

Supply Chain Analytics

Lecture 3: Operation research primer - Optimization and simulation

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Introduction

- Operations Research is an Art and Science
- It had its early roots in World War II and is flourishing in business and industry with the aid of computer
- Primary applications areas of Operations Research include forecasting, production scheduling, inventory control, capital budgeting, and transportation.

What is Operations Research?

Operations

The activities carried out in an organization.

Research

The process of observation and testing characterized by the scientific method.

Situation, problem statement, model construction, validation, experimentation, candidate solutions.

Operations Research is a quantitative approach to decision making based on the scientific method of problem solving.

What is Operations Research?

- Operations Research is the scientific approach to execute decision making, which consists of:
 - The art of *mathematical modeling* of complex situations
 - The science of the development of *solution techniques* used to solve these models
 - The ability to effectively *communicate* the results to the decision maker

What Do We do

1. OR professionals aim to provide rational bases for **decision making** by seeking to **understand** and structure complex situations and to use this understanding to **predict** system behavior and **improve** system performance.
2. Much of this work is done using **analytical** and **numerical** techniques to develop and manipulate **mathematical and computer** models of organizational systems composed of people, machines, and procedures.

Terminology

- The British/Europeans refer to “**Operational Research**”, the Americans to “**Operations Research**” - but both are often shortened to just "OR".
- Another term used for this field is “**Management Science**” ("MS"). In U.S. OR and MS are combined together to form "OR/MS" or "ORMS".
- Yet other terms sometimes used are “**Industrial Engineering**” ("IE") and “**Decision Science**” ("DS").

Operations Research Models

Deterministic Models

- Linear Programming
- Network Optimization
- Integer Programming
- Nonlinear Programming
- Inventory Models

Stochastic Models

- Discrete-Time Markov Chains
- Continuous-Time Markov Chains
- Queuing Theory (waiting lines)
- Decision Analysis
- Game Theory
- Inventory models
- Simulation

Deterministic vs. Stochastic Models

Deterministic models

assume all data are known with **certainty**

Stochastic models

explicitly represent uncertain data via random variables or stochastic processes.

Deterministic models involve **optimization**

Stochastic models

characterize / estimate system performance

History of OR

- OR is a relatively new discipline.
- 70 years ago it would have been possible to study mathematics, physics or engineering at university it would not have been possible to study OR.
- It was really only in the late 1930's that operations research began in a systematic way.

1890

Frederick Taylor
Scientific
Management
[Industrial
Engineering]

1900

- Henry Gantt
[Project Scheduling]
- Andrey A. Markov
[Markov Processes]
- Assignment
[Networks]

1910

- F. W. Harris
[Inventory Theory]
- E. K. Erlang
[Queuing Theory]

1920

- William Shewart
[Control Charts]
- H.Dodge – H.Roming
[Quality Theory]

1960

- John D.C. Little
[Queuing Theory]
- Simscrip - GPSS
[Simulation]

1950

- H.Kuhn - A.Tucker
[Non-Linear Prog.]
- Ralph Gomory
[Integer Prog.]
- PERT/CPM
- Richard Bellman
[Dynamic Prog.]
ORSA and TIMS

1940

- World War 2
- George Dantzig
[Linear
Programming]
- First Computer

1930

Jon Von Neuman –
Oscar Morgenstern
[Game Theory]

1970

- Microcomputer

1980

- H. Karmarkar
[Linear Prog.]
- Personal computer
- OR/MS Softwares

1990

- Spreadsheet
Packages
- INFORMS

2006

- You are here

Problem Solving and Decision Making

- 7 Steps of Problem Solving

(First 5 steps are the process of decision making)

- Identify and define the problem.
- Determine the set of alternative solutions.
- Determine the criteria for evaluating the alternatives.
- Evaluate the alternatives.
- Choose an alternative.

- Implement the chosen alternative.
- Evaluate the results.

