Exploratory Steps Toward Formal Analysis Methods for Knowledge Networks, A Socio Technical Perspective

Paola Di Maio

Modelling and Analysis of
Networked and Distributed Systems
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http://www.cs.stir.ac.uk/events/network-analysis/

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ABSTRACT

Knowledge Networks for Systems Engineering are here considered as STS. In this presentation I attempt to:

- Identify the problem space
- Capture and characterise some of the key factors
- Justify the requirement for formal analysis
- Evaluate Options
- Point to work ahead

LIMITATIONS:
Still exploratory, in progress

MAIN QUESTION
(for this presentation)

What formal methods are adequate for the modelling and analysis of knowledge driven socio technical networks?

DEFINITIONS

FORMAL METHOD: mathematical /**Logical** technique for the specification, development and verification of systems.

KNOWLEDGE: cognitive ability to interpret, understand and apply information and data, and their correlations (and what we have not enough of, as opposed to data and information of which we get saturated with), human characteristic

Note: K is the product of emergence, and a dynamic, adaptive congnitive state (to be 'in the know')

SYSTEM:“a complex whole” formed from a “set of connected things or parts” (Allen, 1984)

STS: System resulting from the interaction of social and technical systems

KNOWLEDGE NETWORK: Network for transmitting information within an organization that is based on informal contacts between managers within an enterprise and on distributed information systems.

highered.mcgraw-hill.com/sites/0073381349/student_view0/glossary.html

FORMAL ANALYSIS http://www.rbjones.com/rbjpub/methods/fm/fm016.htm

A Framework for Formal Analysis

Introduction:

- A framework for formal analysis and abstract modelling.
- Languages, methods, tools.
- Solid logical foundations; carefully articulated philosophical rationale.

Methods supporting reliable deductive reasoning with abstract models in all application domains	**Philosophy** underpinning and delineating the scope of applicability of the methods	**Logic** modern classical logical foundations deliver the full power of applicable mathematics
	Languages providing precision notations, both general and domain specific	**Software** provides effective support for formal analysis and modeling

Philosophy:

- Epistemology, phil. logic, mathematics and engineering underpin the framework.
- Varieties of philosophical analysis are considered, a new one is presented.

History: varieties of 20thC philosophical analysis are contrasted with the formal analysis advocated here	**Logic**: an analysis of the nature of logical truth leads to firm logical foundations for formal analysis	**Engineering**: a formal analytic position is elaborated on the application of logic through mathematics in science and engineering
Epistemology: familiar fundamental epistemological distinctions are identified on which formal analysis is predicated	**Mathematics**: the logicist thesis is re-affirmed and related to other positions in mathematical philosophy	**Philosophy**: applications of formal analysis in philosophy are considered

Logic:

Single powerful classical logical foundation system provides a touchstone for analytic truth.

Feature	Pedigree	Rationale
modern predicate calculus	Frege	expressive for mathematics
the iterative conception of set	Cantor	clean semantic bedrock
logical type theory	Russell	consistency and discipline
axiomatic set theory with separation	Zermelo	consistency and flexibility
simply typed lambda-calculus	Church	uniform variable binding
replacement axiom for sets	Fraenkel	logical strength in set theory
simple polymorphism	Milner	more flexible type system

Gordon's polymorphic Higher Order Logic, and a classical set theory with universes and polymorphic urelements, provide a strong, conservative, pragmatic, implementable logical foundation system for formal analysis

