Prescriptive Analytics and Optimization

Veterans Analytics Course

Sept 16-17, 2020

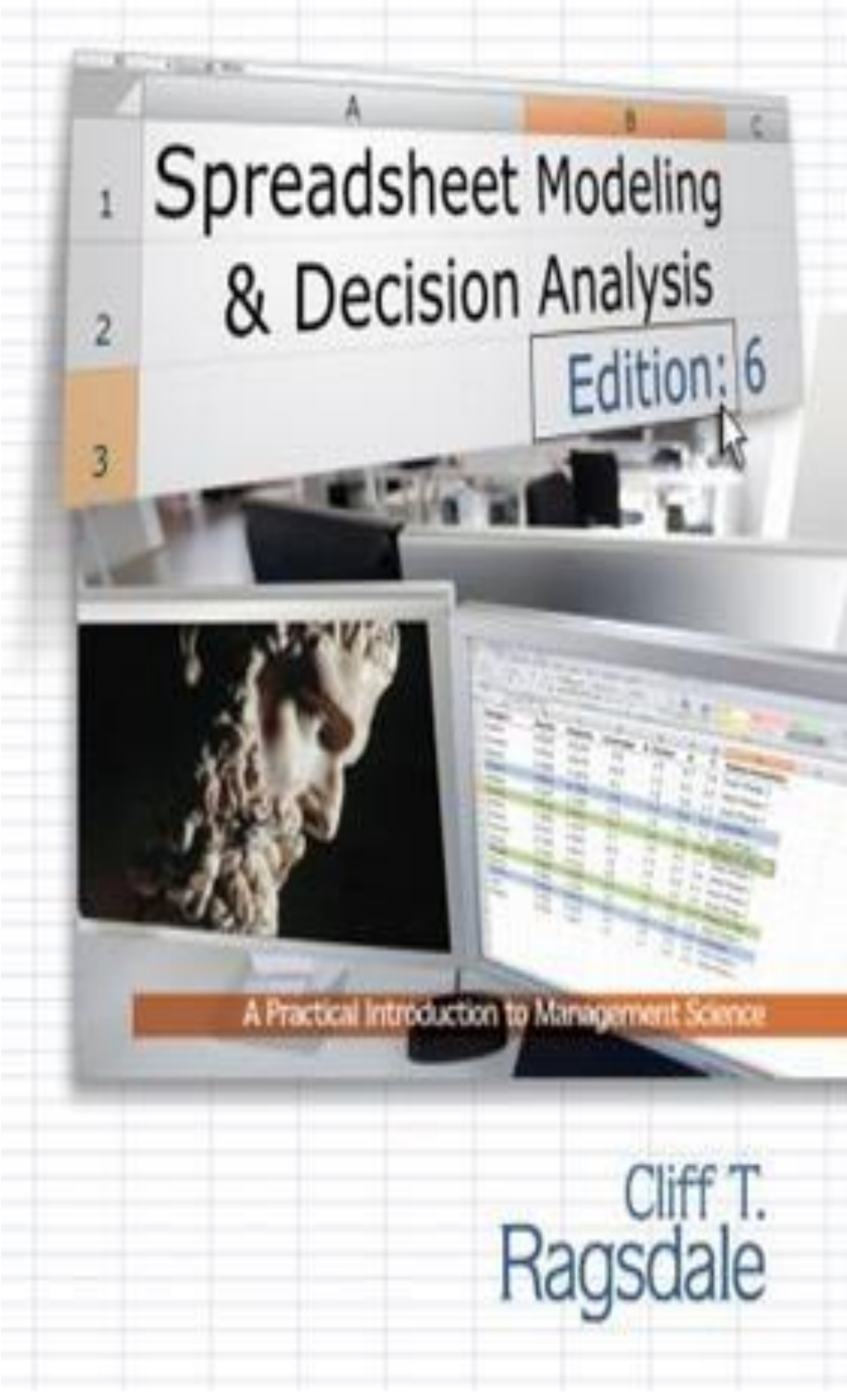
Provided by: CANA Advisors

Prescriptive Analytics

Intro to prescriptive analysis, use cases and sample applications

Reference

Cliff T. Ragsdale. 2012. Spreadsheet Modeling and Decision Analysis (6th. ed.). South-Western Thomson Learning.



ThriftBooks. "Spreadsheet Modeling and Decision... Book by Cliff T. Ragsdale." ThriftBooks. Accessed August 27, 2020. https://www.thriftbooks.com/w/spreadsheet-modeling-and-decision-analysis-with-cd-rom-and-microsoft-project-2003-120-day-version_cliff-ragsdale/254394/.

So far…

- Descriptive Models (ex. Simulation)
  - Known functional relationship
  - Independent variable values uncertain
- Predictive Models (ex. Regression)
  - Unknown functional relationship
  - Independent variable values known
- Prescriptive Models (ex. Linear programming)
  - Known functional relationship
  - Independent variable values known

relationship between dependent and independent variables

$$Y = f(X_1, X_2, \dots, X_k)$$

Dependent Variable

Independent Variables

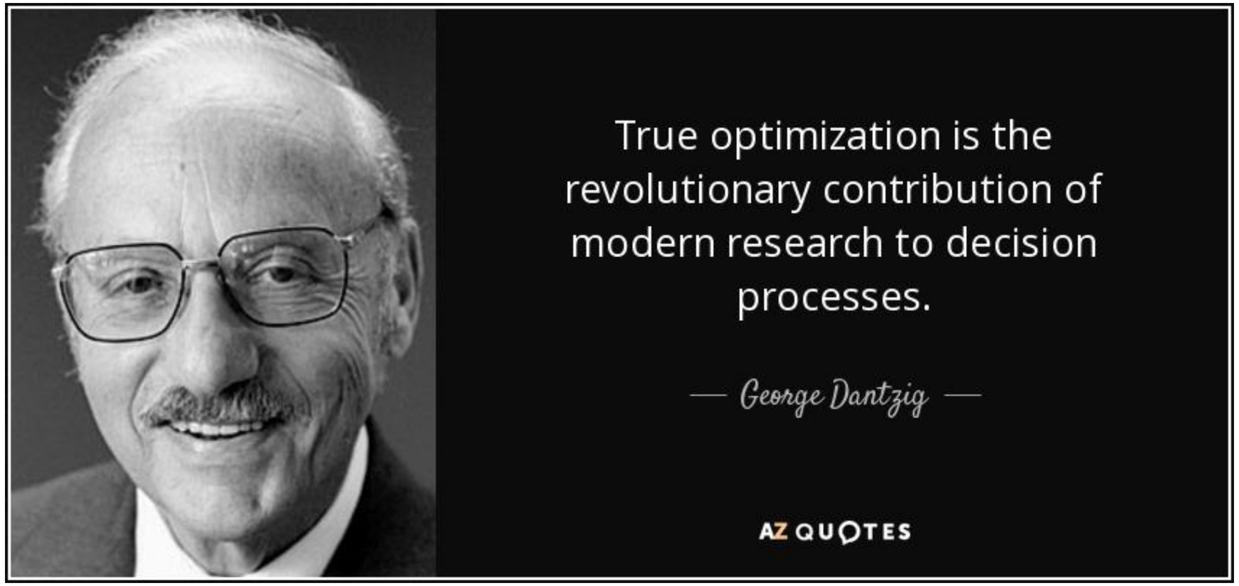
Simple Example

$$PROFIT = f(REVENUE, EXPENSES)$$

Select a model technique that fits the problem. Prescriptive models tell the decision maker what to do

Prescriptive Examples

- Product Mix Production
- Manufacturing Circuits
- Warehousing/Logistics
- Financial Planning
- Google Maps/Route Planning
- Minimizing Cost
- Limited Time
- Limited Resources



Prescriptive models tell the decision maker what to do, decision makers want the OPTIMAL solution

A-Z Quotes. "George Dantzig Quote." Accessed August 27, 2020. https://www.azquotes.com/quote/586942.

