Session 2: Capacity Management

Canan Adelman

UIC Business
IDS 532: Introduction to Operations Management

August 31, 2021

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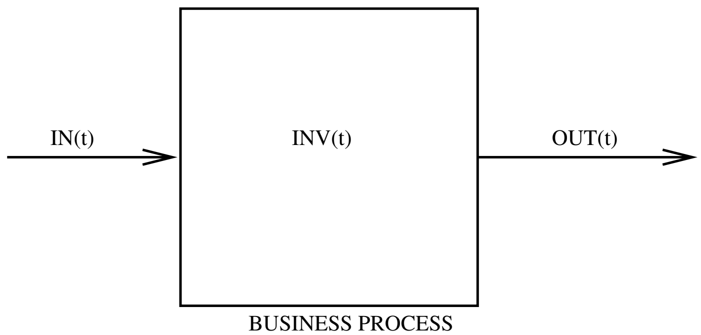
Last Class

1. Operations and Marketing Reconciliation
2. Operations Quadrangle
3. 

4. Little's Law
5. Capacity Analysis

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Agenda

1. Buildup graphs
2. Capacity expansion
3. Managing product mix
4. Linear programming

National Cranberry Cooperative

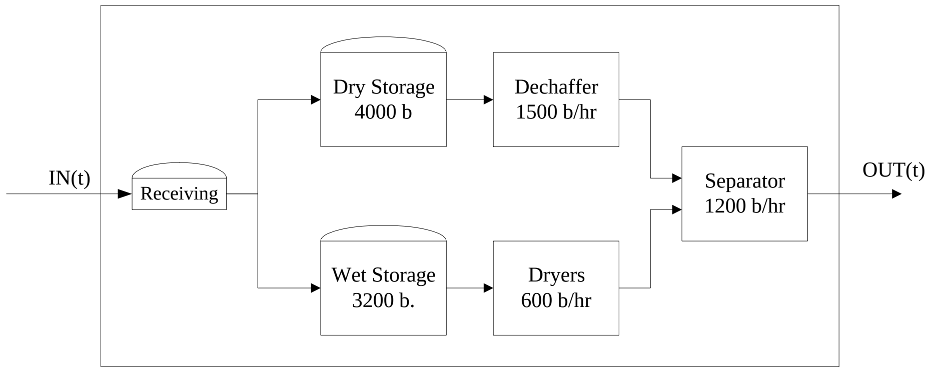
NCC Capacity expansion
19000 b/day, 70/30 wet/dry

# extra dryers	# extra separators	Makespan		
0*	0	22.2	=	$\max\left\{\frac{.7(19000)}{600}, \frac{19000}{1200}\right\}$
1*	0	16.625	=	$\max\left\{\frac{.7(19000)}{800}, \frac{19000}{1200}\right\}$
2	0*	15.8	=	$\max\left\{\frac{.7(19000)}{1000}, \frac{19000}{1200}\right\}$
2*	1	13.3	=	$\max\left\{\frac{.7(19000)}{1000}, \frac{19000}{1600}\right\}$
3	1*	11.875	=	$\max\left\{\frac{.7(19000)}{1200}, \frac{19000}{1600}\right\}$
3*	2	11.08	=	$\max\left\{\frac{.7(19000)}{1200}, \frac{19000}{2000}\right\}$

* constraining resource

What is the capacity of the NCC plant?

Capacity of NCC



- We let $\lambda = \lambda_w + \lambda_d$
- We want to maximize $\lambda_w + \lambda_d$
- subject to the following constraints:
  - $\lambda_w \leq 600$
  - $\lambda_d \leq 1500$
  - $\lambda_w + \lambda_d \leq 1200$
  - $\lambda_w \geq 0, \ \lambda_d \geq 0$

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Capacity of NCC: Linear Program

$$\max \ \lambda_w + \lambda_d$$

subject to:

$$\begin{aligned} \lambda_w &\leq 600 \\ \lambda_d &\leq 1500 \\ \lambda_w + \lambda_d &\leq 1200 \\ \lambda_w &\geq 0 \\ \lambda_d &\geq 0 \end{aligned}$$

