R for Travel Demand Modelers: Experience at the Oregon DOT

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Overview

- Background
- History of the use of R at the Oregon DOT
  - Examples
  - Lessons learned
- Wrap up
  - Overall lessons learned
  - Ideas for future

Background

My Background

- Worked for ODOT for 26+ years
- Worked as a transportation analyst and modeler for 14+ years
- Prior to travel modeling, worked on transportation planning, land use planning, and transportation/land use policy development
- No formal training in computer programming (although I do read about programming and computer languages on the side)

Travel Modeling at ODOT

- Transportation Planning Analysis Unit (17 persons)
  - Modeling
  - Facility Analysis and Simulation
  - Systems Analysis
- Travel modeling for 3 small MPOs and over a dozen smaller urban areas
- Statewide modeling
  - Integrated statewide modeling
  - Transportation sector greenhouse gas modeling

5

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Transportation Planning and Modeling in Oregon

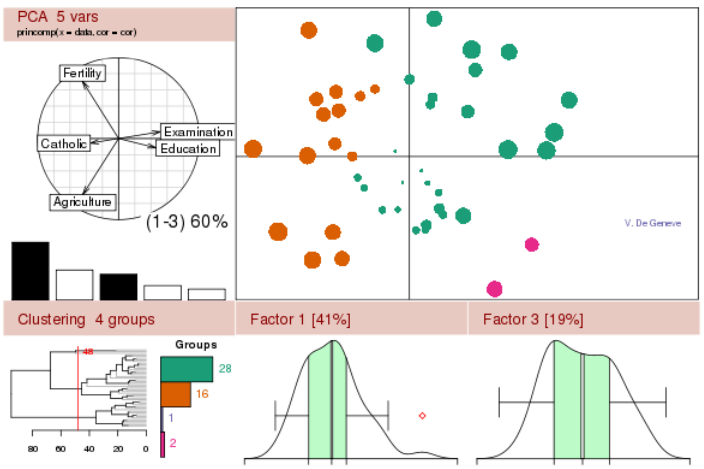
- Strong state planning requirements
  - Land use
  - Transportation and land use coordination
  - Rules and legal challenges
- High expectations for modeling
  - Public and decision makers expect models to be used to inform policy
  - Support for advancing model development
- Good coordination between state and regional agencies

6

Discovering R

- Dissatisfaction with toolset being used to build and implement models
- Interested in more modern numerical computing environment (e.g. MATLAB)
- Interest in data visualization
- Interest in open source software
- Came across R in an article about geostatistical analysis using GRASS and R

The R Project for Statistical Computing

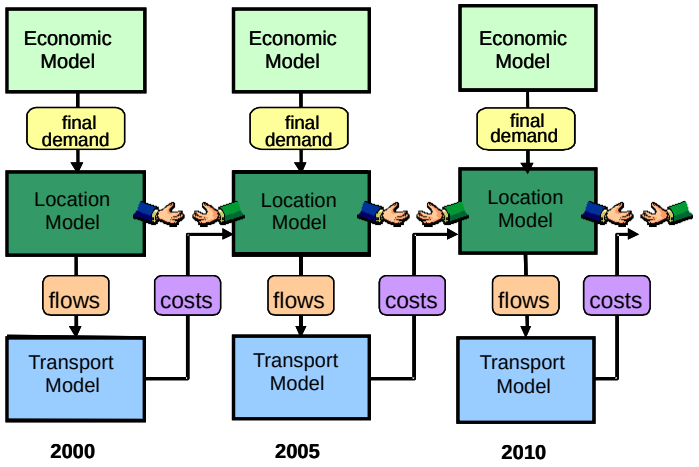


History and Examples of Use

Beginnings

- Started using in 2001
- Learned the basics by using it to analyze survey data
- First big win was using R to automate running our 1st generation statewide model