SOCIO TECHNICAL SYSTEM

CONSTANT CHANGE/EVOLUTION
CAUSAL DEPENDENCIES
INTERACTIONS AND TRANSFORMATIONS
PSYCHOLOGICAL AND SOCIAL FACTORS
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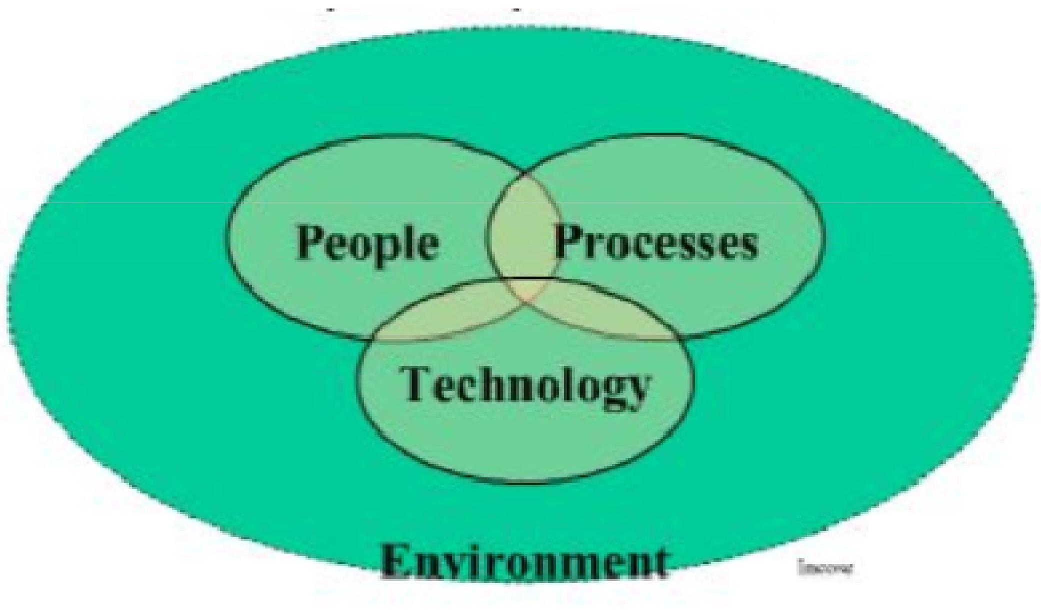
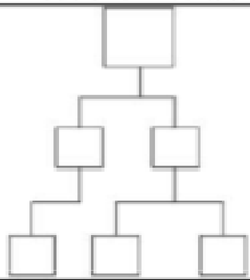
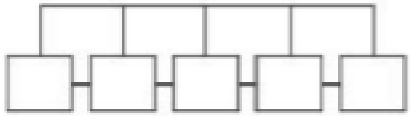
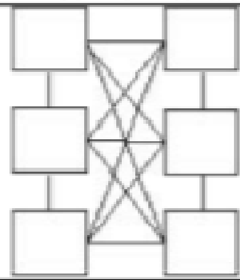
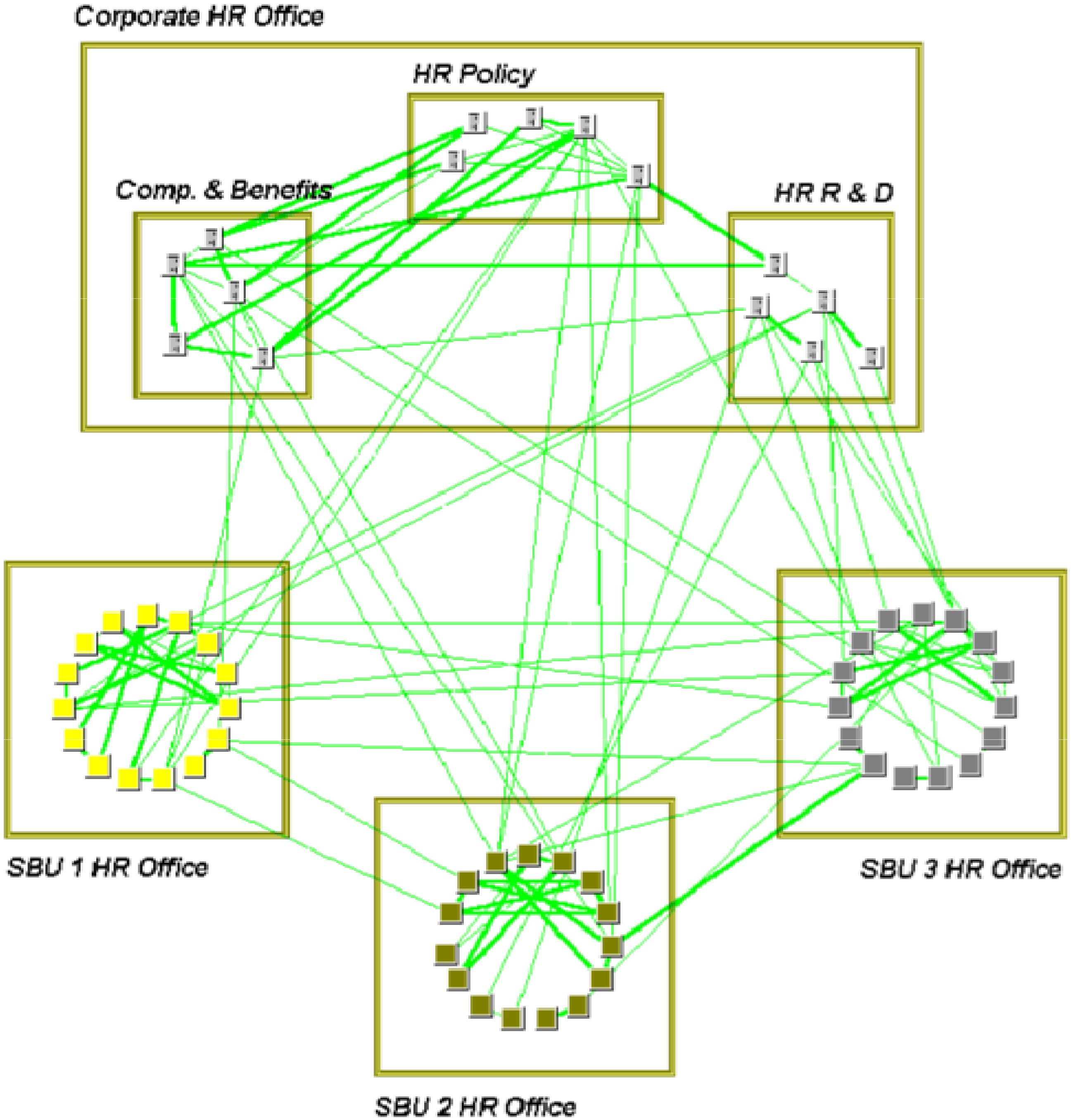


	Production Network	Development network	Innovation Network
Illustration			
Nature of the system	Mechanical	Organic	Dynamic
Aim	Effective production of a pre-designed product for the focal company	Sharing knowledge between actors. Shared knowledge benefits the actors individually	Constant creation of innovations and new knowledge
Structure	Vertical	Horizontal	Diagonal
Relationships	Determined by hierarchy	Reciprocal, seeking consensus	Spontaneous, abundant
Social connections in the network type	Not many. Interaction is restricted to production-related matters	Every organization (actor) is represented by a person. These representatives keep up personal relations with each other	There are a lot of connections between the firms' personnel
Duration of co-operation	Long-term. Dyadic relations are important investments	Can be either long-term or short term	Co-operation sustained until innovation is complete
Knowledge and competence	Defined, explicit	Experiental, hidden, tacit	Intuitive, potential
Information flow	One-way, top-down	Multi-way, horizontal	Chaotic, sporadic
The role of communication in the network	Clear rules and regulations. Possibly a shared ERP system	Casual interaction between people in a specific region	A lot of entropy, i.e. excess communication and information
Importance of location	Subcontractors can be located geographically anywhere as long as logistics and information flows are functioning	Requires face-to-face communication	Regionality is pronounced in the development of innovations, but some actors can still be located geographically elsewhere
Management and leadership method	Orders, direct use of power	Dialogue, empowerment	Personal networking skills, relinquishing power



Corporate HR Office
HR Policy
Comp. & Benefits
HR R & D
SBU 1 HR Office
SBU 2 HR Office
SBU 3 HR Office

A technological system is defined as:

... networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse and utilizetechnology.
Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services.

.....They consist of **dynamic knowledge and competence networks** (Carlsson and Stankiewicz, 1991).....

