Requirements Engineering:

Panacea or Predicament?

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OUTLINE

THE STATE OF PRACTICE & RESEARCH

CHALLENGES TO R.E.

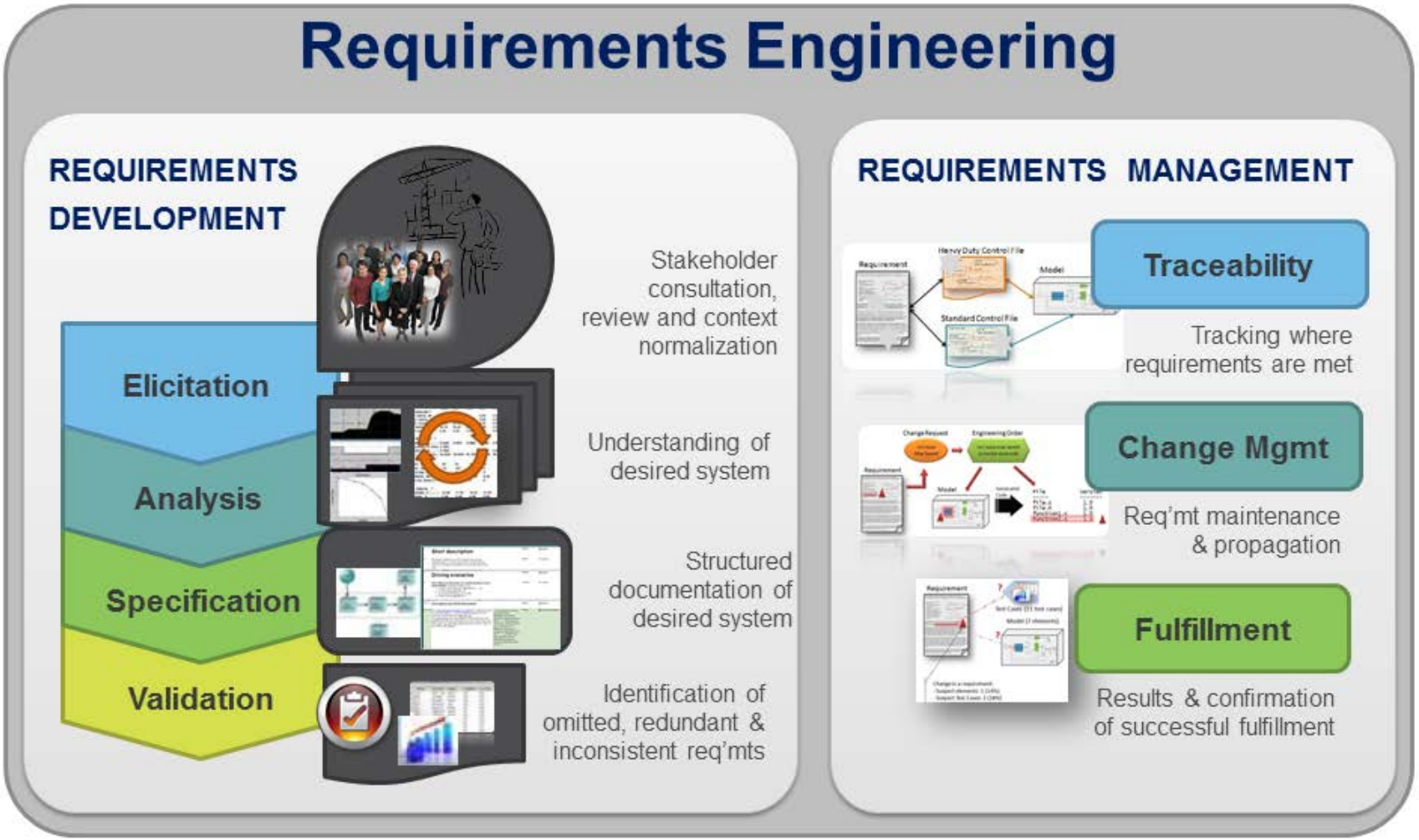
RESEARCH ISSUES FOR R.E.

Requirements & R.E.

- Requirements
  - A set of desirable functional and non-functional properties that must be possessed or met by a system or system component to satisfy an agreed set of organisational goals
- Requirements Engineering
  - “The branch of systems engineering concerned with ‘real-world’ goals for, services provided by, and constraints on, software intensive systems” [1]
  - “The systematic process of developing requirements through an iterative co-operative process of analyzing the problem, documenting the resulting observations in a variety of representation formats an checking the accuracy of the understanding gained” [2]

[1] IEEE-Std.'830' (1984). IEEE Guide to Software Requirements Specifications, The Institute of Electrical and Electronics Engineers, New York.
[2] Loucopoulos, P. and Karakostas, V. (1995). *System Requirements Engineering*. London, McGraw Hill.

Requirements Lifecycle



About Requirements Engineering

- It has a 40 years history
- Much research activity as evidenced by
  - 17 volumes of Requirements Engineering journal
  - Frequent publications in related journals (IEEE TSE, IEEE Software, ACM TOSEM, Software: Practice & Experience, Information Systems, Software Quality, Software & Systems Modelling)
  - Many conferences and workshops (IEEE/ ACM RE, REFSQ, REPOS, Agile RE, REET, REV, MoDRE, WER, CAiSE, ICSE
- Considered by industry as a most critical development activity

A Study 20 Years Ago

$4.5M - 17 Projects from

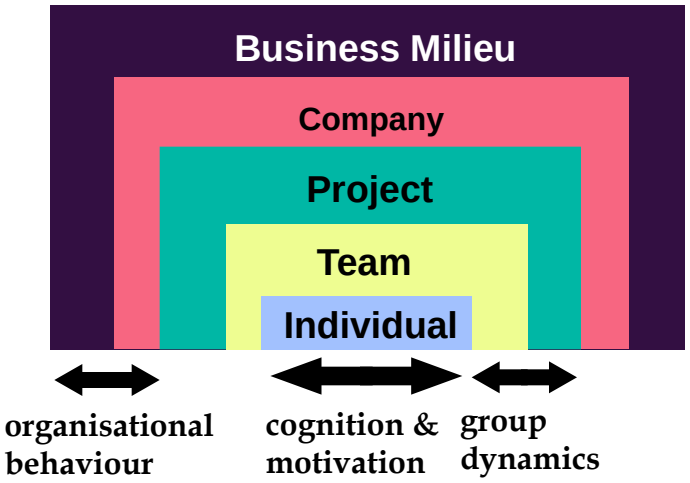
Manufacturing

Telecommunications

Consumer electronics

Aerospace

Approach



Findings

- The thin spread of application domain knowledge
- Fluctuating and conflicting requirements
- Communication and coordination breakdowns

Lubars, M., Potts, C. and Richter, C. (1993). *A Review of the State of the Practice in Requirements Modelling*, IEEE International Symposium on Requirements Engineering, IEEE Computer Society Press, (ed.), San Diego, California, pp2-14.

Requirements Specification

- Consider a procurement project for a national health service for which different bids may be made
- Requirements need to be defined in sufficient abstraction so that a solution is not pre-defined and as to allow alternative technological implementations
- Once the contract has been awarded the contractor must write a definition as a reference document against which the contract can be validated by the client

Separation of Concerns

- User requirements
  - Statements in natural language plus diagrams of the services the system provides and its operational constraints. Written for customers.
- System requirements
  - A structured document setting out detailed descriptions of the system's functions, services and operational constraints. Defines what should be implemented so may be part of a contract between client and contractor.

Examples of Requirements

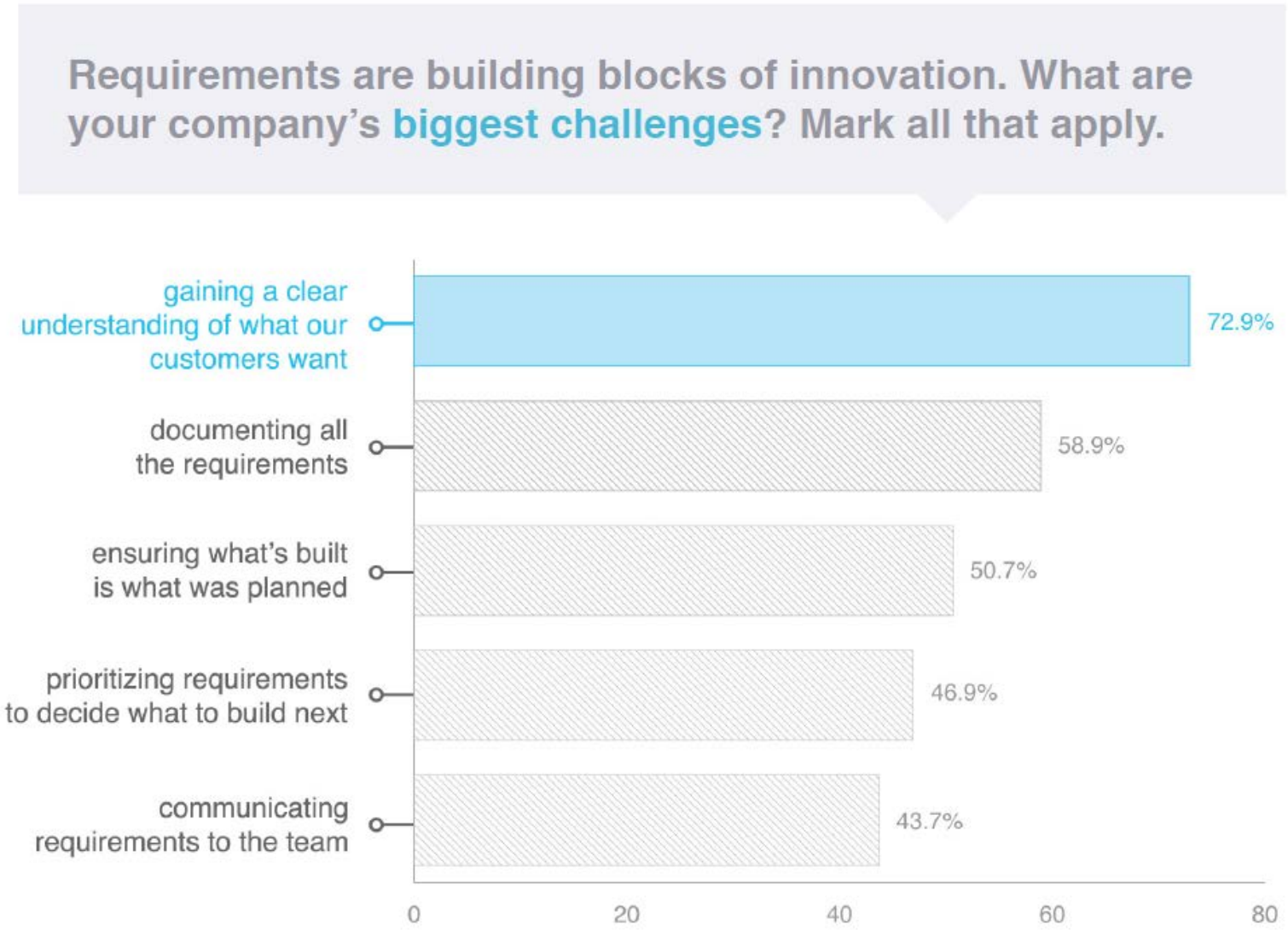
- Functional requirements
  - “If a patient requires multiple drugs treatment the system should warm physicians about conflicting medications”
- Non-functional requirements
  - “System downtime should not exceed 10 seconds”
- Domain requirements
  - “The system must be implemented in a way that patient information conforms to the statutory personal data protection act”

The State of R.E. Practice

- Survey of 808 participants
- Key findings
  - requirements used for both innovation and enhancing existing products
  - mixed approach to requirements
  - process is complex due to number of requirements as well as continuous change of requirements
  - ‘primitive’ tools still used
- Let’s have a look at some data

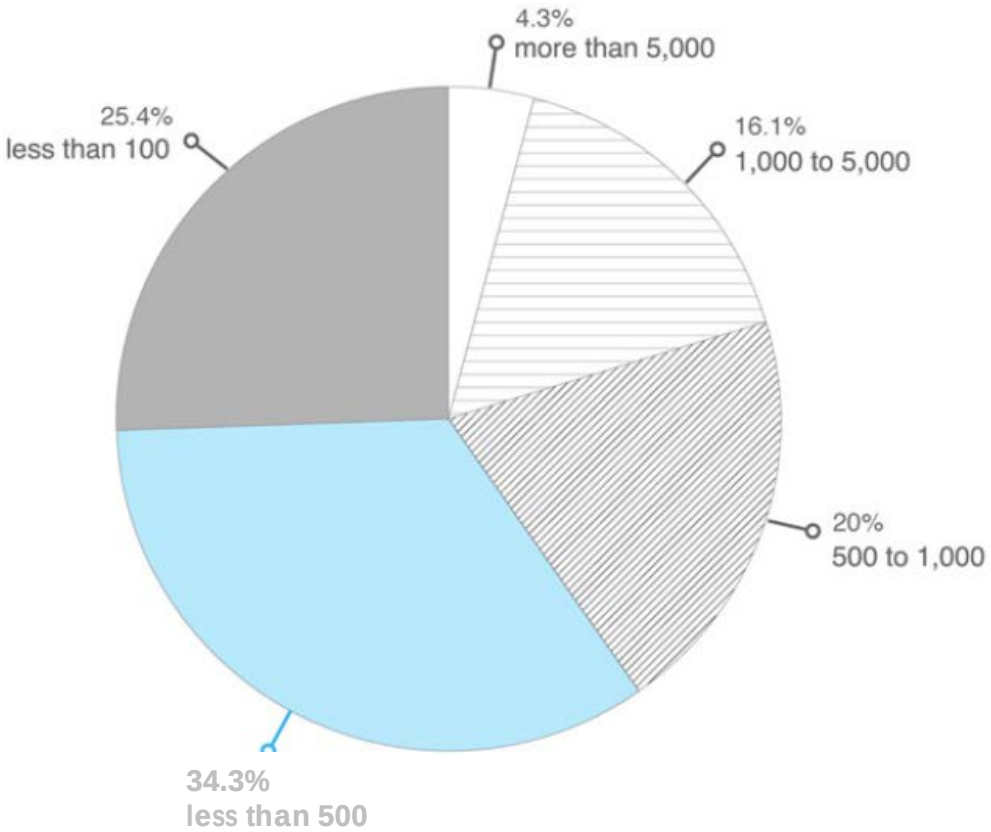
Source: Jama Software Survey (2011)

