Logistics of Constructing a Washington D.C.-Baltimore Rapid Transit Line

Washington Metropolitan Area Transit Authority
Maryland Transit Administration

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Table of Contents

Sponsors

Washington Metropolitan Area Transit Authority (WMATA):

1. transportation agency created by the Library of Congress
2. operates in the District of Columbia, Maryland, and the Commonwealth of Virginia
3. rapid transit service (Metrorail)
4. bus services (Metrobus)
5. paratransit (MetroAccess)
6. currently contructing new lines in Virginia (Silver Line) and in Maryland surburbs of D.C. (Purple Line)

Sponsors (cont.)

Maryland Transit System (MTA Maryland):

1. transportation agency operated by the state of Maryland
2. operates in the Baltimore-Washington Metropolitan area
3. numerous bus lines
4. Light Rail
5. Metro Subway
6. MARC train

D.C. Metro Map

WMATA existing lines and stations, June 2012

Relevance

Problem area:

- D.C. and Baltimore have similar worker populations

Table: Workers Who Use Public Transportation

City	# of workers	# of cars, trucks, or vans
Washington, D.C.	293,532	127,494
Baltimore	269,917	186,961

- 43% of D.C. workers commute in cars, trucks, or vans
- 69% of Baltimore workers commute in cars, trucks, or vans
- it is apparent that large populations of workers of both cities rely heavily on vehicles to commute
- a subway line between the two cities would greatly reduce traffic volume, jams, and accidents
- sponsors would find this model relevant

Problem Statement

- WMATA has no plans to expand the Metrorail system to the city and suburbs surrounding Baltimore
- MTA Maryland's Metro Subway system only operates within city limits
- residents of Greater Washington-Baltimore Metropolitan area have limited access to public transportation to travel between the two cities
- current public transportation methods:
  - AMTRAK fares too expensive for daily commute
  - MARC operates rush hours on weekdays
- both sponsors operate under two separate government agencies
- our task is to provide a model that can predict the operating capacity for a such a line based on published transportation statistics

Deliverables: From Sponsor to Team

1. most recent data and statistics from Maryland Department of Transportation by Oct 19, 2012
   - contingency plan: if data not received by the assigned time, we will obtain data published on the Department of Transportation website
2. computing resources
3. timely responses to inquiries
4. small expenses relevant to work

Deliverables: From Team to Sponsor

1. mathematical model of traffic flow at various hours of the day (morning, noon, evening)
2. traffic flow will model highways I-495 and I-95
3. analytical report on the results of traffic flow model to determine if a subway line is viable
4. time permitting, design of the subway line
5. R package with documentations and codes to reproduce test results
6. technical report and presentation summarizing the work done

Gathering the Data

1. contact statisticians through sponsors at Maryland Department of Transportation for the most recent data on highway mobility and traffic trends between D.C. and Baltimore
2. receive data through email (if electronic)
3. receive data through regular mail (if paper copies)
4. determine of data is relevant/useable to traffic model
5. contact statisticians in the event of needing additional data

Gathering the Data - Contingency Plan

In the event that we do not receive data from Maryland Department of Transportation by Oct 19, 2012:

1. visit the Maryland Department of Transportation website at `http://sha.md.gov/index.aspx?PageId=682`
2. download "2012 Maryland State Highway Mobility Report"
3. browse through "Traffic Trends" section
4. look for other relevant sources through Google, such as MARC and AMTRAK train statistics

M. Bando Model of Optimal Velocity

1. assumptions:
   - Newtonian law of acceleration
   - a car will drive at maximum speed with enough distance from the car in front
   - a car will maintain optimal velocity depending on distance from the car in front
2. governing equations:

$$\frac{dx_i}{dt} = v_i$$

$$\frac{dx_i}{dt} = a[V(x_{i+1} - x_i) - v_i]$$

$$V(b) = tanh(b-2) + tanh(2)$$

3. initially, cars are uniform; traffic jam occurs when the model becomes unstable