Decision variables, constraints, objective function

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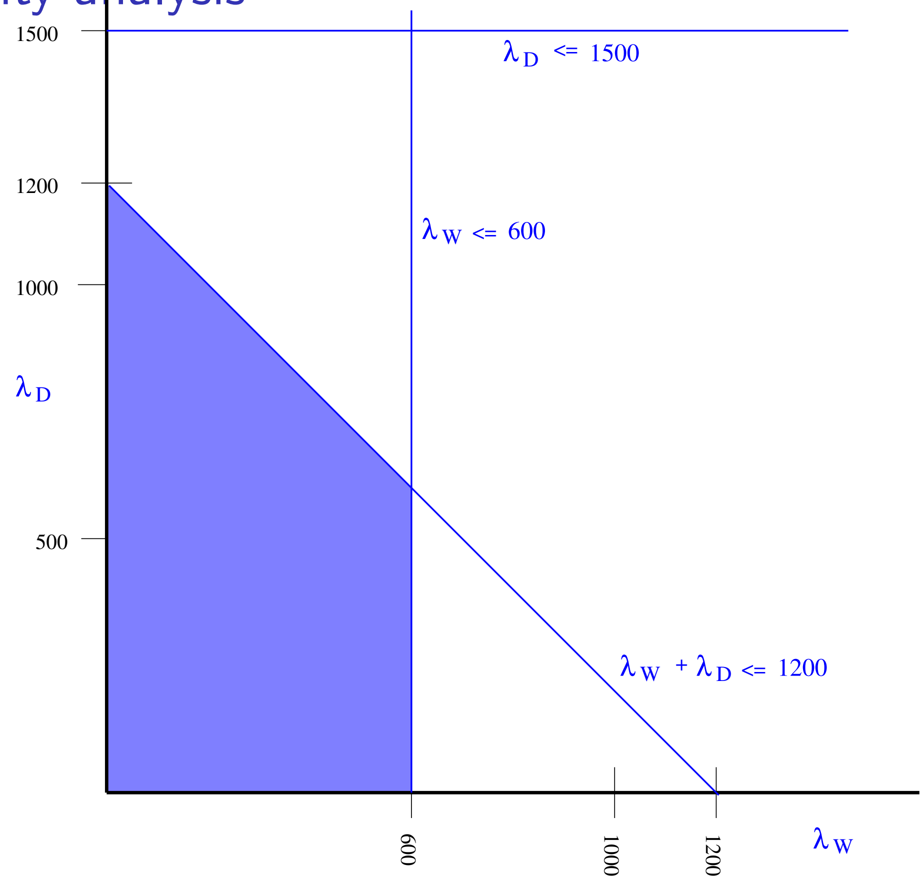
Capacity analysis



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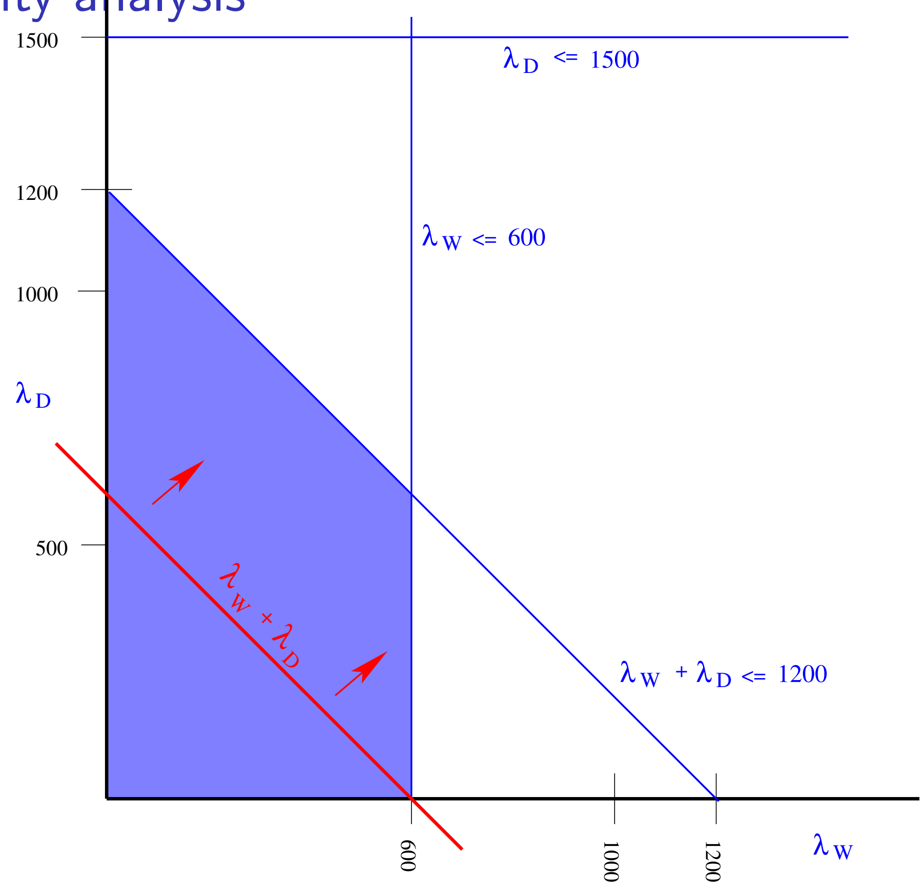
Capacity analysis



