Incorporating Uncertainty into Transportation Decision Making:

A Sustainability-Oriented Approach

Christy Mihyeon Jeon, Ph.D.

Transportation Engineer

Parsons Corporation

Atlanta Model Users Group Meeting

August 27, 2010

Outline

- Objectives
- Literature Review / Current Practices
- Atlanta Case Study Overview
- Sensitivity Analysis
- Conclusions
- Limitations

Objectives

- To demonstrate how uncertainties can be incorporated when MCDM* method is used
- To examine the sensitivity of competing plans' desirability to regional priorities and weights for sustainability parameters
  - Transportation system effectiveness
  - Environmental integrity
  - Economic development
  - Social equity and public health

*Multiple Criteria Decision Making

Current Practices (1)

- Sustainability measurement through performance indicator systems
- Creation of indicators around specific themes
- Performance measures should be developed to capture a community's broader visions, goals, and objectives.

Current Practices (2)

- Analytical tools used to assess sustainability
  - Scenario planning
  - Graphical models and system dynamics approaches
  - Integrated transportation and land use models
  - Simulation and decision analysis models
- Multidimensional themes of economic, environmental, and social impacts
- More integrative models or software suites

Uncertainty Modeling

- Scenario methods
- Sensitivity Analysis
- Decision theory techniques using probabilistic approaches
  - Decision flow diagrams
  - Game simulation
  - Monte Carlo simulation

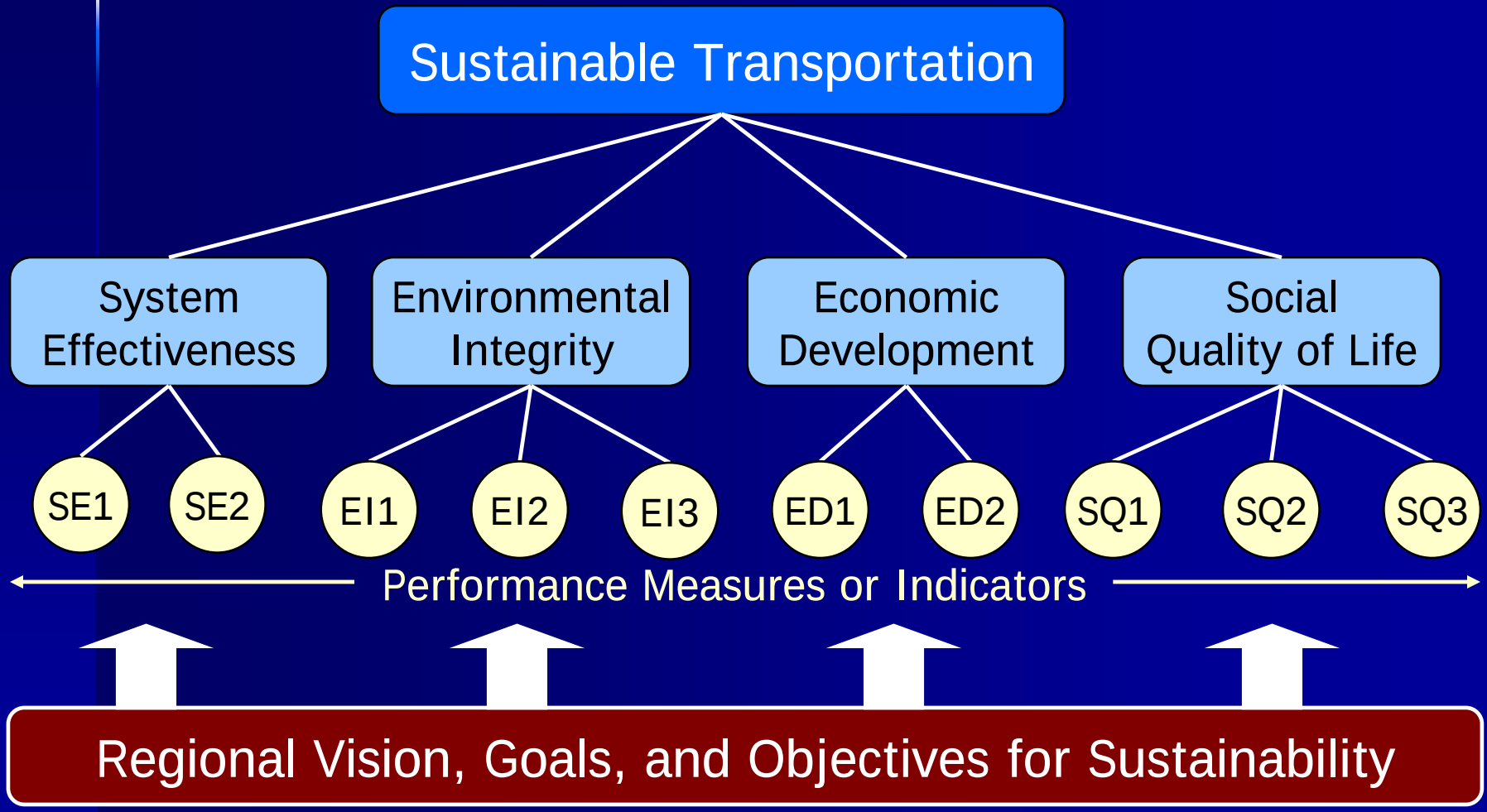
*World Commission on Environment and Development
**The Center for Sustainable Transportation (Canada)

Sustainability

- Sustainable development meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED* 1987)
- Sustainable Transportation (CST** 2002)
  - allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations;
  - is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy;
  - limits emissions and waste within the planet ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise.

