Digital Technologies and Value Creation

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Learning objectives of today

Goals:

- Learn how to formulate linear and integer programs and solve them in Excel Solver
- Understand the case that is central to your final assignment

How will we do this?

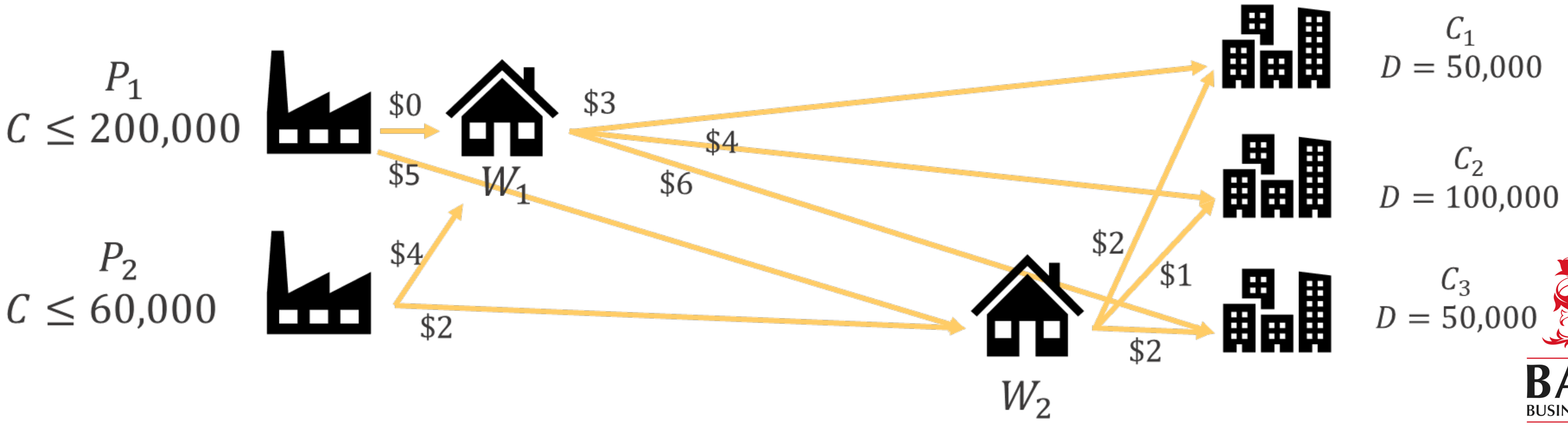
- Exercises in Linear and Integer Programming
- Case discussion

Linear programming

A distribution example

We direct the logistics for a firm that produces and manages

- A single product
- Two plants: P1 with capacity 200,000 units and P2 with capacity 60,000. The manufacturing costs are identical.
- Two warehouses with equal holding costs: W1 close to production, W2 close to the customers
- Three customer regions C1, C2, C3 with demands 50,000, 100,000, and 50,000 units



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Modeling the problem

Decision variables: how much we ship from one place to another.

- Plants to warehouses: $x_{P_1\to W_1}, x_{P1\to W_2}, x_{P_2\to W_1}, x_{P_2\to W_2}$
- Warehouses to customers: $x_{W_1\to C_1}, x_{W_1\to C_2}, x_{W_1\to C_3}, x_{W_2\to C_1}, x_{W_2\to C_2}, x_{W_2\to C_3}$

Constraints: in = out, demand satisfied, capacity.

- In=out at W_1: $x_{P_1\to W_1} + x_{P_2\to W_1} = x_{W_1\to C_1} + x_{W_1\to C_2} + x_{W_1\to C_3}$
- In=out at W_2: $x_{P_1\to W_2} + x_{P_2\to W_2} = x_{W_2\to C_1} + x_{W_2\to C_2} + x_{W_2\to C_3}$
- Capacity: $x_{P_1\to W_1} + x_{P_1\to W_2} \leq 200{,}000$ and $x_{P_2\to W_1} + x_{P_2\to W_2} \leq 60{,}000$
- Demand satisfied: $x_{W_1\to C_1} + x_{W_2\to C_1} \geq 50{,}000$ and $x_{W_1\to C_2} + x_{W_2\to C_2} \geq 100{,}000$ and $x_{W_1\to C_3} + x_{W_2\to C_3} \geq 50{,}000$
- Quantities are nonnegative: $x_{P_1\to W_1} \geq 0, x_{P1\to W_2} \geq 0, \ldots$

Objective: minimize cost

- $0x_{P_1\to W_1} + 5x_{P1\to W_2} + 4x_{P_2\to W_1} + 2x_{P2\to W_2} + 3x_{W_1\to C_1} + 4x_{W_1\to C_2} + 6x_{W_1\to C_3} + 2x_{W_2\to C_1} + x_{W_2\to C_2} + 2x_{W_2\to C_3}$

Solve the problem with the Excel solver

From linear to integer programming

Limits of Linear Programming

The previous example assumes that the quantities we use (e.g., products to ship) can be **any number.**

If we had scheduled people instead of units of product, we could not have done this: what is 2.64 persons?