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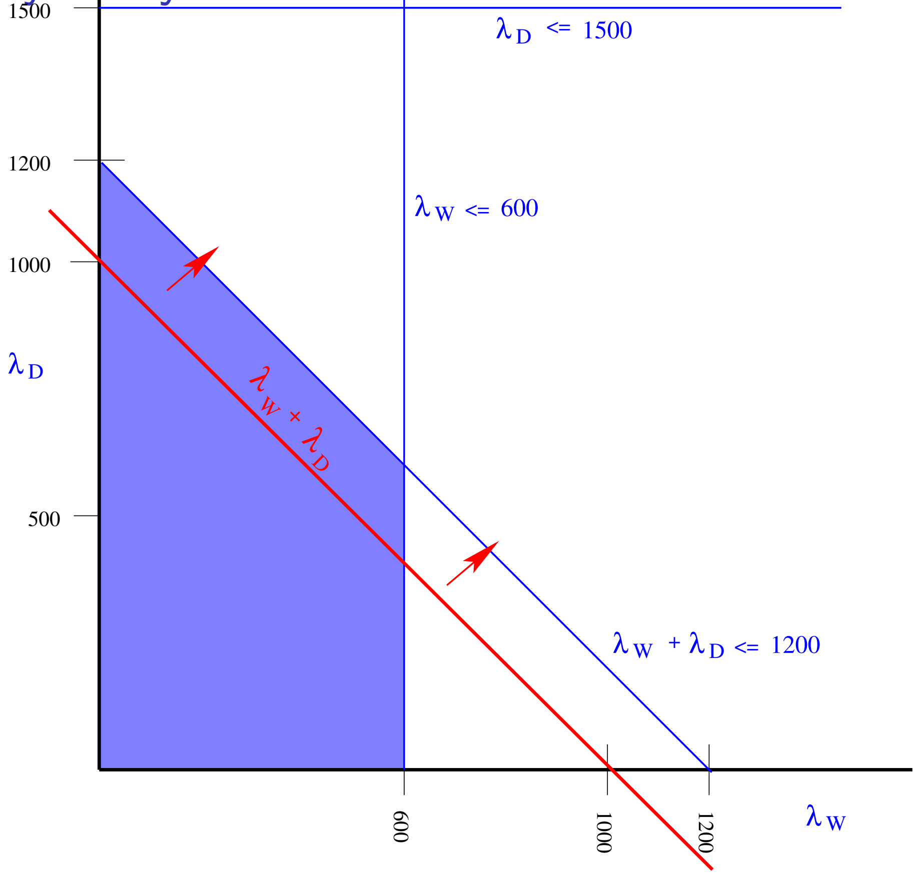
Capacity analysis



