Use of Mesoscopic Simulation for Hurricane and Other Emergency Evacuation Planning with CUBE AVENUE

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Transportation modeling tools

- Macroscopic Modeling
- Mesoscopic Modeling
- Microscopic Modeling

Introduction to Mesoscopic Modeling

Transportation demand modeling is mostly done on a strategic 'MACROSCOPIC' level

- Can cover a very large area, but...
- ...some "inability" to model the required level of detail in congested areas.

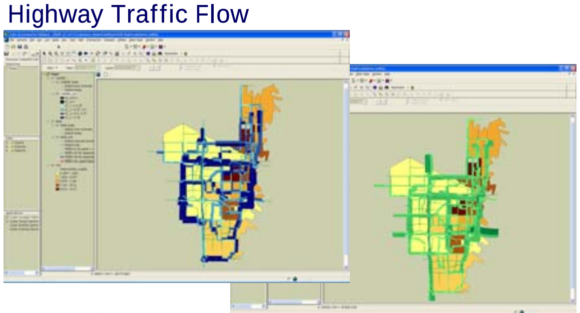
For traffic engineering / traffic control / intelligent traffic management 'MICROSCOPIC' models have become very popular and useful

- Capture perfectly extreme level of details, but...
- ...require extensive data and can hardly be applied at a regional scale

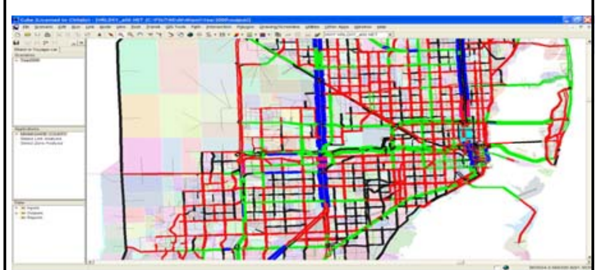
Macroscopic Modeling

- Macroscopic Models generally consider the entire system and estimate routing and flows through a network for a time period.
- Currently used for almost all strategic (long-range) planning
- Very fast analysis of very large areas.
- Models the behavior of people taking into account:
  - Why people are making trips
  - Why they select a particular mode
  - Why they select a particular route

Highway Traffic Flow



Highway Traffic Flow



Microscopic Modeling

- Applications:
  - Infrastructure geometry design
  - Traffic operations
  - Multi-modal transportation planning (pedestrians, bikes, buses, auto and other modes)
  - Transit planing (BRT, Bus Only Lane, Light Rail)

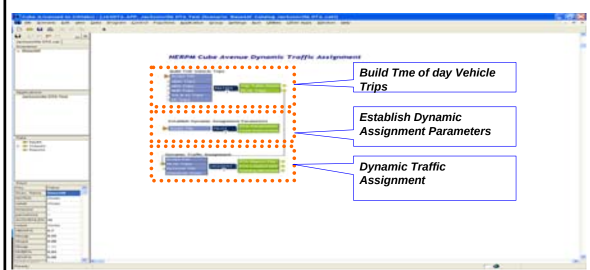
Mesoscopic Models

- With mesoscopic models, it is still possible to quickly analyze larger areas with a more detailed model which overcomes the pitfalls of the macroscopic travel demand models.
  - Takes into account intersection configurations and controls
  - More detailed estimates of delay, travel time, and capacities
  - Enforces capacity limitations and the effects of queues 'blocking back'
  - Models flow curves and changing demand throughout an analysis period
  - Allows vehicles to respond to traffic conditions and change their route

Dynamic Traffic Assignment (DTA)

- Method of system-level (regional) assignment analysis which seeks to track the progress of a trip through the regional network over time
- Accounts for buildup of queues due to congestion and/or incidents
- A bridge between traditional region-level static assignment and corridor-level micro-simulation

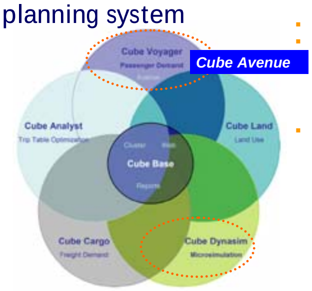
Dynamic Traffic Assignment



Why use DTA?

