Engineering Healthcare: Towards An Integrative and Adaptive Service System

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Engineering and Healthcare: Examples of "Technobiology"

Engineering Discipline	Example	Scope
Biomedical	PillCam	Can Capture 50K Gastrointestinal Images
Chemical	Tissue	Engineering Stem Cells To Create Muscles, Bones, Nerves, Blood Vessels, Etc.
Electrical	National Health Information Structure	A Nationwide System of Electronic Records That Congress Is Exploring
Environmental	Sunshine Vitamin	Sunlight Spurs Body's Production of Vitamin D Which Can Reduce Instances of Cancer, High Blood Pressure, Diabetes, Etc.
Industrial	Evidence-Based Protocols	Data Mining Analysis of Past Treatments Can Yield New Protocols
Material	Synthetic Polymers	A Drug/Polymer Composite Can Be Injected , Providing A Long-Term Release of Drug
Mechanical	Haptics	Sensing and Manipulating of Objects and Environments Through Touch
Systems	Healthcare Design	Towards An Integrative and Adaptive Service System

Outline

- Background
- Service System
- Decision Framework
- Adaptive Framework
- Integrative Framework
- Concluding Remarks

Background: U. S. Employment As of April 2006

Industries	Employment (M)	Percent
Trade, Transportation & Utilities	26.1M	19.0%
Professional & Business	17.2	12.6
Healthcare	14.8	10.8
Leisure & Hospitality	13.0	9.5
Education	13.0	9.5
Government (Except Education)	11.7	8.5
Finance, Insurance & Real Estate	8.3	6.1
Information & Telecommunication	3.1	2.2
Other	5.4	3.9
SERVICES SECTOR	112.6	82.1
Manufacturing	14.3	10.3
Construction	7.5	5.5
Agriculture	2.2	1.6
Mining	0.7	0.5
GOODS SECTOR	24.7	17.9
TOTAL	137.3	100.0

Background: Jobs For Engineering Graduates

Economic Sector	1984-1985 Graduates	2004-2005 Graduates
Services	28.6%	68.9%
Manufacturing	71.0%	28.9%
Agriculture	0.0%	0.0%
Construction	0.4%	2.1%
Mining	0.0%	0.0%
TOTAL	100.0%	100.0%

Source: *Rensselaer Polytechnic Institute*, Career Development Center

Background: Information/Communication Technology (ICT) Driven Customization

- **Customization: Meeting the needs of a consumer market that is partitioned into an appropriate number of segments, each with similar needs, e.g., vaccinations, semantic querying of large biomedical image datasets**
- **Mass Customization: Meeting the needs of a segmented cconsumer market, with each segment being a single individual, e.g., personalized medicine, high performance data-intensive computing**
- **Real-Time Mass Customization: Meeting the needs of an individualized consumer market on a real-time basis, e.g., robotic-assisted surgeries, from "intermittent go to" to "continuous assist" Web**

Service System: Scope

- **Definition: Knowledge-Intensive Agents Or Components Which Work Together As Providers and Consumers To Create Value**
- **Components:**
  - **People – characterized by behaviors, values, knowledge, etc.**
  - **Processes – characterized by collaboration, customization, etc.**
  - **Products – characterized by software, hardware, infrastructures, etc.**
- **Range:**
  - **From Self-Service To Partial-Service To Full-Service**
  - **From Tell-Me To Show-Me To Do-It –For-Me**

Service System: Critical Differences

FOCUS	SERVICES	GOODS
Production	*C*o-Produced	*P*re-Produced
Variability	*H*eterogeneous	*I*dentical
Physicality	*I*ntangible	*T*angible
Product	*P*erishable	"*I*nventoryable"
Objective	*P*ersonalizable	*R*eliable
Satisfaction	*E*xpectation-Related	*U*tility-Related
Life Cycle	*R*eusable	*R*ecyclable
OVERALL	*CHIPPER*	*PITIRUR*