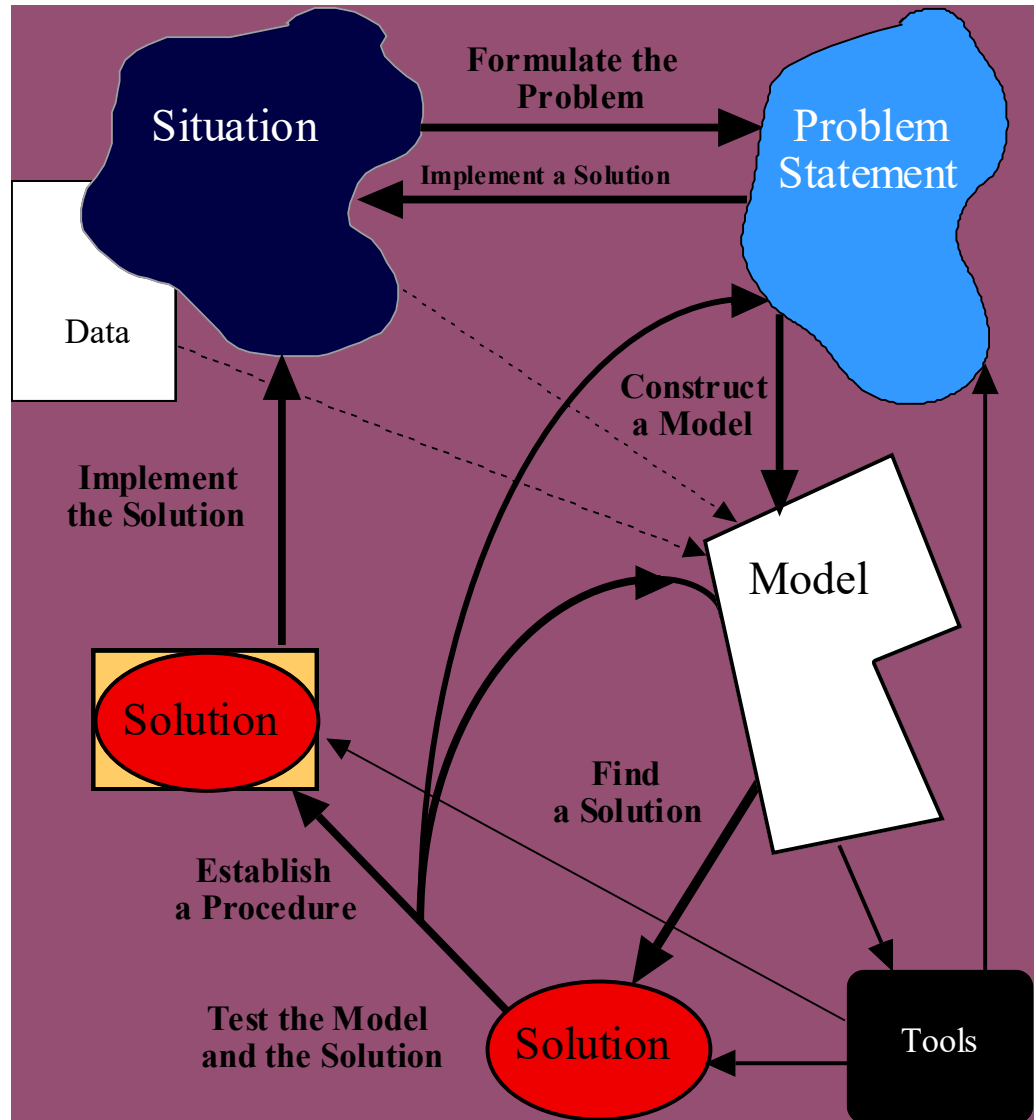
Quantitative Analysis and Decision Making

- Potential Reasons for a Quantitative Analysis Approach to Decision Making
 - The problem is complex.
 - The problem is very important.
 - The problem is new.
 - The problem is repetitive.