UPS's ORION

- Started in 2008, ten-year refinement
- Penalizes left turns
- Saves millions of gallons of fuel each year and avoids emissions equivalent to over 20,000 passenger cars.
- Heart of UPS My Choice® services

"Our basic routines were already good and allowed us to save about 85 million miles a year. When we put Orion on top of those, it shaved off an extra 100 million miles, and the savings got up to 185 million miles a year"

CNN, Jacopo Prisco. "Why UPS Trucks Never Turn Left." CNN. Accessed August 27, 2020. https://www.cnn.com/2017/02/16/world/ups-trucks-no-left-turns/index.html.
———. "Why UPS Trucks Never Turn Left." CNN. Accessed August 27, 2020. https://www.cnn.com/2017/02/16/world/ups-trucks-no-left-turns/index.html.

Unsplash. "Photo by Who?Du!Nelson on Unsplash." Accessed August 27, 2020. https://unsplash.com/photos/4WioHGG7K2o.

The Optimization Model

Decision Variables, Constraints, Objectives

Optimization Elements

- **Decisions variables:** $X_1, X_2, \dots, X_k$

- **Constraints:**

	LHS		RHS
Less than or equal	$f(X_1, X_2, \dots, X_k)$	$\leq$	b
Greater than or equal	$f(X_1, X_2, \dots, X_k)$	$\geq$	b
Equal to	$f(X_1, X_2, \dots, X_k)$	$=$	b

- **Objective:** $MAX\ (or\ MIN):\ f(X_1, X_2, \dots, X_k)$

Optimization problems involve three elements: decision variables, constraints and the objective. Can also have more than one objective (multi-objective problems).

Mathematical Formulation

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

Subject to:

$$f_l(X_1, X_2, \ldots, X_k) \leq b_l$$
$$f_k(X_1, X_2, \ldots, X_k) \geq b_k$$
$$f_m(X_1, X_2, \ldots, X_k) = b_m$$

Each functional relationship can be different as can the values on the right-hand side (RHS). Art and science to formulate.

As an Aside

- Different programming techniques exist for different problems, i.e. non-linear programming, integer programming, mixed-integer programming, networks

- We will only be covering Linear Programming today!

USMC Engine Example Problem

- Contract for a highly efficient engine to outfit two different vehicles (Orange and Blue) of which it has a plethora
- USMC receives engine and under an existing maintenance contract installs the engine into the two different vehicles
- USMC will only receive 200 engines during the next production cycle
- Main difference between the two models is the amount of labor and rubber material each model requires
  - Orange vehicles use 9 hours of labor and 12 feet of rubber material
  - Blue Vehicles use 6 hours of labor and 16 feet of rubber material
- Maintenance contract only has 1566 labor hours and 2,880 feet of rubber material available for the next production cycle
- USMC estimates cost avoidance savings of $350 for each Orange and $300 for each Blue vehicle

How many of each vehicle model should be outfitted?

Formulate Problem

1) Understand the problem
2) Identify the decision variables, what fundamental decision must me made?
3) State the objective function as a linear combination of the decision variables
4) State the constraints as linear combinations of the decision variables
5) Identify any upper or lower bounds on the decision variables

Formulate Problem Con't

1) **Understand the problem**: How many Orange and Blue to request to maximize cost avoidance savings, while using no more than 200 engines, 1566 labor hours and 2,880 feet of rubber material.
2) **Identify the decision variables**, what fundamental decision must me made: How many Orange and Blue vehicles to request be made, so let's represent: $Orange\ as\ X_1$ and $Blue\ as\ X_2$
3) **State the objective function** as a linear combination of the decision variables: $MAX\ 350X_1 + 300X_2$

Formulate Problem (Cont.)

4) State the constraints as linear combinations of the decision variables:
   a) Engine: $1X_1 + 1X_2 \leq 200$
   b) Labor: $9X_1 + 6X_2 \leq 1{,}566$
   c) Rubber Material: $12X_1 + 16X_2 \leq 2{,}880$

5) Identify any upper or lower bounds on the decision variables
   a) $X_1 \geq 0$
   b) $X_2 \geq 0$

Formulate Problem (Cont.)

$MAX: \quad 350X_1 + 300X_2$

Subject to:

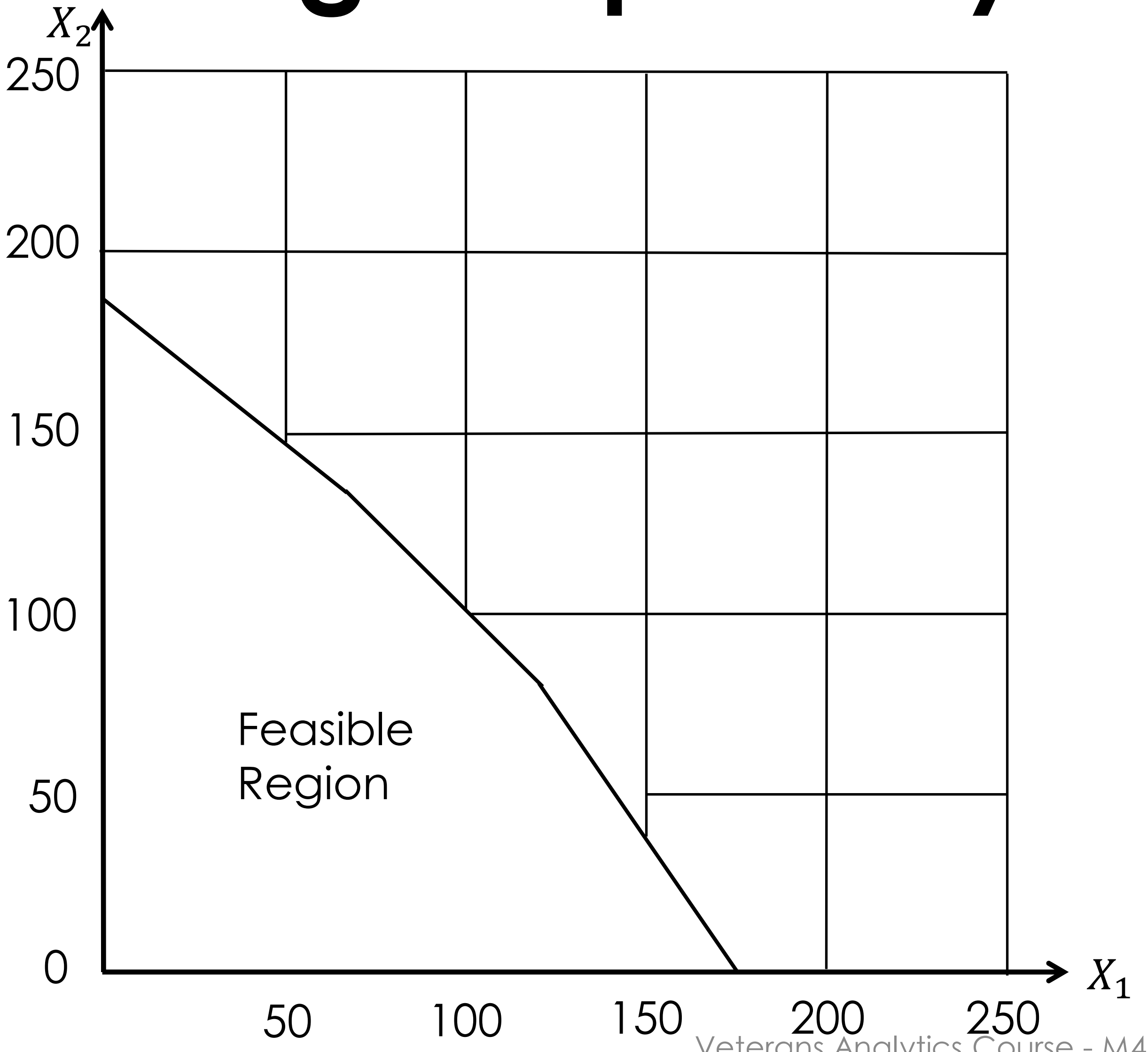
$$
\begin{aligned}
1X_1 + \quad 1X_2 &\le 200 \\
9X_1 + \quad 6X_2 &\le 1{,}566 \\
12X_1 + 16X_2 &\le 2{,}880 \\
X_1 \quad &\ge 0 \\
X_2 &\ge 0
\end{aligned}
$$

