Reinventing Urban Transportation and Mobility

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Ann Arbor, MI
Outline

- Motivation
- Technology enablers
- Some case studies
- The MIDAS Ritmo projet
- Conclusion
The First/Last Mile Problem
The First/Last Mile Problem
The Importance of Mobility

- Car ownership in the US
  - best predictor of upwards social mobility

  The relationship between transportation and social mobility is stronger than that between mobility and several other factors, like crime, elementary-school test scores or the percentage of two-parent families in a community

  Nathaniel Hendren, Harvard University

Congestion

- The cost of congestion
  - in 2013, 124 billions
  - predicted to be 184 billions in 2030
The Challenge

Can we transform mobility in a scalable way?
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Connectivity

© Qatar Mobility Innovations Center
Automated Vehicles
Progress in Analytics

Prescriptive Analytics
What should I do?

Diagnostic Analytics
Why did it happen?

Predictive Analytics
What will happen?

Descriptive Analytics
What has happened?

Analytics Focus
Past Present Future

Source: http://ibm.co/1gJyfl3
Progress in Optimization

“If you only knew optimization from 10 years ago, you probably don’t have the techniques needed to solve real-world sport scheduling problems”

– Mike Trick, Professor at CMU, 2008

“The following do make a big difference (and are much more recent ideas)”

– Complicated variables
– Large neighborhood search
– Constraint programming (ideally combined with integer programming).
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Canberra
Planned City

- Garden city
  - Walter Griffin

- Design principle
  - self-contained communities
  - greenbelt
  - “bush capital”

- Many towns
  - city centers
  - infrastructure

- Started in 1913
Urban Transportation

- The problem: off-peak bus service
  - long routes
  - 1-hour frequency
  - buses running almost empty
  - buses are expensive
Hub and Shuttle in Canberra
Urban Transportation
Public Transportation

- Descriptive Analytics
  - bus boarding and alighting
  - Discovering true O/D pairs from individual trips
- Predictive Analytics
  - Predictive models for travel demand
- Prescriptive Analytics
  - designing the network
    - Benders decomposition
  - online vehicle routing
    - under uncertainty
Hub and Shuttle Transportation

\[
\begin{align*}
\min & \quad \sum_{r \in T} \sum_{i,j \in N} c_{ij}x_{ij} + \sum_{r \in T} \sum_{h \in H} \sum_{l \in H} \gamma_{hl}y_{hl} + \sum_{h \in H} \sum_{l \in H} \beta_{hl}z_{hl} \\
\text{s.t.} & \quad \sum_{h \in H} z_{hl} = \sum_{l \in H} z_{lh} \quad \forall h \in H \\
& \quad y_{hl} \leq z_{hl} \quad \forall r \in T, \forall h, l \in H \\
& \quad \begin{cases} 
1 & \text{if } i = or(r) \\
0 & \text{otherwise} \\
-1 & \text{if } i = de(r) 
\end{cases} \quad \forall r \in T, \forall i \in N \\
\end{align*}
\]

Figure 2  The MIP Model for the BusPlus HSPTS.
Nature of the Trips

Figure 3  Possible Trip Patterns (Not Showing Direct Taxi Trips).

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>T-Filtered</th>
<th>$H_{10}$ Reduction (%)</th>
<th>T-Filtered</th>
<th>$H_{20}$ Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>21282</td>
<td>14324</td>
<td>32.69</td>
<td>17294</td>
<td>18.74</td>
</tr>
<tr>
<td>Tuesday</td>
<td>21029</td>
<td>14184</td>
<td>32.55</td>
<td>17084</td>
<td>18.76</td>
</tr>
<tr>
<td>Wednesday</td>
<td>21418</td>
<td>14451</td>
<td>32.53</td>
<td>17401</td>
<td>18.76</td>
</tr>
<tr>
<td>Thursday</td>
<td>21487</td>
<td>14486</td>
<td>32.58</td>
<td>17499</td>
<td>18.56</td>
</tr>
<tr>
<td>Friday</td>
<td>19809</td>
<td>13398</td>
<td>32.36</td>
<td>16013</td>
<td>19.16</td>
</tr>
</tbody>
</table>

Table 1  Effectiveness of Trip Filtering. Column Total gives the initial number of trips. Columns T-Filtered report the number of trips after trip filtering. Columns Reduction give the trip reduction in percentage.
## Case Study

<table>
<thead>
<tr>
<th>Day</th>
<th>BusPlus</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Buses ($)</td>
<td>Cost ($)</td>
</tr>
<tr>
<td>Monday</td>
<td>45728.57</td>
<td>369420.37</td>
</tr>
<tr>
<td>Tuesday</td>
<td>45728.57</td>
<td>362746.82</td>
</tr>
<tr>
<td>Wednesday</td>
<td>46436.58</td>
<td>372214.03</td>
</tr>
<tr>
<td>Thursday</td>
<td>45899.13</td>
<td>376147.06</td>
</tr>
<tr>
<td>Friday</td>
<td>43893.83</td>
<td>350709.85</td>
</tr>
</tbody>
</table>

*Table 5: Time and Cost Comparison Between BusPlus and Action.*
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Rush Hours
Saturday Afternoon in AA
Prescriptive Evacuations
Prescriptive Evacuations
Prescriptive Evacuations
Prescriptive Evacuations
Urgent flood prevention measures needed for Warragamba Dam

November 3, 2012
Tim Barlass

A one-in-1000 flood around the Hawkesbury Nepean, such as that in Queensland early last year, would cause up to $8 billion in total damages affecting 14,000 homes and requires urgent preventative measures, according to a group of 10 western Sydney councils.

