Part 1
Introduction to Modelling and Decision Analysis

- What is Business Analytics and why it is useful for businesses today?
- Characteristics and benefits of modelling
- Discuss the modelling approach to decision making
- Discuss the problem-solving framework for leveraging business opportunities

Introduction

- We face numerous decisions in life and business. Its not always easy to make good decision.
  - For any given situation there are often numerous possible courses of action.
- Decision analysis
  - A means of systematically identifying, evaluating & choosing best course of action.
- We can use computers to analyse the potential outcomes of decision alternatives.

What is Business Analytics?

- A field of study that uses computers, statistics, and mathematics to solve business problems.
- Considerable overlap with:
  - Operations Research
  - Management Science
  - Decision Science

Home Runs in Business Analytics

- **Chevron**
  - Developed optimization tool for
    - Operational & strategic planning
    - Mixing crude oils
    - Planning capital expenditures
  - Benefits:
    - Annual savings of $1.0 billion

Home Runs in Business Analytics

- **Dell**
  - Built analytics models to
    - Optimize hardware configurations
    - Optimize its website’s design
    - Optimize promotion design and timing
  - Benefits:

    Increased profit by $142 million

Home Runs in Business Analytics

- **Kroger**
  - Analytics team created models to determine reorder point & order up to quantities for items in 1,950 in-store pharmacies
  - Benefits:
    - Reduced prescription stock outs by 1.6 million
    - Lowered inventory by over $120 million
    - Increased revenue by $80 million

Home Runs in Business Analytics

- **National Broadcast Network Company**
  - Gov't owned broadband provider in Australia
  - Developed tool to optimize design of network servicing 8 million locations
  - Benefits:
    - Reduction in network design time
    - Savings of ~$1.7 billion

Home Runs in Business Analytics

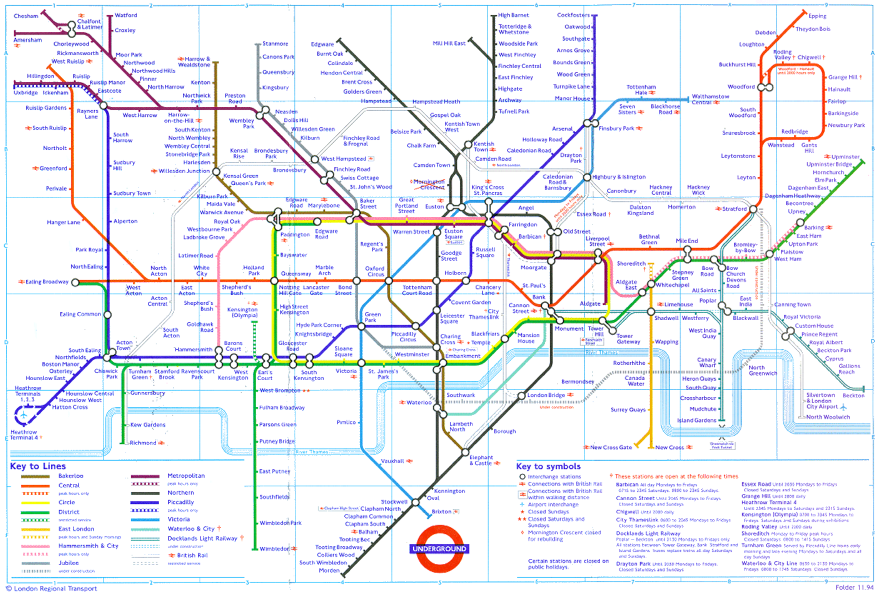
- **Alliance for Paired Donations (APD)**
  - Transplant patients needing a kidney often have potential donors who are incompatible
  - APD finds exchanges with other patient-donor pairs to optimize paired matches
  - Benefits:
    - 220 lives saved since 2006
    - Value of savings: *priceless*

A Modelling Approach to Decision Making

- A model is
  - A structure which has been built purposely to exhibit features and characteristics of some other objects
- Everyone uses models to make decisions
- Types of models:
  - Mental (arranging furniture)
  - Visual (blueprints, road maps)
  - Physical/Scale (aerodynamics, buildings)
  - Mathematical (what we’ll be studying)

Characteristics of Models

- Usually *simplified* versions of things they represent
- A *valid* model accurately represents the *relevant characteristics* of the object or decision problem being studied



A more formal definition

- A model is a device which behaves approximately like part of the real world:
  - Train-sets, dolls, toy prams…
  - Small aircraft replicas in wind tunnels…
  - Sponge-rubber men used in car crash…
  - The solar system as a number of small balls moving in ellipses round a larger ball...

Models for Decision Making

May include:

- Mathematical equations
  - Mathematical Models
- Structured set of rules or steps to follow
  - Algorithms and Discrete Event processes
- Simulation of real events
  - Queuing models, waiting lines
- Statistical techniques
  - Data Analysis, Equation Fitting

Modelling: Why bother?

- Real Understanding:
  - The process may reveal hidden inner relationships within the system.
  - Formal Analysis (assumptions/relationships)
  - Experimentation - can be used repeatedly
  - To large extent, independent of the data
  - Variety of models for the same problem

Relisten the explaination

Benefits of Modelling

- **Economy**
  - Less costly to analyze decision problems.
- **Timeliness**
  - Deliver needed information more quickly than their real-world counterparts.
- **Feasibility**
  - Used to do things that would be impossible in reality.
- **Insight & understanding**
  - That improves decision making.

Advantages of Using Models

- Less expensive and disruptive than experimenting with real world system
- Models enable us to ask ‘what if’ questions and test the sensitivity of particular values
- Models force a consistent, systematic approach to a problem
- Models require managers to be specific about constraints and goals
- Models can reduce the time taken to make decisions

Disadvantages of Using Models

- May be expensive to develop and test
- May be misused and misunderstood because of their complexity (e.g., there may be too much variables)
- Models may down play the value of non-quantifiable information
- May oversimplify the variables of the real world

What is a "Computer Model"? = Spreadsheet model

- A set of mathematical relationships and logical assumptions implemented in a computer as an abstract representation of a real-world object or phenomenon.
- Spreadsheets provide the most convenient way for business people to build computer models
  - Spreadsheets are commonplace on most computers.
  - They are the tool of choice for today's managers.
  - They facilitate decision-making process by making it easier to play out various what-if scenarios.

Example of a Mathematical Model

Profit = Revenue - Expenses

or

Profit = *f*(Revenue, Expenses)

or

$$Y = f(X_1, X_2)$$

Dependent variable

Independent variables

A Generic Mathematical Model

$$Y = \quad \boldsymbol{f}(X_1, X_2, \ldots, X_n)$$

Where:

Y is DEPENDENT for the variable of X_i

Y = dependent variable

(aka bottom-line performance measure)

X_i = independent variables

(inputs having an impact on Y)

$\boldsymbol{f}(\cdot)$ = function defining the relationship between Y & X_i

Mathematical Models & Spreadsheets

- Most spreadsheet models are very similar to our generic mathematical model:

$$Y = \boldsymbol{f}(X_1, X_2, \ldots, X_n)$$

- Most spreadsheets have input cells (representing X_i) to which mathematical functions ($f(\cdot)$) are applied to compute a bottom-line performance measure (or Y).

