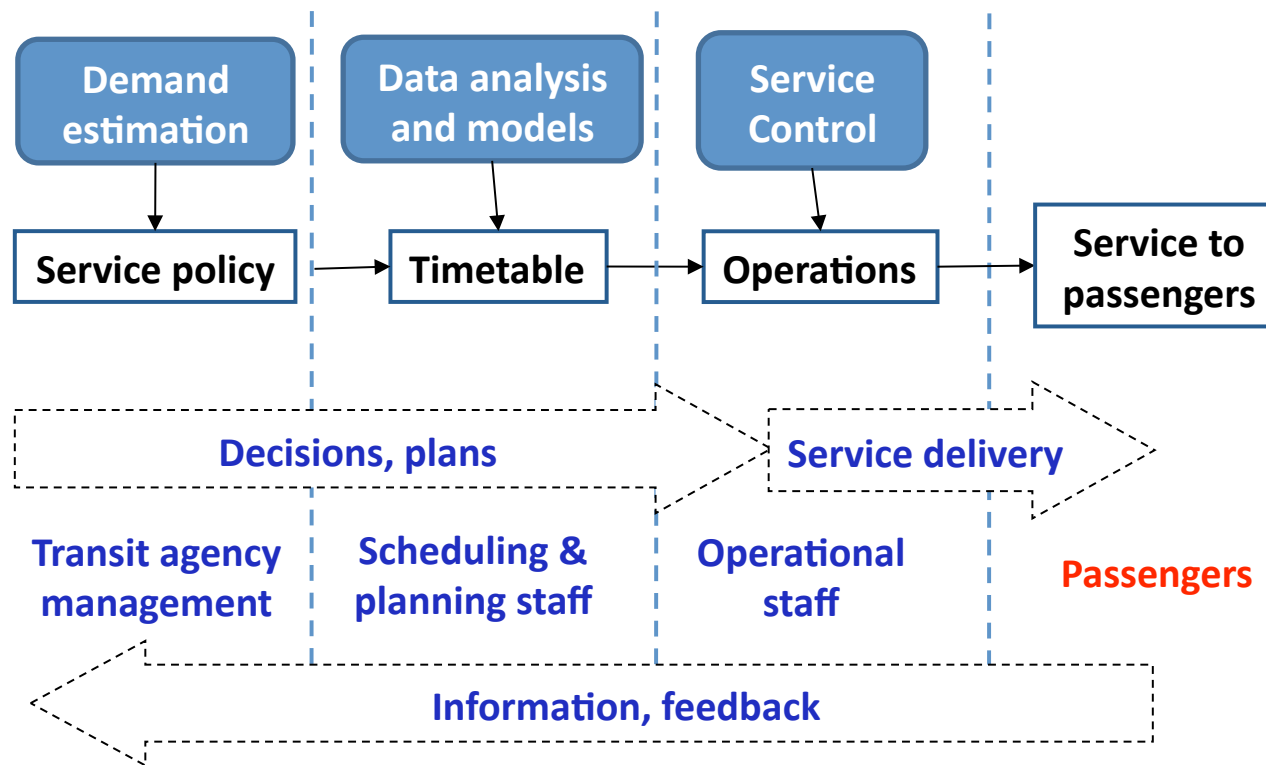
Reality

- **Most ADCS systems are implemented independently**
- **Data collection is ancillary to primary ADC function**
 - **AVL - emergency notification, stop announcements**
 - **AFC - fare collection and revenue protection**
- **Many problems to overcome:**
 - **not easy to integrate data**
 - **requires substantial resources**

Key Transit Agency/Operator Functions

- **Service and Operations Planning (SOP)**
 - Network and route design
 - Frequency setting and timetable development
 - Vehicle and crew scheduling
 - Off-line, non real-time function
- **Service and Operations Control and Management (SOCM)**
 - Dealing with deviations from SOP, both minor and major
 - Dealing with unexpected changes in demand
 - Real-time function

Transit Service Delivery Process*



* Source: "Diagnosis and Assessment of Operations Control Interventions: Framework and Applications to a High Frequency Metro Line." MST Thesis, André Carrel; MIT, 2009.

Key Transit Agency/Operator Functions (cont'd)

- **Customer Information (CI)**
 - Information on routes, trip times, vehicle arrival times, etc.
 - Both static (based on SOP) and dynamic (based on SOP and SOCM)
 - Both pre-trip and en-route
- **Performance Measurement and Monitoring (PMM)**
 - Measures of operator performance against SOP
 - Measures of service from customer viewpoint
 - Traditionally an off-line function

Impact of ADCS

IMPACT ON SOP

- **AVL:** detailed characterization of route segment running times
- **APC:** detailed characterization of stop activity (boardings, alightings, and dwell time at each stop)
- **AFC:** detailed characterization of fare transactions for individuals over time

IMPACT ON SOCM

- **AVL:** identifies current position of all vehicles, deviations from SOP

IMPACT ON CI

- **AVL:** supports dynamic CI
- **AFC:** permits characterization of normal trip-making at the individual level, supports active dynamic CI function

