Sustainability in production & logistics:

Progress and methodological challenges

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Purpose of the paper

- To introduce the concepts and methodological challenges of sustainable production and logistic systems
- To review several case studies
- To review several recent EU initiatives towards sustainable manufacturing
- To present the basic elements of DSS - the enablers for the decisions in sustainable production and logistics

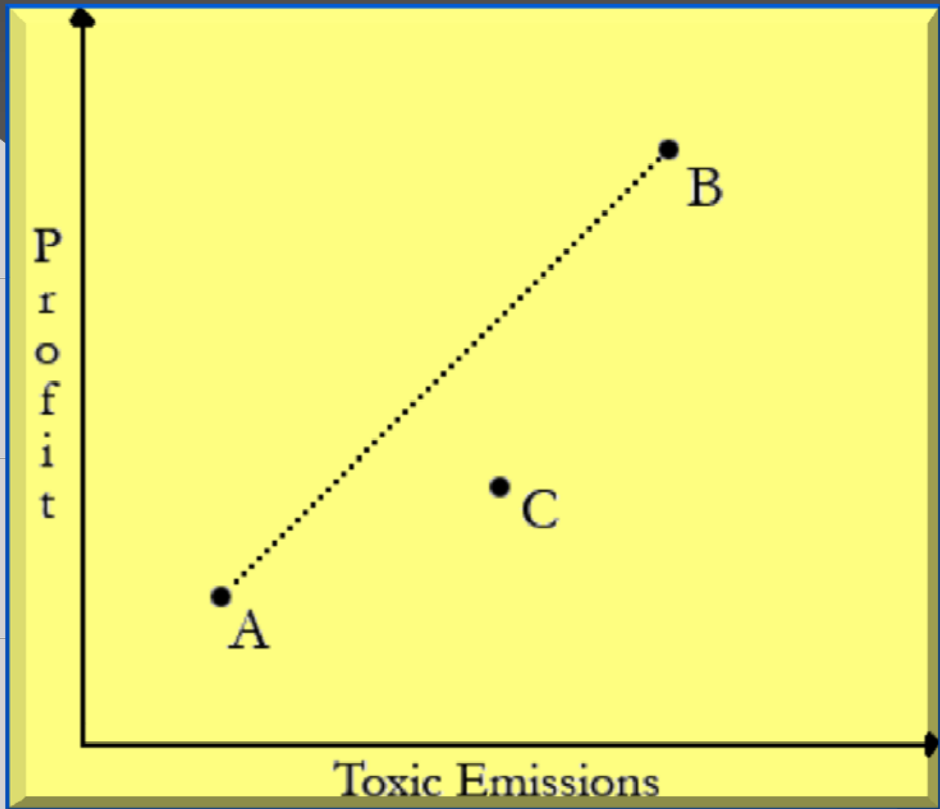
Outline

- =>Introduction and Problem Definition
- Recent global case studies and impacts on production & logistics of the future
- Related recent European initiatives
- Decision Support Systems-enabling tools
- Conclusions, observations, challenges
- References

Introduction with examples

- Differing views and definitions of “sustainability”
- Economic and Risk Analysis of Sustainable Agribusiness and Food Distribution Systems

Challenge: Environment vs. Profitability Trade-offs and Risks



A: Low toxic emission with low profit
B: High toxic emission with high profit
→ C: We should find the negotiable point between two objects such as toxic emission and profit

The Context: Sustainable Development (SD)

- The conception of SD was originally defined in the 'Brundtland Report' (1987),
- Rio Summit (1992)
- Agenda 21 (1992).
- World Business Council for Sustainable Development (WBCSD) proposed
  - the concept of “eco-efficiency” (EE)
  - SD Reporting on Striking the Balance (2003)
  - AGENDA 2050 : the New Agenda for Business (at the World CEO Forum, New Delhi, 2010)

Sustainability is a control problem

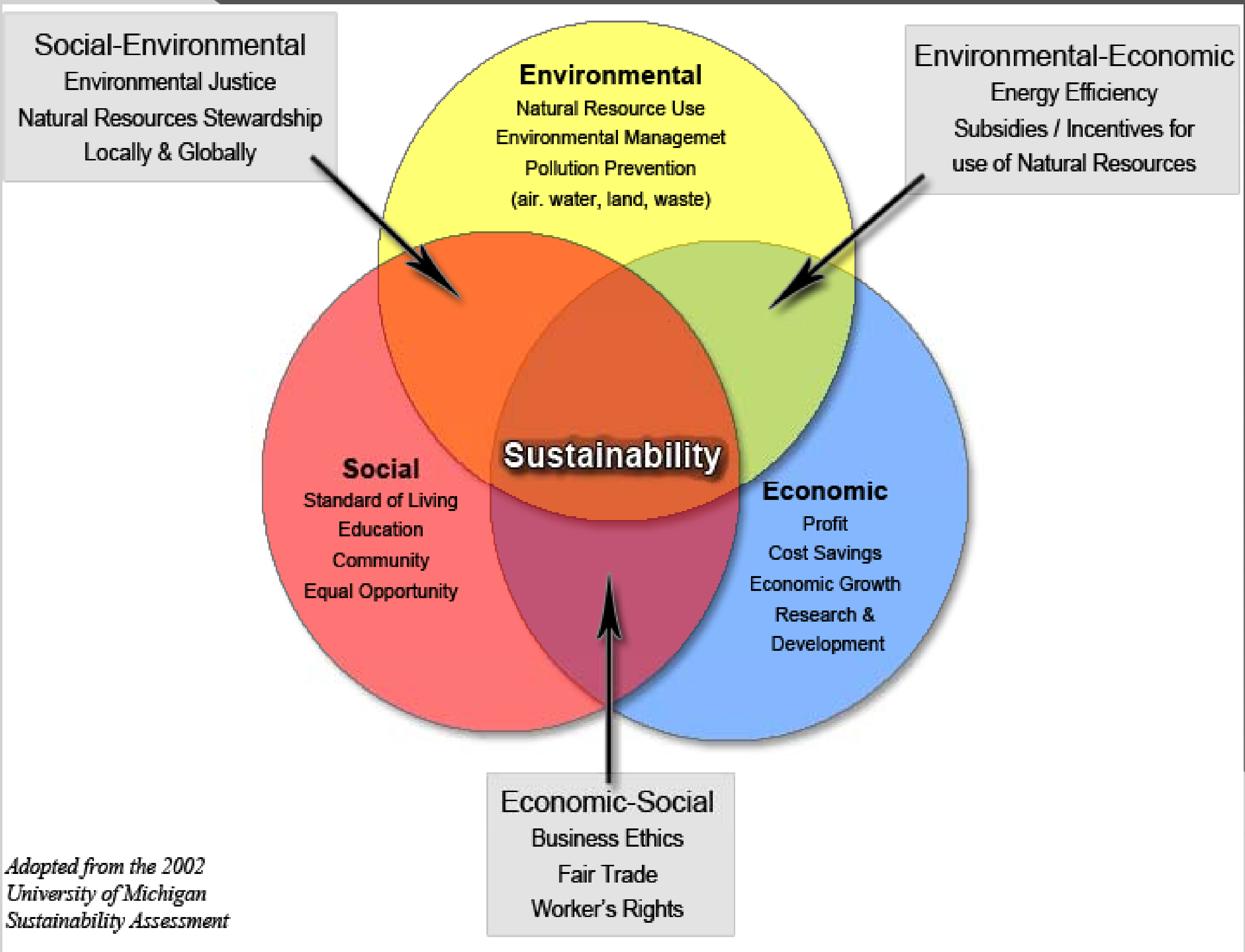
Examples:

- Sustainability for pollution control
- Urban traffic planning and control
- Sustainable groundwater planning and control
- Optimal control for sustainable environmental management
- Resource sustainability for product design and control
- Recycling optimization with control theory
- Robust control for closed-loop supply chain design
- Using control and automation for waste collection

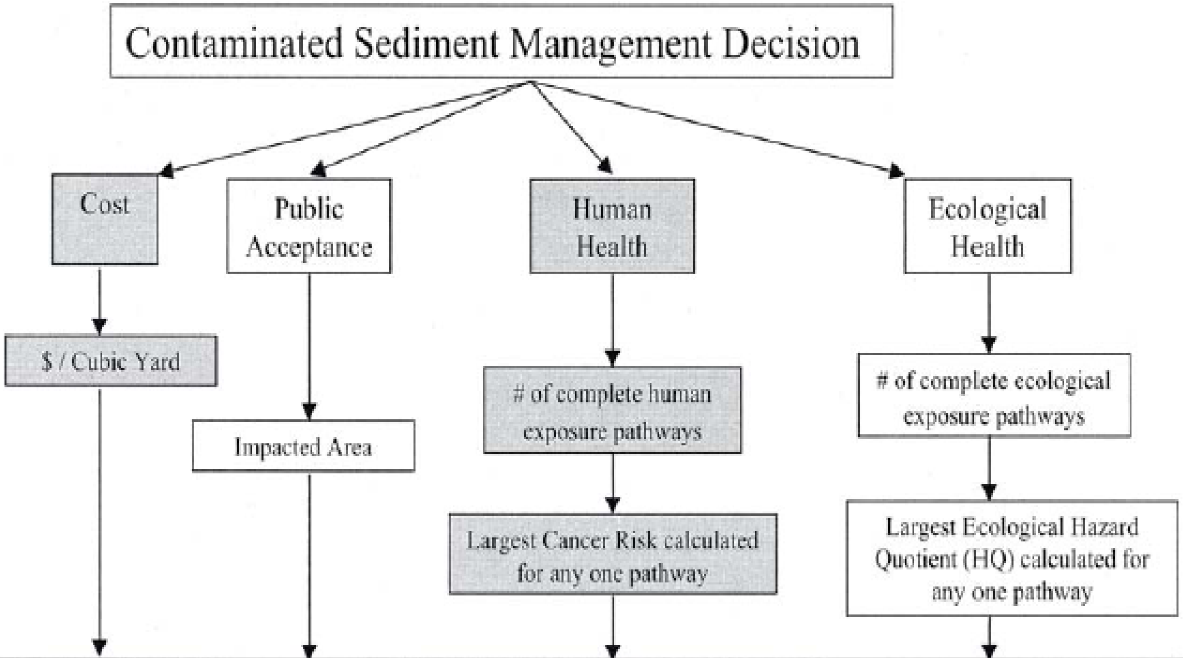
The dynamic interaction between economy and ecology:Cooperation, stability and sustainability for a dynamic-game model of resource conflicts by J. Scheffran (2000)

Problem Definition

- Sustainability is a challenging multi-variable problem along six dimension



Multi-criteria decision process (example)



	Cost	Public Acceptance	Human Health		Ecological Health	
	$ / CY	Acres	pathways	Max. Cancer Risk	Pathways	Max. HQ
Choice A	20	1000	24	$1.0 * 10^{-3}$	38	1800
Choice B	40	200	18	$1.0 * 10^{-4}$	23	1500
Choice C	60	5	12	$1.0 * 10^{-6}$	14	10

(Kiker et al., 2005)

Problem Definition & Progress

- Three sub-criteria factors
  - Environmental factors
    - Total solid wastes (%)
    - Specific energy consumption (Gcal/tcs)
    - Specific emission rate (mmg)
    - Risks and recoverability (%; %-$)
    - Other environmental threats and potential disasters
  - Social factors
    - Employee satisfaction
    - Quality of life
    - Expenditure on peripheral development
    - Diversity & opportunity
    - Reputation and visibility

Problem Definition & Progress

› Economic factors
- Gross margin
- Turnover ratio
- Net profit
- Average capital employed
- Total income or revenue; market share
- Investment in new processes and products(%)
- Inventory ratio (%)
- Flexibility and agility
- Economic complexities and dependencies

Problem Definition & Progress

Main challenging decisions

- How to maximize the satisfaction of the multiple criteria in each area (environment, social and economic) ?
- How to model and set the constraints?
- How to select the two or three key objective criteria from the six dimensions (environment, social and economic, and their interactions) rationally?
- How to handle the modeling of different kinds of industries with different criteria (objectives) ?
- Tremendous political and cultural challenges

Collaborative mechanisms for sustainability-driven production & logistics

CRP
Cooperation Requirement Planning (I+II)

We must consider effectively and in parallel multiple sustainability criteria based on the characteristics of each parameter and with various situations

CRP is helpful when new constraints are added. Within CRP-II, the formulation can be revised in real time, adapted to temporal changes and constraints

LOCC
Lines of Command & Communication

Most industries are influenced by sustainability objectives. Between them, there are mutually useful dynamic information flows , e.g., environmental policy changes, social trends changes. By LOCC, these information flows can be used to negotiate and develop collaborative formulations and emergent organization changes