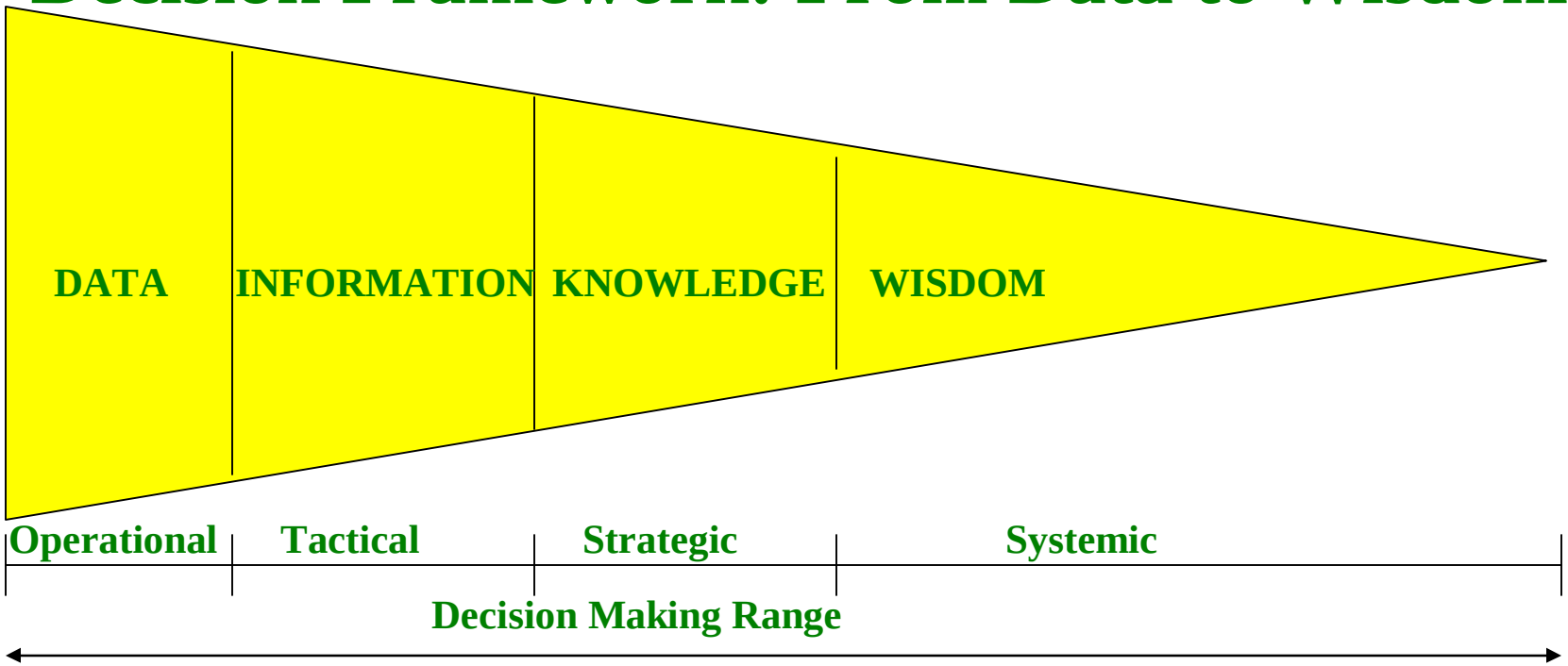
Service System: Traditional and Electronic

	SERVICE ENTERPRISES	
ISSUE	**TRADITIONAL**	**ELECTRONIC**
• Co-Production Medium	Physical	Electronic
• Labor Requirement	High	Low
• Wage Level	Low	High
• Self-Service Requirement	Low	High
• Transaction Speed Requirement	Low	High
• Computation Requirement	Medium	High
• Data Sources	Multiple Homogeneous	Multiple Non-Homogeneous
• Driver	Data-Driven	Information-Driven
• Data Availability/Accuracy	Poor	Rich
• Information Availability/Accuracy	Poor	Poor
• Size	Economies of Scale	Economies of Expertise
• Service Flexibility	Standard	Adaptive
• Focus	Mass Production	Mass Customization
• Decision Time Frame	Predetermined	Real-Time

Service System: Supply and Demand Management Methods

	DEMAND/CONSUMER	
SUPPLY/ PROVIDER	**Given**	**Flexible**
Given	**1. No Management (NM)** Price Established At Point Where Given Demand Matches Given Supply	**3. Demand Chain Management (DCM)** Revenue Management Dynamic Pricing Expectation Management Target Marketing Auction
Flexible	**2. Supply Chain Management (SCM)** "Inventory" Control Production Scheduling Distribution Planning Capacity Rationing Reverse Auction	**4. Real-Time Customized Management (RTCM)** Customized Bundling Customized Revenue Management Customized Pricing Customized Modularization Customized Co-Production Systems

