DNSC 6306 - Decision Models

Course Introduction

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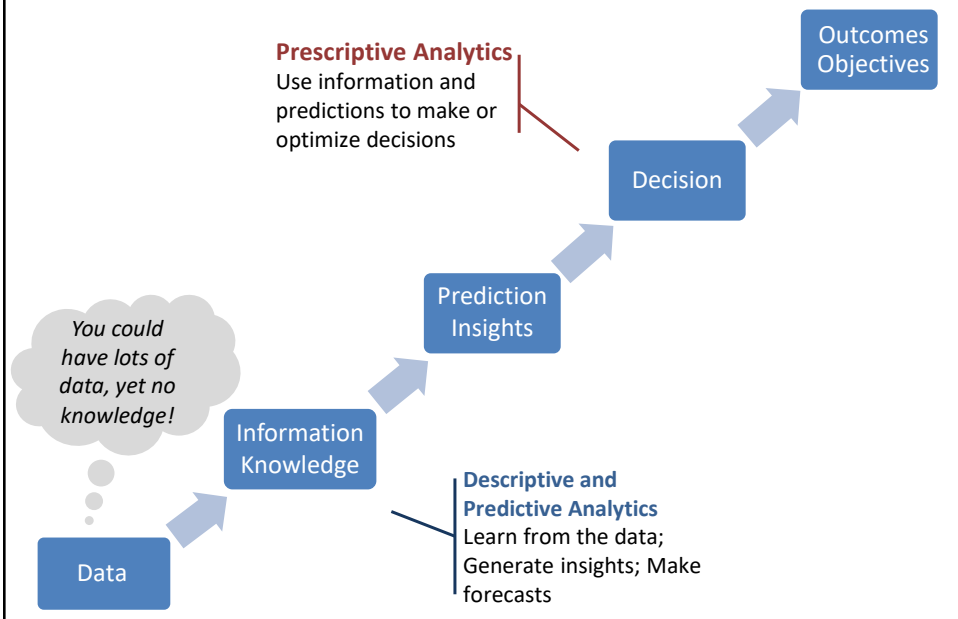
Data-based Decision-making and the Business Analytics Value Chain



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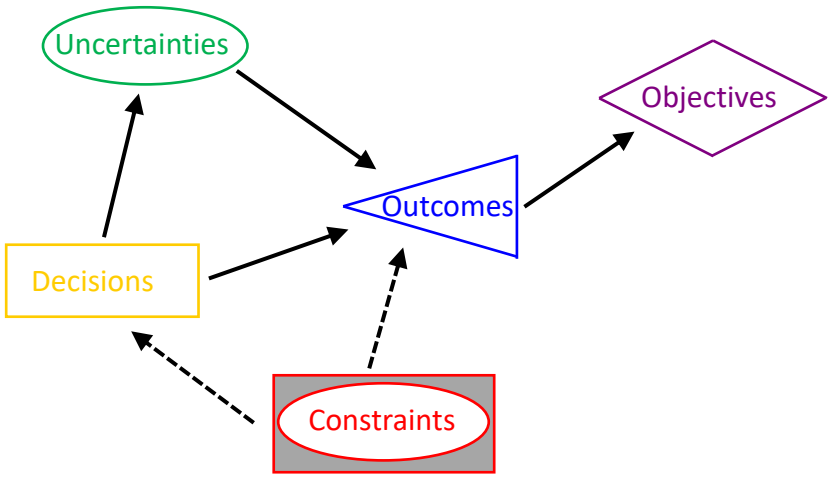
The Building Blocks of Decision Models



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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)

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Constrained Optimization for Decision-Making

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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

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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)

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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…

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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**.

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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	→	*Maximize*
Cost	→	*Minimize*
Risk	→	*Minimize*
ROI	→	*Maximize*

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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

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In summary...

An optimization model is defined by:

- some Decision Variables $X_1, X_2, \ldots, X_n$
  whose values we want to decide
- one Objective Function $f(X_1, X_2, \ldots, X_n)$
  which describes the quantity to be optimized,
  i.e. the objective of the problem
- some Constraints $g_i(X_1, X_2, \ldots, X_n) \leq b_i \quad i = 1, \ldots, m$
  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…)

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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.

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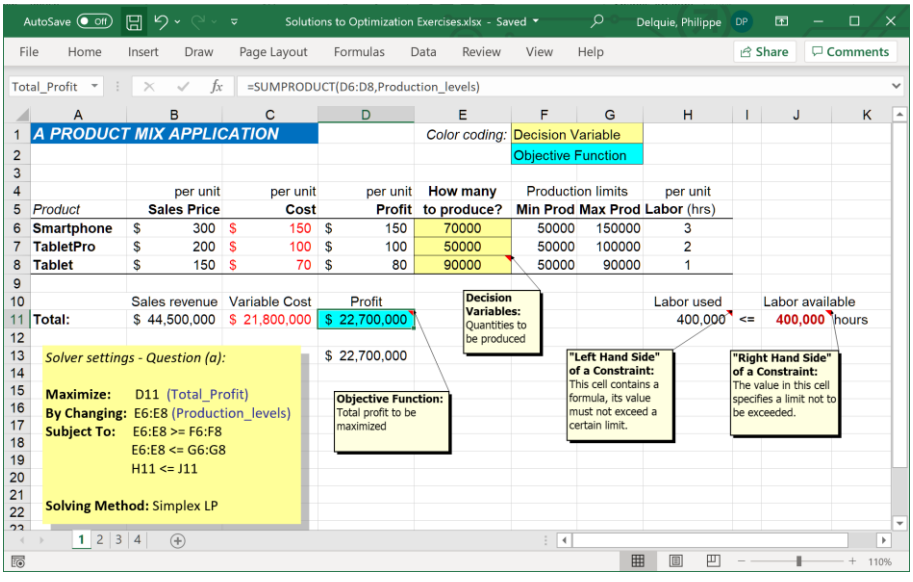
A spreadsheet implementation of the model:



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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*

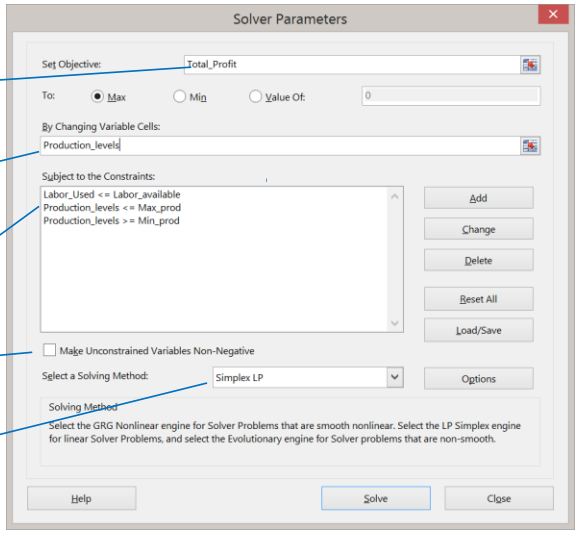
Select the **Objective**, the cell to be optimized (choose *Max* or *Min*)

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)



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

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Workshop

Let us work through more examples…

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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