The aims of this workshop are:

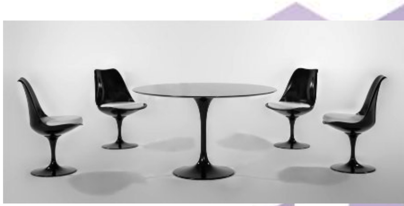
-To understand linear programming and the types of problems that are solved with linear programming.

-To understand how maths and operational research are used in real life.

OPERATIONAL RESEARCH IN EDUCATION

Introduction

- SWEDEBUILD would like to launch a new range of dining furniture that will include some tables and chairs.
- Can you help the production manager find out how many tables and chairs should be made in order to earn the greatest profit?



Explain that SWEDEBUILD is a company that is very similar to IKEA®. This will help the students visualise a real scenario for this work.

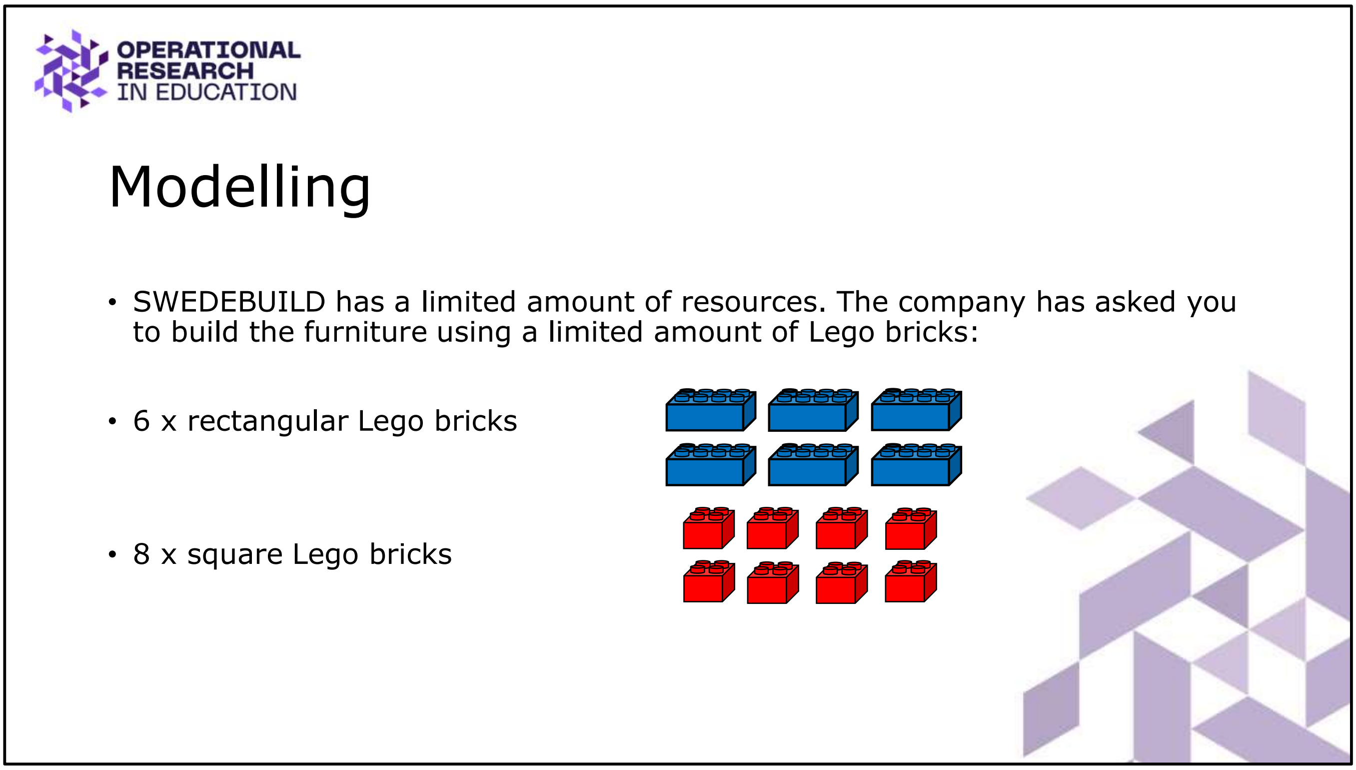
General discussion:

Get the class to discuss what raw materials they would be likely to use (e.g. wood, plastic, metal, fabric), and what costs are associated with making a product (e.g. the raw materials, staff wages, machinery, cost of electricity).

Also discuss what is meant by profit and how this is calculated (may be more relevant for a younger audience).

In order to tackle this problem, we are going to model it using smaller materials (Lego).