JLR
Join / Leave / Remain in **CNO**

When we have some additional constraints and parameters to existing, negotiated formulations, by using JLR analysis and decisions we can estimate effectively the impact of additional (or less) “players” and parameters on the projected sustainability

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Case Studies: Environmentally conscious manufacturing and product recovery- Problem subclasses (Ilgin, Gupta, 2010) (I)

- Environmentally conscious product design
  - Design for X: a)Design for environment; b)Design for disassembly; c) Design for recycling
  - Life cycle analysis
  - Material selection
- Reverse and closed-loop supply chains (reverse logistics)
  - Network design
  - Simultaneous consideration of network and product design issues
- Optimization of transportation of goods
- Selection of used products

Case Studies: Environmentally conscious manufacturing and product recovery Problem subclasses(Ilgin, Gupta, 2010) (II)

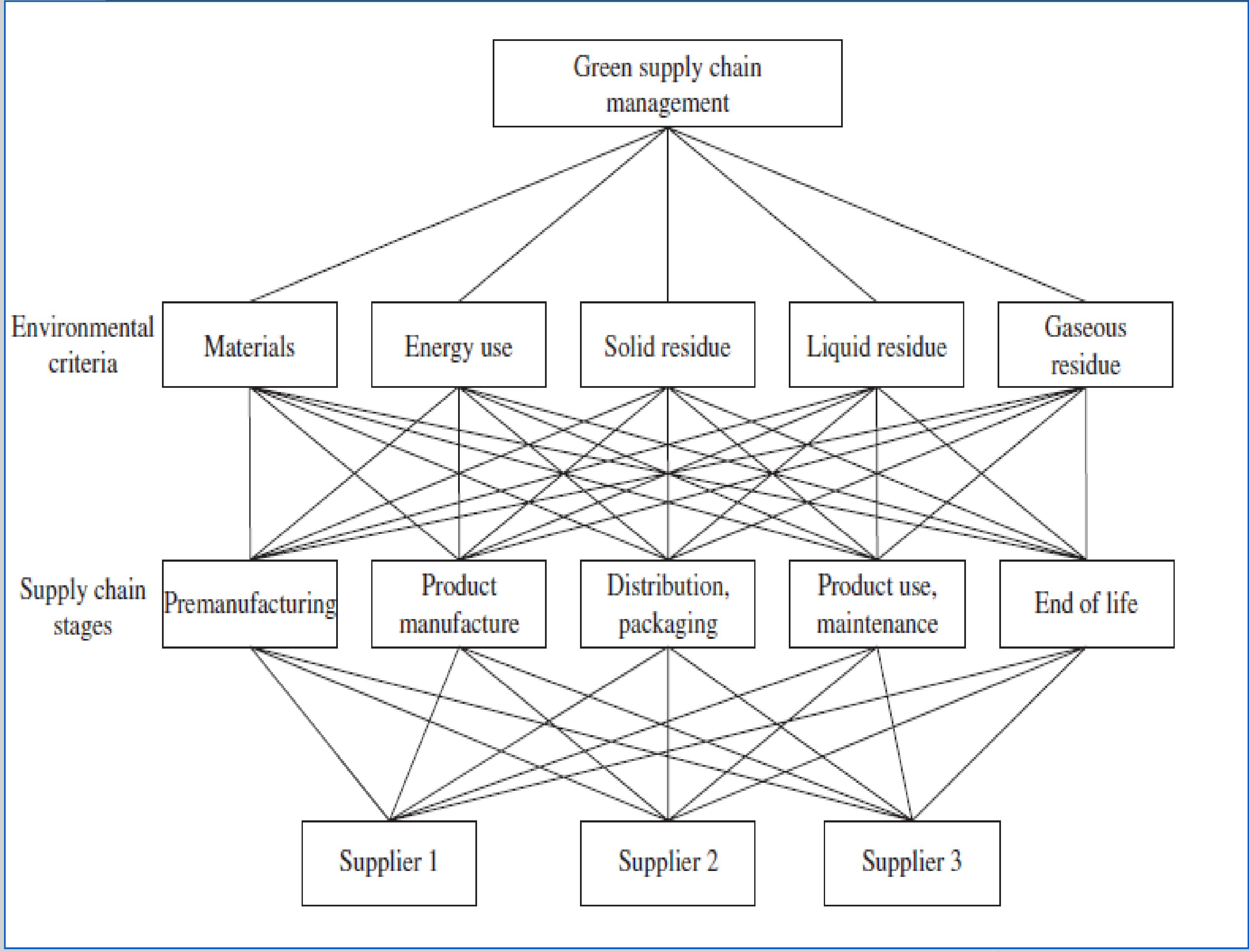
- Remanufacturing
  - Forecasting (estimation of product returns)
  - Production planning & scheduling
  - Capacity planning
  - Inventory management
- Disassembly
  - Scheduling & sequencing
  - Line balancing
  - Line balancing
  - Disassembly to order systems [and lot sizeing]
  - ……….

Case Studies: Supply chain sustainability

- There are relationships between environmental management and product/service supply chains; there are social and sustainability dimensions.
- Researchers seeks the potential benefit of O.R. methods in the wider arena of sustainable planning and development, e.g., green supplier selection.
- Case studies describe using a more holistic approach in exploring sustainable planning and development in the context of depot locations and route selection in/near urban areas

The green supply chain hierarchy

(Lu et al., 2007)



Case Studies: Sustainable energy future

- Analyses of the combined use of scenario building and *participatory multi-criteria analysis* (*PMCA*) in the context of renewable energy future.
- Methodological points of view: Scenarios have been applied increasingly in decision-making about long-term consequences by projecting different possible pathways into the future.

Case Studies: Sustainable transportation

- Characterizing the emergent thinking on what constitutes transportation sustainability and how to measure it.
- While there is no standard definition for transportation system sustainability, it is largely being defined through impacts of the system on the economy, environment, and general social well-being.
- Measured by combination of system effectiveness and efficiency, and the impacts of the system on the natural environment.

Case Studies: Sustainable construction industry

- Sustainable development of production facilities for construction industry's suppliers, with organizational procedures and company responsibilities.
- Focus on **assessment and subsequent reassessment to determine areas where the company can improve its sustainability performance and be able to demonstrate real progress towards sustainability.**
- Responsibility taken on by senior management is a must.
- **Sustainable development is a process of continuous improvement** (see next slide).