.....The material aspect of systems is central in the **Large Technical Systems (LTS)** approach. technology involving infrastructures,
e.g. electricity networks, railroad networks, telephone systems, videotex, internet.....

(FROM: http://www.ksinetwork.nl/downs/output/publications/ART029.pdf

Knowledge Networks for Systems Engineering

MAIN ISSUES:

- K is **essential** to critical decisions, which rests on humans
- Engineers are familiar with data and information, rather than 'knowledge'
- SEngineering BOK is a challenge for the practice (they tend to have a components engineering perspective)
- Knowledge exchange is limited
- Knowledge Management is a challenge for the practice

KNOWLEDGE ENGINEERING

- Knowledge is essential factor to

- innovate
- ensure dependability
- decision making at all levels

- Knowledge Management Requirements are increasing
- Knowledge Networks are essential to satisfy these requirements

MORE GENERAL K CHALLENGES

- Information overload
- Exponential Increase of knowledge requirements
- Very fast knowledge exchanges
- Very fast systems development cycles
- Can't keep up with progress in different areas
- Convergence of many disciplines
- Difficult to stay on top of everything
- Too much knowledge to grasp/reason with/model/represent
- Very rapid changes, short iterations make project planning diffcult

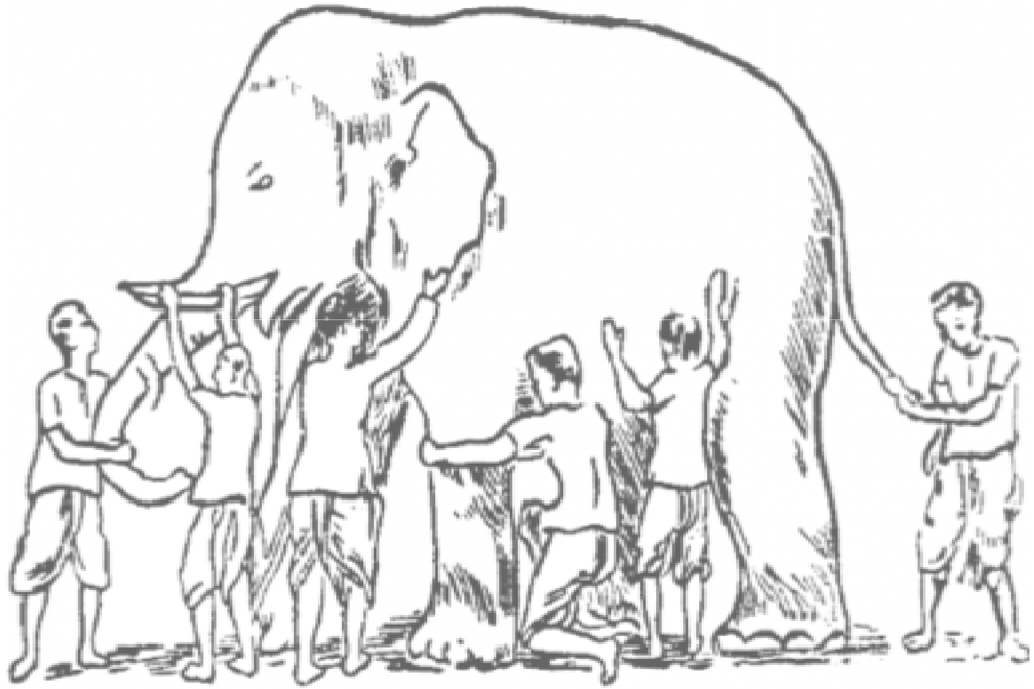
PROBLEMS CAUSED BY LACK OF K

- Limited ability to make decisions!
- Systems which can be theoretically perfect, but that in practice display various classes of flaws
- Error/Accident/Risks that derive
- General lack of awareness
- In commercial terms: no ability to innovate, general cluelessness, no 'edge'
- Sometimes unintelligent outcomes
- All/most problems caused by inadequate K

KNOWLEDGE DISCONNECTEDNESS

Working Definition: when knowledge about a fact, or set of facts is fragmented, and is not accessible as a whole, results in 'very few know something', K is often mistaken for belief, opinion, or awareness of something (do you know ?...)

an old metaphor of the elephant and the blind men



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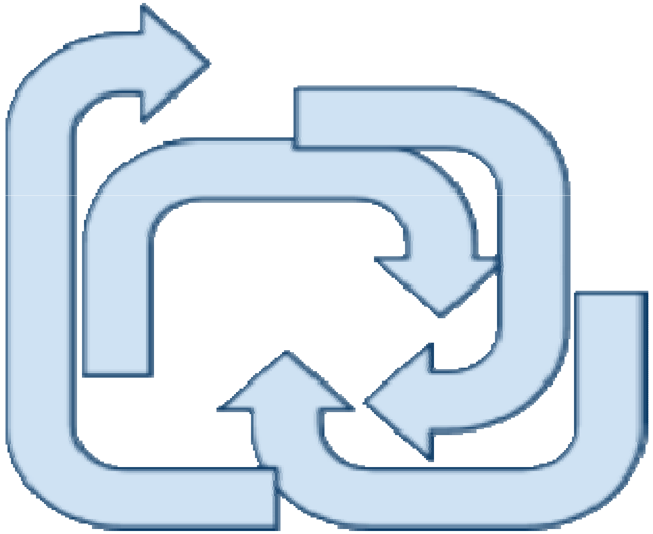
mage source: mcckc.edu/~lewis/gs/blindmen.htm

MORE SPECIFIC PROBLEMS

- Despite mission critical, fault tolerant, zero tolerance systems, systems fail sometimes with fatal consequences
- Human factors, more specifically the poor modelling of socio technical factors is identified as a key contributing factor

KD COMPLEX PROBLEM

MADE UP OF DIFFERENT PROBLEM SPACES:



TECHNICAL
COGNITIVE
ORGANISATIONAL
SOME ARE POLICY

BUT MOST PROBLEMS ARE COMPOUND
(problem entanglement)
PROBLEM CHAIN/DEPENDENCIES

(DOCTORAL RESEARCH /A FRAMEWORK)

JUSTIFICATION:THE NEED FOR FORMAL ANALYSIS IN STS

Seven Principles of Sociotechnical Systems Engineering ... Development methods must support formal analysis for dependability. Sociotechnical - Martyn Tomas

1. Preserve the real world requirements
2. Keep the humans in the loop
3. Training is a first-class system component
4. Human behaviour must be made dependable
5. Don't set traps
6. Plan for deviant behaviour
7. Development methods must support formal analysis for dependability

www.indeedproject.ac.uk/wstse/programme/.../thomas08principles.ppt

Keep the humans in the loop

"why is it doing that?"

