Multicriteria Decision Making in Supply Chain Management

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Agenda

Symposium Themes

- ❑ Multiple Criteria Decision Making (MCDM)
- ❑ Supply Chain Engineering (SCE)
- ❑ Health Systems
- ❑ Analytics
- ❑ Teaching Decision Sciences

Symposium Organizers

My former PhD students

Multicriteria Decision Making (MCDM) An Overview

- MCDM Basics
- MCDM Difficulties
- Basic MCDM Concepts
- MCDM Classification
- Multi Criteria Selection Problems
- Multi Criteria Mathematical Programming Methods

MCDM Basics

- Most optimization models are based on single objective, such as, minimize cost or maximize profit
- In the real world, decisions are based on multiple and conflicting objectives.
- How to compare "apples" and "oranges"?
- In MCDM, decision alternatives are measured by several conflicting criteria. The problem is to choose the best alternative.

MCDM Difficulties

- No optimal solution
- Not possible to compare two solutions objectively
- Need to involve the Decision Maker (DM) – one of the rare areas of Operations Research, where the DM plays a key role during the solution process!

Basic MCDM Concepts

- Ideal Solution: Best values achievable for each objective ignoring other objectives!
- Dominated Solution: Possible to improve an objective without losing achievements on the other objectives
- Efficient/Non-dominated Solution: Can improve an objective only at the expense of at least one other objective

MCDM Classification

1. **Multi Criteria Selection Problems (MCSP)**

- ❑ Finite number of alternatives
- ❑ Alternatives measured by conflicting criteria
- ❑ Rank the alternatives from best to worst

Applications

- ❑ Buying a car, house, computer, etc.
- ❑ Ranking colleges (e.g: U.S. News)
- ❑ Supplier Selection under single sourcing

MCDM Classification (continued)

2. **Multi Criteria Mathematical Programming (MCMP) Problems**

- ❑ Alternatives are defined by explicit constraints, resulting in infinite number of alternatives
- ❑ Several conflicting objective functions
- ❑ Determine the Best Compromise Solution

MCMP Applications

- ❑ Portfolio Optimization
- ❑ Quality Control
- ❑ Health Planning
- ❑ Project Management
- ❑ Supply Chain Network Design

Multi Criteria Selection Problems

Ranking Methods

- Rating method (Simplest)
- Pairwise Comparison/Borda Method ↓
- Analytic Hierarchy Process (AHP) (Complex)

Issues

- DM's cognitive burden
- DM's consistency
- Single or multiple DMs

Multi Criteria Mathematical Programming Methods

- Approaches that do not use any knowledge of DM's preferences
  - Compromise programming
- Approaches that use pre-specified preferences of the DM
  - Goal programming
- Interactive approaches that use progressively revealed preferences

Supply Chain Engineering (SCE)*

Supply Chain Engineering emphasizes the design of the supply chain network and uses mathematical models and methods to determine the optimal strategies for managing the supply chain.

***Ravindran and Warsing, *Supply Chain Engineering: Models and Applications,* CRC Press, 2013.**

U. S. Logistics Business (2014)

- **$1.3 trillion, accounts for 8.5% of US GDP**
- **Employs 6 million people**
- **Delivers daily 48 million tons of freight, worth $48 billion**
- **Industry needs 1.4 million new supply chain workers by 2018**
  - **270,000 per year**
  - **8 jobs for each applicant!**

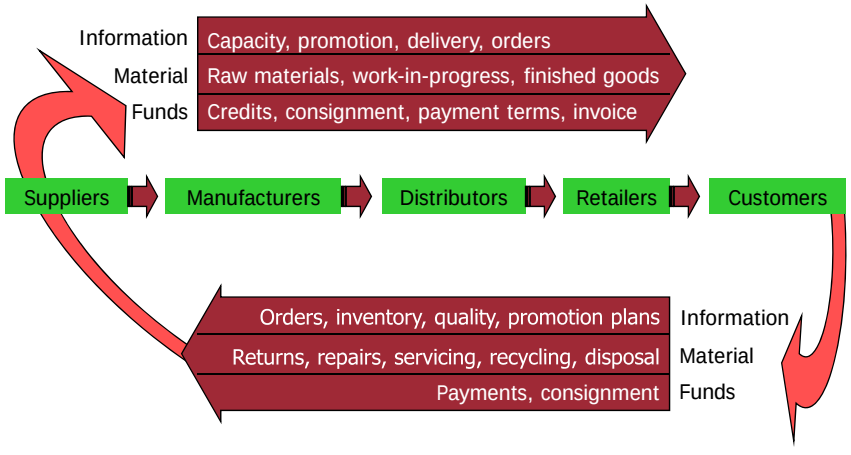
What is a Supply Chain

A Supply Chain Consists of:

(1) A collection of locations that includes suppliers, manufacturers, distributors, retailers, and customers.

(2) A connected set of activities concerned with planning, coordinating and controlling materials, parts, and finished goods from supplier to customer.

Supply Chain Flows



Source: Adapted from Hau Lee, *SCMR*, Sep-Oct, 2000.

