

Engineering
Science



Social
Science

Bridging the Unspannable Chasm: *Qualitative Knowledge Construction for Engineering Systems*

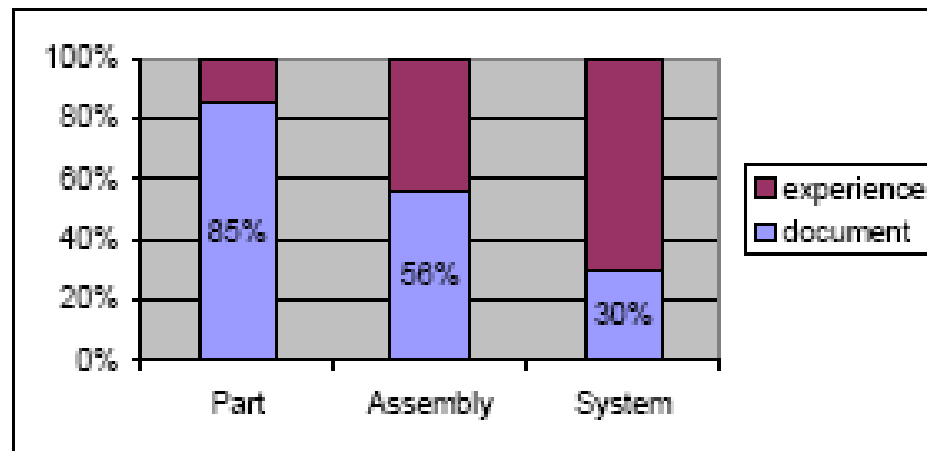


Jason E. Bartolomei
Susan S. Silbey
Daniel E. Hastings
Richard de Neufville
Donna H. Rhodes

Research Motivation:

Address Known Procedural Limitations

- **Where does knowledge exist in an Engineering System?**
 - System-level knowledge resides in the minds of engineers
 - Avoid common “black-box” effect

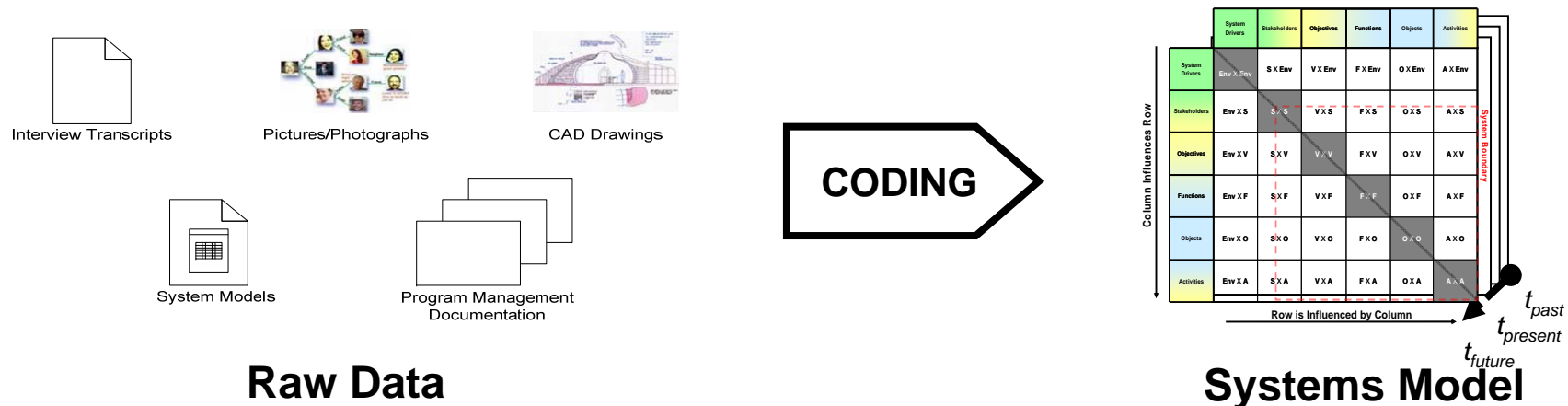


From: Qi Dong 2001

- **Qualitative Social Science has developed useful approaches to elicit systems knowledge**
 - Grounded Theory, Case Studies, other

What is Qualitative Knowledge Construction?

- A research method for translating qualitative data into quantifiable data structure that combines qualitative social science methods with quantitative/engineering methods



Benefits:

- Fosters data transparency and traceability
- Enables better book keeping for systems modeling