Categories of Mathematical Models

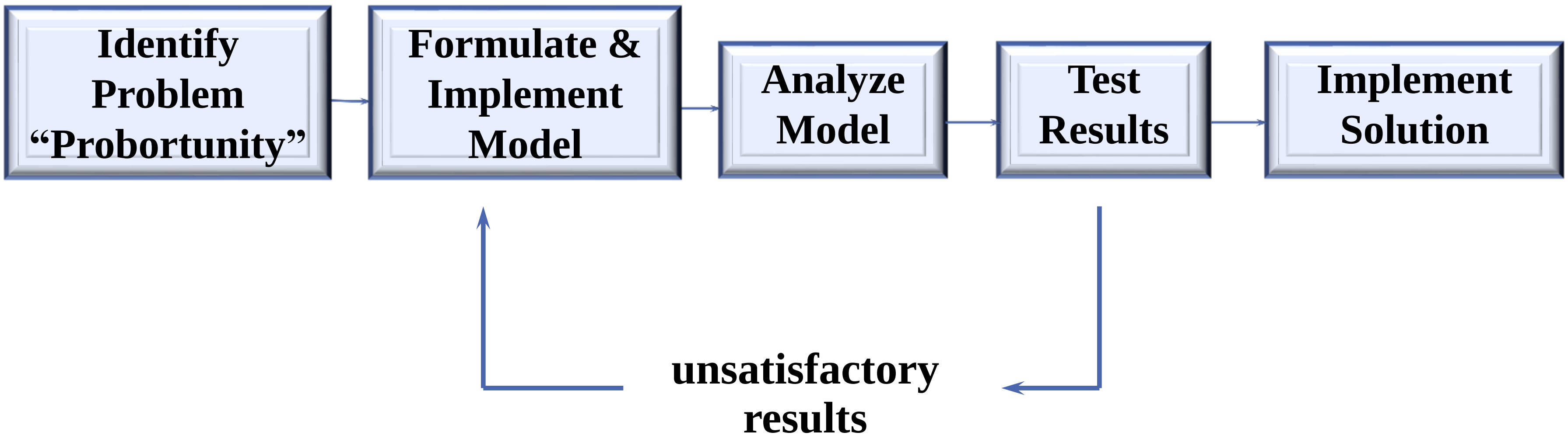
Model Category	Relationship Form of *f*(·)	Independent Variables	OR/MS Techniques
Prescriptive	known, well-defined	known or under decision maker's control	LP, Networks, IP, CPM, EOQ, NLP, GP, MOLP
Predictive	unknown, ill-defined	known or under decision maker's control	Regression Analysis, Time Series Analysis, Discriminant Analysis
Descriptive	known, well-defined	unknown or uncertain	Simulation, PERT, Queueing, Inventory Models

How to Use a Model

It wont make a decision for you,
but it would help you make a decision

- Don’t accept an answer without further analysis and questioning. Get better insight; question our assumption; get relationship between variables - Like BRAINSTORMING
- A mathematical model is only one of a number of tools for decision making.
- If the answer is unacceptable, the reasons for unacceptability should be spelled out and incorporated in a modified model.
- An acceptable answer is only an option.
- By successive questioning of the answers and altering the model, it is possible to clarify the options available and obtain a greater understanding of what is possible in a real situation.

The Problem-Solving Framework for Leveraging Business Opportunities



Psychology of Decision Making

- Models can be used for structural aspects of decision problems.
- Other aspects cannot be structured easily, requiring intuition and judgment.
- *Caution*: Human judgment and intuition are not always rational!
- Errors in human judgment often arise because of *anchoring* and *framing* effects associated with decision problems.

Anchoring Effects

- **Arise when trivial factors influence initial thinking about a problem.**
- **Decision-makers usually under-adjust from their initial "anchor."**

anchor.

- **Example:**
  - What is 1x2x3x4x5x6x7x8? 好似好大，其實一樣 — Median estimate = 512
  - What is 8x7x6x5x4x3x2x1? — Median estimate = 2,250

The product is the same in both cases: 40,320

MONASH University

Framing Effects

- Refers to how decision-makers view a problem from a win-loss perspective.

- The way a problem is framed often influences choices in irrational ways…

Framing Effects 1

- Suppose you've been given $1000 and must choose between:

  A1. Receive $500 more immediately => Most popular

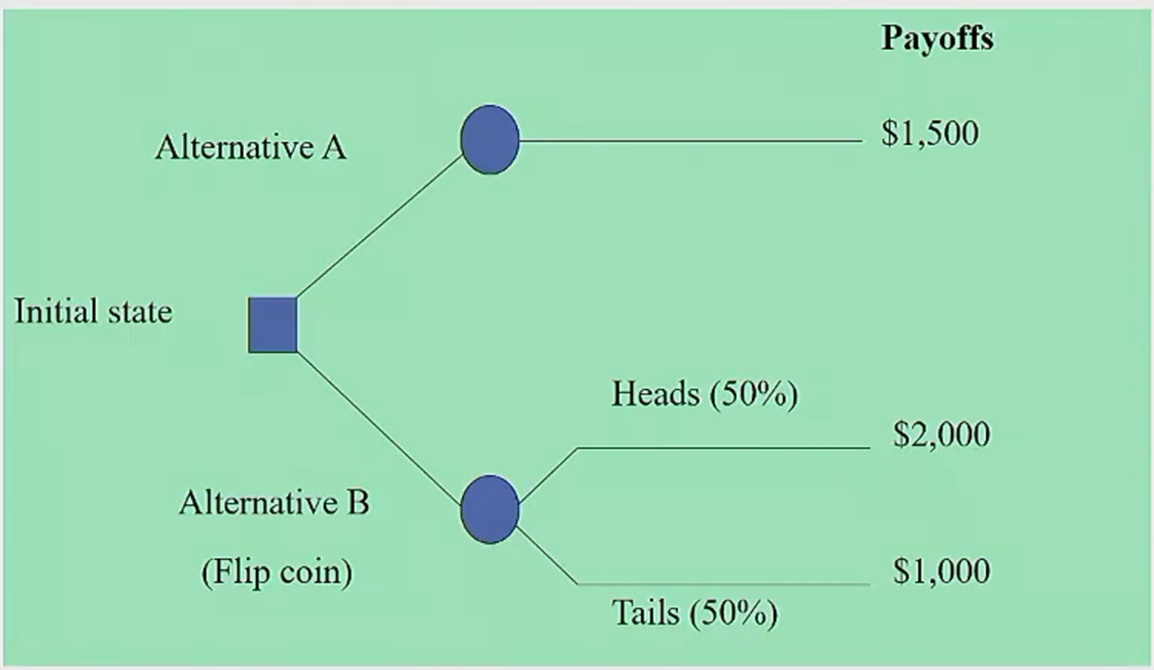
  B1. Flip a coin and receive $1000 more if heads occurs or $0 more if tails occurs.

- Now suppose you've been given $2000 and must choose between:

  A2. Give back $500 immediately

  B2. Flip a coin and give back $0 if heads occurs or give back $1000 if tails occurs. => Most popular

A Decision Tree for Both Examples



看似不同，其實一樣

Framing Effects 2

DARK PATTERNS !

Which option would you select?

This food is 95% fat free

vs

This food consists of 5% fat

You generally obtain different answers from the same person.

Good Decisions vs. Good Outcomes

- Good decisions do not always lead to good outcomes...

- A structured, modelling approach to decision making helps us make good decisions, but can't guarantee good outcomes.

What is a good decision?

A balance among

- What we know
- What we can do
- What we want

		Outcome Quality	
		Good	Bad
Decision Quality	Good	Deserved Success	Bad Luck
	Bad	Dumb Luck	Poetic Justice

Part 2
Introduction to Optimisation and Linear Programming

- Discuss the characteristics of optimisation problems
- Explore the use of linear programming (LP) in solving optimisation problems
- Solving LP problems using graphical approach

Introduction

- We all face decision about how to use limited resources such as:
  - Oil in the earth
  - Land for dumps
  - Time
  - Money
  - Workers

Mathematical Programming...

- A field of management science that finds the optimal, or most efficient, way of using limited resources to achieve the objectives of an individual of a business.
- *Also referred to as …* Optimisation

Applications of Optimization

- **Determining Product Mix**
  - How many of each product to produce to **maximise profits** or to satisfy demand at **minimum cost**?
- **Manufacturing**
  - Eg. For a circuit board, what is the drilling order that **minimises total distance** the drill bit must be moved?
- **Routing and Logistics**
  - What is the **least costly** method of transferring goods from warehouses to stores?
- **Financial Planning**
  - How much to save in superannuation to **minimise tax liability**?