Goal is to maximize cost avoidance savings by determining the values for X_1 and X_2 that maximizes the objective while simultaneously satisfying all constraints

Linear Programming

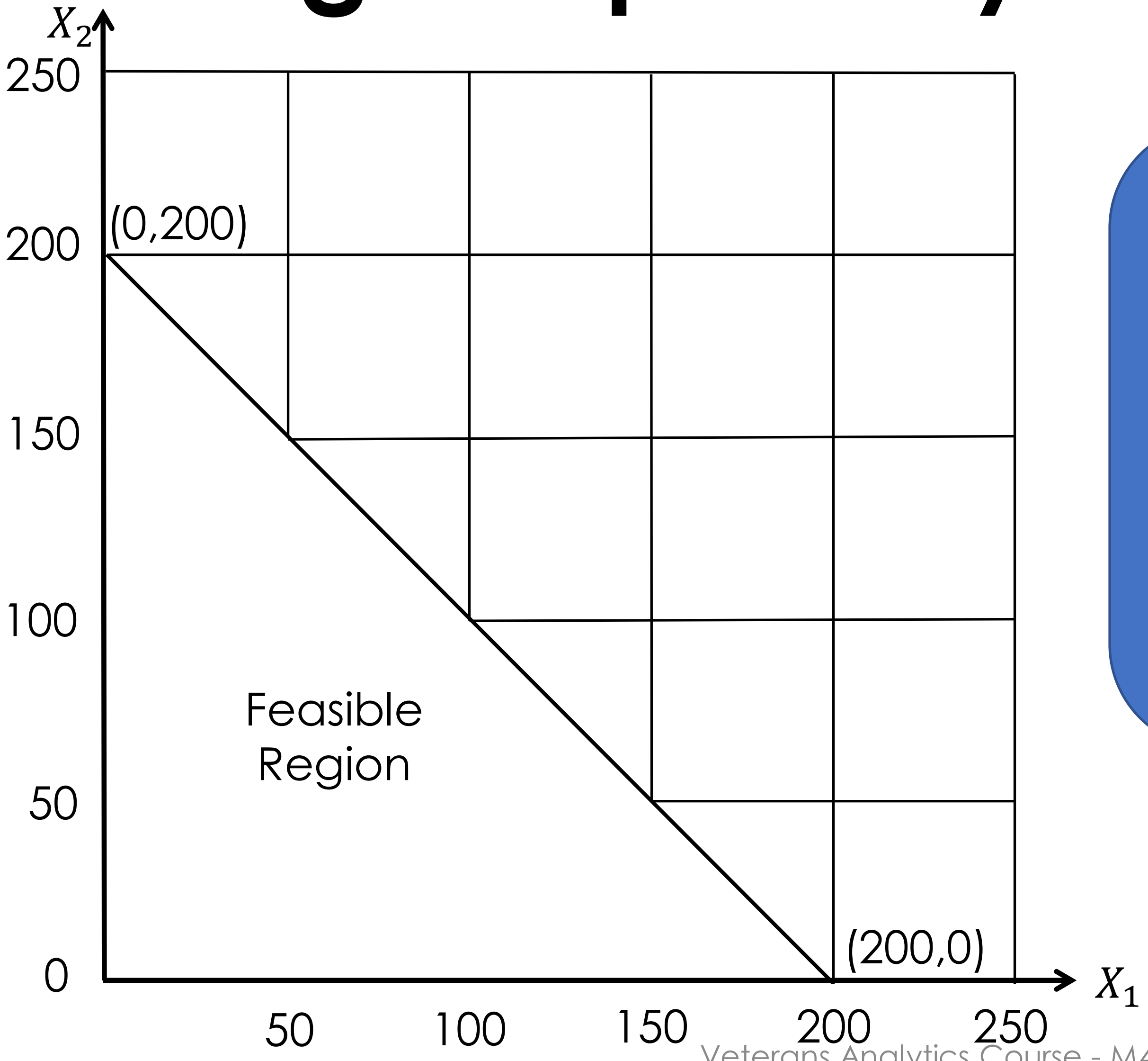
Solving Graphically

Solving Graphically



Uses linear objective function and linear constraints to solve by determining feasible region, the area where values satisfy all constraints

