PUSHING THE ENVELOPE:
MANAGING TRANSPORTATION SYSTEMS
UNDER COMPETING OBJECTIVES

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Introduction

Private car use continues to increase in most urban areas around the world...

**Problems:**
Traffic Congestion; Environmental Degradation; High Fuel Consumption; etc...
THE REALITY...

Existing Mass Transit in Large Cities: Crushing densities, Crawling speeds

PUSHING THE LIMIT?
THE PROMISE…
BUS RAPID TRANSIT (BRT)
Increasing role of containerization and container handling

Intermodal freight fastest growing form of rail traffic

Major revitalization of rail transport through intermodal
Intermodal freight transportation vulnerability

Transfer nodes: points of high vulnerability

Greater exposure through multiple transfers

Transfer nodes also “choke” points or bottlenecks in system: amplifies economic impact severity of additional delay

Rail mounted gantries for intermodal traffic
Multimodal, multi-jurisdictional perspective: bottlenecks and vulnerabilities at modal interfaces

Aggressive use of tools for economically efficient (but fair) allocation of resources: PRICING

Flexible operational strategies, dynamically adaptive (e.g. lane use, contraflow, transit preemption, fleet reassignment...)

Managing spatial and temporal pattern of demand along with the network’s operational features (supply-side) integral to managing network performance

City logistics (goods distribution) integral element of network management in areas with sensitive urban fabric

Integrating security considerations without impeding mobility

Strategic connection between transport infrastructure/services and land use development: strategic guided partnership vs. reactive lagged disequilibrium
Congestion Pricing as Demand Management Tool

1. Pricing increasingly viewed as one instrument along with *two* main other controls for integrated transportation system management:
   1. Traffic controls: ramp metering, signal coordination
   2. Information Supply: advanced traveler information systems, parking information systems, variable message signs (VMS)…

2. In real-time: with improved sensing and information technologies, can determine prices, traffic controls and information strategies adaptively, online, based on current and anticipated state of the system
Hot lanes typically considered with new facilities or addition of a lane to existing facilities. Conversion of general purpose lanes discouraged in US.

Single Occupant Vehicles allowed to use HOV lanes for a toll

Toll rates vary based on traffic conditions or time of day so as to maintain high level of service on managed lane

*Facilitated by AVI and automatic toll collection*
Value Pricing, Managed Lanes

- Value pricing
  - Let travelers choose between two adjacent roadways: priced but free-flowing vs. free but congested
- Applications
  - Predetermined toll values
    - SR-91 in Orange County, California
    - Harris County, Texas
  - Reactive
    - I-394 Minnesota
    - I-15 FasTrak in San Diego, California
CITY LOGISTICS

- “The process of totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, traffic congestion and energy consumption within the framework of a market economy”

  Taniguchi et al. (2001)
CITY LOGISTICS

KEY CHARACTERISTICS

TWO WAY INTERACTION

Impact on traffic congestion
Impact on urban fabric and environment

Urban Traffic Congestion and Environment

Impacted by traffic congestion and constraints of urban fabric and environment
CITY LOGISTICS

IMPLICATIONS

NEED TO INCLUDE EFFECT OF CITY LOGISTICS DELIVERIES AND COMMERCIAL ACTIVITIES IN SIMULATION MODELS OF URBAN TRAFFIC

MUST CONSIDER TIME-VARYING TRAFFIC CONGESTION AND OPERATIONAL CONSTRAINTS IN ROUTING AND LOGISTICS OPTIMIZATION MODELS
Objectives for Network Performance Optimization

Operational Efficiency (Capacity)
Maximize Total Throughput

Economic Efficiency
Allocation to Competing User Classes

Reliability
Consistency and Predictability of Service Levels

Resilience
Ability to withstand shocks and recover from extreme man-made and natural events

Sustainability
Energy and Environmental Quality
Reliability of Travel

Many sources of unreliability:

- Interactions over space and time; e.g. traffic flow regime change under congested conditions
- External perturbations (changes in demand and supply characteristics)
- Individual link and/or particle stochasticity

**Result:** Tripmakers traveling between an origin and destination in the same departure window experience different travel times; lack of travel time predictability affects ability to schedule business and personal activities; delay and loss of productivity.

**Critical Factor for Business and Services that Rely on Physical Mobility**
PARETO EFFICIENCY AND TRADE-OFFS

- cost
- INEFFICIENT REGION
- PARETO FRONTIER
- Ideal Point
- INFEASIBLE REGION
- time
PARETO EFFICIENCY AND TRADE-OFFS

Competing operational performance goals in large-scale transportation systems: Are we on the Pareto envelope?
How to Push the Envelope?

