EVALUATION:

Based On
Perspectives on Efficiency in Transportation
and
Identifying Winners and Losers in Transportation

David Levinson
## Four Perspectives on Efficiency

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Profession</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility and Safety</td>
<td>Engineers</td>
</tr>
<tr>
<td>Utility (Consumer’s Surplus)</td>
<td>Economists</td>
</tr>
<tr>
<td>Productivity</td>
<td>Managers</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Planners</td>
</tr>
</tbody>
</table>
Reason for Multiple Measures

- Planning, investment, regulation, design, operations, management, and assessment.
- Each profession claims to represent traveler.
- Professions take the "objective" viewpoint of the omniscient central planner (who may in fact be an engineer, manager, or economist) rather than the "subjective" perspective of the travel consumer.
Criteria for Choosing MOE

1. Different measures (e.g. transit and auto level of service) should be collectively complete in that one could combine them to attain an overall measure.

2. Each measure should scale or aggregate well (e.g. it should be possible to combine measures of auto level of service measured on separate links or for separate trips).

3. The measure should align with user experience and be understood by those users.

4. The performance indicator must be measurable, or calculable from available (observable) data.

5. The measure should be predictable, or able to be forecast

6. It must be useful in a regulatory or control context (so that the measure can be used to allow or restrict new development to maintain standards, or to help guide operational traffic engineering decision).
NORMATIVE AND POSITIVE

• To say that the speed on a link is 50 kilometers per hour tells us nothing about whether that is good or bad, it simply is.

• By comparing the measure to a normative standard (for instance, a speed limit), we can then determine whether we have a speeding problem (the speed limit is 30 kph), a congestion problem (the speed limit is 110 kph), or no problem.
Mobility

- Highway Capacity Manual (segments)
- Texas Transportation Institute (metro areas)
- Quantitative and Qualitative
- Auto and Non-auto
- Scale: Intersection, Link, Subnetwork, Trip, Network
- Basis: Time or Flow
# Roadway Mobility Measures

<table>
<thead>
<tr>
<th>Measurement Scale</th>
<th>Volume and Capacity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection approach</td>
<td>Volume to Capacity Ratio:</td>
<td>Stopped Delay:</td>
</tr>
<tr>
<td></td>
<td>Queue Length</td>
<td></td>
</tr>
<tr>
<td>Total Intersection</td>
<td>Critical Lane Volume:</td>
<td>Average Delay:</td>
</tr>
<tr>
<td>Road Segment</td>
<td>Density:</td>
<td>Average Delay:</td>
</tr>
<tr>
<td></td>
<td>Volume to Capacity Ratio:</td>
<td>Average Travel Time:</td>
</tr>
<tr>
<td>Road Network</td>
<td>Area Cordon:</td>
<td>Average Travel Time (Distance):</td>
</tr>
<tr>
<td></td>
<td>Area Screenline:</td>
<td>Average Percent Delay:</td>
</tr>
<tr>
<td></td>
<td>Average Congestion Index:</td>
<td>Average Trip Time (Distance)</td>
</tr>
<tr>
<td></td>
<td>Average of Area Intersection:</td>
<td>Should Hour Index:</td>
</tr>
<tr>
<td></td>
<td>Distribution Measure:</td>
<td>Distribution Measure:</td>
</tr>
</tbody>
</table>
Qualitative Mobility Measures

Volume & Capacity
- Parking Availability and Cost
- Connectivity
- Conflict with Non-auto System
- Hazard
- Auto Service Stations
- Comfort

Time
- Coverage
- Aesthetics
- Destination Distribution
- Information System
## Non-Auto Mobility Measures

<table>
<thead>
<tr>
<th>Measurement Stage</th>
<th>Volume and Capacity</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk (Bike) and Walk Access and Egress to Transit</td>
<td>Sidewalk (Bikeway) Ratio</td>
<td>Coverage</td>
</tr>
<tr>
<td></td>
<td>Connectivity</td>
<td>Circuity</td>
</tr>
<tr>
<td></td>
<td>Hazard</td>
<td>Delay</td>
</tr>
<tr>
<td></td>
<td>Bicycle Parking</td>
<td>Aesthetic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Travel Time</td>
</tr>
<tr>
<td>Auto Access and Egress</td>
<td>Parking Availability and Cost</td>
<td>Park and Ride Access Time</td>
</tr>
<tr>
<td>Waiting</td>
<td>Waiting comfort</td>
<td>Frequency</td>
</tr>
<tr>
<td>In-Vehicle</td>
<td>Usage</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td>Service Comfort</td>
<td>Reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Absolute Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Relative Time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Directness</td>
</tr>
</tbody>
</table>
Consumer’s Surplus