All humans within the STS must understand the system's behaviour adequately at all times

The system designer should ensure that the users understand what the system is doing

14 February 1990; Indian Airlines A320; Bangalore, India: Controlled flight into terrain during approach. Aircraft hit about 400 metres short of the runway. Four of the seven crew members and 88 of the 139 passengers were killed. The pilot had accidentally caused the A320 to enter "Open Idle descent". This had the effect of delaying "alpha-floor activation" which the PIC probably thought would save them. [See Mellor 1994]

Development methods must support formal analysis for dependability

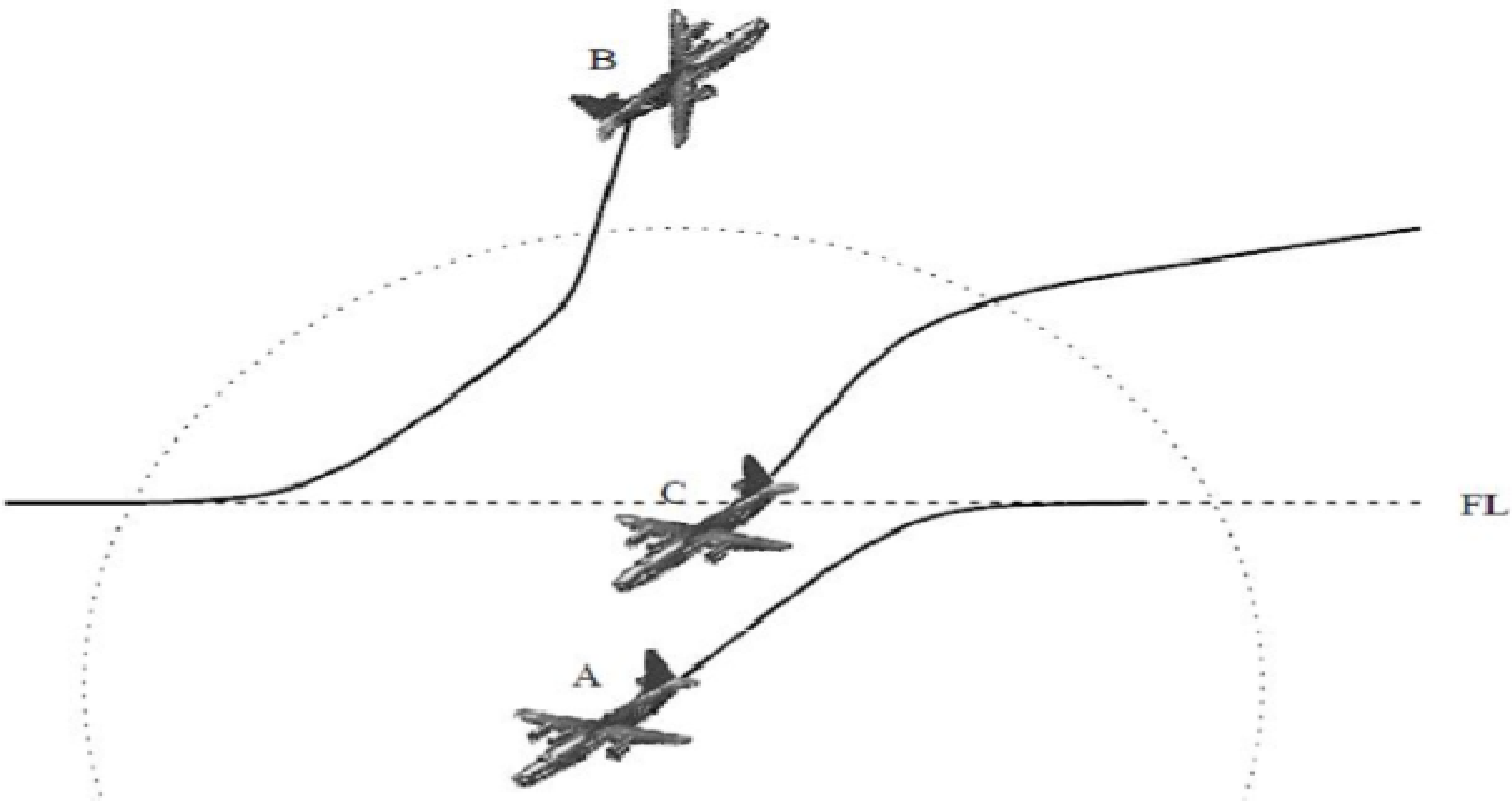
- It is impractical *or impossible* to gain adequate confidence in any significant STS through testing alone
- Formal analysis must therefore be at the core of the dependability case
- The necessary science is incomplete. The engineering methods that exploit the science are immature or have not yet been developed
- Current industry standards for developing critical STS are inadequate
- This is a grand challenge for researchers and for the systems industry.

CASE: Uberlingen =From the PAPER Causal Analysis of the ACAS/TCAS Sociotechnical System

1 July, 2002, a Tupolev 154M operated by Bakshirian Airlines (BTC), a Russian airline, was flying Southern Germany destination in Catalunya. A Boeing 757 operated by the cargo airline DHL was ying northbound over Switzerland Both were operating under Instrument Flight Rules (IFR), compulsory atthis Flight Level.