Characteristics of Optimization Problems

- Decisions
  - One or more decisions that must be made
- Constraints
  - Due to limited resources
- Objectives
  - Goal that decision maker considers when making decision
  - To maximise profit or minimise cost

General Form of an Optimization Problem

MAX (or MIN): $f_0(X_1, X_2, \ldots, X_n)$

Objective Function

Subject to:

$$\begin{aligned} f_1(X_1, X_2, \ldots, X_n) &<= b_1 \\ &\vdots \\ f_k(X_1, X_2, \ldots, X_n) &>= b_k \\ &\vdots \\ f_m(X_1, X_2, \ldots, X_n) &= b_m \end{aligned}$$

RHS

Value of constraints

LHS (Left Hand Side)

Note: If all the functions in an optimization are linear, the problem is a Linear Programming (LP) problem

Linear Programming (LP) Problems

MAX (or MIN): $c_1X_1 + c_2X_2 + \ldots + c_nX_n$

Subject to: $a_{11}X_1 + a_{12}X_2 + \ldots + a_{1n}X_n \le b_1$

$$\vdots$$

$$a_{k1}X_1 + a_{k2}X_2 + \ldots + a_{kn}X_n \ge b_k$$

$$\vdots$$

$$a_{m1}X_1 + a_{m2}X_2 + \ldots + a_{mn}X_n = b_m$$

An Example LP Problem

Blue Ridge Hot Tubs produces two types of hot tubs: Aqua-Spas & Hydro-Luxes.

	Aqua-Spa	Hydro-Lux
Pumps	1	1
Labor	9 hours	6 hours
Tubing	12 feet	16 feet
Unit Profit	$350	$300

There are 200 pumps, 1566 hours of labor, and 2880 feet of tubing available.

Decision: Hw many Aqua-Spa and Hydro-Lux can be produced

5 Steps In Formulating LP Models:

1. Understand the problem.
2. Identify the decision variables.

   X_1=number of Aqua-Spas to produce

   X_2=number of Hydro-Luxes to produce

3. State the objective function as a linear combination of the decision variables.

   MAX: $350X_1 + 300X_2$

5 Steps In Formulating LP Models (continued)

4. State the constraints as linear combinations of the decision variables.

$$1X_1 + 1X_2 <= 200 \quad \} \text{ pumps}$$

$$9X_1 + 6X_2 <= 1566 \quad \} \text{ labor}$$

$$12X_1 + 16X_2 <= 2880 \quad \} \text{ tubing}$$

5. Identify any upper or lower bounds on the decision variables.

$$X_1 >= 0$$

$$X_2 >= 0$$

LP Model for Blue Ridge Hot Tubs

MAX: $350X_1 + 300X_2$

S.T.: $1X_1 + 1X_2 <= 200$

$9X_1 + 6X_2 <= 1566$

$12X_1 + 16X_2 <= 2880$

$X_1 >= 0$

$X_2 >= 0$

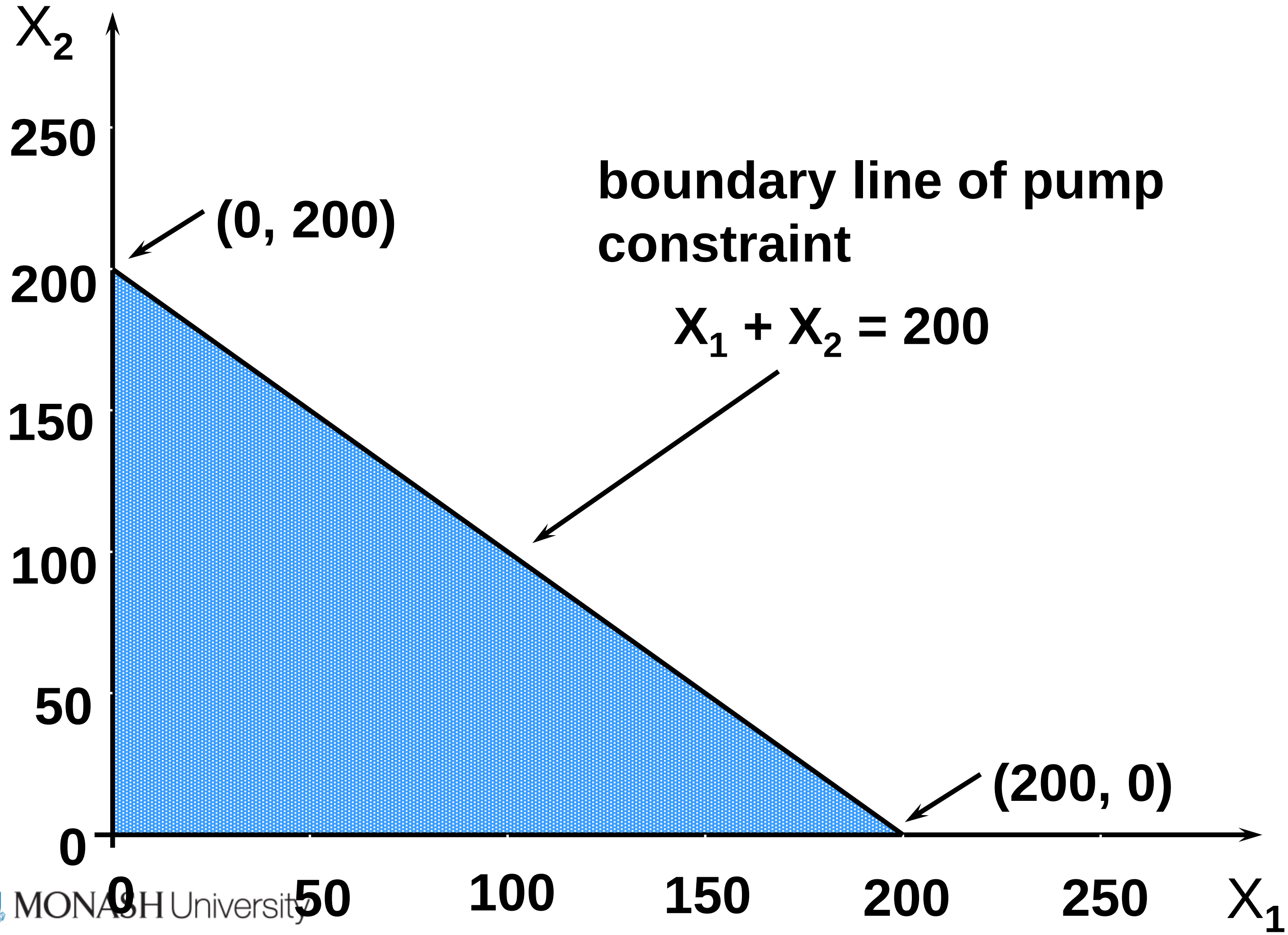
Solving LP Problems: An Intuitive Approach

- Idea: Each Aqua-Spa (X_1) generates the highest unit profit (\$350), so let's make as many of them as possible!
- How many would that be?
  - Let $X_2 = 0$
    - 1st constraint: $1X_1 <= 200$
    - 2nd constraint: $9X_1 <= 1566$ or $X_1 <= 174$
    - 3rd constraint: $12X_1 <= 2880$ or $X_1 <= 240$
- If $X_2=0$, the maximum amount of X_1 you could make is 174 and the total profit is \$350*174 + \$300*0 = \$60,900
- This solution is *feasible*, but is it *optimal?*
- *No!*