Understanding Customer Needs

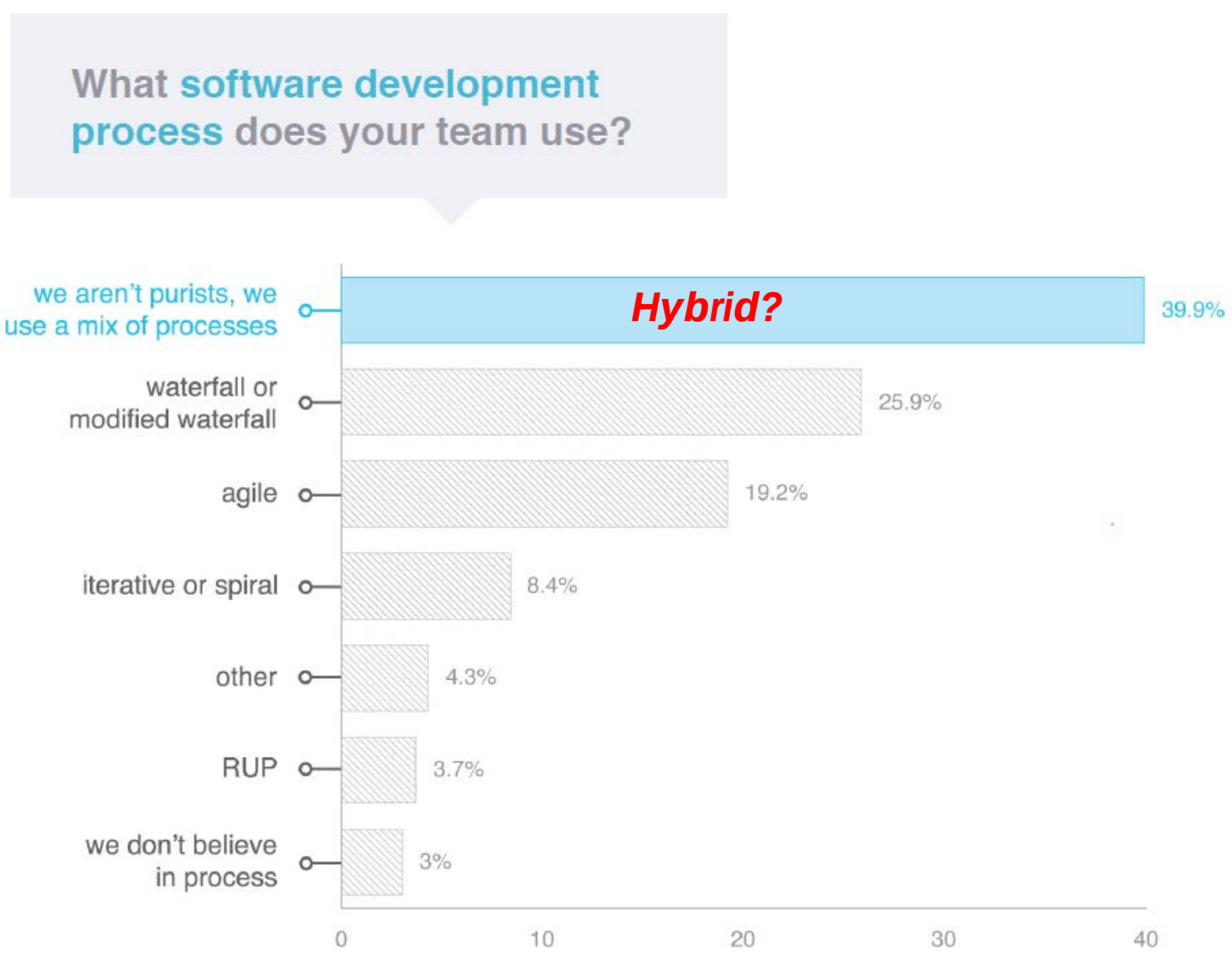


Dealing with Volume of Requirements

Let's talk about **complexity.** On average, how many requirements does a project contain?



Approaches Used



The state of R.E. Research

	Notations	Methods	Tools
Elicitation			
Modelling			
Analysis			
V&V			
Management			

Nuseibeh, B. and Easterbrook, S. (2000). *Requirements Engineering: A Roadmap*, 22nd International Conference on on Software Engineering, (ed.), Limerick, Ireland, June 4-11, 2000, pp35-46.
Cheng, B. H. C. and Atlee, J. M. (2009). *Current & Future Research Directions in Requirements Engineering* in Design Requirements Engineering: A Ten-Year Perspective. K. Lyytinen, P. Loucopoulos, J. Mylopoulos and B. Robinson (eds), Springer.
Hansen, S., Barente, N. and Lyytinen, K. (2009). *Requirements in the 21st Century: Current Practice and Emerging Themes*. Design Requirements Engineering: A Ten-Year Perspective. K. Lyytinen, P. Loucopoulos, J. Mylopoulos and B. Robinson (eds), Springer.

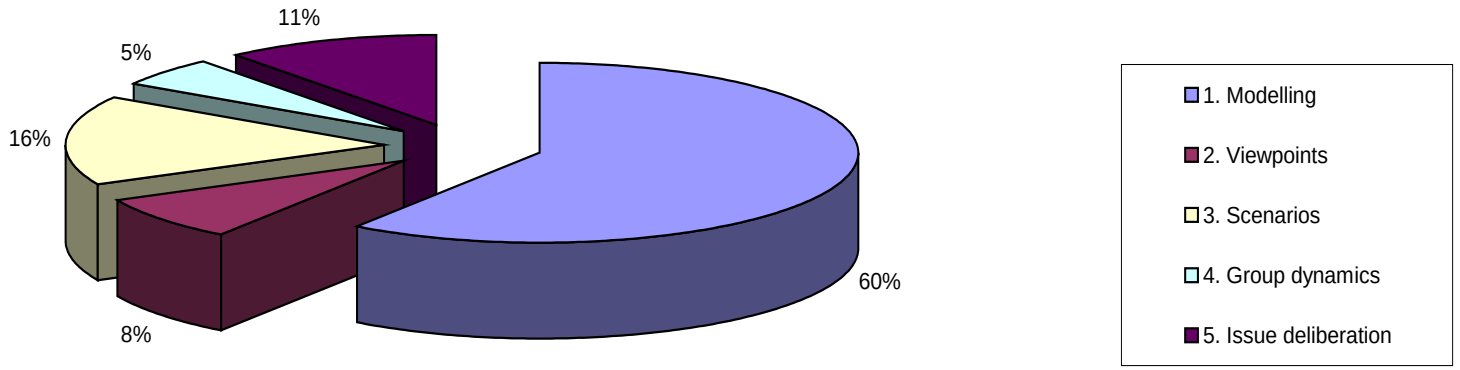
	Notations	Methods	Tools
Elicitation	Goals Use Cases Rules Scenarios Agents NFRs	Stakeholder analysis Metaphors Personas Contextual reqs Inventing reqs	Animation Simulation Invariant generation
Modelling	Object models Goal models Behavioural models Domain descriptions Property languages Notation semantics Problem frames	Reference model Goal-based refinement Aspect-oriented Model elaboration Viewpoints Patterns NL-based facilitation Formalisation heuristics	Model merging Model synthesis Model composition Metrics-based evaluation

	Notations	Methods	Tools
Analysis		Negotiation COTS alignment Conflict management Inquiry-based Evaluation & selection Inspections Checklists Ontologies	Linguistic analysis Consistency checking Conflict analysis Obstacle analysis Risk analysis Impact analysis Causal order analysis Prioritization Metrics-based analysis Variability analysis Evolution analysis
V&V	Model formalisms	Inspection State-based exploration Scenario-based	Simulation Animation Invariant generation Model checking Model satisfiability
Management	Variability modelling	Scenario management Feature management Global RE	Traceability Stability analysis

Volume of Research Output

Comparison of research categories

Requirements Engineering Journal and Requirements Engineering Conference Proceedings



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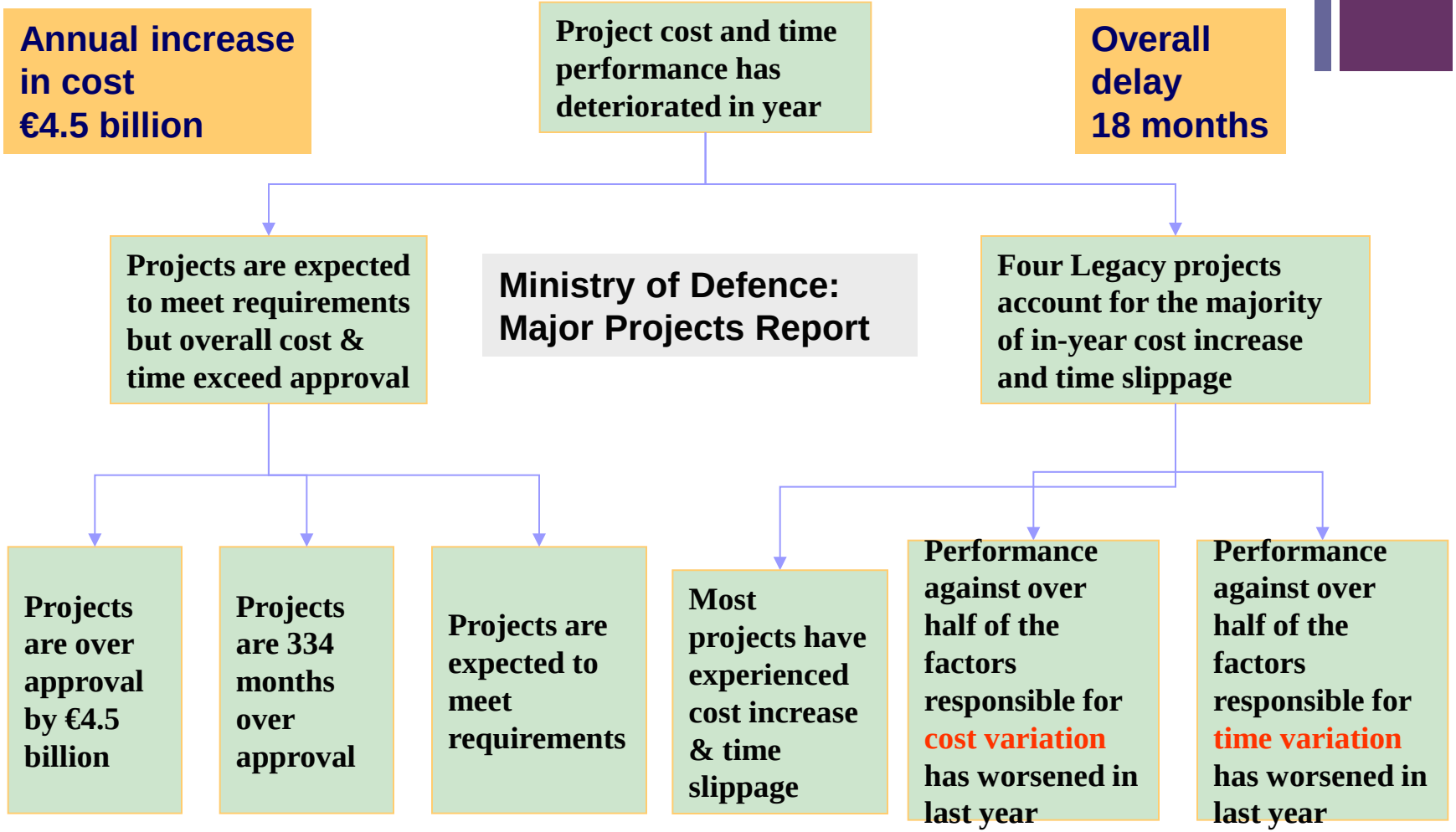
CHALLENGES TO R.E.

RESEARCH ISSUES FOR R.E.

A Study 4 Years Ago



Recommendations

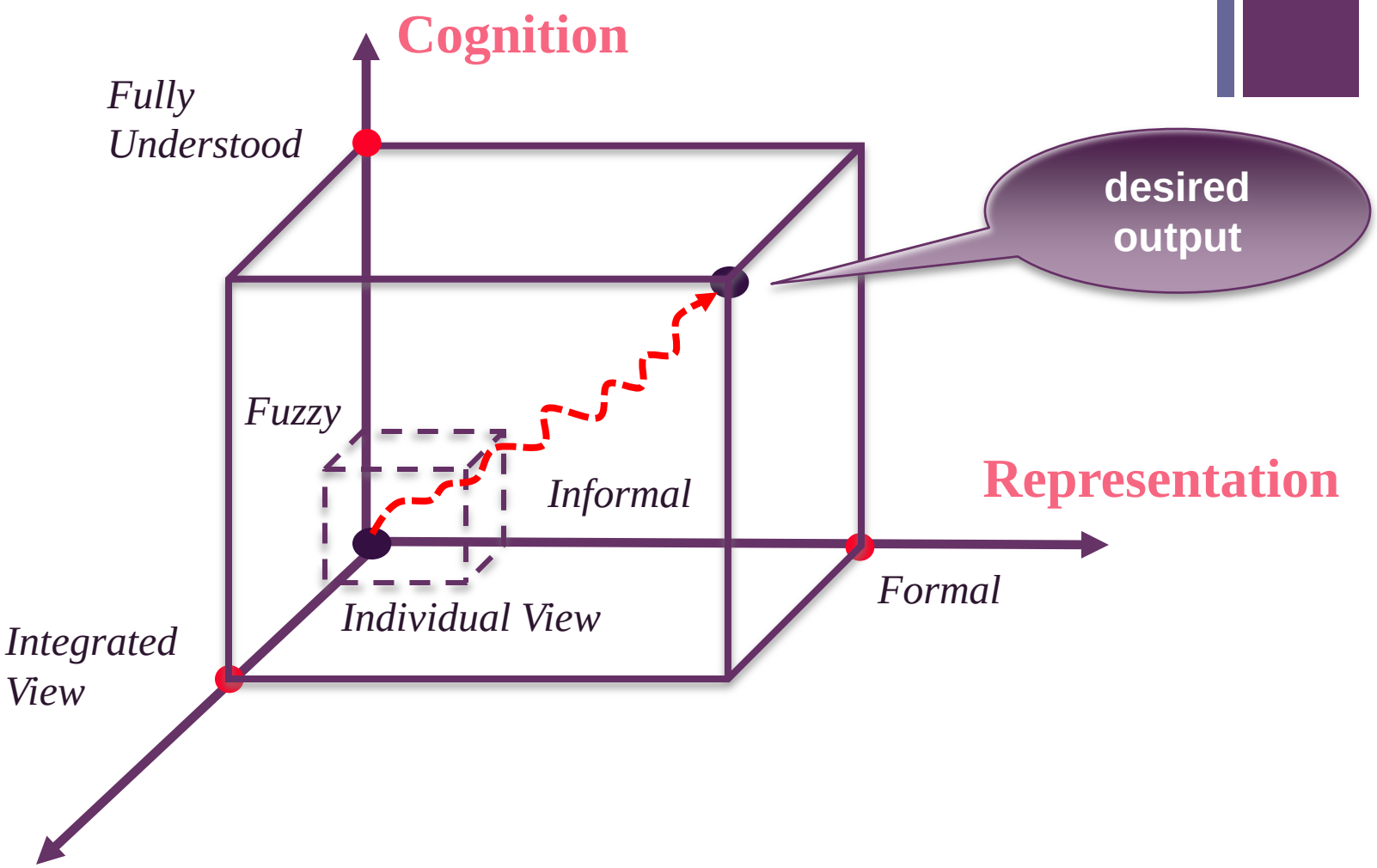
Lessons Learned	The need to address the possibility of a fresh Assessment Phase when there has been a change of procurement strategy **Flexibility in design process**
	The importance of identifying risks and appropriate mitigation strategies from the start of a project onwards **Strategy on risk evaluation**
	The importance of getting early clarification of industry's understanding of the requirement and ability to meet it **Relevance of requirements**
	The need to build flexibility into the budget to respond to unforeseen events **Flexibility in plan**
	The need to address the degree to which optimism may be driving key decisions **Evaluation of alternatives**

Source: Ministry of Defence

Why is R.E. Hard?