Skyguide, the Swiss air trac control organisation, had control of both aircraft, and accordingly responsibility for separation of the aircraft.controller on duty operating two positions, some meters apart, because colleagues were on break..
Another air trac control facility at Karlsruhe had noticed the convergence, but was unable to contact Zurichthrough the dedicated communication channel, which was undergoing maintenance
11 seconds after DHL informed the controller of the TCAS descent, the two aircraft collided.
(sad twist: controller involved was murdered by presumed distraught relative of an accident victim_

Uberlingen collision



Uberlingen cont.d

The responsible investigating authority, the German BFU, issued report in May 2004 [Bun04]. It contains a thorough discussion of the **sociotechnical system** consisting of the Skyguide air traffic control

- Many factors contributing to the accident concern the operation of this system. In addition, BTC's **decision to descend** was cited as a factor. The TCAS avionics was found to have **operated as designed and intended.**
- Also cited as a factor were the many, often contradictory, procedural instructions or advice to pilots on appropriate procedures on reception of a TCAS Resolution Advisory. The report enumerates all these pieces of advice and contains a thorough discussion.
- **BOTTOM LINE:** given the contradictory mess, the only possible decision rests on the **cognitive state** of the person in charg (uh?)

FA FOR STS ARE MUCH NEEDED

Formal Analysis Methods (as we know them) do not take into account human/cognitive/social norms factors
Adequate Methods need to be developed
We can draw from existing practices
for example: Morphological Analysis

Morphological Analysis
http://www.swemorph.com/pdf/it-webart.pdf

- From classical Greek (morphe) :and means shape or form
- Morphology is the study of the shape and arrangement of parts of an object, and how these parts "conform" to create a whole or Gestalt.
- The "objects" in question can be physical objects (e.g. an organism, an anatomy, a geography or an ecology) or mental objects (e.g. word forms, concepts or systems ofideas).

A methodological framework for creating models of systems and processes, which cannot be meaningfully quantified

- Extended typology analysis was invented as early as the 1930's by Fritz Zwicky, professor of astronomy at the California Institute of Technology – the famous Caltech in Pasadena

MORPHOLOGICAL ANALYSIS IS:

A GENERALISED METHOD FOR STRUCTURING AND ANALYSING COMPLEX PROBLEM FIELDS WHICH:

- ARE INHERENTLY NON-QUANTIFIABLE
- CONTAIN GENUINE UNCERTAINTIES
- CANNOT BE CAUSALLY MODELLED OR SIMULATED
- REQUIRE A JUDGMENTAL APPROACH

Source: *Tom Ritchey, 2003-2009*

ritchey@swemorph.com

What is MA used for?

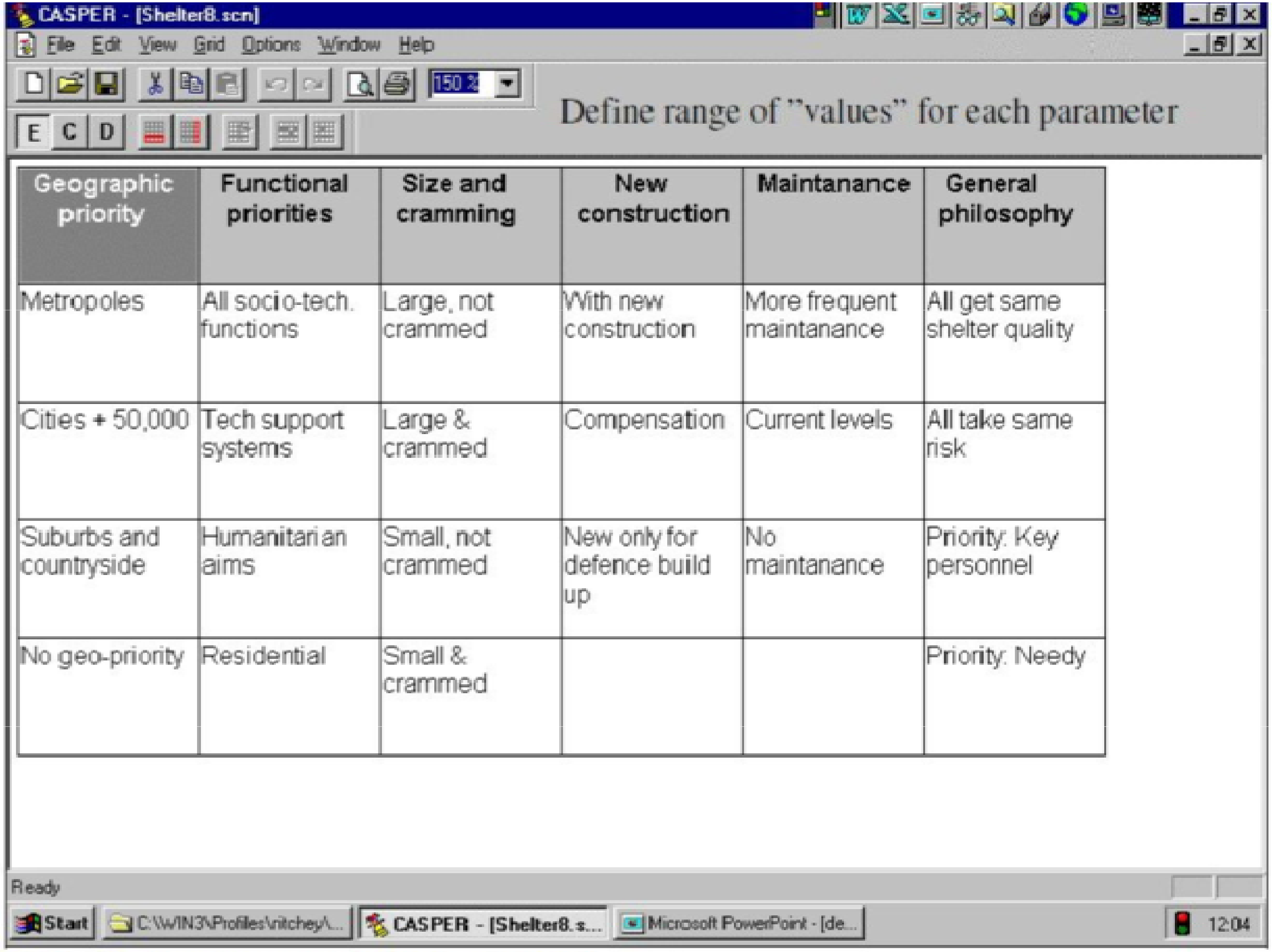
- Complex issue which is not well formulated or defined; (”wicked problem”)
- Well formulated/defined issue, but with no single solution (different solutions depending on…)
- Well defined problem with aspecific solution which can be worked out.