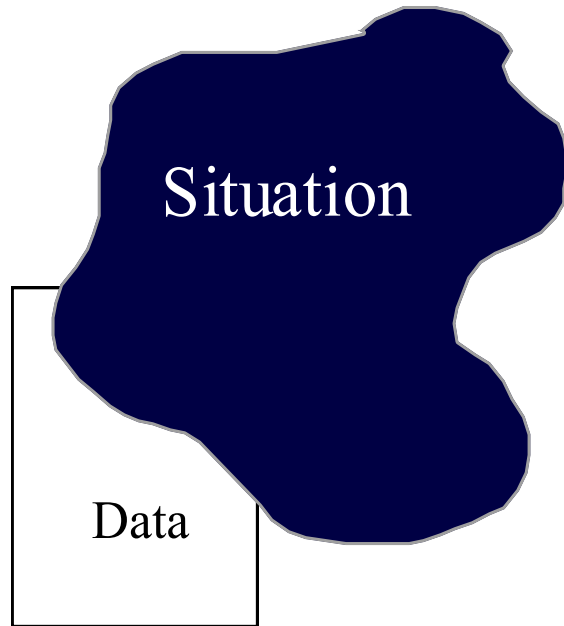
Problem Solving Process

Goal: solve a problem

- Model must be valid
- Model must be tractable
- Solution must be useful



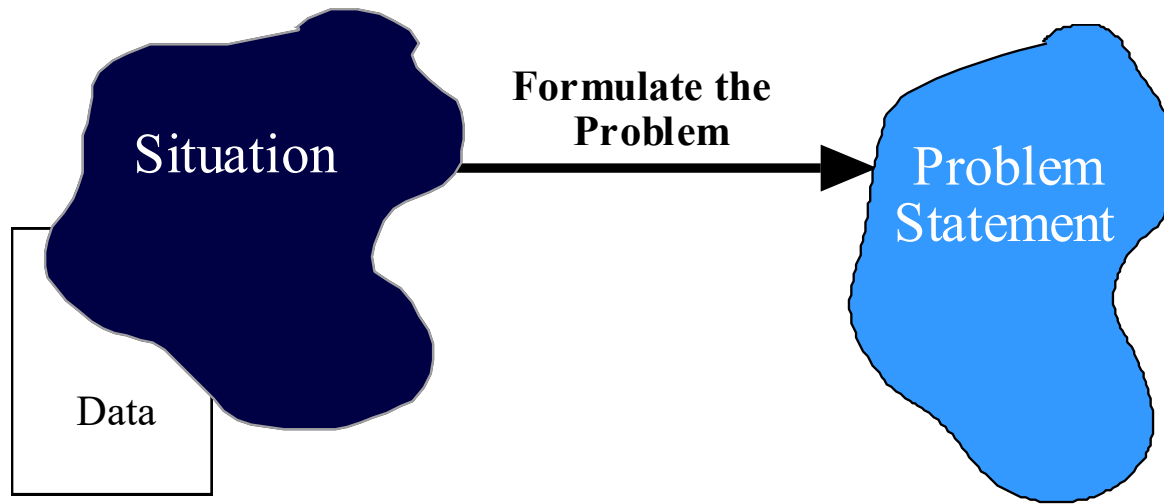
The Situation



- May involve current operations or proposed expansions due to expected market shifts
- May become apparent through consumer complaints or through employee suggestions
- May be a conscious effort to improve efficiency or response to an unexpected crisis.

Example: Internal nursing staff not happy with their schedules; hospital using too many external nurses.

Problem Formulation



- Describe system
- Define boundaries
- State assumptions
- Select performance measures
- Define variables
- Define constraints
- Data requirements

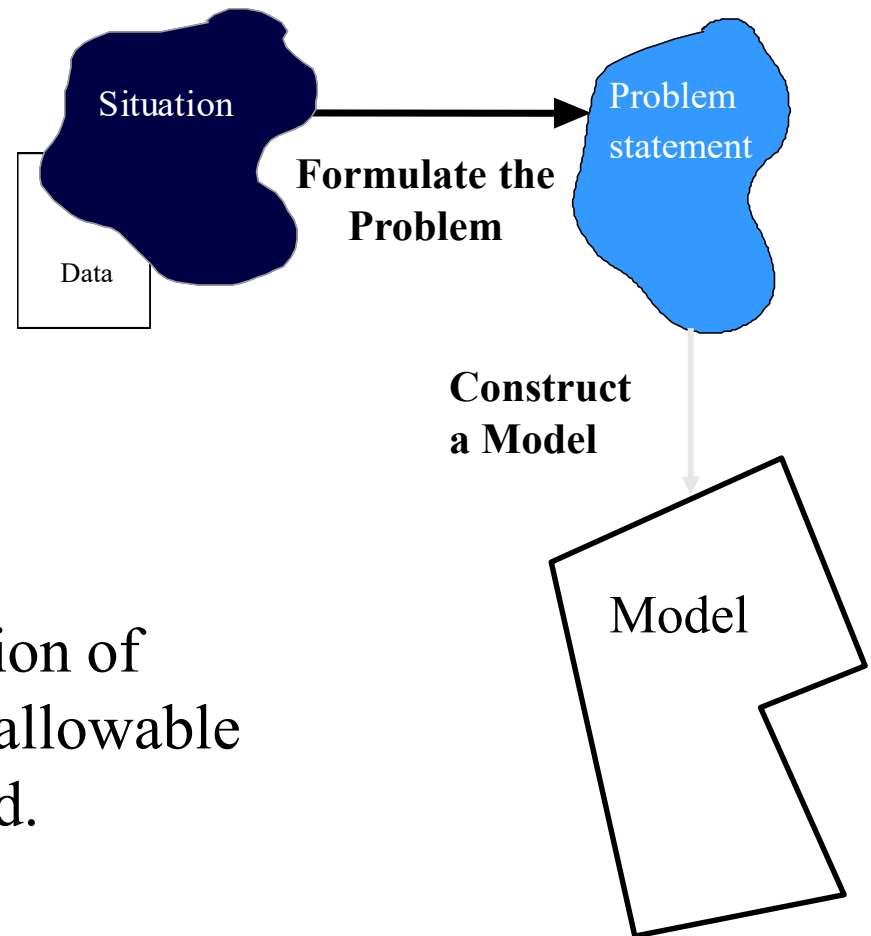
Example: Maximize individual nurse preferences subject to demand requirements.

