

DNSC 6306 - Decision Models

Course Introduction

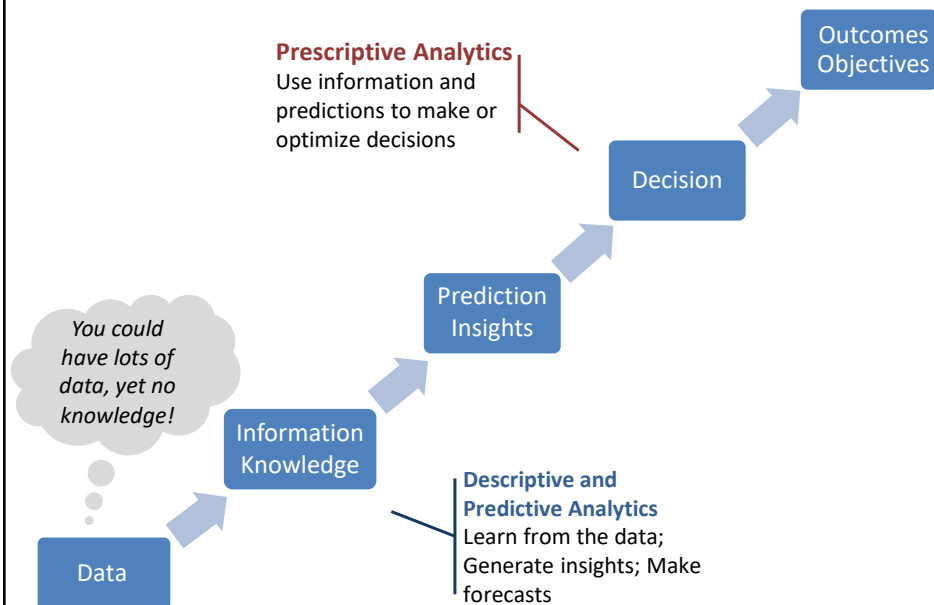
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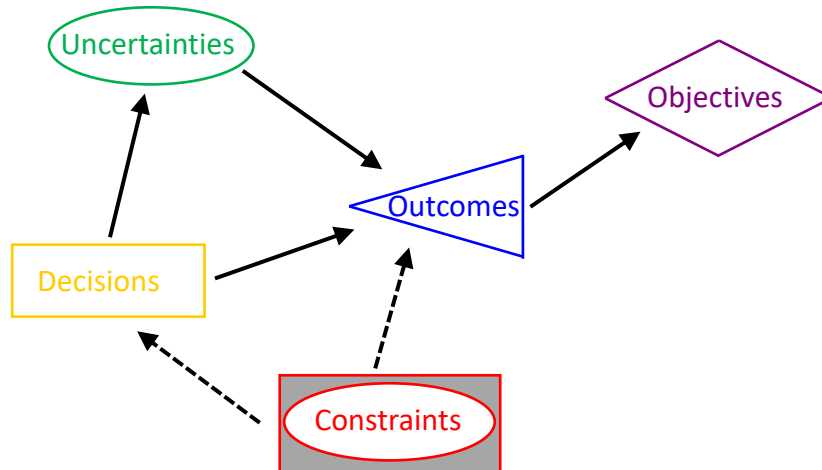
1

Data-based Decision-making and the Business Analytics Value Chain



2

The Building Blocks of Decision Models



3

Practical Things

- ☐ **All material** distributed electronically on Blackboard (Slides, Readings, Cases, Exercises, Solutions, Software, Tutorials)
- ☐ Organized in folders for each session under Course Material
- ☐ Practice exercises are critical for learning
- ☐ **Software tools**
 - MS Excel** with “Add-ins” for Decision and Risk Analysis
 - **Solver** (Optimization)
 - **TreePlan** or **PrecisionTree** (Decision Tree)

