TRB Webinar:

Applying Scenario Methods to Transportation Planning and Policy

October 23, 2014
2:00 PM – 3:30 PM ET

Texas A&M Transportation Institute

RAND CORPORATION

RSG the science of insight

TRB

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

Today's Panelists and Moderator

- **Nidhi Kalra**, *RAND Corporation*
  nkalra@rand.org

- **Mark Bradley**, *Resource Systems Group, Inc.*
  mark_bradley@cox.net

- **Johanna Zmud**, *Texas A&M Transportation Institute*
  j-zmud@tti.tamu.edu

Scenarios for Transportation Policy and Planning

TRB Webinar: October 23, 2014

Johanna Zmud, Texas A&M Transportation Institute
Nidhi Kalra, RAND Corporation
Mark Bradley, Resource Systems Group

Webinar Outline

- Introduction to scenarios
- Expert elicitation approach
- Robust decision making approach
- System dynamics models approach
- Question and answer session

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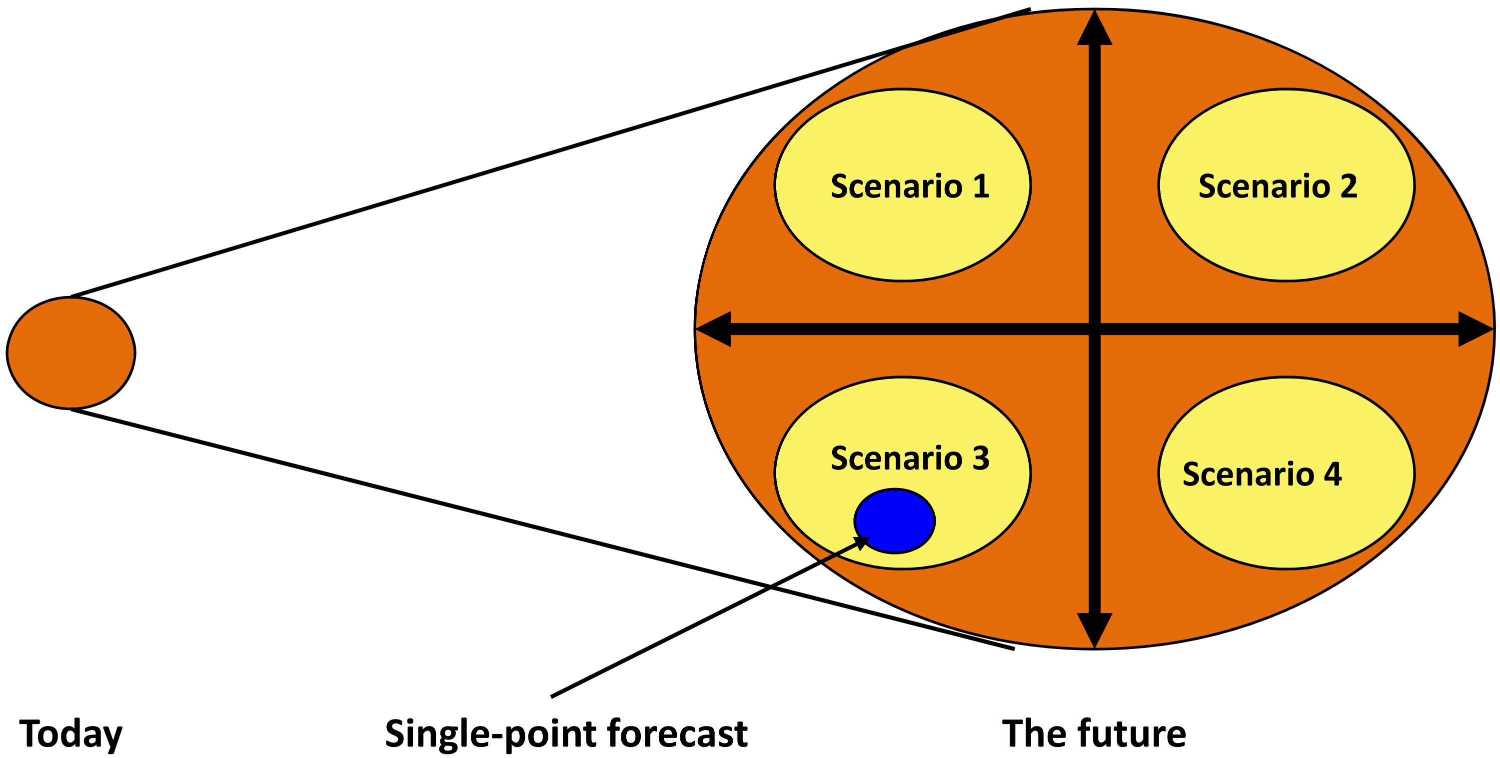
Scenarios: Structurally different stories about how the future might develop



Scenario Planning Process

- Surfacing set of plausible alternative futures
- Determining range of possible consequences
- Identify strategies or policy options that are robust across the set of futures

No single "correct" method

Different contexts require different methods

Why apply scenario planning?

- Increase the chance of making better decisions
  - Support long-range plan development
  - Supplement the capabilities of existing planning models
  - Formalize the consideration of uncertainty in the planning process
  - Facilitate participation in the planning and decision-making processes

Caveats to applying scenario planning

- Misconceptions about what it is and how used
- Too often deteriorate into conventional forecasting
- Devolve to loosely grounded futurist musing

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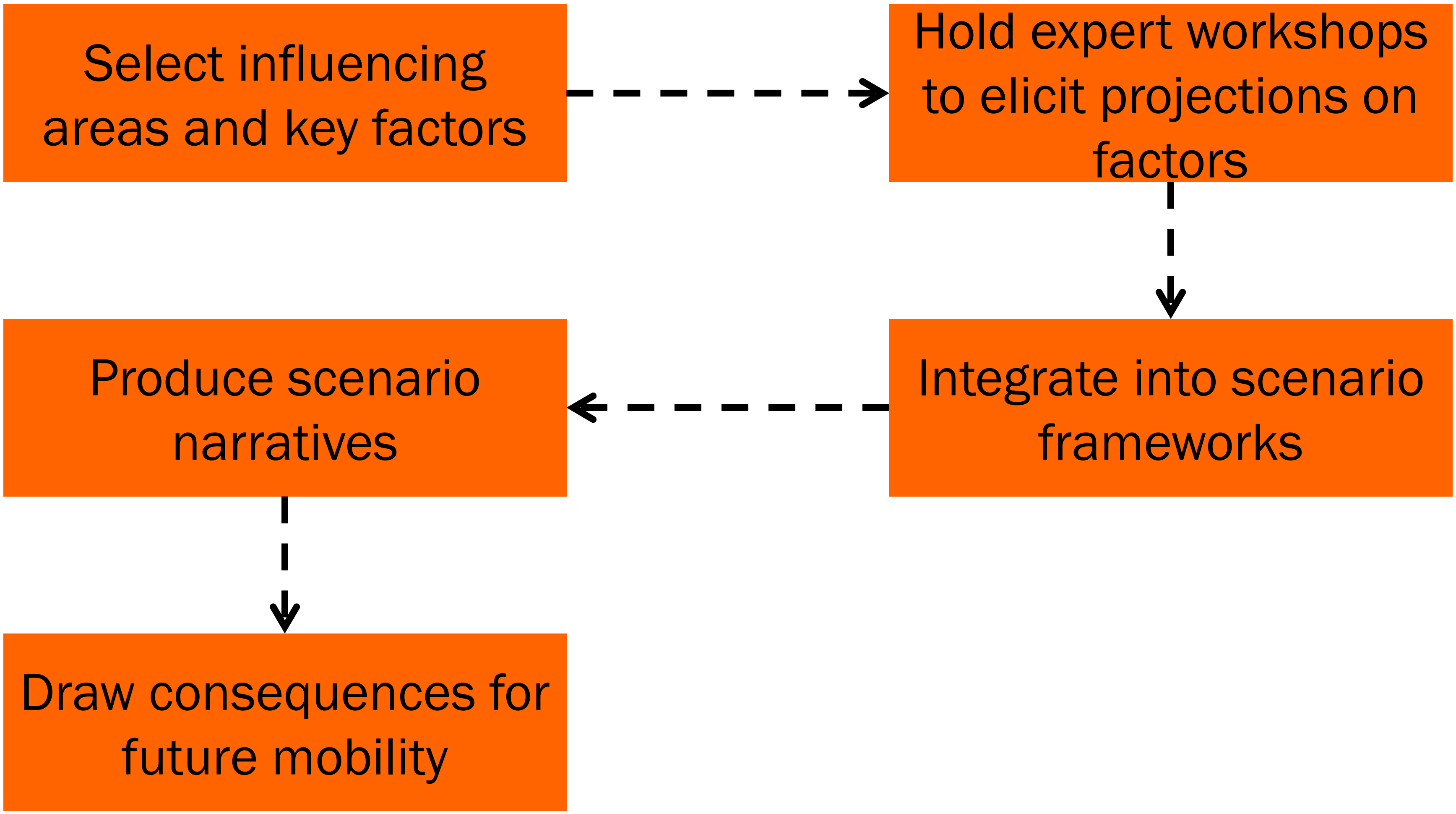
Broad spectrum of techniques to develop scenarios: Our approach



Five influencing areas

Demography

Economy

Energy

Funding and regulation

Technology

Long-term scenarios built upon experts' opinions of future projections on key influencing factors

DEMOGRAPHY
Total population
Share of population by race/ethnic group
Age structure
Population density
Vehicles per 1000 population
Average household size

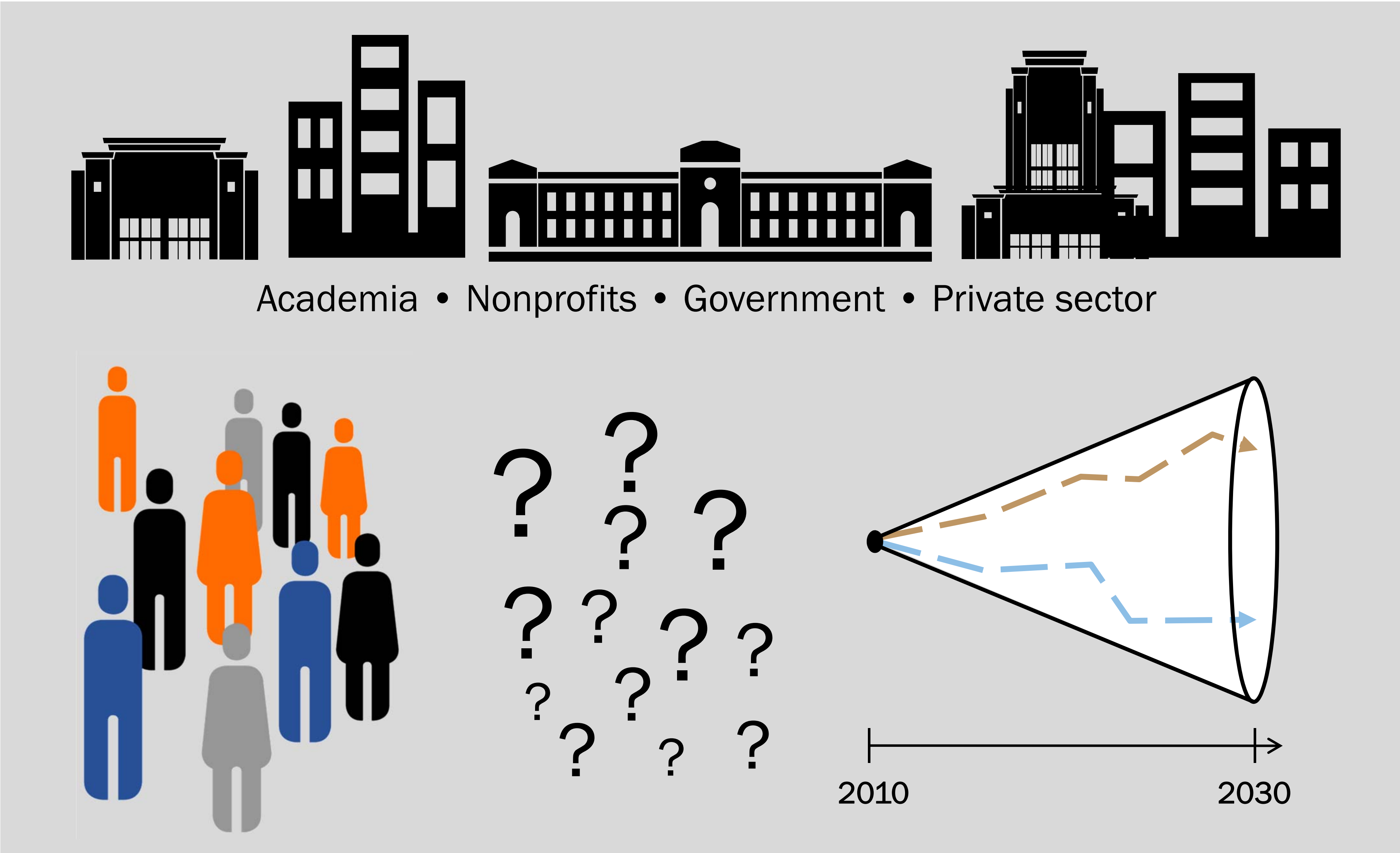
FUNDING AND REGULATION
Cost to drive per mile
Mainstreaming of road pricing to increase revenue
User revenues raised per mile driven
Expenditures on roadways per mile driven
Congestion
Quality and quantity of public transit