Multi-Dimensional Assessment with Sustainability Considerations (Braithwaite, 2007)

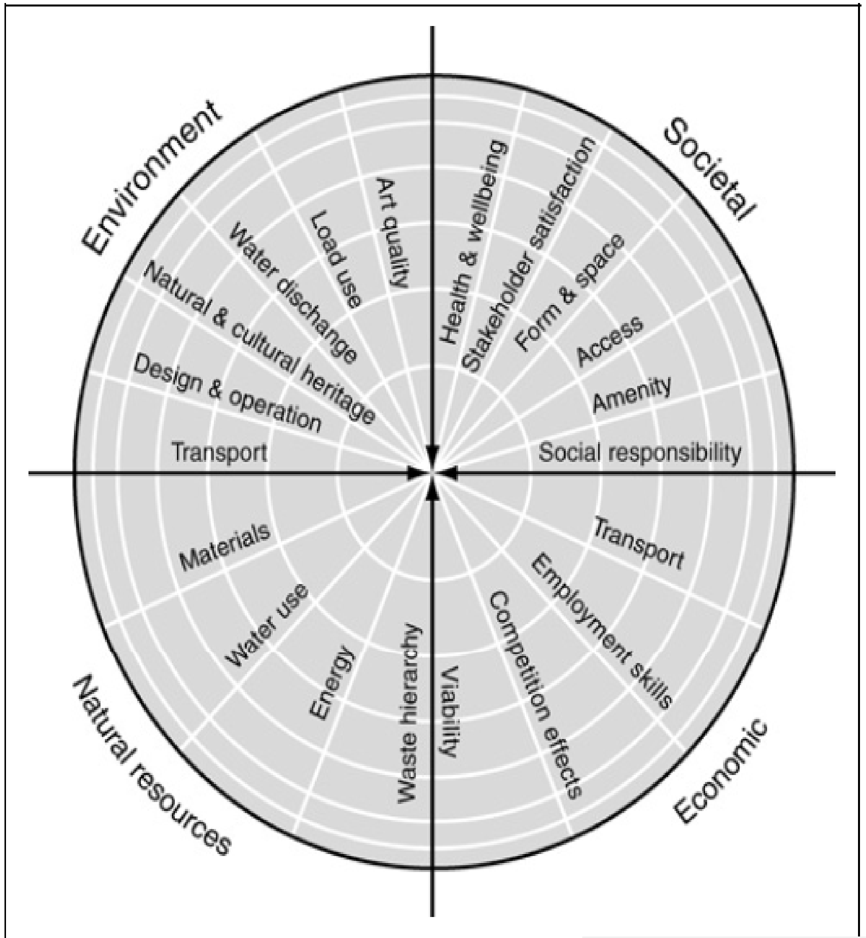
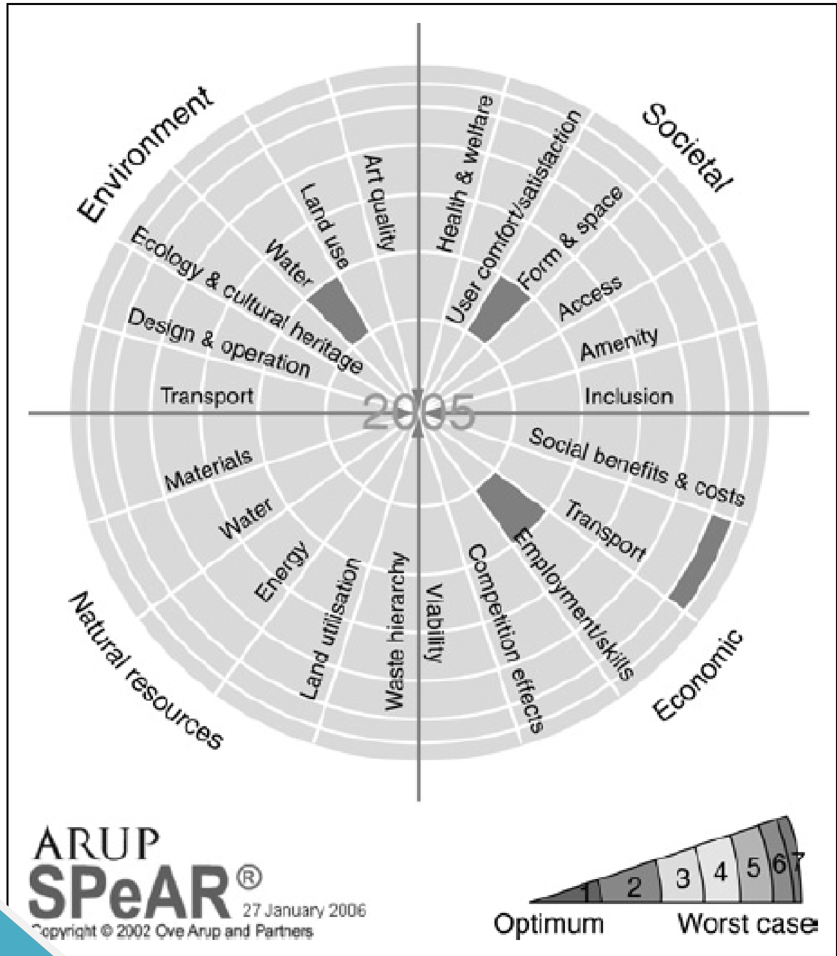


Fig. 1. Spear template

Assessment
After improvement



2005 assessment

Sustainability Case Studies observation

Sustainability-based development is considered:

- More holistic, community-oriented, globally friendly
- More competitive while being collaborative
- More resilient to shocks and risks
- Nimbler in a fast changing world
- More unified in purpose and more sensitive
- More likely to attract and retain customers and employees
- More at ease with regulators, banks, insurers and financial markets.