How Qualitative Knowledge Construction Works

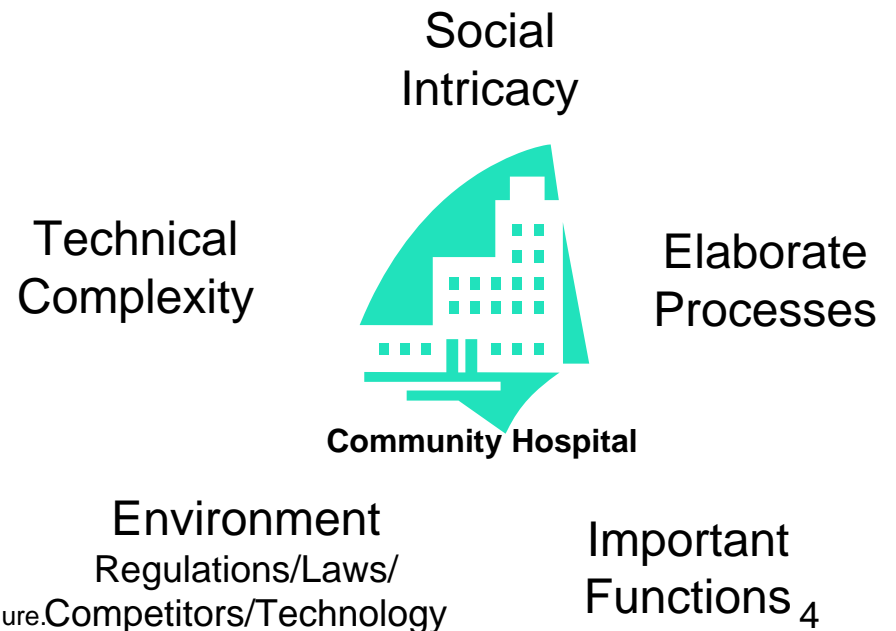
Step 1. Identify System of Interest

QKC Steps

- **Identify system of interest**
 - **Define System Type**
- Develop research questions/analysis objectives
- Collect Data
- Code Data
- Organize Coded Data in Modeling Framework
- Examine Model for missing/conflicted data
- Resolve Missing Data
- Perform Analysis
- Iterate

Engineering Systems definition:

- A class of systems characterized by a high degree of technical complexity, social intricacy, and elaborate processes, aimed at fulfilling important functions in society



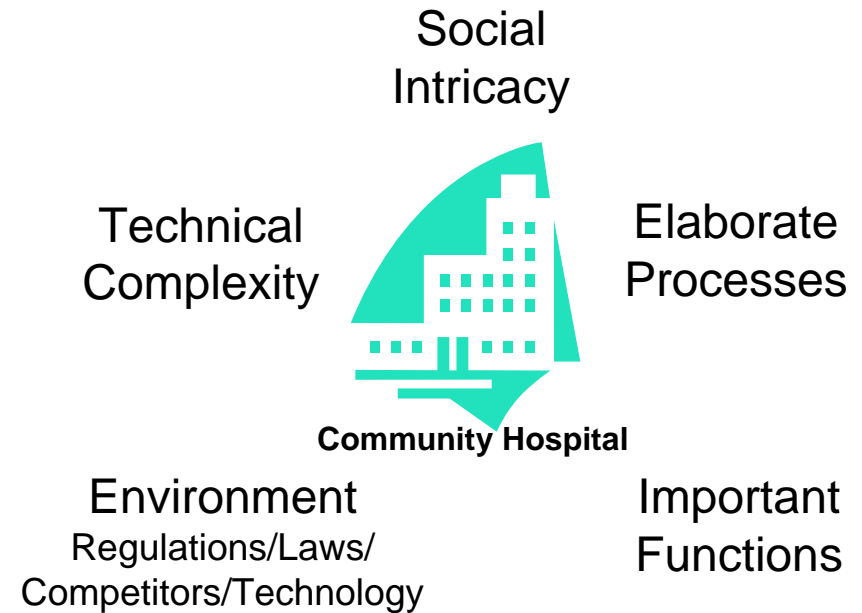
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How Qualitative Knowledge Construction Works

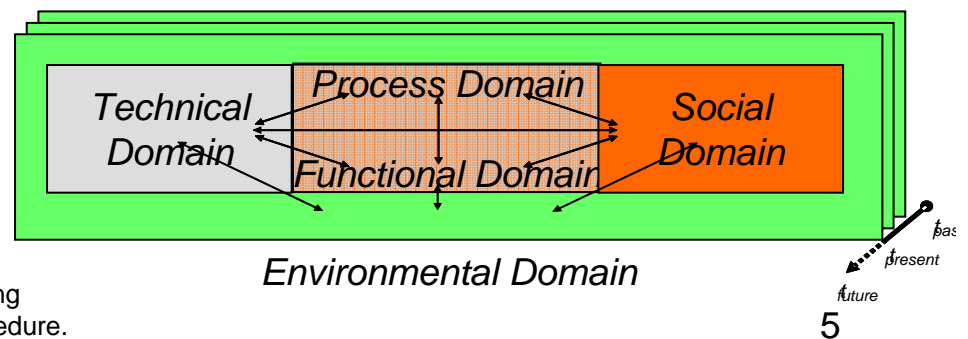
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Engineering Systems Conceptual Model



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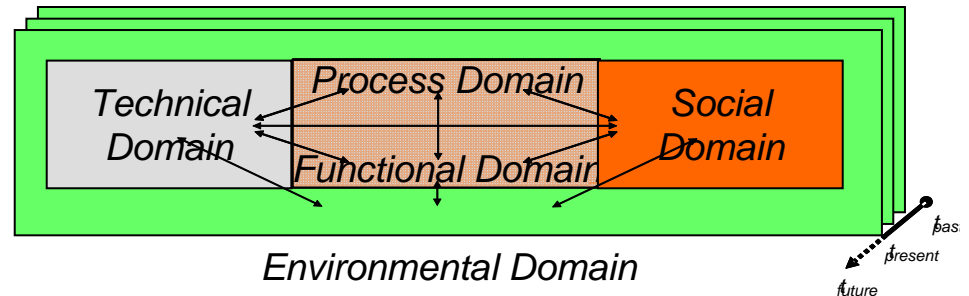
How Qualitative Knowledge Construction Works