Solving Graphically



Plot the First Constraint's boundary lines

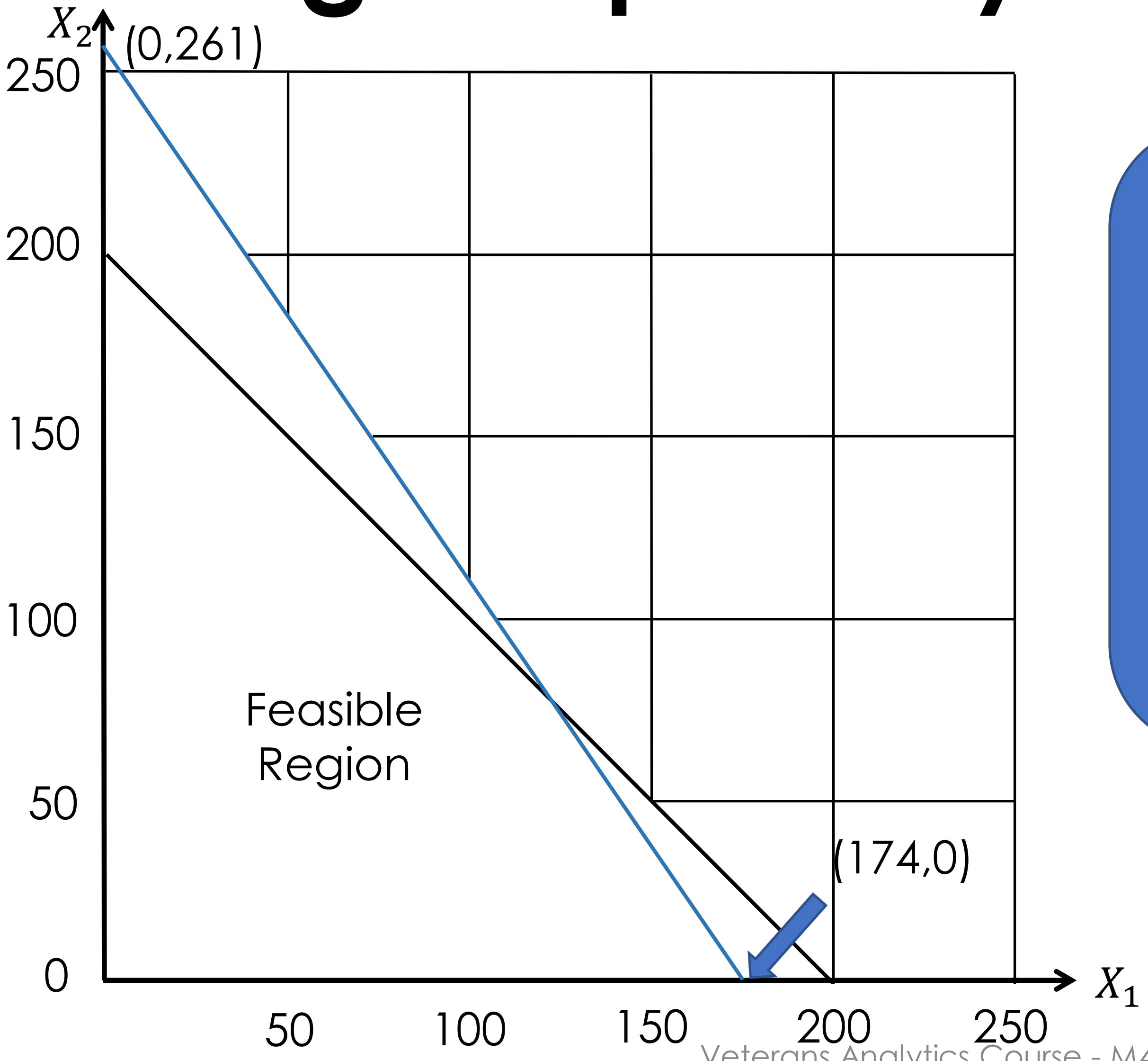
$$1X_1 + 1X_2 = 200$$

and determine which side of boundary satisfies the constraint

$$1X_1 + 1X_2 \leq 200$$

(test point (0,0))

Solving Graphically



Plot the Second Constraint's boundary lines

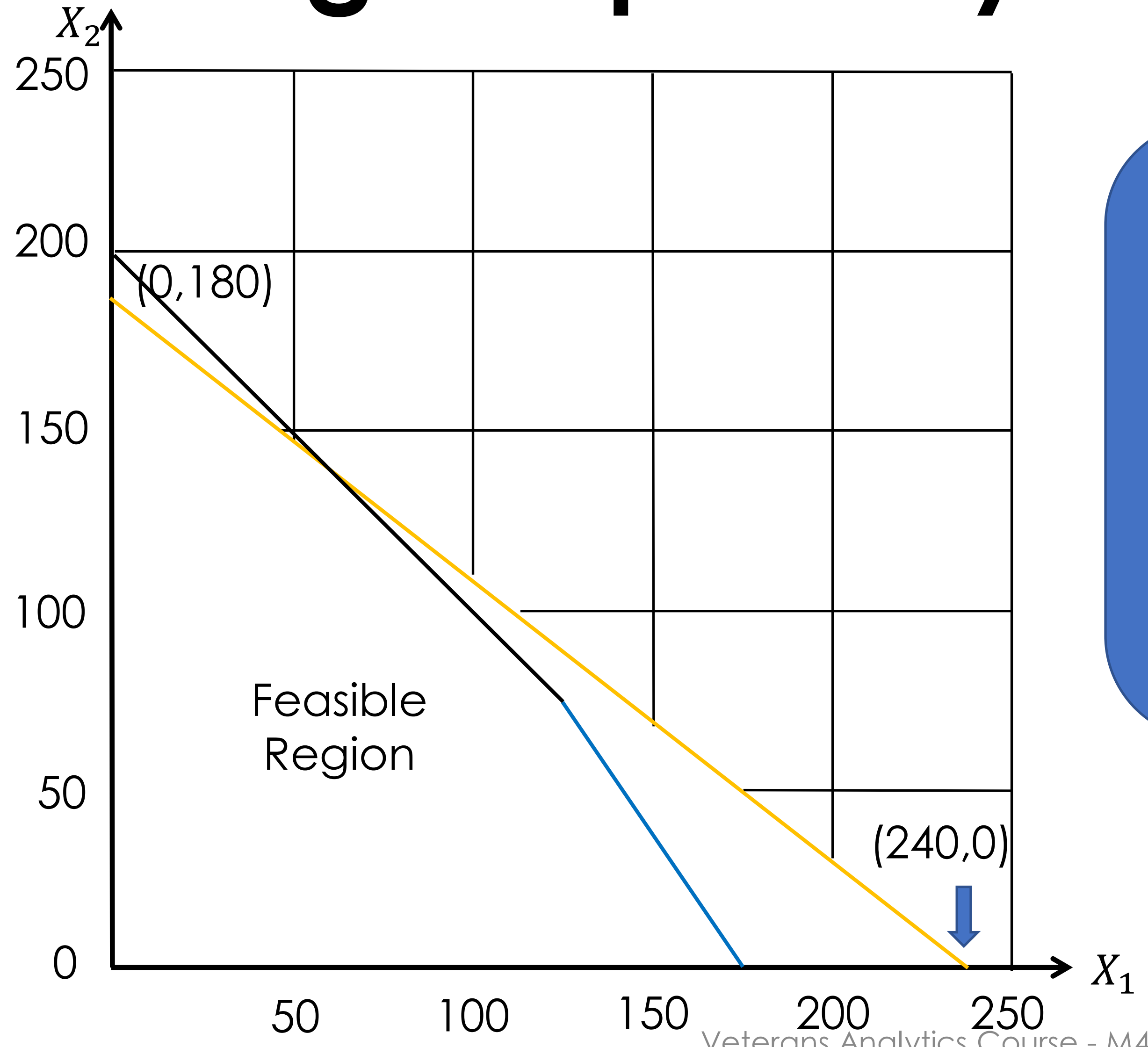
$$9X_1 + 6X_2 = 1{,}566$$

and determine which side of boundary satisfies the constraint

$$9X_1 + 6X_2 \leq 1{,}566$$

(test point (0,0))

