



ASSET MANAGEMENT FOR T&D: PRE-CONFERENCE WORKSHOP

Decision Methods & Analytic Tools for Repair / Replace & Project Prioritization

August 2, 2004
Chicago Illinois

Sponsored by
Center for Business Intelligence

Stephen Chapel & Charles Feinstein
S. Chapel Associates, VMN Group LLC

Agenda

- ➔ • Introduction – Part A
 - Some Common Asset Management Beliefs - Fact or fallacy?
 - History of our Asset Management Research
 - T&D Asset Management Issues – Problems to be solved
- Introduction – Part B: Agenda Modifications
 - Some changes
 - Critical Thinking about Asset Management
- Repair / Replace Decisions
- Prioritization / Project Portfolio Management
- Choosing Analytic Tools



Some Asset Management Ideas – True or False?

- Problems can be solved by organizational change and asset management teams
- "Cost Benefit analysis, the "tried and true" method for ranking projects is a perfectly reasonable way to select projects to fund."
- The first important step is to gather data
- All projects can be valued using the same aggregate measures (i.e. \$)
- Projects are risky because of uncertain financial consequences
- Beta is an appropriate way to measure project risk



Some Asset Management Ideas – True or False?

- An important objective is near-term profitability
- The biggest problem for asset management is insufficient data.
- ROI is a good metric for evaluating investments.
- Ranking is a good way to prioritize projects.
- Strategic alignment is a good metric for prioritizing projects.
- Balanced scorecards are a good way to prioritize projects.
- Hurdle rates are a good way to account for risks.



Agenda

- Introduction – Part A
 - Some Common Asset Management Beliefs - Fact or fallacy?
 - ➔ – History of our Asset Management Research
 - T&D Asset Management Issues – Problems to be solved
- Introduction – Part B: Agenda Modifications
 - Some changes
 - Critical Thinking about Asset Management
- Repair / Replace Decisions
- Prioritization / Project Portfolio Management
- Choosing Analytic Tools



T&D Research 1997 – 2002

- December 1996 Chicago Focus Group
- 1997 - 1998
 - Create the portfolio – distribution planning
 - Produce V1.0 Area Investment Planning Tools
- 1999
 - Start work on Customer Needs & Reliability projects
 - V1.5 Strategy Model & V2.0 LoadDynamics
 - Methodology design for Project Prioritization (AEP)

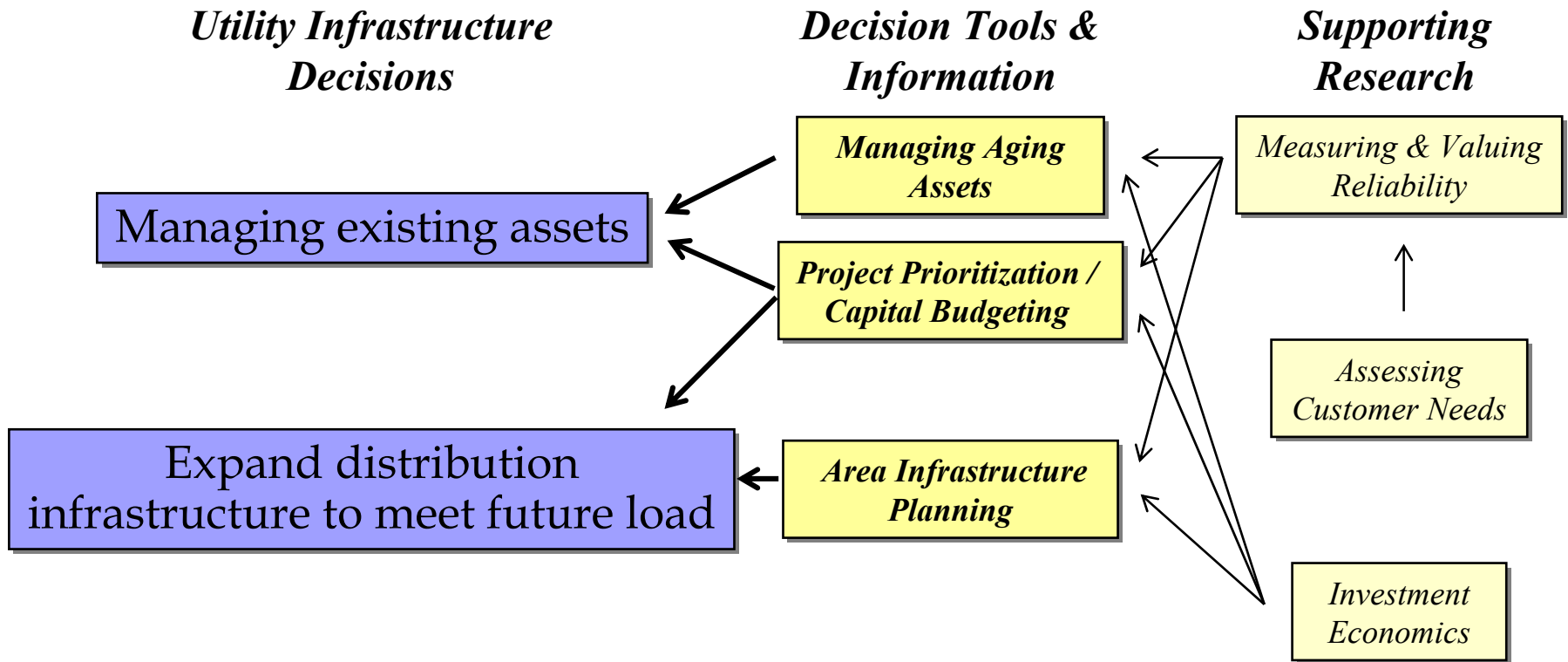


T&D Research 1997 – 2002 cont.

- 2000
 - Aging Assets - Started
 - Project Prioritization – method & software designed
 - Customer Needs & Reliability – EPRI white papers
 - Area Investment Planning – tech transfer
- 2001: Focus on Aging Assets and Project Prioritization
- 2002:
 - Continued focus on Aging Assets and Project Prioritization
 - Some work on Measuring & Valuing Reliability
- 2003:
 - Aging Assets – refine existing software & explore better ways to analytically address the problem
 - Project Prioritization: Refine existing software & continue improve methods for measuring T&D value



Utility Infrastructure Decision Making – The Focus of Our Work



Underlying Objective: Minimize the lifecycle costs of distribution infrastructure while meeting customer needs for reliability & power quality



Agenda

- Introduction – Part A
 - Some Common Asset Management Beliefs - Fact or fallacy?
 - History of our Asset Management Research
 - ➔ – T&D Asset Management Issues – Problems to be solved
- Introduction – Part B: Agenda Modifications
 - Some changes
 - Critical Thinking about Asset Management
- Repair / Replace Decisions
- Prioritization / Project Portfolio Management
- Choosing Analytic Tools



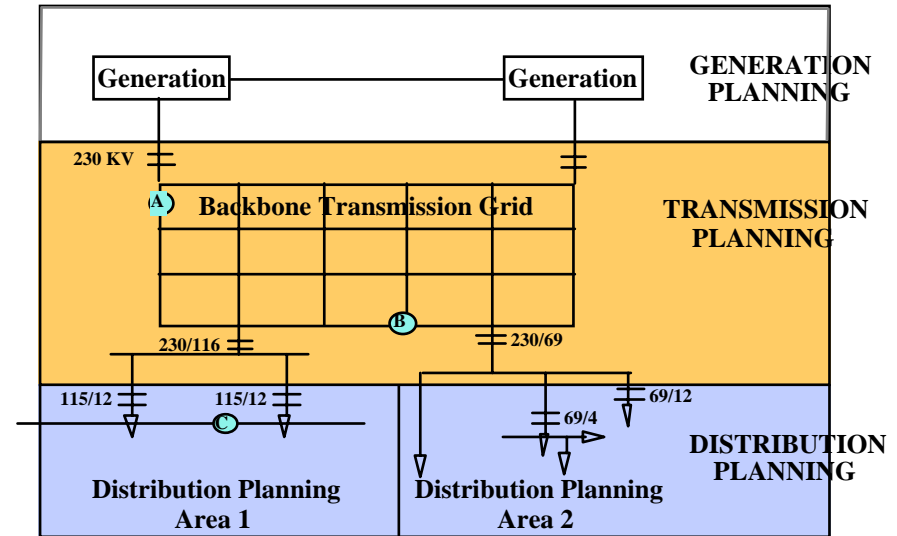
T&D Asset Management is Complex

- What about reliability - how far can we push the system before falling off the edge?
- How do we get the right-sized capacity when it is needed?
- Can we save \$ by deferring maintenance?
- What risks are we taking by practicing “doing-less” decision making (do we really know how close we are to the edge)?