Other new related terms

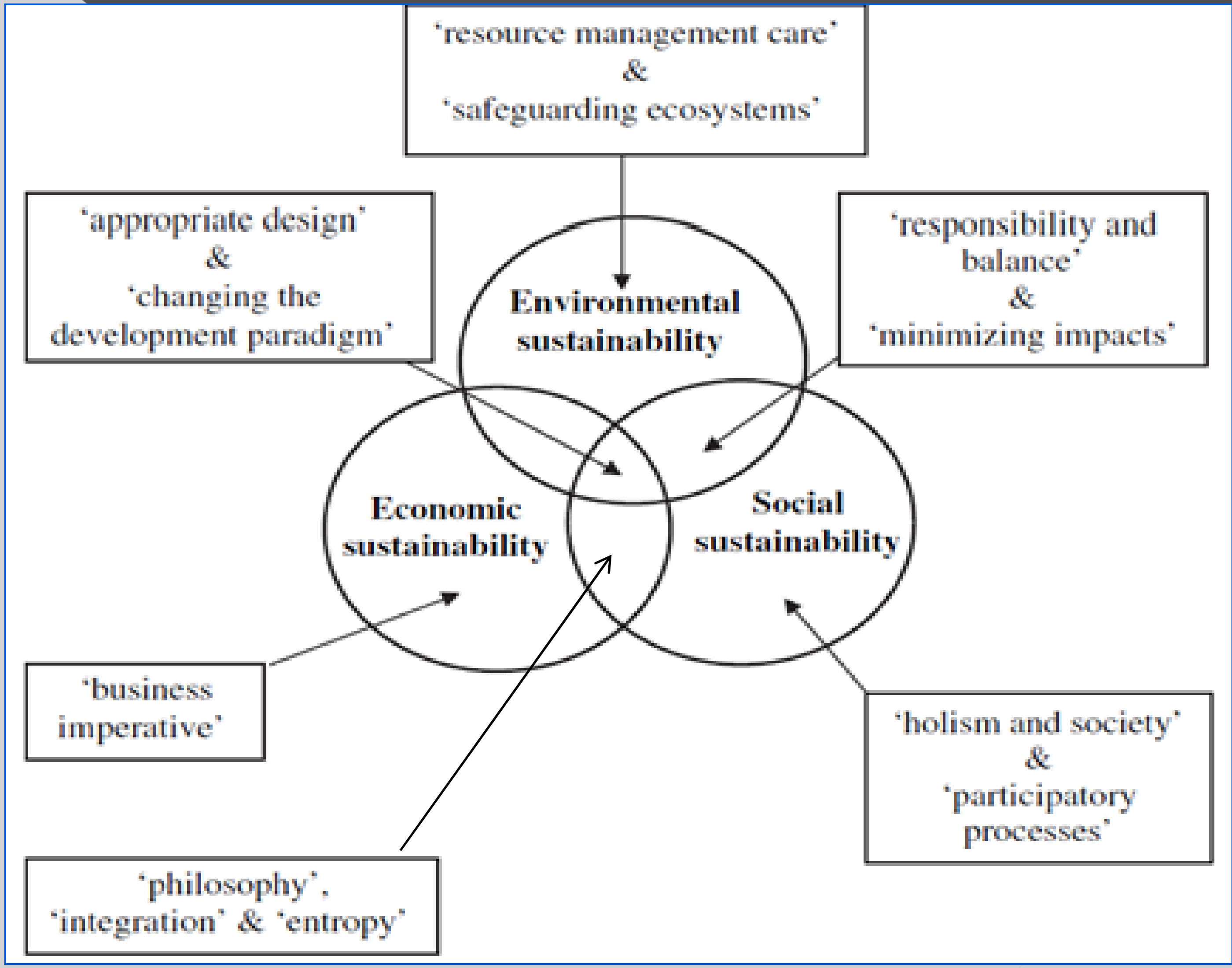
(Chang , Lu, Lin ,2006)

Recycling Oriented Society (ROS) a society in which the mass consumption of natural resources is restrained and the environmental burden is minimized [*Japan Basic Low for Protecting and creating ROS*, 2001)

Industry Ecology (IE) is used to study the relationship between various industrial activities and products and the environment. it is meant to reflect industrializations impact on nature, and it not only considers the balance between benefits of E-E-S (environment, economy, and society), but also emphasizes development strategies that emphasize environmental protection.

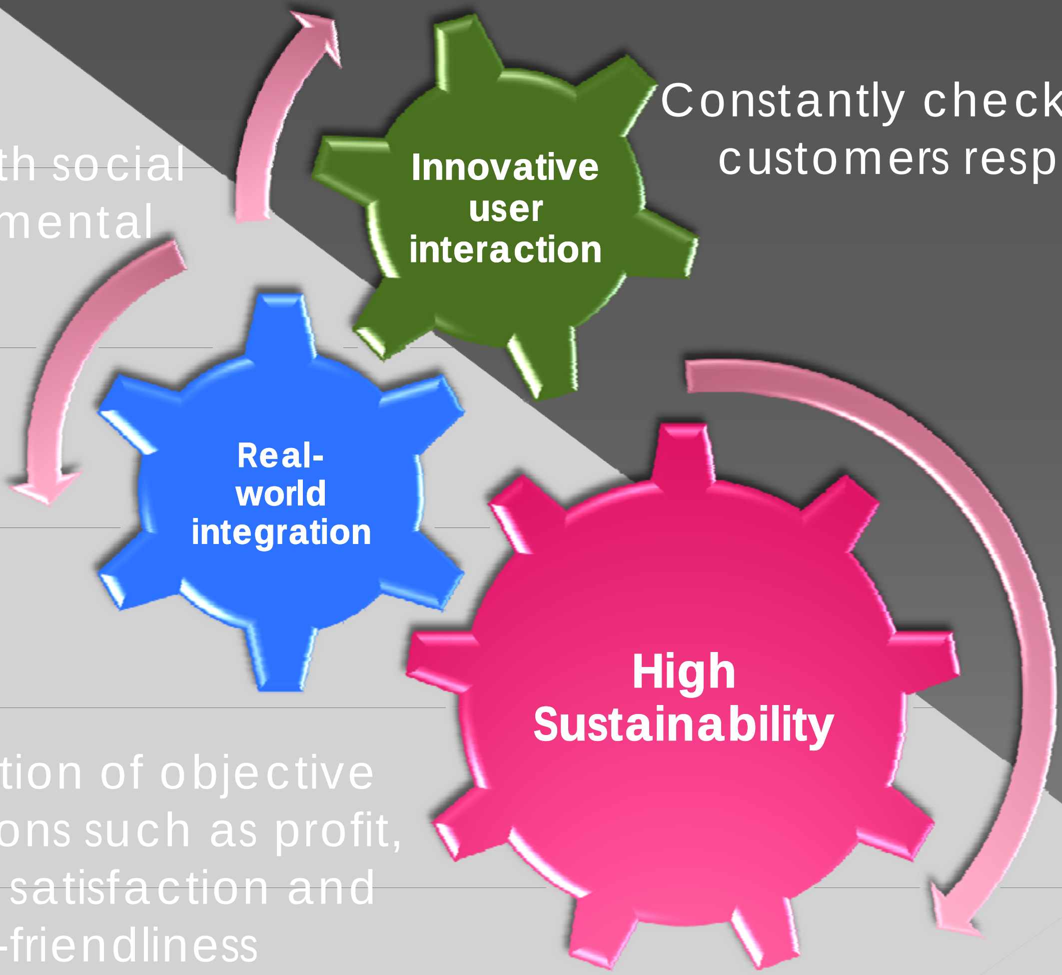
Eco-industrial parks (EIP), eco-towns implies that factory products, by-products, and even wastes, can be used by others to optimize material recycling, energy and money. They are specific implementation of the conceptions of the terms ROS, IE, industrial symbiosis, industrial metabolism, zero emission