- Why NOT use traditional (Static) assignment?
  - No impact of queues
  - No ability to deal with upstream impacts
  - Links do not directly affect each other
  - Not conducive to time-series analysis
- Why NOT use traffic micro-simulation?
  - Study area of interest too large and complex
  - Too much data and memory required
  - Too many uncertainties to model accurately

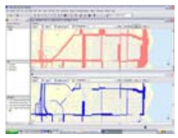
A comprehensive transportation planning system



- Cube has two parts:
- Cube Base: the user interface comprised of 3 sections:
  - Application Manager : flow-chart style tool for building model systems
  - Scenario Manager: tool for applying the model to multiple scenarios
  - Graphics: editing of all data in text, tabular and graphical form
- 'Functional Libraries:
  - VOYAGER
  - TP+
  - TRANPLAN
  - TRIPS
  - CARGO
  - AVENUE
  - DYNASIM
  - Analyst
  - LAND (in development)
  - LOGIT (in development)

Cube Avenue

- representing vehicles as discrete packets or individual vehicles
- assigning a specific time of departure from the origin point in the network to each packet or vehicle
- routing the vehicles along multiple paths in response to dynamic traffic conditions
- representing queues and bottlenecks including 'blocking back' or the formation of queues on a roadway segment or at an intersection which spill back up-stream to block roadway segments which feed into the roadway segments
- Evacuation modeling, greater analysis of geometrics, traffic control and ITS strategies
- Quantify impacts of upstream traffic congestion



Mesoscopic Models' Applications

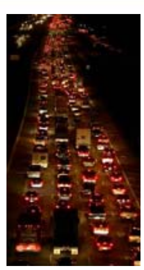
- A mesoscopic model allows to complete new types of analyses:
  - Quantify impacts of upstream traffic congestion
  - Measure queuing at intersections and merge points in a network
  - Isolate secondary impacts from one intersection through another
  - Evaluate the benefits of ITS (intelligent transportation system) projects
  - Simulate alternative infrastructure, operational, and policy changes to optimize
  - Emergency evacuation plans and strategies
  - Test strategies to improve arrival and departure from stadiums and other special event facilities
  - Congestion pricing concept; HOT (High Occupancy Toll) Lanes, Roadway tolling

Study Motivation

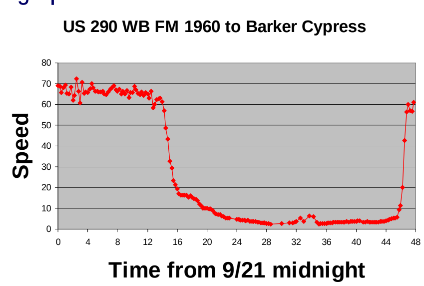
- In September 2005, Hurricane Rita landed east of Houston
- Well over 1 million people attempted to evacuate from the eight county region
- Severe congestion as a result

Retreat!

- Evacuation routes became "parking lots".
- Some people spent more than 18 hours on the evacuation routes
- Fatal accidents, abandoned cars, and other safety issues



Crawling Speed



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In response…

- H-GAC coordinated with various governmental agencies to develop a hurricane evacuation plan.
- H-GAC was asked to develop a tool for evacuation planning.

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Goal of this model

- Re-generate the Rita evacuations
- Provide evacuation demands
- Estimate traffic volumes and delays
- Sensitive to various scenarios and plans
- Apply to non-evacuation planning (corridor, sub-area, ITS, etc)

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Challenge - Model Size

- 8-county region with 4.7 million population in 2000 and is expected to grow to over 7.7 million by 2035.
- 3000 zones and 43,000 links
- 7,700 Square miles from CBD to rural area
- Around 14,000,000 daily trips modeled
- Long trip: average work trip length over 20 minutes, with almost 10% over 40 minutes

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Challenge - Demands

- Little Survey data for Rita event
- Future evacuation demands could be varied in
  - Time period
  - Response rate and number of trips
  - Origin and Destination
- Interaction between evacuation, normal daily, and non-evacuation traffic

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Challenge - Network

- Network change during evacuation
- Sensitive to Policy Factors
  - Contra-flow lane
  - Shoulder lane use
  - HOV lane opens to public
  - Ramp closure
  - Signal timing
- Facilities become unavailable due to flooding, high wind, or other disasters

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H-GAC Expectation

- Validation
  - Normal Day Traffic
  - Rita
  - Year 2010 Scenario
- Able to adjust evacuation trip tables for different situations
- Sensitive to policy factors
- Allow road changes within evacuation

H-GAC Study Area

Houston TranStar Rita Evacuation Survey

- Solicited participation on website
- Participants responded to questions online
- 6,570 respondents
- 6,286 usable household responses
- 3,886 households evacuated by car or truck