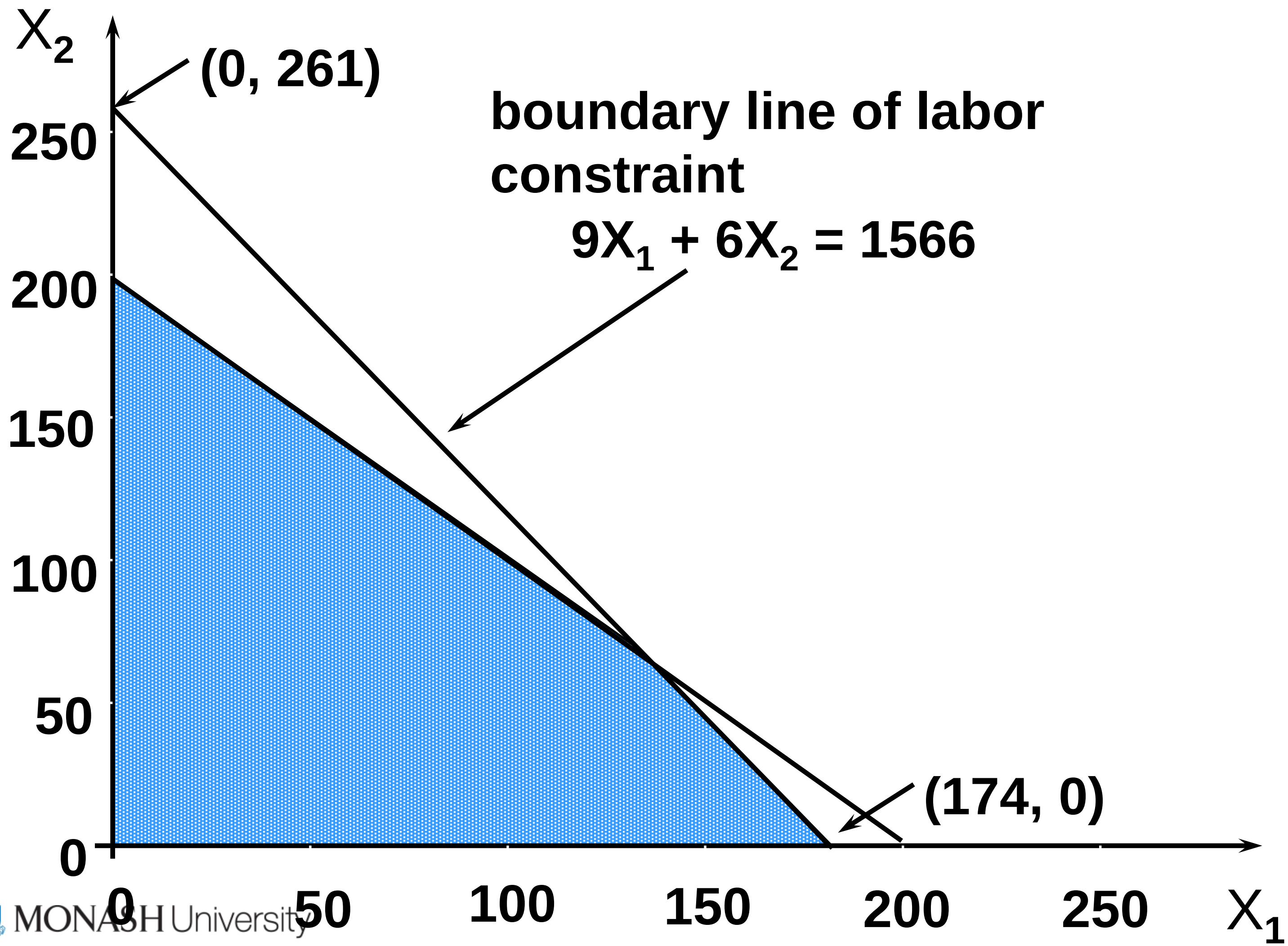
Solving LP Problems: A Graphical Approach

- The constraints of an LP problem defines its feasible region.
- The best point in the feasible region is the optimal solution to the problem.
- For LP problems with 2 variables, it is easy to plot the feasible region and find the optimal solution.