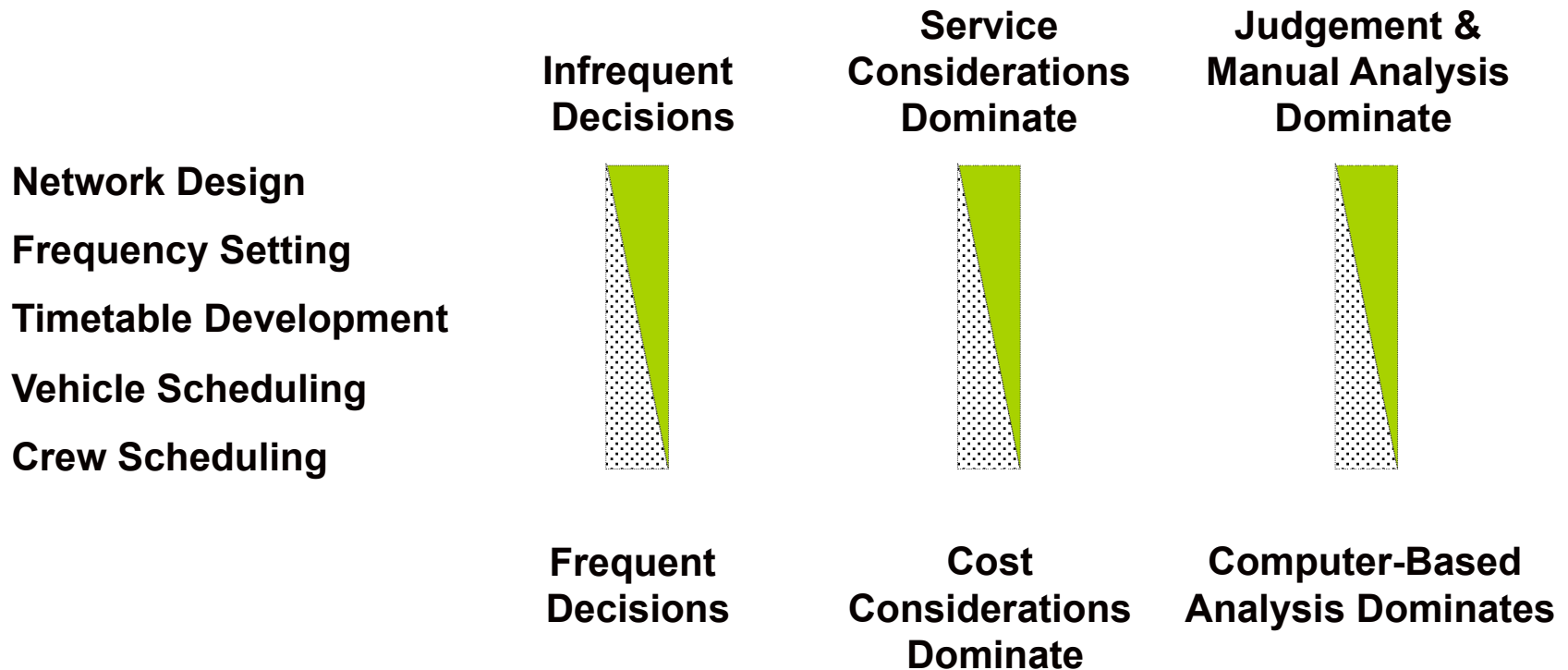
IMPACT ON PMM

- **AVL:** supports on-time performance assessment
- **AFC:** supports passenger-oriented measures of travel time and reliability

Traditional Relationships Between Functions

- **SOP serves as the basis for both SOCM and CI**
- **Reasonable as long as SOP is sound and deviations from it are not very large**
- **Input data to the SOP has improved as a result of ADCS**
- **Fundamentally a static model in an increasingly dynamic world**