4

Constrained Optimization for Decision-Making

5

Optimization: a central tool of Business Analytics

Widely used for Prescriptive Analytics (decision making)

- **Operations:** Supply chain, Procurement, Production planning, Scheduling, Human Resources planning, Facility location, Transportation, Network flow, Vehicle routing, **Fleet management**, etc.
- **Resource Allocation**, cash flow management, capital budgeting, funding liabilities...
- Selecting **Efficient Portfolios** of projects and assets, Risk-return analysis
- Diversification to **Mitigate Risk**

Also works behind the scene in Predictive Analytics (learning from data)

- Classification problems
- Multivariate regression
- Machine learning

6

6

Optimization Models for Decision Making

Find how to best use
the resources available
(e.g., money, labor, time,...)

to

Achieve a best level of
something you care about
(e.g., profit, cost, risk, return,...)

Decisions

Objectives

- ☐ Extract maximum value from Resources and Activities
- ☐ Build efficient Portfolios of projects
- ☐ Explore vast, complex combinations of possibilities
- ☐ Develop insights into the key trade-offs inherent in your business activities (e.g., cost vs. performance, risk vs. reward)

7

7

Guiding principle for building an Optimization Model

Describe the problem in terms of **three elements**:

1. What must be decided? → *The Decision Variables*
2. What is to be achieved/optimized? → *The Objective*
3. What limits must be observed? → *The Constraints*

A surprisingly **wide array of business problems** can be thought of in those terms

Let's review the three model elements in turn...

8

8

Building an Optimization Model (1)

1. Decision Variables

- Represent parameters under management's control, whose values are to be decided
- Should be defined in a way to describe all possible decisions
- We may need to be creative in defining decision variables to be able to formulate the optimization model

Examples of Decision Variables:

- *how much to invest in a security*
- *whether to fund a project or not*
- *how much cash to hold*
- *how many bonds of each type to buy*
- *production levels in each period*
- *how much to ship along a route*
- *number of people to hire*
- *amounts to source from various suppliers*
- *how much to bid for a contract*

Together, the values of the decision variables will define a policy or plan of action.

9

9

Building an Optimization Model (2)

2. Objective Function

- Defines the goal of the problem, the target to be optimized
- Provides a criterion to compare alternative solutions
- Is an outcome (not a decision), driven by decision variables and constraints

Examples of Objective Function:

Profit	→	<i>Maximize</i>
Cost	→	<i>Minimize</i>
Risk	→	<i>Minimize</i>
ROI	→	<i>Maximize</i>

10

10

Building an Optimization Model (3)

3. Constraints

- Describe what is feasible, required, or desired...
 - **Operational / Technical**
Fulfill payment liabilities
Quantity produced cannot exceed Production Capacity
Expenditures cannot exceed total Budget
 - **Legal / Regulatory**
Minimum cash holding requirements
Pollutant emissions cannot exceed regulatory limit
 - **Logical**
All parts of the budget must add up to 100%
- Must be expressed as a function of the decision variables

11

11

In summary...

An optimization model is defined by:

- **some Decision Variables** X_1, X_2, \dots, X_n
whose values we want to decide
- **one Objective Function** $f(X_1, X_2, \dots, X_n)$
which describes the quantity to be optimized,
i.e. the objective of the problem
- **some Constraints** $g_i(X_1, X_2, \dots, X_n) \leq b_i \quad i = 1, \dots, m$
which reflect the economic, legal, and technical
realities under which we must operate

When the Objective Function f and the Constraints g_i 's are all **linear**, the optimization model is said to be a "Linear Programming" (LP) problem. In that case, use the "Simplex LP" solving method (provides great advantages)

Issue: what if there are multiple objectives? (to be discussed later...)