Automating the 1st Generation Statewide Model



11

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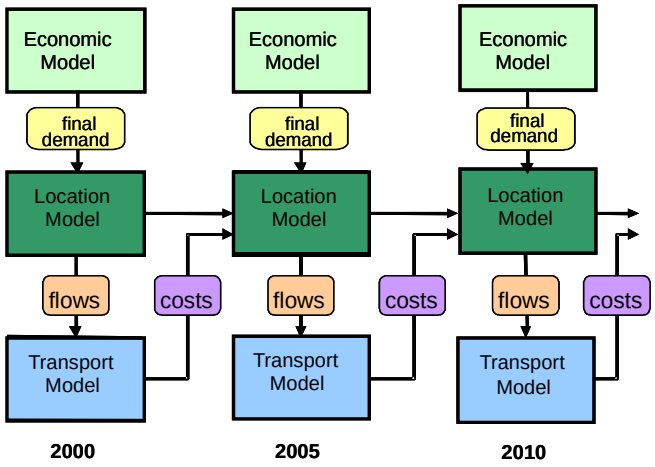
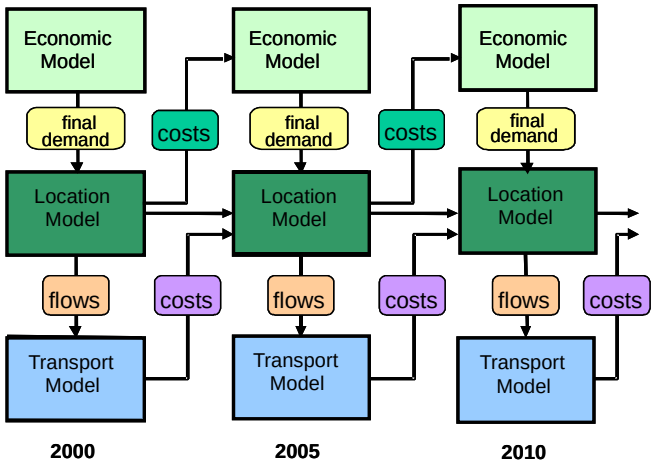
Automating the 1st Generation Statewide Model



12

Extending the 1st Generation Statewide Model



13

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Beginning Lessons

- R is a full featured programming language
  - Can be used to control other programs
  - Can parse and manipulate text files
- A modest programming effort can yield big productivity gains
- R can be used to graft extensions onto models written in other platforms

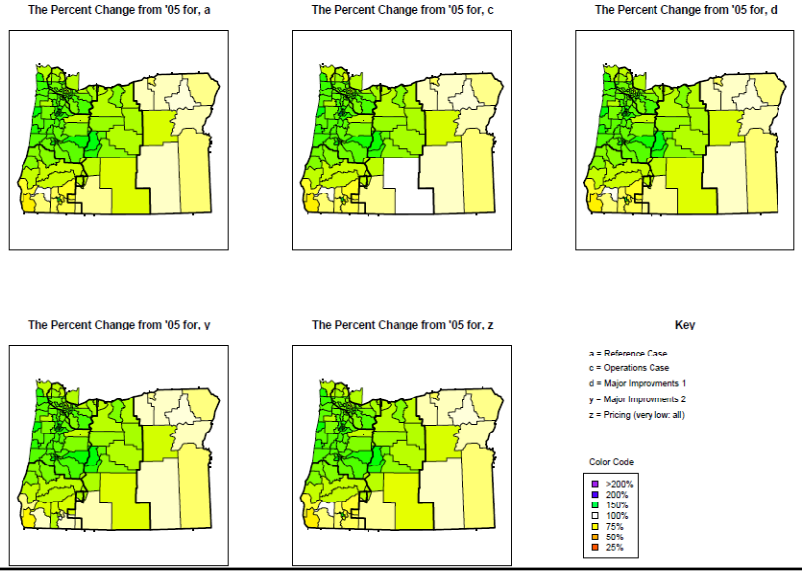
14

Managing Inputs and Outputs

- Since R could produce well formatted text files, we could use it to automate the input file production
  - Bridge study – identifying possible weight restricted links
- Using the excellent graphical capabilities of R, we produced a large number of graphical outputs
  - Done automatically after each model run
  - Developed new ideas and extended ideas over time