Solving Graphically



Plot the Third Constraint's boundary lines

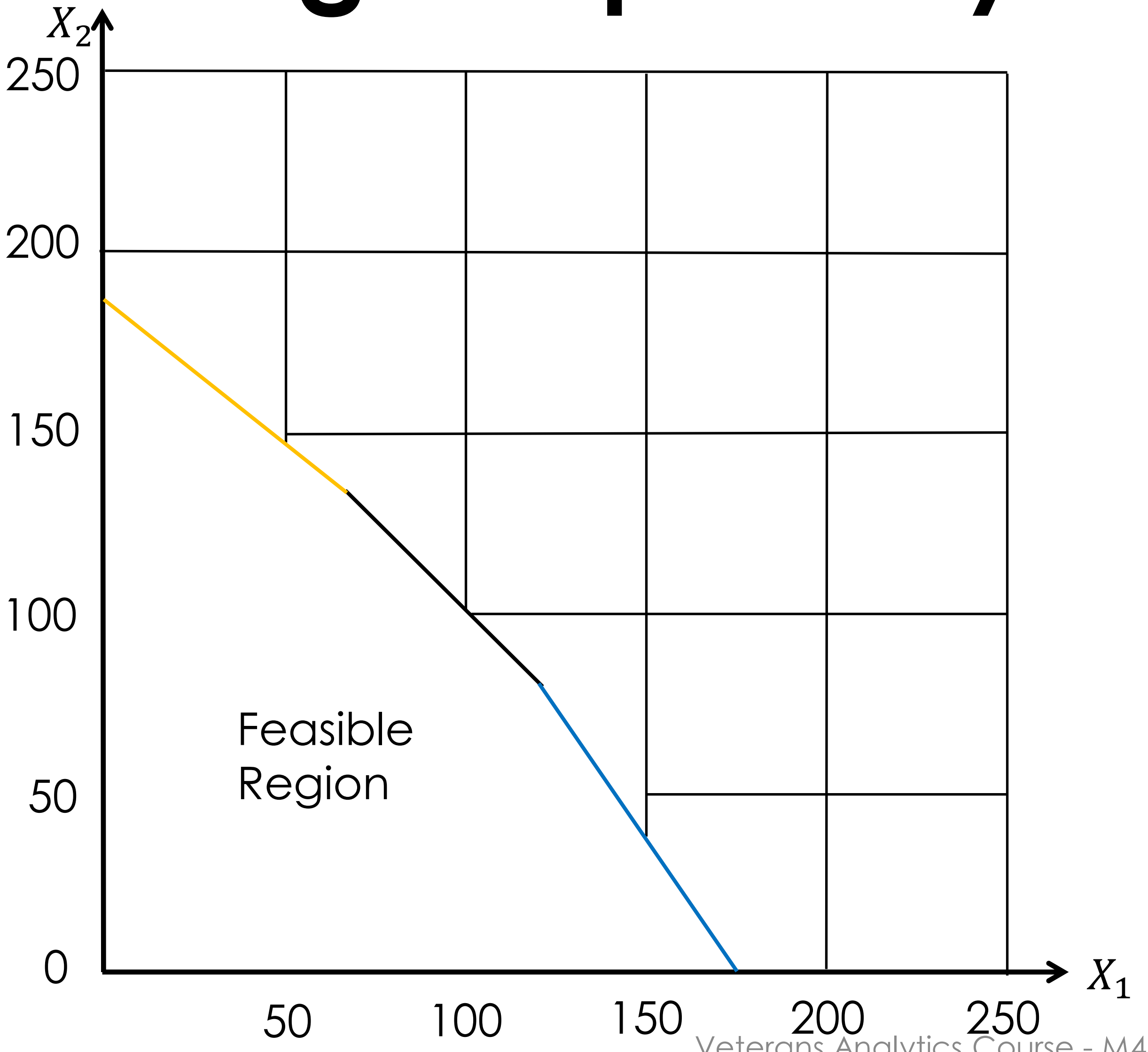
$$12X_1 + 16X_2 = 2{,}880$$

and determine which side of boundary satisfies the constraint

$$12X_1 + 16X_2 \leq 2{,}880$$

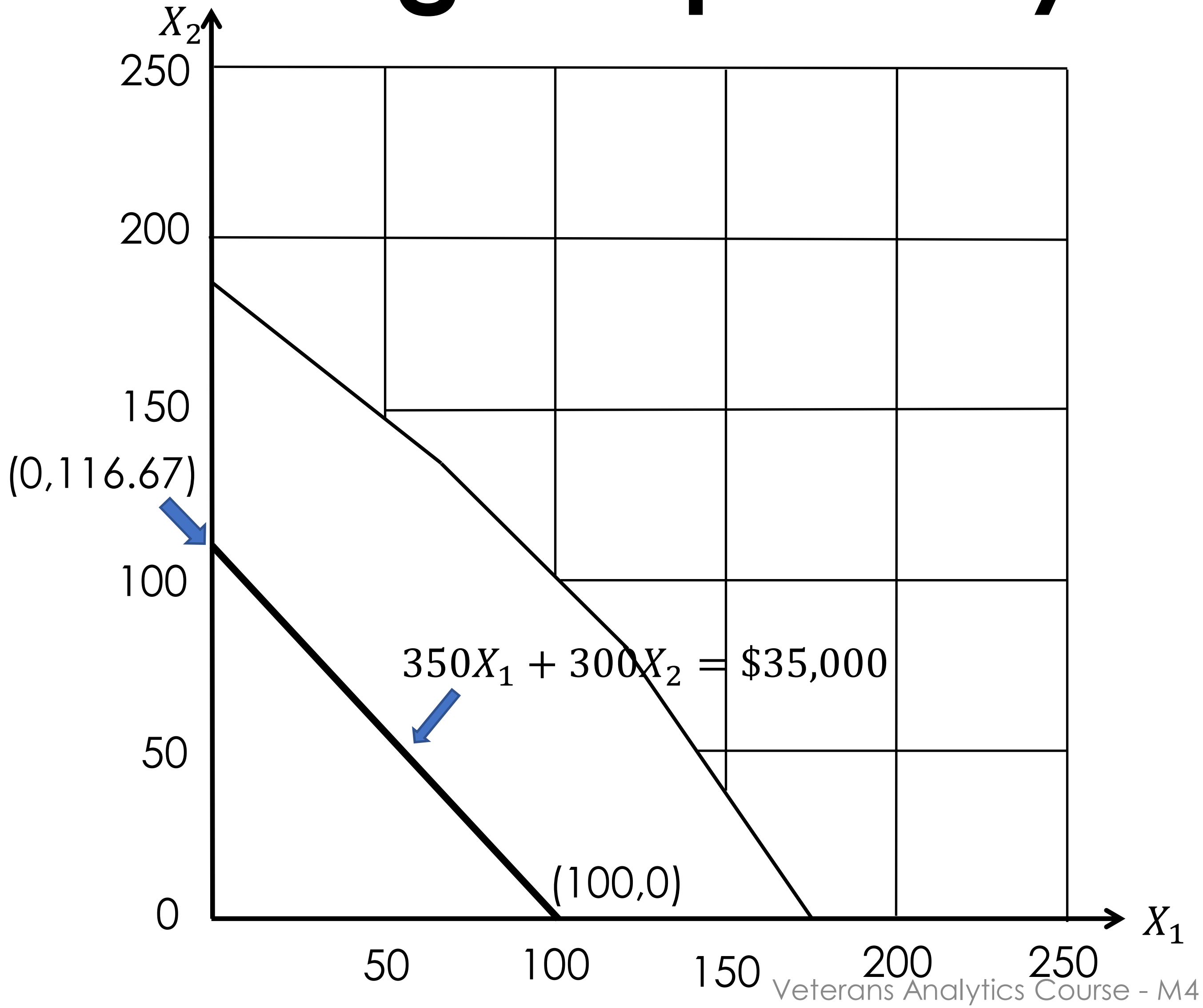
(test point (0,0))