Integer programming is **linear programming** with **additional constraints** added on:
- Can require that our variables be **binary (0/1)**
- Can require that our variables be **integers (0,1,2,…)**

So objective = linear, constraints = linear + binary/integer constraints

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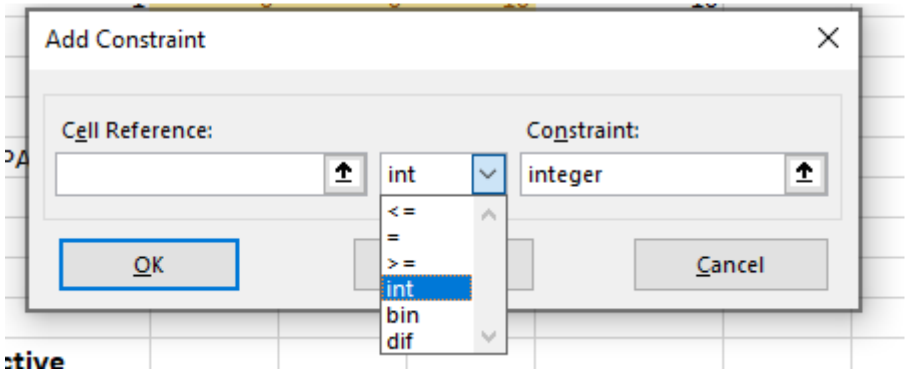
How to add these constraints in the Excel Solver?



Open *Tutorial 4_Activity.pdf*

Work on Situation 1

Activity recap

Decision variables: how many units of each cargo to add to each compartment
Represent this using **integer variables:** x_{ij}, where i is the cargo type and j is the compartment

Constraints:
Weight limitations in all compartments

$$2x_{1F} + 1.6x_{2F} + 2.5x_{3F} + 1.3x_{4F} \leq 12$$
$$2x_{1C} + 1.6x_{2C} + 2.5x_{3C} + 1.3x_{4C} \leq 18$$
$$2x_{1B} + 1.6x_{2B} + 2.5x_{3B} + 1.3x_{4B} \leq 10$$

Volume limitations in all compartments

$$1{,}000x_{1F} + 1{,}150x_{2F} + 1{,}400x_{3F} + 780x_{4F} \leq 7{,}000$$
$$1{,}000x_{1C} + 1{,}150x_{2C} + 1{,}400x_{3C} + 780x_{4C} \leq 9{,}000$$
$$1{,}000x_{1B} + 1{,}150x_{2B} + 1{,}400x_{3B} + 780x_{4B} \leq 5{,}000$$

Non-negative values

$$x_{ij} \geq 0 \text{ for all } i, j$$

Activity recap

Objective: maximize total profit:

$$640(x_{1F} + x_{1C} + x_{1B}) + 640(x_{2F} + x_{2C} + x_{2B}) + 900(x_{3F} + x_{4C} + x_{5B}) + 377(x_{4F} + x_{4C} + x_{4B})$$

Decision Variables

	Front	Center	Back	TOTAL CARGO
1	0	2	5	7
2	1	0	0	1
3	4	5	0	9
4	0	0	0	0
TOTAL COMPARTMENT	5	7	5	

Objective
13220

Activity: IP in practice

Open *Tutorial 4_Activity.pdf*

Work on Situation 2

Activity recap

Decision variables: which project should we invest it?

Represent this using **binary variables:**

$$x_1 = 1 \text{ if we invest in project 1, 0 otherwise}$$

Same for $x_2, \ldots, x_6$

Constraints:

Initial investment less than 4M:

$$1.3x_1 + 0.8x_2 + 0.6x_3 + 1.8x_4 + 1.2x_5 + 2.4x_6 \leq 4$$

If the investment is taken on then the cost appears. Otherwise, it is multiplied by 0 and disappears.