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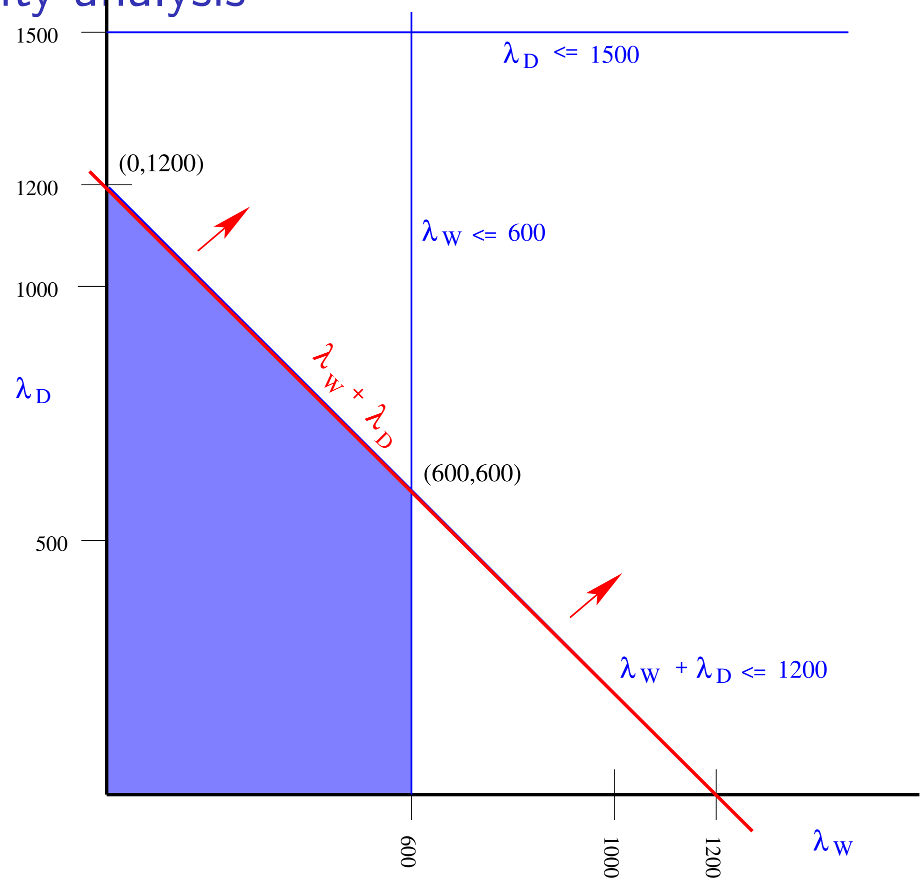
Capacity analysis



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Capacity analysis

The 70/30 Product Mix Constraint

$$\frac{\lambda_W}{\lambda_W + \lambda_D} = .70$$
$$\lambda_W = .70\ \lambda_W + .70\ \lambda_D$$
$$.30\ \lambda_W = .70\ \lambda_D, \text{ or,}$$
$$\lambda_D = 30/70\ \lambda_W$$

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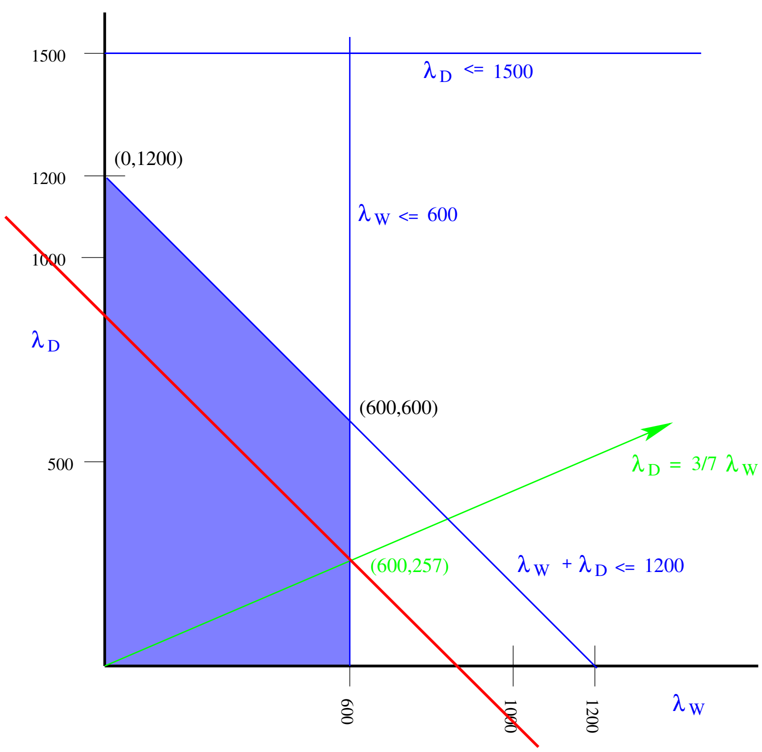
Capacity analysis



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Capacity analysis

Product Mix Constraints in General

$\lambda_D = (\%DRY/\%WET)\ \lambda_W$

Year	% WET	%DRY	%DRY/%WET	λ_W	λ_D	Capacity
1	70	30	30/70	600	257	857
2	75	25	25/75	600	200	800
3	82	18	18/82	600	132	732
4	88	12	12/88	600	81	681
5	93	07	7/93	600	45	645

Merton Trucks

What is the main issue facing Merton Truck?