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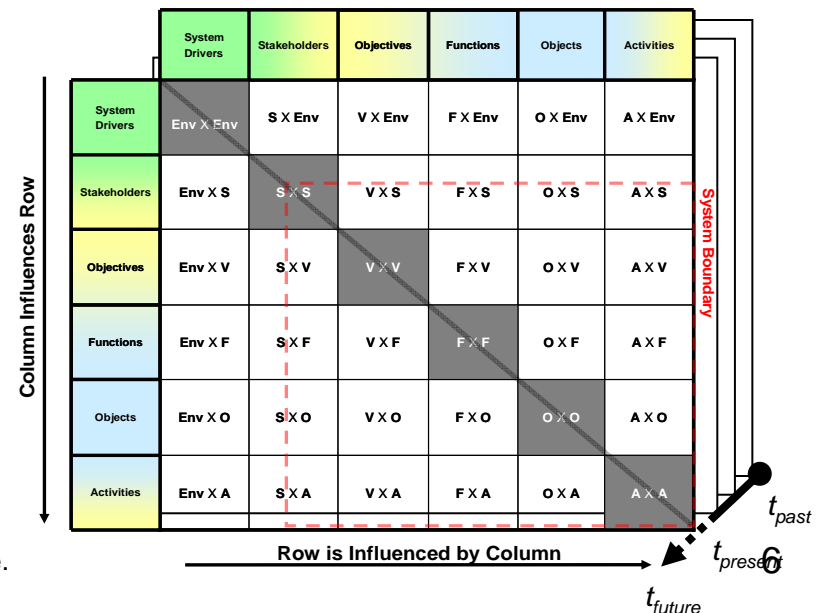
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Engineering Systems Conceptual Model



Engineering Systems Data Structure



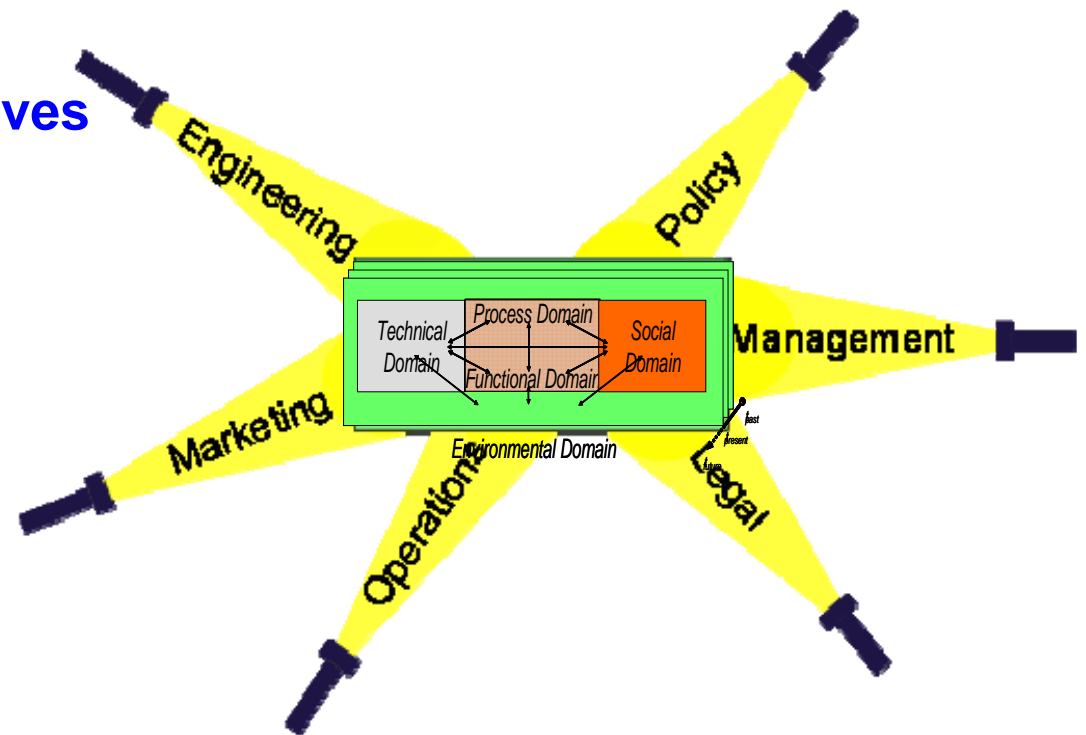
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How Qualitative Knowledge Construction Works

Step 2. Define Research Questions/Objectives for Analysis

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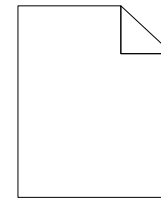
How Qualitative Knowledge Construction Works