State of Research/Knowledge in SOP



Service Planning Hierarchy

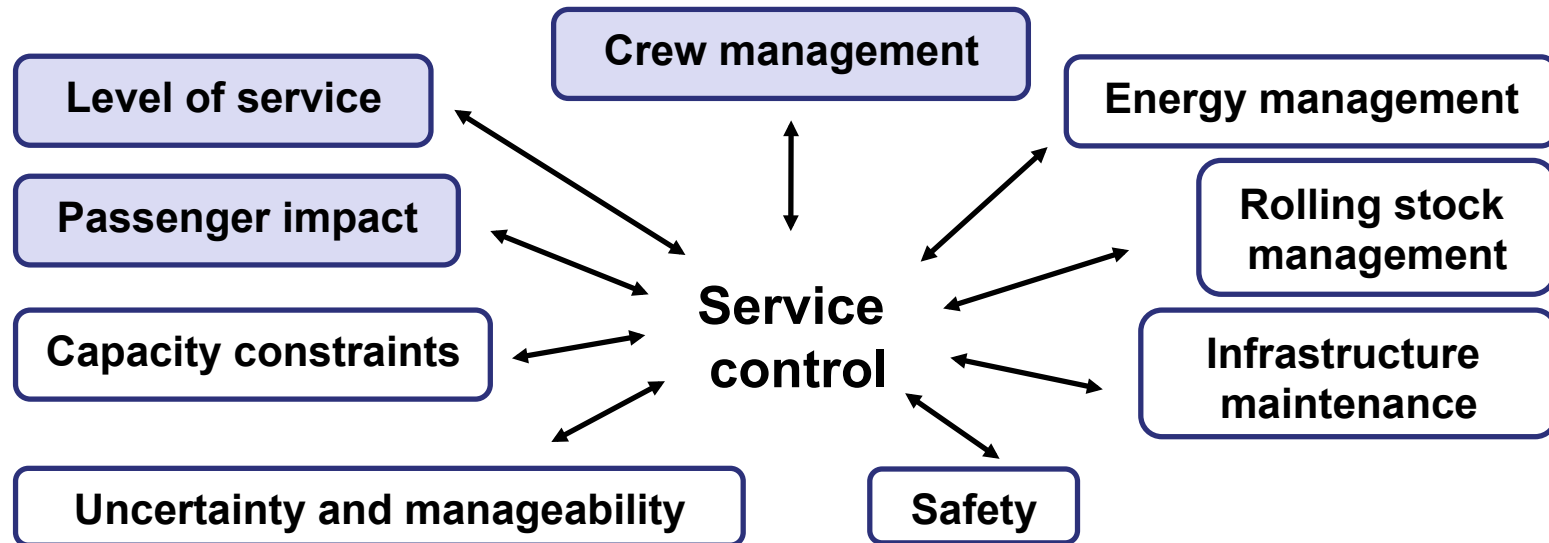
State of Research/Knowledge in SOP

- **Advanced in vehicle and crew scheduling (operations planning)**
- **Limited in past by weak data, less of a problem now**
- **Limited in service planning: rules of thumb and experience still dominate**
- **Much research has been simplistic in terms of formulation of objectives and constraints**
- **Inadequate recognition of uncertainty in model formulation**
- **Substantial opportunities remain for better models**

State of Research/Knowledge in SOCM

- **Advances in train control systems help minimize impacts of small incidents**
- **Major disruptions still handled in individual manner based on judgement and experience**
- **Little effective decision support for controllers**
- **Models suffer from deterministic formulation of highly stochastic systems**
- **Simplistic view of objectives and constraints in model formulation**
- **Substantial opportunities remain for better models**

Rail Operations Controllers Decision Factors



- These factors can trigger service control interventions or place constraints on interventions performed for other reasons
- Conflicts between objectives are frequent
- How can we best coordinate and integrate these objectives and constraints?

Source: "Diagnosis and Assessment of Operations Control Interventions: Framework and Applications to a High Frequency Metro Line." MST Thesis, André Carrel; MIT, 2009.

State of Research/Knowledge in CI

- **Next vehicle arrival times at stops/stations well developed and increasingly widely deployed**
- **Pre-trip journey planner systems widely deployed but with limited functionality in terms of recognizing individual preferences**
- **Strongly reliant on veracity of SOP**
- **Ineffective in dealing with major disruptions**

Evolution of Customer Information

- **Operator view --> customer view**
 - **route-based --> OD-based**
- **Static --> dynamic**
 - **based on SOP --> based on SOP modified by current system state**
- **Pre-trip and at stop/station --> en route**
- **Generic customer --> specific customer**
- **Active systems --> passive systems**

State of Research/Knowledge in PMM

- **Generally takes the operator rather than customer perspective**
 - **route- or stop-based measures rather than OD measures**
 - **lack of measures of reliability**
 - **lack of recognition of non-linear response in terms of customer satisfaction**
- **Based on achieving SOP as ultimate goal**

Examples of Recent Research Based on ADCS

- **Trip chaining based on entry-only AFC transactions and AVL data**
- **Travel behavior analysis: modal preferences and access distance**
- **Reliability metrics at OD level**

OD Matrix Estimation in CTA Bus Network

Objective:

- Estimate bus passenger OD matrix for CTA at:
 - single route level
 - network level

CTA Network attributes:

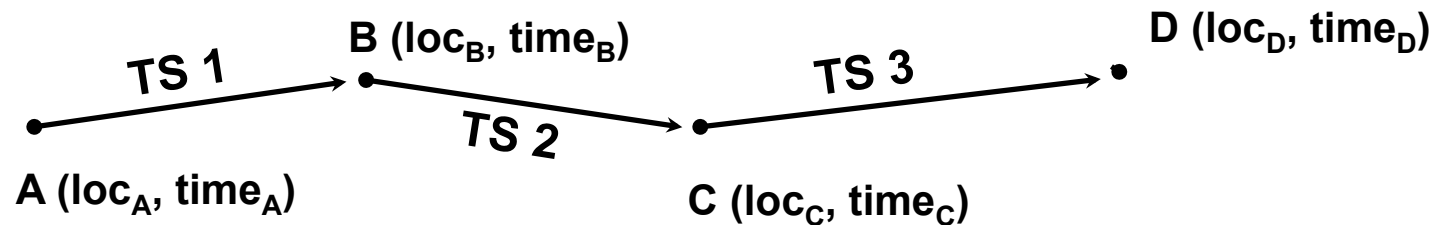
- multi-modal rail and bus system
- entry-control-only operations

Source: "Bus Passenger Origin-Destination Matrix Estimation Using Automated Data Collection Systems."
Alex Cui, MST Thesis, MIT, June 2006

Trip Chaining: 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.