What product mix to select to maximize contribution.

Merton Trucks

Contribution towards Fixed Costs is (Revenue - Var Costs)

- Model 101: 39,000-24,000-4,000-8,000 = \$3,000 per truck
- Model 102: 38,000-20,000-4,500-8,500 = \$5,000 per truck
- THEREFORE WE SHOULD MAKE AS MANY 102s AS POSSIBLE! ???

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Contribution if only produce Model 101

- How much can we produce?
  - Max production = MIN $\{$ 4000/1, 6000/2, 5000/2 $\}$ = 2500
- thus, Contribution = 2500(3000) = 7,500,000

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Contribution if only produce Model 102

- Max production $= \text{MIN}\ \{\ 4000/2,\ 6000/2,\ 4500/3\ \} = 1500$
  - How much can we produce?
- thus, Contribution $= 1500\ (5000) = 7{,}500{,}000$

Current Policy

1000 M101's
1500 M102's (As many as possible)
Total Contribution $= 1000\ (3000) + 1500\ (5000) = \$10.5$ M

- Are they operating at their capacity with this policy?
- Is this the best policy?

Is there a better policy?

- 2000 M101's
- 1000 M102's

Total Contribution $= 2000\ (3000) + 1000\ (5000) = \$11.0$ M

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A Framework for Capacity Planning

There are many product mix solutions that Merton might choose.

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A framework

Let:

X1 = Number of 101 to produce

X2 = Number of 102 to produce

We seek to:

Maximize 3000 X1 + 5000 X2

subject to:

- Engine Assembly:
  - $X_1 + 2X_2 \leq 4000$
- Metal Stamping:
  - $2X_1 + 2X_2 \leq 6000$
- Model 101 Assembly:
  - $2X_1 \leq 5000$
- Model 102 Assembly:
  - $3X_2 \leq 4500$
- Non-negativity:
  - $X_1 \geq 0, \quad X_2 \geq 0$

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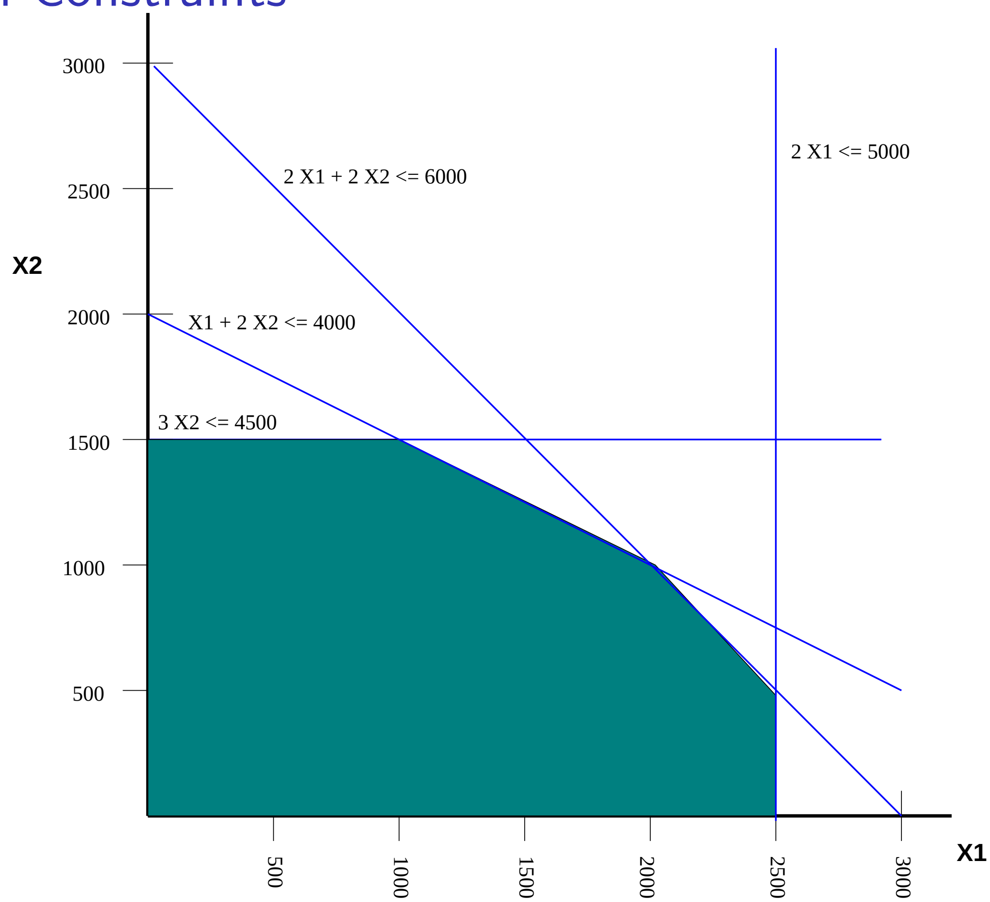
Graph Constraints



