SEAri Short Course Series

Course: PI.26s Epoch-based Thinking: Anticipating System and Enterprise Strategies for Dynamic Futures

Lecture: Lecture 3: Related Methods for Considering Context and Time

Author: Adam Ross and Donna Rhodes

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This course was taught at PI.26s as a part of the MIT Professional Education Short Programs in July 2010 in Cambridge, MA. The lectures are provided to satisfy demand for learning more about Multi-Attribute Tradespace Exploration, Epoch-Era Analysis, and related SEAri-generated methods. The course is intended for self-study only. The materials are provided without instructor support, exercises or "course notebook" contents. Do not separate this cover sheet from the accompanying lecture pages.

Systems Engineering Advancement Research Initiative

[PI.26s] Epoch-Based Thinking: Anticipating System and Enterprise Strategies for Dynamic Futures

Lecture 3
Related Methods for Considering Context and Time

Dr. Donna H. Rhodes
rhodes@mit.edu

Dr. Adam M. Ross
adamross@mit.edu

Massachusetts Institute of Technology

Outline

- Context and time as aspects of complex systems and enterprises
- Context aspect
- Temporal aspect
- Legacy and emerging approaches
- Unique focus of epoch-based thinking

Five Aspects Taxonomy

STRUCTURAL	related to form of system components and their interrelationships
BEHAVIORAL	related to function/performance, operations, and reactions to stimuli
CONTEXTUAL	**related to circumstances in which the system or enterprise exists**
TEMPORAL	related to the dimensions and properties of systems over time
PERCEPTUAL	related to stakeholder preferences, perceptions and cognitive biases

Rhodes, D. and Ross, A., *Five Aspects of Engineering Complex Systems: Emerging Constructs and Methods*, IEEE Systems Conference, April 2010

Thinking About Context: Product Lines

Categories emerged from action research project in commercial product line company

- Technical Context – structure of the product line
- Business Context – effort and resources applied/to be applied
- Organizational Context – organization/structure/behaviors/motivation
- Geographical Context – where product developed and marketed
- Historical Context – evolution of the product line

Product line approach introduces new level of complexity in designing artifacts and engineering processes…the conceptualization of context influence shape of the process. Design decisions can be justified by a specific constellation of product line context. (Fricker and Stoiber)

Fricker, S. and Stoiber, R., Relating Product Line Context to Requirements Engineering Processes Using Design Rationale, Proceedings of PiK, 2008

Five Aspects Taxonomy

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Examples of Methods Attempting to Understand/Predict Future Conditions or Events

Qualitative methods
- The Delphi method
- Market research
- Panel consensus
- Grass-roots forecasting
- Historical analogy

Time series methods
- Moving average
- Exponential smoothing
- Box Jenkins
- Trend projections

Causal methods
- Regression analysis
- Econometric models
- Input/output models
- Life-cycle analysis
- Simulation

"True time-based analysis is difficult and may be inappropriate as details are shrouded by uncertainty in early design"