Three Dimensions of Sustainability

Atlanta Case Study Overview



Atlanta Case Study Overview

Sensitivity Analysis

Sustainable Transportation

Multicriteria Decision Analysis

Decision Support Tool

System Effectiveness

Environmental

Economic

Social Quality of Life

SE1

SQ1

SQ3

Spatial and Environmental Analysis

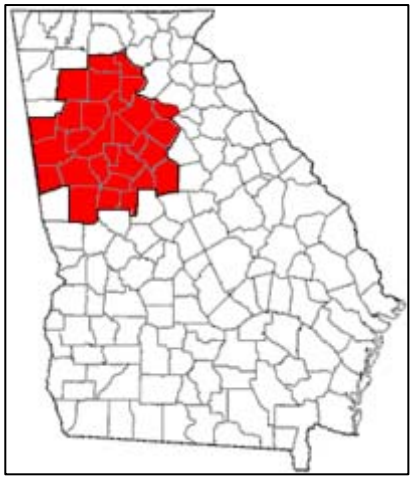
Literature Review and Case Study

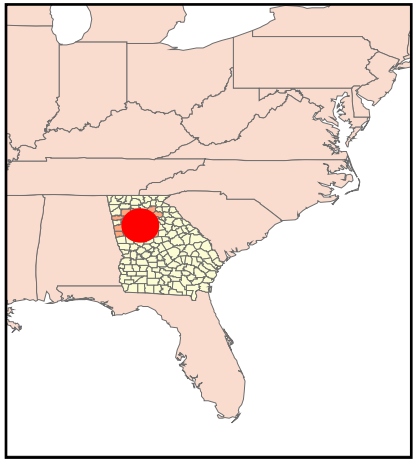
Atlanta 13 counties

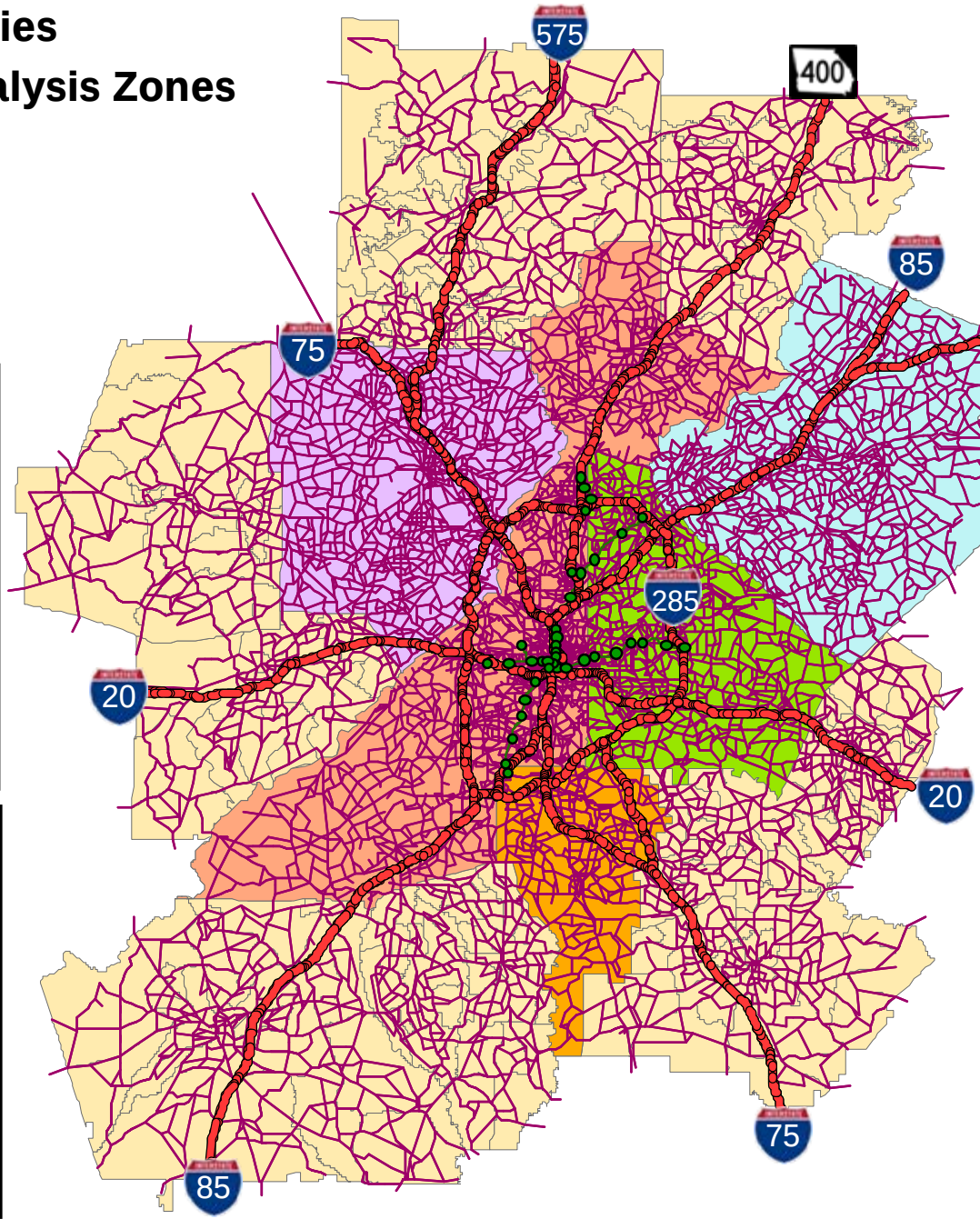
1,683 Traffic Analysis Zones

 # Nodes 18,570

 # Links 40,073







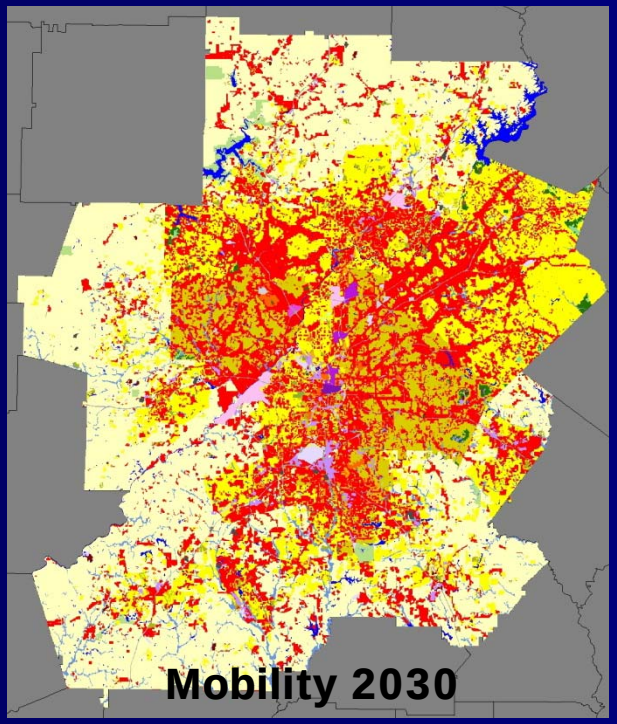
Legend

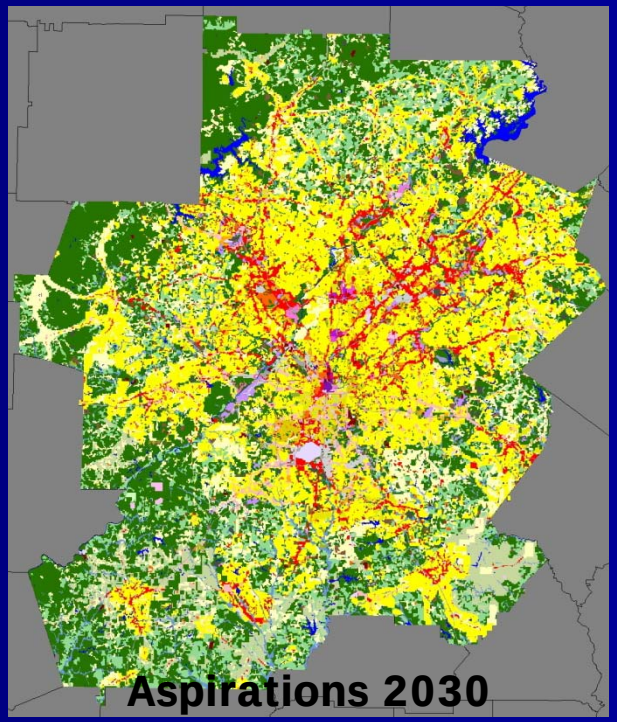
- Marta Stations
- freeway
- Marta Network
- Major Road 2005
- Clayton County
- Cobb County
- Dekalb County
- Fulton County
- Gwinnett County
- Traffic Analysis Zone

Scenarios Evaluated

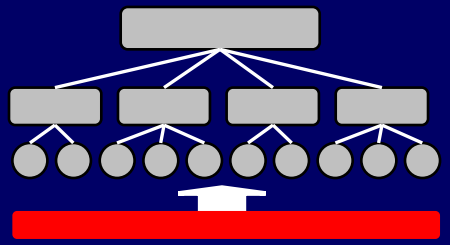
- Two future scenarios and the present system

(1) Baseline 2005 (2) Mobility 2030 (3) Aspirations 2030 – Test Case



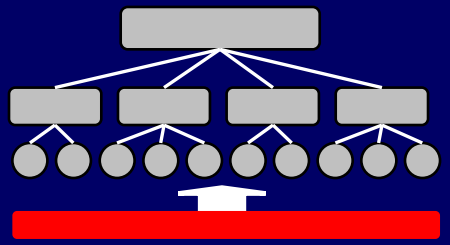


Sustainability Issues



- One of the fastest growing areas in the U.S.
  - Population 6M by 2030 (62% up from 2005)
  - Employment 4.2M by 2030 (65% up from 2005)
- Severe congestion and traffic delay
  - 10th most congested freeway system in the U.S.
- Limited transit options / high automobile dependency
  - Automobile share at 94% of total home-based work trips
- Air quality issues
  - Non-attainment area for ozone and fine particulate matter
- Social equity issues and water consumption/erosion problem

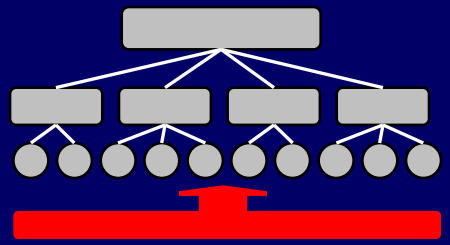
Regional Goals*



- Improve accessibility and mobility for all people and freight
- Encourage and promote safety, security, and efficient development, management, and operation of the surface transportation
- Protect and improve environment and quality of life
- Support economic growth and development

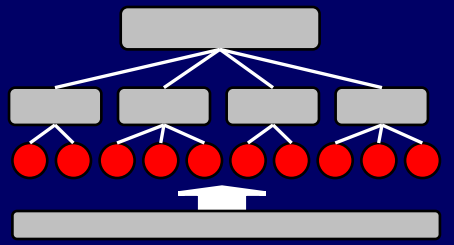
***Updated in July 2007**

Performance Measures



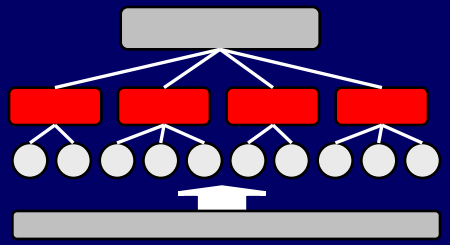
Sustainability Dimension	Goals and Objectives	Performance Measures