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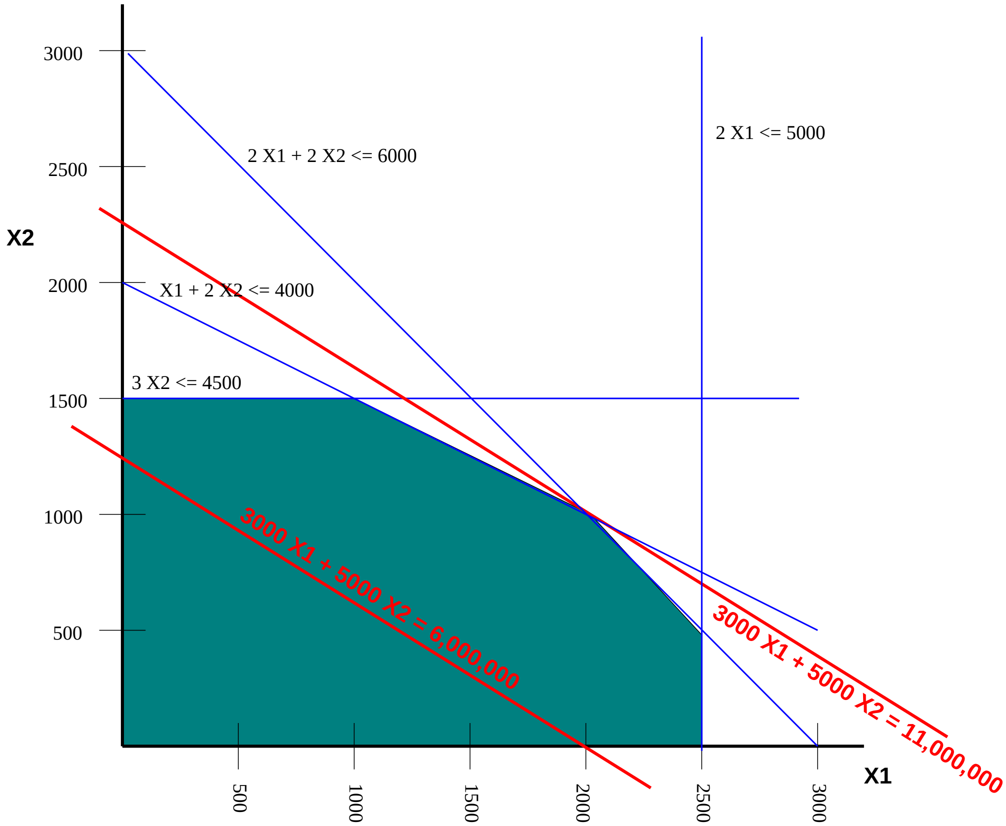
Find Optimal Solution