Generalized Cost (C)

C₁
C₂

Demand

S₁
S₂

Quantity of Trips

Q₁
Q₂

CS

ΔCS

e
d

0

a

b

c
Consumer’s Surplus Criticisms

- Transportation rather than activities as the base for consumer's surplus
- Aggregation error involved.
- No consideration of choice and the existence of non-user benefits in the consumers’ surplus metric.
- The costs and benefits associated with spillovers and externalities are often improperly captured
# Productivity Measures

<table>
<thead>
<tr>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity of Public Labor ($P_{GL}$)</td>
<td>$P_{GL} = \frac{\sum T_i}{\sum H_i}$</td>
</tr>
<tr>
<td>Productivity of Private Labor ($P_{PL}$)</td>
<td>$P_{PL} = \frac{\sum T_i}{\sum D_i}$</td>
</tr>
<tr>
<td>Productivity of Public Capital ($P_{GK}$)</td>
<td>$P_{GK} = \frac{\sum T_i}{\sum K_i}$</td>
</tr>
<tr>
<td>Productivity of Private Capital ($P_{PK}$)</td>
<td>$P_{PK} = \frac{\sum T_i}{\sum V_i}$</td>
</tr>
</tbody>
</table>

Where: $T = $ Travel on the system in question (person-km or ton-km), $H = $ Hours of labor by employees of the highway agency (including professional drivers), $D = $ Hours of time by the driver and passengers spent on the network in question (excluding professional drivers), $K = $ Dollars of public capital spent (building and maintaining the infrastructure), $V = $ Dollars of private capital spent (the share of the cost of owning and operating a vehicle, exclusive of taxes to pay for public capital for its use on the network in question), $l$ denotes links in the set of links $L$ under question.
## Accessibility Measures

<table>
<thead>
<tr>
<th>Description</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility ($A$) in zone $i$ depends on the opportunities (e.g. jobs $P$) in zone $j$ and the transportation cost $c_{ij}$ between them</td>
<td>$A_i = \sum_j P_j f(c_{ij})$</td>
</tr>
<tr>
<td>Job - Worker Ratio ($R$) in zone $i$ at radius $r$ (in transportation cost) is the Jobs ($P$) within radius $r$ divided by Workers ($Q$) within radius $r$</td>
<td>$R_i = \frac{\sum_{j=1}^i P_j}{\sum_{j=1}^i Q_j}$</td>
</tr>
<tr>
<td>Density ($D$) in zone $i$ is the sum of jobs and workers within radius $r$, divided by the area contained within</td>
<td>$D_i = \frac{\sum_{j=1}^i P_j + Q_i}{\pi r^2}$</td>
</tr>
<tr>
<td>Difference ($\Delta$) in zone $i$ is the difference between the number of jobs and workers in radius $r$</td>
<td>$\Delta_i = \sum_{j=1}^i P_i - Q_i$</td>
</tr>
<tr>
<td>Force ($F$) between zones $i$ and $j$ is the product of the jobs ($P$) in zone $j$ and the workers ($Q$) in zone $i$ and a function of the transportation cost $c_{ij}$ between them</td>
<td>$F_i^j = \delta^i j \cdot b_{ij} (c_{ij})$</td>
</tr>
</tbody>
</table>
Accessibility

![Graph showing Accessibility]

- Propensity, Normalised Trips
- Job Supply
Travelers and Subjectivity

• Just as Einstein noted that the point of view of the observer shaped the measurement of time, point of view also affects the perception of time as a measure of transportation level of service.