System Effectiveness	A1. Improve Mobility	**A11. Freeway/arterial congestion**
	A2. Improve System Performance	**A21. Total vehicle-miles traveled**; A22. Freight ton-miles; A23. Transit passenger miles traveled; A24. Public transit share
Environmental Sustainability	B1. Minimize Greenhouse Effect	**B11. CO_2 emissions**; B12. Ozone emissions
	B2. Minimize Air Pollution	**B21. VOC emissions**; B22. CO emissions; **B23. NO_x emissions**
	B3. Minimize Noise Level	B31. Traffic noise level
	B4. Minimize Resource Use	B41. Fuel consumption; **B42. Land consumption**
Economic Sustainability	C1. Maximize Economic efficiency	C11. User welfare changes; **C12. Total time spent in traffic**
	C2. Maximize Affordability	C21. Point-to-point travel cost
	C3. Promote Economic development	**C31. Employment**; **C32. Land Consumed by retail/service**
Social Sustainability	D1. Maximize Equity	D11.Equity of welfare changes; D12.Equity of exposure to noise; **D13. Equity of exposure to emissions**
	D2. Improve Public Health	**D21. Exposure to emissions**; D22. Exposure to noise
	D3. Increase Safety and Security	D31. Accidents per VMT; D32. Crash disabilities; D33. Crash fatalities
	D4. Increase Accessibility	D41. Access to activity centers; D42. Access to major services; D43. Access to open space

Evaluation Results



Sustainability Dimensions	Performance Measures	Unit	Baseline 2005	Mobility 2030	Aspirations 2030
System Effectiveness	Average Freeway Speed ♦	MPH	47	42	42
	Total VMT per capita •	Mile/Day	35	32	32
Environmental Measures	CO_2 Emissions •	Ton/Day	72,306	110,764	110,764
	VOC Emissions •	Ton/Day	118	53	53
	NO_X Emissions •	Ton/Day	210	38	38
	Land Consumption •	Acre	30,513	30,216	30,968
Economic Measures	Vehicle Hours Traveled per commuter•	Minute	13	16	16
	Employment ♦	Million	2.64	3.32	3.31
	Land Consumed by Retail ♦	Acre	161,663	532,637	217,170
Social Measures	Spatial Equity of Exposure to VOC ♦	SEI*	19	24	24
	Spatial Equity of Exposure to NO_X ♦	SEI*	20	24	24
	Income Equity of Exposure to VOC ♦	IEI**	94	87	64
	Income Equity of Exposure to NO_X ♦	IEI**	94	88	67
	Exposure to VOC •	HII***	1355	458	4135
	Exposure to NO_X •	HII***	2270	319	2767