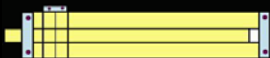


T&D Asset Management is Mostly About Solving Investment Problems

- 40% to 50% of electric utility net investment
- Business issues
 - Minimizing investment costs
 - Having “right” infrastructure to meet customer needs
 - Making money
- Key strategic needs
 - Managing assets
 - Linking investment and O&M decisions to customer needs

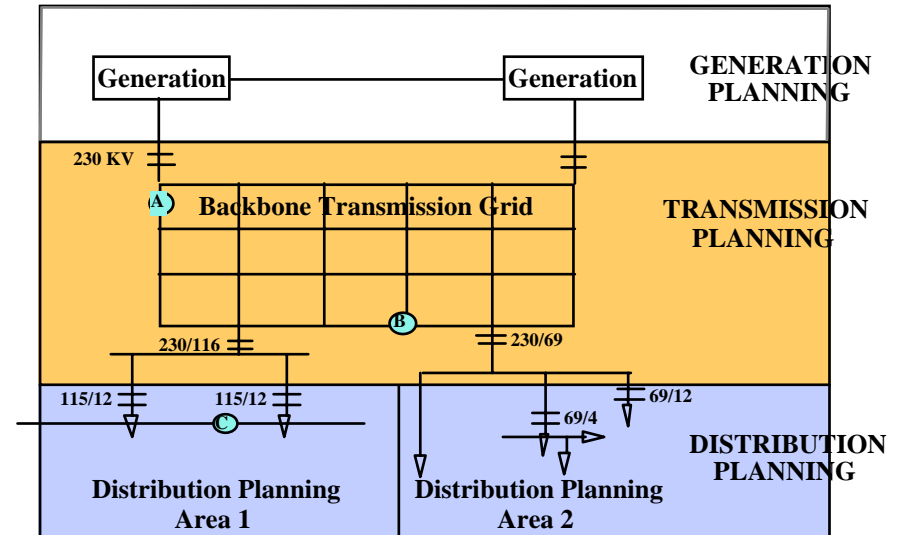


Net Invest.	
Gen.	= \$8.7B
Tran.	= \$4.5B
Dist.	= <u>\$13.5B</u>
Total	= \$26.7B



T&D Asset Management

- Two driving facts
 - Very low revenue to asset ratio
 - Large embedded asset base
- Substantial care and feeding is required
 - Repair / Replace
 - Expand / Prepare for future
 - Reliability

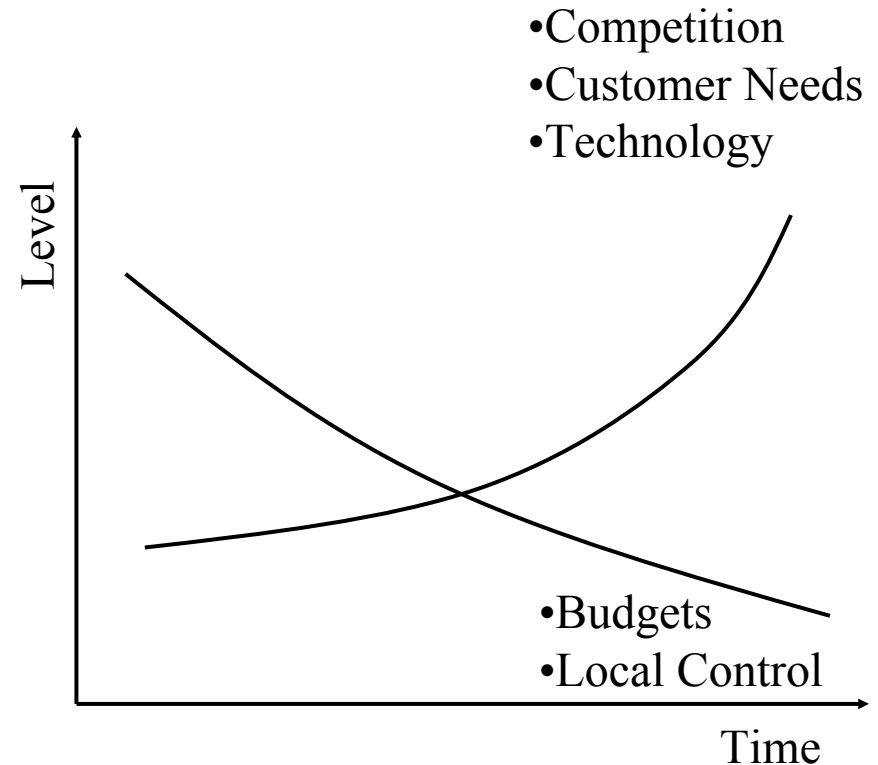


<u>Net Invest.</u>	
Gen.	= \$8.7B
Tran.	= \$4.5B
Dist.	= <u>\$13.5B</u>
Total	= \$26.7B

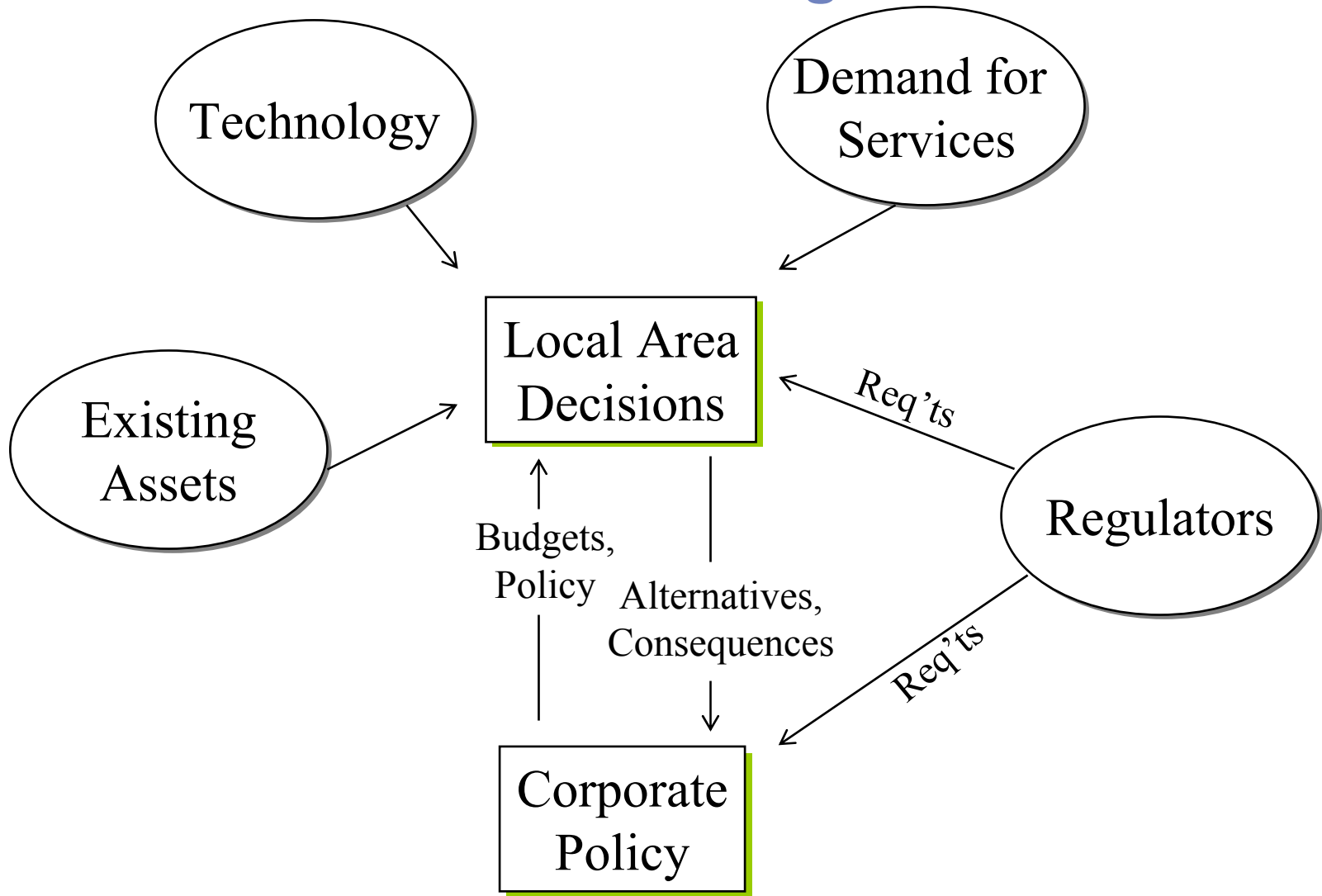


Opposing Trends are Changing the Business

- Increasing levels of key drivers
 - Restructuring & deregulation
 - Regulatory & Corporate scrutiny
 - Customers demand for reliability and service quality
 - Technology change
- Reduced budgets & increased corporate control
- Together these are creating a collection of problems