- Businesses operate in a rapidly changing environment
- Different stakeholders have different goals, and priorities
- It is not clear at the outset of what exactly the value of the system might be
- Requirements are influenced by political considerations that are not normally externalized

Dimensions of Requirements



Pohl, K. (1994). "The Three Dimensions of Requirements Engineering: A Framework and its Applications." Information Systems 19(3): 243-258.

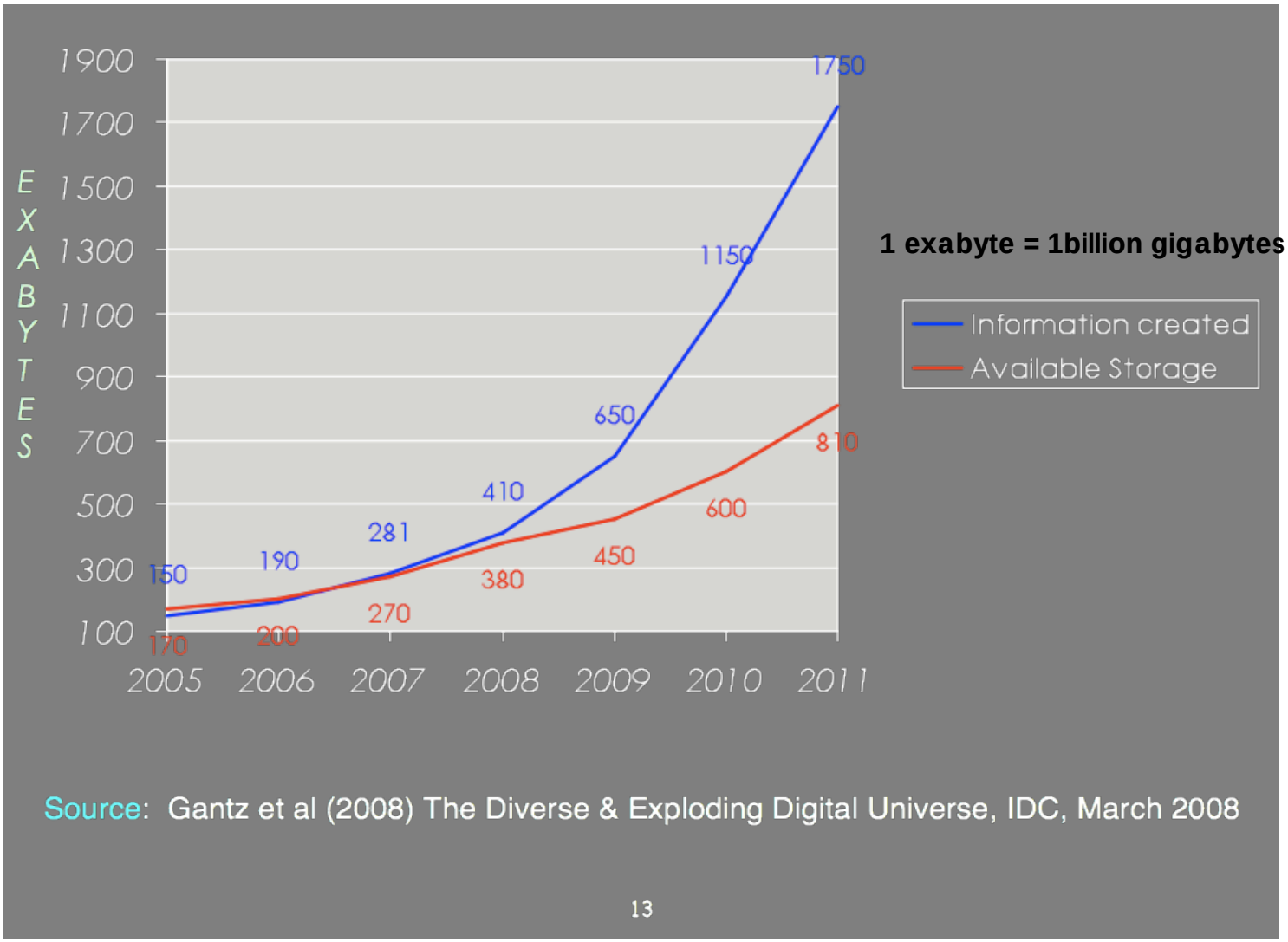
Challenges

- Despite the plethora of practical methods, techniques & tools practice still suffers
- Research has not been successfully transferred to practice except perhaps for some standards e.g. OMG
- Real world requirements for new systems raise new challenges

Towards a New Business Ecology

- A shift from physical, to service to digital wealth
- Understanding people's behaviour and using it for their benefit or using it to gain revenue
- Ex1: Lifelong contextual footprint
  - where we have been, with whom, at what pace etc
  - a balance between economic benefits and issues about privacy, trust and security
  - services of the future will focus on this balance
- Ex 2: Energy
  - understanding consumers' behaviour
  - adapting supply & demand

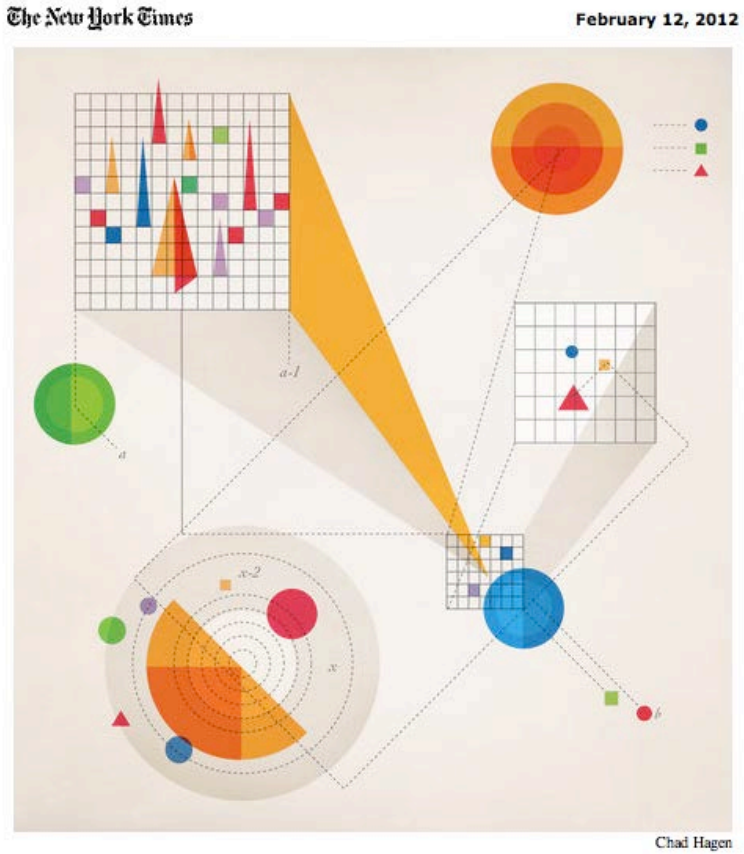
Information Processing



Implications

- 60%-70% refers to individuals
  - 50% of this attributed to individual's actions
  - The rest is 'ambient' content
- 85% of this information runs through digital devices owned by enterprises
  - Enterprise liability – security, privacy
  - Enterprise responsibility – search, discovery, environmental footprint
  - Enterprise opportunity – innovation, transformation

Digital Economy



- "Data is the new class of economic asset like currency & gold"
- A study of 179 large companies found that those adopting "data-driven decision making" achieved productivity gains that were 5-6 percent higher than any other factor

Utility at Different Levels

Individuals

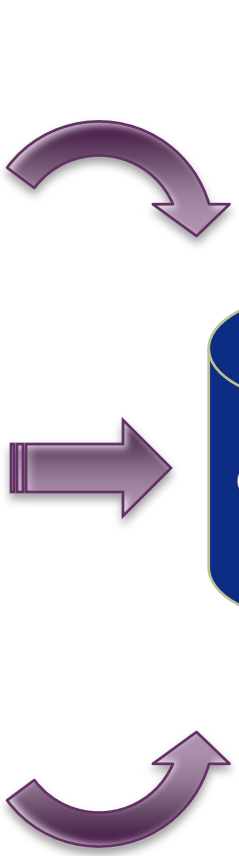
Data Type: 'Crowdsourced
Incentives: Pricing/ offers, improved service
Requirements: Privacy standards, 'opt out' ability

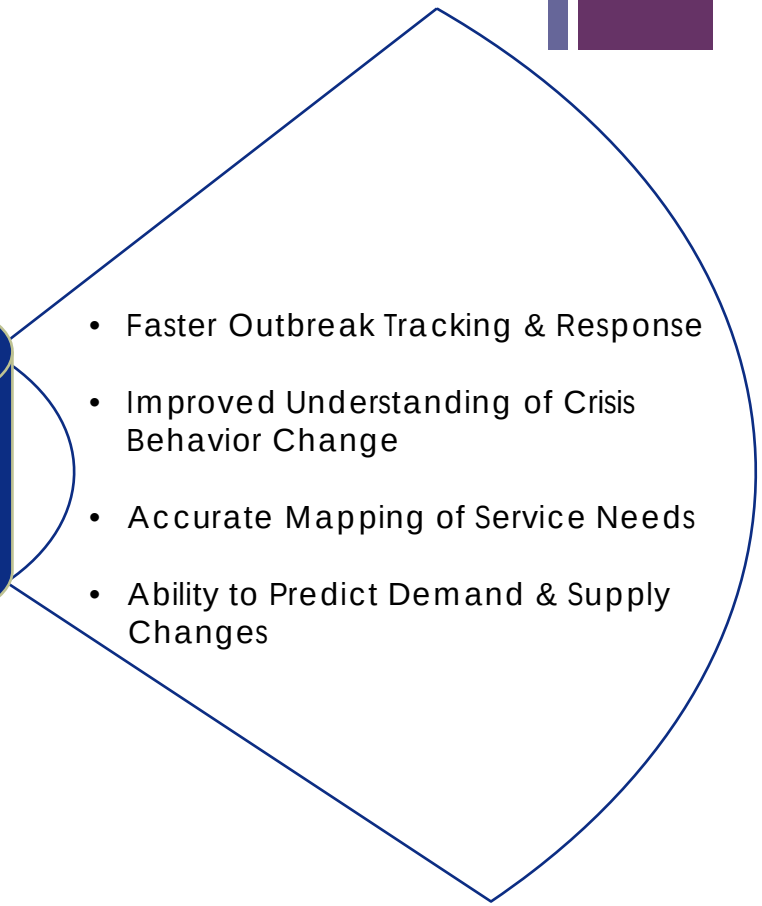
Public Sector

Data Type: Census, health, tax
Incentives: Improved services, efficiency in expenditure
Requirements: Privacy standards, 'opt out' ability

Private Sector

Data Type: Transactions, spending & use
Incentives: Customer behaviour, prediction on trends
Requirements: Business models





Source: Big Data Big Impact, World Economic Forum, Jan 2012

Example: AMR's in Germany

- According to EU directive, 80% of households will have to have smart readers (AMRs)
  - For a large to medium sized German utility, which has about 240,000 conventional meters, quarter-hour meter readings would produce 960,000 sets of meter data to be processed and stored each hour once replaced by smart meters.
- The technology
  - Available technology to read data, deliver data, timestamp data.
  - Available technology to manage 'big data'
- The use
  - Data can be relevant to different market players in different resolutions and aggregations as a basis for other services.
  - New features like complex tariffs, load limitations etc.
  - Optimization of processes with respect to quality, speed and costs
  - Leading to new services, products and solutions – some of which we do not even know today.

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RESEARCH ISSUES FOR R.E.

A Change in Focus for R.E.