Dimensional Index



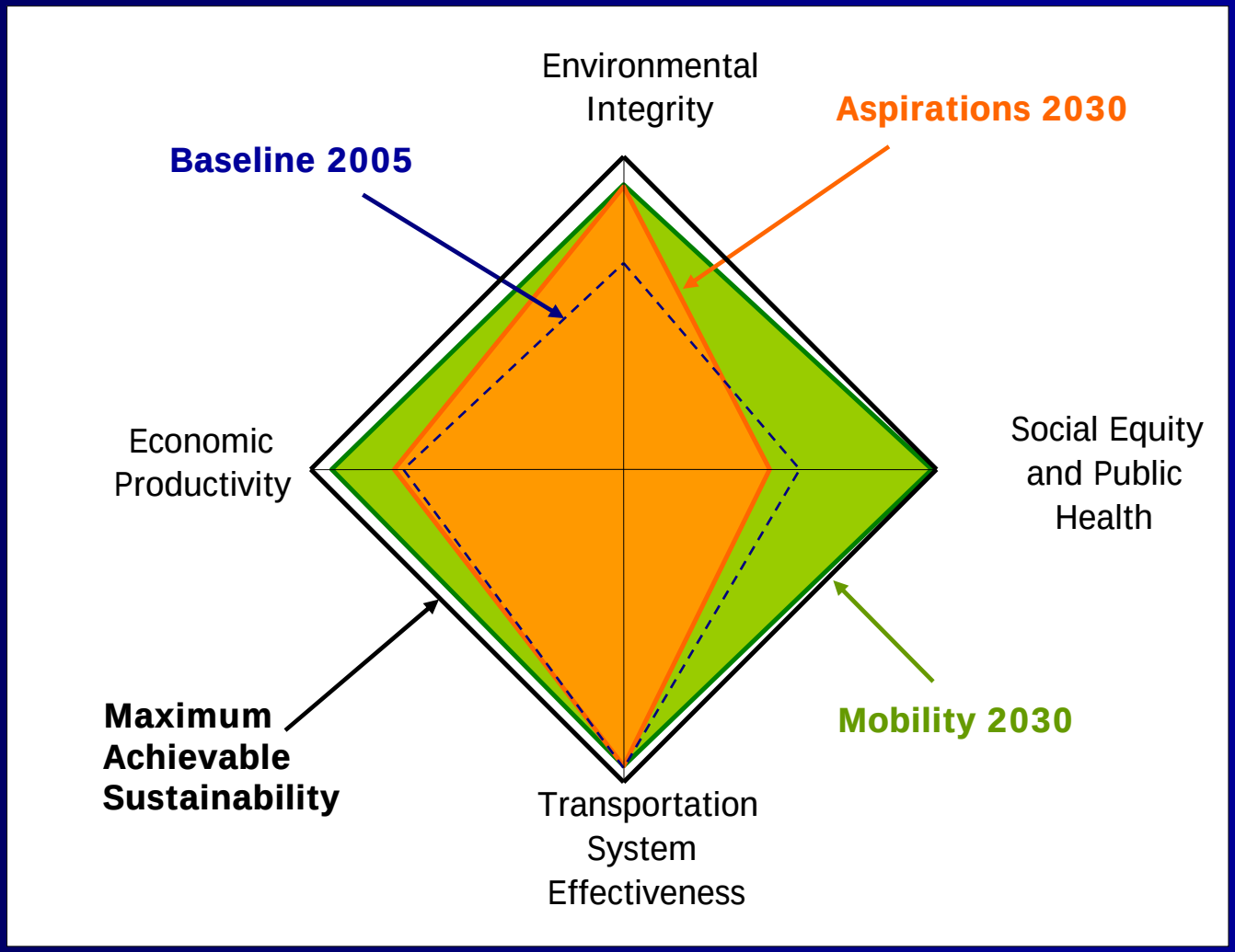
Multiple Criteria Decision Making Method

- Valuing by normalization and weighting (neutral)
- Aggregated by obtaining weighted sum of normalized criteria values:

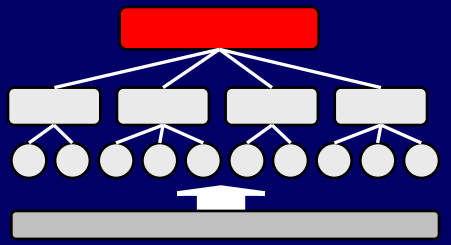
$$U_i = \sum_{j=1}^{n} w_j r_{ij}$$

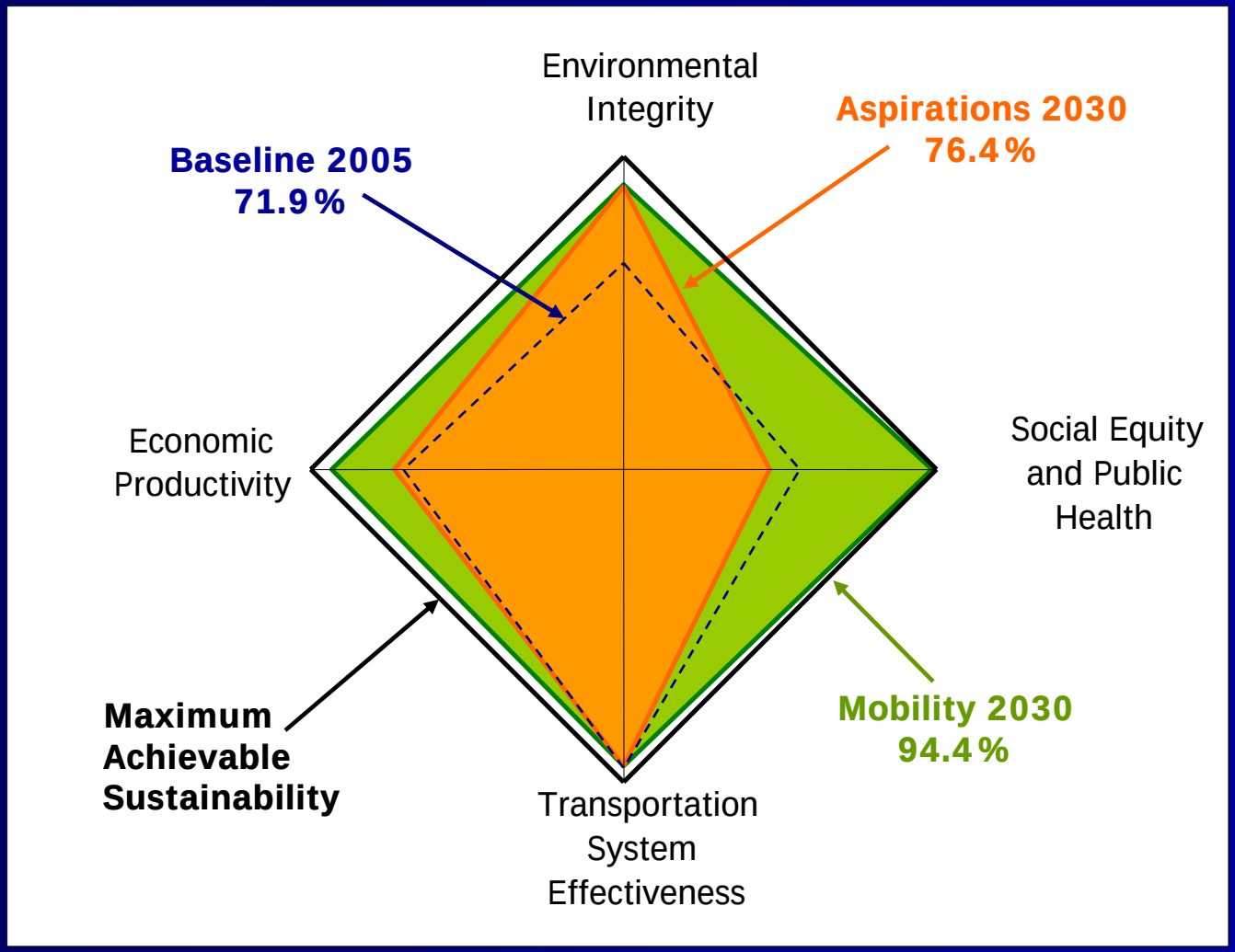
Sustainability Indexes	Baseline 2005	Mobility 2030	Aspirations 2030
Environmental Dimension	0.656	0.913	0.907
Social Dimension	0.566	0.984	0.467
System Effectiveness Dimension	0.953	0.948	0.948
Economic Dimension	0.703	0.931	0.734