Solving Graphically



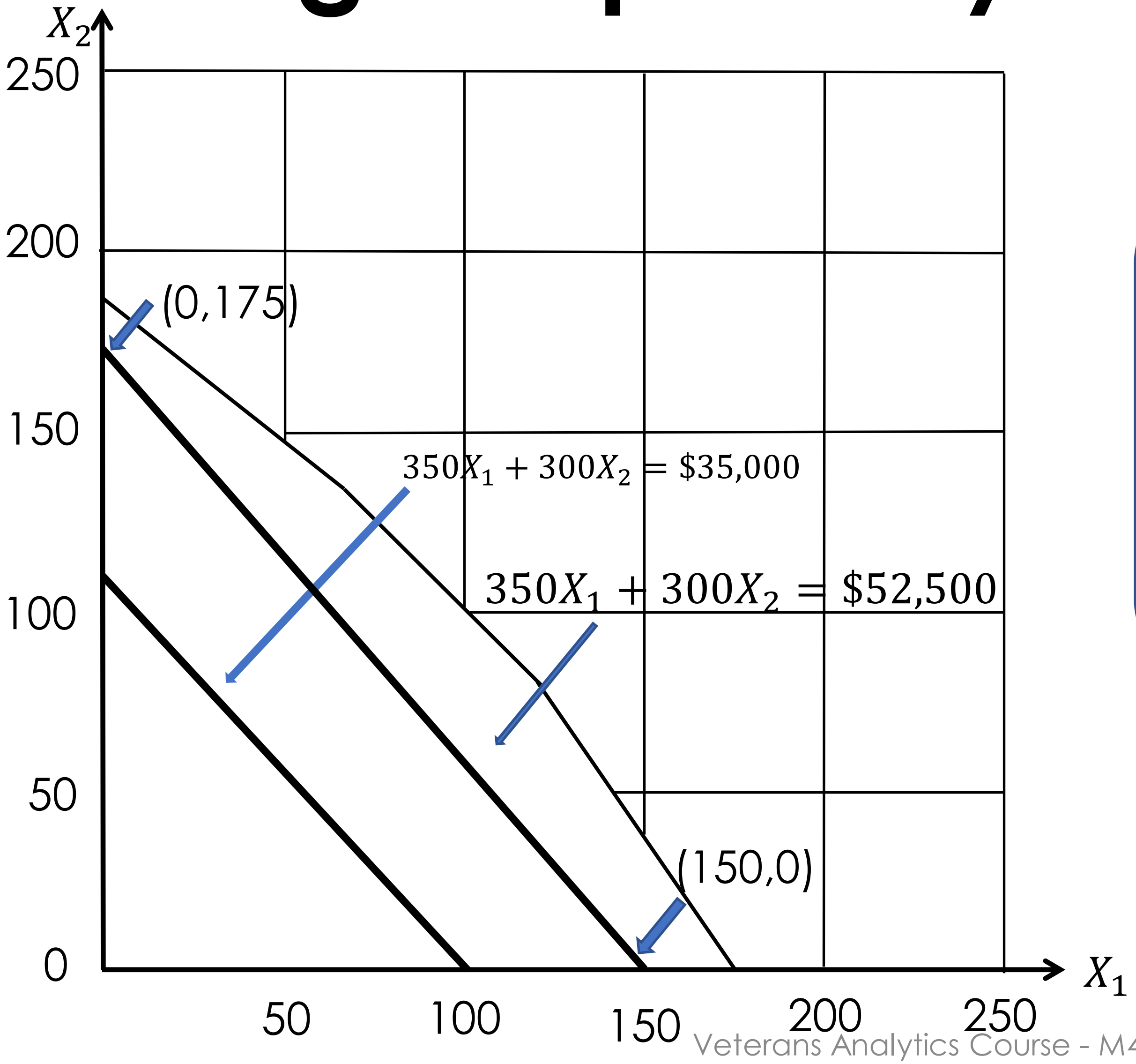
Plot the Objective Function to find solution, if optimal solution exists for finite objective function, will occur where boundary lines intersect

Solving Graphically



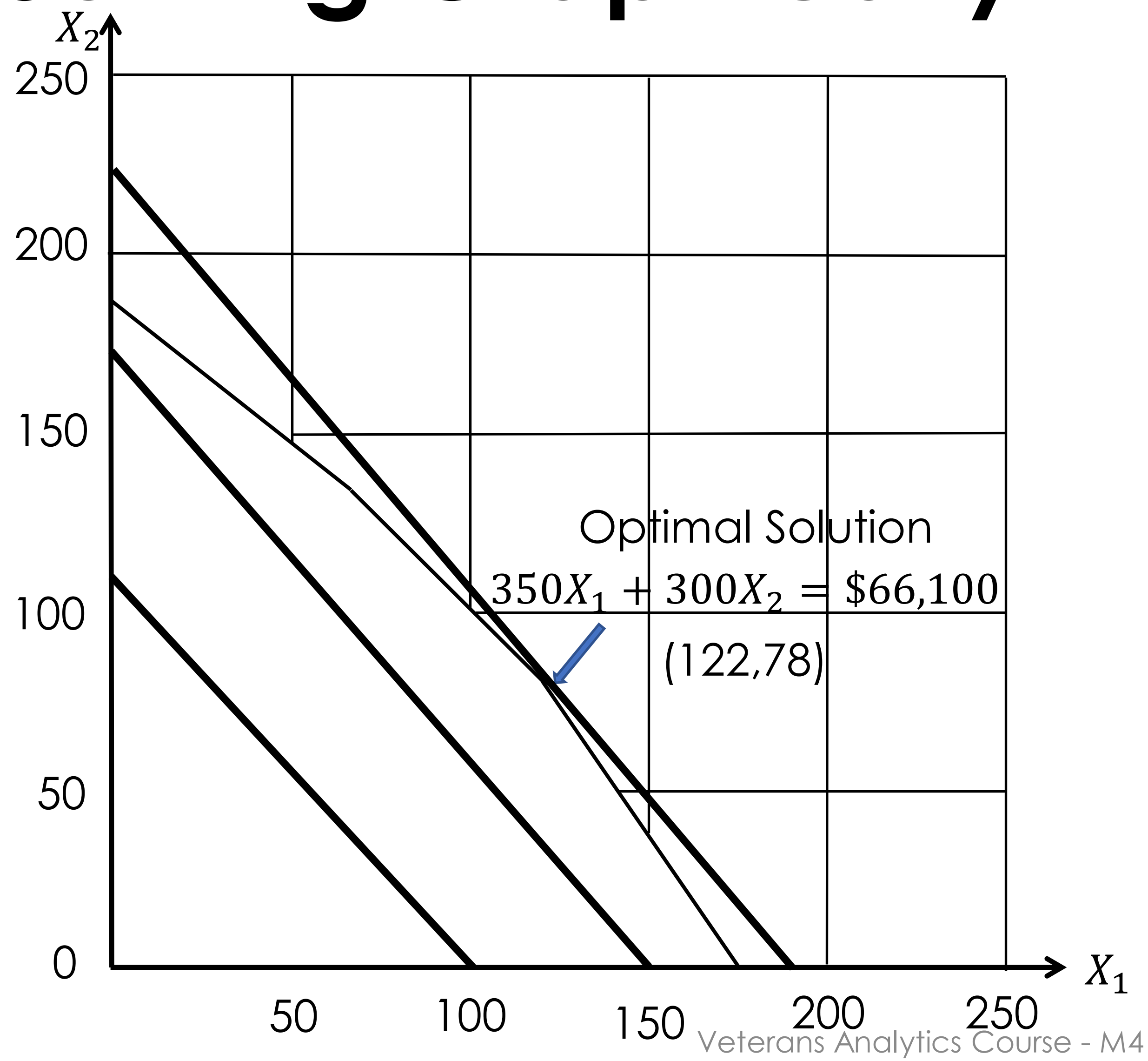
Plot the Objective Function to find solution, if optimal solution exists for finite objective function, will occur where boundary lines intersect, try when objective is equal to $35,000

Solving Graphically



Plot the Objective Function to find solution, if optimal solution exists for finite objective function, will occur where boundary lines intersect, try when the objective is equal to \$52,500