TRADITIONAL	CONTEMPORARY
The context is a reasonably stable system ecology	The context is a rapidly changing system ecology
Emphasis on business process improvement via IS	Emphasis on enterprise and market transformation via IS
A key issue is that of alignment	A key issue is that of innovation
System properties predictable	Emergent system properties
Development based on a decision paradigm	Development based on a design paradigm
Clear separation between system and user	The human is no longer outside the system but an integral part of it

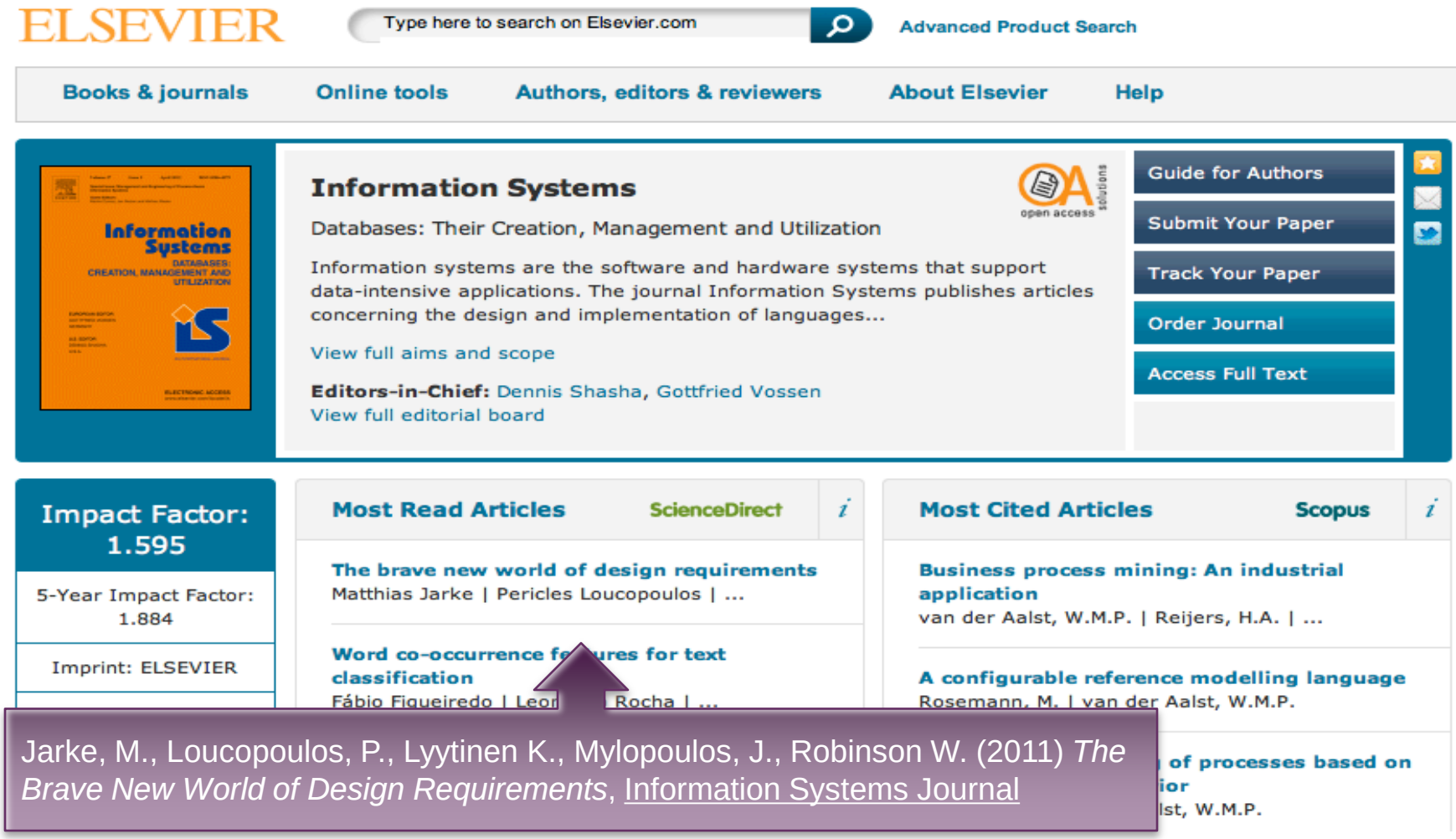
(see Dustdar' keynote talk)

NSF-funded Project

- Workshop held in Cleveland
  - see http://weatherhead.case.edu/requirements/reqs-attend.html
- workshop held in Dagsthul
  - see http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=08412

Lyytinen, K., Loucopoulos, P., Mylopoulos, J., Robinson W. (2010) *Design Requirements Engineering: A ten-year Perspective,* LNBIS, Springer.

A Recent Publication



Jarke, M., Loucopoulos, P., Lyytinen K., Mylopoulos, J., Robinson W. (2011) *The Brave New World of Design Requirements*, Information Systems Journal

Aims and scope of the Initiative

- Objective was to “bring new paradigms, concepts, approaches, models, and theories into the development of a strong intellectual foundation for software design” (Call for SoD) as it relates to the *process of capturing and managing design requirements.*

- *Develop principles, theoretical foundations and practical guidance for identifying, soliciting, deriving and managing design requirements for software intensive systems in the 21st century.*

Motivation for Workshops

- Software design involves much more than its traditional focus

- Different contexts
  - Organization design (organizational design options, rules/routines, business models, and change)
  - Industrial design (e.g. pervasive applications),
  - Media design (e-commerce and media applications),
  - Human computer interaction design (new modalities of interaction),
  - Business architecture and modular design (e.g. open business platforms),
  - Design theory (cognitive models, design principles)

Research Issues

- On the R.E. Process
  - What are the fundamental concepts of design and their influence on requirements?
- On Intertwining
  - What are mutual impacts between system and environment?
- On Evolution
  - How to deal with multiple stakeholders' requirements over time?
- On Conceptual Modelling
  - How to deal with a plethora of modelling paradigms?

Research Challenge: R.E. Process

"A point I want to emphasize in the requirements process is we do not usually know what the goal is. I will assert that this is a deep fact of reality that is ignored in much of the literature about requirements. We do not know what we are trying to build. The hardest part of most designers of complex systems is not knowing how to design it, but what it is you are trying to design. When we talk about eliciting requirements, we are talking about deciding what it is we are trying to design"

Fred Brooks

- We do not know the development goals at the outset
- The development tree emerges as we progress
- The development tree is not about decisions but about tentative designs
- The goodness function cannot be evaluated incrementally, the whole tree has to be searched
- The constraints keep changing

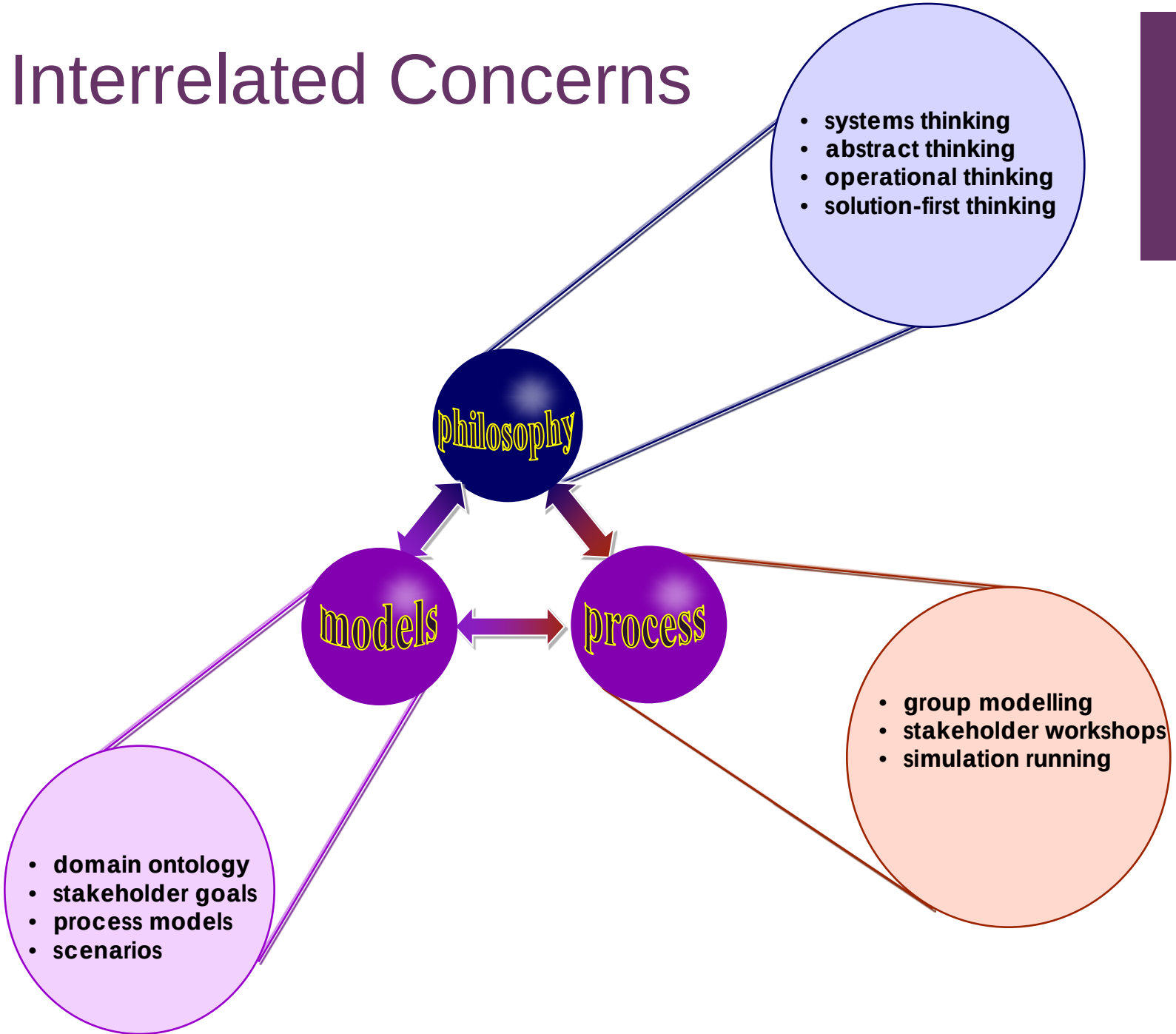
Fred Brooks (2010), The Design of Design, Addison-Wesley

Related Work

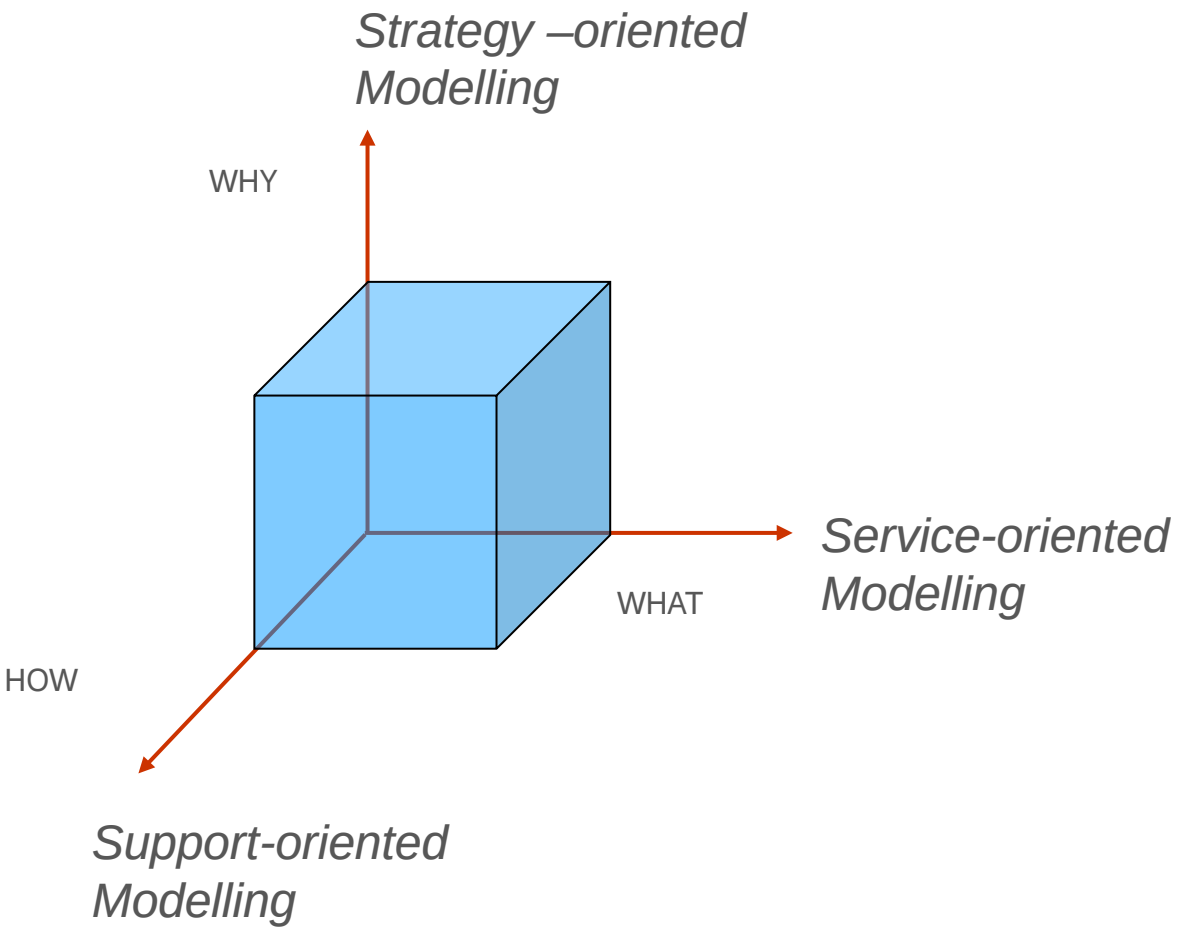
- A number of empirical studies e.g. [1] have shown that
  - There is no meaningful division between analysis and synthesis but rather a simultaneous learning about the nature of the problem and the range of possible solutions
  - A design solution may itself lead to a new design problem
- “As one ponders the tradeoffs there comes a new understanding of the problem in hand and with it may come a change in design goals” [2]
- The use of models is significant in the design process [3]
  - Models are not just outputs but are also inputs to the thought process

[1] Bryan Lawson (2006) How Designers Think: The Design Process Demystified, Elsevier
[2] Schön, D. A. (1983) The Reflective Practitioner: How Professionals Think in Action. New York, Basic Books
[3] Carroll, J. M. (2002). Scenarios and Design Cognition. IEEE Joint International Conference on Requirements Engineering (RE'02), Essen, Germany