• Moving towards trip-based measures of effectiveness will more closely align with user experience
Motivation

• Welfare comprises efficiency and equity.
• An allocation is *Pareto Efficient* if there is no other allocation in which some other individual is better off and no individual is worse off.
• Benefit/Cost analysis concerned with net benefits, not distribution.
• Transportation projects and policies create both winners and losers from mobility, accessibility, environmental, and economic standpoints.
Some Terms

• **Horizontal equity**: allocation of benefits and costs among individuals and groups who are similar.

• **Vertical equity**: distribution of benefits and costs across different groups.

• **Process equity**: equal access to the planning and decision making process.

• **Result equity**: examines the outcome.
# Environmental Costs

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Long Run Average Cost ($/vkt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>$0.13</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>$0.0174</td>
</tr>
<tr>
<td>Freeflow Time</td>
<td>$0.15</td>
</tr>
<tr>
<td>Congestion</td>
<td>$0.0045</td>
</tr>
<tr>
<td>Accidents</td>
<td>$0.031</td>
</tr>
<tr>
<td>Noise</td>
<td>$0.006</td>
</tr>
<tr>
<td>Air Pollution</td>
<td>$0.0056</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$0.34</strong></td>
</tr>
</tbody>
</table>
NIMBY and Equity

- NIMBYs - Not in My Back Yard ‘selfishly’ oppose new road projects
- Assumed to be on “property value” grounds.
- May in fact be on “mobility” basis.
- Neighbors do not gain mobility benefits in same way as through trips. Roads often benefit non-locals at expense of locals.
- Most projects create both winners and losers.
- Losers use politics to stop projects which may have an overall net benefit to society.
Example 1: Y-Network

- Inelastic Trip Productions and Attractions
- Inelastic Trip Production, Elastic Trip Attractions
- Elastic Trip Productions and Attractions
Example 2: Network Bridge

- n=10 origins and destinations
- m=n(n-1)=90 markets
- Elastic demand
- 42 markets using bridge are better off
- 48 markets not using bridge are worse off
- N(Losers) > N(Winners)
Example 3: Network Grid

- Same number of markets.
- Elastic Demand
- Some traffic not using improved link also benefits.
- $N$(Winners) > $N$(Losers)
Measuring Equity: Lorenz Curve and Gini Coefficient

Gini Coefficient = $A_1/(A_1+A_2)$
**Measuring Equity: Entropy**

\[ H = - \sum_{j} (y_j \cdot \log_k y_j) \]

- \( H \) = the entropy statistic
- \( y_j \) = the proportion of average net gains to the \( j^{th} \) class
- \( k \) = the log base

To analyze traffic data, we can take:

\( y_i = \) proportion of total delay accrued by each individual

\( H \) statistic approaches zero as the distribution approaches complete inequality
Measuring Equity: Redundancy

\[ R = 1 - \frac{H}{H_{\text{max}}} \]

- \( R \) = the measure of redundancy
- \( H \) = the calculated entropy
- \( H_{\text{max}} \) = the maximum possible entropy

- \( R \)-value of 0% represents complete equality
**Twin Cities Ramp Meters**

**TH169 mobility vs. temporal equity**

- **Gini Coefficient**:
  - **Metering On Case**
  - **Metering Off Case**

- **Ave. Travel Delay (sec)**
  - **OD Pair**

- **Twin Cities Ramp Meters**

- **Graph**
  - **X-axis**: OD Pair
  - **Y-axis**: Gini Coefficient and Ave. Travel Delay (sec)
  - **Legend**:
    - Metering On Case
    - Metering Off Case
Twin Cities Ramp Meters 2

TH169 mobility vs. spatial equity

Gini Coefficient

Ave. Travel Speed (mph)

- Metering On Case
- Metering Off Case

More Equitable

Time

Environmental Justice

- Environmental Justice considers "fair treatment for people of all races, cultures, and incomes (Executive Order 12898)" regarding the development of environmental laws and policies.
- Considers only environment.
- Considers only a few groups.
- Only a partial consideration of equity.
## Equity Impact Statement

<table>
<thead>
<tr>
<th>Stratification</th>
<th>Process</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Opportunity to Engage in Decision-Making</td>
<td>Mobility Economic Environmental Health Other</td>
</tr>
</tbody>
</table>

Population
Spatial
Temporal
Modal
Generational
Gender
Racial
Cultural
Ability
Income
Conclusions

• Four Classes of Efficiency Measures: Mobility, Utility, Productivity, Accessiblity.