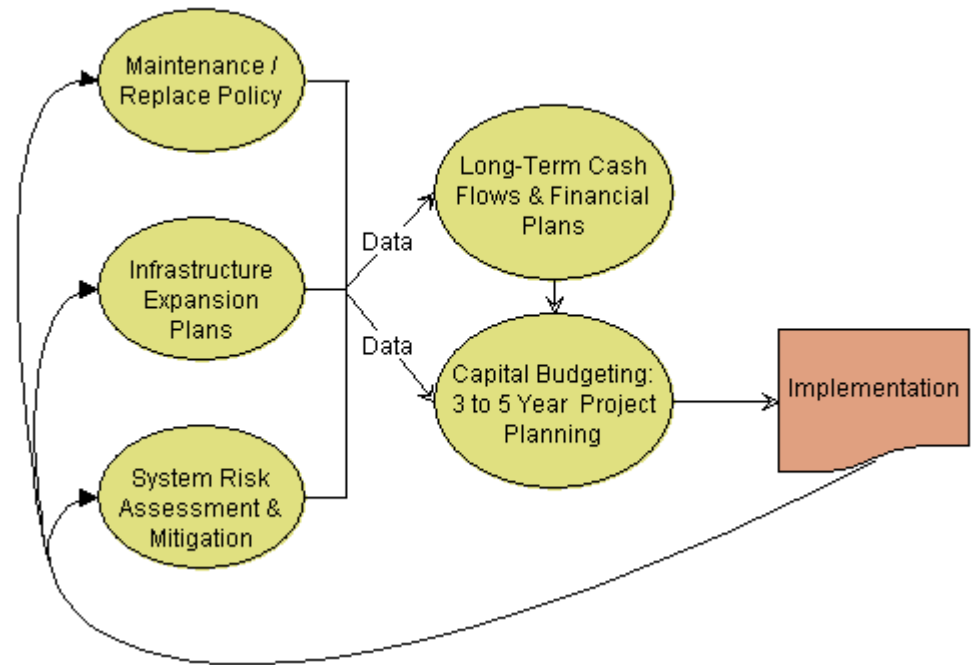


Nature of Business Planning Problem



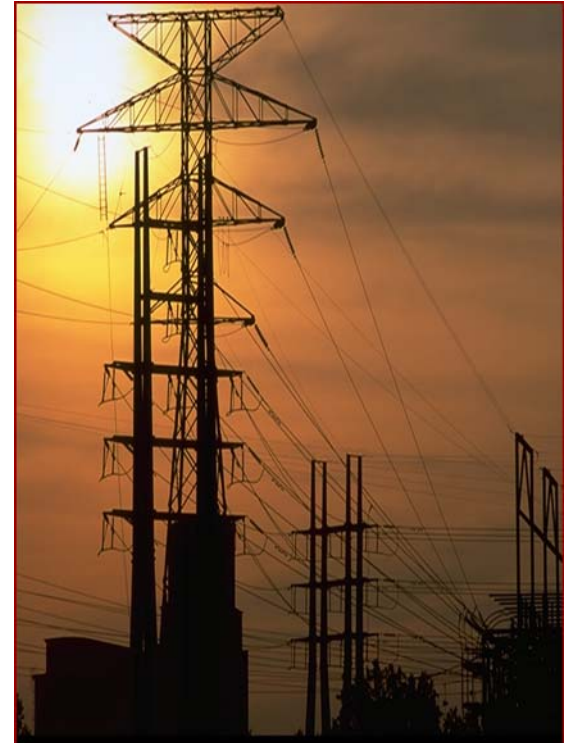
T&D Asset Management – Project Planning & Financial Planning

- Fundamental engineering economic problems
 - Maintenance / Repair / Replace
 - Capacity expansion
 - System Risk Assessment & Mitigation
- Financial planning problems
 - 3 to 5 year Capital Budgeting / Project Planning
 - Long-Term Financial Planning



In Summary T&D presents special challenges

- Huge investment in assets
- Regulations / Oversight
- “Right” infrastructure for customer needs
- Competitive pressures - extract maximum value from every asset
- Performance vital to other industries & economy
 - Recent NE power blackout estimated to cost \$7-10B
 - Loss of electric power to city of New York costs about \$36m/hr



Agenda

- Introduction – Part A
 - Some Common Asset Management Beliefs - Fact or fallacy?
 - History of our Asset Management Research
 - T&D Asset Management Issues – Problems to be solved
- ➔ • Introduction – Part B: Agenda Modifications
 - Some changes
 - Critical Thinking about Asset Management
- Repair / Replace Decisions
- Prioritization / Project Portfolio Management
- Choosing Analytic Tools



Published CBI Agenda

- Balance Cost for Repair vs. Replacement
 - Make repair replace decisions
 - Choose technologies that can expand reliability
 - Maintain customer satisfaction while assets are offline
 - Model corporate factors that can shape decisions
- Financial Planning versus Project Planning
 - Design plan of projects that maximize value
 - Project evaluation – Trading-off revenue, reliability, safety environment
 - Develop cost saving strategies
- Select Asset Management Tools to Measure Risk
 - Software that models & organizes data
 - Risk assessment models
 - Financial planning designs



Some Changes: Chuck's and Steve's Agenda

- Introduction – nature of asset management problem
- Repair / Replace Decisions
 - Problem statement
 - Objectives of analytic system
 - Technical overview - how solved
- Prioritization / Project Portfolio Management
 - Problem statement
 - Objectives of analytic system
 - Technical overview - how solved
- Choosing Analytic Tools



Critical Thinking about Asset Management

- Order of operations: specific problem statement → methodology → data & judgment → analysis
 - Problem statement: what is the problem, what is a solution
 - Data gathering: the next-to-last thing you do
- Asset Management is Financial Engineering
- Essential to specify V^2D^2 :
 - Values: what the company wants to accomplish
 - Variables: what is measurable and determines how much value is achieved
 - Decisions: or controls, what can actually be chosen
 - Dynamics: the effect of controls on variables over time
- Methodology
 - Captures fundamental relationships among V^2D^2
 - Does not impose false criteria, false methods, false theories



Critical Thinking (cont'd)

- Role of Data
- Role of Judgment
- Analysis
 - Art of analysis
 - How to compute and what the computations mean
 - Financial Engineering objectives



Agenda

- Introduction – Part A
 - Some Common Asset Management Beliefs - Fact or fallacy?
 - History of our Asset Management Research
 - T&D Asset Management Issues – Problems to be solved
- Introduction – Part B: Agenda Modifications
 - Some changes
 - Critical Thinking about Asset Management
- ➔ • Repair / Replace Decisions
- Prioritization / Project Portfolio Management
- Choosing Analytic Tools





Repair and Replace Strategy for Aging Distribution Systems Assets

Steve Chapel
S. Chapel Associates
and
Charles D. Feinstein
VMN Group

August 2004



Outline



- The Aging Asset problem
- Substation transformer example—single asset
- The need for a Learning Model – group exercise
- Aging Asset model structure-single asset
- Control of Asset Population - Cable Case Study
- Organizational Issues

The Aging Asset Problem

- Given
 - An asset type (e.g., transformers, cables, poles, etc.)
 - A set of asset characteristics
 - Age
 - Condition
 - Failure modes
 - Uncertainties in future performance
 - Observables and Unobservables
 - Costs
 - A set of alternatives
 - Repair
 - Replace
 - Rebuild
 - Refurbish
 - Test
 - Maintain
- What should we do, when, and under what conditions?

Problem Statement

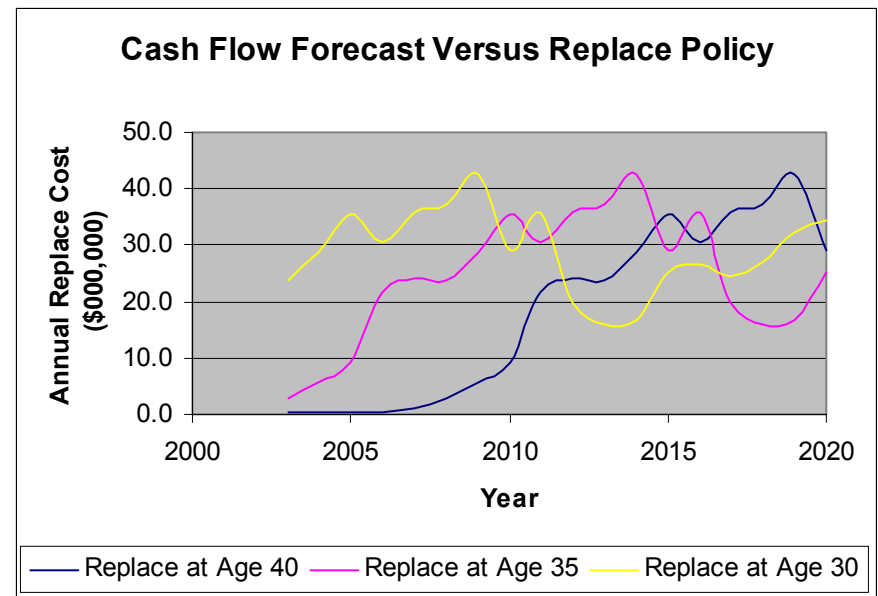
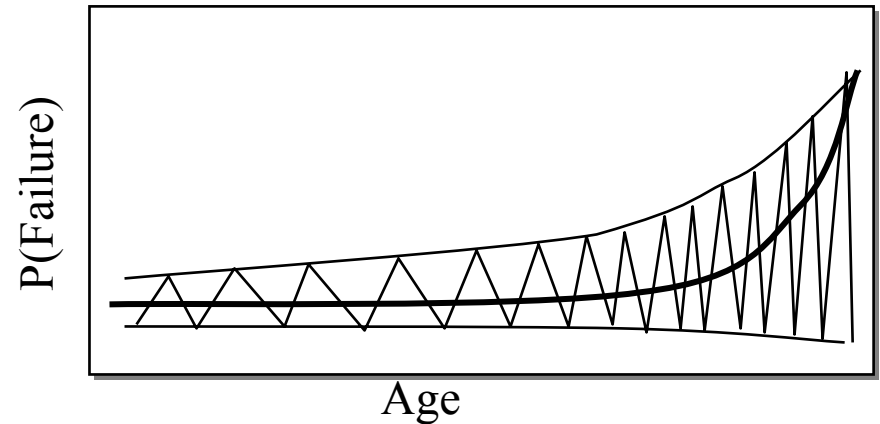
- The current system contains (x miles of cable, y power transformers, z breakers, ...). These assets are aging and may present a risk of failing in groups at the same time. The company is not satisfied with its current replacement policy.
- Objective: develop a least-cost strategy for repair/replacement of these assets
- Specify a forecast of the expenses by category associated with this strategy