Step 3. Collect Data

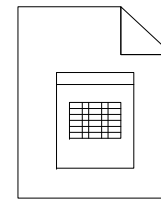
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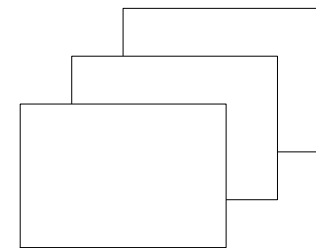
Documentation



Interview Transcripts



System Models



Program Management
Documentation

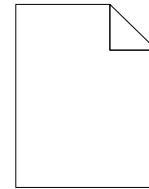
How Qualitative Knowledge Construction Works

Step 4. Code Data

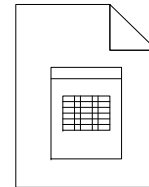
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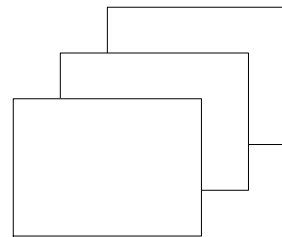
Documentation



Interview Transcripts

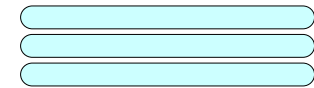
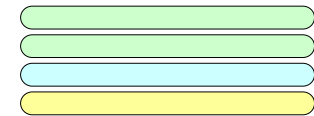


System Models



Program Management Documentation

Codes



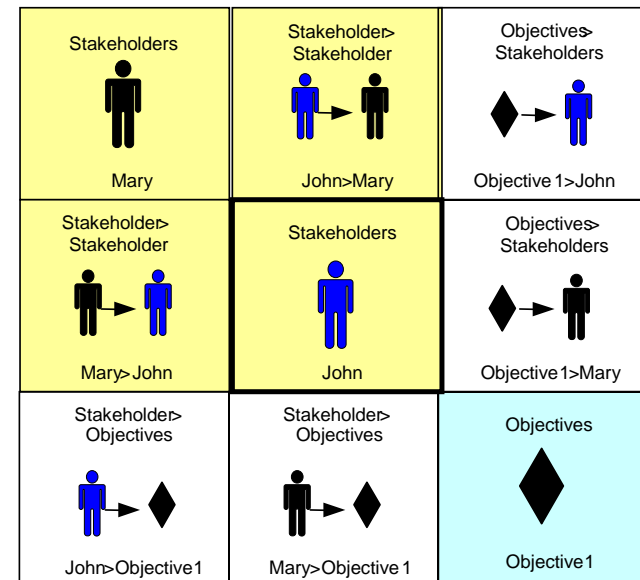
Coding Example

Data

Interview Transcript with Mary: Date: 12/1/00
Interviewer: Who is your primary customer? Mary: John
Interviewer: How frequently do you contact John? Mary: John and I participate in a weekly telecon to discuss the progress we are making on Objective 1.
Interviewer: Please explain Objective 1? Mary: Objective 1 can be described as follows.....

Codes

- Stakeholders**Mary**
- Stakeholders**John**
- Mary**>interacts with>**John**
- John**>interacts with>**Mary**
- Objectives**Objective 1**