• Each is a gauge, none should be exclusive.

• None captures the subjective perspective of travelers.

• New measures must be developed which do reflect the customer.
Conclusions: Equity is Efficient

• Equity a central issue for transportation, not just because it is ‘right’ but also because it is efficient if we actually want to implement projects. (An un-implemented project serves no one).

• Need to think beyond single project: Develop means for compensation of losers from gains of winners. Side payments, bargains, and bundles of projects may accomplish this.

• Danger of log-rolling turning into pork barrel.

• Equity must be broadly considered.

• Things need not be strictly fair, but the unfairness inherent should not be unknown.
Growth in Traffic and Network

Growth in Network and Traffic

- Total rural and urban mileage
- Total rural and urban VMT (thousands)
Engineering Systems

- We are interested in systems with the following characteristics:
  - Technologically Enabled
  - Large Scale (large number of interconnections and components)
  - Complex
  - Dynamic, involving multiple time scales and uncertainty
  - Social and natural interactions with technology
  - May have Emergent Properties
ES Requires

• An Interdisciplinary Perspective—technology, management science and social science

• The incorporation of system properties, such as sustainability, safety and flexibility in the design process. (These are lifecycle properties rather than first use properties.)

• An Enterprise Perspective

• The incorporation of different stakeholder perspectives
ES Examples

- Military Aircraft Production & Maintenance Systems
- Commercial & Military Satellite Constellations
- Megacity Surface Transportation Systems
- The Worldwide Air Transportation & Air Traffic Control System
- The World Wide Web & the Underlying Internet
- Automobile Production & Recycling Systems
- Consumer Supply Logistics Networks
- Electricity Generation & Transmission Systems
Hierarchy of Knowledge

- 1. Observation
- 2. Classification
- 3. Abstraction
- 4. Quantification and Measurement
- 5. Symbolic Representation
- 6. Symbolic Manipulation
- 7. Prediction
Disciplines with ES

• Systems Engineering
• Operations Research
• Engineering Management
• Technology Policy
**Systems Architecture**

- an abstract description of the entities of a system and the relationships between those entities.
- System engineering theory works most smoothly when the product can be broken into modules that are relatively independent - Modular.
- When products cannot be decomposed simply, or when their behaviors interact, they are called integral.
Examples of Desirable and Undesirable Anticipated and Emergent System Properties Influenced by Architecture

<table>
<thead>
<tr>
<th></th>
<th>Anticipated</th>
<th>Emergent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirable</td>
<td>Electric power networks share the load.</td>
<td>Blackouts are associated with increased births.</td>
</tr>
<tr>
<td></td>
<td>Hub-spokes airline routes shorten the length of trips.</td>
<td>Hub-spokes plus waiting time creates a business opportunity in airport malls.</td>
</tr>
<tr>
<td>Undesirable</td>
<td>Power networks can propagate blackouts.</td>
<td>Blackouts are associated with increased births.</td>
</tr>
<tr>
<td></td>
<td>Hub-spokes causes huge swings in workload and resource utilization at airports.</td>
<td>Airport operators become dependent on mall rental income, making it difficult to modify airline route structures.</td>
</tr>
</tbody>
</table>
4 Types of Architectures

- The functional architecture (a partially ordered list of activities or functions that are needed to accomplish the system’s requirements)
- The physical architecture (at minimum a node-arc representation of physical resources and their interconnections)
- The technical architecture (an elaboration of the physical architecture that comprises a minimal set of rules governing the arrangement, interconnections, and interdependence of the elements, such that the system will achieve the requirements)
- The dynamic operational architecture (a description of how the elements operate and interact over time while achieving the goals)
Why is System Architecture Important?