Plotting the First Constraint

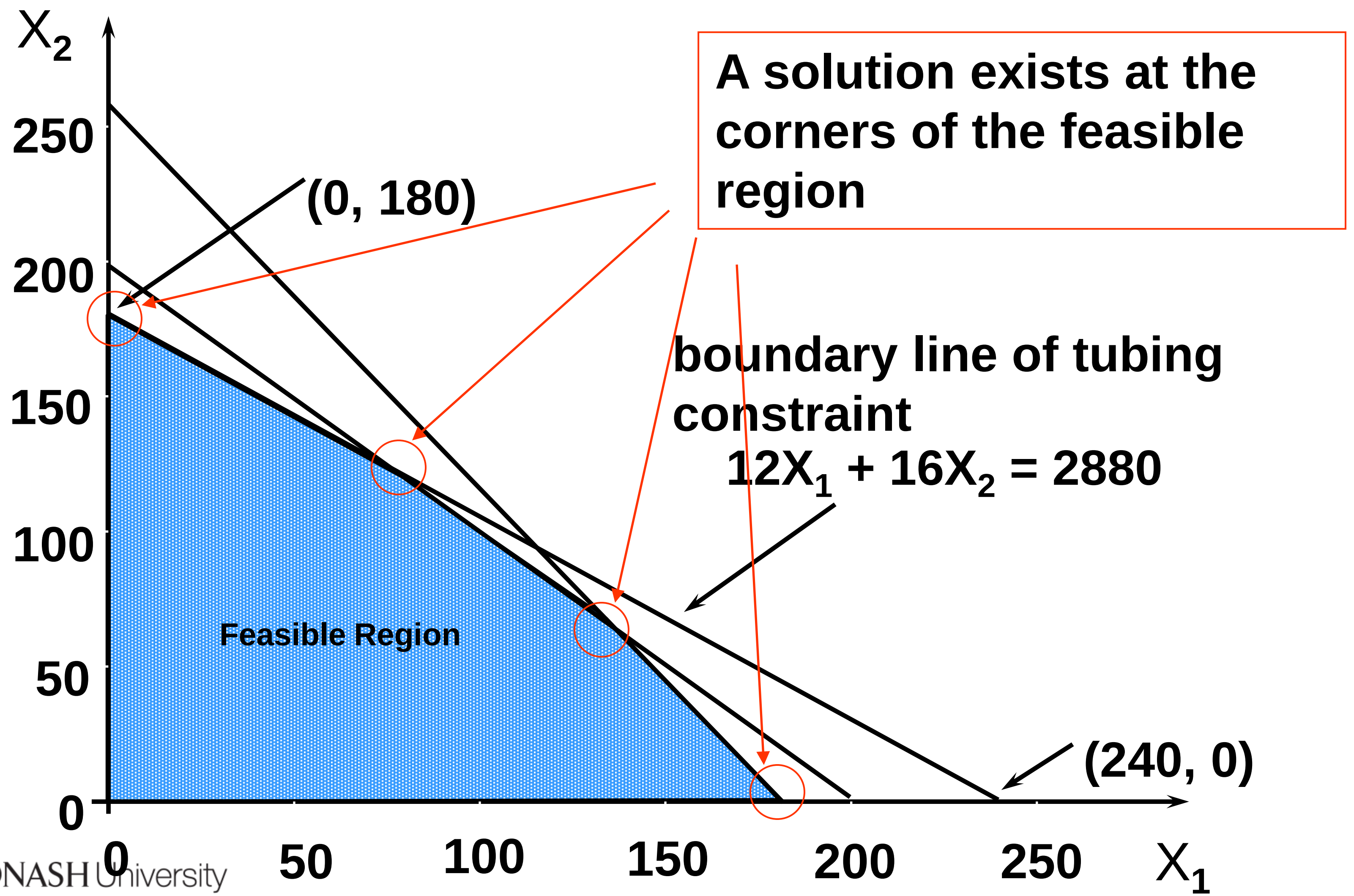


Plotting the Second Constraint

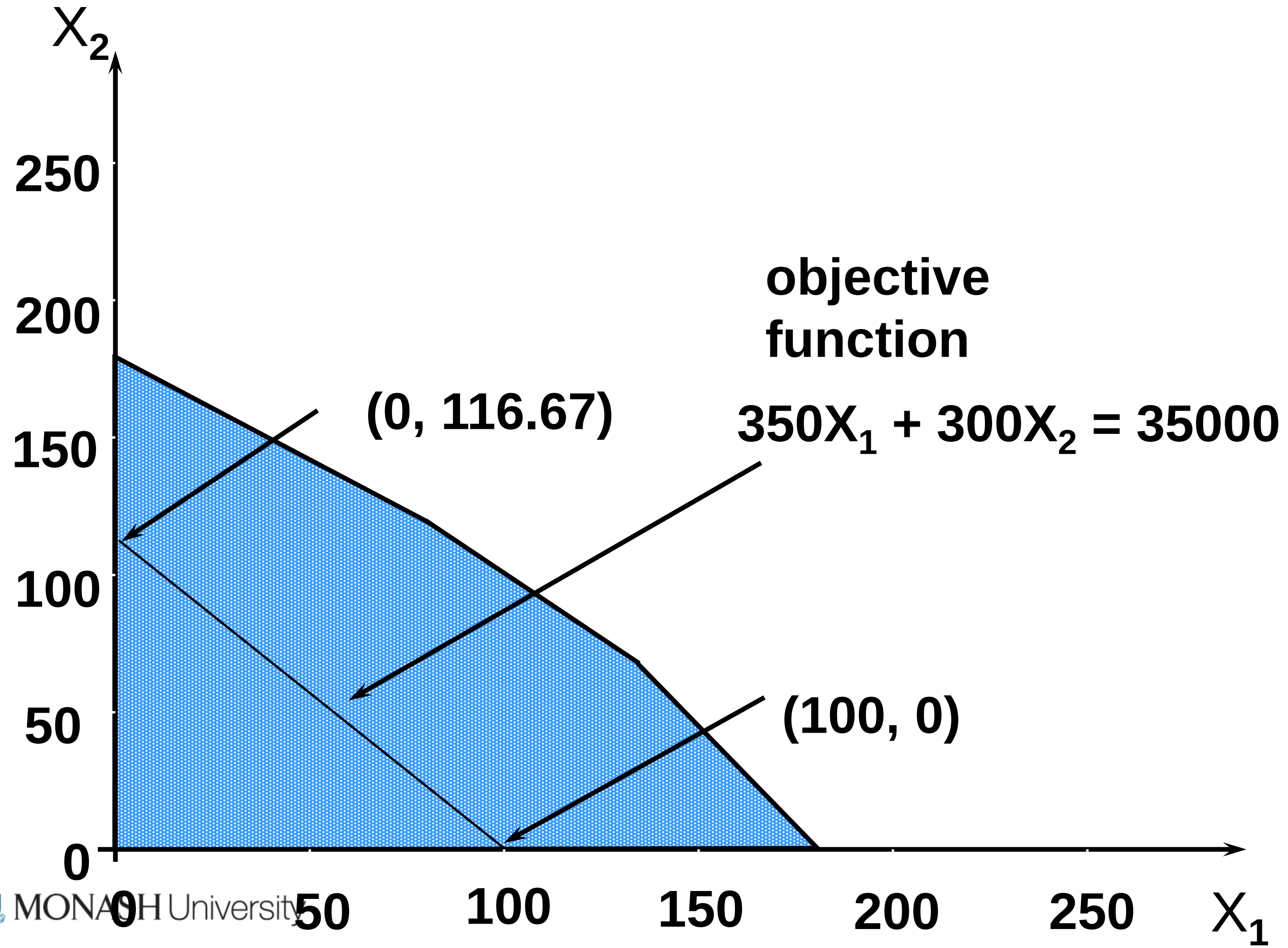


Plotting the Third Constraint

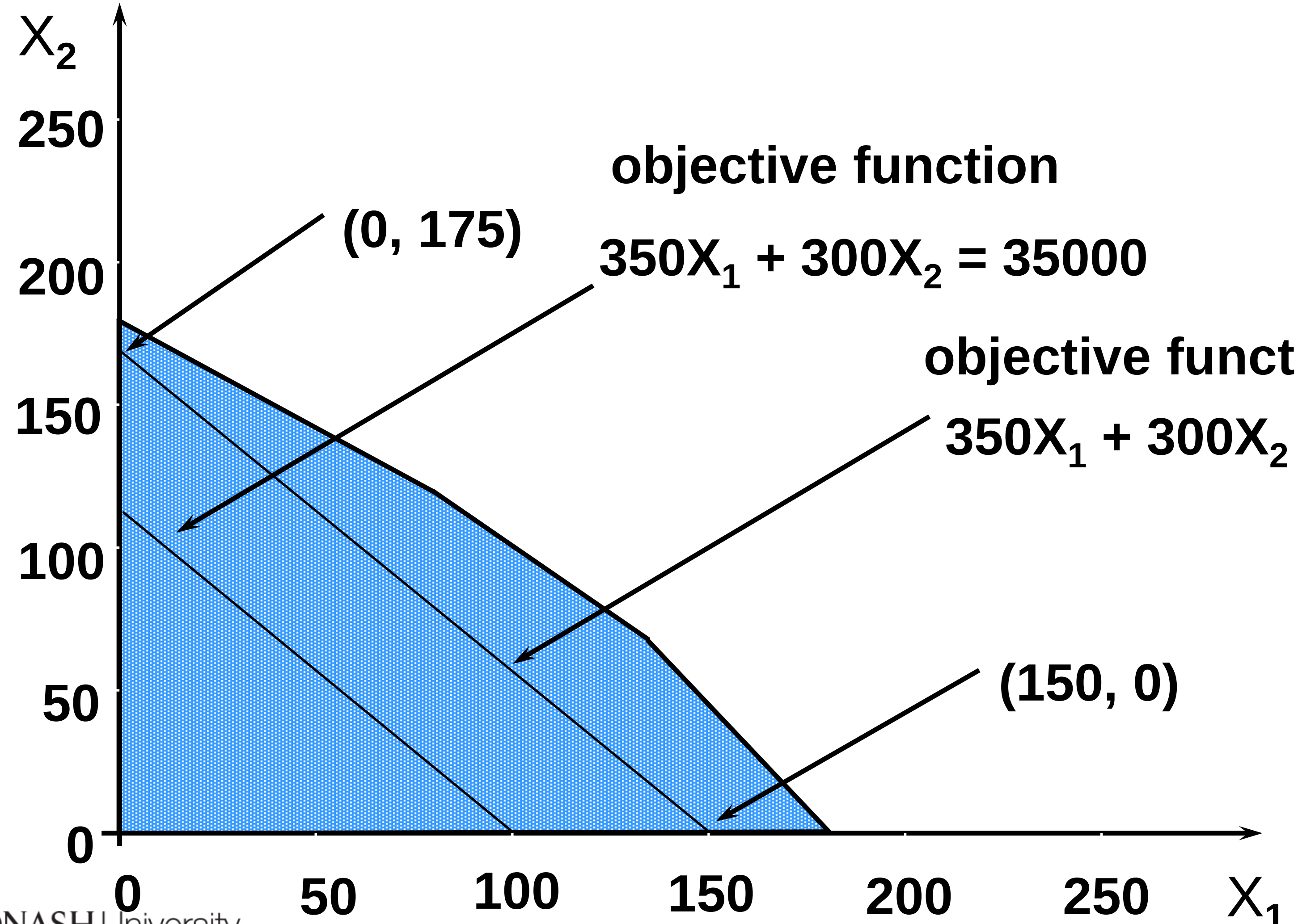
Feasible != Optimal



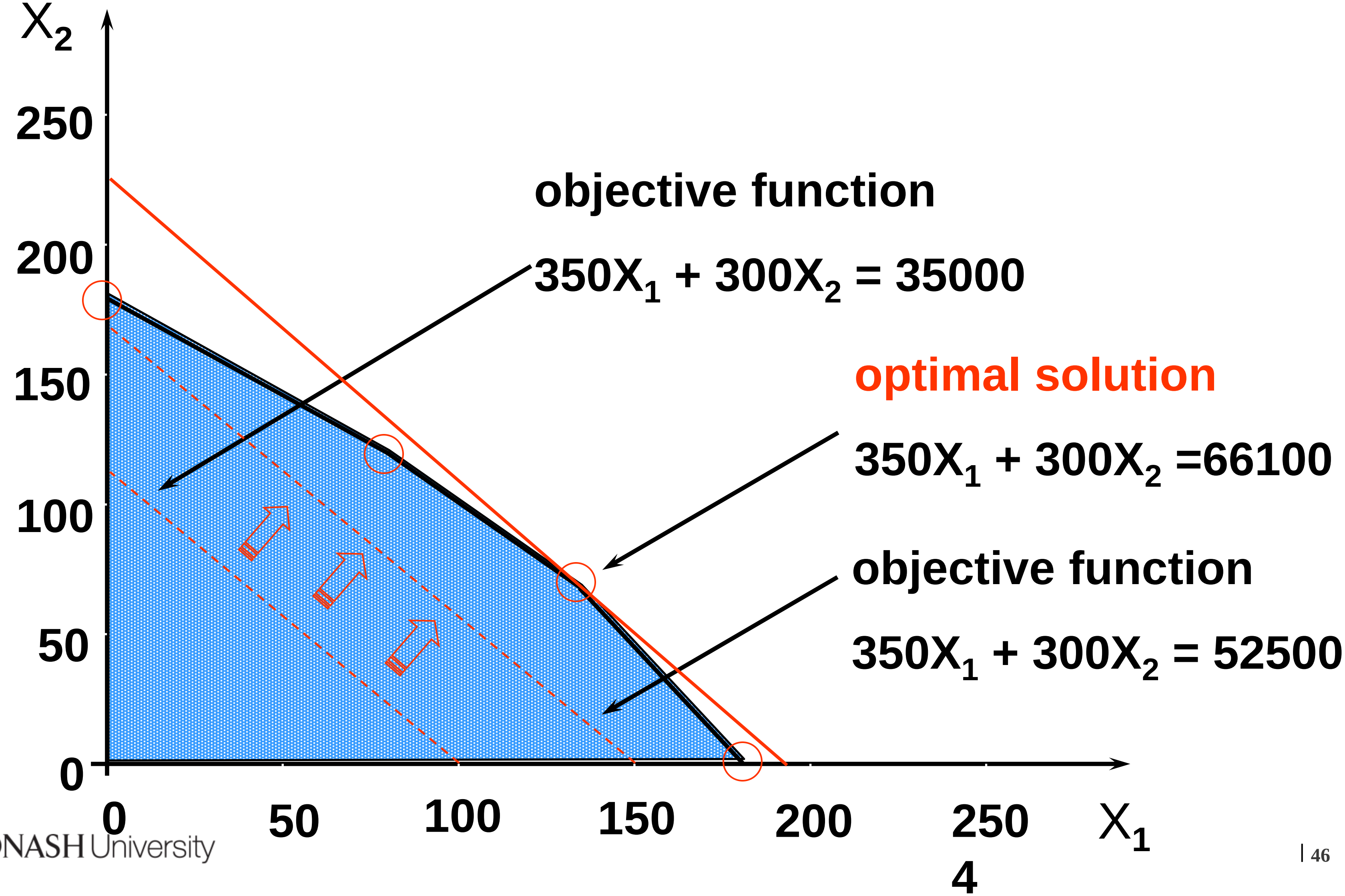
Plotting A Level Curve of the Objective Function



A Second Level Curve of the Objective Function



Using A Level Curve to Locate the Optimal Solution