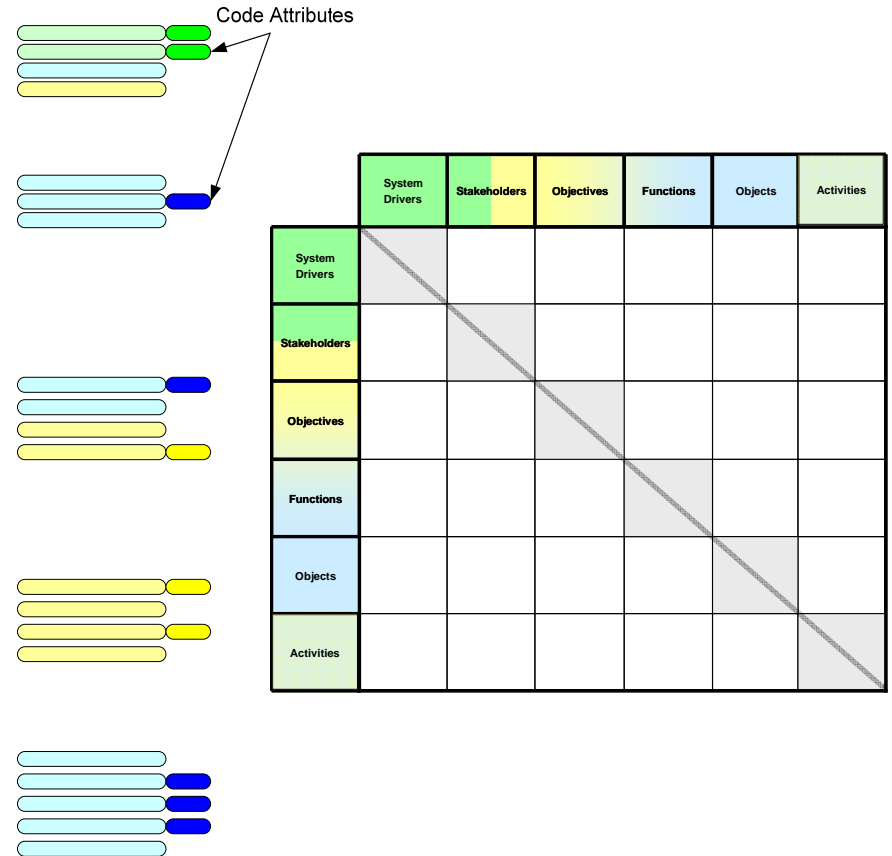


How Qualitative Knowledge Construction Works

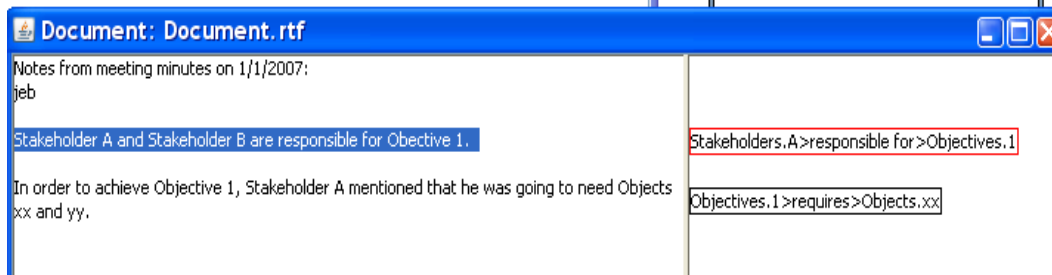
Step 5. Code Data

QKC Steps

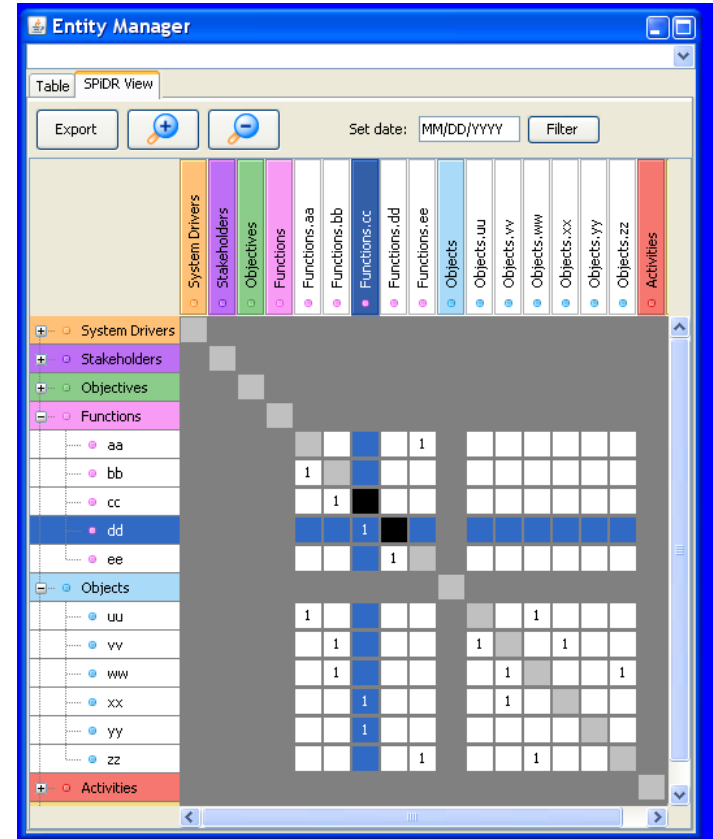
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Systems Modeling and Representation Tool (SMaRT)



Qualitative Coder



Matrix View

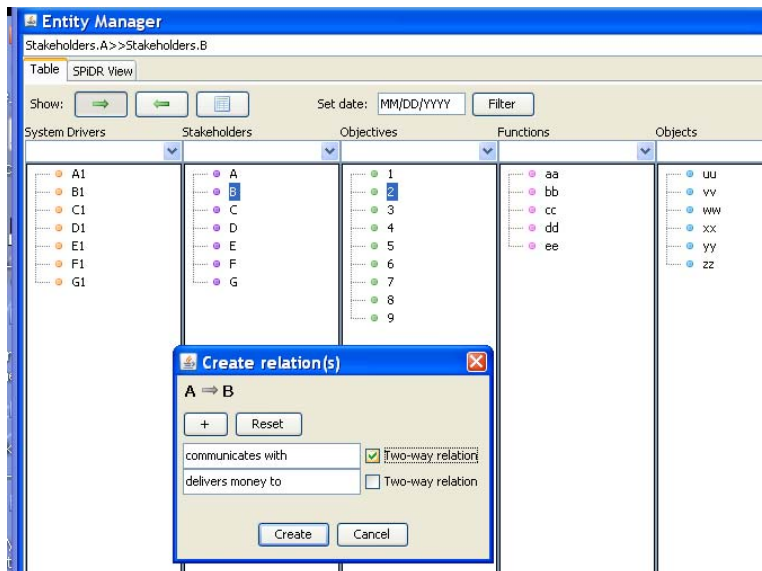
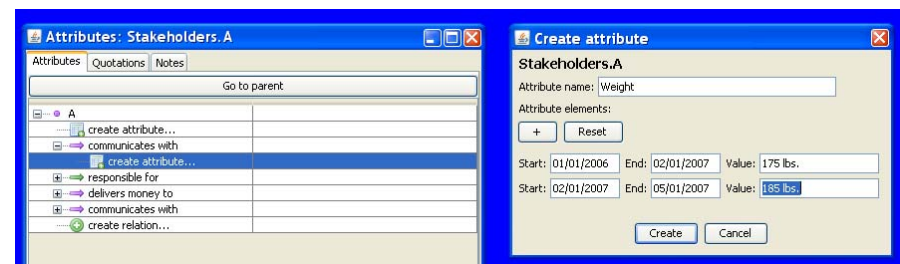