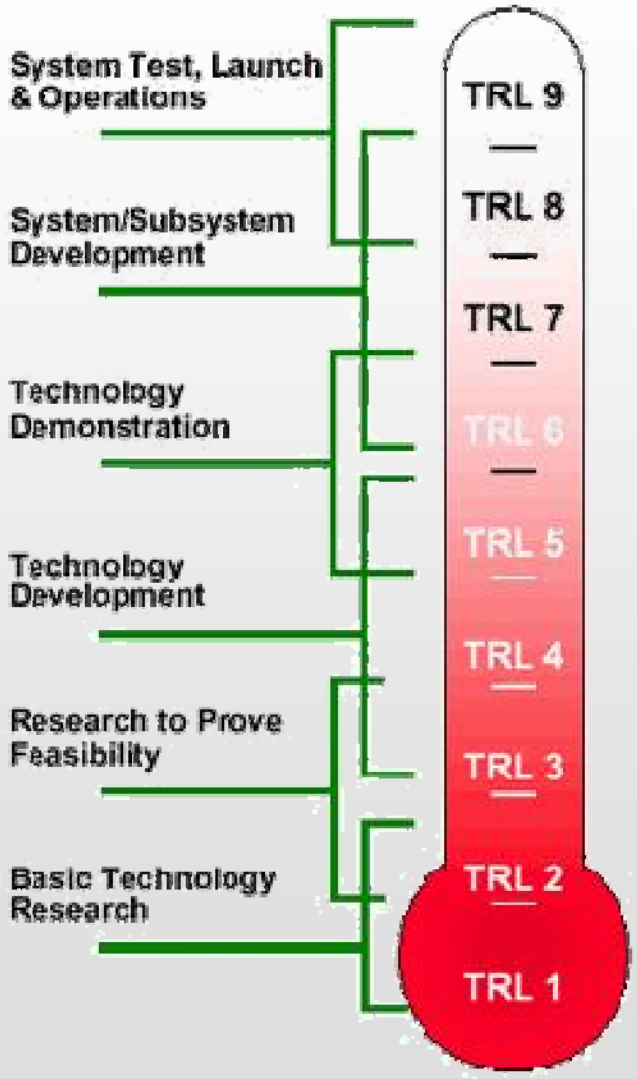
Stakeholder Interview, Ross 2006

Uncertainty Over Time

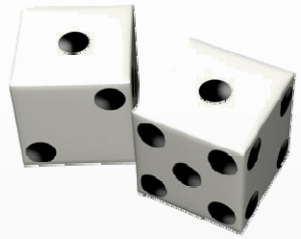
Methods Accounting for Uncertainty

- Qualitative methods
  - Ranking/sorting/categorizing: “low-risk”, “medium risk”, “high-risk”
  - Futures techniques, morphological analysis, scenario planning
- Semi-quantitative methods
  (can be used to initialize quantitative methods)
  - Technology readiness levels (TRLs)
  - Margins (estimates based on historical performance)

(Thornton 2004, NASA 2007)



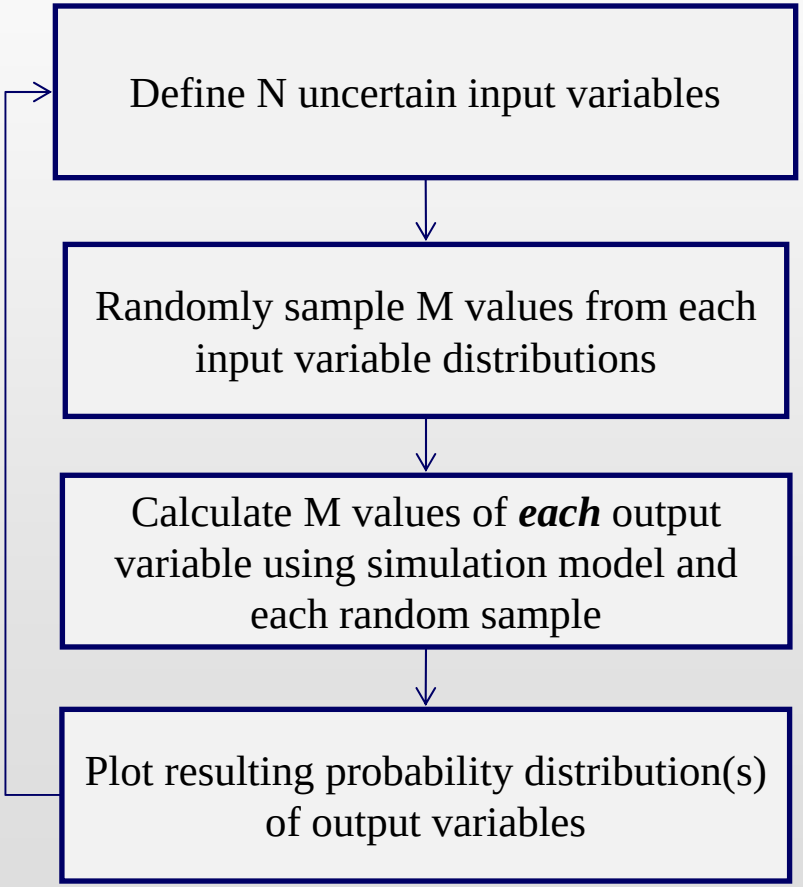
Monte Carlo Simulation



Q: What is the expected outcome distribution given quantifiable systematic uncertainties?