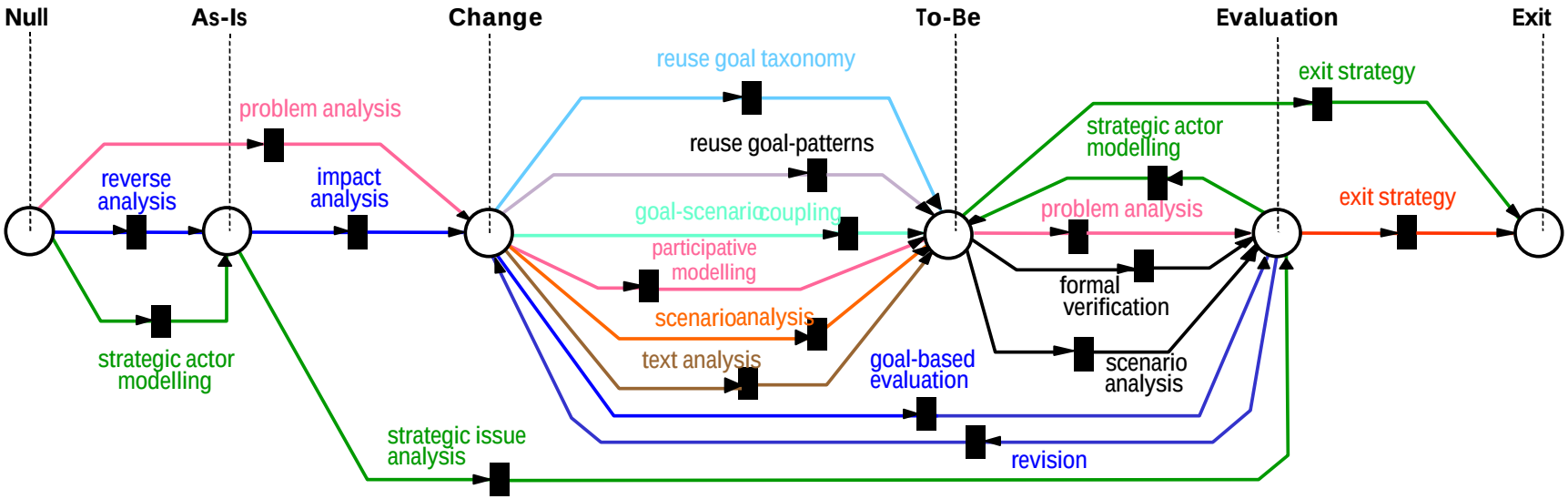
Interrelated Concerns



Orhogonality of Modelling Views

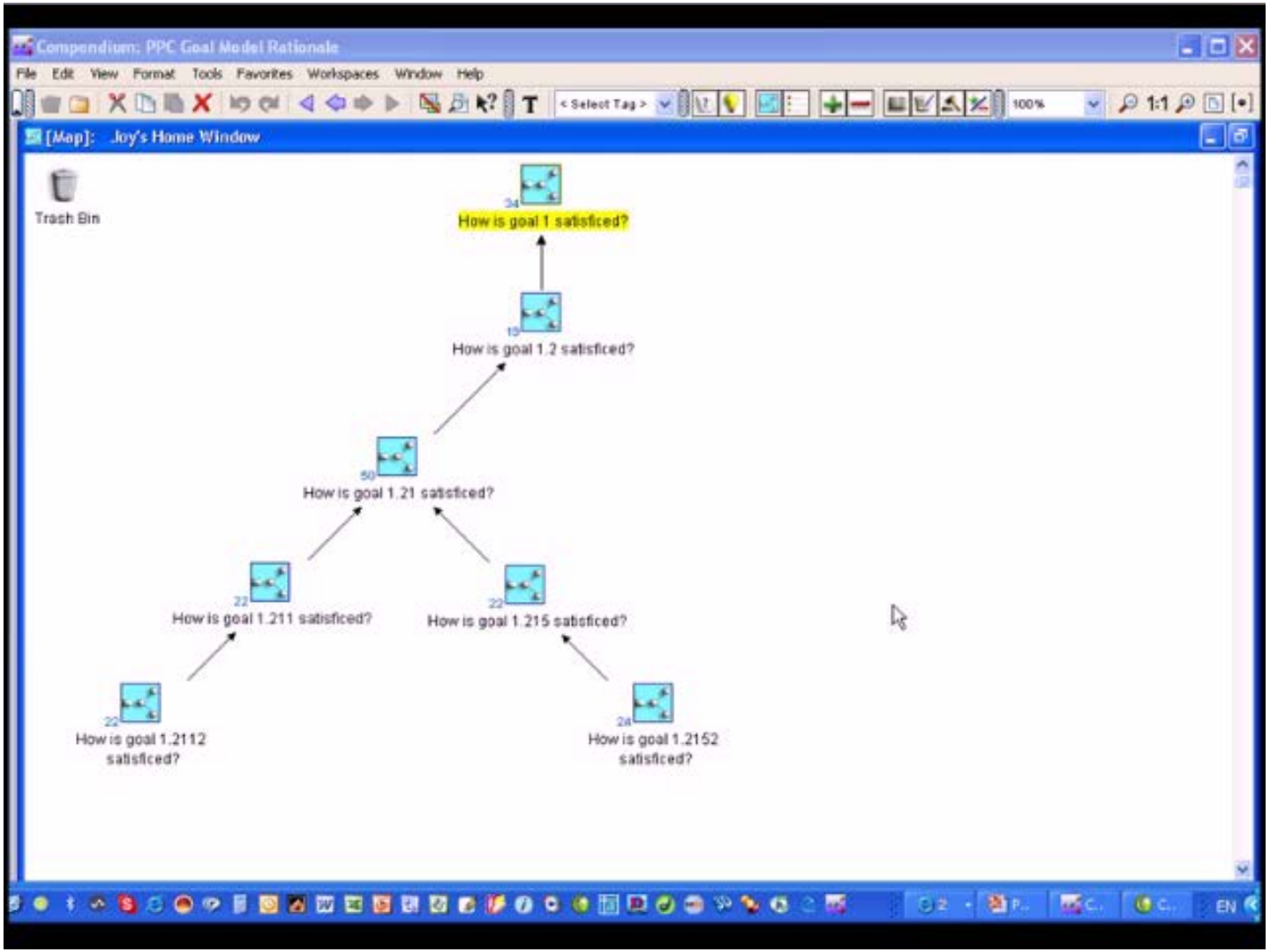


Flexibility in Process



- Can we deploy alternative methodological strategies to suit the emergent problems?

Reasoning about the process



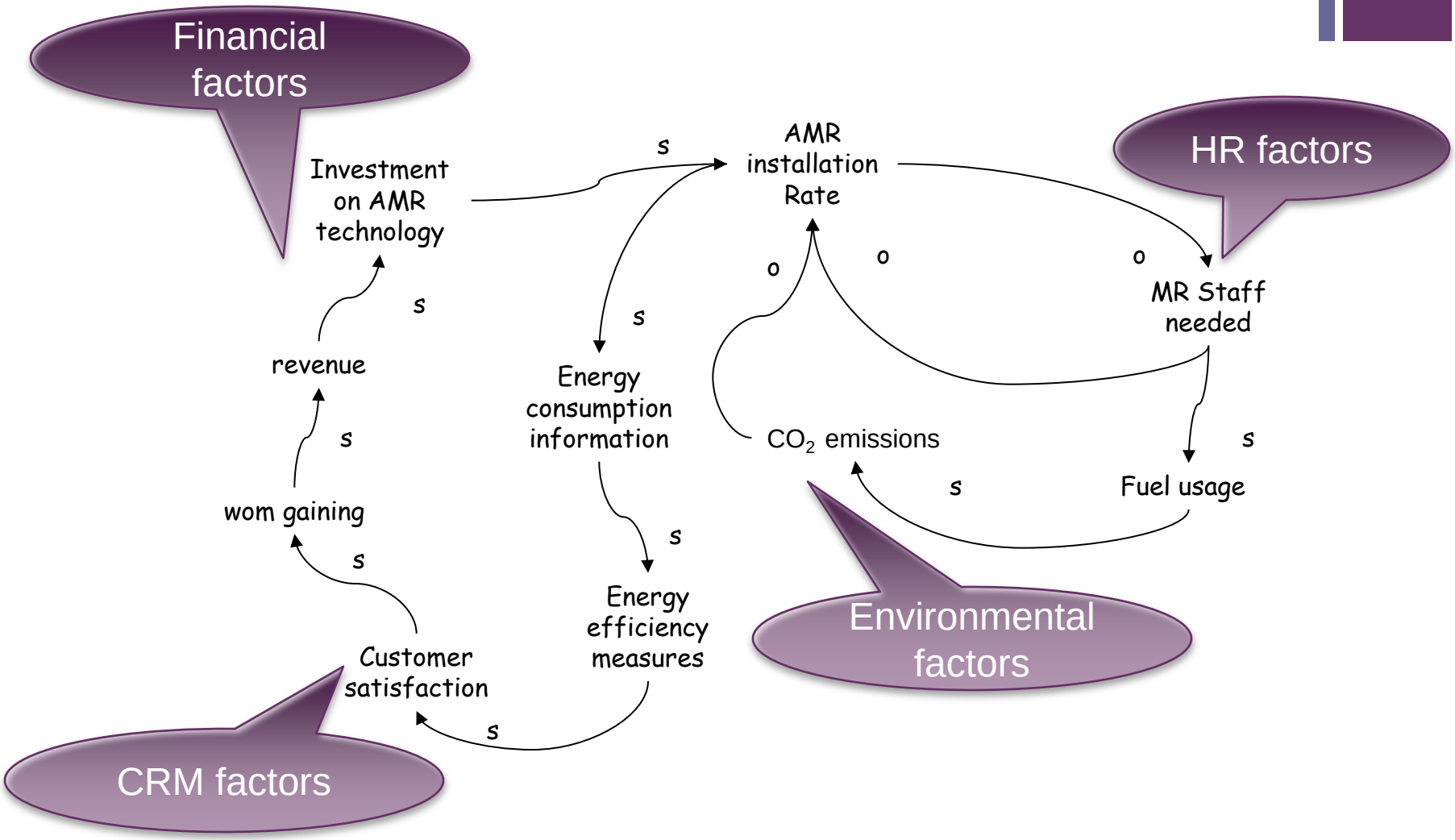
Based on: Louridas, P. and Loucopoulos, P. (2000) *A Generic Model for Reflective Design*, ACM Transactions on Software Engineering and Methodology (TOSEM), Vol. 9, No. 2, 2000, ACM, New York, pp. 199-237.

Research Challenge: Intertwining

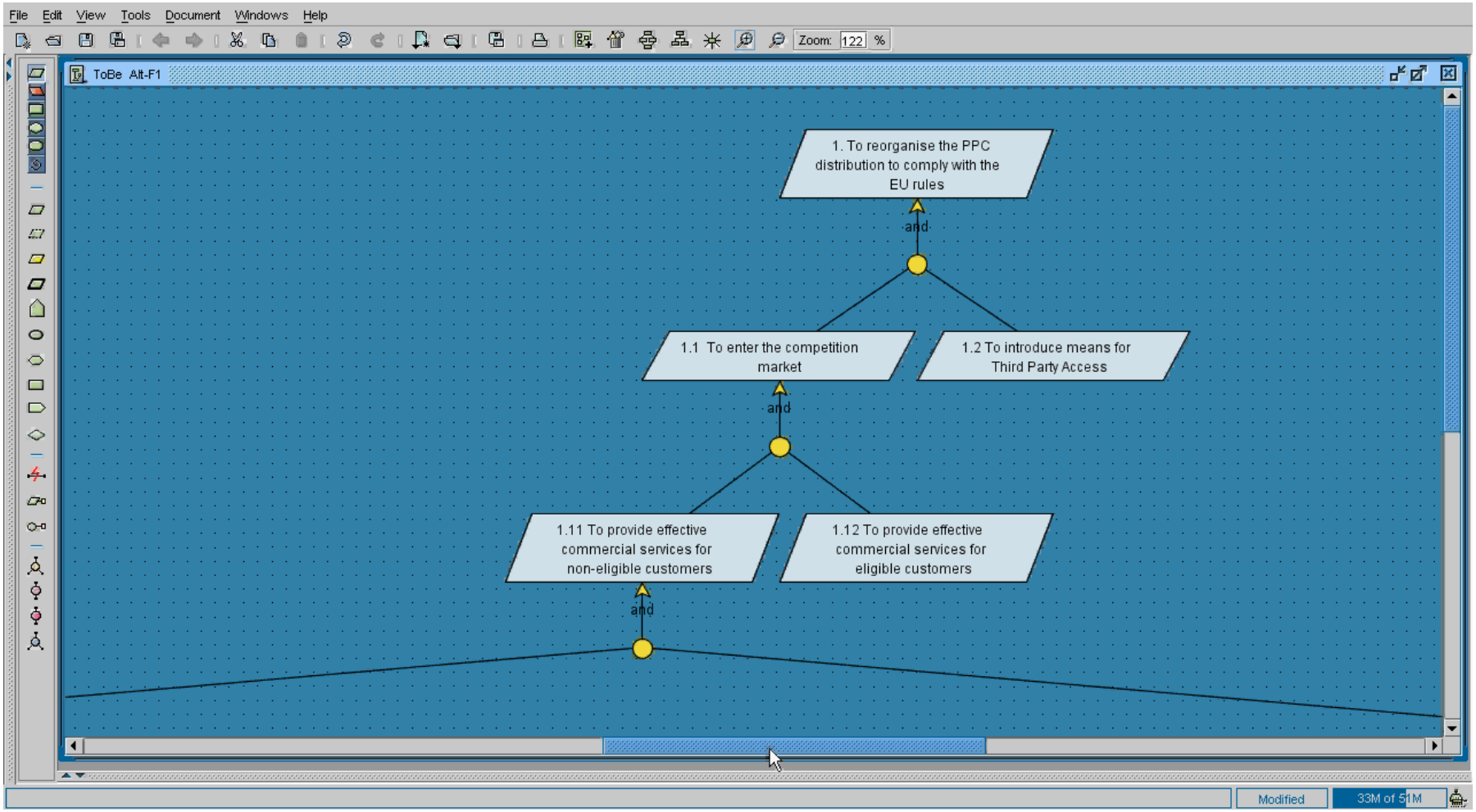
- The interplay between ‘subject’ and ‘system’ worlds has become more intricate, complex, dynamic and emergent

- Should design requirements be considered as part of a multi-system, socio-technical ecology that drives organizational innovation?