- Mess
- Problem
- Puzzle

(Russell Ackoff: Redesigning the Future, 1974; Michael Pidd: Tools for Thinking, 1996.)

HOW TO PERFORM MA

1. Need a 'messy' problem (just look around, no shortage)
2. Get 5-7 specialists to solve it in small iterative steps
3. Define parameters, 6-8 enough for most problems, real world can never be complete
4. define values for each parameter (sometimes on a scale)
5. get the morphological field everyone is happy with, keep it small
not a table but a multidimensional configuration space
6. get rid of all the values which are contradictory (resulting in internal inconsistencies)
7. How do you reduce the field? You do this by comparing each condition with every other condition, and asking the question: Can these two conditions coexist? This is done by way of a cross-consistency assessment, with the help of a cross-consistency matrix



Geographic priority	Functional priorities	Size and cramming	New construction	Maintanance	General philosophy
Metropoles	All socio-tech. functions	Large, not crammed	With new construction	More frequent maintanance	All get same shelter quality
Cities + 50,000	Tech support systems	Large & crammed	Compensation	Current levels	All take same risk
Suburbs and countryside	Humanitarian aims	Small, not crammed	New only for defence build up	No maintanance	Priority: Key personnel
No geo-priority	Residential	Small & crammed			Priority: Needy

Slide 8: Proto morphological field

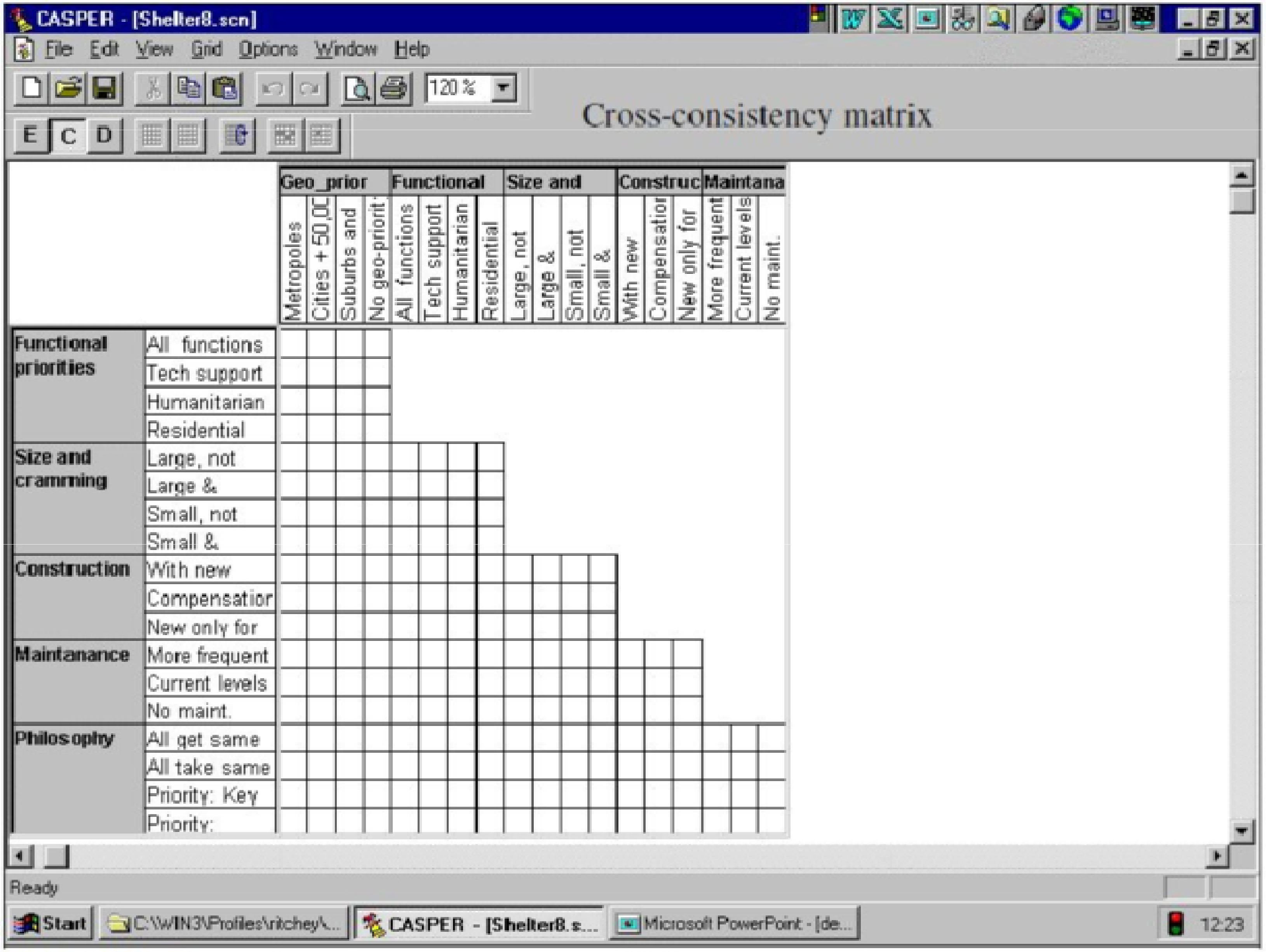
The totality of the parameters and their respective values is a *morphological field*. V

Casper - [EkoEng3K.SCN]