Sustainability education for cleaner production (Carew and Mitchell, 2008)



Impacts on production and logistics of the Future -- challenges

Adaptive systems with social policy and environmental policy



Constantly checking the customers response

Maximization of objective combinations such as profit, customer satisfaction and eco-friendliness

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European Initiatives

- Article 174 of the Lisbon Treaty sets the basic principles of European policy on environment *(precautionary principle and "polluter pays")*
- The Economic Recovery Plan of EC (26.11.2008) includes
  - Factories of the Future (FoF)
  - Energy efficient buildings
  - Green cars

FoF PPP Strategic Multi-annual Roadmap

- To address the development of next generation of production technologies
- Elaborated by
  - Ad-Hoc Industrial Advisory Group for FoF PPP (created in March 2009)
  - European Technology Platforms: MANUFUTURE(Future Manufacturing Technologies)+ EuMat(Advanced Engineering & Technologies), ESTEP(European Steel Technologies), FTC(Future Textiles and Clothings), FOOD (Food for Life), ARTEMIS (Advanced Res. And Techn. For Embedded Intelligence and Systems), NESSI (Networked European Software an Services Innitiative), EUROP(European Robotics Platform)

Assumptions

- " A factory is more than a smart combination of autonomous machines...; it is an entity which focuses on intelligent person-machine co-operation in which advanced technology is as important as a sound ethical basis for stabilizing local and global manufacturing, All this will directly impact on the sustainability on the EU manufacturing industry
- "Technology , though it plays an important role is only one term in the equation. Human skills , organizational structure , the mid-and long-term goals and the rule for financial **decisions** are at least as important"
- FoF PPP initiative is part of the EU response to the current economic crisis, placing sustainability alongside with competitiveness , profitability and employment as strategic goals

Features

- Subdomains:
  - Sustainable Manufacturing
    - new Eco-factory model: optimized energy utilization,reduction of environmental impact
    - Green product manufacturing: integrated preventive environmental strategy, diminishing emissions and wastes, recycling, safety and ergonomics for operators and users
  - ICT- enabled intelligent manufacturing:
    - Smart factory involving process automation, planing, simulation, and optimization, robotics
    - Virtual factory to allow distributed networked manufacturing
    - Digital factory for better life product lifetime mangement from product conception to disassembly/recycling involving simulation, modelling and knowledge management
  - High performance manufacturing,
  - Exploiting new materials

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- Introduction and Problem Definition
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Decision-making process (H Simon, 1960)

- **Intelligence**
  - Setting Objectives
  - Situation identification
  - Problem Classification
- **Design**
  - Choosing an approach
  - Model Building
  - Alternatives identification/design
- **Choice**
  - Model experimentation
    - Model solving
    - Result interpretation
  - Choice
  - Sensitivity analysis

H Simon (1916-2001)

Basic Methods

- ntered methods : Nominal group, Brainstorming, Devil Advocate , Philips 66, Delphi, scenario building,
- Grapho-analitic methods: *influence diagrams, decision trees*
- Data and document analysis: Data warehouses, OLAP ,Business intelligence
- –optimisation : LP, NL P
-
- Multicriteria analysis: MADM), AHP, ELECTRE,
- Game theory
- : expert systems, fuzzy, genetic algorithms, neural networks, genetic algorithms, intelligent agents

Limits and constraints of the decision-makers

- .
  - problem data,
  - reasoning ,
  - methods and techniques.
- of
  - assistants,
  - IT products.
- (urgency , simultaneity)
-
-
-

ls

Human support syst-HSS (Holsapple, Whinston,1995)

***nd accepting user's requests** on:*

- ***Needed information*** (descriptive knowledge, results of an analysis, clarification of a previous response help to formulate a question, evaluation of a possible action…)
- ***Orders to HSS*** to receive& accumulate new information

- ***Answers /feed-backs to user's requests*** (sending the needed info, feed-back to clarify the user's request...)
- ***Unsolicited(proactive) messages*** when decision situations or undesirable behavior of the user are perceived, new info are identified….

C Holapple

A. Whinston

Definition

A Decision Support System (DSS) is an anthropocentric, adaptive, and evolving information system meant to implement some of the functions of a possible Human Support System that would be otherwise needed to help the decision-maker to overcome his/her limits and constraints he/she might encounter when approaching decision problems that count.

In the manufacturing and logistic milieu the DSS is frequently utilized to facilitate problem solving under time pressure when "crisis" situation show up.