ROLE OF EMERGING TECHNOLOGIES AND ADVANCED OPERATIONAL CONCEPTS

![Graph showing cost over time with a downward trend]
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Sustainability
Energy and Environmental Quality
Throughput vs. Reliability

Breakdown

Graph showing throughput vs. reliability with a breakdown point indicated.
PUSHING THE ENVELOPE

More

Reliability

Higher

Throughput
THROUGH TECHNOLOGY INTELLIGENT MANAGEMENT SYSTEMS
Technological Drivers

4 DEVELOPMENT TRENDS
Development trend # 1: Handset Capabilities, Wireless Internet

Precise Location Enables Wide Variety of LBS Apps

**GAMING**
Interactive Gaming
GeoCaching
Location aware games for individuals/groups

**PERSONAL SECURITY**
Roadside Assistance
Weather Warning
Child Finders
GeoFencing

**ENTERPRISE**
Fleet Management
Asset Monitoring
Personnel
Productivity

**POINTS OF INTEREST**
City Guides
Mobile Yellow Pages
Navigation
Traffic reroute

**PEER-TO-PEER**
Buddy Groups
Dating
Geo-marked photo sharing
Mobile Blogging

**COMMERCE**
Mobile Coupons
Customer Service

**m-commerce**

**e-logistics**
**m-logistics**
Example: Sense Networks Inc.

Citysense

Tracking cell phone signals for social networking

→ travel pattern prediction
PROBE-BASED CONNECTED NAVIGATION SYSTEM: Third-Party Private Subscriber ITS Service

TruTraffic
The most accurate and current traffic data

Routing: Choice is good.

Most portable GPS devices today offer you only a single route choice to your destination. Dash goes the extra mile by presenting up to three different routes to a destination, and uses its traffic information to calculate your Estimated Time of Arrival (ETA) for each route. The traffic-based travel times you get from Dash are more accurate, helping you decide which route is best for you. Even after you’ve selected a route, Dash even automatically alerts you when traffic conditions change significantly.

Traffic snapshot
Dash can also give you a quick snapshot of traffic in your area. Our map views let you easily visualize current traffic conditions around your location on major and secondary roads. Additionally, traffic conditions on your route are easily identifiable by color. Dash uses accepted conventions to quickly convey traffic at a glance. Stop-and-go traffic is red, moderate congestion is yellow, relatively unobstructed is orange, and free-flowing roads are green. If the lines are solid, they represent live traffic derived from the Dash Driver Network—the most timely and accurate source available. If they are dashed, the traffic data is either 3rd party sensor or historical data. As the Dash Driver Network grows in your area you'll see more and more of the dashed lines become solid. You've never had this much traffic information on the road before. And knowledge is power.
Satellite-based mobile asset tracking and communication: Tool for truck fleet management and freight tracking
Deployment Key Technologies: Field Elements

AVI and E-Seal Readers (Overhead)

E-Seal

In-Truck AVI Transponder

Disposable Electronic Container Seal

Weigh-In-Motion (CVISN)
eSeal Readers at Border
Telemobility and Telelogistics

• Internet + mobility →

**TELEMOBILITY** and
**TELELOGISTICS**

May entail changes in:

- **Nature** of the activities themselves (doing what?)
- **Location/spatial** characteristics of the activities
- **Inter-person and inter-firm interaction** in activities
- **Process of activity generation and scheduling**: more dynamic (real-time) activity generation and scheduling;
Development trend # 2: Inexpensive wireless sensor networks

Coming to markets near you in next few months...

Relative low cost and high performance of such systems would enable deployment at larger scale than envisioned originally.

In the limit, nano-scale sensors with massively parallel deployment.
Mobile units + wireless internet:
Provides particle (user-centric) views of system

Inexpensive wireless sensors
Provides view from perspective of infrastructure or fixed assets

REAL-TIME INFORMATION
**Explosion of real-time information on system state**

- Calls for methods geared for shorter term engineering and business applications

- Calls for methodologies for real-time decision making under real-time information

  **REAL-TIME DECISION-MAKING METHODOLOGIES**, e.g. DYNASMART-X for traffic estimation and prediction.

- Calls for methods to extract knowledge from undifferentiated data

  **KNOWLEDGE EXTRACTION**, e.g. through data mining
Development trend # 3:
Network Simulation-Assignment Modeling for Advanced Traffic System Management