ECONOMY
Economic growth
Income distribution
Labor force participation
Sector employment
Freight movement

TECHNOLOGY
Market penetration of broadband
Telecommuting share
Online shopping share of retail sales
Development of data privacy regulations
Adoption of telematic services
Market penetration of advanced driver assistance systems
Market penetration of autonomous vehicles

ENERGY
Introduction of GHG emission reduction systems
Electricity power generation sources
Electric vehicle charging infrastructure
Electricity prices
Adoption of alternatively fueled vehicles
Oil consumption
U.S. oil production
Oil price

We gathered input from ~50 experts representing a diverse array of institutions

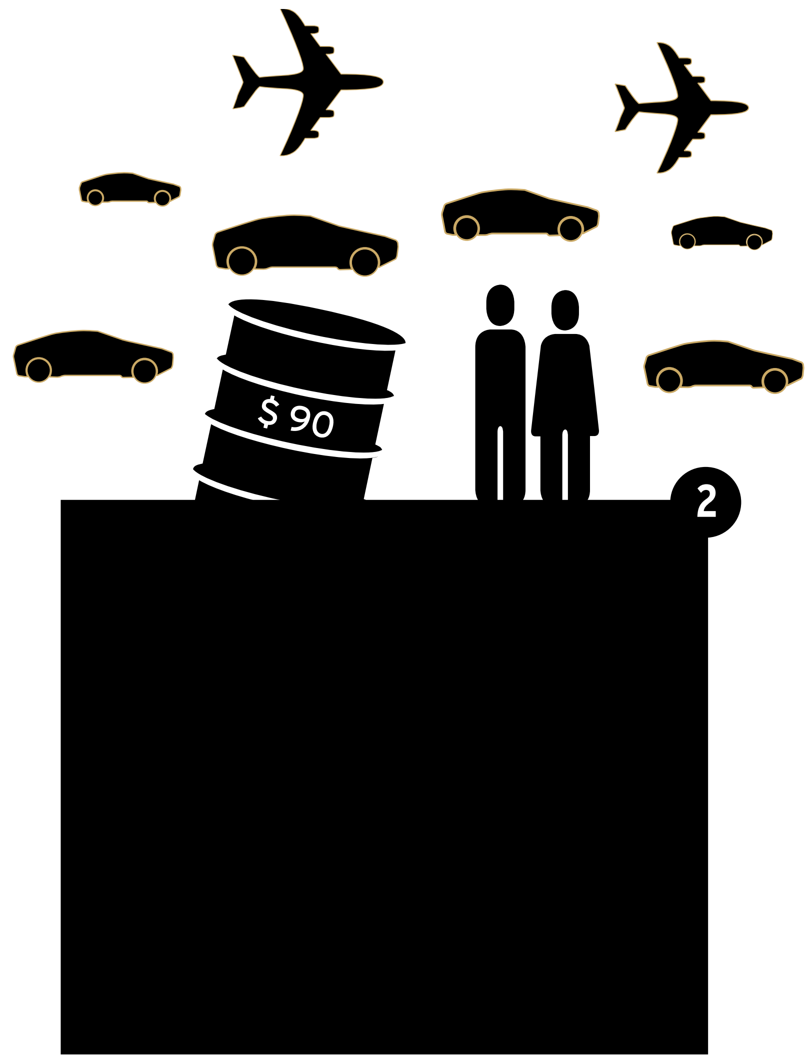


Building designs by Brad Goodwin and Antonis Makriyannis via The Noun Project

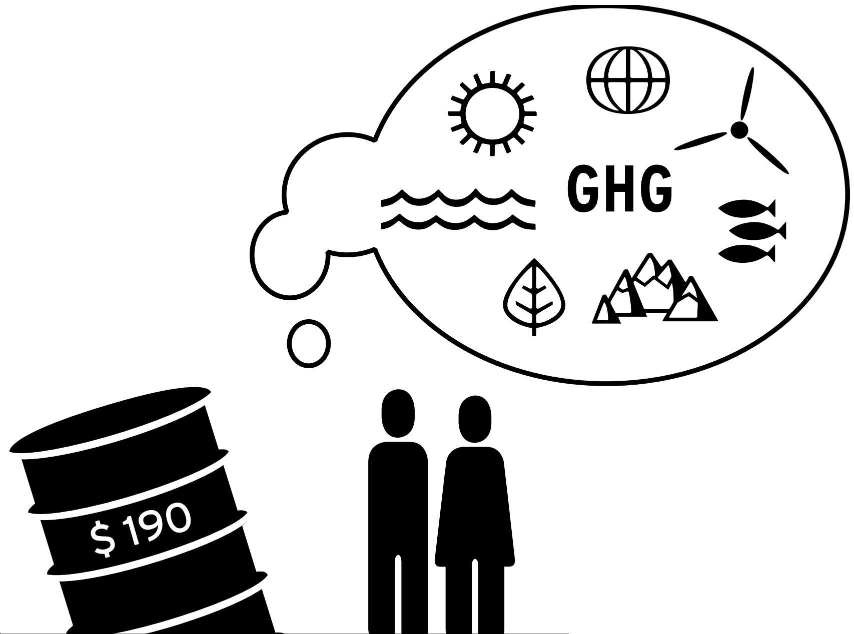
This drove development of two opposing scenarios

NO FREE LUNCH

FUELED AND FREEWHEELING



Scenario 1: No Free Lunch



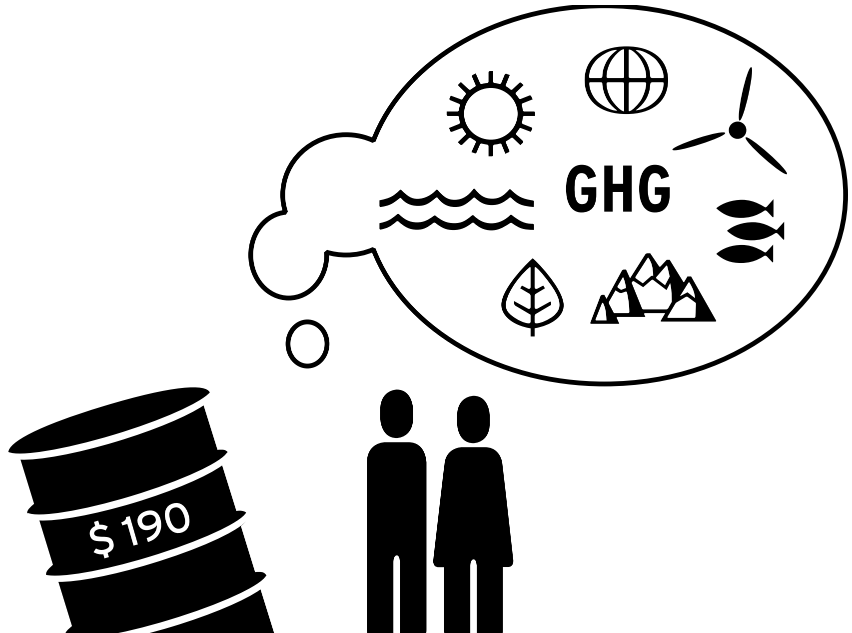
1

When evidence about climate change and very high oil prices combine to create changing attitudes about regulating GHG emission reduction

2

High oil prices • More innovation • Renewable energy • Electric vehicles • More telework Shorter trips • Carbon tax • More expensive vehicles • Better infrastructure • Road pricing Greater car sharing • Higher transit use • Densification • AFVs • Rail freight transport

Scenario 1: No Free Lunch



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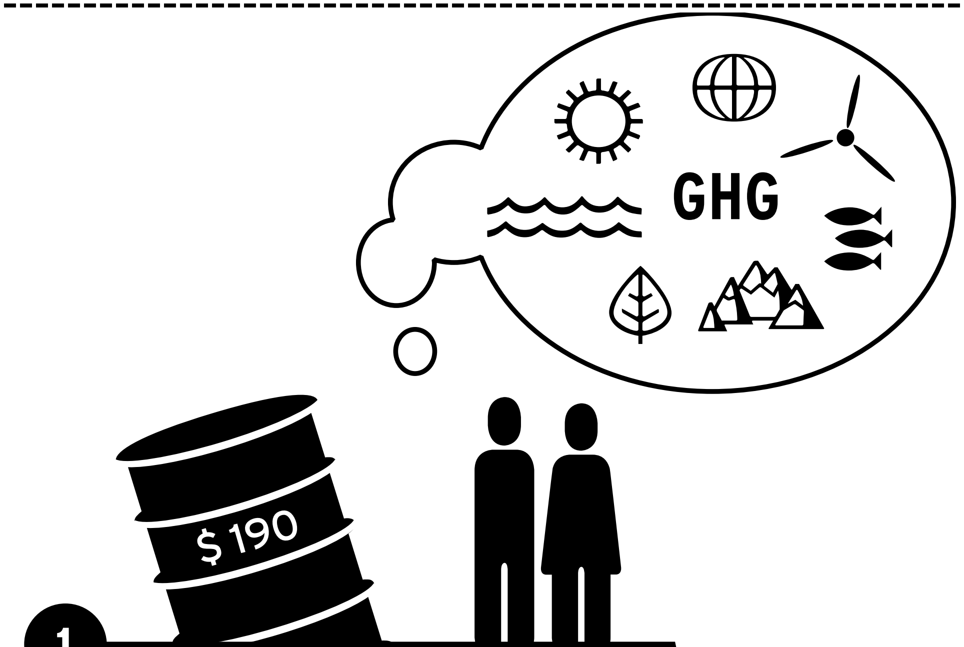

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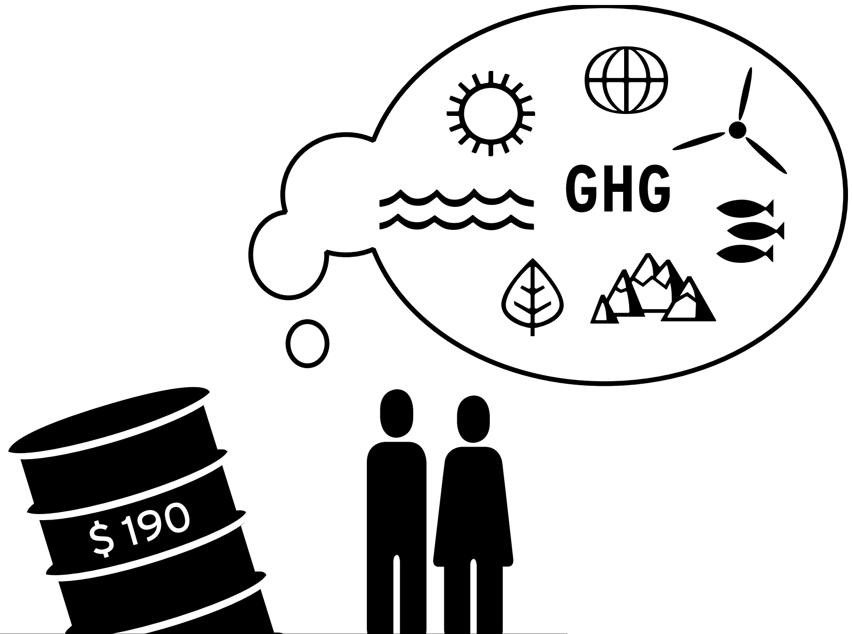