Solving Graphically

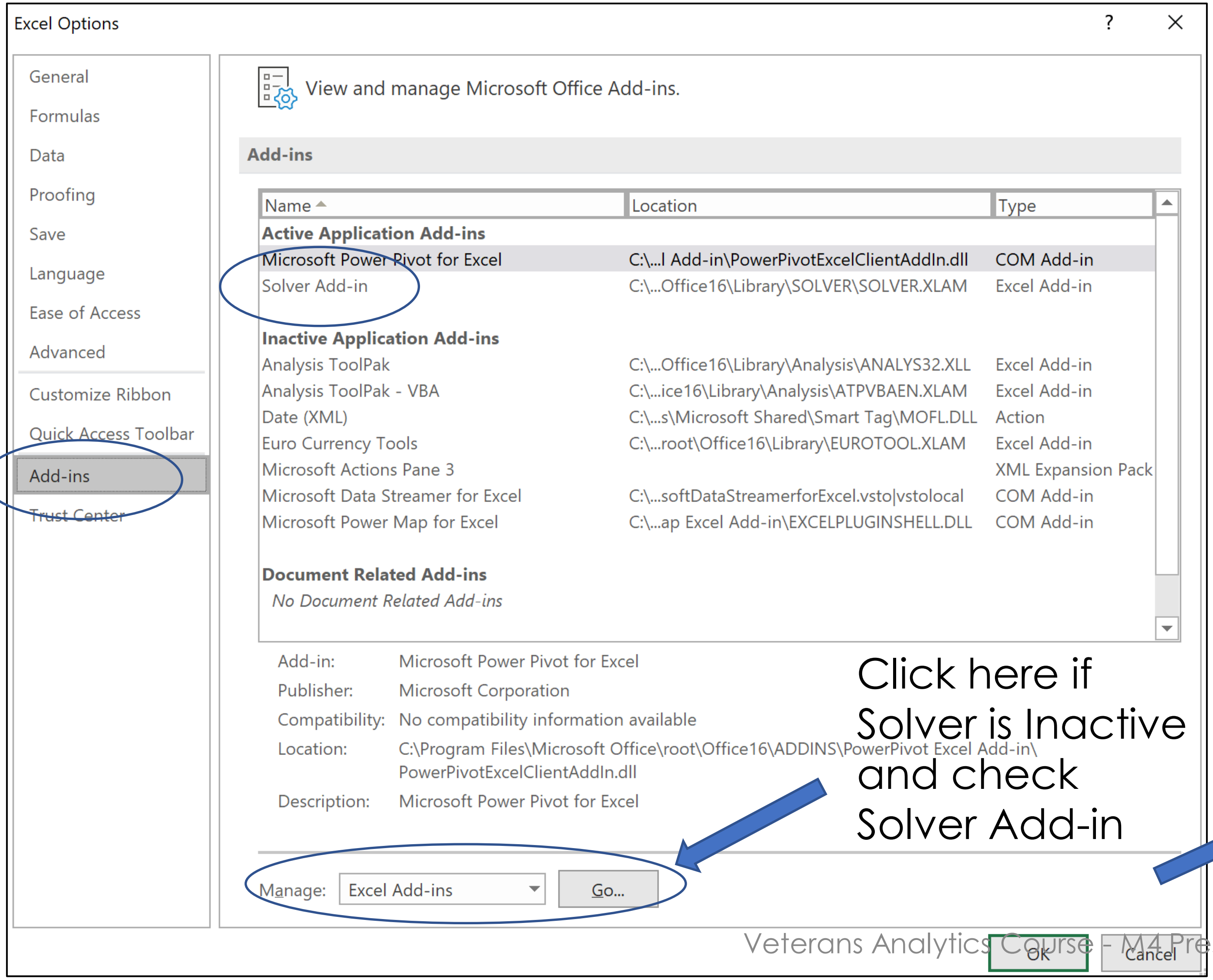


Plot the Objective Function to find solution, if optimal solution exists for finite objective function, will occur where boundary lines intersect

Practical Excel Example

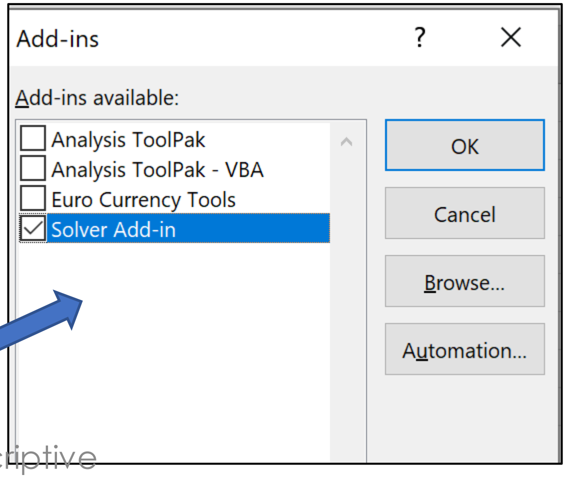
USMC Orange and Blue Vehicle Production

Ensure Solver is active



Click here if Solver is Inactive and check Solver Add-in

- File, Options, Add-ins to verify Solver is active
- If inactive, go to Manage Excel Add-Ins and click Go to enable Solver



Demonstration

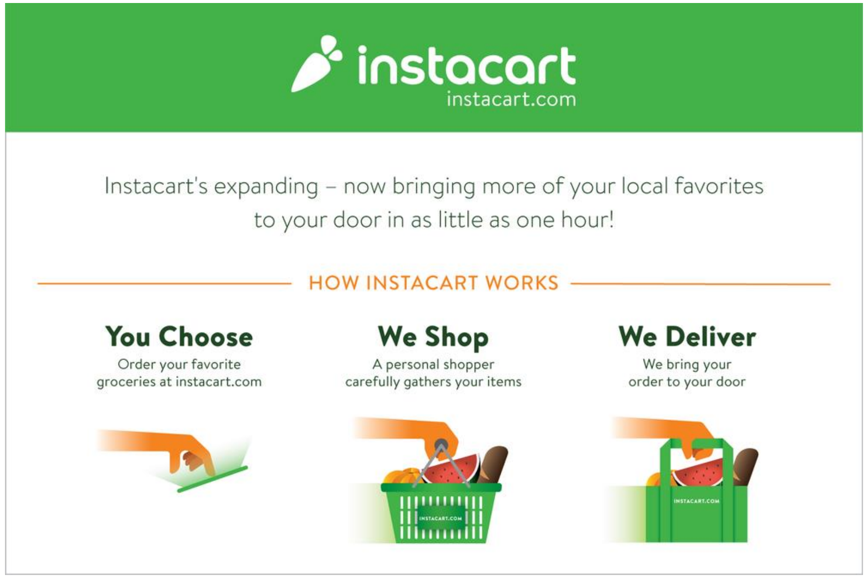
Case Study

Grocery delivery application

Individuals place order through an app
Variety of retailers
Pickers in store (full time or part)
Delivery