**REAL TIME DYNAMIC TRAFFIC ASSIGNMENT SYSTEM**

- Irvine network overview:
  - 326 nodes and 626 links.
  - 70 actuated-controlled urban intersections.
  - 61 traffic demand zones

- Morning peak period (4:00 AM – 10:00 AM)
- 30-second observation intervals on 19 freeway links
- 5-minute observation interval on 28 arterial links
Link Density Estimation and Prediction

Subject to considerable academic development in the area of algorithm development and testing

Rapidly coming to market, in conjunction with asset tracking and management technologies

Prospect for tie-ins with predictive traffic management tools, e.g. DYNASMART-X
Example of Collaborative Logistics:
Vendor-management Inventories (VMI)
Online Inventory Routing Problem (OIRP)
Results Summary (for scenarios studied)

- Giesen, Mahmassani and Jaillet (2006) developed dynamic routing methods for collaborative Vendor-Managed Inventory logistics systems

- On-Line Inventory Routing Strategies:
  - **Decrease** average total cost by 21% vs. off-line static methods
  - **Decrease Variability** in average cost
    - Benefits tend to be higher when clusters of customers are close to each other and/or near to the depot (case 3)

- Benefits of dynamic strategies tend to increase:
  - with higher inventory costs
  - with greater demand variability
Anticipatory Pricing Strategy for Managed Lane Operation
Effective **flow and lane management** calls for **dynamic (state-dependent) pricing**
Anticipatory Pricing Strategy for Managed Lane Operation

- What differentiates anticipatory from reactive pricing?
  - Network state prediction
  - Use predicted traffic conditions
  - Calculate link toll within the prediction horizon and implement it in real time

![Diagram of Link Toll Generator, Toll values, Traffic Prediction, Real World Traffic connections]
Reactive Pricing Strategy

• How does reactive pricing work?
  – obtain the prevailing traffic measures/conditions
  – adjust current link tolls accordingly
  – communicate to drivers via local VMS at the entry point
  – could also disseminate via radio, in-vehicle equipment, mobile, internet etc.
Anticipatory Pricing

INTRODUCE PREDICTION IN THE CONTROL LOOP

- Link Toll Generator
- Toll values
- Real World Traffic
- Traffic Prediction
- Predicted data
- Traffic data
The Test Bed Network: CHART

- I-95 corridor between Washington, DC and Baltimore, MD, US
- 2 toll lanes
- 2241 nodes
- 3459 links
- 111 TAZ zones
- 2 hours morning peak demand
Pricing Strategies Compared

- No pricing (base case)
- Static pricing
  - Predetermine the time-varying link tolls based on the historical information
- Reactive pricing
  - Set time-varying link tolls based on prevailing traffic conditions
- Anticipatory pricing
  - Set time-dependent link tolls based on predicted traffic conditions

OBJECTIVE: AVOID BREAKDOWN—optimize throughput, reliability, under economically efficient allocation
Illustrative Results – Travel Time

- Warm-up period: increase in travel time at the beginning
- With the anticipatory pricing strategy, the travel times become steady after 1 hour (free flow condition)
- Static pricing strategy provides free flow condition on the toll lanes, but reduces the LOS on the alternative freeway lanes
Illustrative Results – Traffic Measures

- Concentrations averaged over links along the congested portion of toll road, weighted by the link length
- Throughputs measured at downstream of where traffic breaks down in base case (no pricing)
- Anticipatory pricing strategy can provide higher throughput while maintaining lower concentration (steady traffic flow)
Illustrative Results – Toll Variation
CRITICAL ROLE OF PREDICTION IN REAL-TIME INTELLIGENT TRANSPORTATION SYSTEM MANAGEMENT

Information Provision Pricing
Traffic Control Container Handling
Collaborative Fleet Management
Integrated Corridor Management (ICM) refers to the

- **Coordination** of individual network operations between adjacent facilities to create an **interconnected system** capable of **cross-network travel management**, along major corridors in metropolitan areas.

- Aggressive and targeted application of intelligent transport system (ITS) technologies to influence not only
  - operational performance of highway facilities, but also
  - the demand for travel in the corridor.