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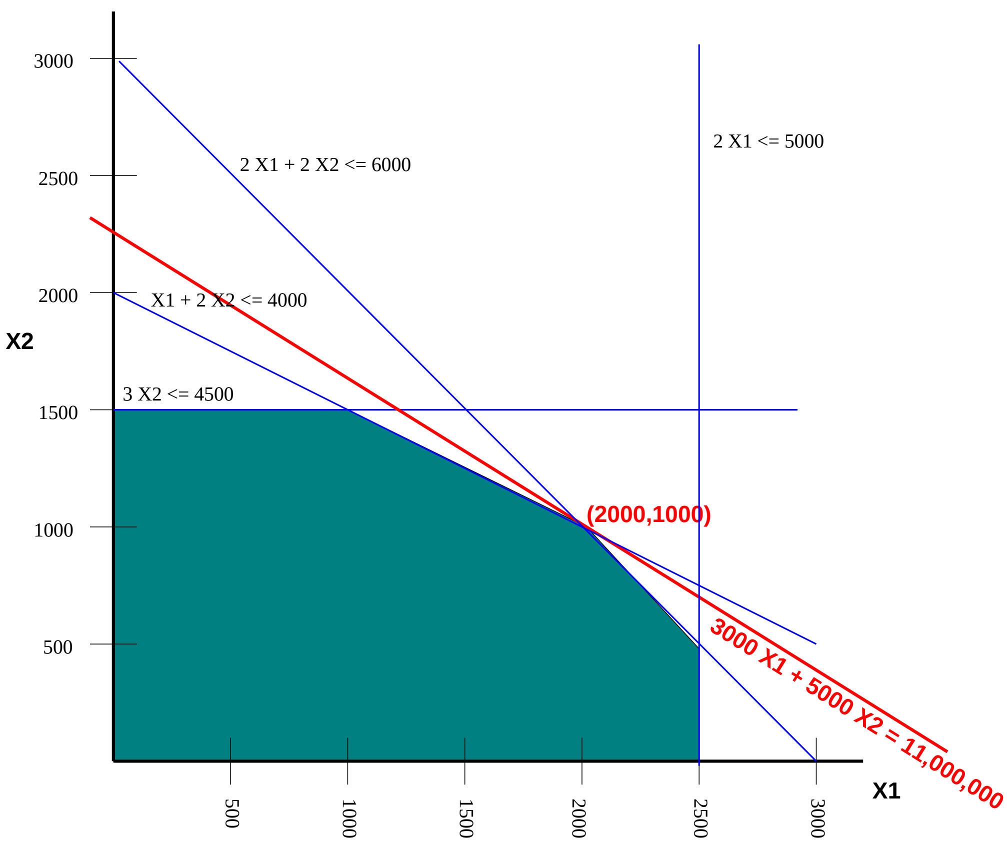
Find Optimal Solution



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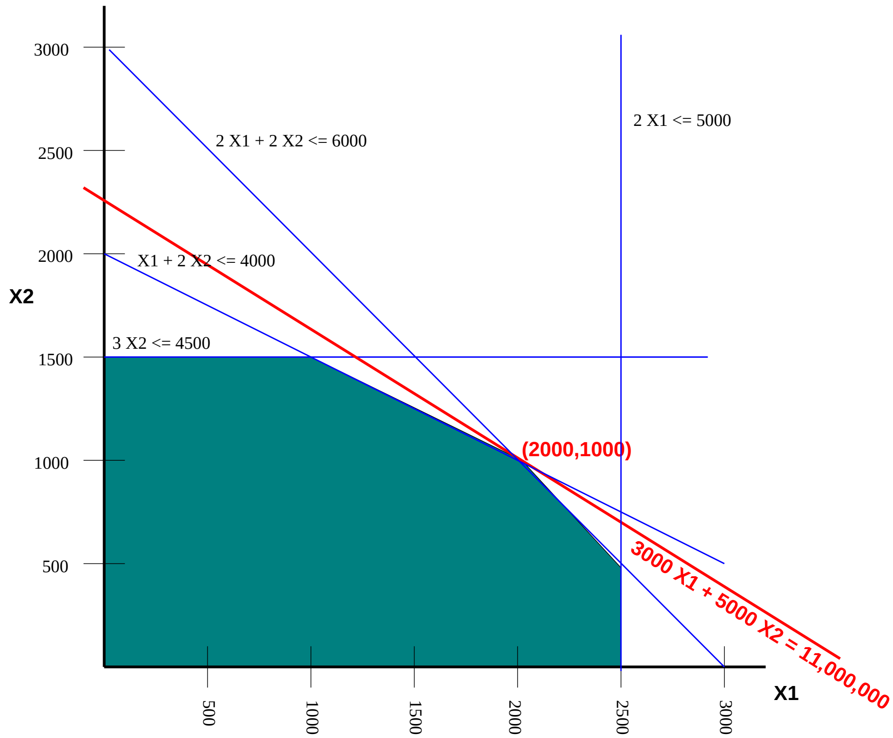
Find Optimal Solution