Data Preparation

- Data preparation is not a trivial step, due to the time required and the possibility of data collection errors.
- A model with 50 decision variables and 25 constraints could have over 1300 data elements!
- Often, a fairly large data base is needed.
- Information systems specialists might be needed.

Constructing a Model

- Problem must be translated from verbal, qualitative terms to logical, quantitative terms
- A logical model is a series of rules, usually embodied in a computer program
- A mathematical model is a collection of functional relationships by which allowable actions are delimited and evaluated.



Example: Define relationships between individual nurse assignments and preference violations; define tradeoffs between the use of internal and external nursing resources.

Model Development

- [Models](#) are representations of real objects or situations.
- Three [forms of models](#) are iconic, analog, and mathematical.
 - [Iconic models](#) are physical replicas (scalar representations) of real objects.
 - [Analog models](#) are physical in form, but do not physically resemble the object being modeled.
 - [Mathematical models](#) represent real world problems through a system of mathematical formulas and expressions based on key assumptions, estimates, or statistical analyses.

Advantages of Models

- Generally, experimenting with models (compared to experimenting with the real situation):
 - requires [less time](#)
 - is [less expensive](#)
 - involves [less risk](#)

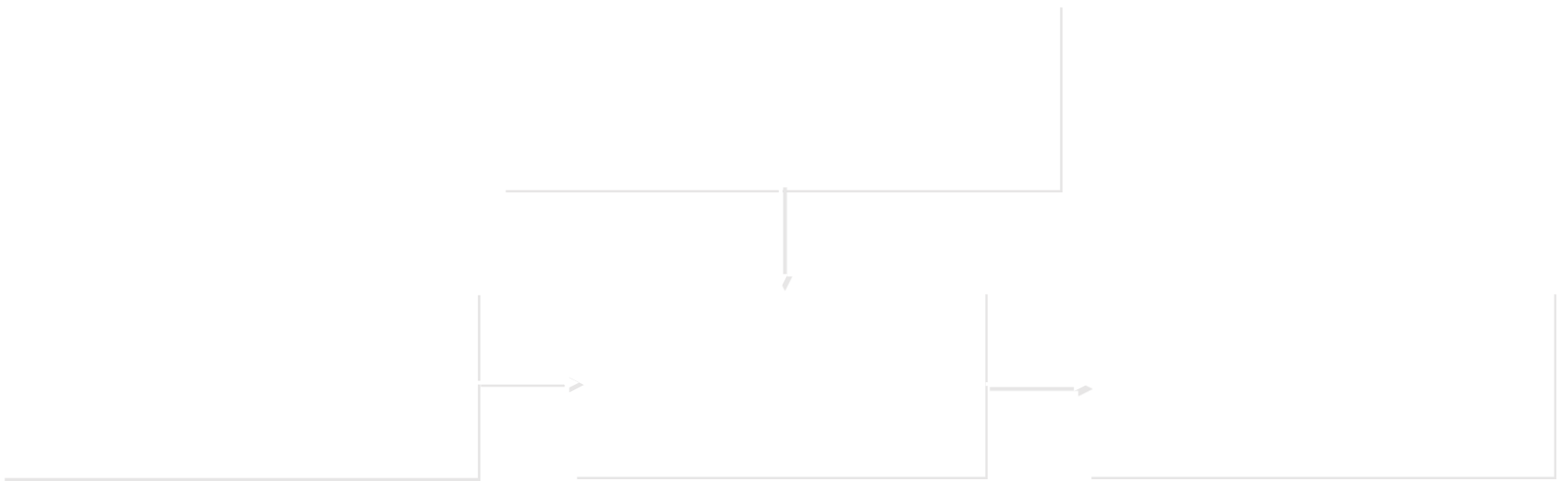
Mathematical Models

- Cost/benefit considerations must be made in selecting an appropriate mathematical model.
- Frequently a less complicated (and perhaps less precise) model is more appropriate than a more complex and accurate one due to cost and ease of solution considerations.