Calculating the Optimal Solution

- The optimal solution occurs where the “pumps” and “labor” constraints intersect.
- This occurs where:

$$X_1 + X_2 = 200 \qquad (1)$$

and $$9X_1 + 6X_2 = 1566 \qquad (2)$$

- From (1) we have, $X_2 = 200 - X_1$ (3)
- Substituting (3) for X_2 in (2) we have,

$$9X_1 + 6\,(200 - X_1) = 1566$$

$$\rightarrow \quad X_1 = 122$$

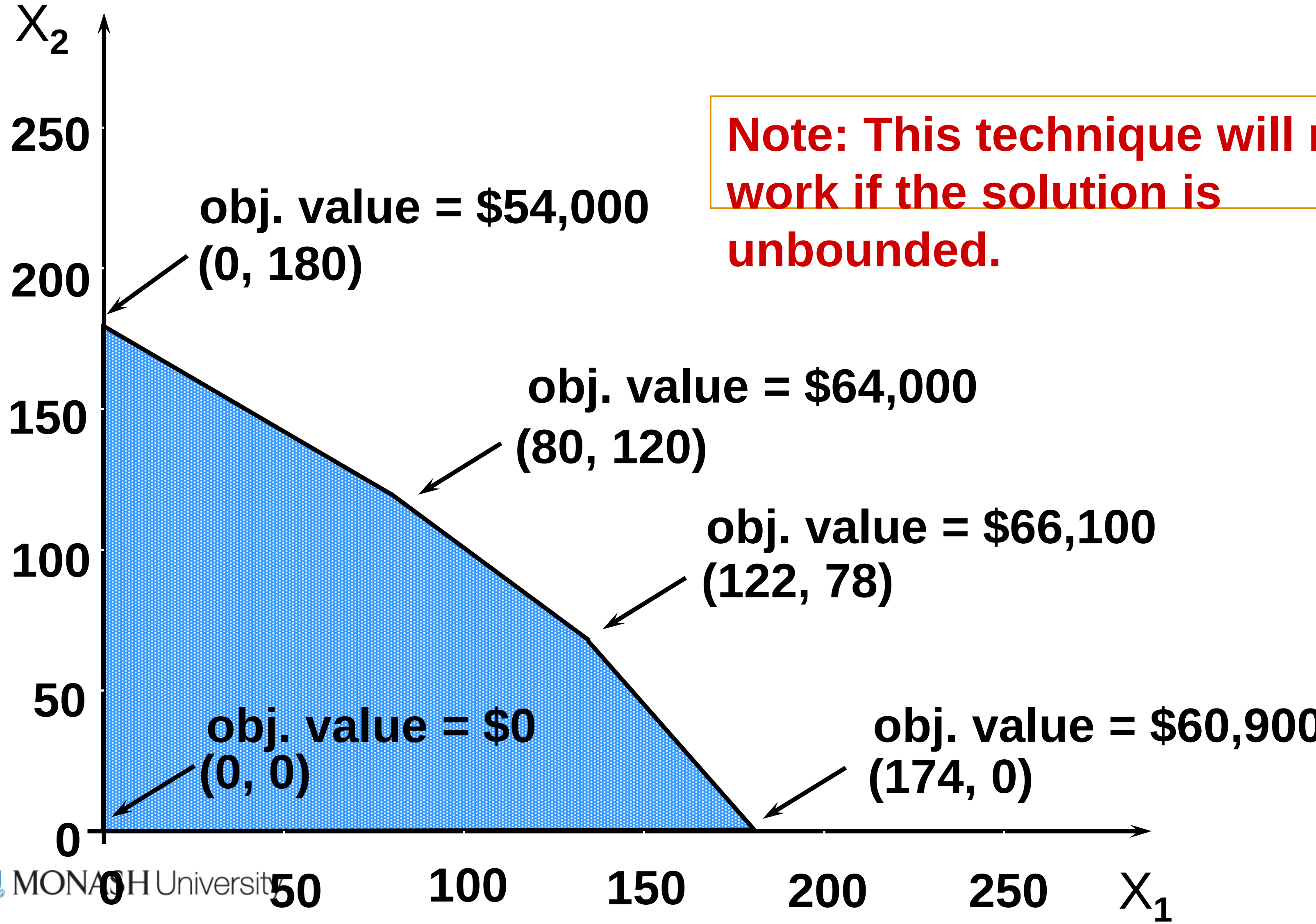
- So the optimal solution is:

Substituting $X_1=122$ in $X_2 = 200 – X_1 \rightarrow X_2= 78$

Total Profit = \$350*122 + \$300*78 = \$66,100

Enumerating The Corner Points

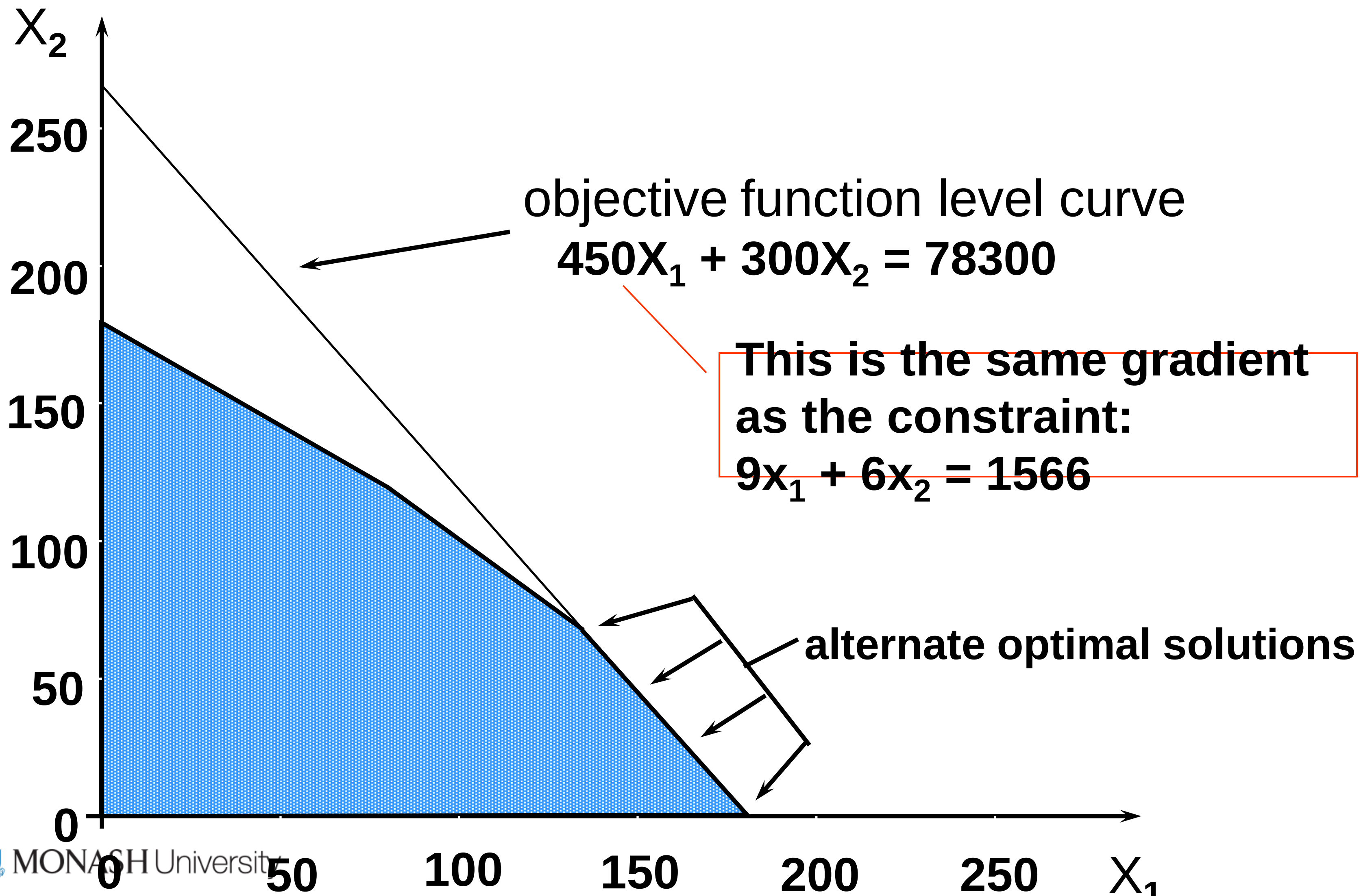
Note: This technique will not work if the solution is unbounded.



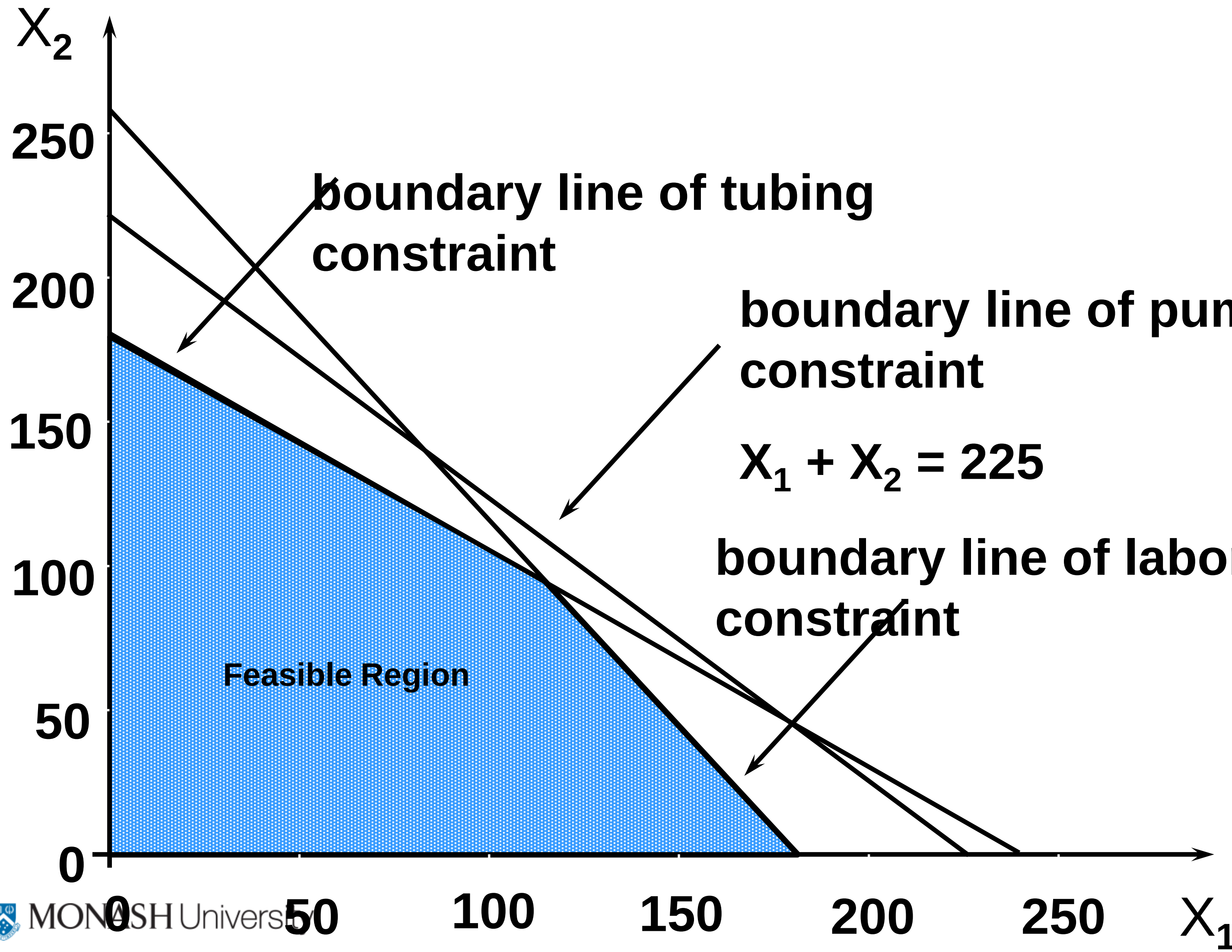
Special Conditions in LP Models

- A number of anomalies can occur in LP problems:
  - Alternate Optimal Solutions
  - Redundant Constraints
  - Unbounded Solutions
  - Infeasibility