12

12

Optimization Modeling: a worked-out example

Mathematical Model Formulation for “Product Mix” Exercise:

□ The Decision Variables

X_1 = number of Smartphones to produce

X_2 = number of TabletPros to produce

X_3 = number of Tablets to produce

□ The Objective Function

Maximize: Profit = $\$150 \cdot X_1 + \$100 \cdot X_2 + \$80 \cdot X_3$

□ The Constraints

$50,000 \leq X_1 \leq 150,000$

$50,000 \leq X_2 \leq 100,000$

$50,000 \leq X_3 \leq 90,000$

$3 \cdot X_1 + 2 \cdot X_2 + 1 \cdot X_3 \leq 400,000$ hours

Note: the Objective Function and all the Constraints involve linear operations of the Decision Variables
→ the **Simplex LP** solving method should be selected for solving.

13

13

A spreadsheet implementation of the model:

The screenshot shows a spreadsheet titled "Solutions to Optimization Exercises.xlsx" with the following data:

Product	Sales Price	Cost	Profit	How many to produce?	Min Prod	Max Prod	Labor (hrs)
Smartphone	\$ 300	\$ 150	\$ 150	70000	50000	150000	3
TabletPro	\$ 200	\$ 100	\$ 100	50000	50000	100000	2
Tablet	\$ 150	\$ 70	\$ 80	90000	50000	90000	1

The Solver settings are as follows:

- Maximize: D11 (Total_Profit)
- By Changing Variable Cells: E6:E8 (Production_levels)
- Subject to the Constraints:
 - E6:E8 >= F6:F8
 - E6:E8 <= G6:G8
 - H11 <= J11
- Solving Method: Simplex LP

Callouts in the spreadsheet include:

- Decision Variables:** Quantities to be produced (pointing to E6:E8)
- Objective Function:** Total profit to be maximized (pointing to D11)
- Left Hand Side of a Constraint:** This cell contains a formula, its value must not exceed a certain limit. (pointing to E6:E8)
- Right Hand Side of a Constraint:** The value in this cell specifies a limit not to be exceeded. (pointing to J11)

14

14

Optimization with Excel's Solver at a glance*

In Excel go to: *Data > Analysis > Solver*

If Solver does not appear: *File > Options > Add-ins > Manage: Excel Add-ins - Go... ☒ Solver Add-in*

Select the **Objective**, the cell to be optimized (choose *Max* or *Min*)

Select the **Decision Variables**

Declare the **Constraints** that apply (including integer or binary constraints) by clicking "Add"

Check this box to specify that all Decision Variables must be ≥ 0

Select **Simplex LP** if the Objective and Constraints are **linear** functions of the Decision Variables (solving **will be faster**, more reliable)

The screenshot shows the 'Solver Parameters' dialog box in Excel. The 'Set Objective:' field is set to 'Total_Profit'. The 'To:' section has 'Max' selected. The 'By Changing Variable Cells:' field is set to 'Production_levels'. The 'Subject to the Constraints:' list contains three constraints: 'Labor_Used <= Labor_available', 'Production_levels <= Max_prod', and 'Production_levels >= Min_prod'. The 'Make Unconstrained Variables Non-Negative' checkbox is unchecked. The 'Select a Solving Method:' dropdown is set to 'Simplex LP'. The 'Solving Method' section contains a note: 'Select the GRG Nonlinear engine for Solver Problems that are smooth nonlinear. Select the LP Simplex engine for linear Solver Problems, and select the Evolutionary engine for Solver problems that are non-smooth.' The 'Options' button is visible. At the bottom are 'Help', 'Solve', and 'Close' buttons.

*For more details: refer to *Solver Tutorial.pdf*

15

15

Workshop

Let us work through more examples...

16

16

Summary on Optimization for Prescriptive Analytics

Optimization is the central business analytics tool for:

- **Resource Allocation** decisions
- Managing **Business Operations**
- **Efficient Portfolios** of projects, products, or investments

An Optimization model is entirely specified by:

- The set of **Decisions Variables**
- The **Objective Function**
- The set of **Constraints**

The scope of applications of Optimization models is enormous

17