A one in 1000 flood is one that has a 0.1 per cent chance of happening each year.

The Western Sydney Regional Organisation of Councils last night called on the state government urgently to address threats of potential floods around the Hawkesbury Nepean.

A repeat of the 1867 flood would cause up to $1.7 billion in direct damages and $3 billion in total damages, the group said.

"This would affect an estimated 7600 homes, with about 1200 of those destroyed," WSROC chairman Mark Greenhill said.\footnote{Source: The Sydney Morning Herald, November 3, 2012}
Scheduling Evacuations

Traffic crawls along Interstate 10 west of downtown Houston ahead of Hurricane Rita.
Disaster Management
The Inputs
### Scheduling Evacuations

#### Time-expanded evacuation graph

Going from 2 to B takes 1 hour
At most 10 vehicles per hour

Node 2 is flooded at 11:00

At most 10 vehicles per hour
Scheduling Evacuations

- Large-scale optimization model
  - that needs to be solved in real time

- 185 nodes
  - 458 edges

- 21212 nodes
  - 58290 edges

10h horizon
5min steps

Pascal Van Hentenryck 2016
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  - project vision
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Data Science at Michigan

MIDAS is the focal point for researchers across the University of Michigan engaged in data science.

FIRST ROUND OF CHALLENGE INITIATIVE AWARDS ANNOUNCED
Four projects, two each in transportation and learning analytics, were awarded $1.25 million in the first round of the MIDAS Challenge Initiative Awards. See the announcement for more information.
Project Vision

- On-Demand Multimodal Transportation System
  - multiple fleets of vehicles
    - buses, shuttles, cars, light-rail, bicycles, pedestrian
  - on-demand
    - address the first/last mile problem
  - human-centered mobility
    - one click to order and trip tracking
  - congestion management and quality of service
    - routing and dispatching
    - traffic lights and lane priorities
  - pricing
    - differentiated service
  - infrastructure optimization
    - road and bridge condition optimization
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UM Transit System

- Some figures
  - 50,000 commuting trips a day
  - 7.4 millions a year
  - 75% capacity utilization
  - increasing congestion issues
Bus Routes and Capacity

**Passengers Left at Bursley (Thurs., 2/5/15)**

- **Passengers Left at Stop**

**Passengers Left at Pierpont (Thurs., 1/29/15)**

- **Passengers Left at Stop**
The Research Team

- Ceren Budak, Assistant Professor, School of Information.
- Amy Cohn, Industrial and Operations Engineering.
- Rebecca Cunningham, M.D., Emergency Medicine,
- Tawanna Dillahunt, School of Information.
- Robert Hampshire, Transportation Research Institute.
- Jerome Lynch, Civil and Environmental Engineering
- Jim Sayer, Transportation Research Institute.
- Pascal Van Hentenryck, Industrial and Operations Engineering.
- Michael Wellman, Computer Science & Engineering.
University Of Michigan Parking & Transportation Services

The PTS Department provides parking and transportation services to employees, students, departments and visitors at the University of Michigan Ann Arbor campuses. We operate and maintain more than 27,000 parking spaces, provide campus bus service 360 days a year with roughly 60 buses serving 12 routes, maintain a fleet of approximately 1,000 vehicles of various types and uses, and offer vanpools and other alternative transportation options available to the campus community.

What's New

Free Bike Light Giveaway

Posted: 02/29/2016

To promote bike safety and support The Rival’s Challenge (physical activity competition) and Max Commuter,
A unique facility for testing connected and automated vehicles

Artist's conception of a simulated urban environment at U-M developed in conjunction with the Michigan Dept. of Transportation to evaluate new approaches to mobility before they are tested on actual roads.
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  - some early steps
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UM Mobility Data
UM Mobility Data

- Application for experiment
  - filed in eResearch

- Development in collaboration with
  - Information and Technology Services (ITS)
    - Bill Burns (Manager, Mobile/Portal/Web) and Jane Zhao
    - Tom Amerman (Director Application Development)
  - Advanced Research Computing
    - Brock Palen, Jeffrey Sica

- Location data
  - Real time
UM Buses (Commuter North)
UM Buses

[Map of UM Buses routes]

[Graph showing number of people boarded and number of buses running on route NW over 24 hours]
UM Buses (NE Shuttle)
Census Data
Michigan App
Stay connected to U-M with the official University of Michigan app. News, events, locations, class resources, and more are at your fingertips. Look up a person or bus route, find an available computer lab, and see what's on the menu at your favorite dining hall.

Download for iOS | Download for Android
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Conclusions

- **Living Mobility Lab**
  - unique experimental laboratory
    - 50,000 transit trips and >30,000 car trips a day
    - data-rich environment
    - freedom to experiment

- **Next generation urban transportation systems**
  - multimodal transportation system
    - on-demand service for first/last mile mobility
    - economy of scale and congestion management
    - pricing
    - optimization of the underlying optimization