Trip-Chaining Method for OD Inference

Key Assumptions for Destination Inference to be correct:

- No intermediate private transportation mode trip segment
- Passengers will not walk a long distance
- Last trip of a day ends at the origin of the first trip of the day

Summary Information on the Data Used

- **Overall AFC data (single weekday, all bus routes):**
 - 545,000 bus passenger trips using farecard
 - From these, 436,000 with boarding stop (~80% identification rate)
 - From these, 244,000 with destination (~56% inference rate)

CTA Travel Behavior Analysis

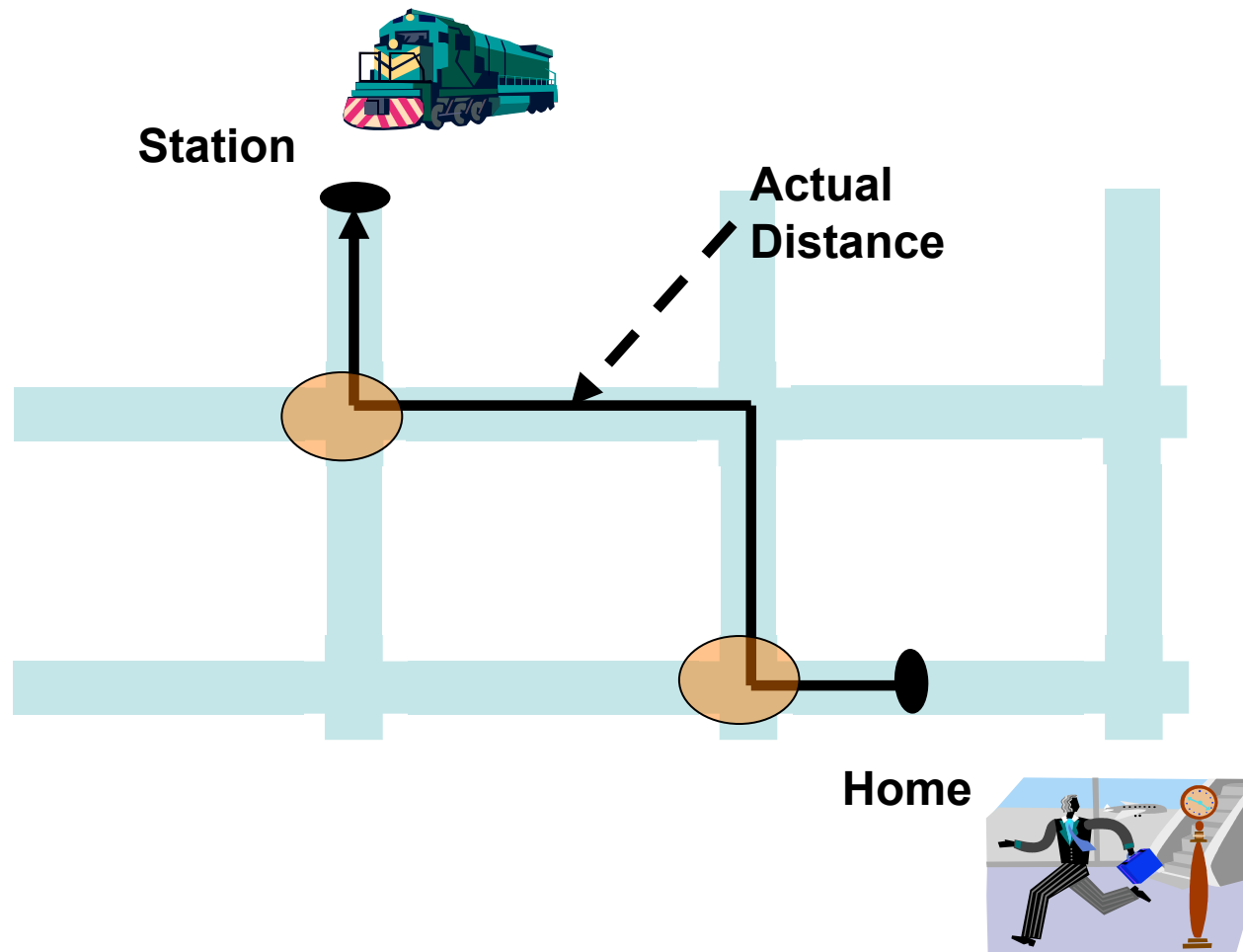
- **Use of CTA Chicago Card analysis of bus vs. rail preferences***

* Source:

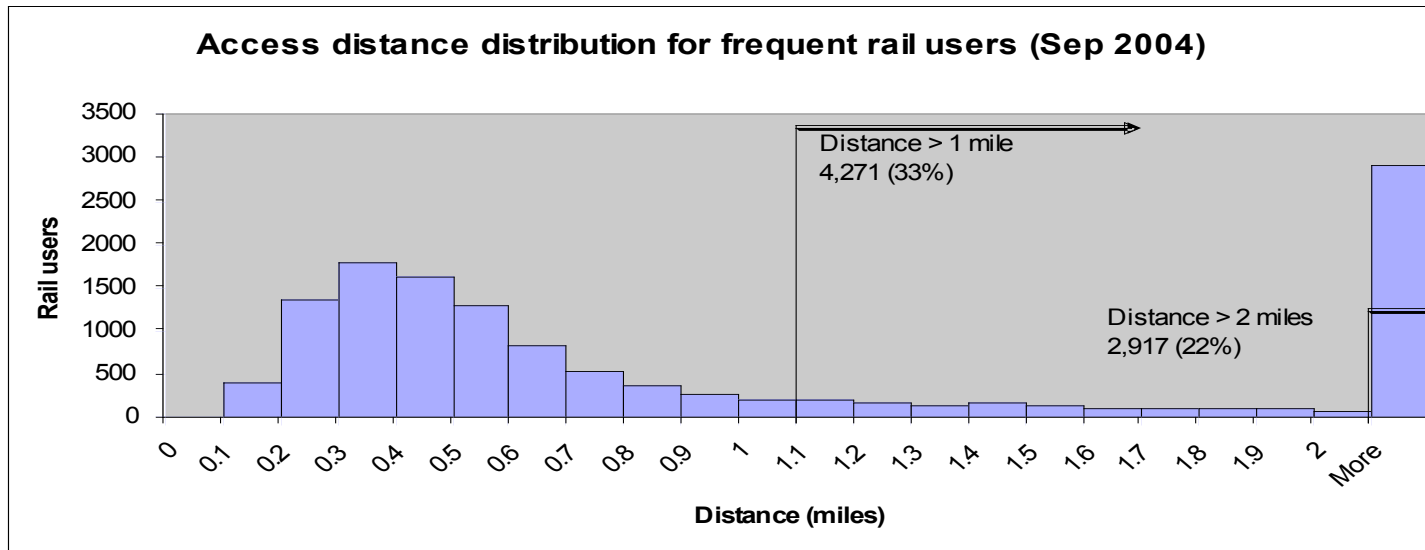
Gupta, S., " Understanding Transit Travel Behavior: Value added by Smart Cards." MST Thesis, MIT, 2006.

Utsunomiya, M., J. Attanucci, N.H.M. Wilson, "Potential Uses of Transit Smart Card Registration and Transaction Data to Improve Transit Planning." Transportation Research Record 1971, pp 119-126 (2006).