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Scenario 2: Fueled and Freewheeling

2

When cheap and abundant energy, relatively low oil prices, and a lack of regulation combine to create high transport demand

High per capita VMT • Suburbanization • High immigration • Low unemployment • More cars
Cheap to drive • Significant congestion • Crumbling infrastructure • Demand for air travel
Fuel-efficient cars • No new taxes • Geographic winners and losers

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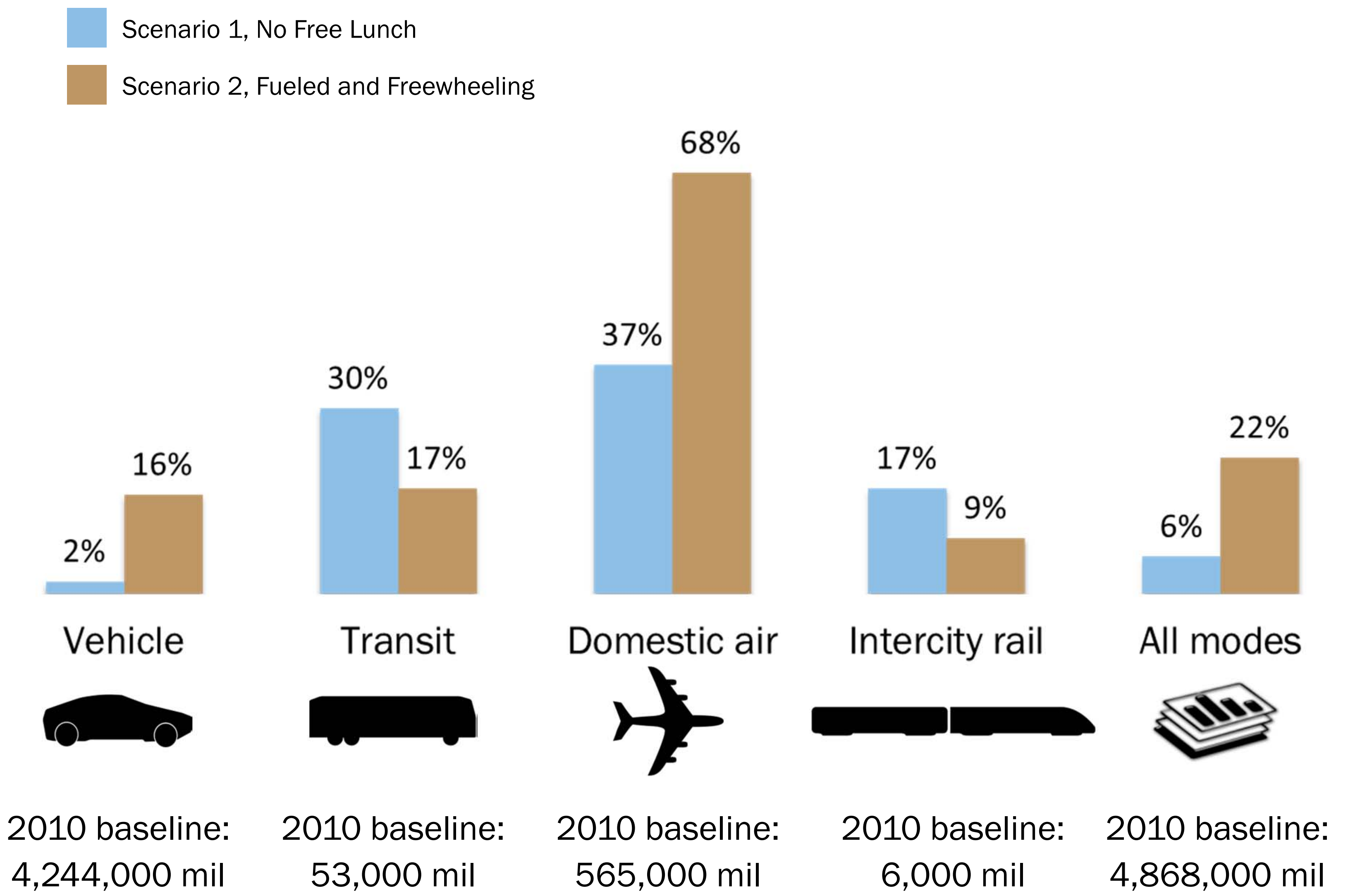
Increase in passenger miles traveled in 2030 from 2010 Baseline

Scenario 1, No Free Lunch

Scenario 2, Fueled and Freewheeling

Increase in passenger miles traveled



Red dusk, China stumbles

China

Major debt crisis

Economic stagnation

Local government debt

United States

Supply-chain uncertainties

Tight domestic credit market

Infrastructure spending stagnates

Lower vehicle and air travel

Higher transit travel

Autonomous vehicle revolution

AV Market

15 percent of fleet

Costs declined

Legal and technical issues resolved

Transportation Impacts

Crash rates decline

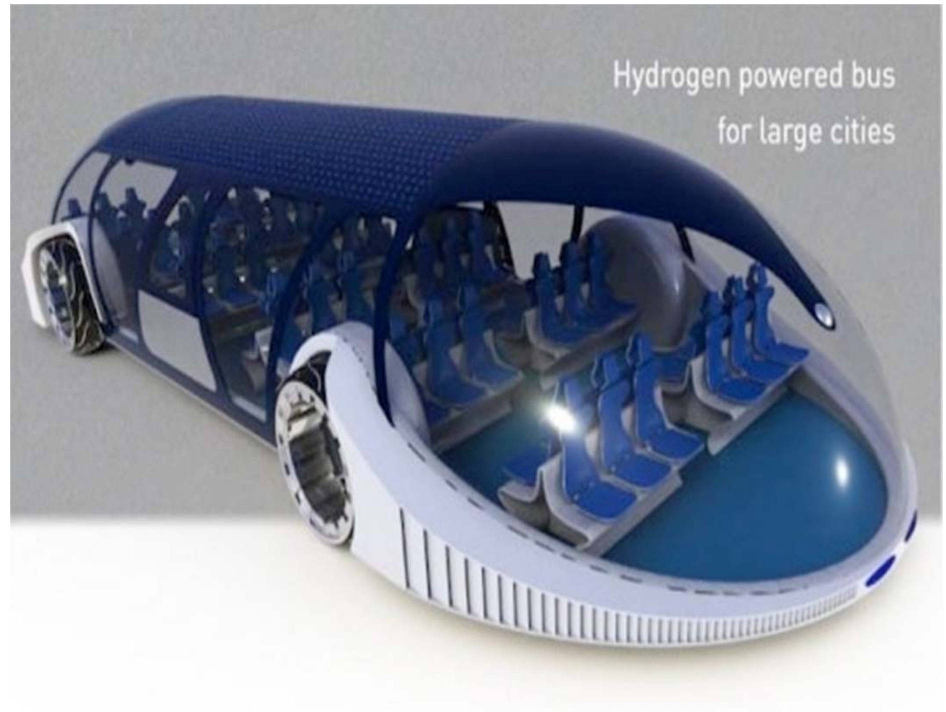
Driver’s licensing declines

Vehicle miles traveled increases

Urban congestion increases

Summary

- Apply scenario planning approach
  - to understand, to identify, to visualize plausible scenarios
  - So planning for the future can focus decisions to be made today



Thank you!

J-zmud@tti.tamu.edu

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How to Make Transportation Infrastructure Decisions in an Uncertain Future

A Case Study Conducted with the Port of Los Angeles

Nidhi Kalra, RAND Corporation
Robert Lempert, RAND Corporation
Klaus Keller, Penn State

TRB Webinar: October 23, 2014

The most calamitous failures of prediction usually have a lot in common. We focus on those signals that tell a story about the world as we would like it to be, not how it really is. **We ignore the risks that are hardest to measure, even when they pose the greatest threats** to our well being…

We abhor **uncertainty** even when it is an irreducible part of the problem we are trying to solve.

-Nate Silver. The Signal and the Noise

How can we know *today* what course of action will work *tomorrow*?

The Port of Los Angeles (PoLA) Is One of the World's Largest Container Shipping Facilities

PoLA is concerned about the potential impact of climate change on its infrastructure and operations

Agencies with Coastal Infrastructure Face Major Challenges from Sea Level Rise

- Managing risk is hard because there is much controversy over extent and timing of sea level rise
- Particularly for low-probability, high-impact increases of 1+ meters by 2100

How should agencies decide when to adapt to extreme climate threats?

We Worked With POLA to Understand and Structure the Decision Challenge

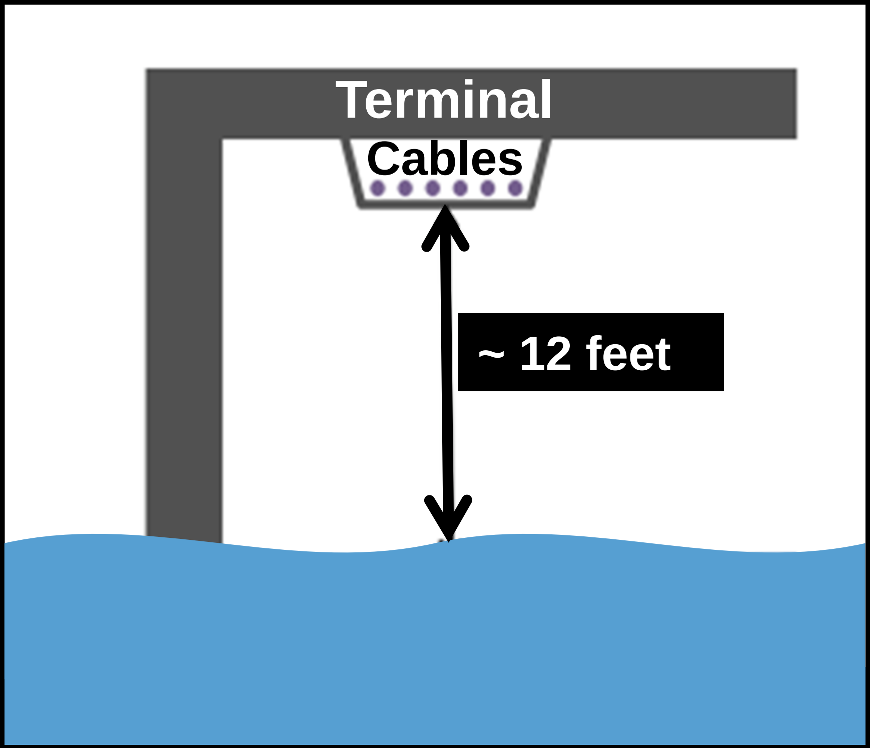
PoLA Was Considering Protecting Four Facilities