- Developed in 1940s
  (Metropolis and Ulam 1949)
- Relies on repeated random/pseudo-random sampling
- Can be applied to problems that are not deterministically solvable

"Top-down" or "bottom-up" probabilistic view of uncertainty



Scenario Planning

- Scenario planning refers to a broad set of methods used to make strategic decisions

	Narrative	**Computational**
Description	Thickly-descriptive, Internally consistent	Parametric enumeration of future contexts
Pros	Compelling, more detail, plausible	Many futures, surface counterfactuals
Cons	Few future contexts considered	Computationally intensive

- Differing degrees of automation in computational scenario generation
  - Morphological
  - Expert systems

(Wack 1985, Ringland 1998, Eriksson 2002, Lempert et al 2003, Harries 2003)

Scenario planning allows strategic management of uncertain contexts

The Art of the Long View (Schwartz)

EIGHT STEP PROCESS

1) Isolate the decision
2) Identify key forces in local environment
3) Isolate driving forces
4) Rank driving forces by importance and uncertainty
5) Select scenario logics
6) Flesh out scenarios
7) Play out implications
8) Search for markers

"You can tell that you have good scenarios when they are both plausible and surprising; when they have the power to break old stereotypes; and when the makers assume ownership of them and put them to work. Scenario-making is intensely participatory, or it fails." (Schwartz, 1996)

Schwartz, P., The Art of the Long View, 1996

Environmental Scanning

Environmental scanning is a process for information gathering, analysis and dissemination for tactical and/or strategic purposes

- involves gathering factual and subjective information on environments in which enterprise operates now or may in future

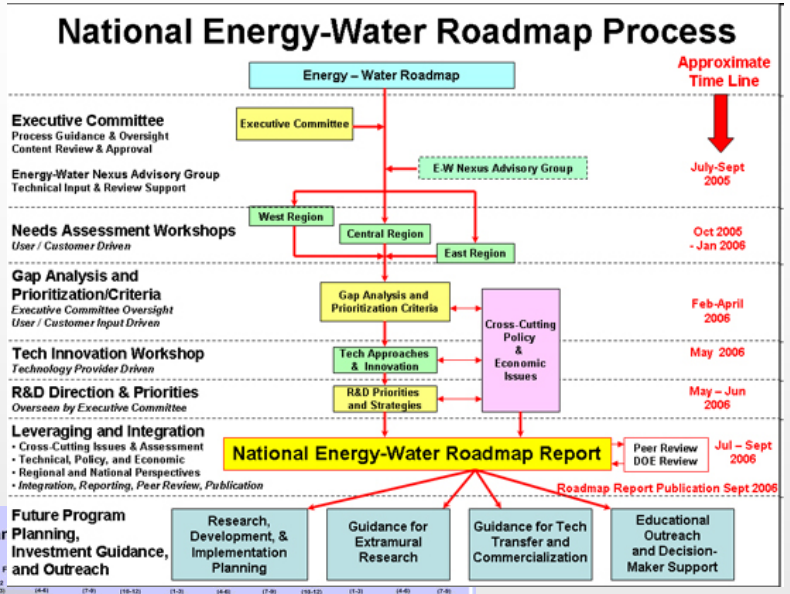
Three scanning approaches:

- Ad-hoc scanning: Short term, infrequent look usually initiated by a critical driver
- Periodic scanning: done on a regular schedule (e.g. annual)
- Continuous scanning – ongoing structured process for gathering information on a broad range of environmental factors

Roadmapping

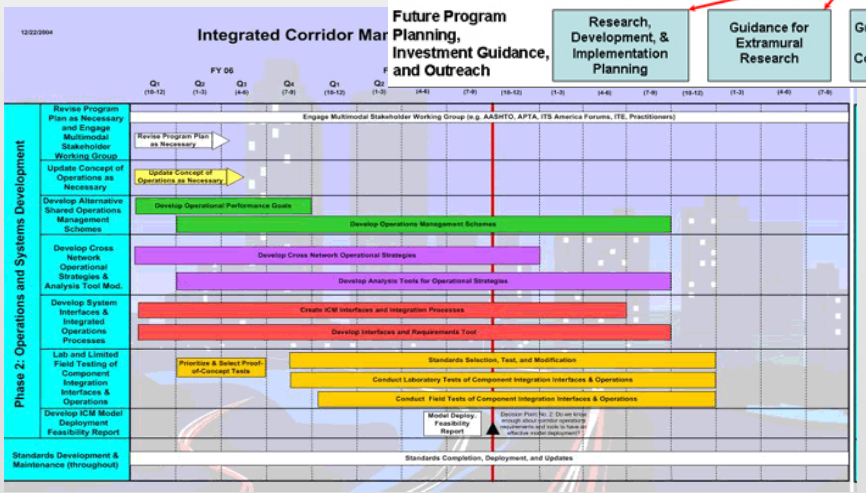
A "roadmap" is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field.