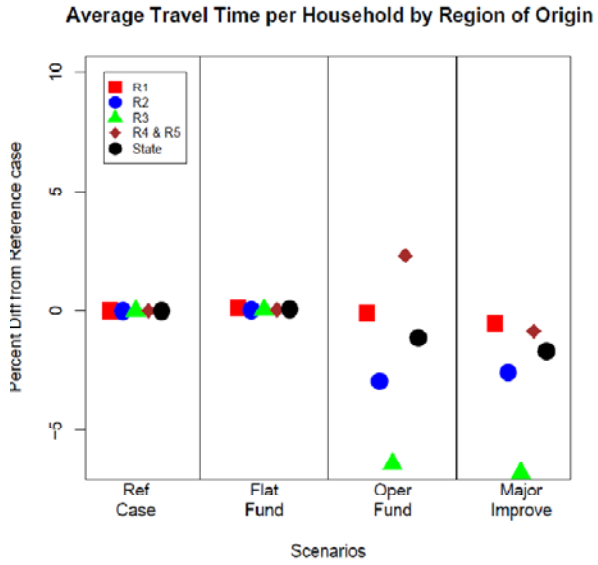
15

Mapping Output Example



16

Custom Chart Example



17

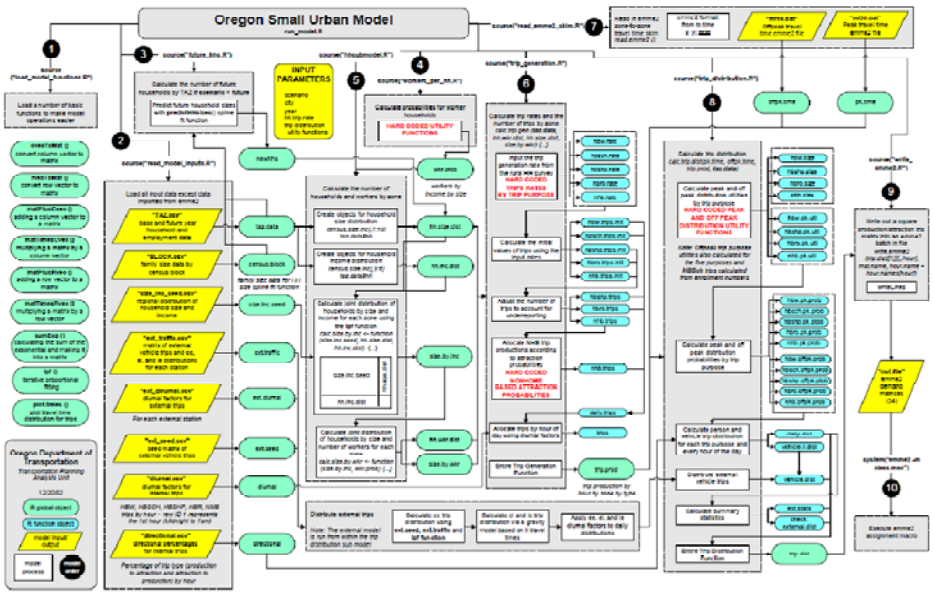
Lessons: Managing Inputs and Outputs

- Using R to generate input files:
  - Reduces tedium for data entry
  - Improves capabilities and reduces error
  - Can improve documentation and reproducibility
- Using R for visualizing outputs:
  - Can generate standard graphics automatically
  - Can visualize whatever you can imagine
- Collaboration and using a common object naming approach

18

Implementing a New Travel Demand Model

- Oregon Small Urban Model
  - New model, based on recent household survey
  - 3-step, destination choice
- Use R's built in matrix capabilities to do all of the model computations (except for traffic assignment)
- Use R to control the process, including calling the traffic assignment software



Lessons: Implementing a New TDM

- R can be used to develop relatively large model applications
- The combination of specifying a common small urban area model structure and implementing it in R:
  - Increased the speed at which we could develop and deploy small urban models
  - Simplified model applications
  - Increased our productivity