Bottom of terminals

Top of terminals

Berths 206-209

Alameda and Harry Bridges Crossings



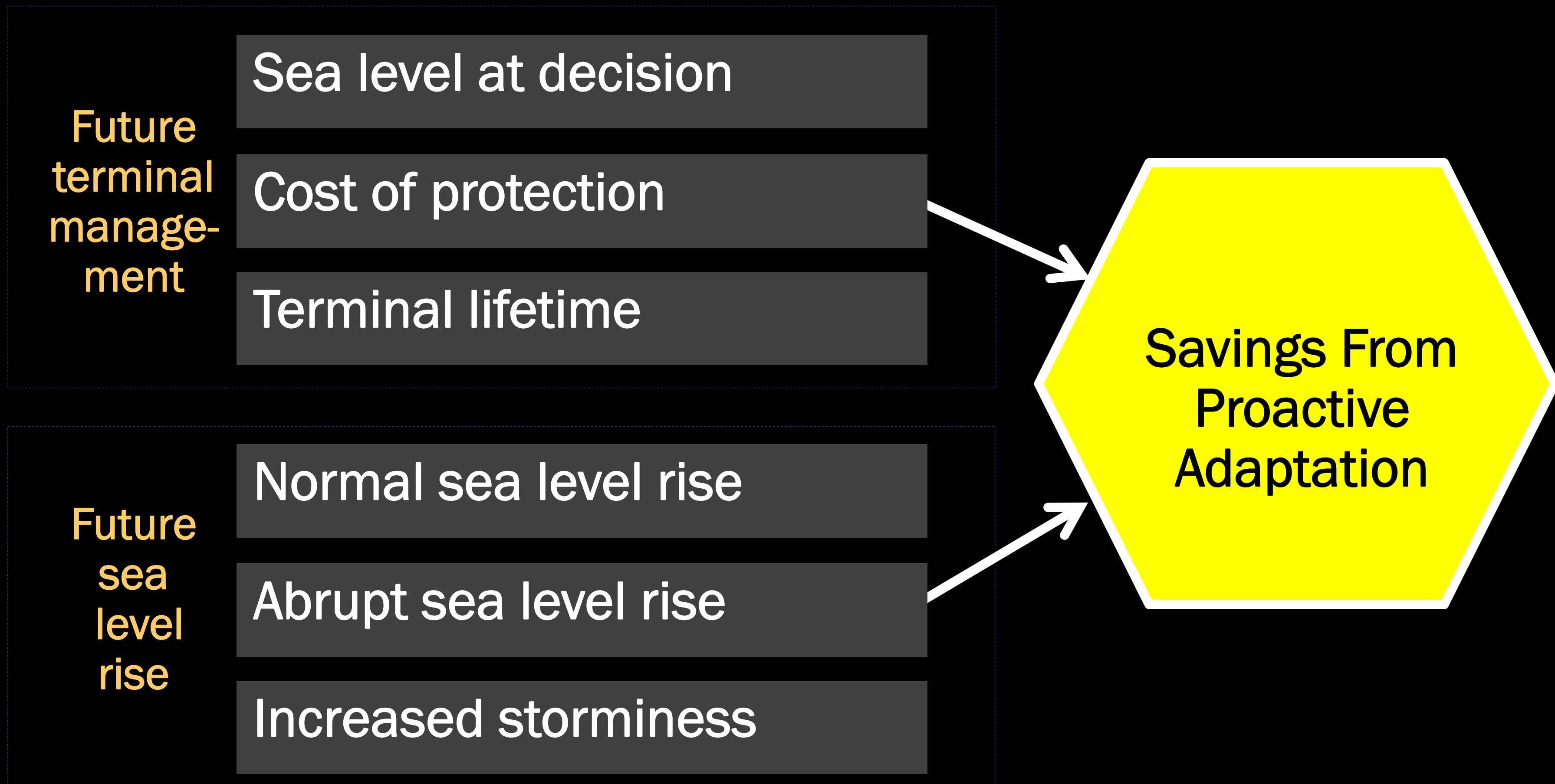
Does It Make Sense For PoLA To Be Proactive and Adapt at the Next Upgrade?

We Built a Simple Model to Calculate the Economic Savings from Adapting Proactively

Savings From Proactive Adaptation

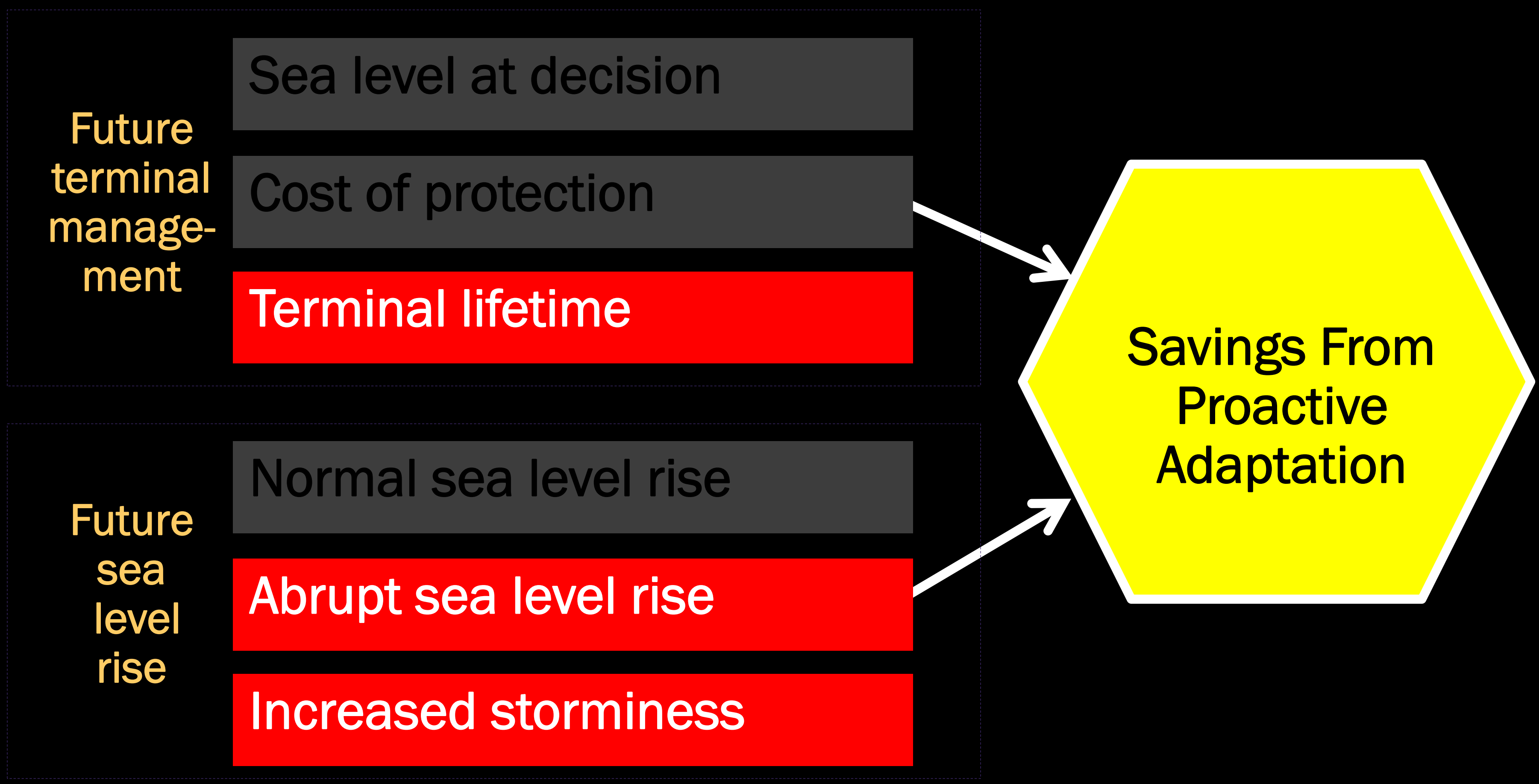
PoLA should be proactive, adapting at next upgrade, if anticipated savings are positive

The Savings Depend On Several Uncertain Parameters



PoLA should be proactive, adapting at next upgrade, if anticipated savings are positive

Some Parameters <u>Deeply Uncertain</u>



Traditional Analyses Ask Us To Make Predictions about These Future Conditions

What will future conditions be?

↓

Under those conditions, does being proactive produce savings?

↓

How sensitive is the decision to those conditions?

←

- Projections
- Probability distributions
- Scenarios

Predicting the Unpredictable Can Lead Us Astray…

1. Encourages bias. We believe in the prediction that leads to the decision we already favor.

1. Invites gridlock. We have no way of dislodging ourselves or others from our biases.

1. Can lead to poor decisions. We don't know how our decision performs if the future surprises us – *as it often does!*

Robust Decision Making Helps Us Make Good Decisions ***Without Predictions***

RDM helps us
discover scenarios
that drive our decision.

We use these scenarios to
assess merits of our choices,
not to make predictions
about the future.

In what future scenario does being proactive produce savings?

↓

How likely would this scenario have to be to justify being proactive?

↓

What does evidence suggest about that likelihood?

- Ran 500 simulations of plausible future conditions
- Calculated value of being proactive in each future
- Analyzed futures in which being proactive produces savings

Robust Decision Making

In what future scenario does being proactive produce savings?

↓

How likely would this scenario have to be to justify being proactive?

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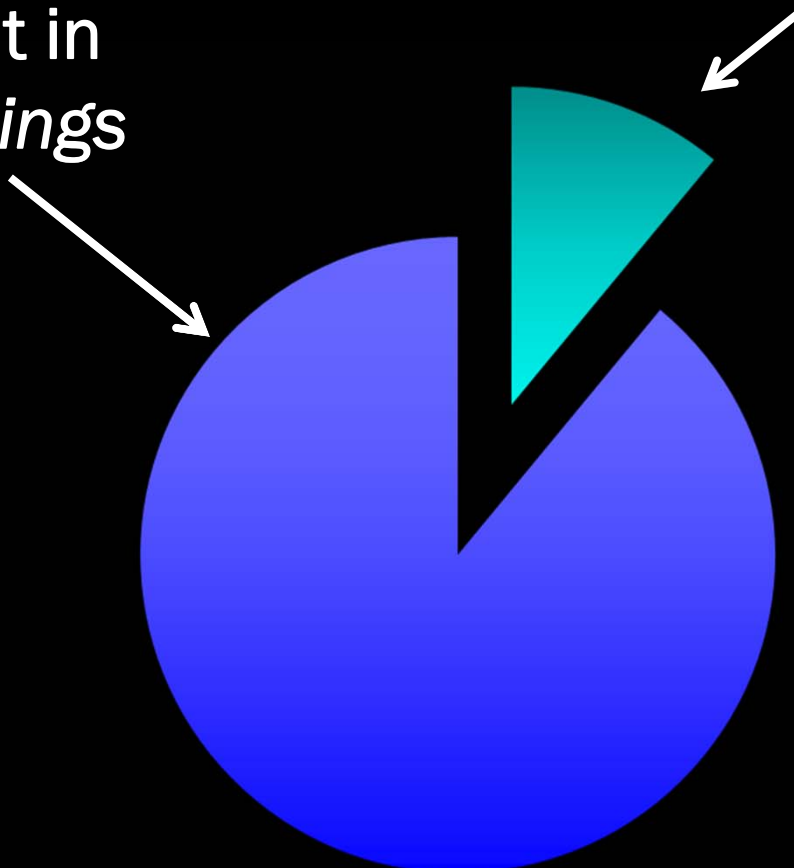
What does evidence suggest about that likelihood?

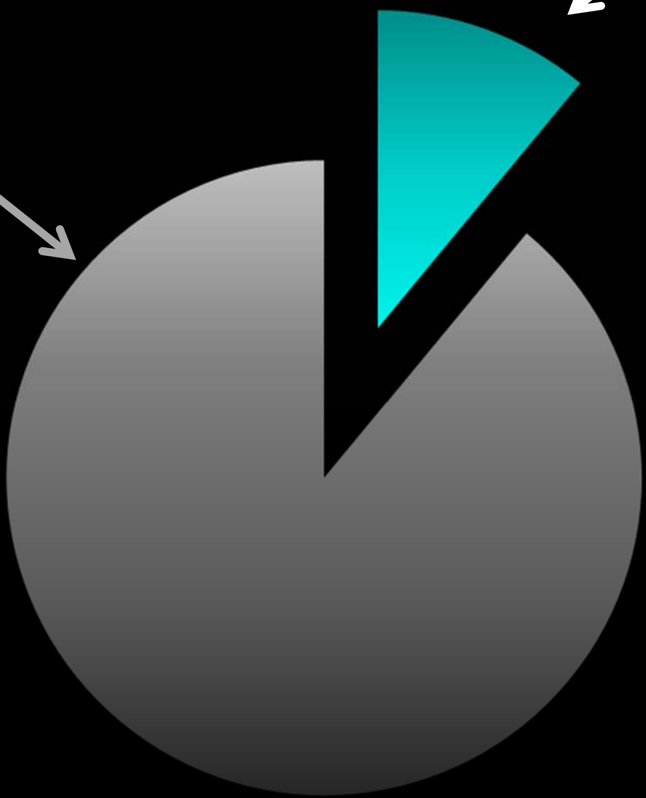
Being Proactive Produces Savings for PoLA in Very Few of the 500 Simulated Futures

A few futures have *positive savings*

The vast majority of futures result in *negative savings (cost)*



Being Proactive Produces Savings for PoLA in Very Few of the 500 Simulated Futures



Statistical Analysis Reveals The Specific Future Scenario in Which We Expect Savings

"Savings Scenario"

- Terminal Lifetime → long
- Abrupt SLR → aggressive
- Storminess → significant

Robust Decision Making

✓ In what future scenario does being proactive produce savings?