Table View



Attribute Window

How Qualitative Knowledge Construction Works

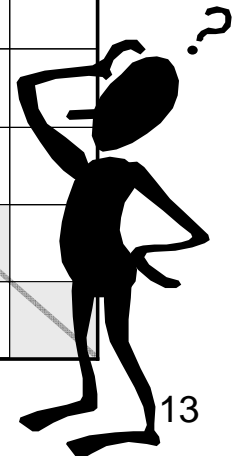
Step 6/7. Examine Model for Missing Data/Resolve Missing Data

QKC Steps

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- **Examine Model for missing/conflicted data**
- **Resolve Missing Data**
- Perform Analysis
- Iterate



	System Drivers	Stakeholders	Objectives	Functions	Objects	Activities
System Drivers						
Stakeholders						
Objectives						
Functions						
Objects						
Activities						



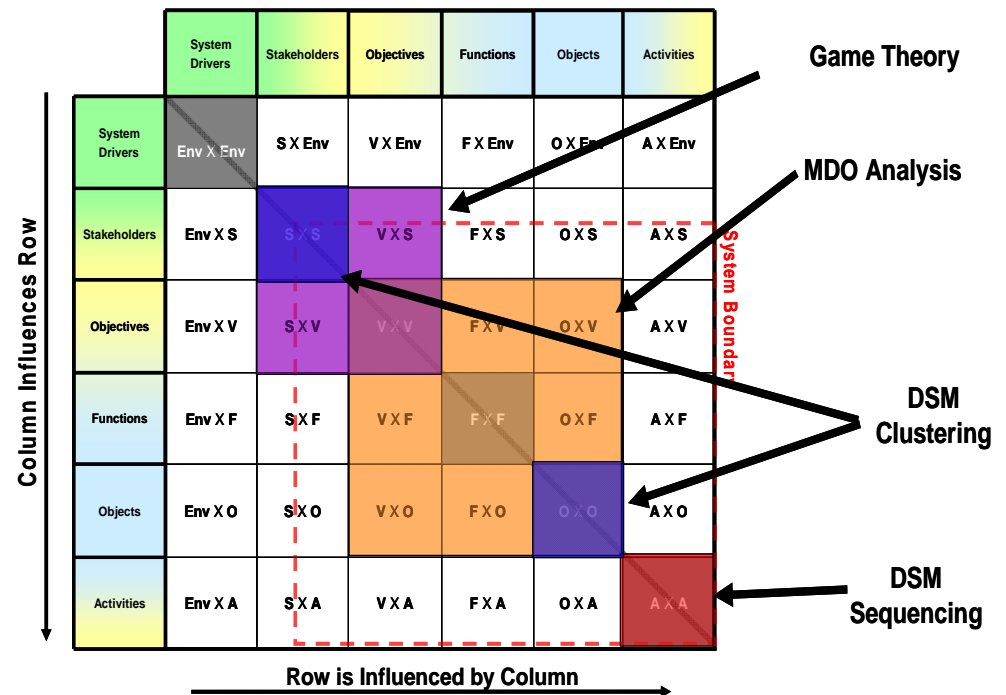
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How Qualitative Knowledge Construction Works

Step 8. Perform Analysis

QKC Steps

- Identify system of interest
- Develop research questions/analysis objectives
- Collect Data
- Code Data
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- Resolve Missing Data
- **Perform Analysis**
- Iterate