21

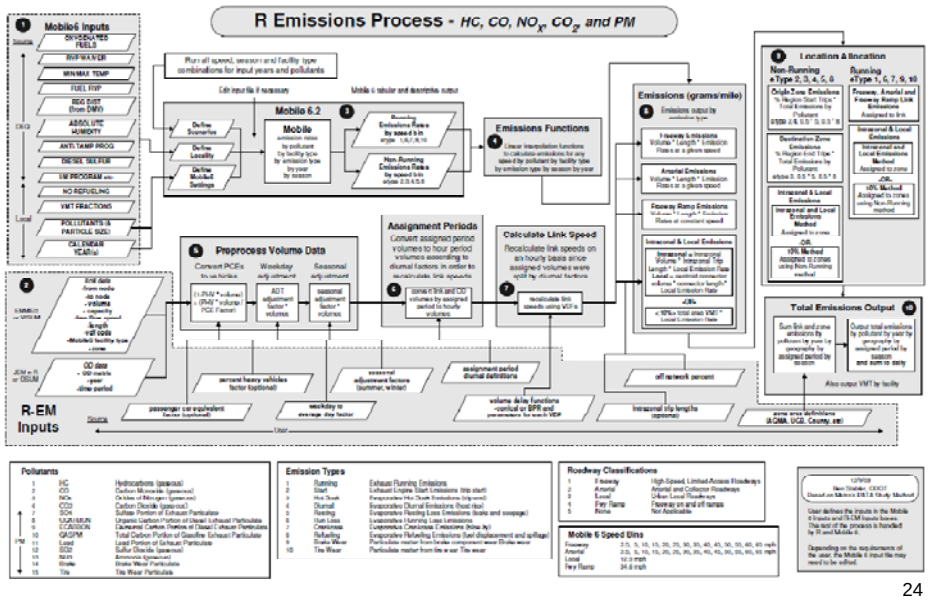
Lessons: Implementing a New TDM

- Features of the language simplify programming and reduce need to program loops
  - Built in vectorization of the language
  - Variety of data types and corresponding iterators
- Data structures are important to the language
  - The choice of data structure can simplify understanding and programming
  - Important to communicate the data structure in the program code

22

Automating Post-Processing for Air Quality Analysis

- OSUM interested MPO modelers in the potential of R for travel modeling
- MPOs were interested in having the air quality analysis process automated
- Requires managing data from multiple sources and running multiple applications
- Uses R to control the process



Lessons: Air Quality Modeling

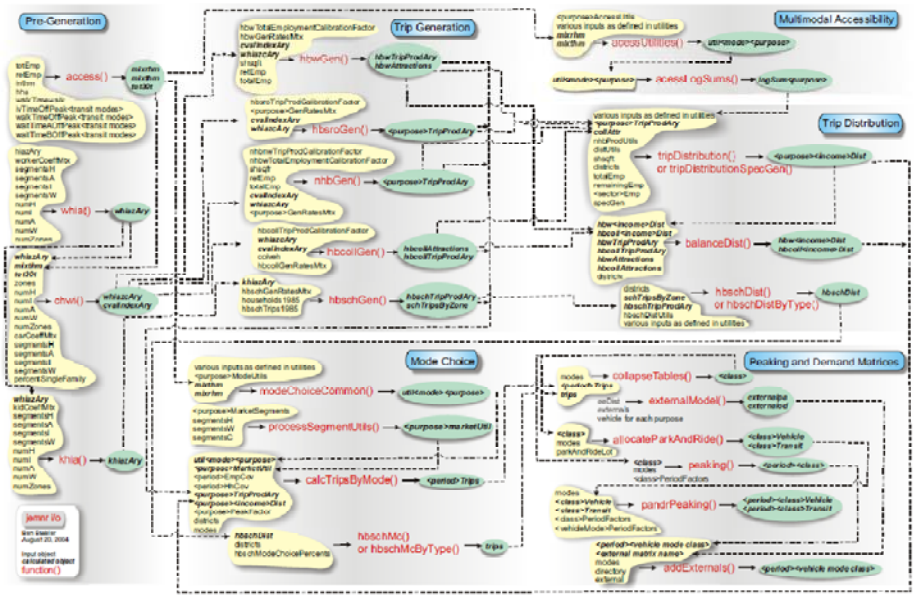
- R very capable for tying together multiple data sources and model software and managing the process
- R facilitated rapid development
- Reduced the amount of time required for air quality analysis
- The flexible structure of lists makes it easy to tie together related data that is represented in several different forms
  - Caution: don't make lists too complicated or it can be difficult for others to understand the code