Dimensional Index



Composite Index

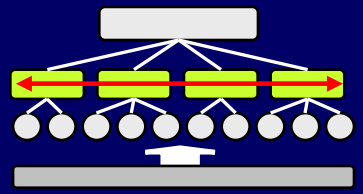


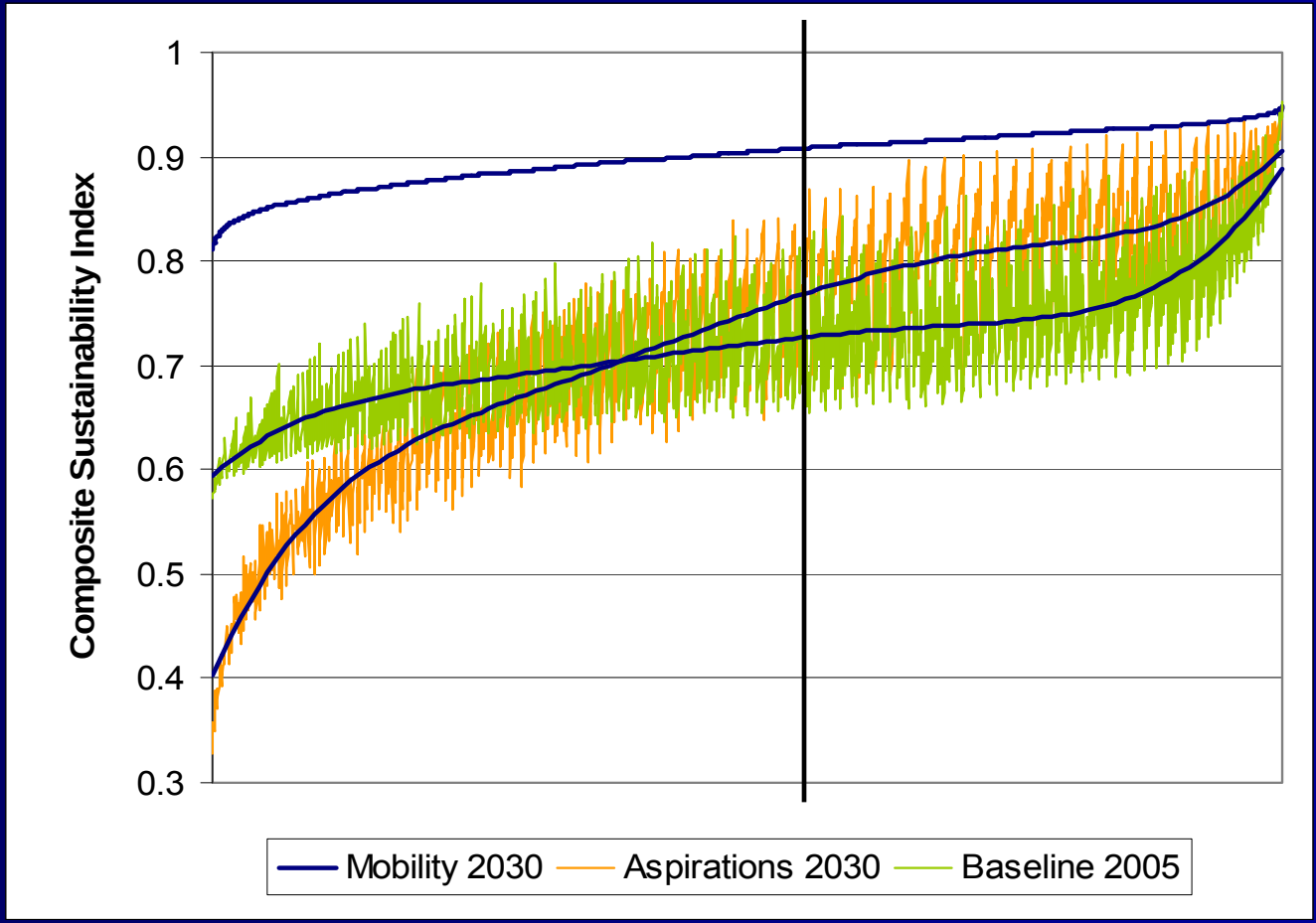


Sensitivity Analysis

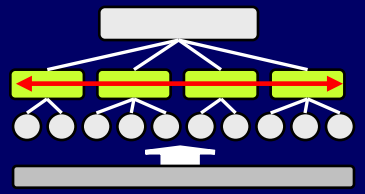
- To complement the use of subjective weights in MCDM methods
- To discuss how different regional priorities or goals influence decision making
- To enable decision makers to accommodate uncertainties
- To shed light on which alternative best achieves different regional priorities and goals