Key Activities in Supply Chain Engineering

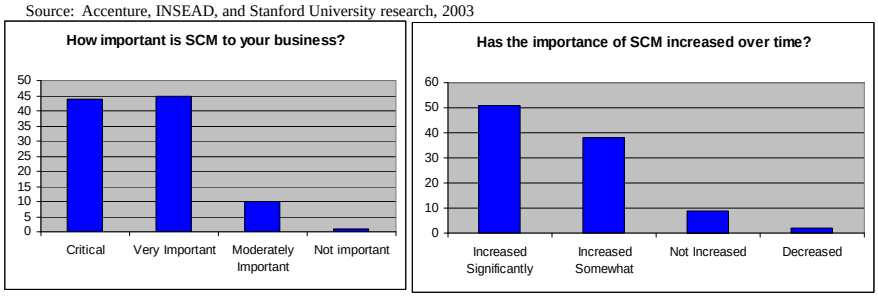
- Design of the supply chain network, namely the location of plants, DCs, etc.
- Procurement of raw materials and parts from suppliers to the plants
- Management of the production and inventory of finished goods to the customers

SCE Activities (continued)

- Management of the transportation and the logistics network to deliver the final products to the warehouses and retailers
- Management of the integrity of the supply chain network by mitigating supply chain disruptions at all levels.

Importance of supply chain management

Source: Accenture, INSEAD, and Stanford University research, 2003



Supply chain becomes a competitive differentiator *

- Accounting for as much as seventy percent of operating costs
- Typically comprising at least half of all assets
- Driving a significant percentage of promised synergies for many mergers and acquisitions

* Presentation: "Supply Chain Mastery in the Global Marketplace", Narendra Mulani, POMS Conference, Chicago, April 30, 2005

Supply Chain Decisions

1. Strategic Decisions
   - Supply chain design
   - Long term impact
   - Several years
   - High demand uncertainty
2. Tactical Decisions
   - Supply chain planning
   - Medium term impact
   - Quarterly/monthly
   - Medium demand uncertainty

Supply Chain Decisions

3. Operational Decisions

- Supply chain operations
- Short term impact
- Weekly or daily
- Low demand uncertainty

Strategic Decision Examples

- ❑Network design
  - - Location of Factories, DCs
  - - Capacity decisions
- ❑Make/Buy
  - - Internal
  - - Outsource
  - - Alliances/Partners
- ❑IT System

Tactical Decisions Examples

- Purchasing/Production decisions
- Inventory policies
- Transportation strategies
- Distribution policies

Examples of Operational Decisions

- Allocation of orders to inventory or production
- Set delivery schedules
- Place replenishment orders

Conflicting Criteria in SCE

1. SC Efficiency
   - Make and deliver at low cost
2. SC Responsiveness
   - Deliver a variety of products quickly
   - Handle customization
   - High level of customer service
3. SC Risk
   - Hazard risks
   - Operational risks

Top 25 Supply Chains (Gartner Rankings)

- ❑Top 5 are Apple, McDonald's, Amazon, Unilever and Intel
- ❑Attributes of supply chain leaders
  - Carry 15% less inventory
  - 60% faster-to-market
  - Complete 17% "more perfect" orders
  - Have 35% shorter cash-to-cash-cycle
  - 5% higher profit margins

Contributions of my PhD students (1971 – 2015)

- 29 PhD dissertations completed
- 4 in progress
- Purdue (9), Oklahoma (7) and Penn State (13)
- Single objective optimization (5)
- Multiobjective optimization (24)
- MCDM in SCE (13)
  - All at Penn State (2001-2015)
  - Covered SC inventory control, network design, SC risk, supplier selection, SC sustainability

Jeff Arthur (Purdue, 1977)

Title: Contributions to the theory and applications of Goal Programming

- Multiple objective optimization
- Efficient algorithms for solving linear and integer goal programming problems
- Use of "Partitioning" and "Variable Elimination" methods
- Applied to Nurse Scheduling at the Indianapolis Medical center

P. Balasubramanian (Purdue, 1977)

Title: Optimal resource utilization in communicable disease control

- Developed a dynamic growth and control model for syphilis
- Used "Black Box" optimization to evaluate cost-benefits of control programs to minimize disease incidence
- Applied to real world data for Chicago metro area
- Research is applicable now to control Ebola!

S. Sadagopan (Purdue, 1979)

Title: Multi-criteria mathematical programming – a unified interactive approach

- Developed an interactive algorithm, called Pairwise Comparison Method (PCM), to solve bi-criteria nonlinear mathematical programming problems
- Applied to the U.S. Air Force Health Evaluation and Risk Tabulation (HEART) program to control heart disease among AF personnel.
- Use of simulation optimization method due to stochastic criterion

Wan-Seon Shin (Oklahoma, 1987)

Title: Interactive methods for multi-objective mathematical programming problems

- Developed interactive methods to solve MCMP problems
- Extended Sadagopan's method to more than two criteria
- Applied to quality control problems

Rodolfo Portillo (Penn State, 2008)

Title: Resilient global supply chain network design optimization

- Developed multicriteria integer programming models for global supply chain network design
- Applied to Kimberly Clark – Latin American Operations
  - KC – LAO sells products in 22 countries, with 21 manufacturing plants, 45 DCs, 100 customer zones and 22 branches.
- Case study discussed in my Supply Chain Engineering text book

Ufuk Bilsel (Penn State, 2009)

Title: Disruption and operational risk quantification models for outsourcing operations

- Mathematical models to quantify hazard risks and operational risks
- Use of extreme value distributions for hazard risk and Taguchi's loss functions for operational risks
- Multicriteria mixed integer programming models to select primary and back-up suppliers considering disruption risk

Most Recent Dissertations at Penn State

1. Nok Kungwalsong (2013)
   "Managing disruption risks in global supply chains"

2. Subramanian Pazhani (2014)
   "Design of closed loop supply chain networks"

3. Aineth Torres (2015)
   "Multi-objective decision support system for sustainable supplier management"