File Edit View Grid Options Window Help

Victim	Type of crime (10 general examples)	Method	Types of solutions available	Legislation	Influence motives
Consumer	Cheating on taxes/tolls etc.	False information to official	Physical/visible controls	Standard regulations	Influence goal
External environment	Environmental crimes	Physical handling	Technical solutions	Order regulations	Influence means
Competitors	Fraud against companies	Bookkeeping	Administrative controls	Permission regulation	Reward
Employees	Crimes to reduce costs	Financial transactions	System and organisational solutions	Proceeding regulations	Sanction
Financers	Limiting competition	International IT- transactions	NONE	NONE	NONE
Owners	Cheating with subsidies	Planned bankruptcy			
The State	Swindles and stock influence	Illegal info transaction			
Market mechanisms	Insider crimes	Price fixing			
	Company plundering				
	Money laundering				

CROSS CONSISTENCY MATRIX



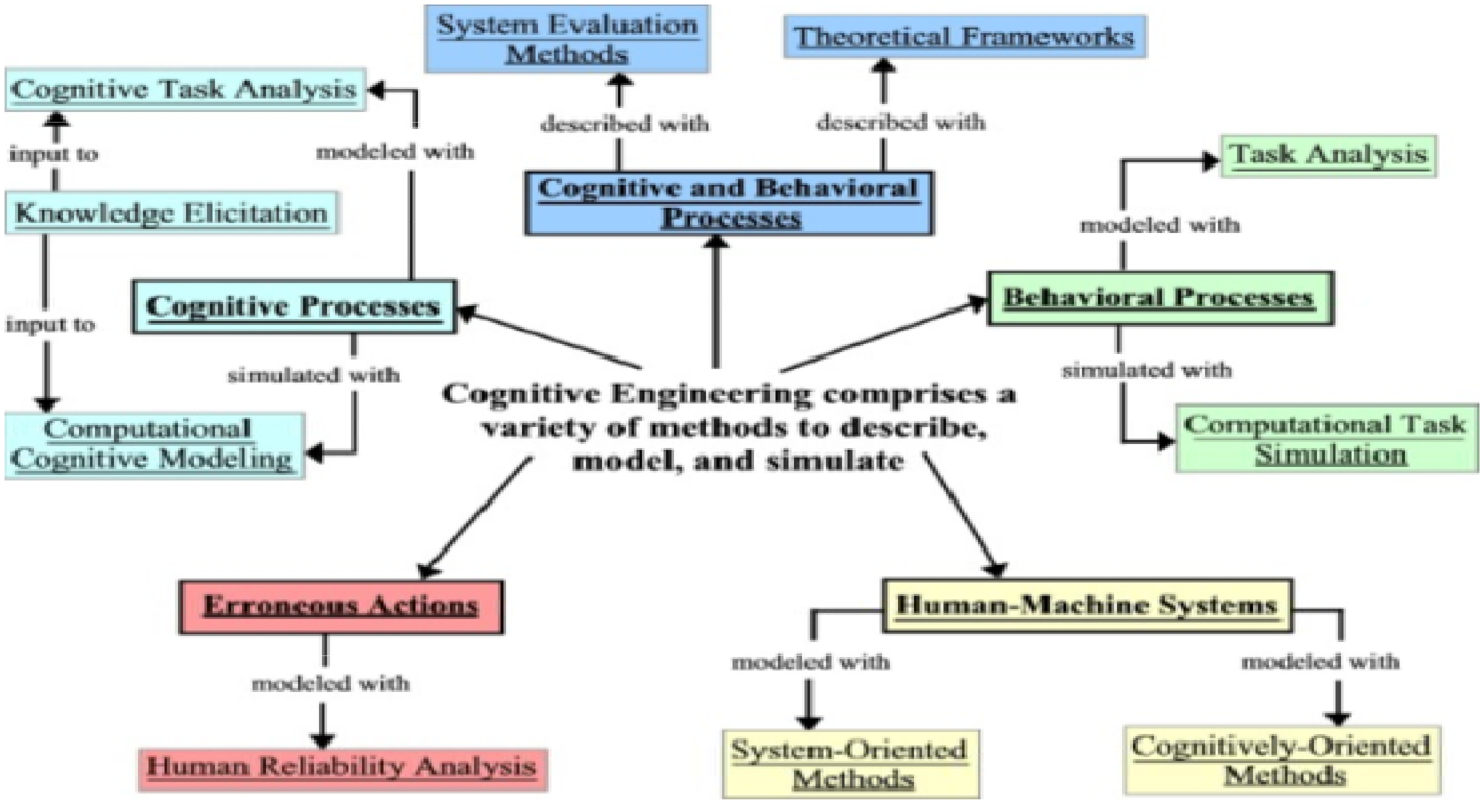
OTHER METHODS OF FA FOR KN

- Social Network Analysis
- Cogntive Engineering
- Dynamic Ontology Modelling

Social Network Analysis (Krebs)

- [SNA] is the mapping and measuring of relationships and flows between people, groups, organizations, computers, URLs, and other connected information/knowledge entities. The nodes in the network are the people and groups while the links show relationships or flows between the nodes. SNA provides both a visual and a mathematical analysis of human relationships. Management consultants use this methodology with their business clients and call it Organizational Network Analysis [ONA].
- To understand networks and their participants, we evaluate the location of actors in the network. Measuring the network location is finding the centrality of a node. These measures give us insight into the various roles and groupings in a network -- who are the connectors, mavens, leaders, bridges, isolates, where are the clusters and who is in them, who is in the core of the network, and who is on the periphery
- Centrality measures: Degree Centrality, Betweenness Centrality, and Closeness Centrality.