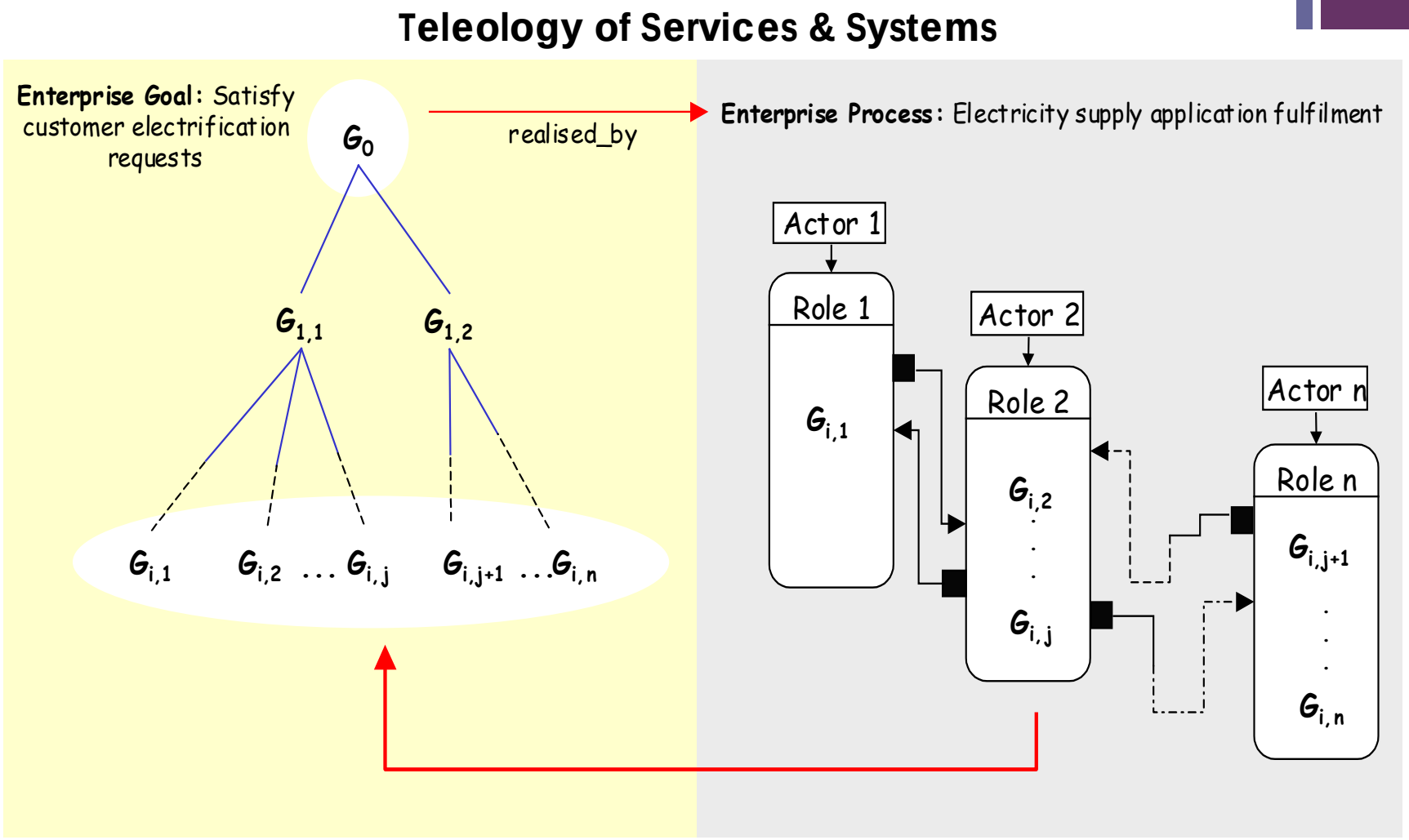
The AMR Example



Business Goals & Requirements



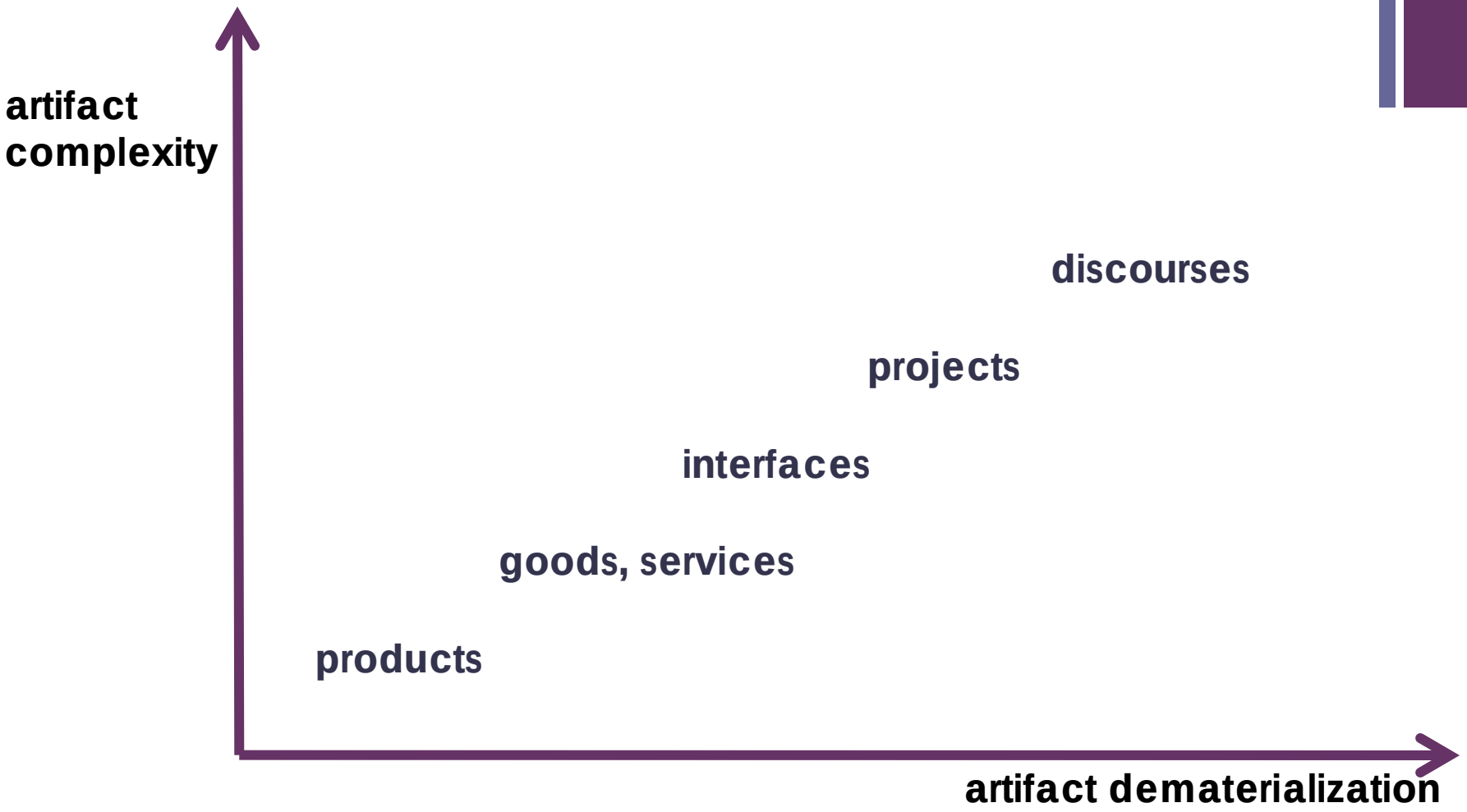
Business Goals & Processes



Research Challenge: Evolution

- The fluidity of design artifact drives the change process
- How to deal with run-time requirements change i.e. once system has been deployed ?
- Evolution at an abstract level
  - Ontology of requirements according to their source ?
  - To evolve an information system it is necessary to evolve its conceptual schema. How can we make the evolution of a conceptual schema more effective and more efficient?
  - How is requirements evolution related to contextual factors, and goals?

The Trajectory of Artifacts



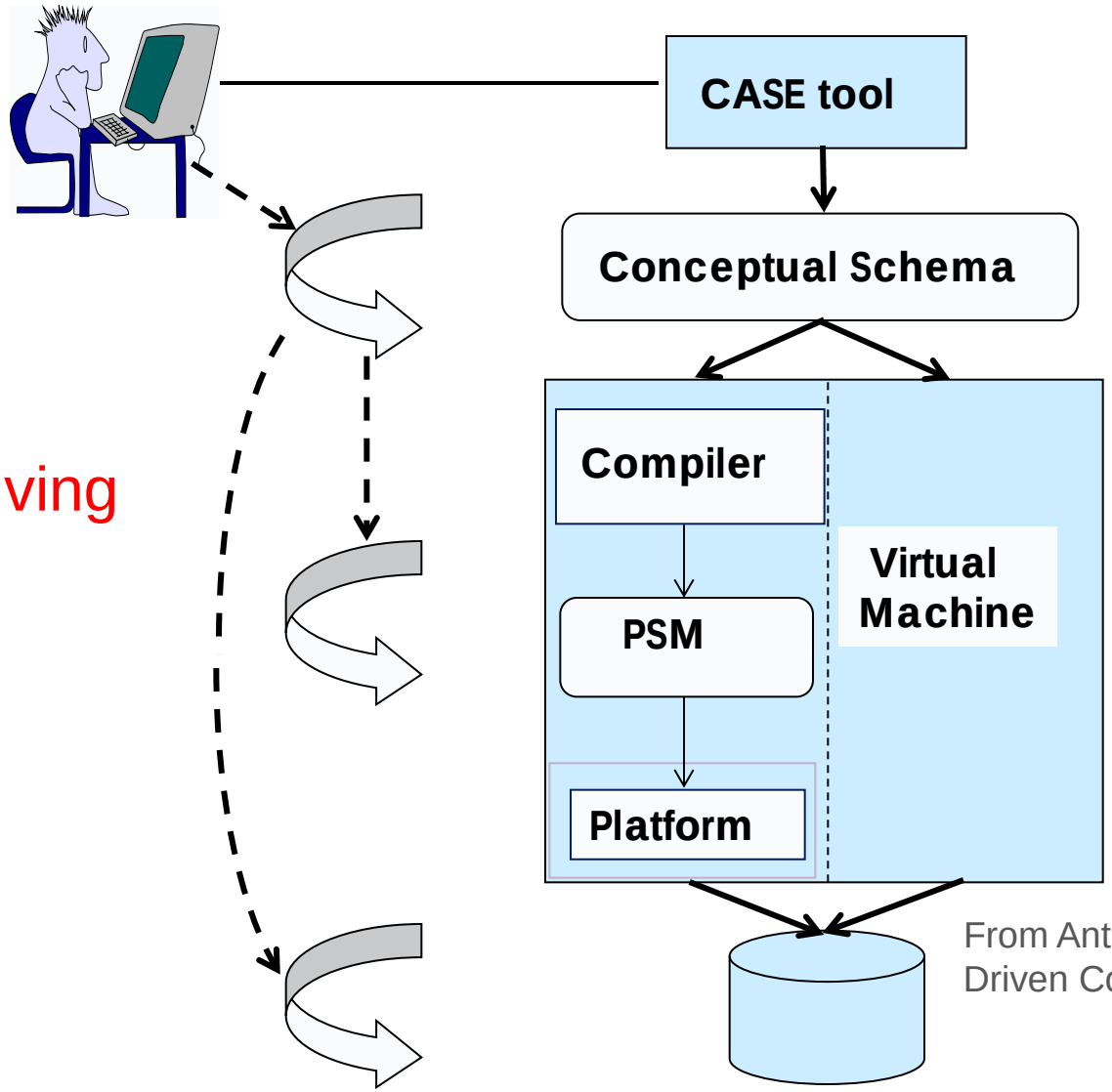
Based on: Krippendorff, K. (2006). *The Semantic Turn; A New Foundation for Design*. New York, Taylor & Francis. [with thanks to Reymen]

Ontology for Change

- Develop techniques and tools for dealing with different classes of requirements
- Hard requirements
  - goals
  - global constraints
- Preferences
  - goals
  - constraints
  - business rules
  - soft goals/ criteria
- Priorities on preferences
- Hard requirements are stable, preferences change often, priorities change very often

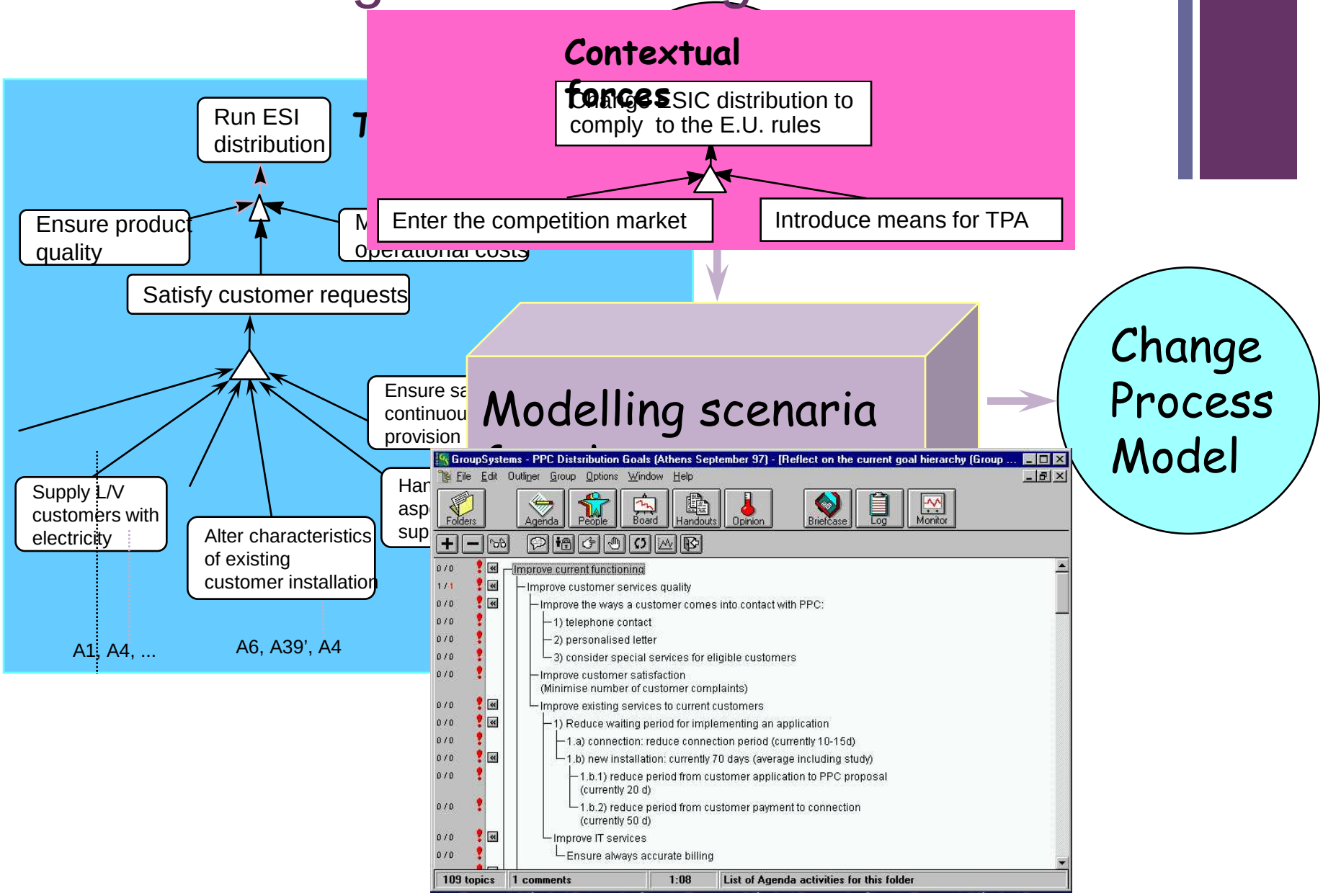
Credits to John Mylopoulos for discussion at Cleveland workshop

Test-Driven Conceptual Modelling?