• Architecture Is A Way To Understand Complex Systems
• Architecture Is A Way To Design Complex Systems
• Architecture Is A Way To Design Standards And Protocols To Guide The Evolution Of Long-lived Systems
• Architecture Is A Way To Manage Complex Systems
Decomposition of Architecture

Things With Architectures

Entities
- Natural Systems
- Designed By People

Other Architectures That Inform Or Constrain The Architectures Of Entities
- Standards & Protocols
- Product Families And Platforms

Designed by People
- Physical
  - Energetic
    - Typical Products
    - Infrastructures
  - Hardware Information Processors
- Non-Physical
  - Software
  - Organizations
  - Intellectual Frameworks
Further Decomposition
Properties

• Delivery of Basic Function: Performance & Cost
• Illities: Flexibility Robustness Scalability Safety Durability Sustainability Reliability Recyclability Maintainability Quality
• Characteristics: Complexity, Emergence, Systems Architecture, Uncertainty
Robustness

- Robustness is defined as “the demonstrated or promised ability of a system to perform under a variety of circumstances, including the ability to deliver desired functions in spite of changes in the environment, uses, or internal variations that are either built-in or emergent” (ESD 2002).
Adaptability

• Adaptability is defined as “the ability of a system to change internally to fit changes in its environment,” usually by self-modification to the system itself (ESD 2002).
Flexibility

- Flexibility is defined as “the property of a system that is capable of undergoing classes of changes with relative ease. Such changes can occur in several ways: a system of roads is flexible if it permits a driver to go from one point to another using several paths. Flexibility may indicate the ease of ‘programming’ the system to achieve a variety of functions. Flexibility may indicate the ease of changing the syscomplexity and rework” (ESD 2002).
Safety

• Safety is defined as “the property of being free from accidents or unacceptable losses.” Associated with this definition are several others: An accident is “an undesired and unplanned (but not necessarily unanticipated) event that results in a specified level of loss” (human, economic, etc). A hazard is “a state or sets of conditions that, together with worst-case external conditions, can lead to an accident.” Risk is “the level of hazard combined with the likelihood of the hazard leading to an accident, and the duration of exposure to the hazard” (Leveson 1995).
Scalability

Scalability is defined as “the ability of a system to maintain its performance and function, and retain all its desired properties when its scale is increased greatly, without causing a corresponding increase in the system’s complexity” (ESD 2002).
Complexity is Complex

• 1. Behavioral complexity—A system is deemed behaviorally complex if its external behavior is difficult to predict. Unfortunately, it does not take much to achieve this state of affairs. Chaotic and thus unpredictable behavior can be achieved with a relatively simple mechanical arm.

• 2. Interface complexity—A system has a complex interface if it has numerous components, such as knobs and dials, in its interface to humans or to other technical systems. Systems with complex interfaces are usually difficult for humans to operate or successfully integrate with other systems. George Miller wrote a famous paper in psychology called The Magical Number 7±2 (1956). An interpretation of the paper is that humans are limited in their processing ability to dealing with no more than 7±2 different things at any one time.

• 3. Structural complexity—A system is structurally complex if it has numerous components whose interconnection, interaction or interdependence is difficult to describe or understand. Our discussion below will emphasize structural complexity. It is hoped that systems whose structural complexity is reasonably limited will meet the traditional, and some non-traditional, properties and goals without too much difficulty.
### Sustainable Transportation

<table>
<thead>
<tr>
<th>Environment</th>
<th>Economy</th>
<th>Equity</th>
<th>Institutional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to Recycle;</td>
<td>Affordability;</td>
<td>Access &amp; Choice;</td>
<td>Appropriate Use of Land &amp; Resources;</td>
</tr>
<tr>
<td>Assimilative</td>
<td>Cost-efficiency;</td>
<td>Equitable</td>
<td>Comprehensive &amp; Participation &amp;</td>
</tr>
<tr>
<td>Capacity;</td>
<td>Cost</td>
<td>Economic Growth</td>
<td>Long-term Planning; Education;</td>
</tr>
<tr>
<td>Avoidance of</td>
<td>Internalization;</td>
<td>(Share the Gains)</td>
<td>Goals, Performance, and Outcomes;</td>
</tr>
<tr>
<td>Irreversibility;</td>
<td>Economic Growth;</td>
<td>Environmental</td>
<td>Improvement in Automobile</td>
</tr>
<tr>
<td>Precautionary;</td>
<td>Economic Well-</td>
<td>Justice;</td>
<td>Dependency;</td>
</tr>
<tr>
<td>Preventive;</td>
<td>being;</td>
<td>Poverty Reduction;</td>
<td>Technological</td>
</tr>
<tr>
<td>Regenerative;</td>
<td>Effective Use</td>
<td>Social Well-being;</td>
<td>Integration;</td>
</tr>
<tr>
<td>Stewardship;</td>
<td>of Innovation;</td>
<td>Social</td>
<td>International</td>
</tr>
<tr>
<td>Substitutability;</td>
<td>Quality of Life</td>
<td>Responsibility</td>
<td>Cooperation</td>
</tr>
<tr>
<td>Use of Energy</td>
<td></td>
<td></td>
<td>Protection of Health &amp; Safety;</td>
</tr>
</tbody>
</table>