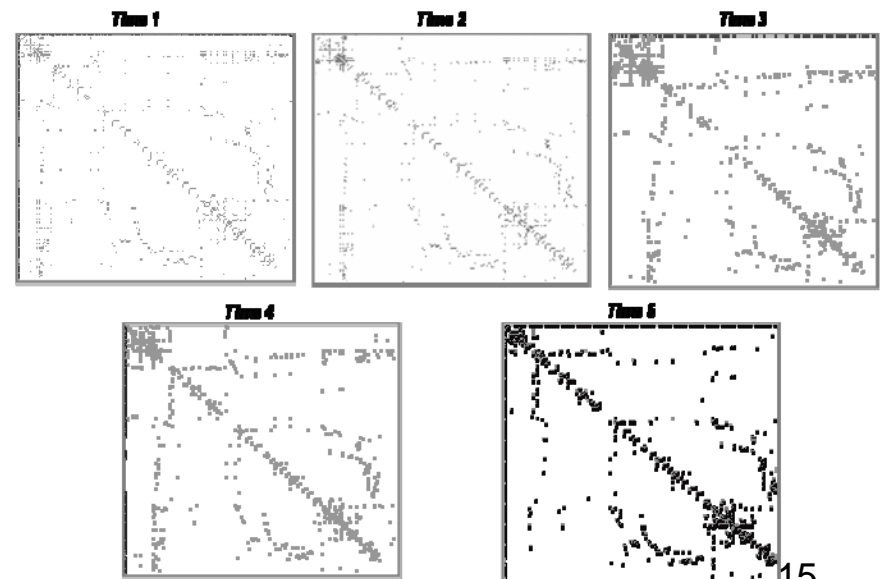


How Qualitative Knowledge Construction Works

Step 8. Perform Analysis

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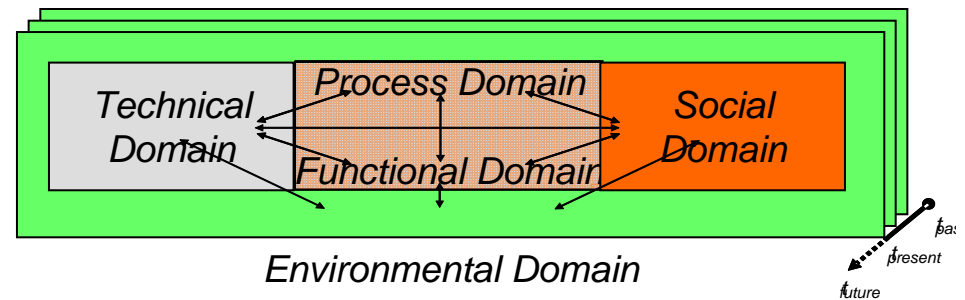
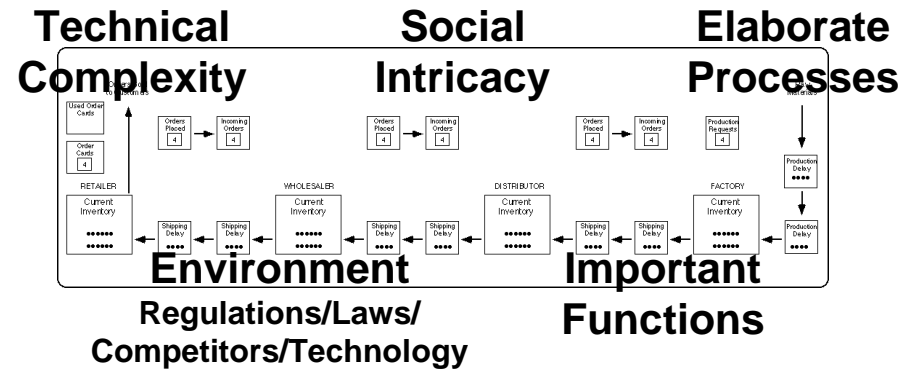


Toy Example

Rethinking the Beer Game

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Toy Example

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- Perform Analysis(-es)
- Iterate

Managers in an executive workshop playing the Beer Game at MIT.

Playing the Game

The game is played on a board that portrays the production and distribution of beer (figures 1-2). Each team consists of four sectors: **Retailer, Wholesaler, Distributor, and Factory** (R, W, D, F) arranged in a linear distribution chain. One or two people manage each sector. Pennies stand for cases of beer. A deck of cards represents customer demand. Each simulated week, customers purchase from the retailer, who ships the beer requested out of inventory. The retailer in turn orders from the wholesaler, who ships the beer requested out of their own inventory. Likewise the wholesaler orders and receives beer from the distributor, who in turn orders and receives beer from the factory, where the beer is brewed. At each stage there are shipping delays and order processing delays. The players' objective is to minimize total team costs. Inventory holding costs are \$50/case/week. Backlog costs are \$1.00/case/week, to capture both the lost revenue and the ill will a stockout causes among customers. Costs are assessed at each link of the distribution chain.

The game can be played with anywhere from four to hundreds of people. Each person is asked to bet \$1, with the pot going to the team with the lowest total costs, winner take all. The game is initialized in equilibrium. Each inventory contains 12 cases and initial

- Comment [j01]: Stakeholder: Retailer
- Comment [j02]: Stakeholder: Wholesaler
- Comment [j03]: Stakeholder: Distributor
- Comment [j04]: Stakeholder: Factory
- Comment [j05]: Stakeholders: Customers
- Comment [j06]: Stakeholder: Customers >communicates to> Stakeholder: Retailer
- Stakeholder: Retailer> delivers beer to> Stakeholder: Customer
- Stakeholder: Retailer>delivers product to> Stakeholder: Customer