Aspects of the Aging Asset Problem

- Optimal management of a single asset
- Optimal policy for entire asset population
- Cash flows for repair/replace for entire asset population
- Role of diagnostic tests

Two Fundamental Problems

- Optimal maintenance and replacement policy
 - Varies by asset class
 - Based on age, performance, and condition information for individual assets
- Cash flow planning
 - Least cost replacement of infrastructure inventory
 - Long term financial planning
 - Policy based on maintenance and replacement policy for individual assets



Optimal Management of a Single Asset

- Repair / replace strategy
- Diagnostic tests
- Individual performance—hazard function
- State of asset
 - Observable
 - Unobservable
- Solution method: state-dependent optimal control

Diagnostic Tests

- Several tests exist for each asset
- Example: Underground Cable Tests
 - Partial Discharge
 - Time Domain Reflectometry
 - Isothermal Relaxation Current
 - Dissipation Factor
 - Dielectric Spectroscopy
 - Wafer Test

Outline

- The Aging Asset problem
- • Substation transformer example—single asset
- The need for a Learning Model – group exercise
- Aging Asset model structure—single asset
- Control of Asset Population - Cable Case Study
- Organizational Issues

Substation Transformer Example

- Decisions
 - Repair (under what conditions?)
 - Replace
 - Maintain
 - Evaluative screening interval
 - Number of mobile, backup substations
 - Number of spares
 - Transfer load

Substation Transformer Example

- Economic Variables
 - Number of customers
 - Type of customers
 - Residential
 - Commercial
 - Industrial/Critical
 - Cost of Action
 - Maintain
 - Rebuild
 - Replace

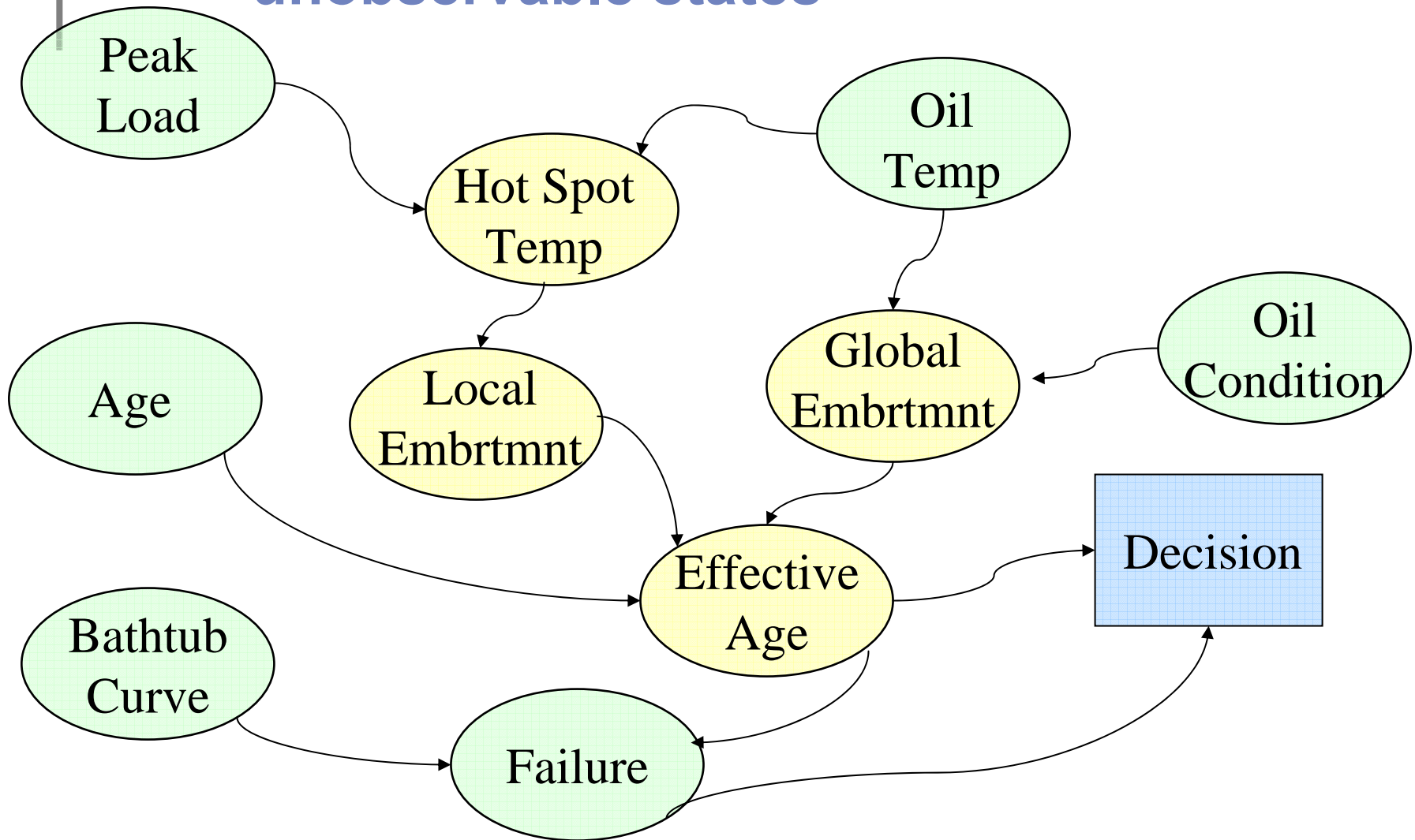
Substation Transformer Example

- Observable States
 - Age
 - Peak load
 - Oil condition (result of chemical test)
 - Oil Temperature (result of temperature test)
- Observable states are “*Decision Contingent*”
 - Policies are contingent on observable states
 - Critical to model decision flexibility

Substation Transformer Example

- *Unobservable States* reflect expert knowledge & problem structure
 - Hot Spot Temperature
 - Function of temperature and peak load
 - Calculable from current and load
 - Oil condition (result of chemical test)
 - Oil Temperature (result of temperature test)
 - Degree of Global Embrittlement (the entire transformer)
 - Condition of insulation
 - Influenced by oil temp (temp can “half or double insulation life”)
 - Degree of Local Embrittlement (around hot spot)
 - Influenced by hot spot temperature
 - Effective Age
 - Influenced by local and global embrittlement
 - Company-specific deviation from Industry Bathtub Curve

Relationship among observable and unobservable states



Outline

- The Aging Asset problem
- Substation transformer example—single asset
- • The need for a Learning Model – group exercise
- Aging Asset model structure—single asset
- Control of Asset Population - Cable Case Study
- Organizational Issues

Inference Example: Why we need Learning Model

- Uncertain Event: “Terrorist attack in USA in next week”
 - You believe the probability is about 1%
 - Simulation: Toss coin ten times, observe zero or one head

Inference Example: Why we need Learning Model

- Uncertain Event: “Terrorist attack in USA in next week”
You believe the probability is about 1%
- Now you receive information: FBI/CIA Intelligence Report
2 possible results: **Threat** “Credible evidence of attack ”
No Threat “ No credible evidence ”

Inference Example: Why we need Learning Model

- Uncertain Event: “Terrorist attack in CA in next week”
You believe the probability is about 1%
- Now you receive information: FBI/CIA Intelligence Report
2 possible results: **Threat** “Credible evidence of attack ”
No Threat “ No credible evidence ”
- Suppose you believe the agencies to be highly reliable:
Given **Attack** 99% chance agencies pick up **Threat**
Given **No Attack** 99% chance agencies say **No Threat**

Why we need Learning Model

Probability calculation:

- Given **“Threat”** Probability of Attack = ?
 - (Or: How many tosses and how many heads?)
- Given **“No Threat”** Probability of Attack = ?
 - (Or: How many tosses and how many heads?)

Outline

- The Aging Asset problem
- Substation transformer example—single asset
- The need for a Learning Model – group exercise
- Aging Asset model structure-single asset
- Control of Asset Population - Cable Case Study
- Organizational Issues