Metrics

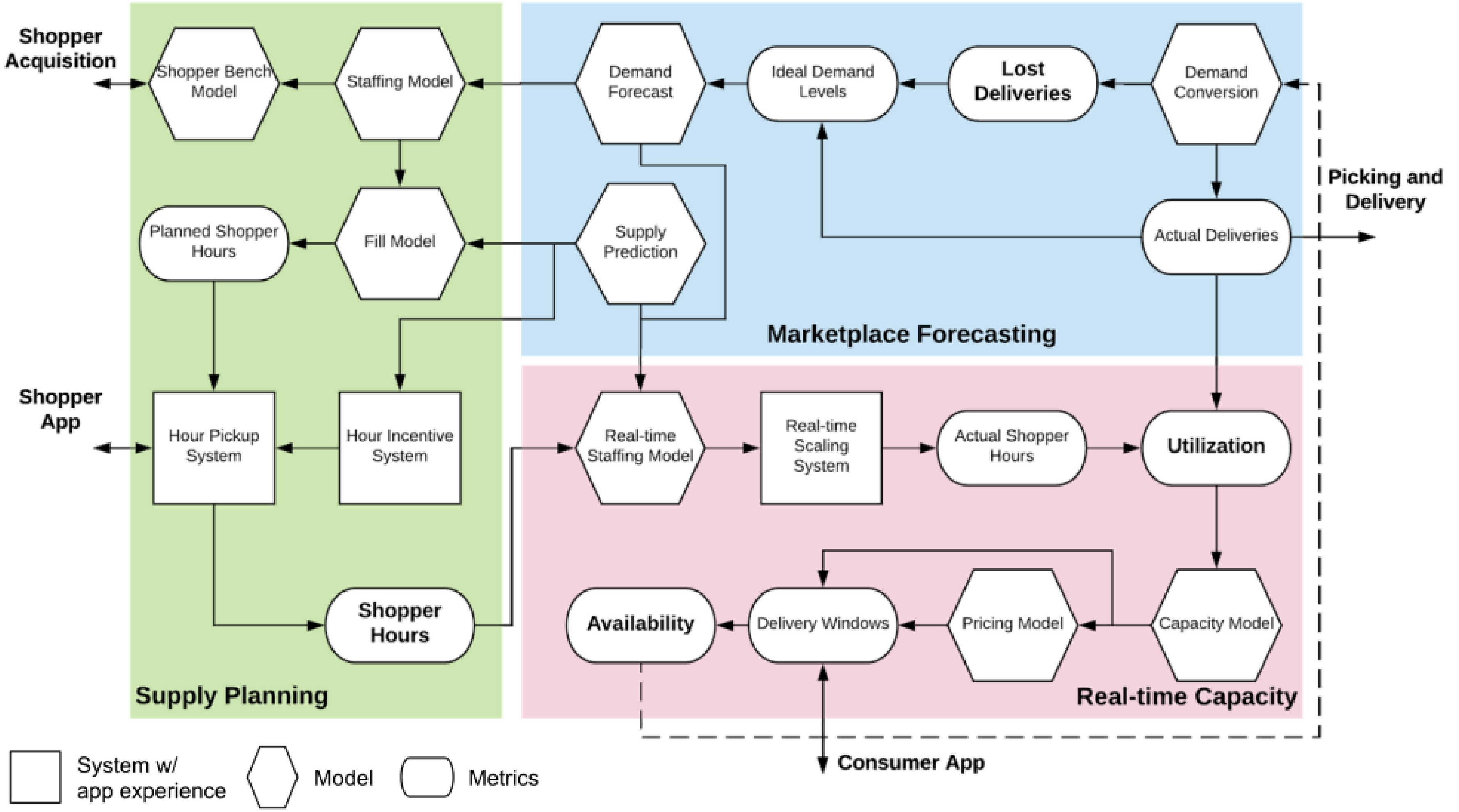
Availability
Idleness
Unmet Demand



Discussion -

How would you begin to formulate an optimization model for this system?
What approach(es) are appropriate?

Case Study

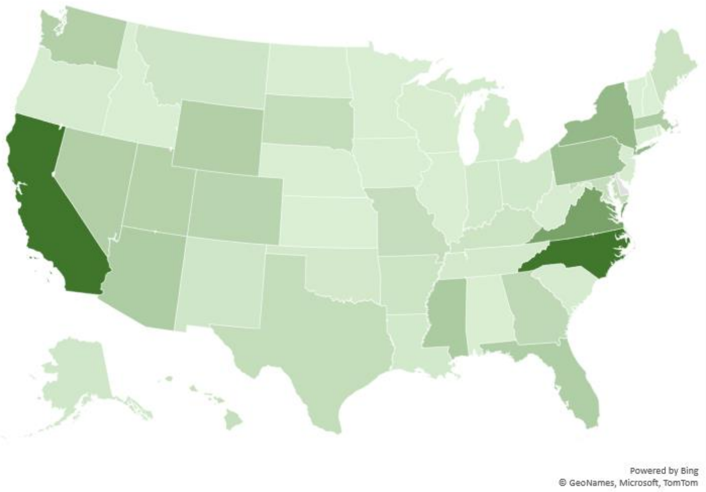


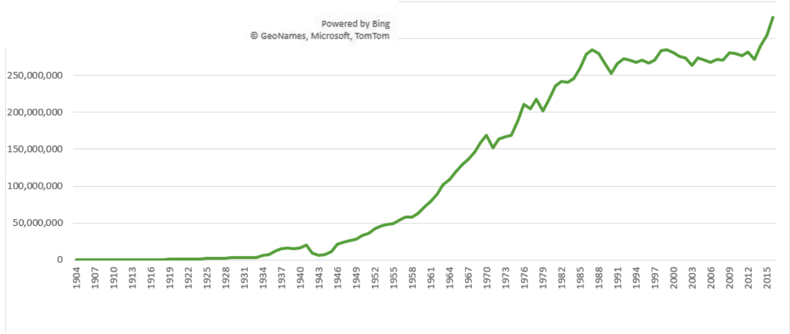
https://tech.instacart.com/instacart-anytime-a-data-science-paradigm-33eb25a5c32d

Thank you and stay curious!

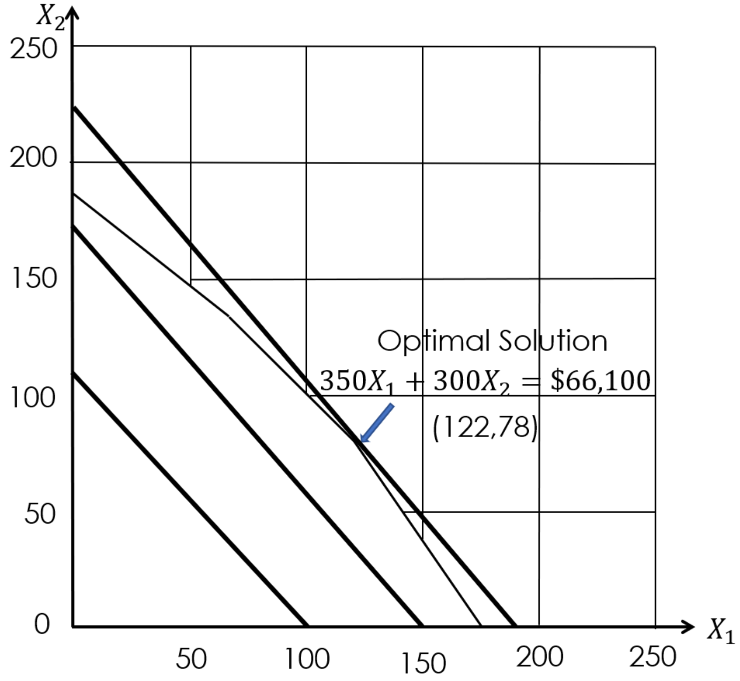
Course Wrap-up

- A look back at what we’ve explored in this class:





$$p(A|B)=\frac{p(A\cap B)}{p(B)}$$



What's next?

We've shared a sample of analytics applications. Where do you go from here?

- Check out local meetups on Meetup.com
- Explore upcoming conferences and events from professional societies like MORS and INFORMS
- Build your online portfolio! Kaggle, TidyTuesday, and Challenge.gov are great places to find inspiration
- Lifelong learning
- Find your Analytics Superpower!

Expand your influence, connections, skills

VETERANS IN ANALYTICS PANEL DISCUSSION

September 17, 2020 – 6:00 pm EDT

John Alexander Harris
Full-Stack Data Scientist
Boxelder Analytics

Randi VanNyhuis
Commercial Intelligence Manager
The Walt Disney Company

Joshua Wilson
Corporate Relationship Manager
America's Warrior Partnership

Dan Hudson
Chief Technology Officer | Chief Data Scientist
ReefPoint Group LLC

Jerome Dixon
Senior Operations Research Analyst
CANA Advisors