25

Implementing a Metropolitan 4-step Model

- Next big project was to implement a metropolitan model in R
  - Joint Estimated Model in R (JEMnR)
- Planned for it to be a joint development effort
- Mode choice increased the complexity substantially

26



27

Lessons: JEMnR

- A structured approach is very important for developing model code that is efficient and maintainable: data, functions, modules
- Make model code a calculation engine. Changeable parts of the model should be input data.
  - Example: All utilities in JEMnR are input data. Utilities can be changed without making any code changes
- JEMnR enabled TPAU staff to handle the workload of developing 3 new MPO models
- R does have a learning curve

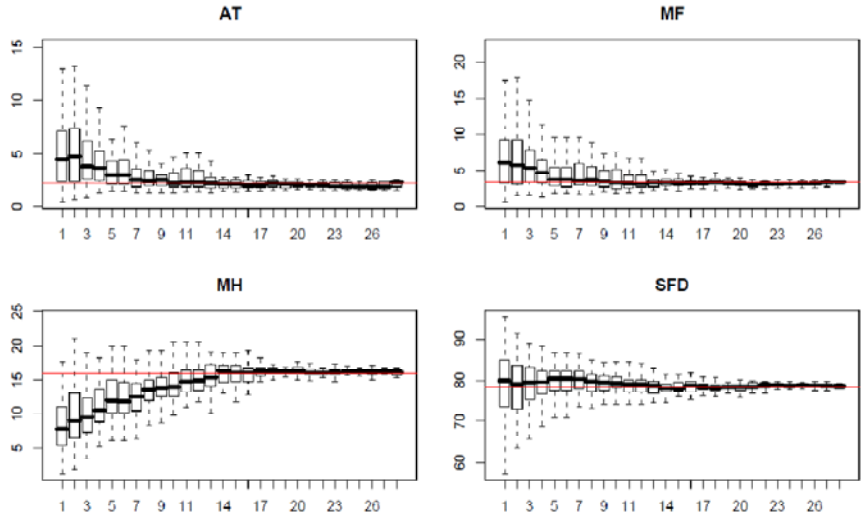
28

Aggregate Land Development Model (ALD)

- ALD is a module in our 2nd generation StateWide Integrated Model (SWIM2)
- Due to the complexity of SWIM2, it was decided to simplify the land development component, using the SWIM1 approach (implemented in R)
- R was used to estimate the parameters of the model as well as implement the model

29

Using Evolutionary Algorithms to Estimate Model Parameters



30

Lessons: ALD

- R facilitated tying the development of the model implementation code and model estimation processes together and enabled more advanced estimation procedures to be used
- R is a good platform for learning about, experimenting with, and implementing new methods
- An R-based model can be managed as a component of a model that is based in another computer language