Cognitive Engineering 1



http://mentalmodels.mitre.org/cog_eng/

Cognitive Engineering 2

		Method	Concept Definition	Requirements Analysis	Function Analysis	Function Allocation	Task Design	Interface and Team Development	Performance, Workload, and Training Estimation
Cognitive Task Analysis	I.A.1	Applied Cognitive Task Analysis (ACTA)							
	I.A.2	Critical Decision Method (CDM)							
	I.A.3	PARI Method							
	I.A.4	Skill-Based CTA Framework							
	I.A.5	Decompose, Network, and Asses (DNA) Method							
	I.A.6	Task-Knowledge Structures (TKS)							
	I.A.7	Goal-Directed Task Analysis (GDTA)							
	I.A.8	Cognitive Function Model (CFM)							
	I.A.9	Cognitively Oriented Task Analysis (COTA)							
	I.A.10	Hierarchical Task Analysis (HTA)							
	I.A.11	Interacting Cognitive Subsystems (ICS)							
	I.A.12	Knowledge Analysis and Documentation System (KADS)							
	I.A.13	Team CTA Techniques							

DYNAMIC DOMAIN/ONTOLOGY ENGINEERING

We are familiar with 'classic' ontology development, in the future we ll rely increasingly on 'dynamic' (evolutionary) ontology modelling techniques

CONCLUSION

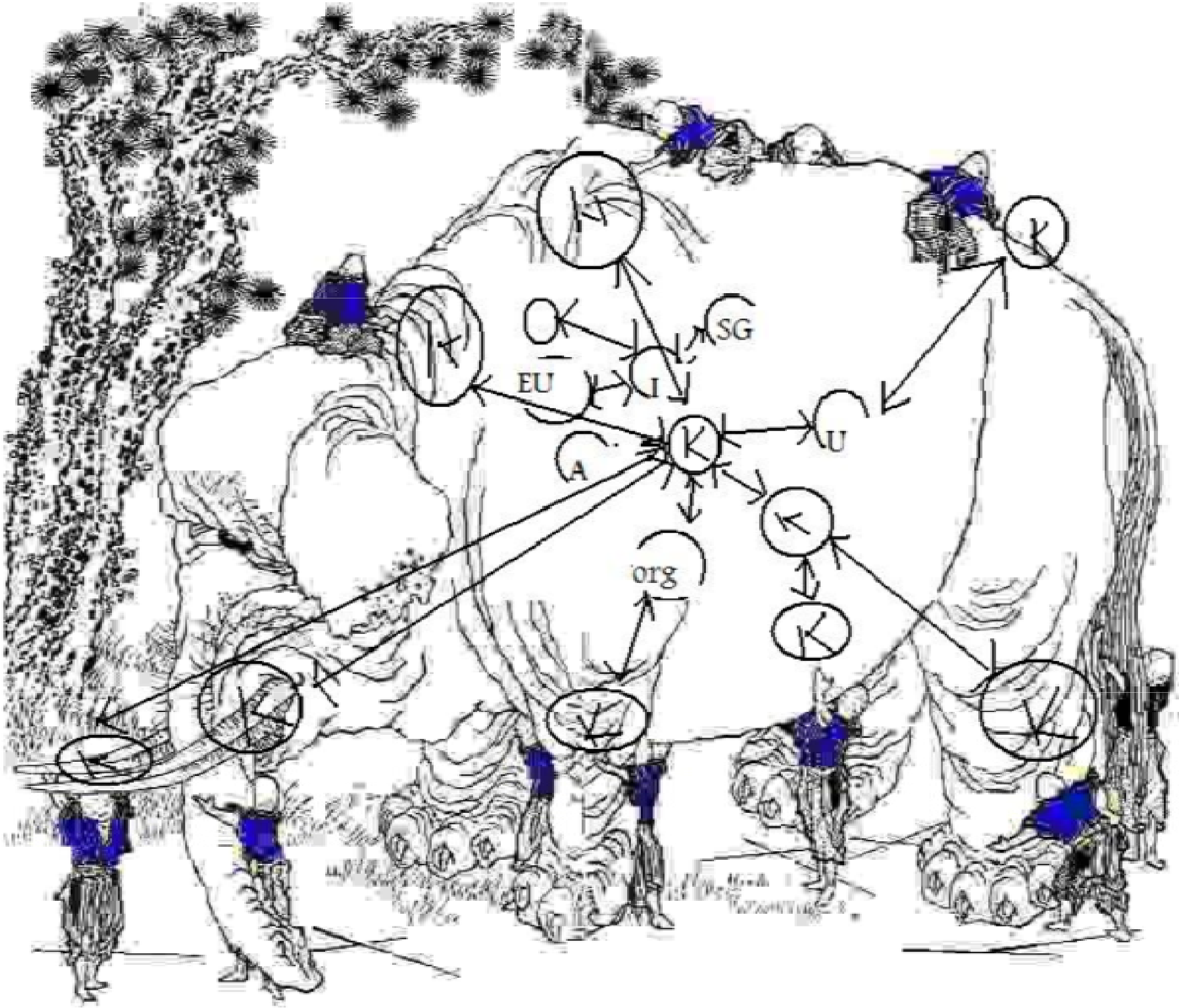
I illustrate some aspects of the problem space and provide rationale and brief overview of FA for STS

----- OOO ------

The motivating questions for this presentation is
What formal methods are adequate for the modelling and analysis of knowledge driven socio technical networks?
we can conclude that

logic based, polymorphic
FA methods are needed

It is expected that new methods will
result from the layered combination of existing methods
benefit from agile approach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References and sources of K

http://www.ksinetwork.nl/downs/output/publications/ART029.pdf
http://www.narcis.info/research/RecordID/OND1321279/Language/en
[PPT] Some Principles of Sociotechnical Systems Engineering
File Format: Microsoft Powerpoint - View as HTML
Seven Principles of Sociotechnical Systems Engineering ... Development methods must support formal analysis for dependability. SociotechnicalSystems ...
www.indeedproject.ac.uk/wstse/programme/.../thomas08principles.ppt
http://www.swemorph.com/pdf/it-webart.pdf
http://www2.chi.unsw.edu.au/pubs/COIERA-07-STS.pdf
http://homepages.cs.ncl.ac.uk/michael.harrison/dsn/andersons_felicim_evolution.p
http://findarticles.com/p/articles/mi_m4153/is_n2_v51/ai_15382647/

"Never underestimate the power of a few committed individuals to change the world. Indeed, it's the only thing that ever has."

Margaret Mead
SGSR President 1972-1973

paola.dimaio@gmail.com