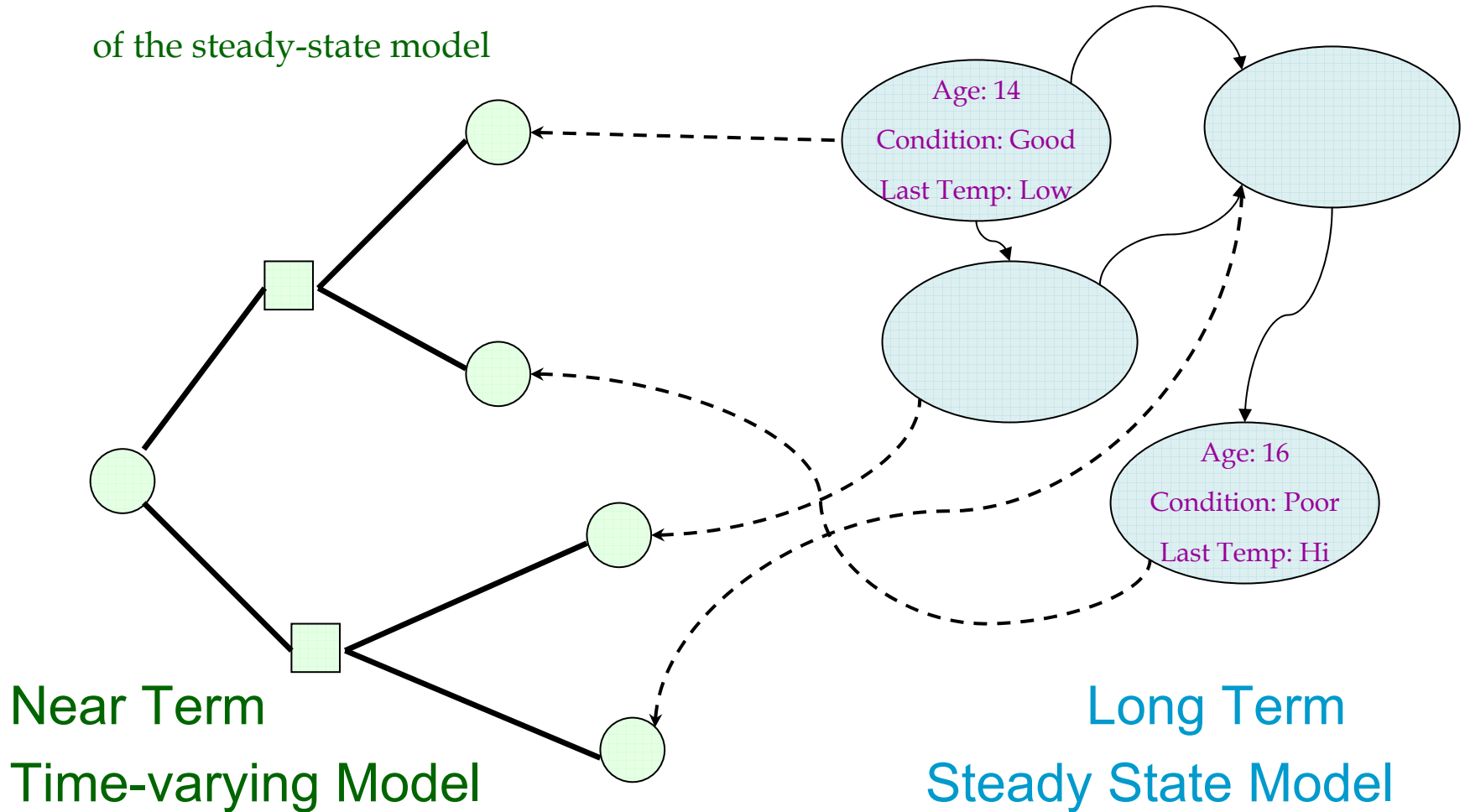


Aging Asset Model Structure-Single Asset

- Two model forms to fit problem characteristics
- **Planning Period**
 - Uncertainties and decisions may change year to year
 - Have detailed knowledge about near-term issues
 - One-of-a-kind events may be on the horizon
 - Stochastic dynamic program yields Time- and State-dependent policy
- **Post-Planning Period**
 - Have less detailed year-to-year knowledge
 - Still need to capture long term policy
 - Markov decision process yields State-dependent policy

Model linkages

▼ Each terminal node of the time-varying model plugs into a state of the steady-state model



Outline

- The Aging Asset problem
- Substation transformer example—single asset
- The need for a Learning Model – group exercise
- Aging Asset model structure-single asset
- Control of Asset Population – Cable Case Study
- Organizational Issues



Optimal Population Management – Underground Cable Case Study

- Compare optimal policy (replacement interval plus allowable failure history)
and
- Non-replacement (continued repair)
- Variation by type
- Variation by capital cost, o&m, customer values

Population Hazard Function -- Example

- A1: Failures:

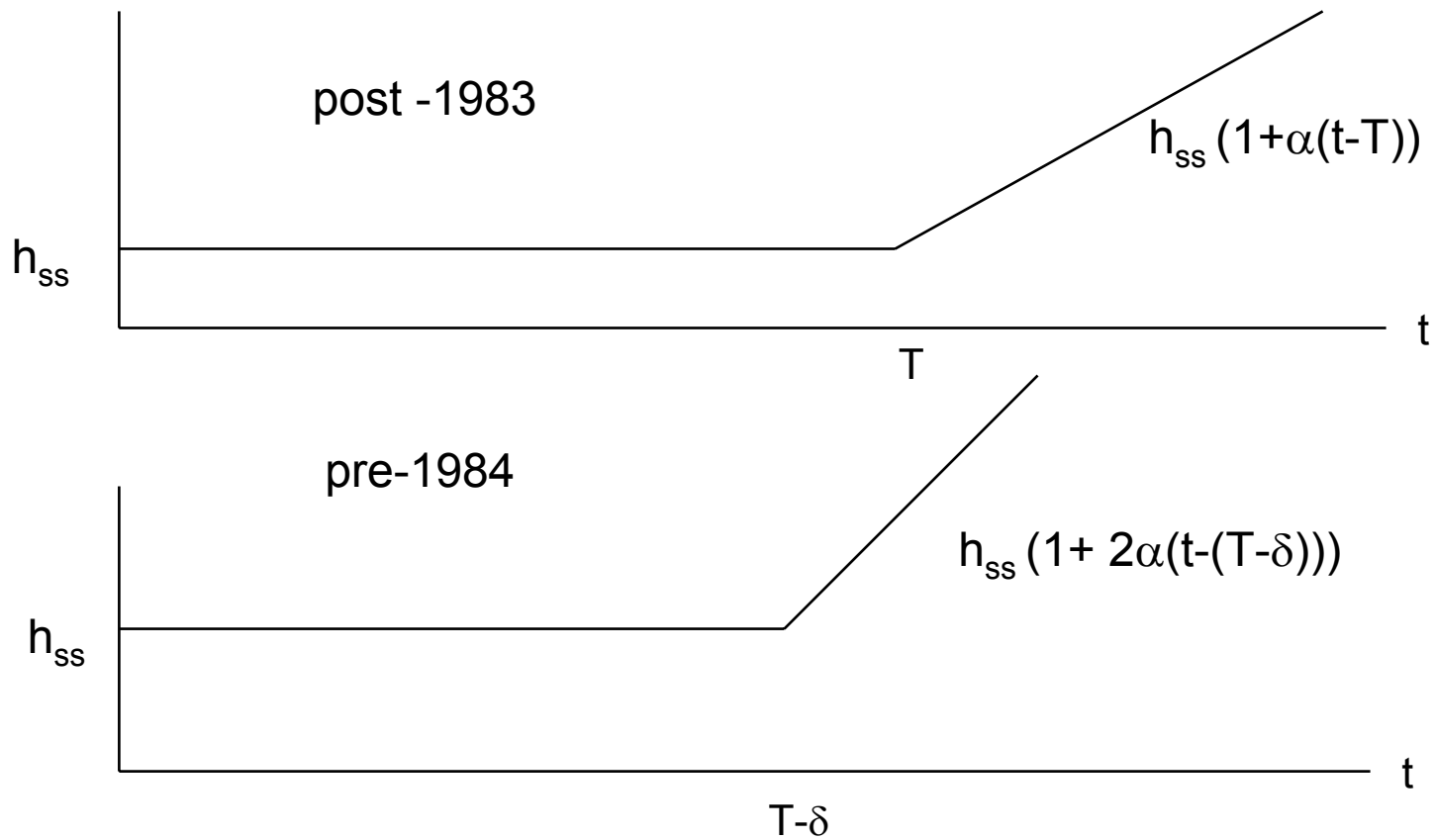
2AWG	1/0	2/0	4/0	500	750
394	152	61	24	*	28

- A2: 85% of failures occur in cable installed prior to 1983 (non-tree retardant)
- A3: 16% of failed segments experience additional failure in the same year

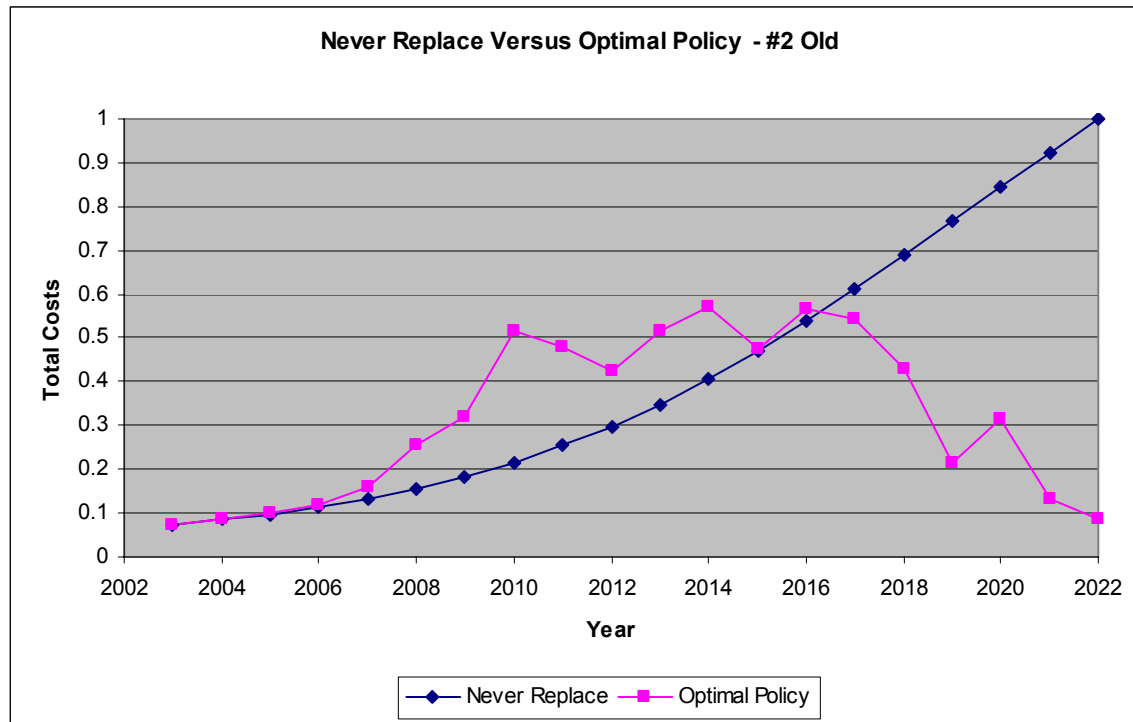
* 500 assumed to fail as 750

Hazard Function (cont'd)