Galvin, R., Science of Roadmaps, Science, May 1998



Source: Sandia.gov

Many types of roadmaps – business, technology, enterprise, science



Source, DOT Website, accessed July 2010

Forecasting

Forecasting is a technique of predicting future events or conditions from the present state.

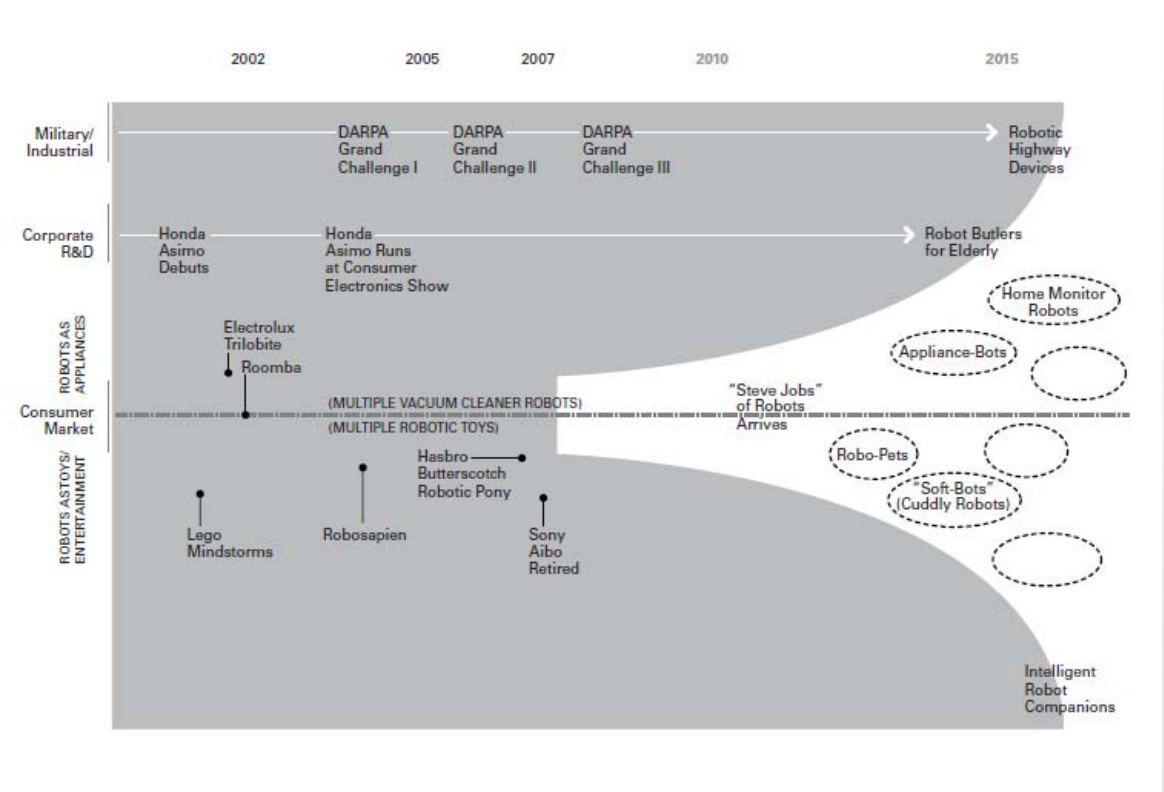
- Predictions can be based on analogies, theory, logic, guesswork, expert opinion, past performance, historical data, or other information.

Forecasting techniques can be cast into three categories (Cook and Russel, 1993):

- **qualitative methods**: use qualitative data, such as aggregate expert opinions to predict the future
- **time series method:** rely on historical data, "focusing on seasonal and cyclical variations and trend extrapolations
- **causal methods:** attempt to define relationships among independent and dependent variables in a system of related equations.

When choosing the type of forecast to use, must weigh the cost of performing the forecast versus cost of inaccuracy in the forecast. Forecasts are often done on events or conditions of the future outside of the control of the design engineer, but which have impact on the future value of the system. From Ross, 2006

Forecasting
Saffo's Cone of Uncertainty



A cone of uncertainty delineates the possibilities that extend out from a particular moment or event. The most important factor in mapping a cone is defining its breadth, which is a measure of overall uncertainty. In other words, the forecaster determines what range of events or products the cone should encompass. Drawing the cone is a dynamic process, and what we see here is just one iteration. (Saffo)

Effective forecasting provides essential context to inform your intuition …broadens your understanding by revealing overlooked possibilities and exposing assumptions .. at same time narrows your decision space