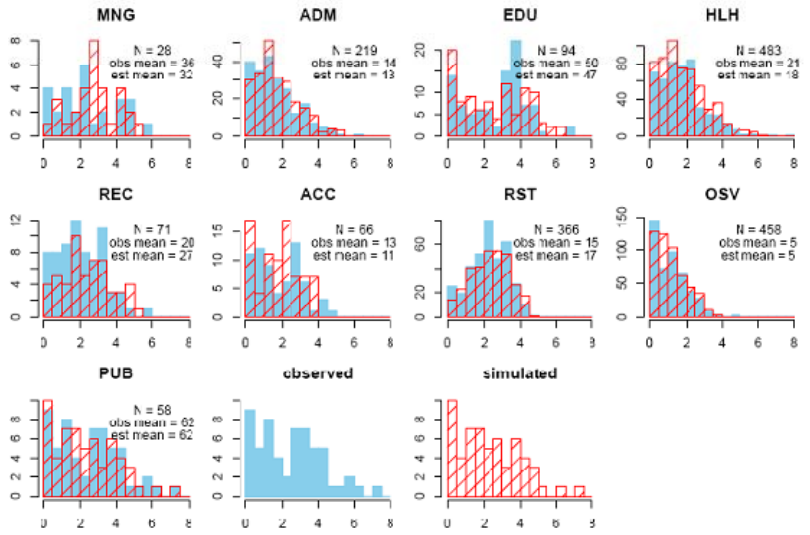
31

Land Use Scenario DevelopeR (LUSDR)

- LUSDR was developed to support a regional planning process to designate urban reserves
- LUSDR uses a different approach to land use modeling
  - Develops many scenarios to assess risks
- R was used for entire process, from data development to implementation
- R used exclusively for data visualization