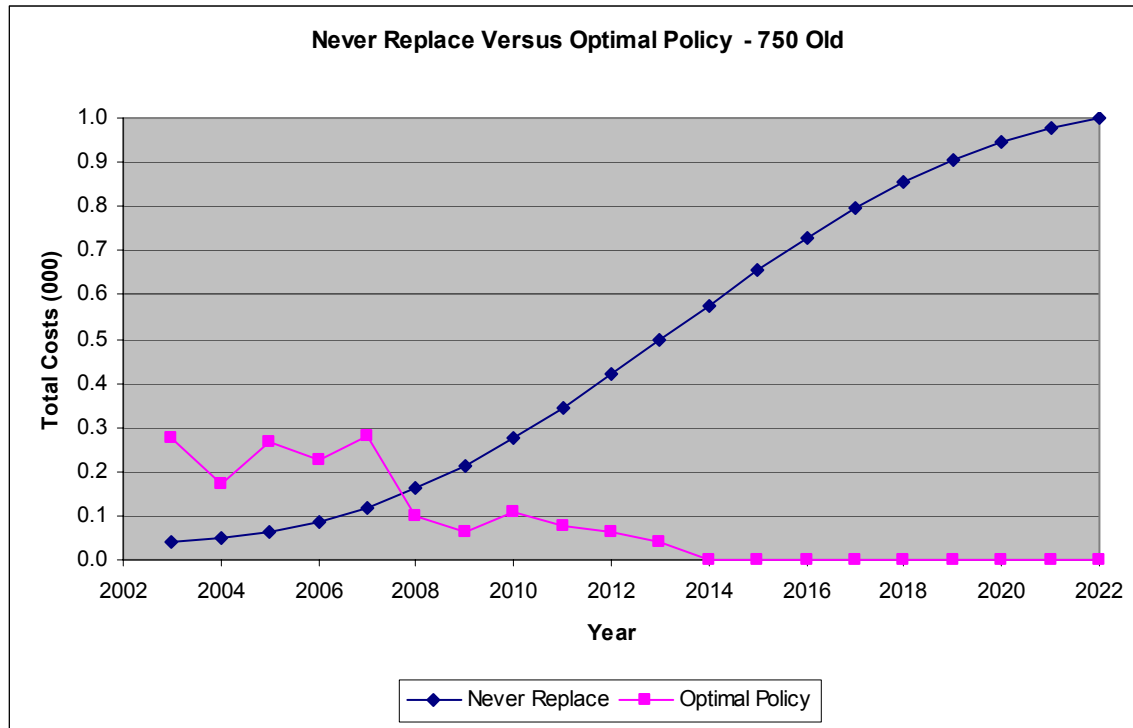
- A4: Two functional forms



Sample Results - Total Costs - Continued Repair & Optimal Replace – #2 Old



Sample Results - Total Costs - Continued Repair & Optimal Replace – 750 Old



Outline

- The Aging Asset problem
- Substation transformer example—single asset
- The need for a Learning Model – group exercise
- Aging Asset model structure-single asset
- Control of Asset Population – Underground Cable Case Study
- Organizational Issues



Organizational Issues—What is aging asset management?

- What is the objective?
- Process or analysis?
- Analytic requirements
 - Data issues
 - Failure rates
 - Equipment characteristics
 - Customer needs and values
 - Utility costs
 - Constraints (budgets, operating, ...?)
 - Commitment to analysis



Prioritization / Project Portfolio Management

Stephen Chapel, S.Chapel Associates
and
Charles D. Feinstein, VMN Group LLC



Agenda

- ➔ ■ Problem statement
- Objectives of analytic system
- Technical overview - how the problem is solved



Problem Definition

- The company does not currently *quantitatively* evaluate and compare all distribution projects. (A formal, repeatable, and uniform approach for valuing projects does not currently exist.)
- The value of doing a particular project is not compared with the values of competing projects.
- For the projects that are evaluated, the company is not satisfied with the current procedures.



Scope of Prioritization Problem

- Large number of projects
- Multiple performance measures
- Projects done for different reasons
- Analysis of uncertainty
- Risk of deferral
- Respond to budget signals



Agenda

- Problem statement
- ➔ ■ Objectives of analytic system
- Technical overview - how the problem is solved



Objectives: Prioritization System

- Level playing field for all projects
- Resolve differences of opinion rationally
 - Techniques for resolving differences of opinion and determining which differences matter
- Defensible logic for peer review
- Transparent analysis
- Completeness with respect to performance measures
 - Multiple performance measures for multiple objectives
- Bias- and error-free

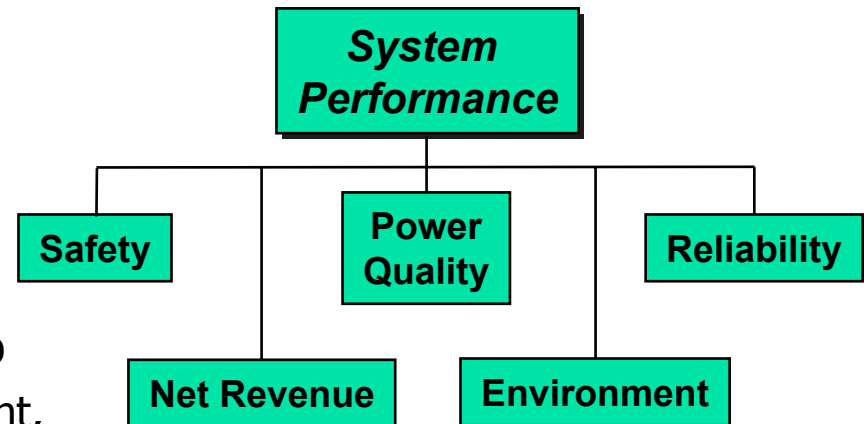


Objectives - continued

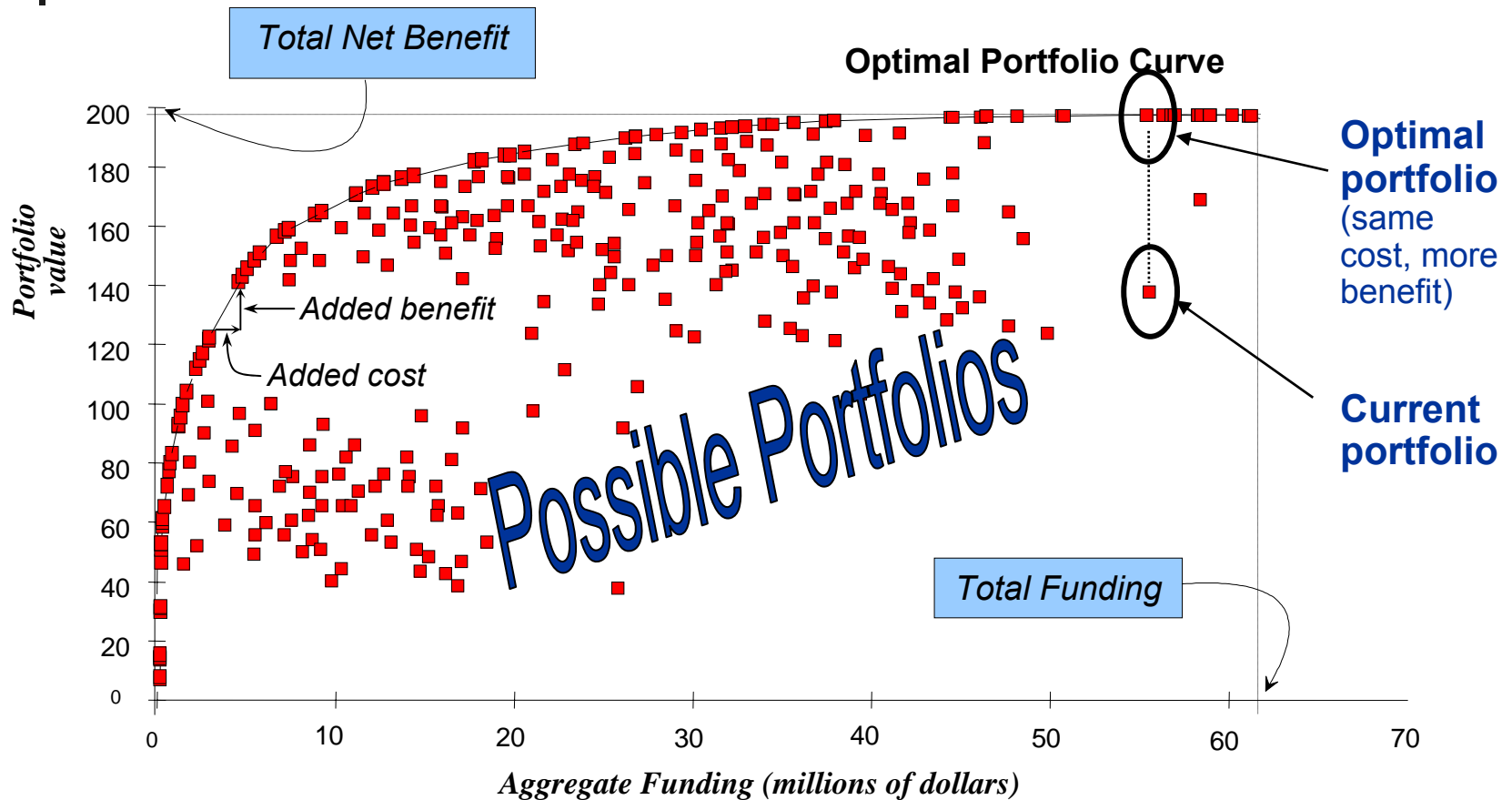
- Practically applicable with respect to time and cost
- Compatible with existing business practices
- Explicit treatment of uncertainty
- Ability to quantify what is lost from insufficient funding
- Software to manage and compare large numbers of diverse activities – client/server database (Oracle, SQL Server)