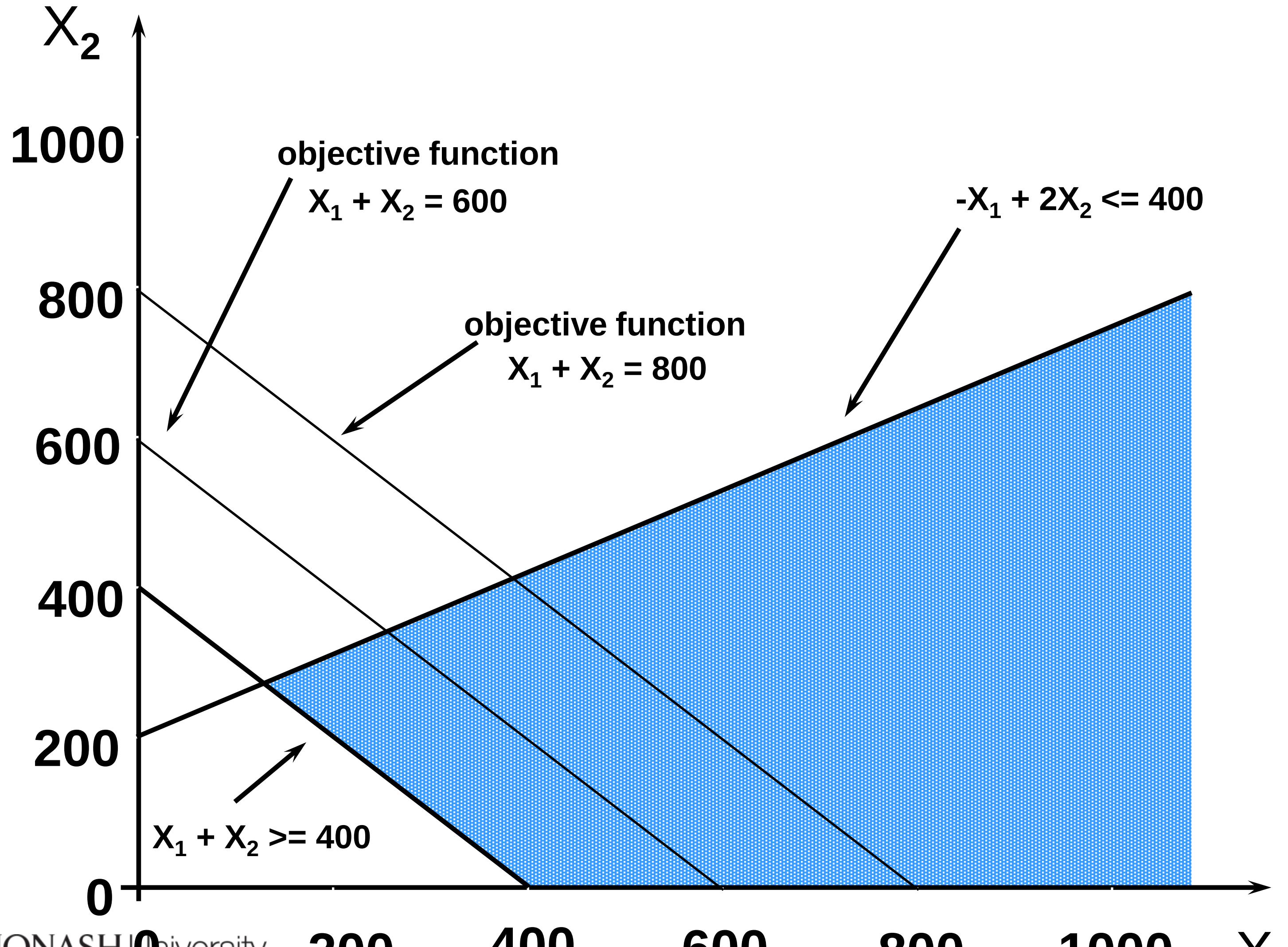
Example of Alternate Optimal Solutions



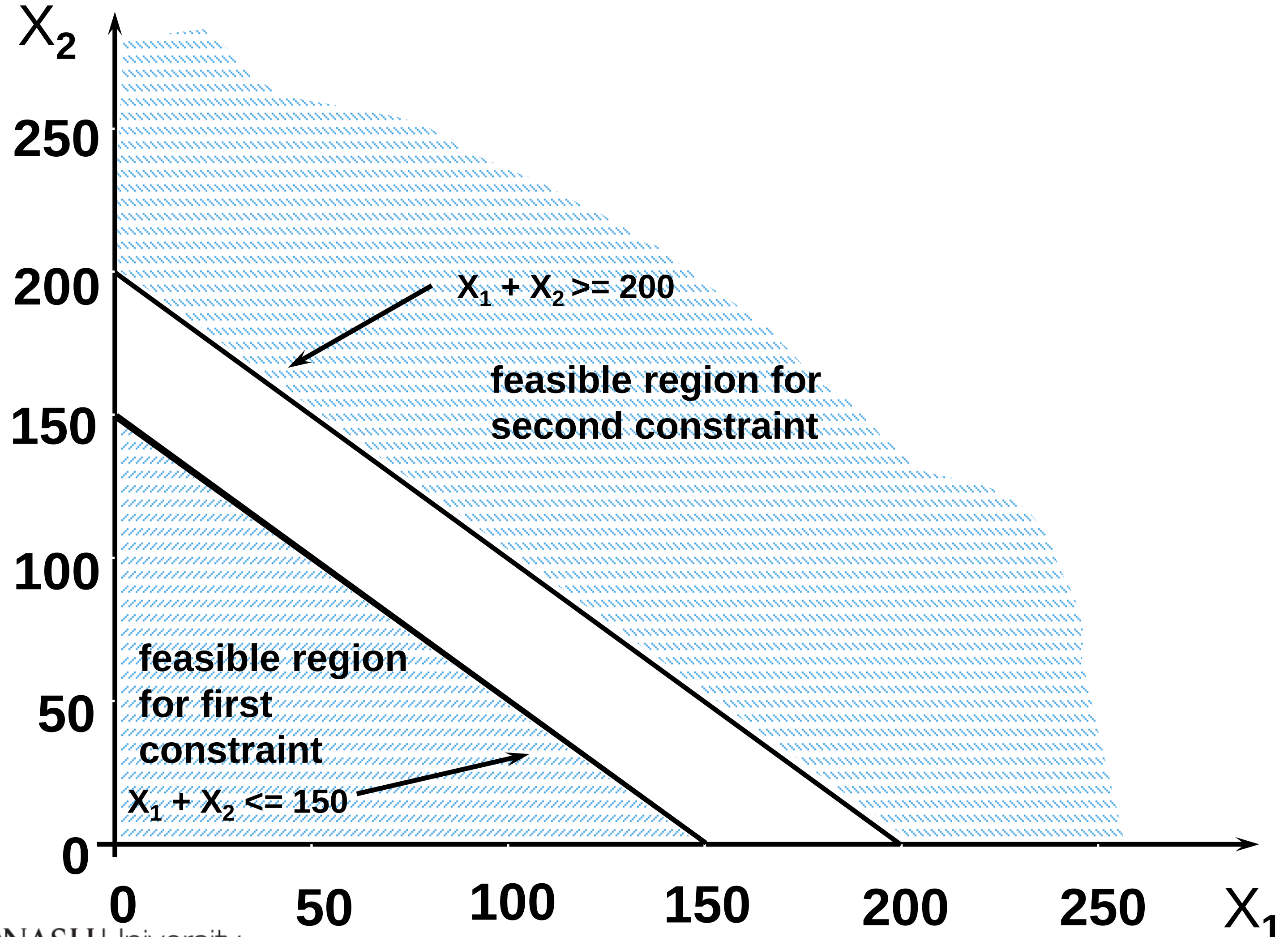
Example of a Redundant Constraint



Example of an Unbounded Solution



Example of Infeasibility



☞ ***There's no tutorial this week***

Please go through the Excel exercises on Moodle on your own to brush up your Excel skills for subsequent exercises in the weeks to come.

Readings for next week's Lecture:

Ragsdale, C. T., Spreadsheet Modelling and Decision Analysis 8th Ed, Cengage Learning, 2017: Chapter 3