Methodology: Calculating Access Distances

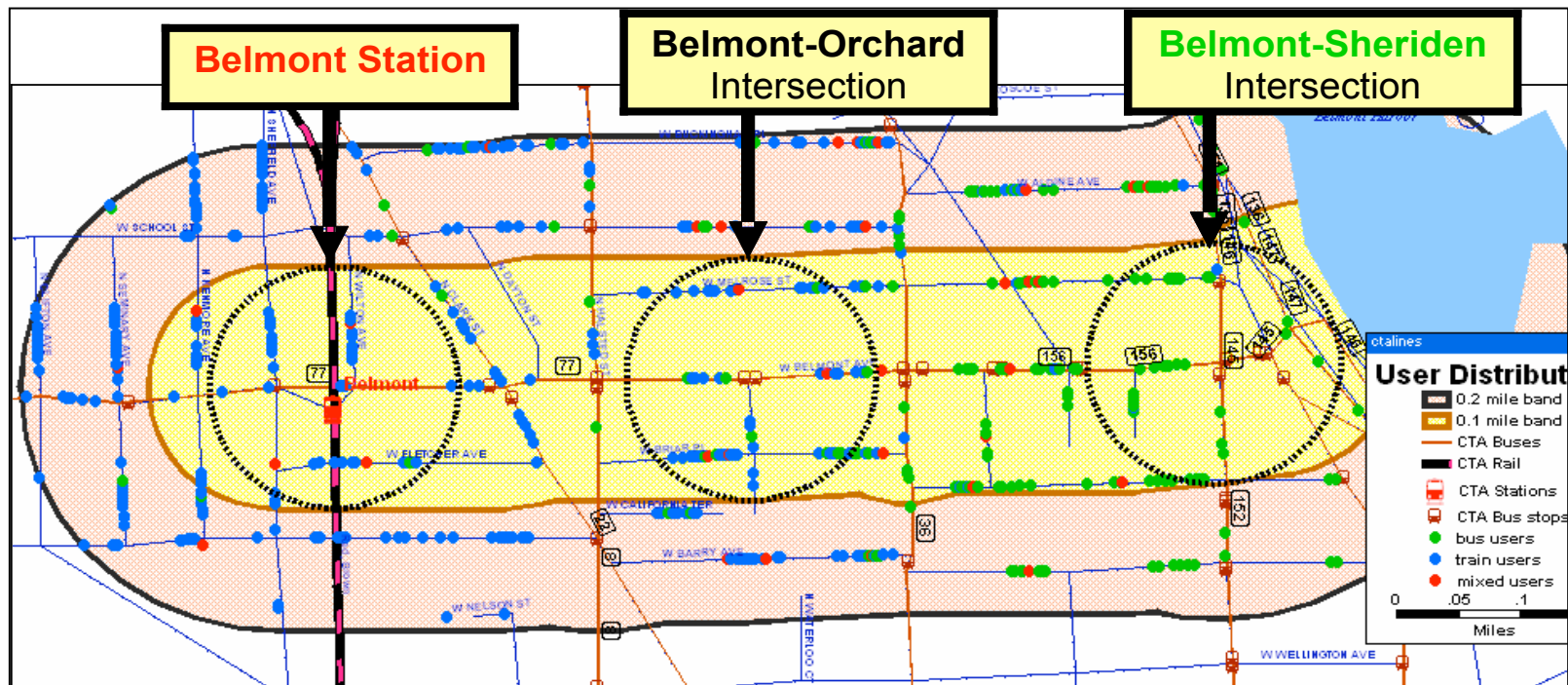


Rail Access Distance Distributions



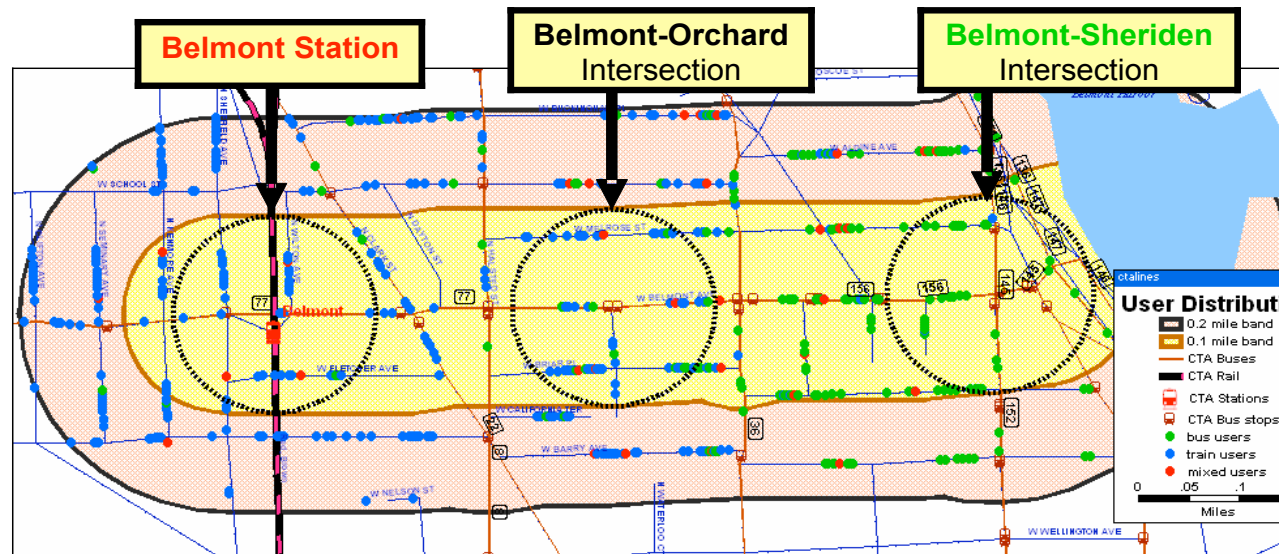
	Frequent and Consistent Rail Customers (%)
Total analyzed	12,973
Access distance \leq 1 mile	8,702 (67%)
Access distance > 1 mile	4,271 (33%)