Objectives - continued

- The system must be:
 - Multi-year
 - Multi-attribute
 - Value driven
- Three key dimensions
 - Objectives of the project portfolio
 - minimizing or maximizing important, measurable aspects of system performance
 - Values
 - capture relative importance of competing objectives.
 - Project attributes
 - describe how each project contributes to attainment of objectives



Objective: Identify the optimal portfolios





Agenda

- Problem statement
- Objectives of analytic system
- ➔ ■ Technical overview - how the problem is solved

Required I/O + Transformations









INPUTS

- Corporate budgets
- Projects + Alternatives
- Objectives
- Values
- Attributes

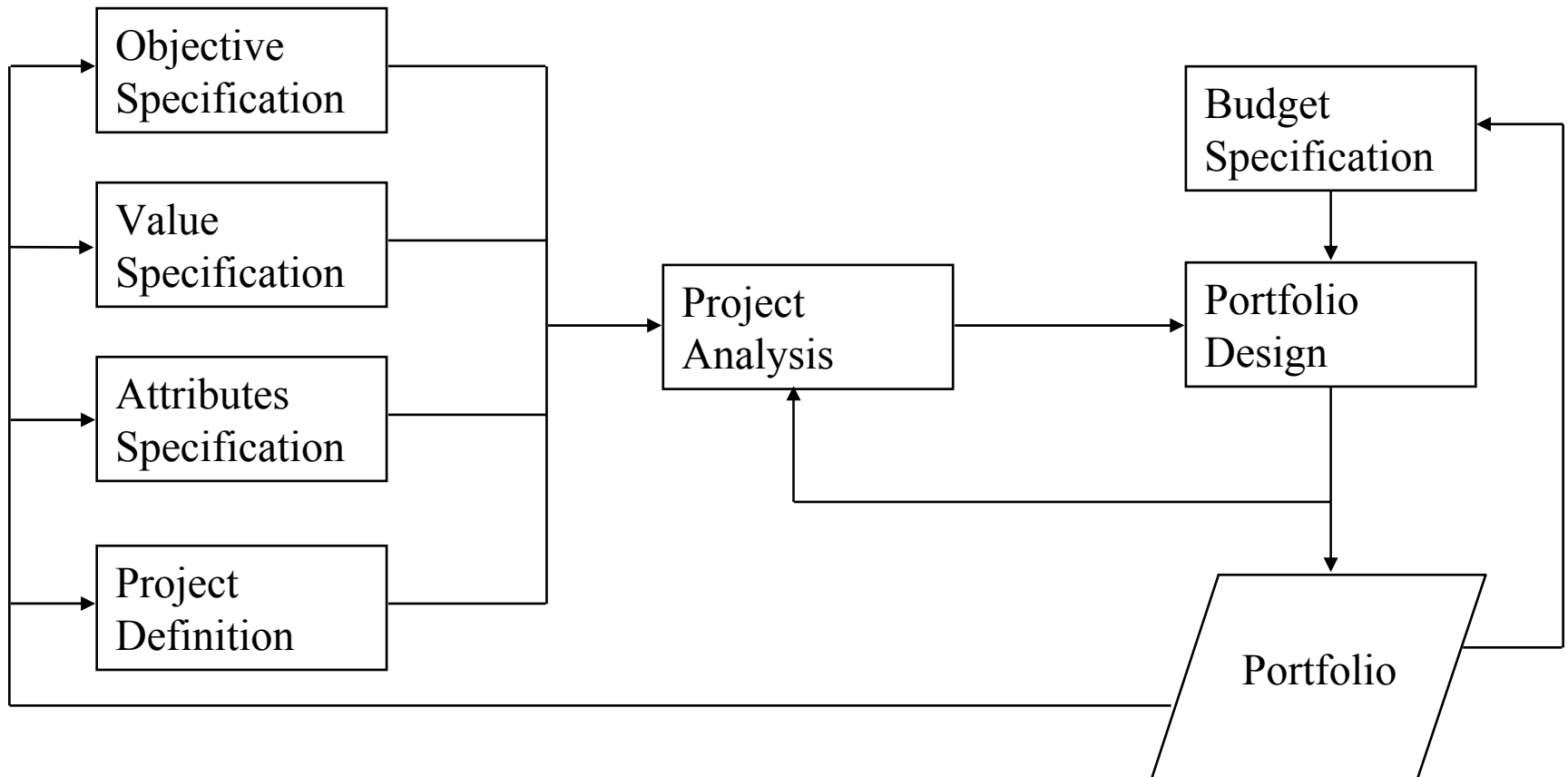
OUTPUTS

- Project Rankings
- Portfolio of projects
- Timing of projects
- Value of additional budget
- Value
- Risks
- Costs

TRANSFORMATION PROCESS

- Attribute + values + objectives 
- Benefits 
- Projects + Alternatives 
- Budget requirements 
- Benefits + budget req'ts 
- Portfolio 
- Δ Budgets 
- Δ Portfolio 

Overview of System Structure



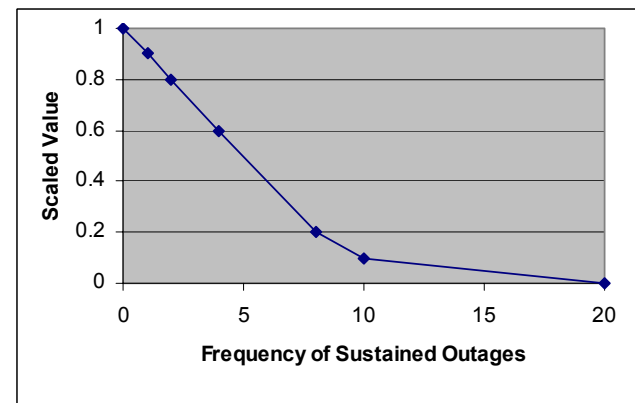
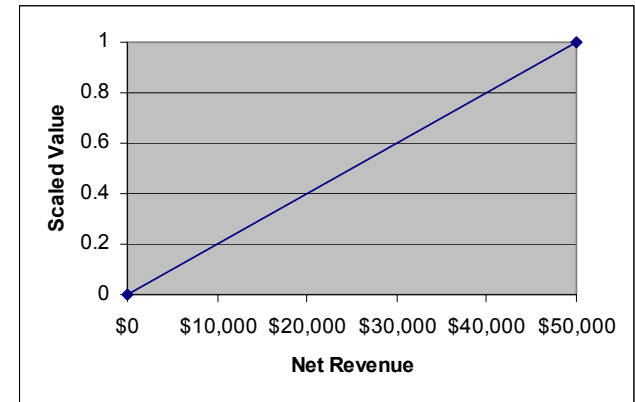