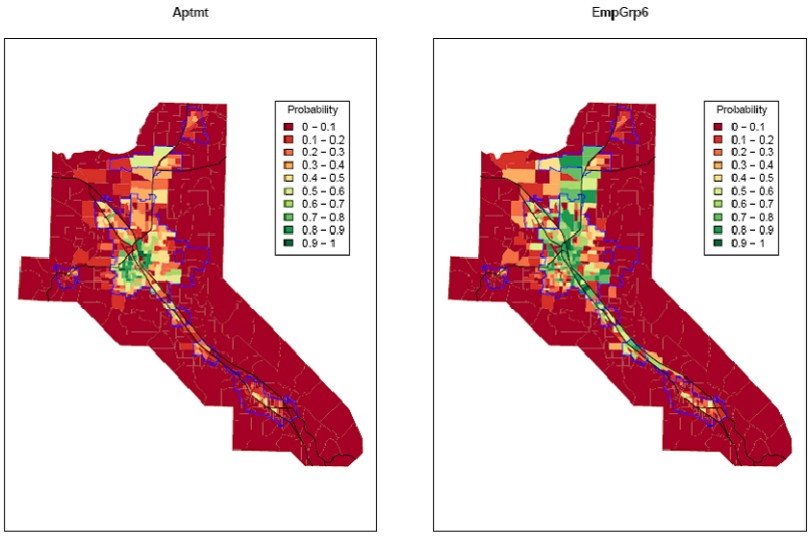
32

Using Graphics in Model Development



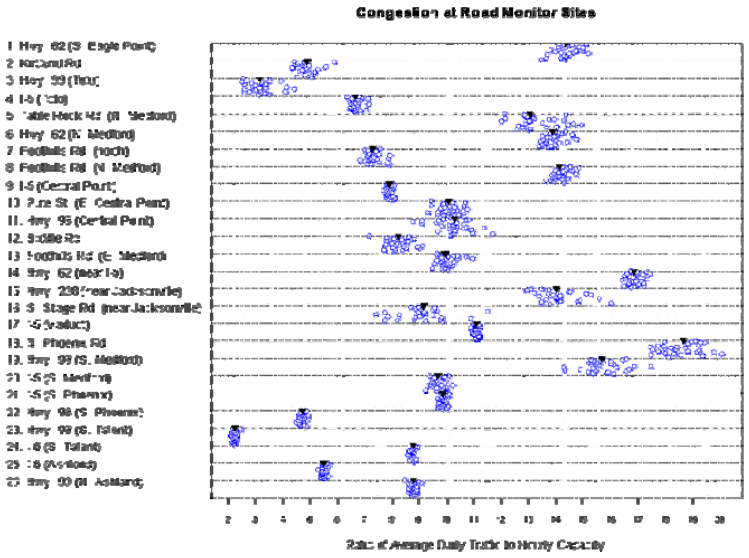
33

Using Graphics in Model Development

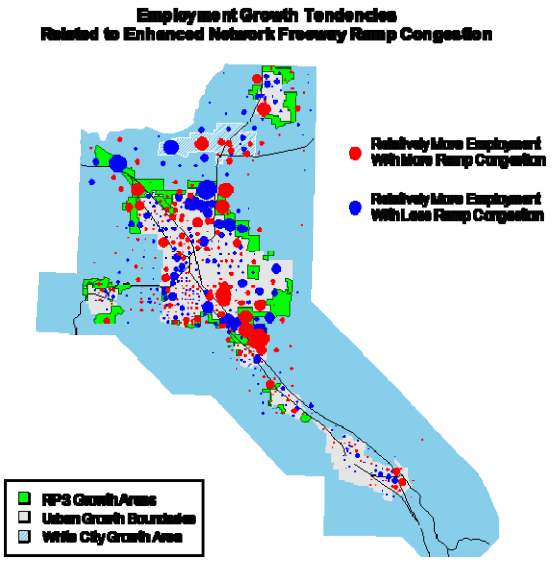


34

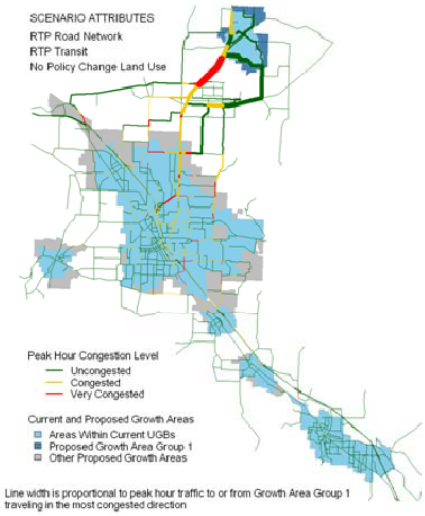
Showing Results of Multiple Scenarios

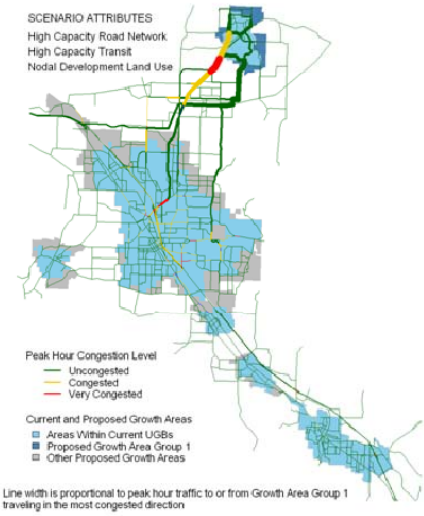


Analyzing Results Graphically



Comparing Scenarios





37

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Lessons: LUSDR

- R facilitated development of a new model quickly
- Wealth of packages enables testing and deployment of different methods
- Agile development process using R enabling successive refinement
- Vectorization helpful for list-based processes as well matrix-based processes

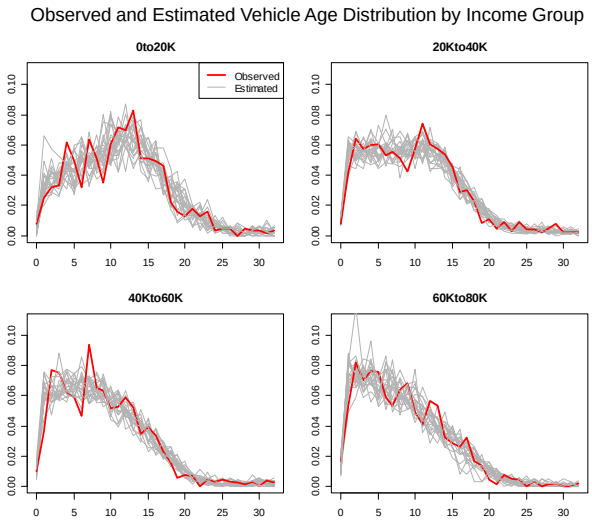
38

GreenSTEP

- A model for calculating greenhouse gas emissions from the transportation sector considering land use, transportation, pricing, vehicles, fuels
- Entire development chain in R: data prep, estimation, implementation, calibration & validation, outputs
- Because model estimation with R scripts, it is all replicable and easily modified
- Build script to assemble model from components