Path Choice Analysis: Sample Users



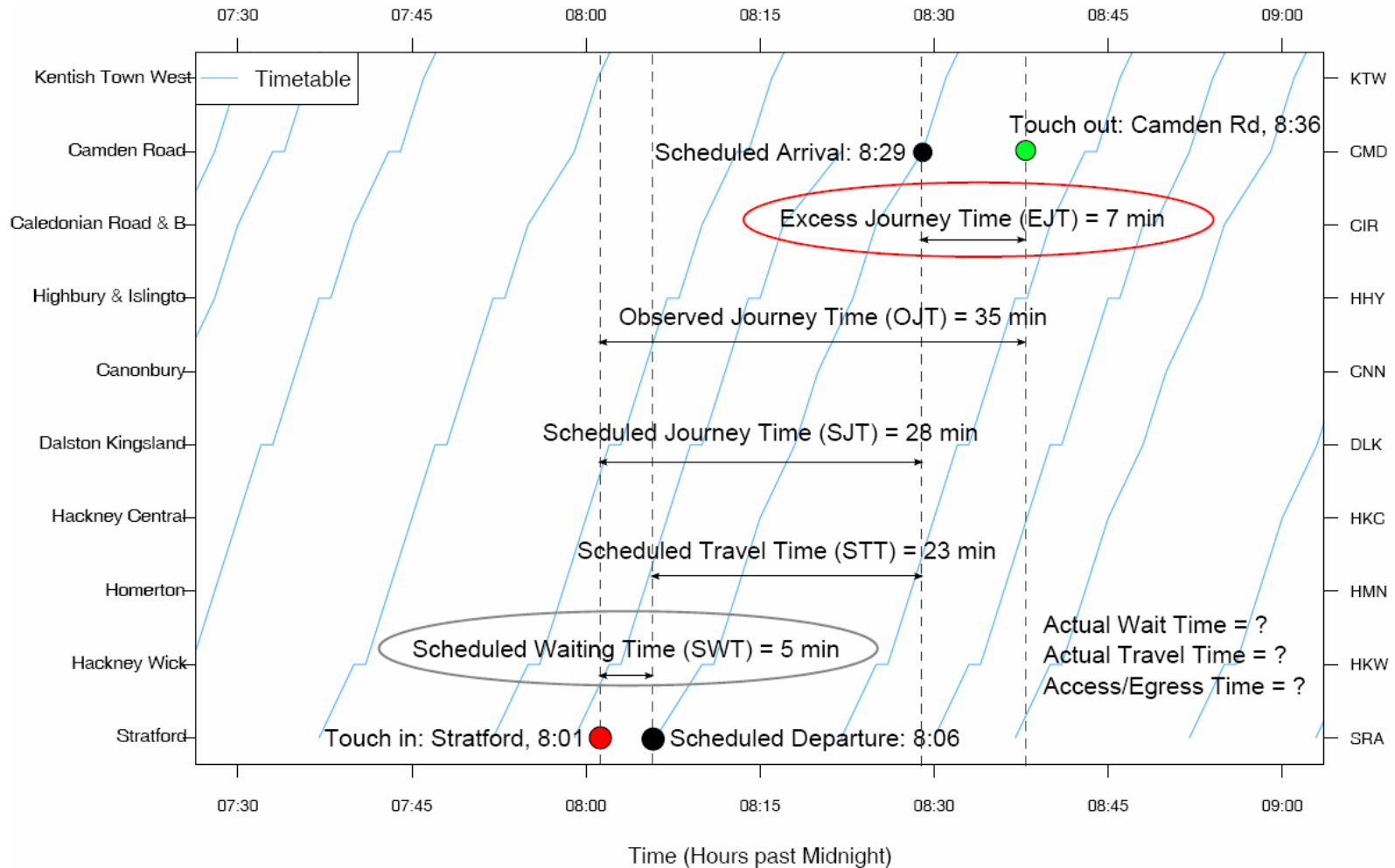
- Multiple rail and bus routes serving the Loop
- Stiff competition between express bus and rail service

Path Choice Analysis : Access Distance

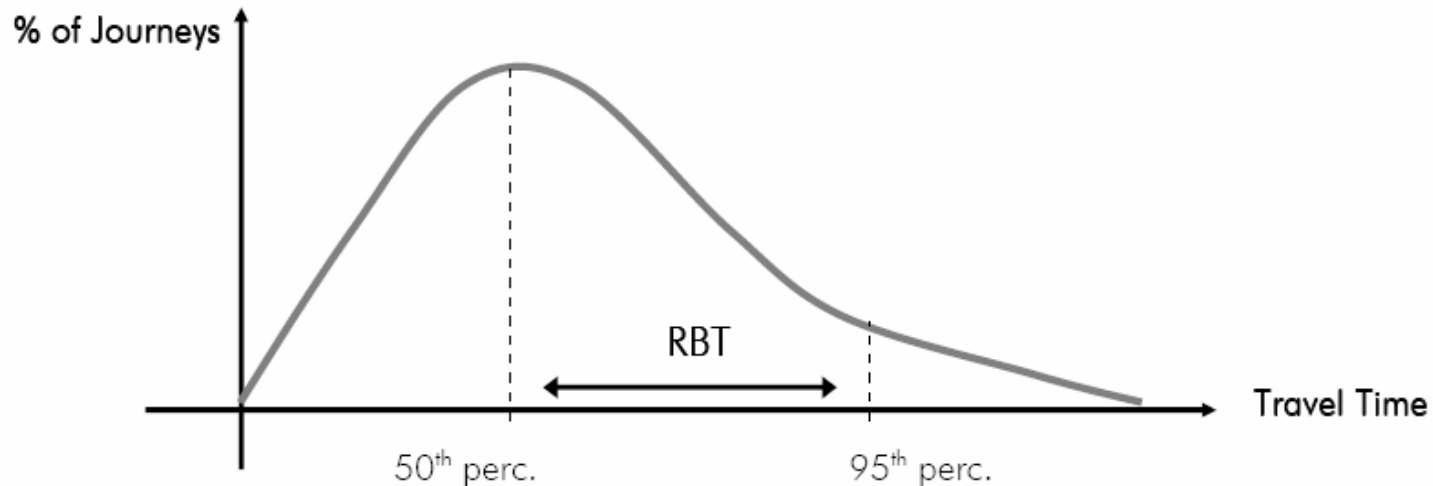


Intersection	Bus	Mixed	Rail	Total
Belmont Station	2	4	73	79
Belmont Orchard	20	9	83	112
Belmont Sheriden	170	10	21	201