Payne-Whitham Model

1. assumptions
   - single lane, straight roads
   - drivers behave predictably and obey all traffic laws
2. governing system of equations:

$$\rho_t + (\rho * v_*(\rho))_x = 0$$

$$v_t + vv_x + \frac{{c_0}^2}{\rho}\rho_x = \frac{v_*(\rho) - v}{\tau}$$

3. at low traffic density, traffic flow is nice and uniform
4. at high traffic density, flow becomes unstable when perturbations grow; instabilities become traveling waves called jamitons

Implementation of Traffic Flow Models

1. both models of traffic flow will be simulated in MATLAB
2. models will incorporate parameters from transportation data and statistics, such as number of cars traveling at certain times of day, average speed of cars, etc
3. after simulating and comparing the two models, we will determine one model to realistically represent the highway traffic flow between D.C. and Baltimore
4. using the chosen traffic model, we will determine if a rapid transit line is viable

Report and Presentation

1. analytical report on the results of traffic flow model simulations, such as accuracy of the model, the effect of changing model parameters on the model, etc
2. determine viability of building a rapid transit line
3. compose an R package with documentation and codes to reproduce results
4. prepare a final report (paper and beamer presentation)

Design of Subway Line (Time Permitting)

1. based on results from traffic flow simulation, decide if a rapid transit line is viable based on parameters such as number of commuters, reduction in frequency of traffic jams and accidents, and financial feasibility
2. research the cost and logistics of building a line
3. set fare prices for all stops (include a flat price)
4. determine the locations of subway stops (places of highest traffic volume)
5. number of subway stops will depend on optimal distances between stops
6. predict the operating capacity of the subway transit line between D.C. and Baltimore

Deliverables: From Sponsor to Team

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Remaining Work

Since work has not begun on the project, we will need to initialize the project as soon as sponsors can provide the deliverables, or activate the contingency plan if they cannot.

- wait for sponsors to send us data by Oct 19; if deadline not met, activate contingency plan
- determine which traffic flow model to use
- write MATLAB code of chosen traffic flow model, implement appropriate initial conditions from transportation data, and plot relevant graphs
- compose analytical report on results of traffic flow model and R package
- time permitting, design a subway line based on model
- presentation of completed work

Future Research

- look into other traffic flow models
- implement more factors other than highway mobility for a more realistic model
- look into MARC and AMTRAK statistics for a different model, since we did not account for the D.C.-Baltimore commuters who take these trains
- if subway design not completed due to limited time, design the line based on all models considered above

References I


US Census.
Baltimore, Maryland Transpotation Statistics.
http://transportation-modes-city.findthedata.org/l/976/Baltimore-Maryland.
Accessed: 10/16/2012.


Christopher T. Field.
A Comparison of the Numbers of Travelers Ricing MARC and Driving I-95 and MD-295.
http://www.getontrac.org/Reports/MARC_Highway_Study_Short.pdf.

Accessed: 10/16/2012.

References II

Morris R. Flynn, Aslan R. Kasimov, Jean-Christophe Nave, Rodolfo Ruben Rsales, and Benjamin Seibold.
Traffic Modeling - Phantom Traffic Jams and Traveling Jamitons.
http://math.mit.edu/projects/traffic/.
Accessed: 10/16/2012.

MTA Maryland.
About the MTA — Maryland Transit Administration.
http://mta.maryland.gov/about-mta.
Accessed: 10/16/2012.

Maryland Department of Transportation.
Maryl and State Highway Mobility Report.
http://sha.md.gov/OOTS/2012_Maryland_State_HIghway_Mobility_Report.pdf.
Accessed: 10/16/2012.

References III

Maryland Department of Transportation.
Maryl and State Traffic Trends Introduction.
http://sha.md.gov/Index.aspx?PageId=253.
Accessed: 10/16/2012.

Yuki Sugiyama.
Oprimal Velocity Model.
http:
//traffic.phys.cs.is.nagoya-u.ac.jp/~mstf/sample/ov_e.html.
Accessed: 10/16/2012.

WMATA.
Metro - About Metro.
http://www.wmata.com/about_metro/.
Accessed: 10/16/2012.