39

Comparing Observed and Estimated Values Considering Stochastic Effects



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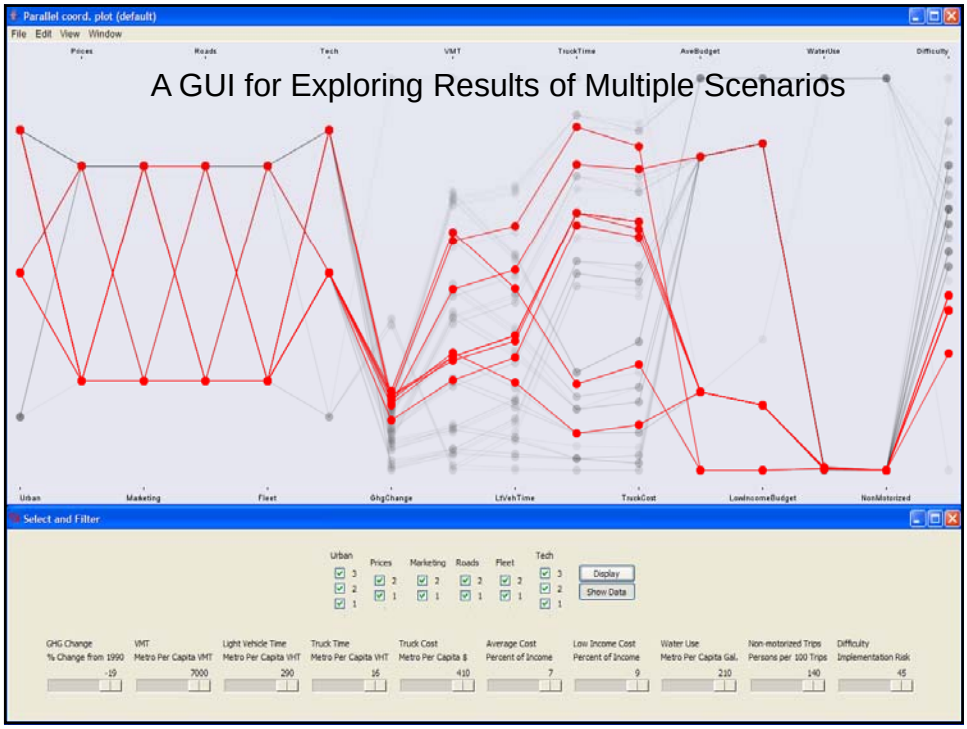

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Lessons: GreenSTEP

- Development in R enabled development of a new model quickly
- Development in an integrated way across all steps enable rapid reestimation and revision
- Agile development process using R enabling successive refinement
- Reproducibility

42

Overall Lessons Learned and Ideas for Future

Lessons Learned

While R is not the best language for systems programming, it has other advantages that outweigh limitations

- Good interpreted programming environment facilitates rapid learning and development
- Built for data analysis. Easy to do things that should be easy to do.
- It can be used every day for routine data tasks so it is easy to stay current
- Very large number of add on packages
- Open source

Lessons Learned

- R is easier to learn to the point of being productive than other programming languages, but it is a programming language nevertheless
  - Can be challenging to get people out of Excel and into R
  - Requires time to learn and experiment
  - Need to build capabilities over time
- Even so, all of our major projects paid off in time savings and improved capabilities in a short amount of time

45

Lessons Learned

- R is a very useful tool to help modelers at state DOTs, MPOs, etc. to develop advanced models without being advanced computer programmers
- The environment facilitates learning and testing of modeling concepts and bringing those concepts into models
- Models developed in this way are not black boxes to the modelers and can more readily maintained and extended by the modelers

46

Ideas for the Future

- Develop a community of transportation modelers using R
  - Website to share ideas and R scripts
  - Collaboration on projects
- Develop a structure supported by packages of functions to facilitate the development of transportation models in R

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