↓

How likely would this scenario have to be to justify being proactive?

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What does evidence suggest about that likelihood?

“Savings Scenario”

Terminal Lifetime →	long
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Robust Decision Making

✓ In what future scenario does being proactive produce savings?

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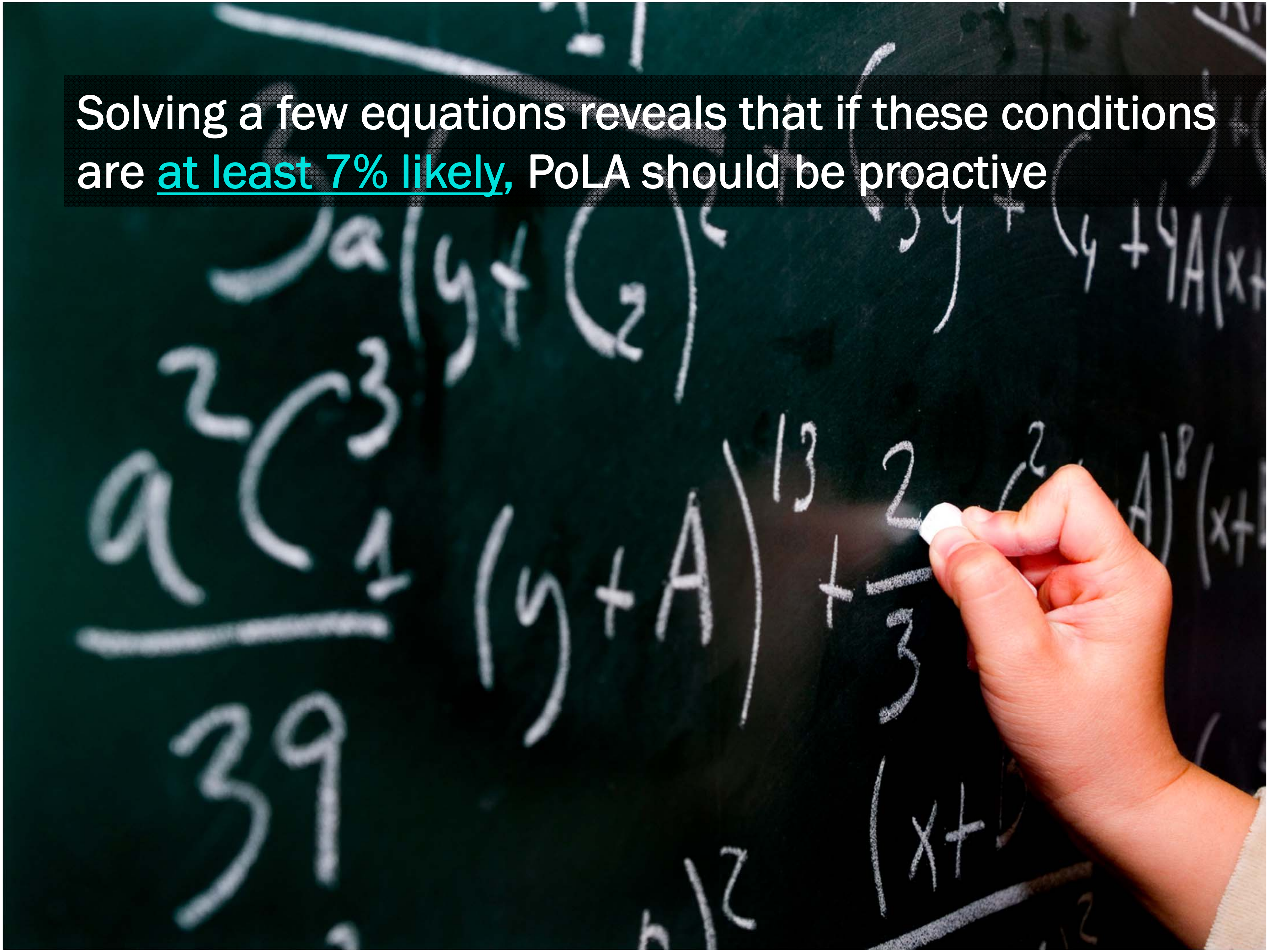
What does evidence suggest about that likelihood?

Solving a few equations reveals that if these conditions are at least 7% likely, PoLA should be proactive



P ("Savings Scenario"

- Terminal Lifetime → long
- Abrupt SLR → aggressive
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) > 7%

Probability

Robust Decision Making

✓ In what future scenario does being proactive produce savings?

↓

✓ How likely would this scenario have to be to justify being proactive?

↓

What does evidence suggest about that likelihood?

P ("Savings Scenario"

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) > 7%

Robust Decision Making

✓ In what future scenario does being proactive produce savings?

↓

✓ How likely would this scenario have to be to justify being proactive?

↓

What does evidence suggest about that likelihood?

We Don't Have Reason To Believe We Would Exceed Even a 7% Threshold

Terminal lifetime → long

But historically, terminal lifetimes have been short

Abrupt sea level rise → aggressive

Increased storminess → significant

There is no evidence yet that
climate change will be quite this aggressive

PoLA Might Reasonably and Defensibly Choose <u>Not To Adapt</u> at the Next Upgrade

Robust Decision Making

✓ In what future scenario does being proactive produce savings?

✓ How likely would this scenario have to be to justify being proactive?

✓ What does evidence suggest about that likelihood?

We Repeated the Analysis For the Other Facilities

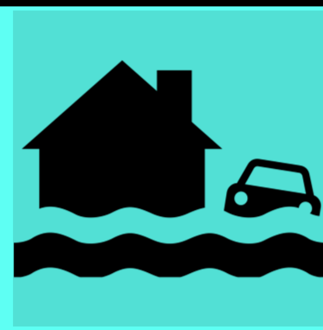
Bottom of Terminals	✗ Don’t adapt yet
Top of terminals	✗ Don’t adapt yet
Berths 206-209	✗ Don’t adapt yet
Alameda and Harry Bridges Crossings	✓ Adapt at next upgrade

Key Takeaways

- Uncertainty and disagreement pose serious threats to good decision making
- Methods like Robust Decision Making use scenarios to reveal the merits of options, not to make predictions
- Agencies can build consensus around good decisions, without good predictions

Robust Decision Making has been used to improve decisionmaking in many applied settings

water management



flood risk management

energy resource management

Robust Decision Making Can Help In Transportation Planning

Many Uncertainties

Complex Planning

The Metropolitan Water District of Southern California is one of the world's largest water resource agencies. It has used Robust Decision Making to inform its long term plans. A manager was recently asked if he trusted the climate models they are using to build these plans.

"…did not necessarily **trust** the climate models,

…but once their analysis was complete they would have

confidence in their contingency plans."

-Groves et al, 2009 (RAND)

Impacts 2050: Dynamic Representation of Socio-Demographic & Travel Scenarios

Mark Bradley, RSG

Long-Range Strategic Issues Research

- NCHRP 20-83 series
- Anticipate future issues so transportation agencies are better prepared to respond to new and emerging challenges
- Enable transportation agencies to shape the future through their decision making by exploring visions of alternative futures

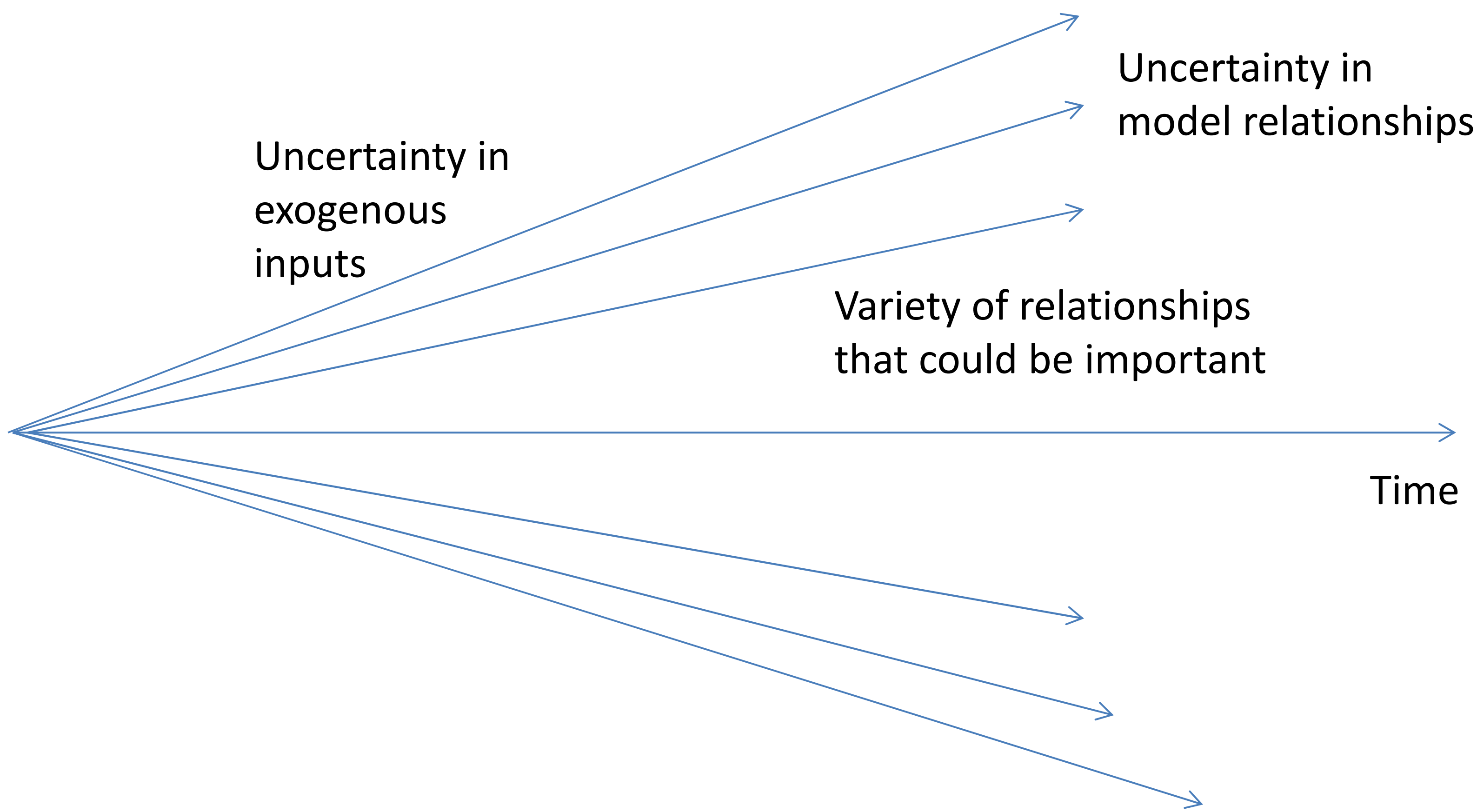
Impact of Socio-Demographics on Travel Demand (20-83 (06))

- Research focuses on understanding:
  - How the composition of the population might change over time
  - How socio-demographic changes will affect ways in which people travel
  - How assumptions about changes in demographic patterns and travel behavior “play out” over time
  - Which assumptions seem to lead to the most contrast across different scenarios

Impacts 2050 Is . . .