Excess Journey Time (EJT)



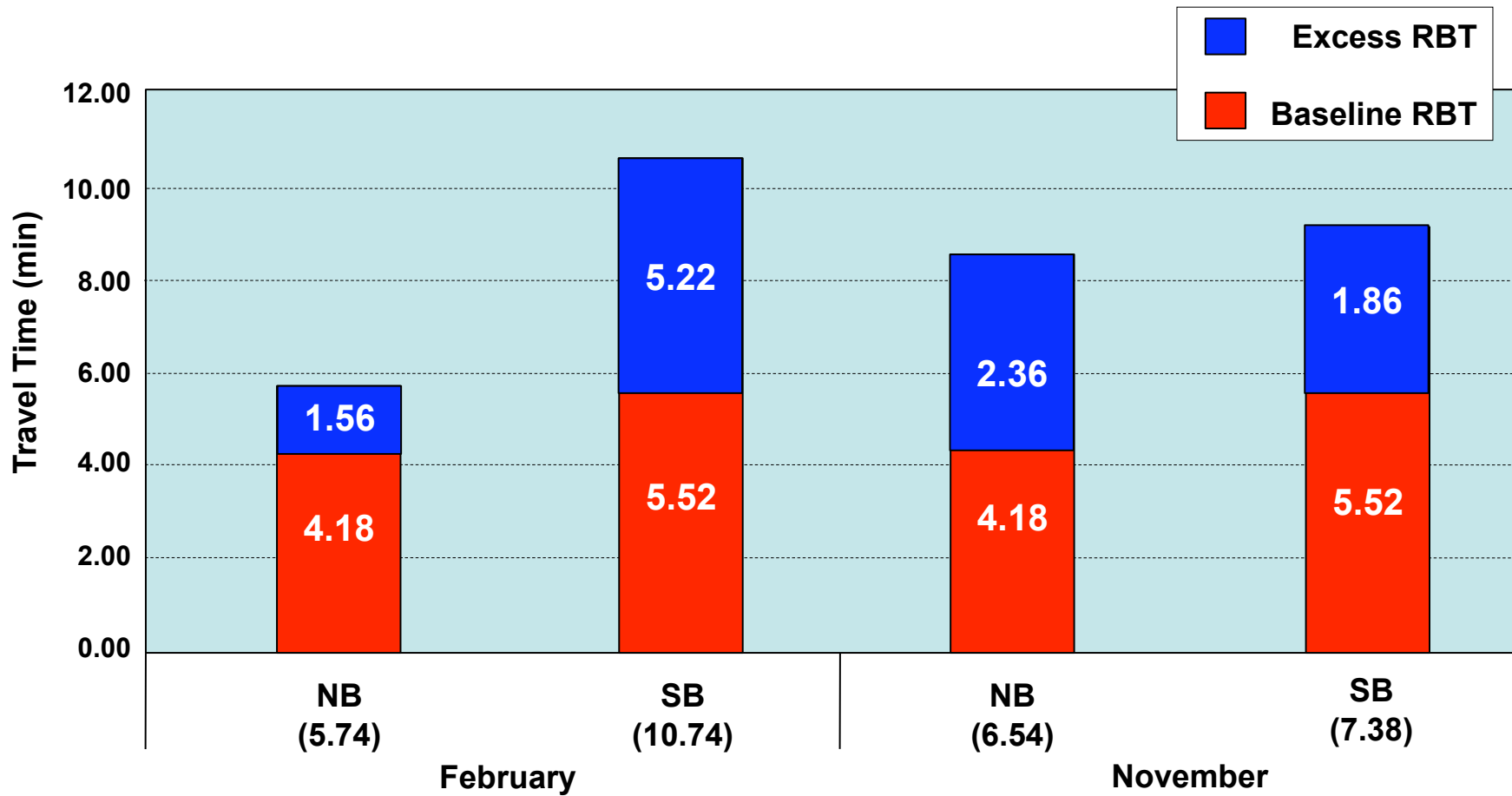
Reliability Buffer Time (RBT)



RBT = 95th percentile travel time – median travel time

**Additional time a passenger must budget
to arrive late no more than 5% of the time**

Line Level ERBT



Victoria Line, AM Peak, 2007

Emerging Possibilities

- **Better understanding of customer behavior through AFC data:**
 - response to service and fare changes at disaggregate level
 - modal preferences
 - access distances
 - path choice
- **More robust SOPs built on better demand-side understanding**
- **Better models and support for SOCM based on clearer understanding of objectives as well as demand**
- **Exception-based CI based on stated and revealed individual preferences, typical individual trip-making, and current AVL data**
- **Integration of AFC and CI functions through payment-capable cell phones**

Remaining Challenges

- **Viewing the SOP, SOCM, and CI functions more holistically, recognizing their interdependencies**
- **Making the SOP more dynamic and capable of reacting to unexpected events on the supply side and unanticipated changes in demand**
- **How can we attract more customers?**
- **How can we finance the system expansions needed to satisfy increased demand?**