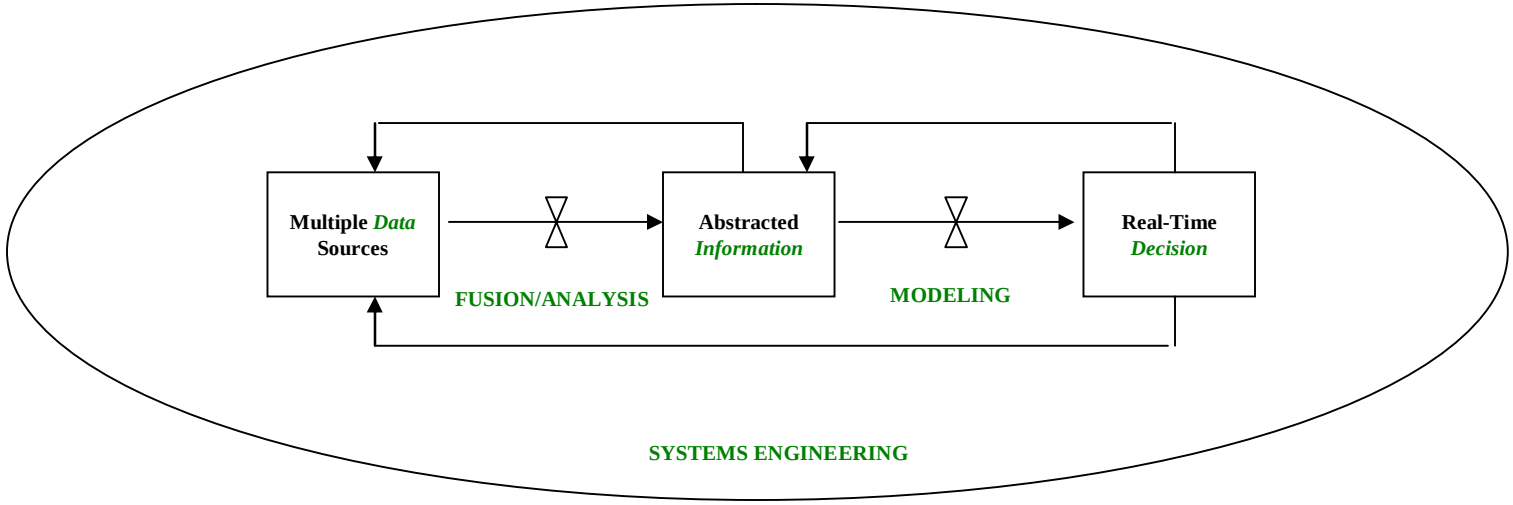
Decision Framework: From Data to Wisdom



- **Data: Basic observation; measurements, transactions, etc.**
- **Information: Processed data; derivations, groupings, patterns, etc.**
- **Knowledge: Processed information plus experiences, beliefs, values, culture; explicit, tacit/conscious, unconscious.**
- **Wisdom: Processed knowledge plus insight and assessment over time and space; theories, etc.**

Ø At Present, We Are In A Data Rich, Information Poor (DRIP) – Not Knowledge – Era

Decision Framework: Decision Informatics



- **Disciplinary Core: 1) Data Fusion/Analysis; 2) Decision Modeling; 3) Systems Engineering.**
- **Applications Core: 4) Global Services; 5) Global Manufacturing.**
- **Focus: A problem solving paradigm that is 1) decision-driven, 2) information-based, 3) real-time, 4) human-centered, and 5) computationally-intensive.**

Adaptive Framework: Model Types

- **Deterministic:**
  - Ø Non-Stochastic
  - Ø Known States
  - Ø Known Steady-State With No Transition
- **Dynamic:**
  - Ø Stochastic
  - Ø Known/Assumed States
  - Ø Assumed Steady-State With Transition
- **Adaptive:**
  - Ø Stochastic
  - Ø Known/Assumed/Unknown States
  - Ø Real-Time

Adaptive Framework: Example Models

- **Strategic:**
  - Ø **Analytic**
  - Ø **Procedures**
  - Ø **Policies**
- **Tactical:**
  - Ø **Simulation**
  - Ø **Allocation**
  - Ø **Distribution**
- **Operational:**
  - Ø **Cognition**
  - Ø **Genetic/Bayesian Networking**
  - Ø **Adaptation/Improvisation**

Adaptive Framework: Example Systems

- **Natural:**
  - Ø **Closed**
  - Ø **Open**
  - Ø **Hybrid**
- **Constructed:**
  - Ø **Closed**
  - Ø **Open**
  - Ø **Hybrid**
- **Virtual:**
  - Ø **Simulated**
  - Ø **Gedanken**
  - Ø **Second Life**

Integrative Framework: Approaches

- **Typological Integration:**
  - Ø **Deterministic**
  - Ø **Dynamic**
  - Ø **Adaptive**
- **Scale Integration:**
  - Ø **Strategic**
  - Ø **Tactical**
  - Ø **Operational**
- **System Integration:**
  - Ø **Natural**
  - Ø **Constructed**
  - Ø **Virtual**

Integrative Framework: System of Systems

- **Physical (degree of systems co-location)**
- **Temporal (degree of systems co-timing)**
- **Organizational (degree of systems co-management: hierarchical, central control versus decentralized, local control)**
- **Operational (degree of systems co-dependency)**
- **Functional (degree of systems co-functioning)**

Concluding Remarks

- Goods è Services
- Supply-Driven è Demand-Driven
- Mass Production è Mass Customization è Real-Time Mass Customization
- Efficiency (meeting demand with minimum cost) è Effectiveness (producing right – quality and safe -- products/services at the right time for the right consumer)
- Physical Space (stores/products) è Virtual Space (Internet/services)
- Deterministic è Dynamic è Adaptive
- Optimal Steady-State è Adaptive Real-Time System è Integrative System of Systems
- Medical Specialists è Medical System (Human and/or Healthcare) Specialists