- A strategic scenario analysis tool
- Comprised of:
  - A Systems Dynamics model that can represent the co-evolution of population, land use, employment, transport supply and travel behavior
  - Scenarios representing divergent visions of alternative futures
- Not intended to replace existing travel demand forecast models

As a model is run further into the future, precision in the inputs and forecasts becomes less possible, and the ability to represent a wide range of scenarios becomes more relevant



Strategic Models Complement Detailed Forecasting Models

Regional Model

- Spatial detail is very important
- Focus is on quantitative accuracy in input data and model parameters
- Running the model and analyzing results is time-intensive

Strategic Model

- Limit spatial detail, run model over many years
- Focus is on including a wide range of model relationships, and on "qualitative accuracy"
- Running the model is relatively quick and easy

Different from sketch planning tool – a different type of model

Systems Dynamics modeling

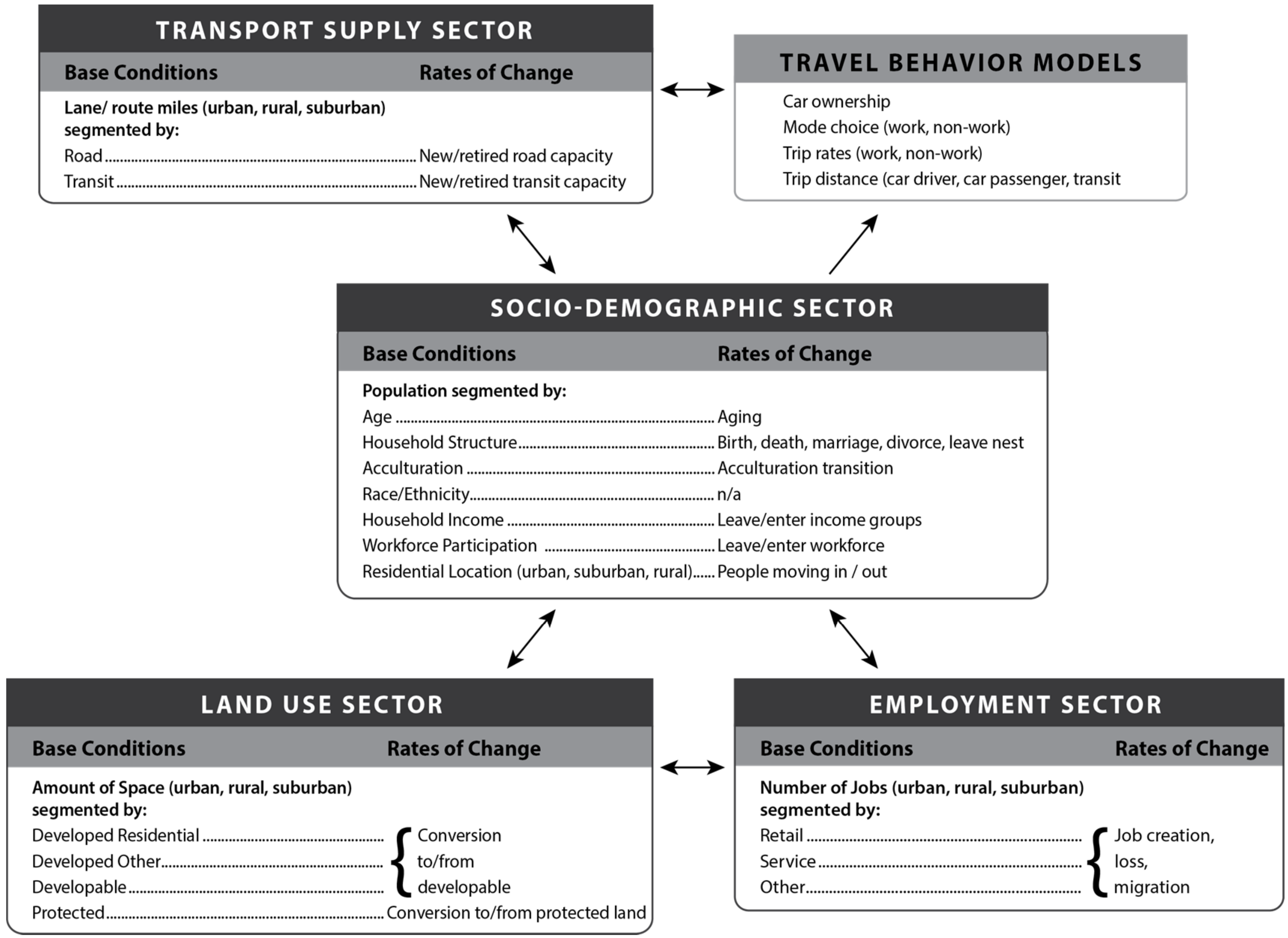
The focus is on relationships between variables **over time**
(rates of change)

Behavior results from **feedback** between system components
(can be limiting effects or reinforcing cycles)

Developed at MIT in 1960's for industrial systems (Forrester).

- "Limits to Growth" Club of Rome study (Meadows, *et al.* 1970's)
- Urban Dynamics (Forrester, 1970's)
- Many applications since in many different fields.

Model Structure



Demographic transition rates

- Basic rates derived from analysis of the Panel Survey on Income Dynamics (PSID) 2003-2009
- Rates for:
  - Birth
  - Death
  - "Marriage"
  - "Divorce"
  - Leave nest/empty nest
  - Enter/leave workforce
  - Enter/leave income group
- The user can apply scenario-specific multipliers on these rates

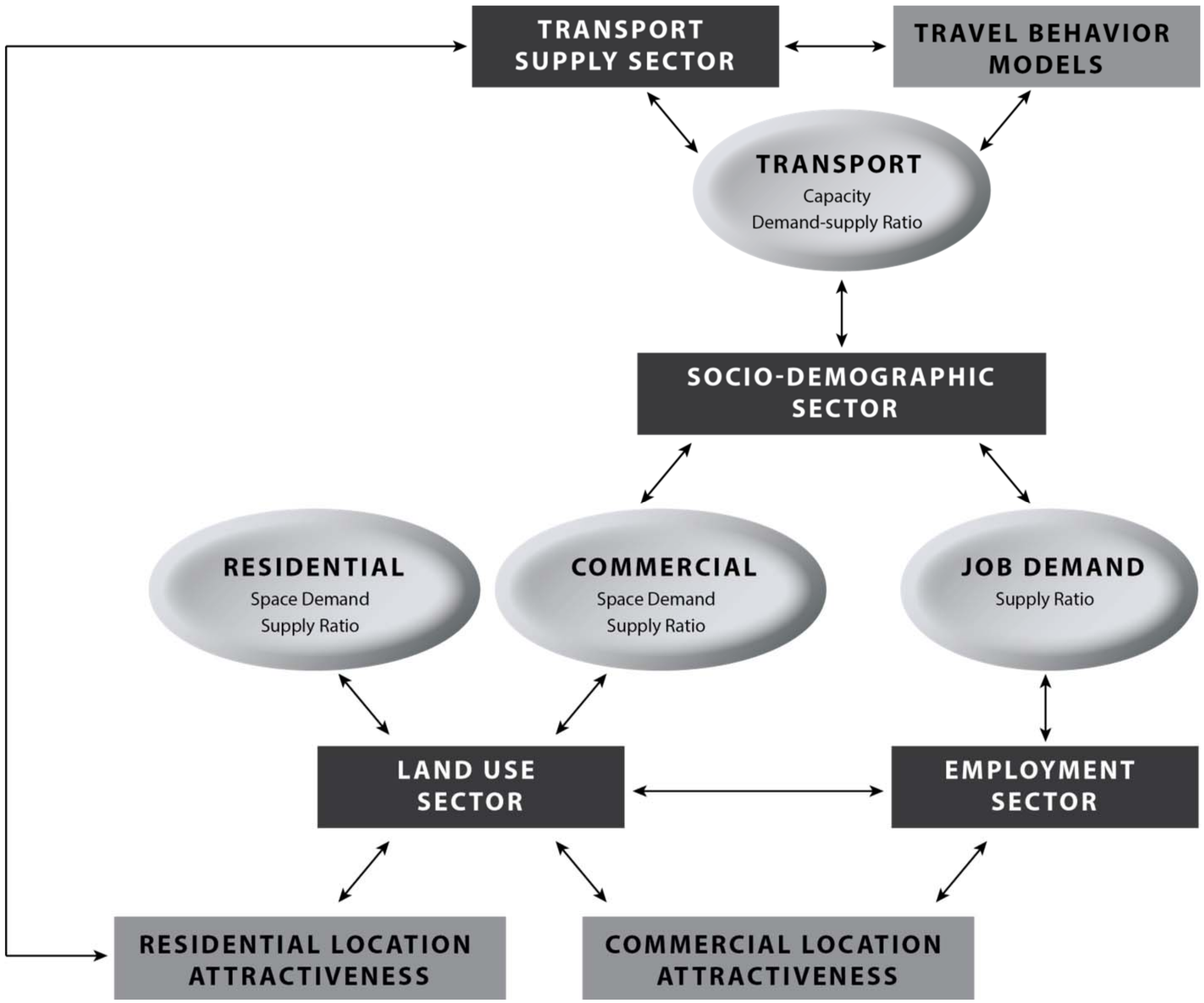
Rates vary by combination of:

- Age group
- Household type
- Race/acculturation

Demographic migration rates

- Three types of migration:
  - Foreign (from / to other countries)
  - Domestic (from / to other regions of the US)
  - Regional (from / to other area types in the region)
- Base rates are derived from Census data, and modified by:
  - Residential attractiveness – function of demand vs. supply of jobs, housing, road capacity
  - User-defined scenario effects

System Dynamics Model



Other feedbacks…

- *The Employment Sector*
  – A very simple model of job creation, loss & migration
- *The Land Use Sector*
  – A very simple model of transition of land between residential, non-residential, undeveloped & protected
- *The Transportation Supply Sector*
  – A very simple model of capacity addition and retirement for roads and transit
- These feedbacks can be turned “on” or “off to investigate the difference between unconstrained and constrained demand, and between responsive and unresponsive supply

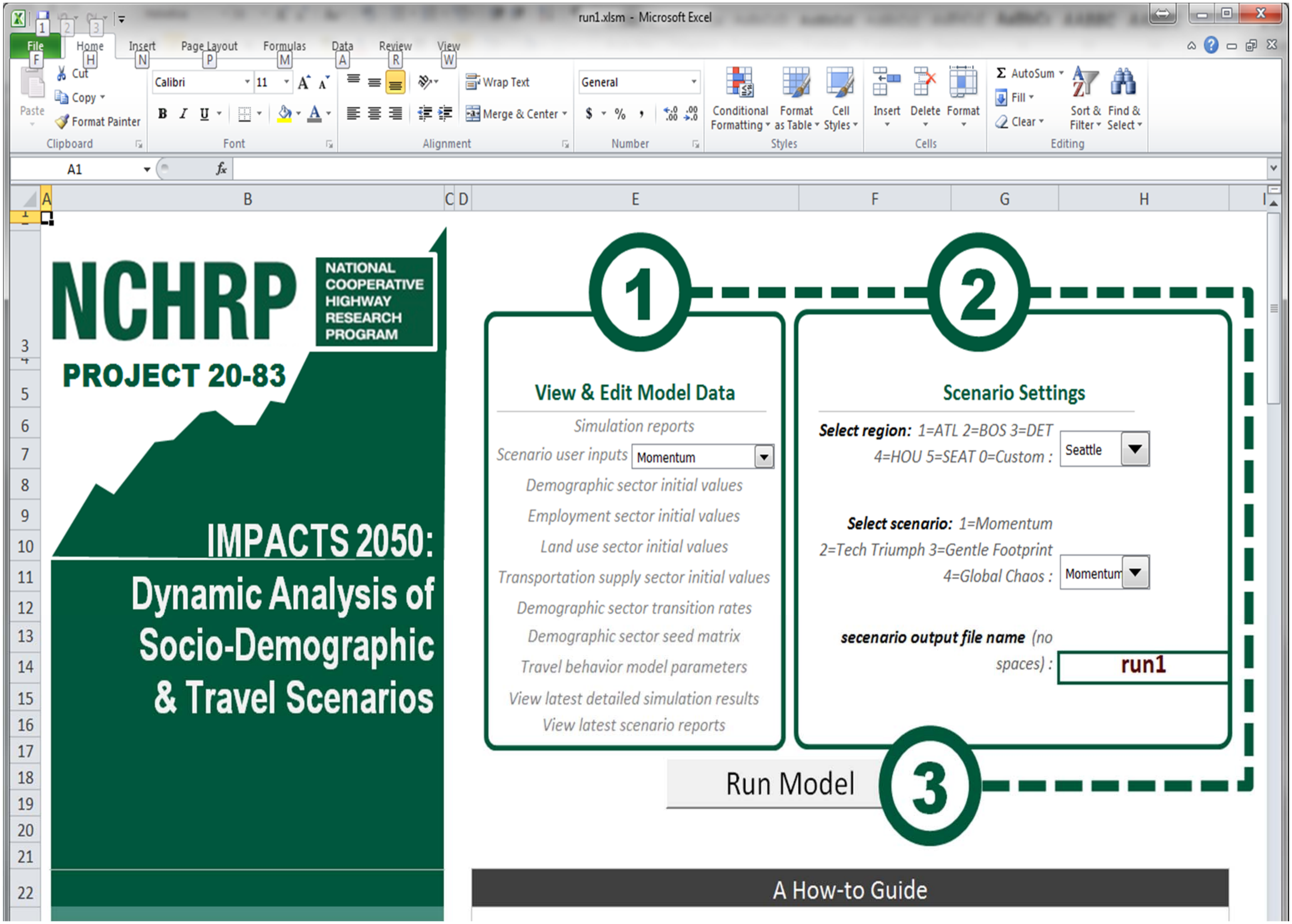
Options for Spatial Detail

- A single area for the entire region
- ***Generic area types (urban, suburban, rural)***
- County-level zones
- Combination of County-level and area types
- Census tract level zones