- Combined application of judiciously matched operational strategies (supply-side) with travel demand management (TDM) approaches to bring about improvement in travel time, delay, fuel consumption and emissions, and **increase the reliability and predictability of travel.**
A VARIETY OF TRANSIT-ORIENTED AND INTERMODAL OPERATIONAL CONCEPTS

Contraflow lanes

Multiple access modes

Bus Priority at Signals
Network Simulation-Assignment Modeling for Advanced Traffic System Management
RECENT GENERALIZATION: DYNASMART-ICM

Modeling Intermodal Choice and Departure Time Dynamics in Simulation-based DTA Framework

Considers Congestion Pricing, Travel Time Reliability, in addition to Transit Operational Strategies and Traveler Information, with Heterogeneous Users

Example of integrating demand and supply in a micro-assignment simulation-based platform
Potential Benefits of ICM

- Corridor-wide Information (Passive Diversion/Roadway Only)
- Proactive Diversion (Multi-Modal where applicable) + operational strategies
- Demand Management/Increased Corridor Capacity

Potential Range of Benefits

- Congested Small Corridor - Non-recurrent
- Congested Small Corridor - Recurrent
- Less-congested Large Corridor - Non-recurrent
- Less-congested Large Corridor - Recurrent
EIGHT BIG THEMES FOR RESEARCH

- EXPLOSION OF REAL-TIME INFORMATION and REAL-TIME DECISION METHODOLOGIES for OPERATIONS: DYNAMIC NETWORK MANAGEMENT (incl. PRICING), INTERMODAL SYSTEMS, COLLABORATIVE LOGISTICS

- WIRELESS INTERNET, PERSONAL MOBILE DEVICES, RF TAGS, E_SEALS:
  - TELEMOBILITY and TELELOGISTICS (CHANGES IN DEMAND), AND
  - PEOPLE/VEHICLES/SHIPMENTS AS PROBES (SOURCE OF REAL-TIME DATA FOR OPERATION, SURVEY DATA FOR PLANNING)
    - From a REAL-TIME ECONOMY to the REAL-TIME SOCIETY

- AUCTIONS and REAL-TIME INTERACTIVE MARKET-BASED MECHANISMS (INCL. PRICING) FOR PROCUREMENT AND CAPACITY ALLOCATION

- PEER-TO-PEER, AD-HOC NETWORKING AS SYSTEM MANAGEMENT APPROACHES: IMPLICATIONS FOR SYSTEM RESILIENCY
EIGHT BIG THEMES FOR RESEARCH (ctd.)

• UNDERSTANDING SYSTEM VULNERABILITY AND RESILIENCY; IMPLICATIONS OF OPERATIONAL CONSIDERATIONS FOR PLANNING AND DESIGN

• USER BEHAVIOR AND RESPONSE: KEY BUILDING BLOCK FOR USE OF INFORMATION AS TOOL FOR POLICY AND CONTROL; BEHAVIOR CHANGE TOWARDS SUSTAINABLE PATTERNS

• NEW BUSINESS MODELS FOR INFRASTRUCTURE DEVELOPMENT, OWNERSHIP AND OPERATION; FOR SYSTEM AND SERVICE DEVELOPMENT AND MANAGEMENT.

• STRATEGIC MOBILITY, ENERGY AND SUSTAINABILITY
Concluding Thoughts:

What Stands in the Way of Pushing the Envelope?
FUNDAMENTAL SOURCE OF DIFFICULTY:

HUMAN BEINGS

The Problem: Optimize dynamic stochastic systems in which people are essential elements.

Physics of the problem involve:

Complex interaction among humans/vehicles over time and space in physical environment (under real-time information).
(Some Vexing)
Characteristics of transportation systems

Cognitive and behavioral limitations of human drivers are at the root of system inefficiency.

Perception time lags, reaction times, and a natural tendency towards over-reaction under stressful situations or perceived risk result in volatility, congestion, instability, frustrating stop-and-go patterns, “phantom bottlenecks”, capacity loss, and other component- and system-level phenomena.

TO DO GOOD PHYSICS, YOU NEED GOOD OBSERVATION
Characteristics of transportation systems

- Behavioral considerations and attitudes of human drivers, households and logistics managers are at the root of fuel inefficient patterns

  ➢ Activity patterns and resource allocation decisions reflect individual preferences and lifestyles acquired in times where fuel supply concerns were minimal.

  ➢ Different time frames for interventions—different impacts from short to medium to long runs

  ➢ Small changes at the margin could have meaningful impact.
Characteristics of transportation systems

– Attitudes of bureaucracies, turf wars. Lack of coordination often hinder successful implementation of network management approaches

➢ Need to evolve institutional frameworks that can support and evolve the processes needed to sustain and improve the transportation system over the medium and long runs

➢ Technology alone will not push the envelope
The Human Factor

Technology alone will not push the envelope
LIGHT AT THE END OF THE TUNNEL?

Thank you

Q & A

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