Saffo, P., Six Rules for Effective Forecasting, Harvard Business Review, July-Aug, 2007

Trend Analysis in Forecasting

- Trend analysis is one of the most often used methods in forecasting
- Observe and register past performance of a certain factor and project it into the future
- Involves analysis of two groups of trends: quantitative, mainly based on statistical data, and qualitative, these are at large concerned with social, institutional, organizational and political patterns
- As trends never speak for themselves, the identification and description of patterns is partly empirical and partly creative activity

Adapted from Wikipedia, accessed July 2010

Backcasting

Reverse-forecasting technique which starts with a specific future outcome and then works backwards to the present conditions. (Business Dictionary)

- Approach that involves identification of a particular scenario and tracing its origins and lines of development back to present
- Typically looks farther into future than traditional scenario planning may look

Morphological Analysis (Ritchey, 2008)

- Morphological analysis is a method for rigorously structuring and investigating the total set of relationships in inherently non-quantifiable socio-technical problem complexes (generalized method from Zwicky in 1940's)
  - carried out by developing a discrete *parameter space* of the problem complex to be investigated, and defining relationships between the parameters on the basis of internal consistency
  - internally linked parameter space is called a m*orphological field*
- Morphological analysis can be employed for:
  - developing scenarios and scenario modeling laboratories
  - developing strategy alternatives
  - analyzing risks
  - relating means and ends in complex policy spaces
  - developing models for positional or stakeholder analysis
  - evaluating organizational structures for different tasks
  - presenting highly complex relationships in the form of comprehensible, visual models

Morphological Analysis for Scenario Elaboration

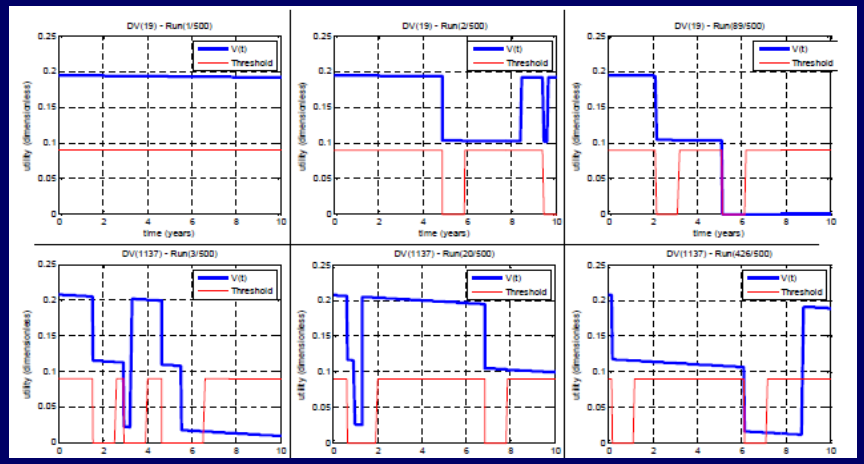
SCENARIO	EPR rules and regulations	Environmental adaptation of products	Required range of information about products	Waste sorting system	Collection system	Recycling system	Dominant EPR market for waste products	Instruments for deposition and burning
Global Crisis (Production gone wild)	Voluntary, branch regulated	Focus on clean materials	Chemicals Material Energy	> 15 commodity groups	Very near premises	Mechanical recycling	International	Recycling: Up Energy: Down
Raw Material Depletion	General legislation toward individual. No monopoly.	Same mix as today	Chemicals Material	> 15 material groups	High density "bring system"	Thermal recycling	National and close international	Recycling: Up Energy: Up
Current policies (Negative trend)	General legislation toward collective Partial monopoly.	Focus on dematerialisation	Chemicals Energy	Same as today	Low density "bring system"	Chemical recycling	Local/regional	Recycling: Down Energy: Up
Current policies (Positive trend)	Finely detailed legislation (who, how & what)		Chemicals only	< 5 commodity groups		Biological recycling		Relative increase of deposition
Green-house effect (Stop emissions)				< 5 material groups				
Batman: High-tech solutions								
Dematerialised production (New materials)								
Green market (ideological paradise)								

Morphological analysis can be used to gain a total picture of what each scenario would imply for each state of each strategy parameter