Mathematical Models

- Relate decision variables (controllable inputs) with **fixed or variable parameters** (uncontrollable inputs).
- Frequently seek to maximize or minimize some objective function subject to constraints.
- Are said to be stochastic if any of the **uncontrollable inputs** (parameters) is subject to variation (random), otherwise are said to be deterministic.
- Generally, stochastic models are more difficult to analyze.
- The values of the decision variables that provide the mathematically-best output are referred to as the optimal solution for the model.

Transforming Model Inputs into Output



Example: Project Scheduling

Consider a construction company building a 250-unit apartment complex. The project consists of hundreds of activities involving excavating, framing, wiring, plastering, painting, landscaping, and more. Some of the activities must be done sequentially and others can be done simultaneously. Also, some of the activities can be completed faster than normal by purchasing additional resources (workers, equipment, etc.).

What is the best schedule for the activities and for which activities should additional resources be purchased?

Example: Project Scheduling

- Question:

Suggest assumptions that could be made to simplify the model.

- Answer:

Make the model deterministic by assuming normal and expedited activity times are known with certainty and are constant. The same assumption might be made about the other stochastic, uncontrollable inputs.

Example: Project Scheduling

- Question:

How could management science be used to solve this problem?

- Answer:

Management science can provide a structured, quantitative approach for determining the minimum project completion time based on the activities' normal times and then based on the activities' expedited (reduced) times.

Example: Project Scheduling

- Question:

What would be the uncontrollable inputs?

- Answer:

- Normal and expedited activity completion times
- Activity expediting costs
- Funds available for expediting
- Precedence relationships of the activities

Example: Project Scheduling

- Question:

What would be the decision variables of the mathematical model? The objective function? The constraints?

- Answer:

- Decision variables: which activities to expedite and by how much, and when to start each activity
- Objective function: minimize project completion time
- Constraints: do not violate any activity precedence relationships and do not expedite in excess of the funds available.

Example: Project Scheduling

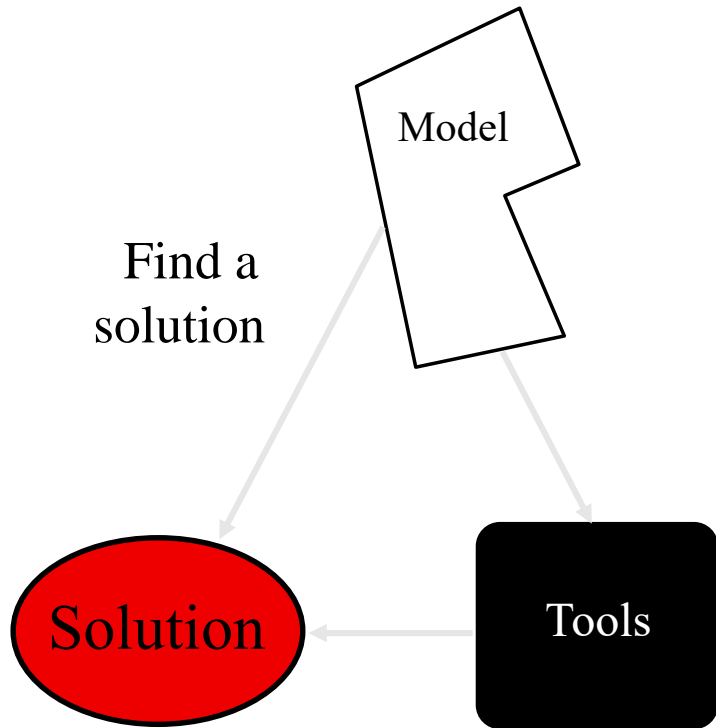
- Question:

Is the model deterministic or stochastic?

- Answer:

Stochastic. Activity completion times, both normal and expedited, are uncertain and subject to variation. Activity expediting costs are uncertain. The number of activities and their precedence relationships might change before the project is completed due to a project design change.

Solving the Mathematical Model



- Many tools are available as discussed before
- Some lead to “optimal” solutions (deterministic Models)
- Others only evaluate candidates → trial and error to find “best” course of action

Example: Read nurse profiles and demand requirements, apply algorithm, post-processes results to get monthly schedules.

Model Solution

- Involves identifying the values of the decision variables that provide the “best” output for the model.
- One approach is trial-and-error.
 - might not provide the best solution
 - inefficient (numerous calculations required)
- Special solution procedures have been developed for specific mathematical models.
 - some small models/problems can be solved by hand calculations
 - most practical applications require using a computer

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