**The Three E’s of Sustainable Transportation**

- **E**
- **E**
- **E**

**“I/C”**

- "I/C" for System Innovation/Change
Twin Cities Transit & Land Use

• Questions:
• Consider Light Rail Transit in Minneapolis and the “Illities” ... Does the system exhibit properties that are desirable, undesirable? What are they?
Sussman’s Key Points

As relayed by David Levinson
People and organizations alter behavior based on transportation system expectations.
Transportation service is part of a broader system - economic, social, and political in nature.
Competition, or its absence, for customers by operators is a critical determinant of the availability of quality transportation service.
Analyzing the flow of vehicles on transportation networks, and defining and measuring their cycle is a basic element of transportation systems analysis.
Queueing for service and customers and storage for vehicles/freight/travelers are fundamental elements of transportation systems.
Intermodal and intramodal transfers are key determinants of service quality and cost.
Operating policy affects level of service
Capacity is a complex system characteristics affected by: infrastructure, vehicles, technology, labor, institutional factors, operating policy, external factors (e.g. clean air, safety, regulation).
Level of service = f(volume); transportation supply. As volume approaches capacity, level of service deteriorates dramatically - the "hockey stick" phenomenon.
The availability of information (or the lack thereof) drives system operations and investment and customer choices.
The shape of transportation infrastructure impacts the fabric of geo-economic structures.
The cost of providing a specific service, the price charged for that service, and the level-of-service provided may not be consistent.
The computation of cost for providing specific services is complex, and often ambiguous.
Cost level of service tradeoffs are a fundamental tension for the transportation provider and the transportation customer, as well as between them.
CONSOLIDATION OF LIKE DEMANDS IS OFTEN USED AS A COST MINIMIZING STRATEGY.
Investments in capacity are often lumpy (e.g. infrastructure).
The linkages between Capacity, Cost, and Level of Service - the lumpiness of investment juxtaposed with the hockey stick level of service function as volume approaches capacity - is the central challenge of transportation systems design.
Temporal peaking in demand: a fundamental issue is design capacity - how often do we not satisfy demand.
Volume = f(level of service);
transportation demand.
Level of service is usually multidimensional. For analysis purposes, we often need to reduce it to a single dimension, which we call utility.
Different transportation system components and relevant external systems operate and change at different time scales (e.g. short run - operating policy; medium run - auto ownership; long run infrastructure, land use).
EQUILIBRATION OF SUPPLY AND DEMAND FOR TRANSPORTATION SERVICE TO PREDICT VOLUME IS A FUNDAMENTAL NETWORK ANALYSIS METHODOLOGY.
Pricing of transportation services to entice different behavior is a mechanism for lowering the negative externalities caused by transportation users on other transportation users and society-at-large.
Geographical and temporal imbalances of flow are characteristic in transportation systems.
Network behavior and network capacity, derived from link and node capacities and readjustment of flows on redundant paths, are important elements in transportation systems analysis.
Stochasticity in supply and demand is characteristics of transportation systems.
The relationship among transportation, economic development, and location of activities - the transportation/land use connection - is fundamental.
Performance Measures
SHAPE TRANSPORTATION OPERATIONS AND INVESTMENT.
Balancing centralized control with decisions made by managers of system components (e.g. terminals) is an important operating challenge.
The Integrality of Vehicle/Infrastructure/Control Systems Investment, Design, and Operating Decisions is Basic to Transportation System Design.