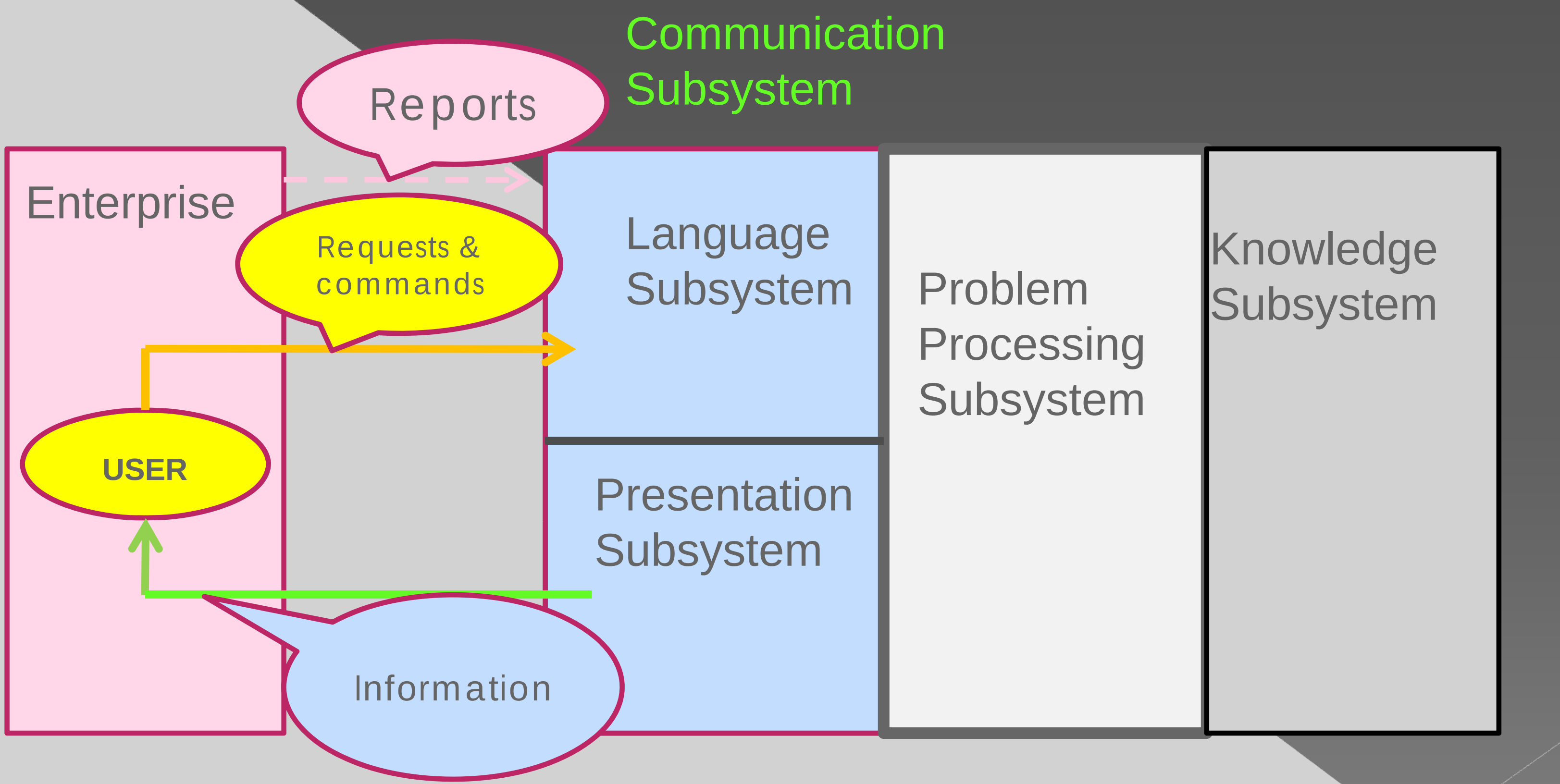
DSS Characteristic Features

- ***Mission:*** to relax the limits&constraints of the human decision-maker in making and adopting a decision
- ***Structure***:
  - *Superclass :* Overall Information system of the organisation
  - *Subclass:* Specific&general-purpose IT&C tools
- ***Attributes:***
  - *"Clientele":* Decision-makers, assistants, other "Knowledge workers"
  - *Qualities:* Anthropocentric, adaptive , evolving
  - *Stored Knowledge:*Descriptive, procedural, reasoning, communication acquired from internal/extern.sources/internally produced
- ***Functions***
  - Computerized versions of the functions of the HSS

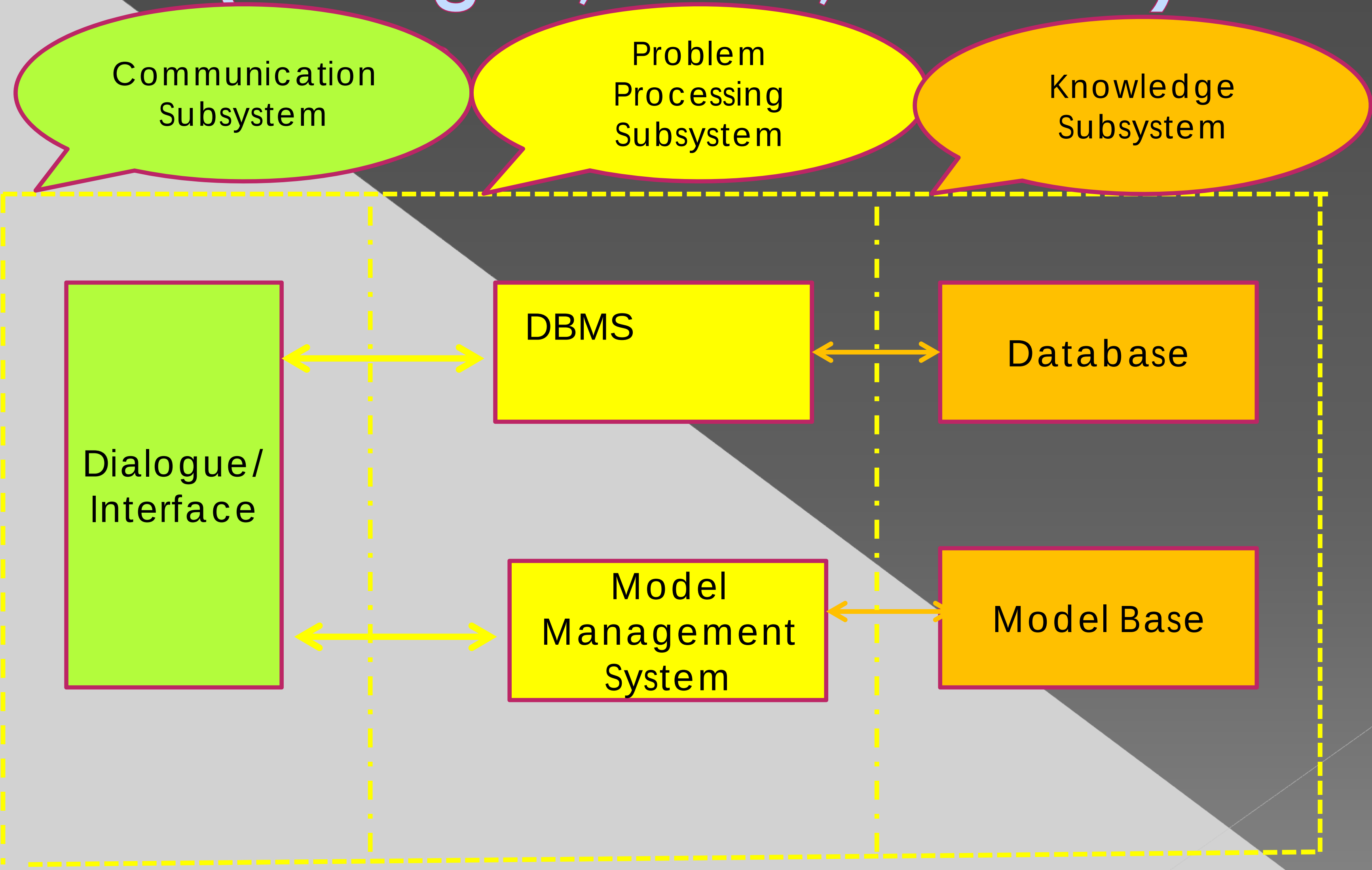
Levels of automation(Sheridan,1992)