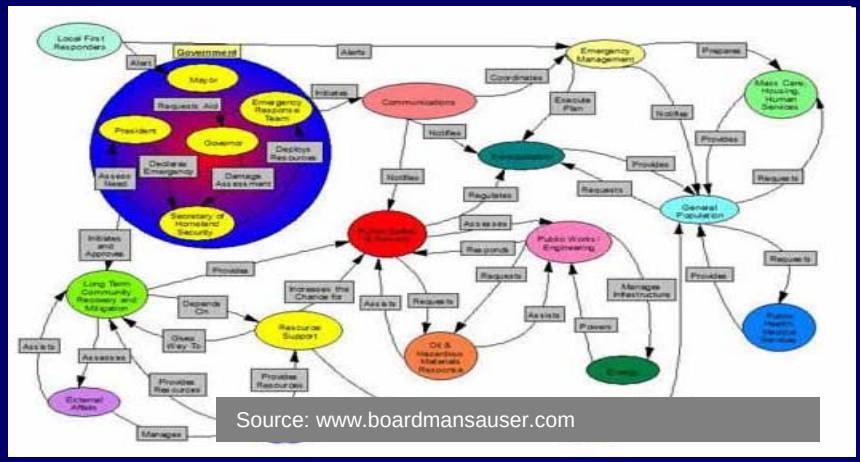
Source, Ritchey, T. 2008

Examples of Legacy and Newer Methods

Monte Carlo Simulation



Systemigram (Boardman)

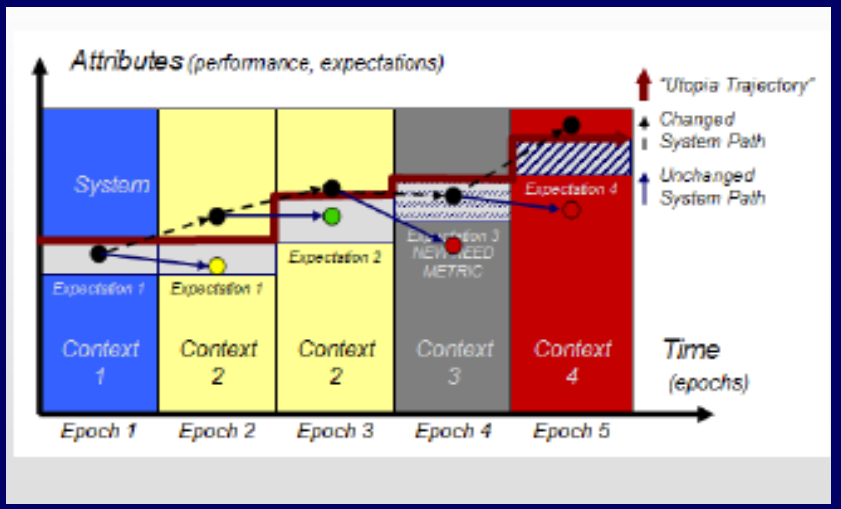


Morphological Analysis (Ritchey)

SCENARIO	Buyer behaviour	Consumption patterns Total: Private import:	Consumer sorting behaviour (trends)	National environmental policy	Price of new raw material vs reclaimed material	Production technology: volume of materials	Technology development: reclaiming technology	EU-directives for import and export of waste
Global Crisis (Production gone wild)	Willing to pay more for green products	Total: Up Private import: Up	Voluntary (ideologically driven)	At the forefront; Holistic approach (legal & econ.)	New: High Reclaimed: High	Much less than today	Very rapid increases	Less restricted than today
Raw Material Depletion	Will to buy green, but will not pay more	Total: Status Quo Private import: Up	Will sort for compensation/ reward	At forefront, but no holistic approach (legal only)	New: High Reclaimed: Low	Somewhat less than today	Substantial increases	Same as today
Current policies (Negative trend)	No interest in buying green products	Total: Up Private import: SQ	Will sort if facing sanctions	Ideological, based on voluntary acceptance	New: Low Reclaimed: High	Same as today	Only marginal increases	More restrictive than today
Current policies (Positive trend)		Total: SQ Private import: SQ	Will resist sorting	Least possible adaptation	New: Low Reclaimed: Low			
Green-house effect (Stop emissions)								
Batman: High-tech solutions								
Dematerialised production (New materials)								
Green market (ideological paradise)								

Source: Ritchey, 2009

Epoch-Era Analysis (Ross & Rhodes)



Summary

- Context and time are important aspects of complex systems and enterprises
- Legacy methods still in use but largely simpler analytic approaches and graphical/narrative approaches
- Newer approaches leverage model-based approaches
  - Epoch-Era Analysis