MORE DETAIL

Started with simple area types to ease data preparation and model useability.

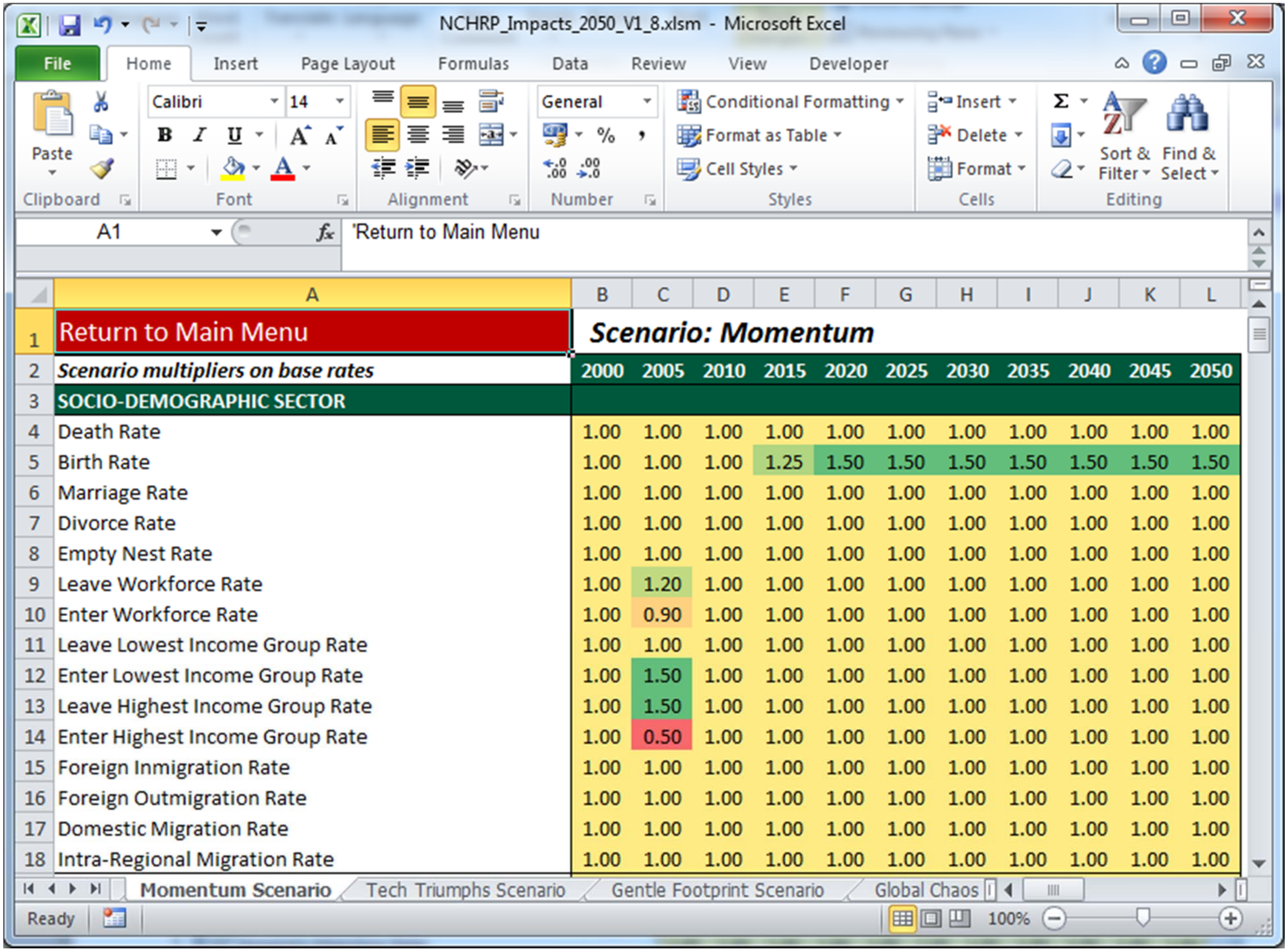
Could move to somewhat more detail in a future version


run1.xlsm - Microsoft Excel
File
Home
Insert
Page Layout
Formulas
Data
Review
View
Cut
Copy
Format Painter
Paste
Clipboard
Calibri
11
Font
Wrap Text
Merge & Center
Alignment
General
Number
Conditional Formatting
Format as Table
Cell Styles
Styles
Insert
Delete
Format
Cells
AutoSum
Fill
Clear
Sort & Filter
Find & Select
Editing
A1
NCHRP
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
PROJECT 20-83
IMPACTS 2050:
Dynamic Analysis of Socio-Demographic & Travel Scenarios
1
View & Edit Model Data
Simulation reports
Scenario user inputs
Momentum
Demographic sector initial values
Employment sector initial values
Land use sector initial values
Transportation supply sector initial values
Demographic sector transition rates
Demographic sector seed matrix
Travel behavior model parameters
View latest detailed simulation results
View latest scenario reports
2
Scenario Settings
Select region: 1=ATL 2=BOS 3=DET 4=HOU 5=SEAT 0=Custom :
Seattle
Select scenario: 1=Momentum 2=Tech Triumph 3=Gentle Footprint 4=Global Chaos :
Momentum
secenario output file name (no spaces) :
run1
Run Model
3
A How-to Guide

Pre-Programmed Scenarios

Based on Delphi panel deliberation

- Momentum
  - Change is based on population dynamics
- Technology Triumphs
  - Innovations mitigate difficult challenges
- Gentle Footprint
  - Public consciousness and political shifting toward taking serious action to curb climate change
- Global Chaos
  - Distressing new normal – financial instability, climate change impacts, isolationism

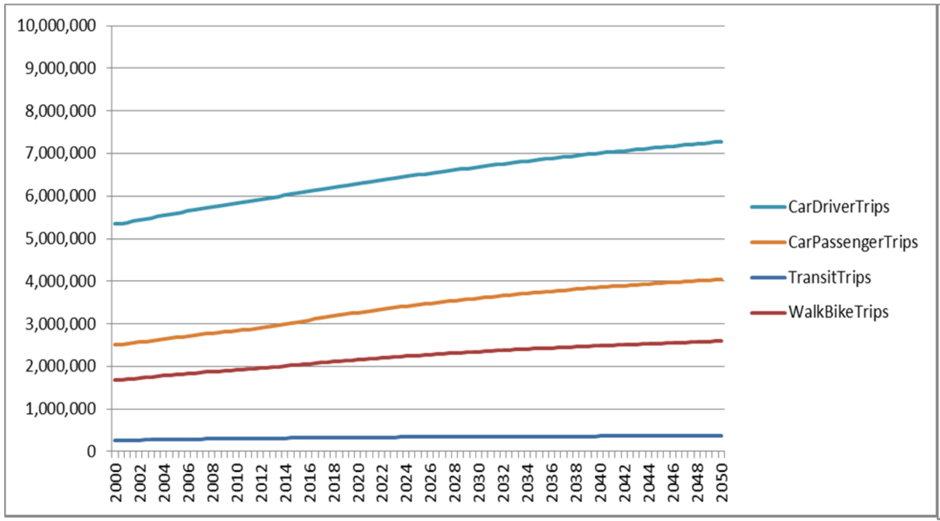


Return to Main Menu	*Scenario: Momentum*										
Scenario multipliers on base rates	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
SOCIO-DEMOGRAPHIC SECTOR											
Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Birth Rate	1.00	1.00	1.00	1.25	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Workforce Rate	1.00	1.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Workforce Rate	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Lowest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Lowest Income Group Rate	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Highest Income Group Rate	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Highest Income Group Rate	1.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Foreign Inmigration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Foreign Outmigration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Domestic Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intra-Regional Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

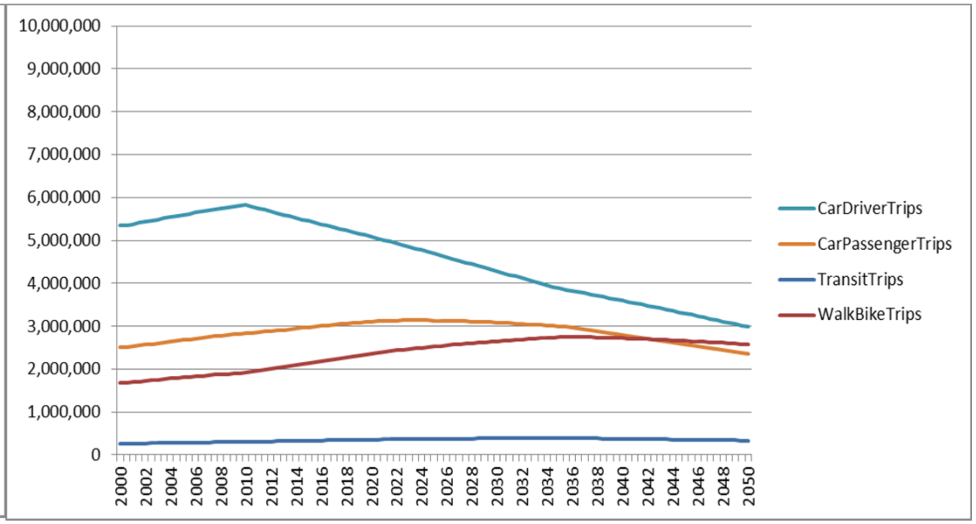
Year	2000	2010	2020	2030	2040	2050
Population	4,247,982	5,262,023	6,300,547	7,076,865	7,691,863	8,225,550
Percent under age 16	23%	22%	22%	23%	23%	23%
Percent over age 60	11%	14%	16%	18%	19%	19%
Percent in single household	13%	19%	21%	23%	24%	24%
Percent in HH w/ children	63%	64%	62%	61%	61%	61%
Percent Immigrants>20 yrs in US	2%	5%	9%	10%	10%	9%
Percent Immigrants<20 yrs in US	8%	10%	9%	7%	5%	4%
Percent White/other	61%	59%	57%	56%	55%	55%
Percent Hispanic	6%	8%	10%	11%	12%	12%
Percent Black	29%	26%	25%	25%	24%	24%
Percent Asian	3%	6%	8%	9%	9%	10%
Percent low income group	31%	32%	34%	34%	33%	33%
Percent in high income group	18%	19%	22%	25%	26%	27%
Percent in workforce	51%	47%	43%	41%	40%	39%
Percent non -car-owning	2.4%	2.5%	2.7%	2.8%	2.9%	3.0%
Percent car-sharing	22.6%	21.8%	21.9%	21.9%	21.9%	21.8%
Avg. car-occupancy-Work	1.13	1.13	1.13	1.13	1.13	1.13
Transit mode share - Work	1.7%	1.9%	2.1%	2.3%	2.4%	2.5%
Walk/bike mode share - Work	5.2%	5.6%	5.9%	6.1%	6.2%	6.3%
Avg. car-occupancy-Non-work	1.82	1.76	1.75	1.75	1.76	1.76
Transit mode share - Non-work	1.5%	1.6%	1.7%	1.8%	1.9%	1.9%
Walk/bike mode share - Non-work	11.2%	11.5%	11.7%	11.8%	11.9%	12.0%
Work trips/capita per day	0.61	0.55	0.51	0.48	0.47	0.46
Other trips/capita per day	2.82	2.86	2.93	2.96	2.98	2.99
Auto VMT/capita per year	11,726	11,115	10,714	10,472	10,336	10,251