Level	Significance
1	**A (System only assists the human, that executes all activities**
2	**B (System offers a complete set of alternatives**
3	**B + C (System narrows the search space)**
4	**D (System recommends an alternative)**
5	**D+E**(System executes the alternative if confirmed by human)
6	**D+F**(System allows a short "veto" time and then executes)
7	**D+G**(System executes the alternative)+**H** (mandatory informs the human)
	………………………………………..
10	**K** (System decides everything, automatically executes, does not inform

DSS Architecture (the BHW Model)



DDM (Dialogue, Data , Models)



Standards for Interface Design

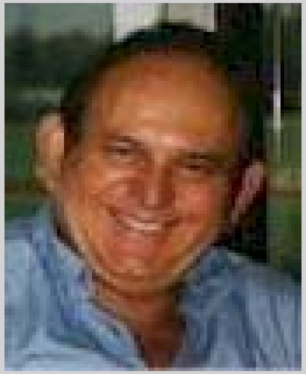
- ***ISO 13407/99*** ("Human Centered Design Processes of Interactive Systems") +***ISO TR 1859/2000*** (" Ergonomics of Human-System Interaction : Human Centered Lifetime process Description")
- ***ISO 9241***
  - ***10, 11&12/98***: Dialog Principles and Guidance on Usability
  - ***13/98:*** User Guidance (prompts, feed-backs, helps, error control)
  - ***14/97:*** Menu Dialogues
  - ***15/98:*** Command Language Dialogues
  - ***16/99:*** Direct Data Manipulation
  - ***17/98:*** Form -Filling Dialogues

Several authors in DSS domain

R. H.Sprague

E. Carson

S. P. Watson



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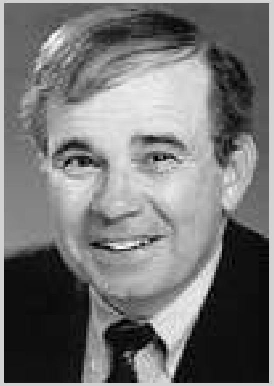

G Nunamaker

P. Gray

Advanced DSS: Early Results

- Tandem Systems (Nof 1981, Kusiak, 1990)
- X DSS/WXDSS (Biswass,Oliff, Sen, 1985)
- Rule-based Models (Bosman, Sol, 1988)
- Hybrid DSS (Singh , 1988)
- Mixed Knowledge DSS (Filip, 1988)

Modern solutions

- **Combined Technologies**
  - AI-based technologies
    - Expert (Systems ES)
    - Genetic Algorithms(GA)
    - Artificial Neural Networks(ANN)
    - Intelligent Agents (IA)
    - Case Based Reasoning(CBR)
  - GIS-based technologies (Spatial DSS)
  - Internet –based DSS
  - Business Intelligence
- **Specific Systems**
  - Multiparticipant /Group [decision] support systems
  - Systems for Top Management (“ executive”): EIS/ESS

Division of Labour

Phase / Activity	User	NM	ES	ANN	CBR	IA
Intelligence						
Setting the objectives	E/I		I/M	I/M	I/M	
Detecting the dec. situation	I/M		I/M	I		
Problem classification	I/M		I/M	I	I/M	P
Design						
Choosing the approach	E/M		I/M		I/M	
Model building	M/I		M/P		M	I/M
Design/identification of alternatives	I/M	P	I/M	I	I	P/M

Legend: P=possible; M=moderate; I =intensive; E =essential

NM=numerical meths; **ES** =expert syst.; **ANN**=Art. neural nets; **;IA** =intelligent agents

Division of Labour (II)

Stage / **Activity**	User	Numerical Methods	Expert System	ANN	CBR	Intell. Agents
Choice						
Model experiment						
Model Solving		E		**I**	**P**	
Parameter modify	I		I			I/**M**
Choice	**E**		P		**M**	**M**
Sensitivity Analysis		I				
						P
Implementation& Evaluation	P					P

Multi-participant DSS

Activity	Tools	Results
Idea Generation	e-Brainstorming; Subject commenting; Group outlining	Primary set of ideas (criteria& alternatives)
Idea Organization	Idea classification, Issue analysis	Reduced set of "key" ideas
Prioritization	Voting, Alternative evaluation, On-line questionnaire	Ordered list of ideas
Setting plans &policies	Policy formulation, Stakeholder analysis	Decision plans and policies
Session Management	"Agenda"	Session agenda
Resource Management	Participants, Whiteboard, Opinion meter, handouts, Event monitor, Individual log, Briefcase	

Ambient Intelligence

-
  - “ubiquitus computing”(Xerox)
  - “ pervasive computing” (IBM)
- res(Arts, 2003):
  - “Embedded” and “ context aware” (“moving electronics in the background”=distributing hardware in the environment in an ubiquitus , non-obtrusive and decentralised way)
  - “Personalised”, adaptive” , and “anticipatory”

Conclusions and Challenges

- Sustainability is essential and complex, but achievable
- Some progress has been achieved in modeling, decision processes, O.R. analyses, measurement, control models and control theory
- Need collaborative mechanisms and information sharing for better sustainability planning and better sustainability control
- Political and cultural constraints may frustrate us
- Education for sustainability is needed
- Complex decision theory and control theory will be useful to solve problems and demonstrate sustainability solutions.
- There are governmental initiatives addressing sustainable manufacturing issues
- ITC tools may enable solving problems

Conclusions and Challenges (cont)

- New I&CTs (Ambient intelligence, Internet of things) have had a strong impact on DSS solutions; traditional concepts are supported now by a sound technological infrastructure
- Other forcast developments
  - Collaborative control schemes will get more ground
  - Wireless mobile communications will influence solutions
  - Mixed models(numeric, symbolic,sub-symbolic, soft computing ...) will be largely ultilised
  - User interfaces will enable man-machine co-operation

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Thank-you for your attention

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