Stakeholders	Customers	Retailer	Wholesaler	Distributor	Factory	Objectives	Functions	Activities	Objects
Customers									
Retailer	1								
Wholesaler		1							
Distributor			1						
Factory				1					
Objectives									
Minimize Retailer Costs		1							
Minimize Wholesaler Costs			1						
Minimize Distributor Costs				1					
Functions									
Sell Beer						1			
Wholesale Beer							1		
Distribute Beer								1	
Produce Beer									1
Activities									
Retailer Sells Beer to Customer	1	1							
Retailer Place Orders to Wholesaler		1							
Wholesaler Ship Beer to Retailer			1						
Wholesaler Place Orders to Distributor			1						
Distributor Ship Beer to Wholesaler				1					
Distributor Place Orders to Factory				1					
Factory Ship Beer to Distributor					1				
Factory Place Orders for Raw Materials					1				
Objects									
Customer Orders						1			
Retailer Inventory							1		
Retailer Inventory In-transit								1	
Retailer Orders									1
Wholesaler Inventory							1		
Wholesaler Inventory In-transit								1	
Wholesaler Orders									1
Distributor Inventory								1	
Distributor Inventory In-transit									1
Distributor Orders									1
Factory Inventory									1
Inventory in Production									1

	Stakeholders	Customers	Retailer	Wholesaler	Distributor	Factory	Objectives	Minimize Retailer Costs	Minimize Wholesaler Costs	Minimize Distributor Costs	Functions	Sell Beer	Wholesale Beer	Distribute Beer	Produce Beer	Activities	Retailer Sells Beer to Customer	Retailer Place Orders to Wholesaler	Wholesaler Ship Beer to Retailer	Wholesaler Place Orders to Distributor	Distributor Ship Beer to Wholesaler	Distributor Place Orders to Factory	Factory Ship Beer to Distributor	Factory Place Orders for Raw Materials	Objects	Customer Orders	Retailer Inventory	Retailer Inventory In-transit	Retailer Orders	Wholesaler Inventory	Wholesaler Inventory In-transit	Wholesaler Orders	Distributor Inventory	Distributor Inventory In-transit	Distributor Orders	Factory Inventory	Inventory in Production			
Stakeholders																																								
Customers		1																																						
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Retailer Place Orders to Wholesaler			1	1													1	1																						
Wholesaler Ship Beer to Retailer				1	1													1	1																					
Wholesaler Place Orders to Distributor					1	1													1	1																				
Distributor Ship Beer to Wholesaler						1	1													1	1																			
Distributor Place Orders to Factory							1	1													1	1																		
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Inventory in Production																																								

SOCIAL NETWORK

OTHER EXTENSIONS/GAME THEORY

**SYSTEM DYNAMICS
(Stocks, Flows)**

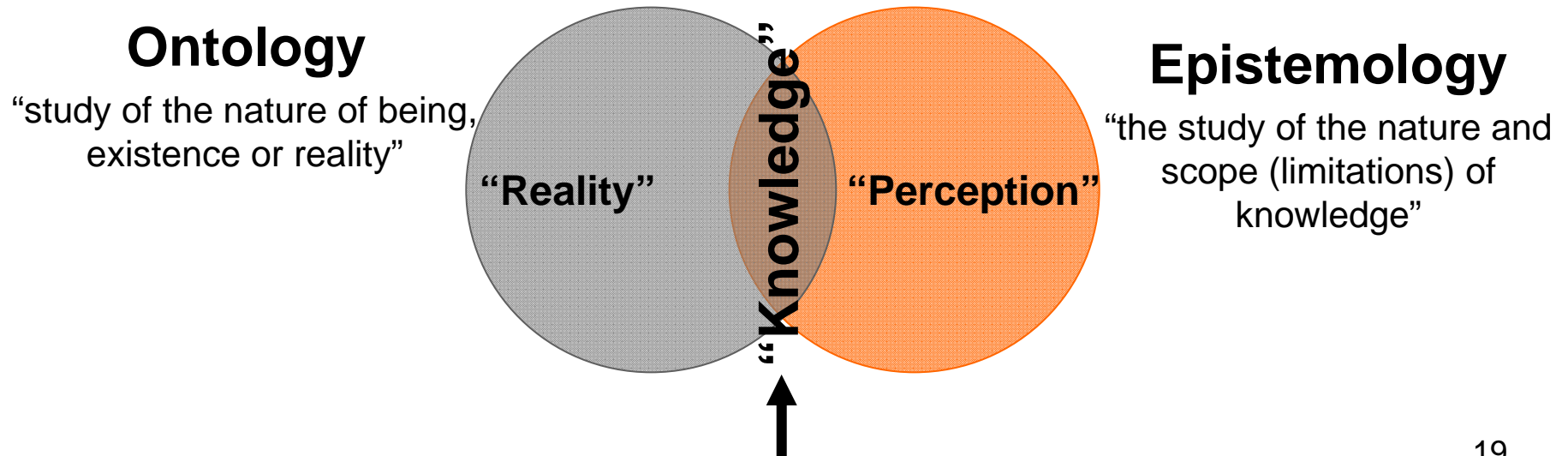
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Way Forward:

Improving the Creation, Management and Use of Engineering Systems Knowledge

From the ESD Strategic Document we learn that the term “engineering systems” can have two key meanings:

1. A class of systems characterized by a high degree of technical complexity, social intricacy, and elaborate processes, aimed at fulfilling important functions in society
2. An emerging field of scholarship that seeks solutions to important, multi-faceted, socio-technical problems



(Better Knowledge = Better Theories, Better Designs, Better Solutions)

Summary