Trips by Mode

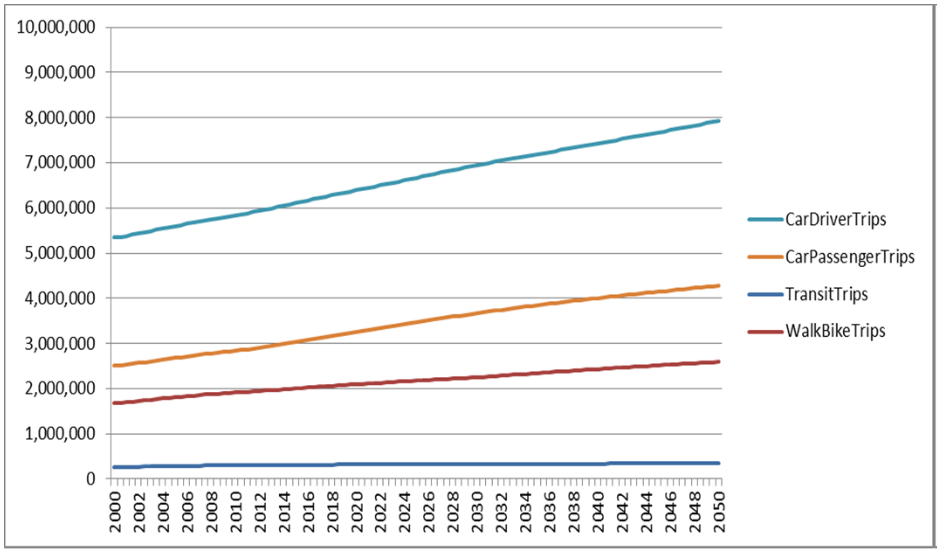
Momentum



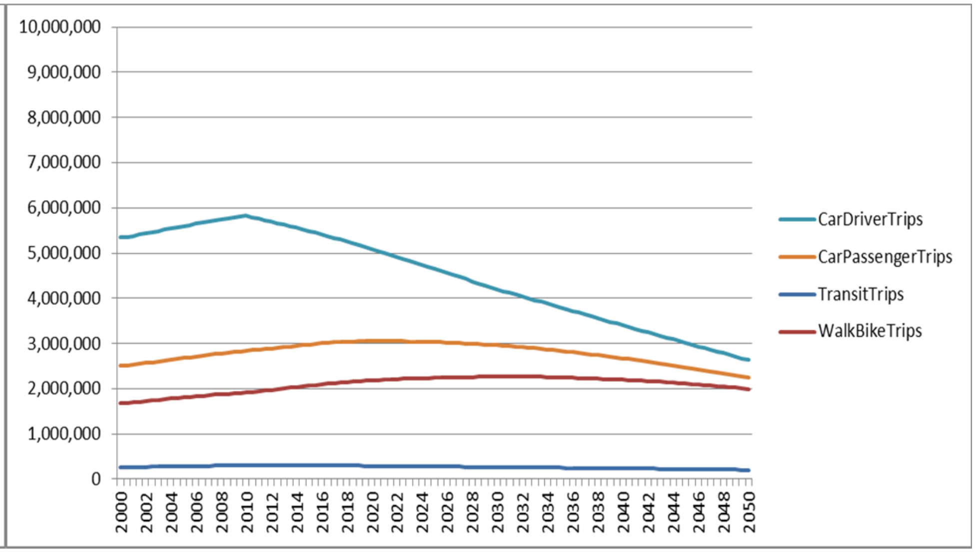
Gentle Footprint



Tech Triumphs

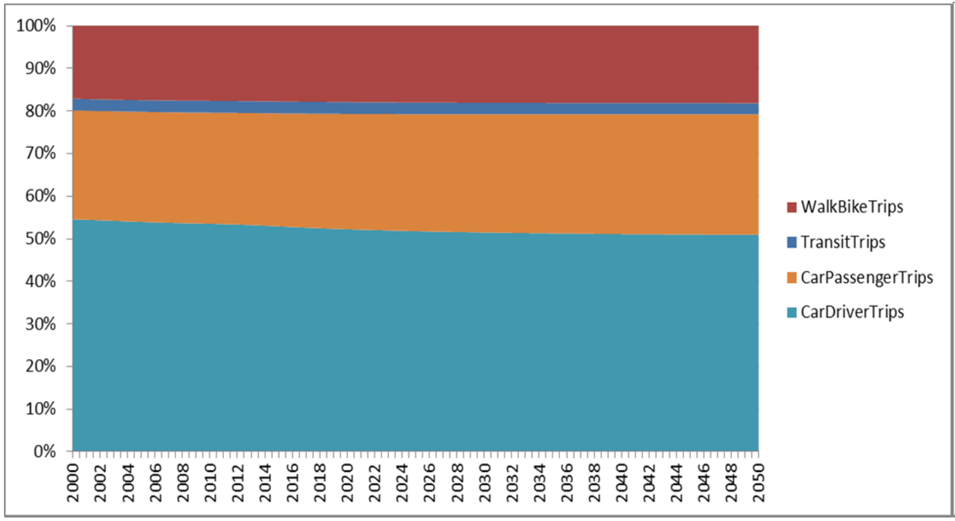


Global Chaos

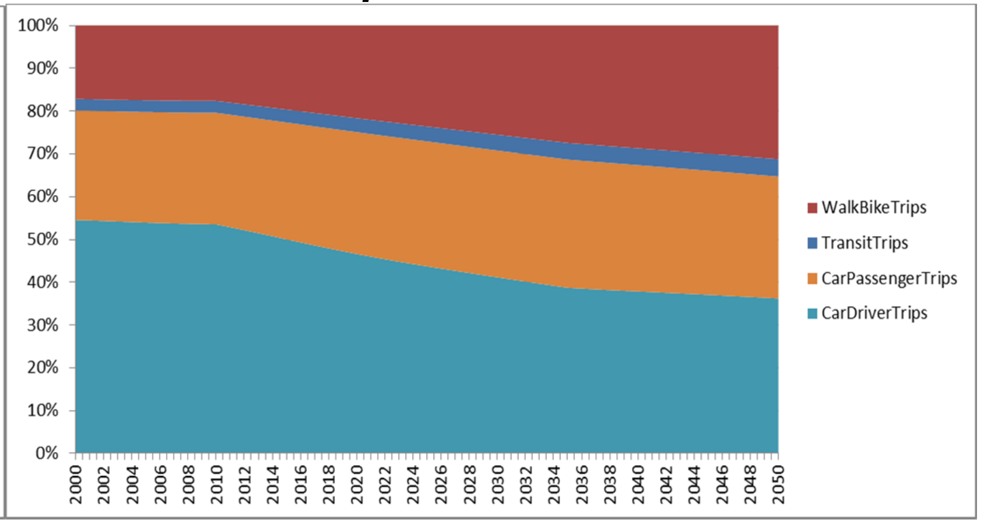


Trip Mode Share

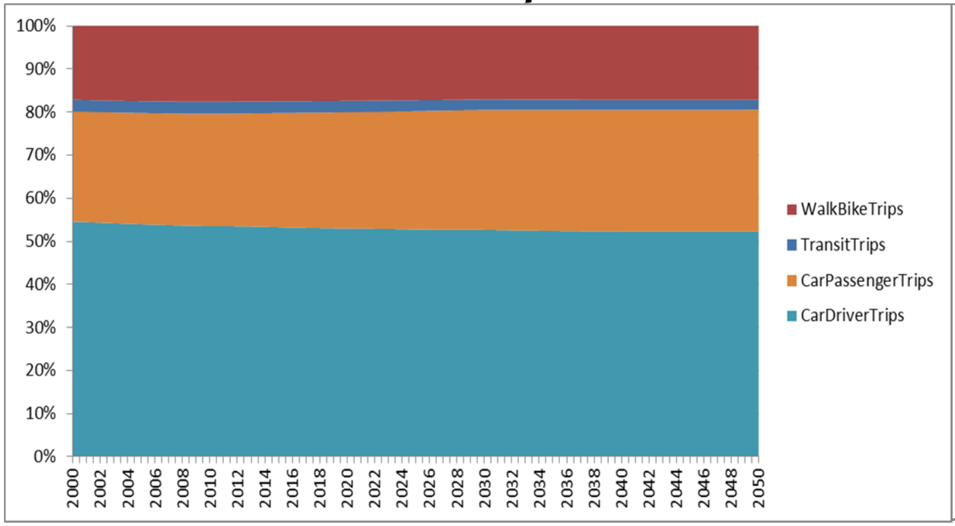
Momentum



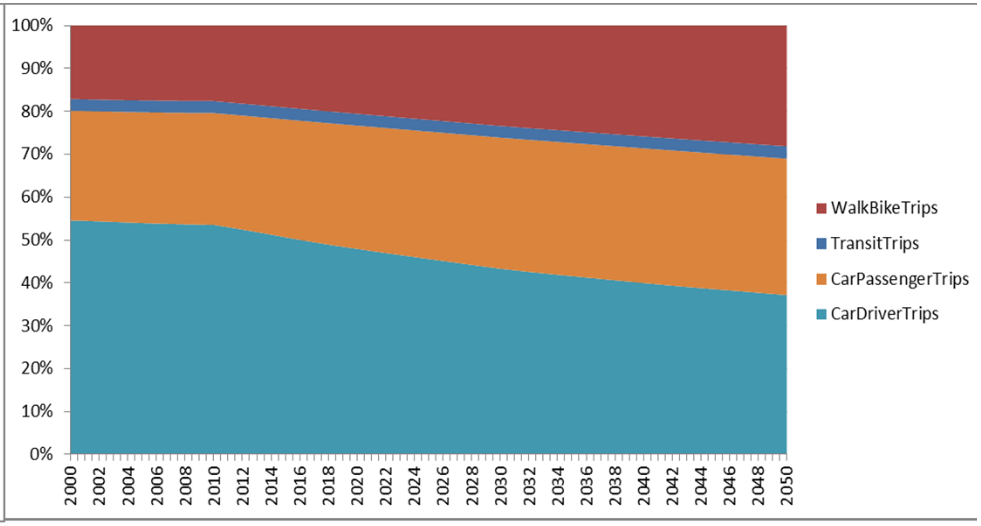
Gentle Footprint



Tech Triumphs



Global Chaos



Scenario Consequences

Factor	Momentum	Gentle Footprint	Global Chaos	Tech Triumphs
Population Growth	→	↓	↓	↑
Household Size	→	↓	↑	↓
Immigration	→	↑	↓	↑
Income levels	→	→	↓	↑
Economic Growth	→	↑	↓	↑
Travel Demand	→	↓	↓	↓
Transit Use	→	↑	↑	↓
Transportation Revenues	→	↑	↓	↑
Energy Costs	→	↑	↑	↓
Climate Change Impacts	→	↓	↑	↓

↓ indicates a decrease; ↑ indicates an increase, and → indicates no change from trend

What's next?

- The project report, scenario tool and user's guide is available for download from TRB…

http://www.trb.org/Main/Blurbs/171200.aspx

- Follow-up project to work with an MPO and DOT to implement the tool with local staff.
- Get user feedback and make further enhancements.