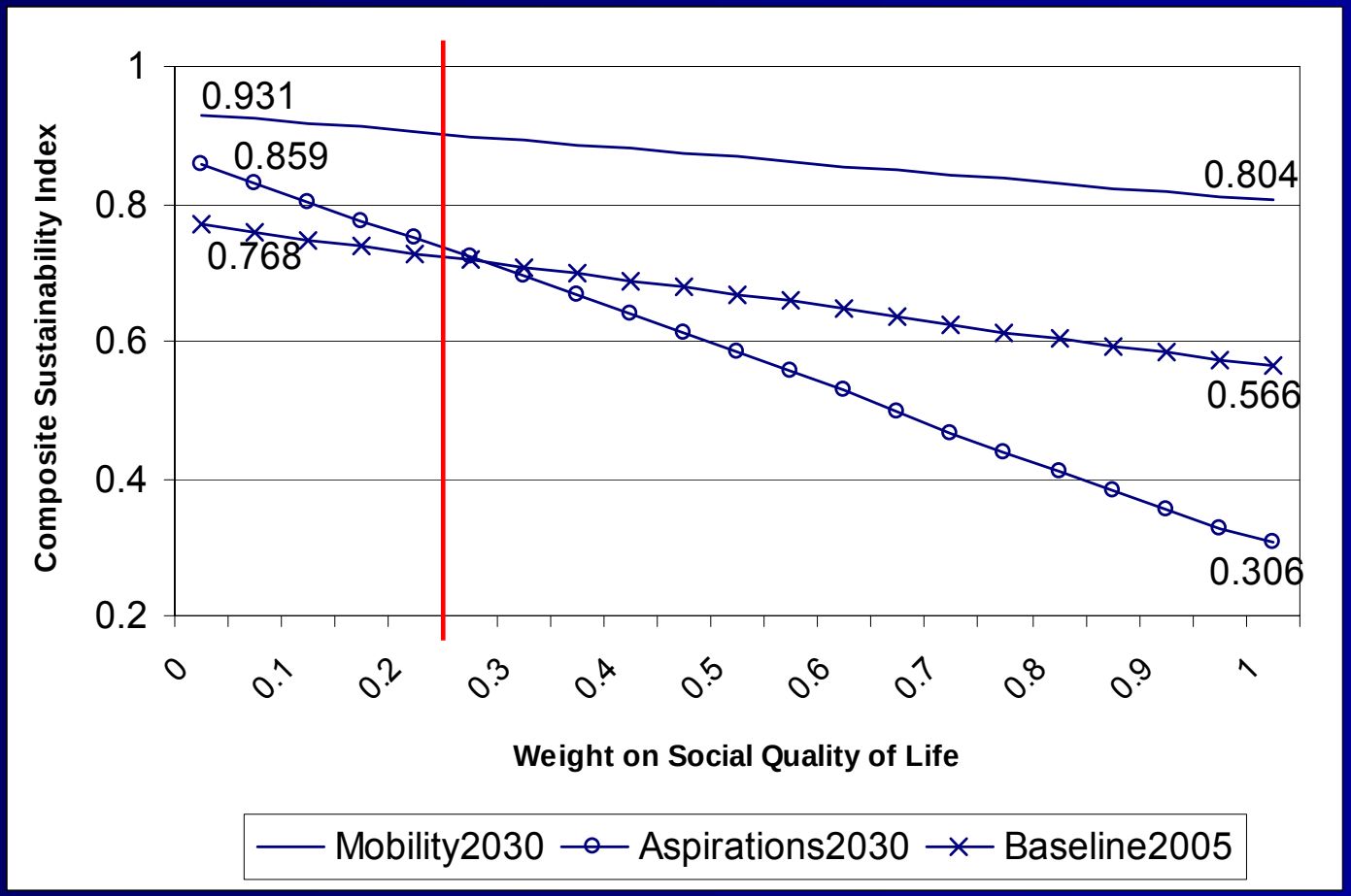
Weights on Dimensions



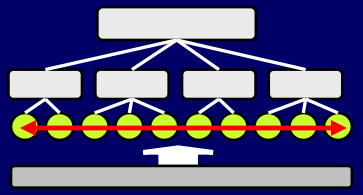


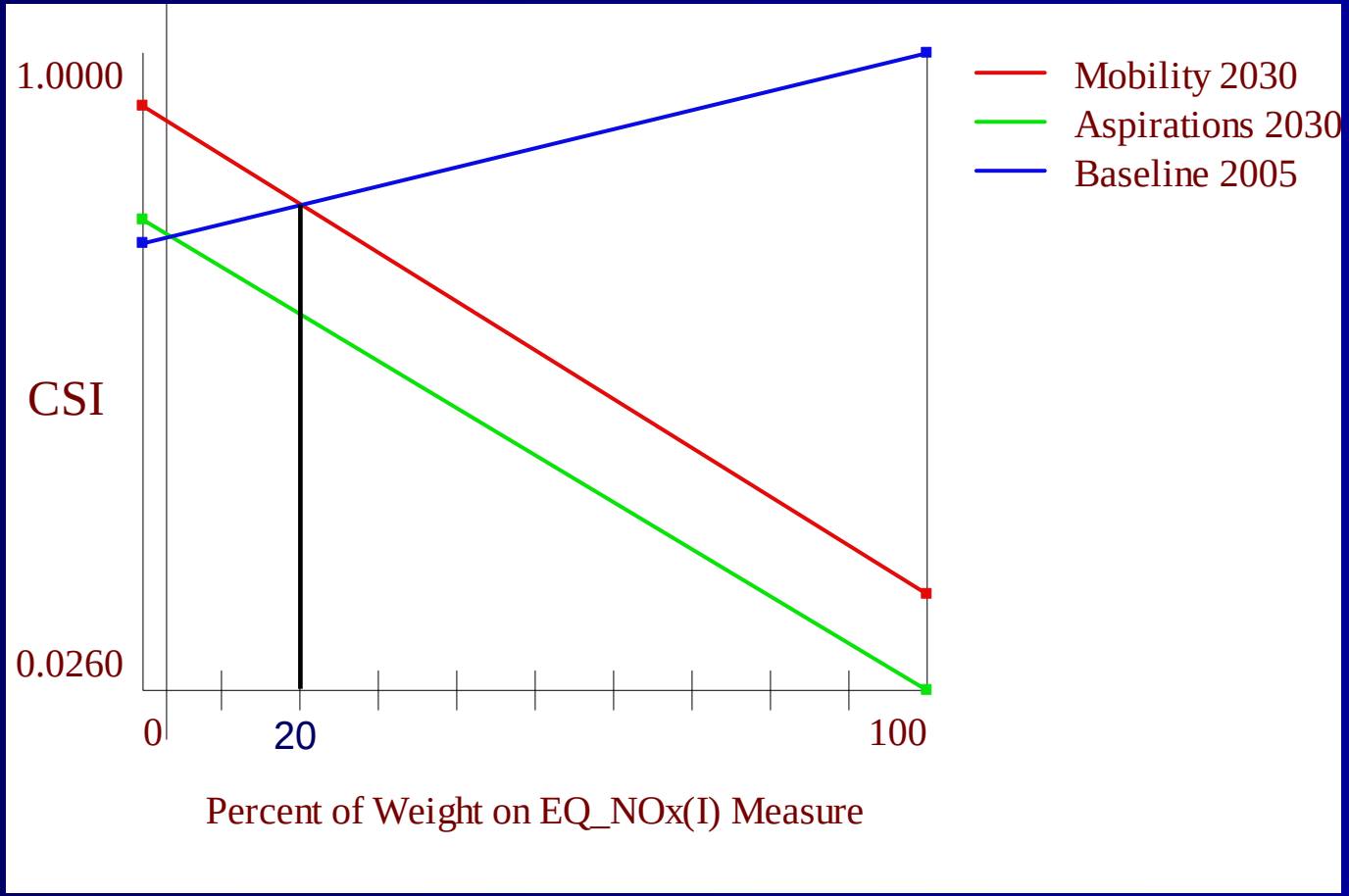
Weights on Dimensions



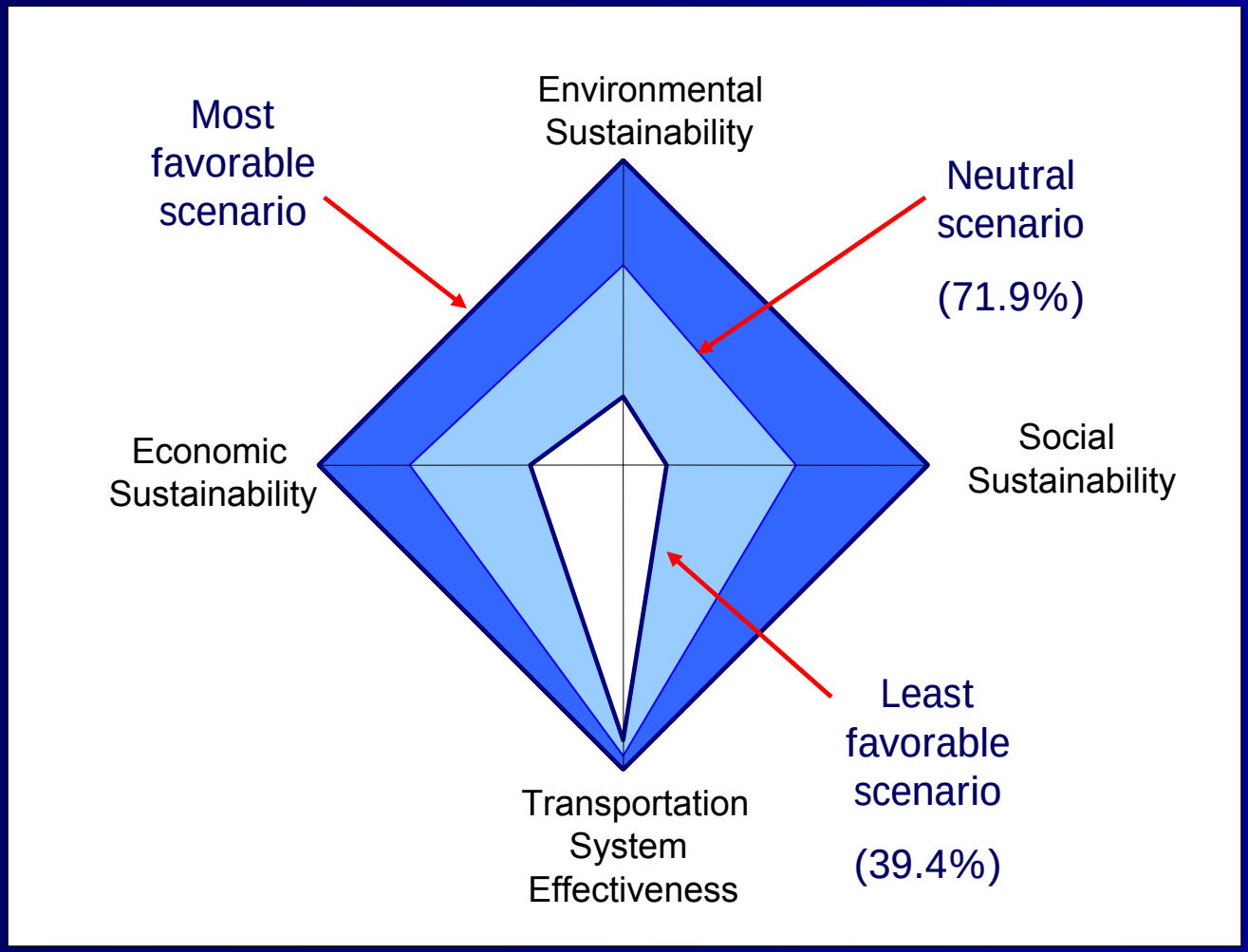


Weights on Measures

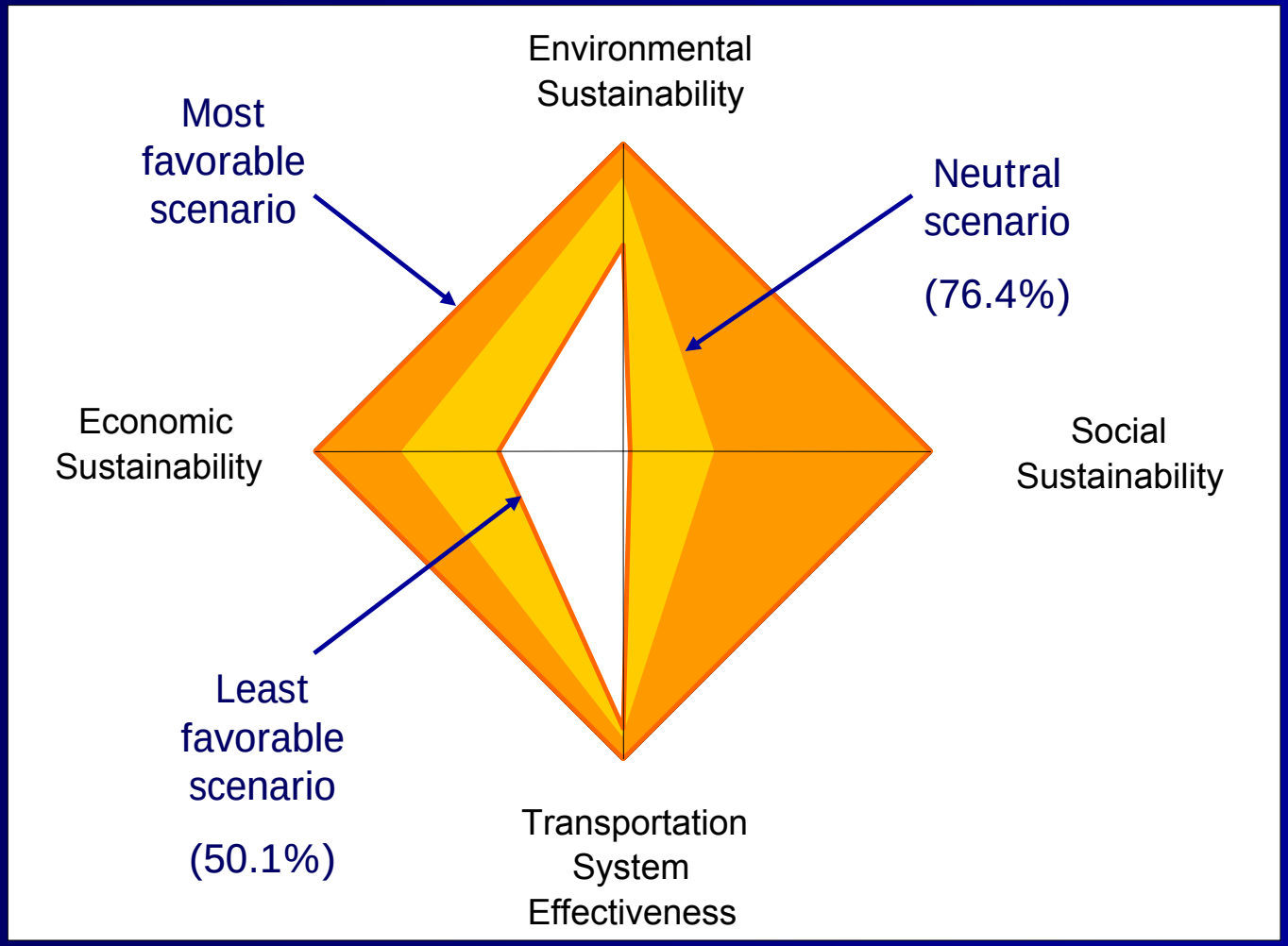




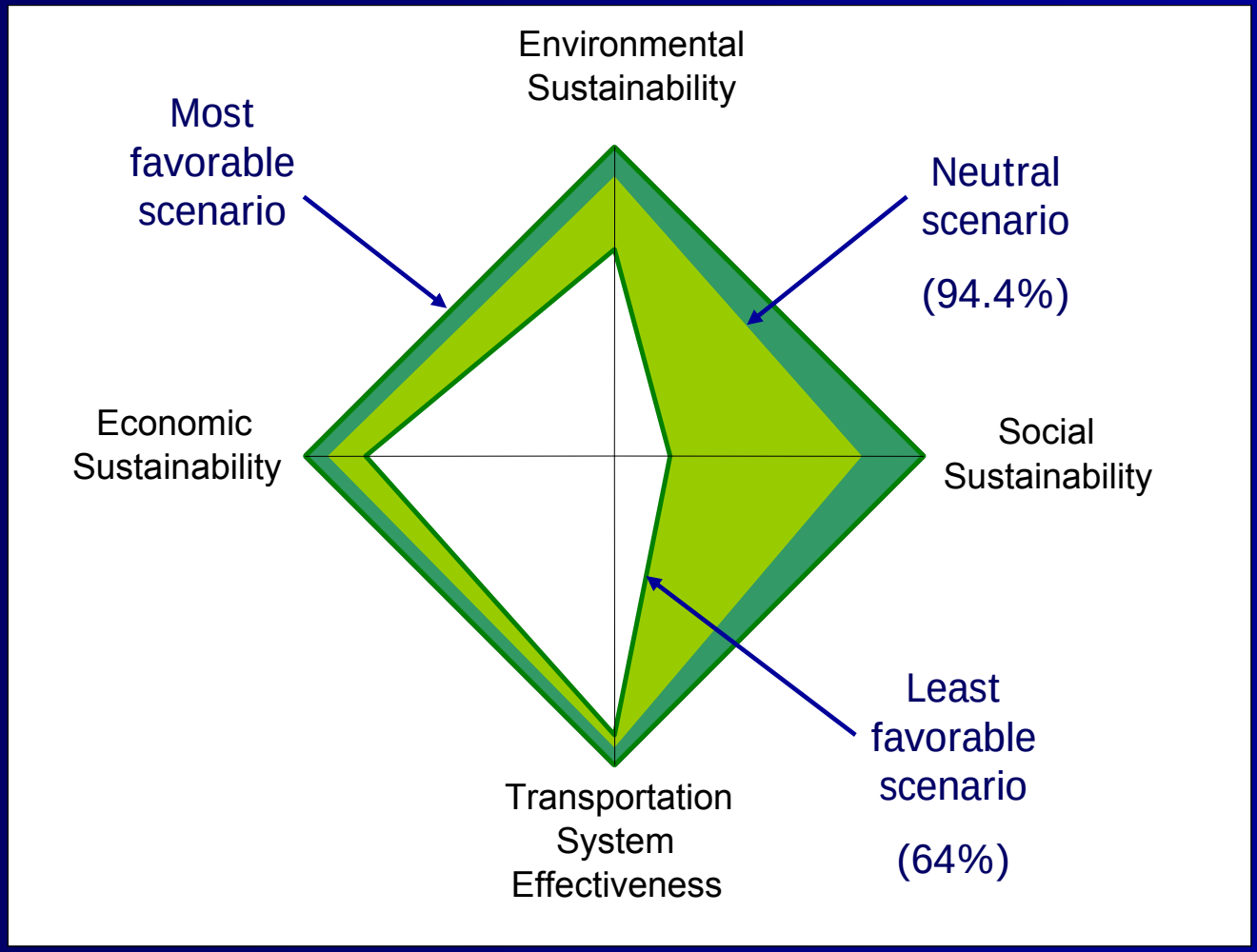
Possible Impacts of "Baseline 2005"



Possible Impacts of "Aspirations 2030"



Possible Impacts of "Mobility 2030"



Conclusions

- Regional priorities or weights play a critical role on deciding the preferred plan alternative.
- Sensitivity analysis shows decision makers which plan is superior relative to his/her priorities.
- Decision makers can overcome uncertainties by understanding outcomes of different weights.
- Switchover information can help consensus building process.

Limitations

- The use of Test Case Scenario (Aspirations 2030)
- Comprehensiveness and effectiveness of performance measures

Questions/Comments

Christy Mihyeon Jeon
christy.jeon@parsons.com