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Constraints:

Average failure risk less than 5%

Number of projects taken on: $x_1 + \cdots + x_6$

Total Failure risk: $6\%\, x_1 + 4\%\, x_2 + 6\%\, x_3 + 5\%\, x_4 + 5\%\, x_5 + 4\%\, x_6$

We should write:

$$\frac{6\%\, x_1 + 4\%\, x_2 + 6\%\, x_3 + 5\%\, x_4 + 5\%\, x_5 + 4\%\, x_6}{x_1 + x_2 + x_3 + x_4 + x_5 + x_6} \leq 5\%$$

Issue: it is non-linear!
How to get around this?

$$6\%\, x_1 + 4\%\, x_2 + 6\%\, x_3 + 5\%\, x_4 + 5\%\, x_5 + 4\%\, x_6 \leq 5\%(x_1 + \cdots + x_6)$$
$$1\%\, x_1 - 1\%\, x_2 + 1\%\, x_3 + 0\%\, x_4 + 0\%\, x_5 - 1\%\, x_6 \leq 0$$

Activity recap

Objective: maximize total expected profit

Decision variables						
	P1	P2	P3	P4	P5	P6
Invest or not?	0.00	1.00	1.00	0.00	0.00	1.00

	Objective
Maximize	0.52

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Integration planning at SFB

Integration planning at SFB

- An (award-winning) case in 3 parts
- Overarching question: how to reduce the headcount after a merger?

- Société Française de Biotechnologie (SFB) was acquired by Big American Pharmaceuticals (BAP), and there should be synergies, so we need less employees
- In France (and Europe more generally), we cannot just fire employees after a merger

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A different approach is needed

- The M&A context in Europe is very different from that in the US. With that in mind, what changes would Kusha have to make to her previous headcount reduction methodology (from her consulting days)?

- What we can do: offer attractive severance packages to give dissatisfied employees a chance to leave (In France: RCC). There are conditions
  - RCCs have to be offered to larger groups, not individuals or groups of just a few people
  - Groups have to be defined objectively and cannot be based on protected characteristics
  - We cannot choose our groups so that employees are implicitly discriminated

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Avoiding the previous problem

- How could she avoid the problem faced in the previous transaction? Given the contradictory forces on employee motivation to leave, could she find a way to rate employees on the likelihood of leaving?

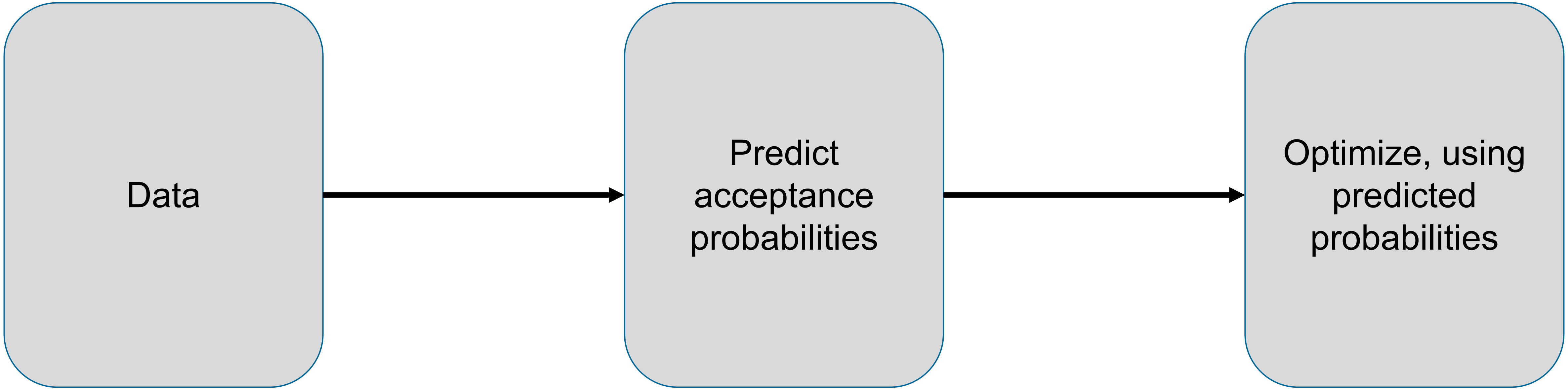
- Will employees take the RCC? That seems like something that a classification model can tell us.
- Luckily, we have “training data” from a previous company merger where everyone was offered an RCC

How can we do well?

- What “cool model” could Kusha develop to simultaneously address those likely to leave and help BAP achieve its reduction targets yet avoid a mass exodus?

- We want to use our predictions to decide who should be offered an RCC
  - Clearly, this is an optimization problem
  - However, remember that we cannot target individuals → What are the decision variables?

The process so far



How to get good predictions

- Pre-processing
  - Combine rare categories within features
  - Merge multiple features to generate new ones
  - Standardize or normalize the data
  - Address outliers
  - Transform features, e.g., by using log values
  - Don’t forget to split your data

- Prediction models
  - Try out different models, such as random forest classifier
  - Perform hyperparameter tuning

The optimization model

- Decision variables
  - Which group to open up to RCC
  - First, need to define the groups (and avoid discrimination issues)

- Constraints
  - Having enough people leave but "avoiding a mass exodus"
  - Keeping proportions stable within the department
  - Sufficient savings

- Objective function
  - Minimize the costs

One last time: please fill out the module evaluation

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Good luck and see you next term!