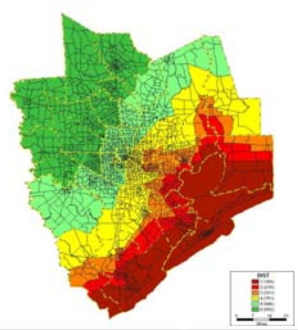
Evacuation Generation Models

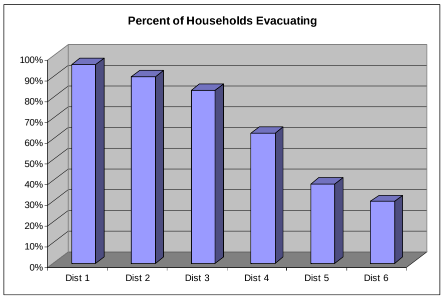
- Models developed for Rita event
- Structured to facilitate exploring different evacuation scenarios

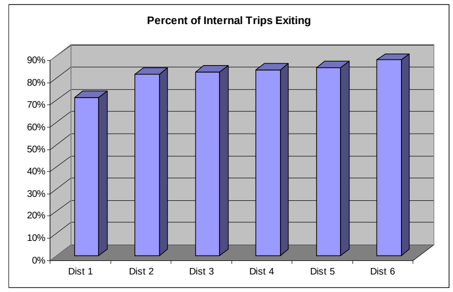
Event Demand Simulation Approach

- Six-day event modeled
- Cross-classification variables:
  - 6 geographical districts
  - 5 household size groups
- Production models:
  - Probability of evacuating
  - Vehicle trips/evacuation household
  - Trip purpose split
- Simple attraction models
- Non-resident trip models

Six Districts







Internal Evacuation Attractions

Households	83.3%
Hotels & Motels	8.4%
Public Shelter	2.0%
Other	6.3%

Rita Evacuation Generation Results

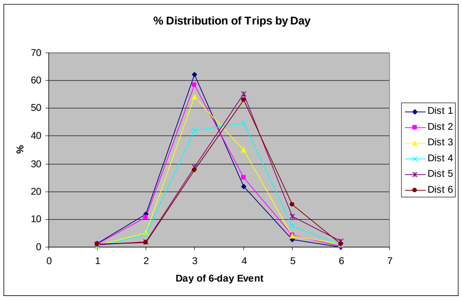
Internal-Internal	218,785
Internal-External	1,040,936
External-Internal (non-residents)	5,406
External-External (non-residents)	21,617

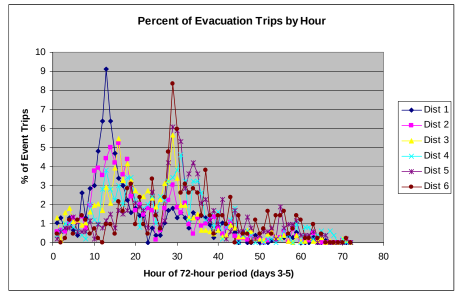
TRIP DISTRIBUTION RESULTS
(normal off-peak speed travel time minutes)

Trip Purpose	Trips	Average Trip Length	90th %-tile Trip Length	Max Trip Length
Trips to Internal Zones	224,189	47	78	156
Trips to External Stations	1,062,757	72	104	176
All Evacuation Trips	1,286,946	68		176

Time-of-day Factors

- Estimated from survey data
- Developed for each of the six districts
- Hourly Distribution for 6-day Event





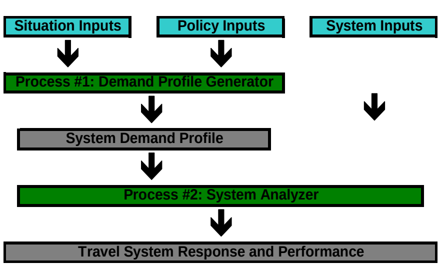
Developing Alternative Scenarios

- Consider adjustments to % households evacuating by district
- Consider adjusting hourly distributions by district
- Consider adjusting vehicle trip rates to reflect taking fewer vehicles by district

Assignment Input Parameter Types

- Needs to be sensitive to variations in THREE distinct types of inputs:
  - Situational (Event-Specific) parameters
  - Policy Change Inputs
  - System and Background Inputs

Two Stages of The Evacuation Model Tool



System Demand Profile

- Background Demand
  - Everyday, regular "average weekday" trips
  - Stratified by hour for a 24-hour period
  - 3 successive weekday periods to comprise 72-hours prior to storm landfall
  - Progressively attenuated because regular trips are not taken once people evacuate
- Evacuation Demand
  - The primary trip out of the storm's path
  - Stratified by hour for 72 hours prior to landfall