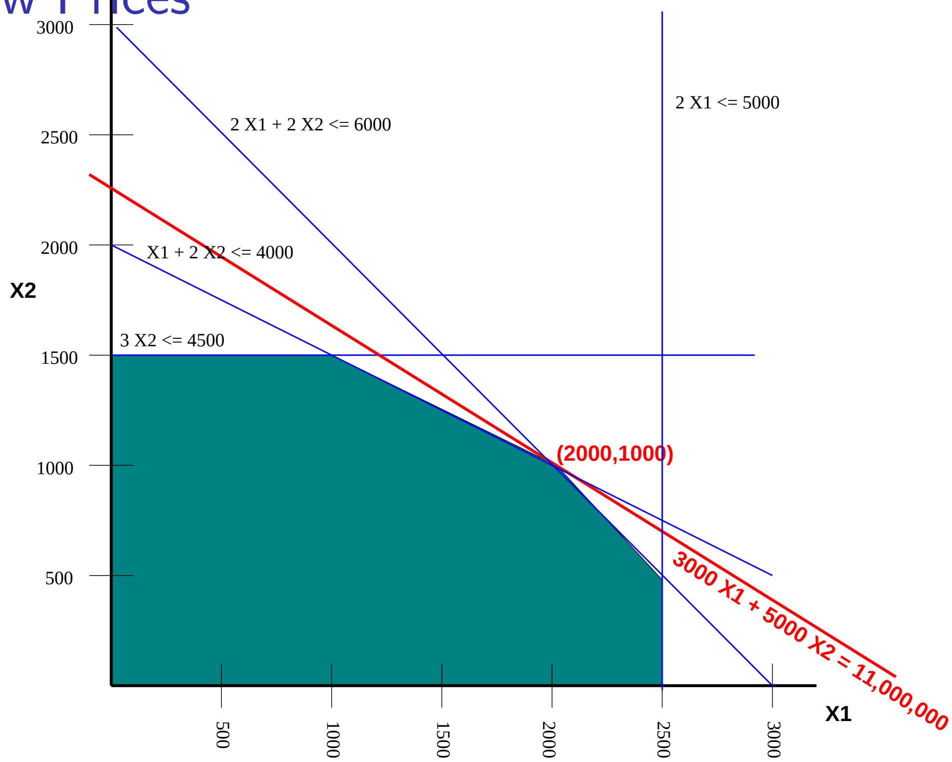


How should management structure the incentives of the sales force?

Excel Solver

- How to solve larger problems
- Which resouce(s) should I expand?
- How much would I pay for one more unit of a given resource?
- How sensitive am I to input data?

Shadow Prices



How much benefit do I get by adding an additional unit of a resource?

The Shadow Price of a Resouce

- given by All Linear Program Solvers
- Shadow Price of a resouce > 0 only when constraint is tight
- For example: Shadow Price on Engine Assembly is 2000
  - One more unit of Engine Assembly is worth \$2000
  - Will make 1999 M101s, and 1001 M102s
  - Contribution $= 3000\ (1999) + 5000\ (1001) =$ \$11,002,000

Practice Exercise: Insulation Problem

An insulation plant makes two types of insulation called type B and type R. Both types of insulation are produced using the same machine. The machine can produce any mix of output, as long as the total weight is no more than 70 tons per day.

Insulation leaves the plant in trucks; the loading facilities can handle up to 30 trucks per day. One truckload of type B insulation weighs 1.4 tons; one truckload of type R weighs 2.8 tons. Each truck can carry type B insulation, type R insulation, or any mixture thereof. The insulation contains a flame retarding agent which is presently in short supply; the plant can obtain at most 65 canisters of the agent per day. One truckload of (finished) type B insulation requires an input of three canisters of the agent, but one truckload of type R insulation requires only one canister.

Carla Linton, the plant manager, has calculated that, at current prices, the contribution from each truckload of type B is $950, and $1,200 for type R. There appears to be no difficulty in selling the entire output of the plant, no matter what production mix is selected.

How much of each kind of insulation should be produced?

Session 2: Overview

- A process flow diagram and build-up graph facilitates analysis
- Capacity can be complex, often depending on product mix
- Capacity expansion analysis
  - What is my path of expansion?
  - What are the gains along this path?
- Framework : Optimize an objective function subject to constraints
  - Use LP solver — such as included in excel
  - Shadow prices — value of a resouce