From Antoni Olive, “The challenge of Test-Driven Conceptual Modelling, RCIS 2008.

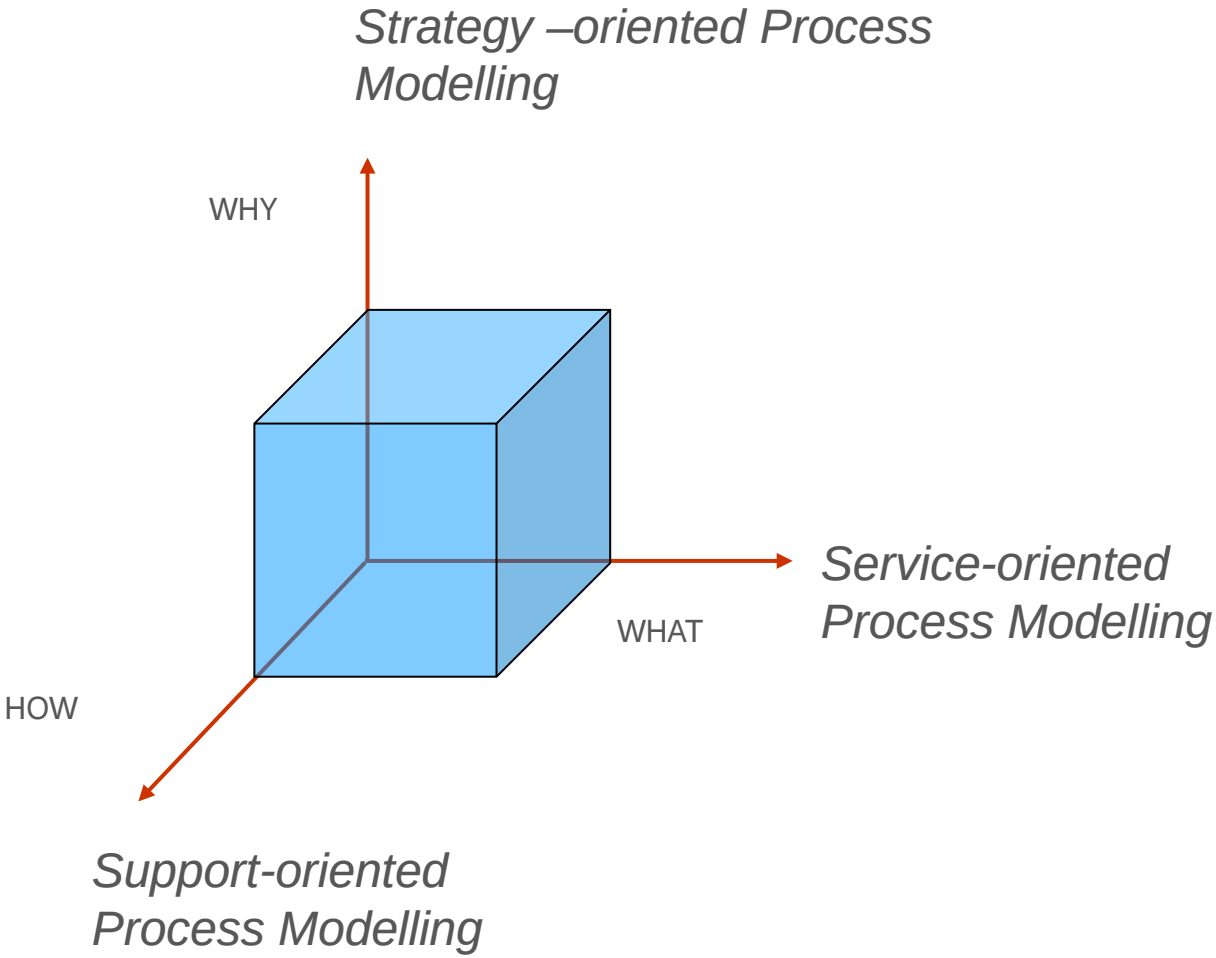
Reasoning about Change



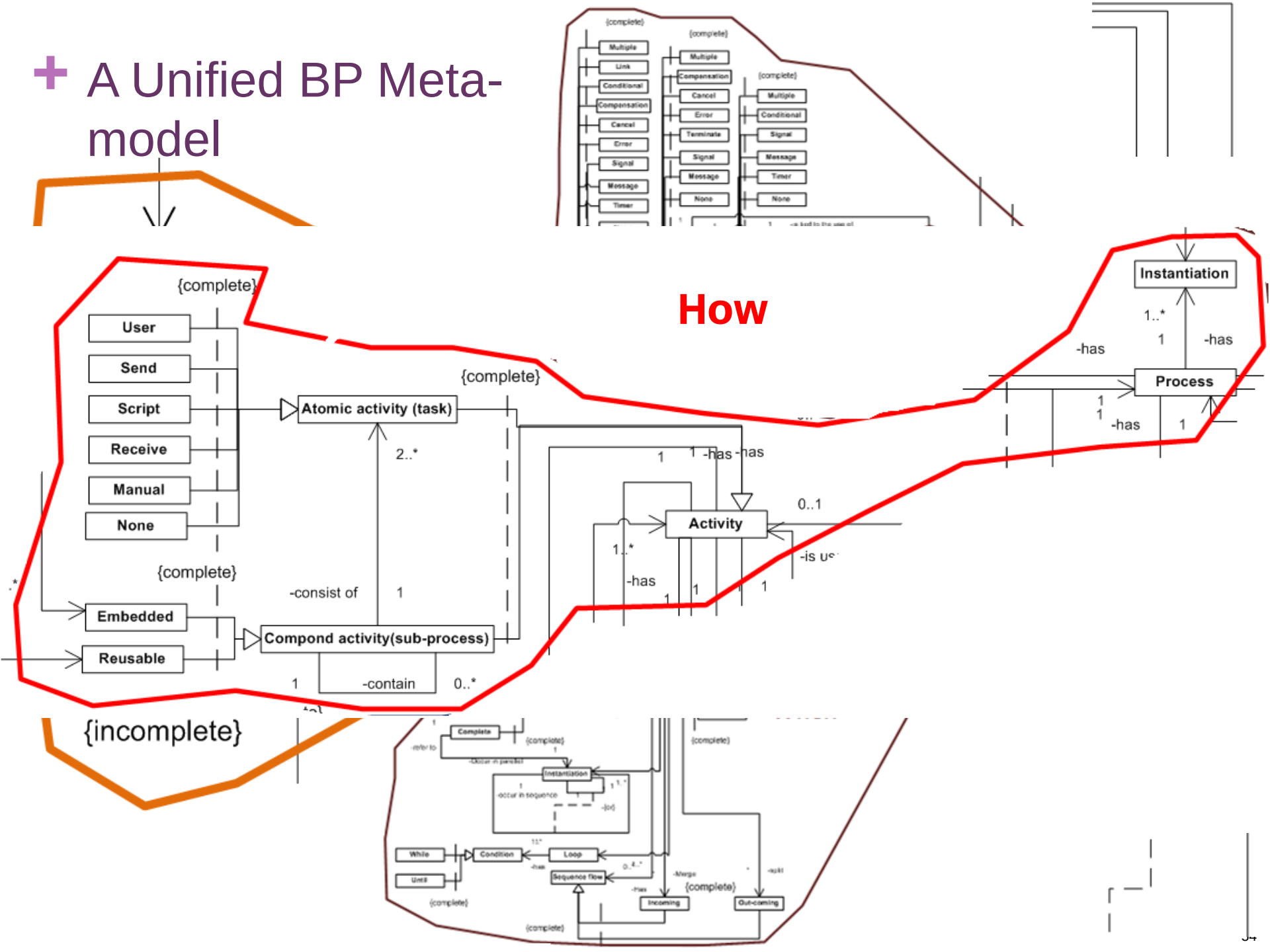
Research Challenge: Modeling

- Modeling is central to R.E.
- There is a ‘Tower of Babel’ of paradigms that hinders the application of models in practice (see Karagiannis’ keynote talk)
- Can we effect some form of unification?
- How can we use models as an exploration of the problem rather than as a solution to the problem?
- How can we use models as archetypes?