Cube Avenue (DTA Module)

- Add-on module to provide DTA capability for the Cube/ Cube Voyager model environment
- Cube User Interface
- Works with regional network in Cube Voyager
- Common scripting language and data requirements
- First full release of Cube Avenue works with latest version of Cube Voyager (4.X)

Cube Avenue Technical Facts

- Unit of travel is the "packet"
  - Represents some number of vehicles traveling from same Origin to same Destination
- Link travel time/speed is a function of
  - Link capacity
  - Queue storage capacity
  - Whether downstream links "block back" their queues
- Link volumes are counted in the time period when a packet leaves the link

Houston Evacuation DTA Existing models and Data

- Tool is an add-on to existing H-GAC travel demand model in Cube
  - Basic highway networks from regional model
  - Adjustments to network based on event parameters
  - Network modifications may vary across time horizon of event
    - Flooding of low-lying links
    - Failure/closure of facilities
    - Reversal of freeway lanes

Houston Evacuation DTA Networks

- Network from regional model
- Coding adjustments
  - Centroid adjustment in downtown
  - Capacity and Storage Adjustment
  - Network Simplification
    - Link Reduction
    - Centroid Connectors
  - Turning Movements/Prohibitions
  - Intersection definition

72 hour Assignment

- Entire 3-day storm approach window
- Individual 1-hour slices allows network changes
- What do we mean by 1-hour slice?
  - 1-hour period of "analysis" from which results are reported
  - Simulation Performed in Continuous Time
  - Departure Time within the Hour is Quasi-Random

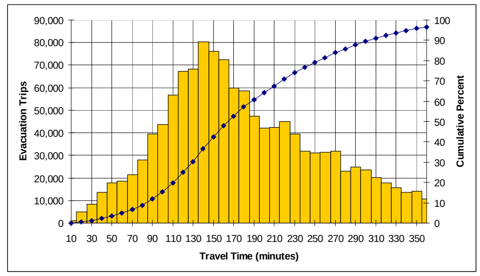
Houston Evacuation DTA Challenges

- Long trip lengths
- Memory Limitation
- Ramp and freeway coding
- Long Running Time

Challenges: Long Trip Lengths

- Houston is a huge region
- Background trips >1 hour not uncommon
- In evacuation conditions,
  - ~95% of trips are longer than 1 hour
  - ~45% of trips are longer than 3 hours

Long Evacuation Trip Lengths



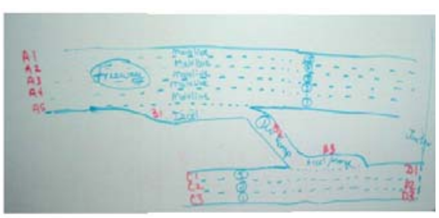
Challenges: Memory Limitations

- Large dimensions of problem size
- Windows XP maximum memory for a single process is 2GB
- Historically has Limited the number of hours or iterations possible

Challenges: Ramp and Freeway Coding

- Texas style slip-ramps
- Networks are coded with Freeways and Frontage roads separated
- Link coding codes through lanes but not accel/decel lanes
- Storage capacity not accurately reflected by default coding

Ramp and Freeway Coding



Challenges: Ramp and Freeway Coding

- Ramp storage capacity as-coded was minimal
- Queues from downstream intersections
- Queues block back onto mainline freeway lanes too frequently due to network simplification

Current Progress

- Developed hourly trip tables for normal daily traffic
- Developed Rita evacuation demand trip table for entire 72-hours
- Calibrate Behavioral Responses to Congestion
- Concurrently Validating “Normal Daily” and “Event” Scenarios
  - Show directional speed difference in peak period
  - VMT and speeds
  - Duration of Congestion
  - Hot Spot Analysis

Future Steps

- Coding traffic signals and other traffic control devices
- Randomly Generate Accidents
- Finalize Distributed Processing
- Finalize Calibration and Documentation

Summary

- Mesoscopic Simulation Offers Both Different Demands and Rewards than Either Macro or Micro Simulations
- A Detailed Understanding of the Demand as Well as the Network are Critical to Reproducing Observed Behavior as well as Likely Responses to Policies
- It is Possible to Add the Dimension of Time to a Regional Model without Large Staff Hour or Consultant Resources
- Results get Better with Better Data (uh duh!)

Cube Voyager for regional planning - traffic flows

Cube Avenue (DTA) for region-wide simulation - queues/ delays

Cube Dynasim for corridor simulation = animations