Natural Units – measure system performance

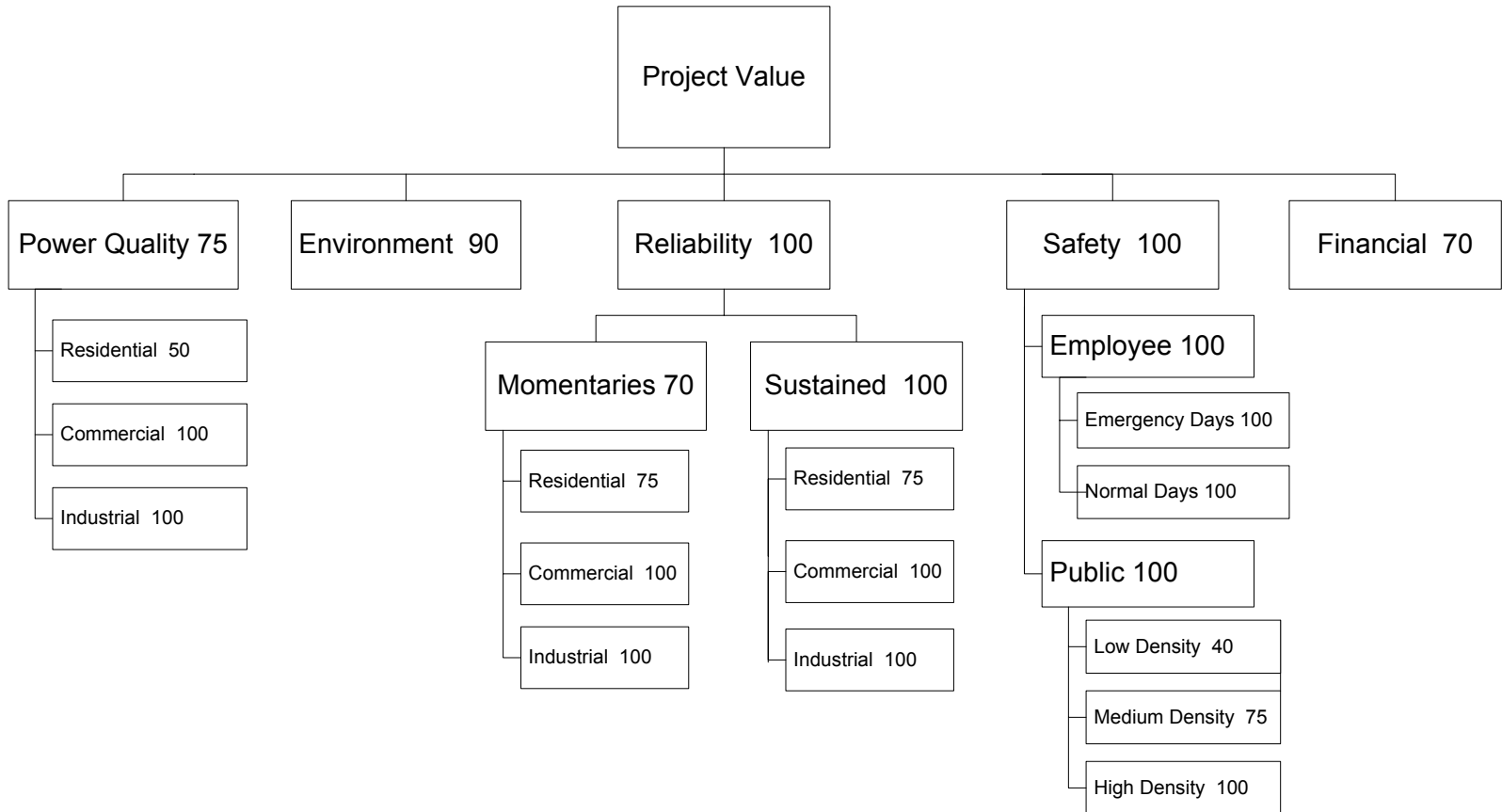
- Power Quality
- Reliability
- Costs / Revenue
- Environmental
- Safety

Scales – measure value of change

- Linear
 - Dollars
 - Customers
- Non-linear
 - Frequency
 - Duration
 - Momentaries

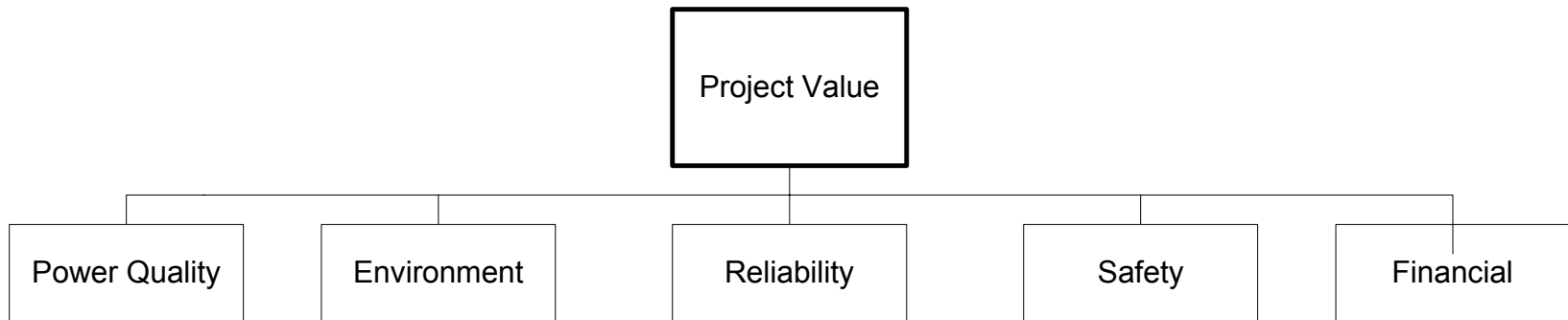


Weights – measure relative value of change



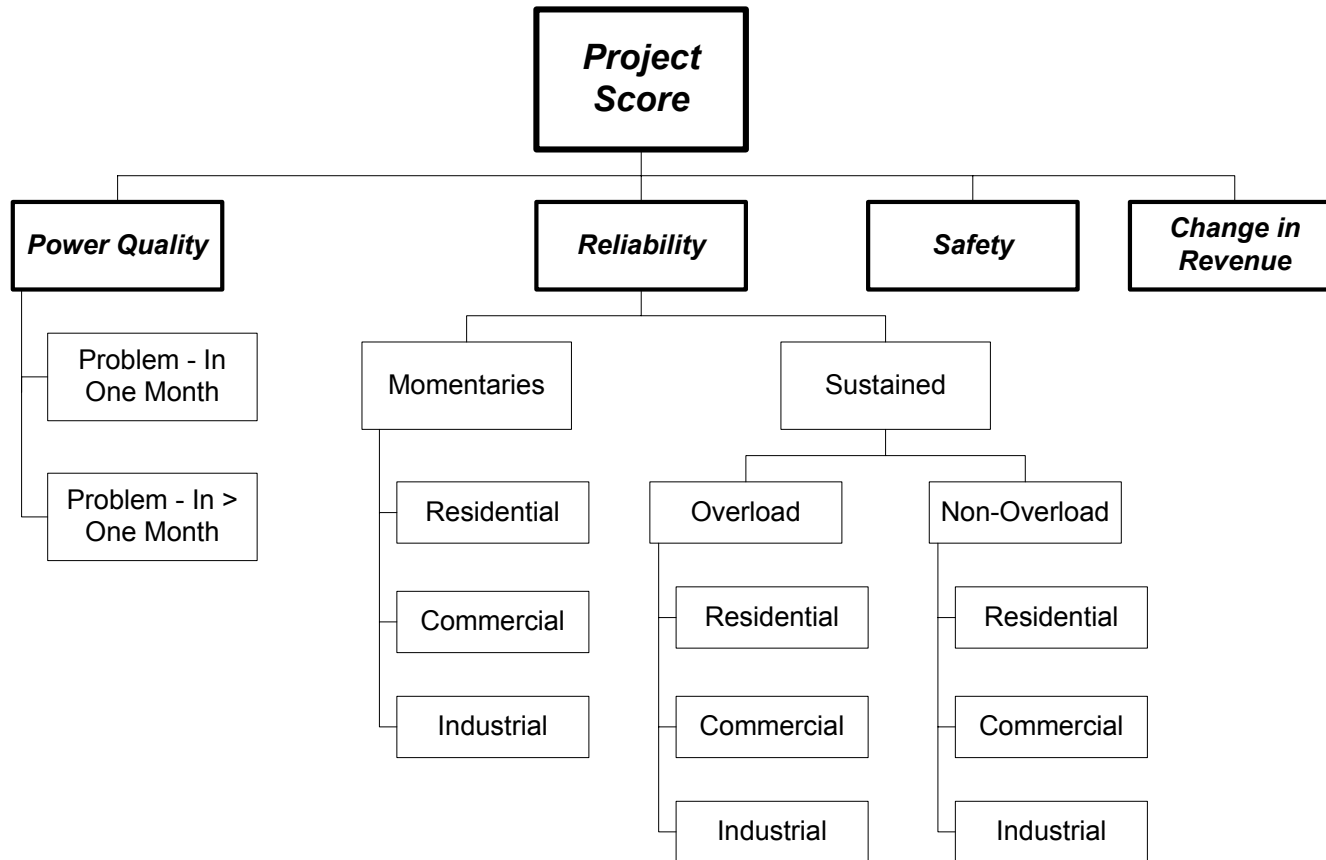
Attribute Structure

- At the highest level, the attributes are essentially the same



- Attribute structure differs in how the high level attributes are measured – another approach follows

Attribute Structure – Alternative Measurements





Choosing Analytic Tools

Charles D. Feinstein, VMN Group LLC
and
Stephen W. Chapel, S.Chapel Associates



What kind of tools do you need?

- Tool choice follows from problem statement – what is a solution?
- Tool choice is guided by recognition of fallacies – what must tools be able to do and what must they avoid?
- Tool choice depends on characteristics of the tools themselves – how does a tool find an answer?



Revisiting the Fallacies

- Methodology: Problems can be solved by organizational change & asset management teams
 - Process vs. rigorous analysis
 - Debate outcomes vs. debate assumptions and logic
 - Cost benefit analysis vs. multi-year value optimization
- Procedural: The first important step is to gather data
 - Data first vs. problem formulation first
- Value Measurement: All projects can be valued using the same aggregate measures (i.e. \$)
 - Single vs. multi-attributes



Revisiting the Fallacies (cont'd)

- Risk Measurement: Projects are risky because of uncertain financial consequences (beta appropriate way to measure project risk)
 - Financial risk vs. uncertainty in system performance
- Decision Objective: An important objective is near-term profitability
 - Project financial return vs. project system contribution
 - Corporate values vs. project specific system performance
 - Profitability vs. service
 - Short term planning vs. long lived assets
 - Reduced costs vs. appropriately guided investments
 - Asset management is a way to become more efficient and thus more profitable



Characteristics of applicable tools

- Captures company values (V)
- Represents measurable consequences (V)
- Identifies contingent decisions (D)
- Evaluates over sufficient time horizon (D)
- Treats changing information (D)
- Incorporates risk
- Provides transparent results
- Repeatable, explainable, modifiable