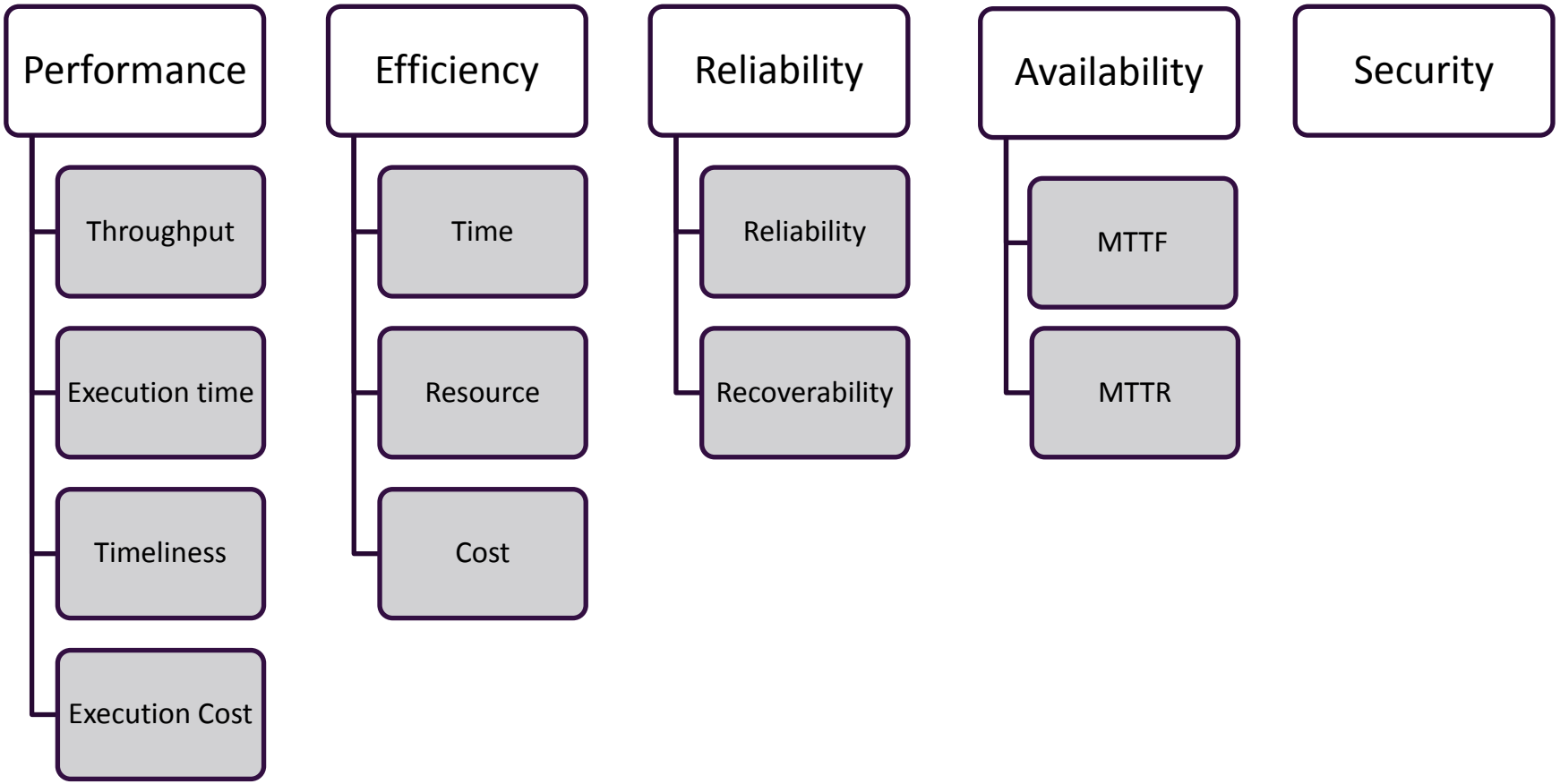
Orhogonality of Modelling Views



A Unified BP Meta-model

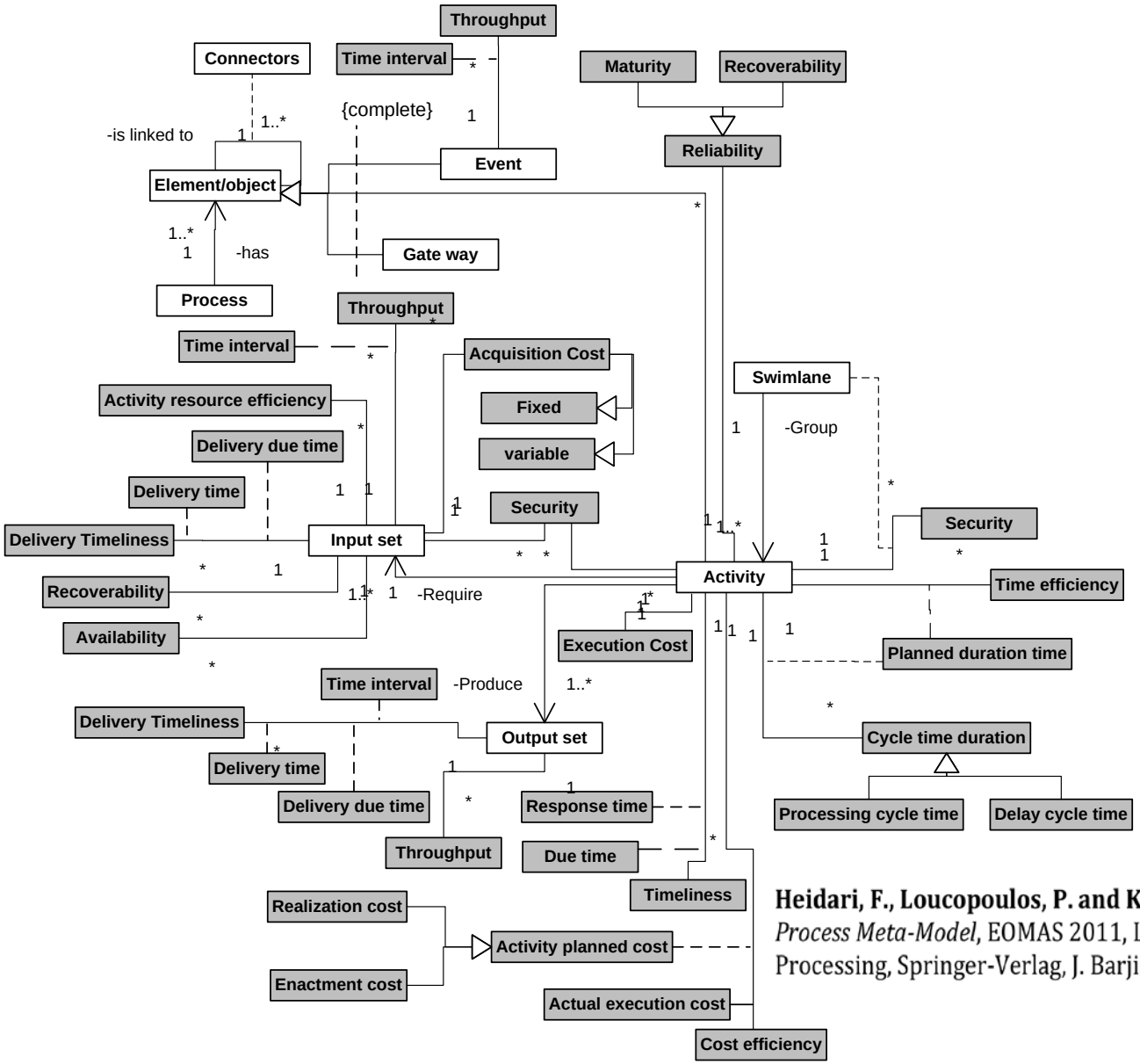


Independent to Notation we can check for



Balushi, T. H. A., Sampaio, P. R. F. and Loucopoulos, P. (2012). *Eliciting and Prioritizing Quality Requirements Supported by Ontologies: A Case Study Using the ElicitO Framework and Tool*, Expert Systems.

Quality-centric Modeling



Heidari, F., Loucopoulos, P. and Kedad, Z. (2011). *A Quality-Oriented Business Process Meta-Model*, EOMAS 2011, Lecture Notes on Business Information Processing, Springer-Verlag, J. Barjis, T. Eldabi and A. Gupta (ed.), London, pp85-99.

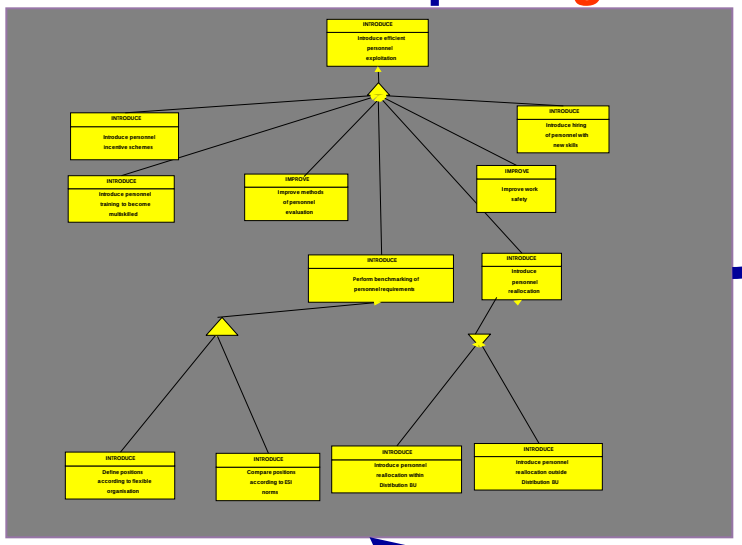
Models for exploration

- Validity of a model is impossible to prove
  - Validation or proof-theoretic approaches are based on certain assumptions
  - Assumptions themselves may be invalid

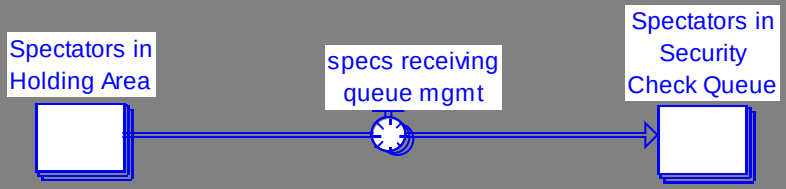
- We must turn attention to gaining confidence in the model
  - Model to be discussable by stakeholders
  - Model to be testable for behaviour using different stakeholders' parameter instantiation

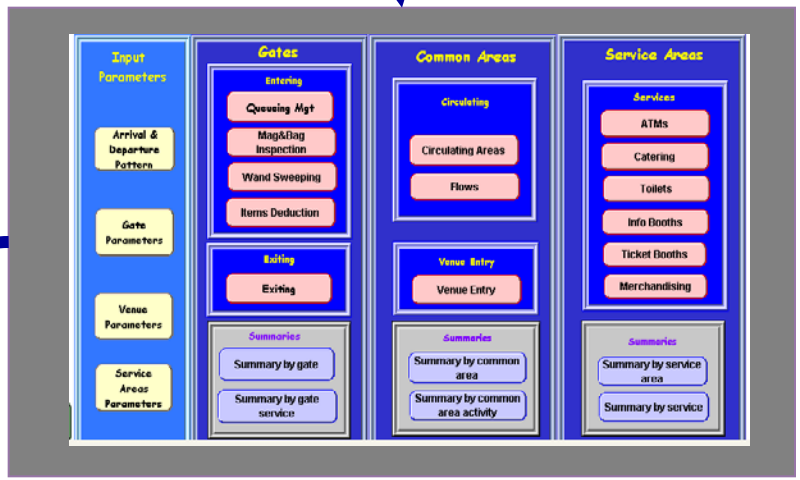
Stakeholders in Model Exploration

stakeholders express *goals*

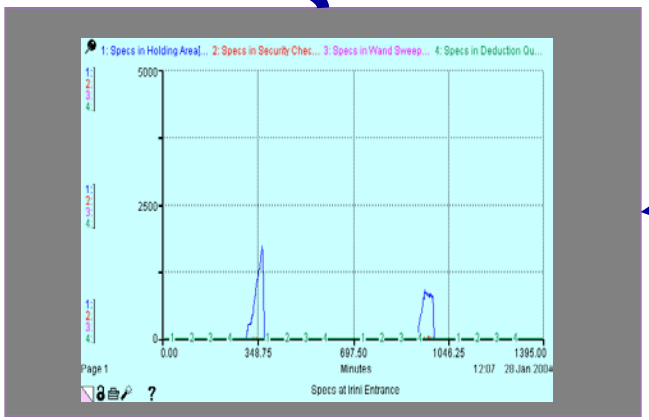


problem area *processes* are defined





stakeholders set *'what-if' scenarios*

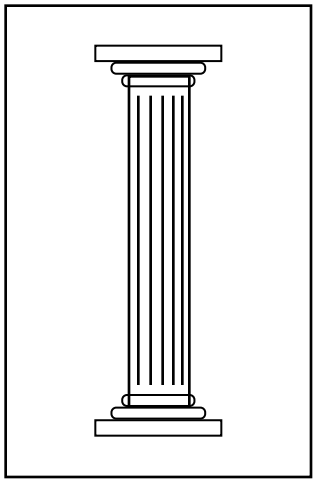


simulated behaviour feeds *decisions*

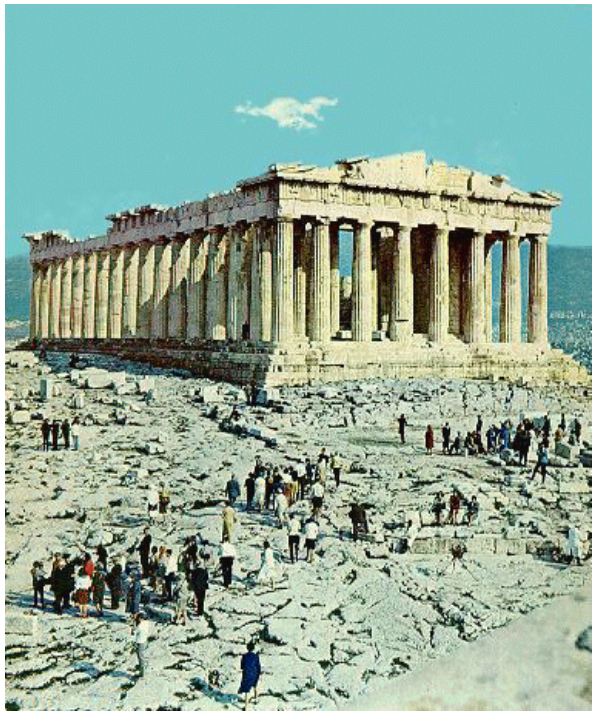
Archetypal Models

A Metaphor

The Doric column



The Parthenon

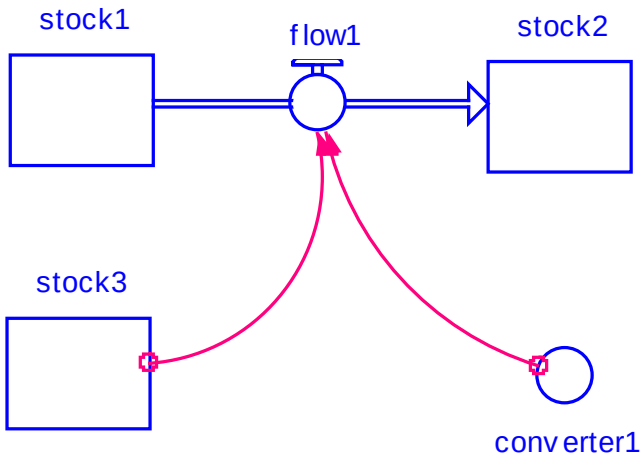


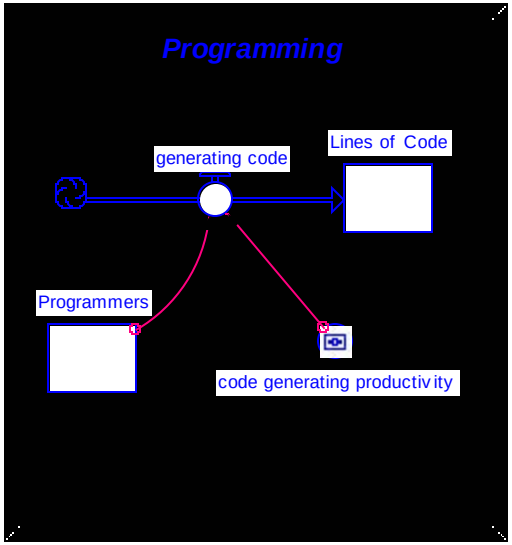
repeated 92 times in the Parthenon

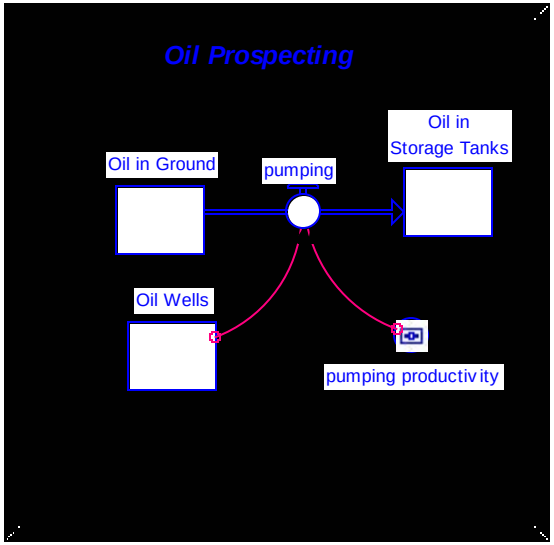
The Poseidon Temple at Sounion

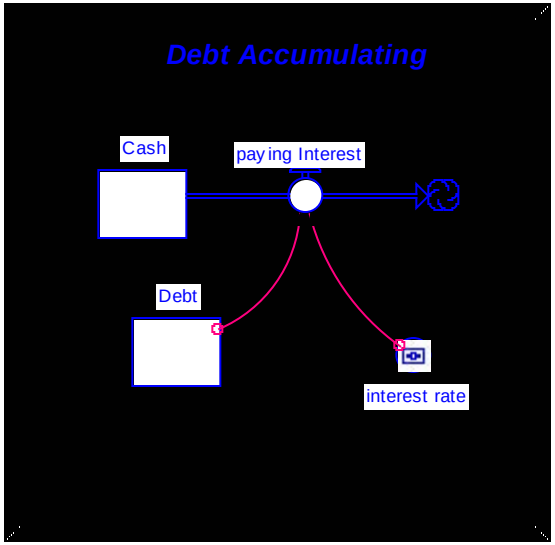
and 38 times in the Poseidon Temple

Example of Archetype









Conclusions

- Requirements is arguably a most critical activity in the system development lifecycle
- PANACEA
  - Many regard existing R.E. approaches as sufficiently robust and relevant
- PREDICAMENT
  - New business models and technologies have highlighted the inadequacy of contemporary RE techniques
- We outlined the need for a new research landscape in RE building on existing successes
- The proposed research themes represent a realistic research agenda which is likely to yield substantial benefits to the community

THANK YOU