A (Natural) History of Interpretive Structural Modeling

Kevin Dye
Outline

- Definition, Examples, Application Walkthrough
- Technical
Interpretive Structural Modeling

- A knowledge elicitation technique which coordinates
  - A formal language for knowledge representation,
  - Directed Acyclic Graphs (DAGs),
  - Partially Ordered Sets (POSETS) and Relations,
  - Binary Matrices & Boolean algebra, with
  - an Abductive Logic Inference Engine that
  - ensures robustness of knowledge acquisition
  - while speeding up model creation.
- Also called a “Problem Formulation” method.
Interpretive Structural Modeling

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Brief History

- Formal Languages
- Graph Theory
- Theory of Relations
- Set Theory
- Binary Matrices
- Boolean algebra
- Hierarchies
- Robustness
- Abduction
- Integration in SW

- Frege, Hilbert
- Euler
- De Morgan
- Russel
- Cayley
- Boole
- Simon, Mesarovic
- Akao, Clausing
- Peirce
- Warfield
Example: Integration of Cyber & EW
Air Force Research Labs

Cross Impact of a Structure of Solutions and Structure of Challenges

Kirk Weigand, Thomas Flanagan, Kevin Dye, Peter Jones
Collaborative foresight: Complementing Long-Horizon Strategic Planning
Technological Forecasting & Social Change, Volume 85, June 2014, Pages 134–152
An Influence Map of Challenges

Fig. 5. Influence map of 20-year strategic challenges.
Boolean Matrix & Directed Graph

Neeraj Sangal, Ev Jordan, Lattix, Inc.
Vineet Sinha, Daniel Jackson, MIT
Using Dependency Models to Manage Complex Software Architecture
Proceedings of the 20th ACM SIGPLAN Conference on Object-oriented programming, systems, languages, and applications
Representational Fluidity

Logic, Diagrams, Sets, Matrices

Logic

Given

A R B
B R C

---------

Then A R C

When R is

Transitive
Asymmetric
Irreflexive

Directed Acyclic Graph

Transitive Reduction

Adjacency Matrix

From-To POSET

A, B
B, C

Transitive Closure

Reachability Matrix

Lower Triangular Form
Inference by Transitivity

Fig. 12. Partitioning unfilled matrix on one element.
Steps in each Stage of Inquiry

(a) Complex Situation

(b) Frame and Focus on a Triggering Question

(c) Articulate Observations

(d) Clarify Meaning

(e) Cluster Inductively

(f) Develop Shared Language

(g) Vote & Rank

(h) Structure Abductively

(i) Interpret Learning

(j) Evaluate Cross-Impact
Future of Energy Efficiency

Figure 1: Plausibility Pattern among Most Important National / Regional Trends / Events

Track 1: Energy Conservation
- (15a) Reducing the gap of energy consumption per capita among countries will increase the national need to save energy in whatever way there is (national)

Track 2: Energy Efficiency
- (87a) The growing interest in "green" and/or "pollution" taxes as a tax shift and how these concepts might have a role in energy conservation (WP3; Regional)

Track 3: Future Lifestyles
- (19a) People embrace compact urban form as a way to reduce automobile use and build community. Public shift in values is driven in part by high energy costs associated with long commutes and accessibility of alternative transportation systems (WP1; National)

Track 4: Energy Supply
- (39a) A rush to build new electricity supply and to rationalize the transmission grid will encourage a return to energy invisibility—papering over the problematic nature of use (WP4; National)

Track 5: The Future
- (47a) Improvements in technology and increased prices will lead to more distributed generation (WP4; National)

Level I
- (105a) If energy reliability is higher than in neighboring areas there will be an incentive for energy intensive industries, such as high technology to locate in the region (WP1; Regional)

Level II
- (15a) Installation of hardware solutions will be more effective than behavioral oriented programs. i.e. installing a CFL will be much more effective in the long term than reminding people to turn off their lights to reduce consumption (WP1; Regional)

Level III
- (46a) Continued concern and more documentation from the scientific community will lend credibility to global warming and lead to more mitigation activity (WP4; National)

Level IV
- (38a) The intensity of the Bonneville Power Administration, the foundation for energy and economic stability in the region, is at risk (WP4; Regional)

Level V
- (15a) Price volatility and/or higher prices for energy will be passed on to end users, consumers such that they get a very strong price signal. This will result in their demanding energy efficiency in all aspects of their home and business energy use. This will carry over into purchase decisions which will foster a strong demand "green or sustainable" products (WP2; National)

(82a) Price signals that reflect the real cost electricity (energy) will drive consumers to demand energy efficiency in all aspects of their domestic and business decisions (WP2; Regional)

(16a) Price volatility and higher prices for energy will be passed on to end users, consumers such that they get a very strong price signal. This will result in their demanding energy efficiency in all aspects of their home and business energy use. This will carry over into purchase decisions which will foster a strong demand "green or sustainable" products (WP2; National)

Produced by the participants at the NEEA Workshop — March 15, 2001
Erroneous Priorities

True influences found by SDD

Groupthink of dot voting

Erroneous Priorities

Through a structured deliberation that cultivates consensus on influence, into a “map” of leverage, managers and leaders gain confidence in their decision-making efficacy. The process makes the rationale for the priority-setting transparent to stakeholders, and establishes ownership in the consensus plan by the participants.

This graphic, taken from the workshop on New Bedford’s Creative Economy, illustrates the “Law of Erroneous Priorities.” In collaborative planning and decision making a common approach to consensus voting is the use of a voting mechanism to establish priorities. South Coast Design has documented that there is almost little correlation of what participants assess as a priority through group voting and what they determine to be the highly leveraging through application of the methodology.
Partitioning

1) Self-Interaction Matrix

2) Block Triangular Matrix

3) Condensed

4) Lower Triangular Matrix

5) Interpret the Design Pattern. In this case it is a strictly, layered System.
Partitioning & Tearing

John N. Warfield

**Binary Matrices in System Modeling,**
*IEEE Transactions on Systems, Man, and Cybernetics,*
**VOL. SMC-3, NO. 5,** September 1973
## “Contextual Transitive Relations”
(as espoused by J. N. Warfield)

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<th>Definitive</th>
<th>Influence</th>
<th>Comparative</th>
<th>Temporal</th>
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<td>right of</td>
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<td>equal or higher</td>
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<td>more useful than</td>
<td>Overlaps in time</td>
<td>has component</td>
<td>Is disjoint with</td>
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<tr>
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<td>Confirms</td>
<td>more important</td>
<td>Is disjoint in</td>
<td>lies above</td>
<td>has non-zero interaction</td>
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<td>Weakens</td>
<td>more critical</td>
<td>than</td>
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Publication Trends

NGRAM of Publication Trends in Google Books

Interpretive Structural Modeling
Object Oriented Analysis
Structured Analysis and Design Technique
R&D on ISM Shifts to Asia ~1980
Structured Modeling Tutorial 1980

Fig. 3. "Map" (or structural model) of structural modeling.

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