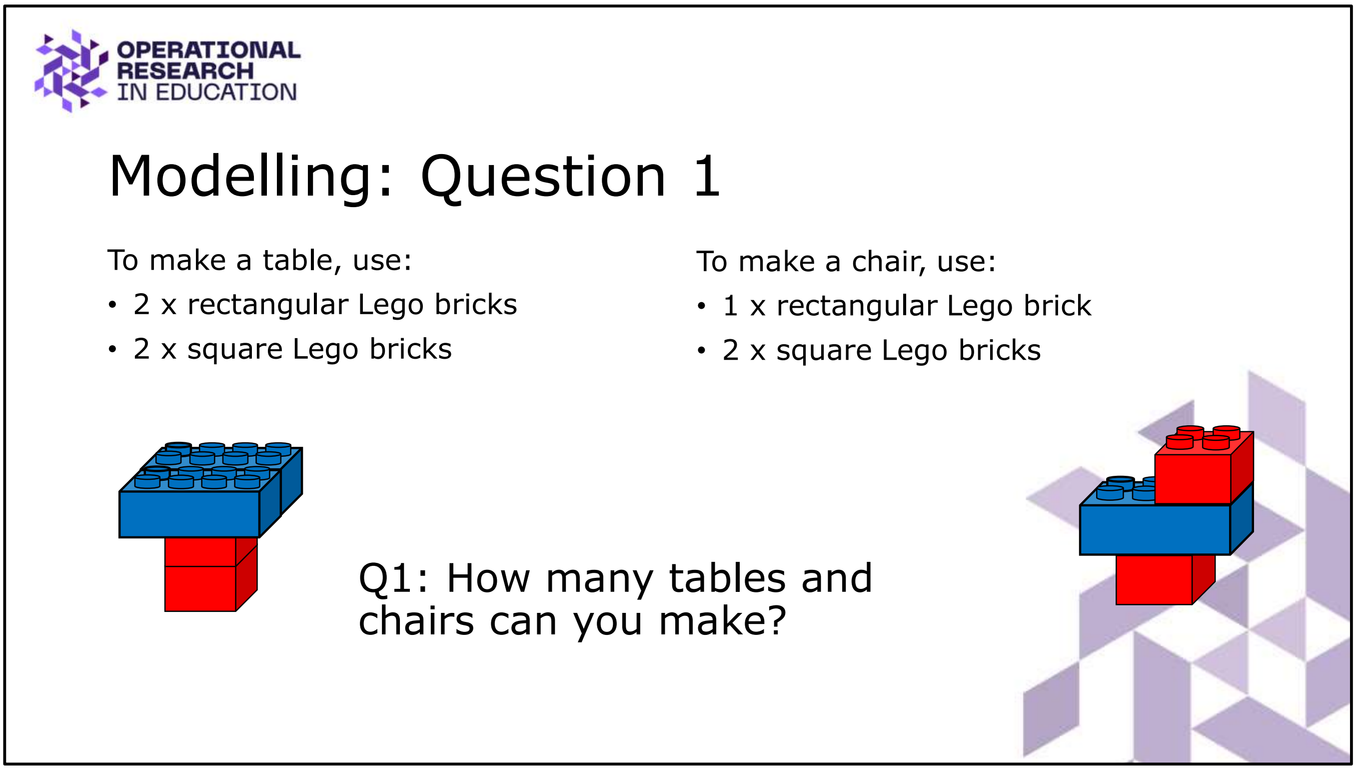
We will assume only one type of raw material and this will be represented by the Lego. We are only going to consider the cost of the raw materials (bricks) and no other associated costs. The design of the tables and chairs has also been simplified.



Discuss the idea of modelling and the benefits of doing this (e.g. saving time and money, having the ability to experiment and make changes without impacting on the real process).

When a real process is modelled, it is simplified and some assumptions are made. This is because it is too complex to model the process exactly: there are lots of different combinations of options and the problem can quickly become very big and 'messy'.

Hand out the Lego bricks to students.



Students can use as many of their bricks as they would like. They can make any quantity/combination they like (i.e. they don't have to make 1 table and 4 chairs).

Student Worksheet Question 1

How many tables and chairs can you make?

Once students have answered question one, choose some tables and chairs at random from the room and ask the students what they notice (we want them to notice that they're the same).

The advantage to them being the same is that they make a good dining set. Remind the students that SWEDEBUILD wants to make a profit, so they need a common design that will ensure the furniture matches and keeps costs to a minimum.

Using a common design to represent the table and chairs uses the least amount of bricks possible, which keeps costs to a minimum and maximises SWEDEBUILD's profit.

Questions 1-4 are working through filling out a table. The answers are:

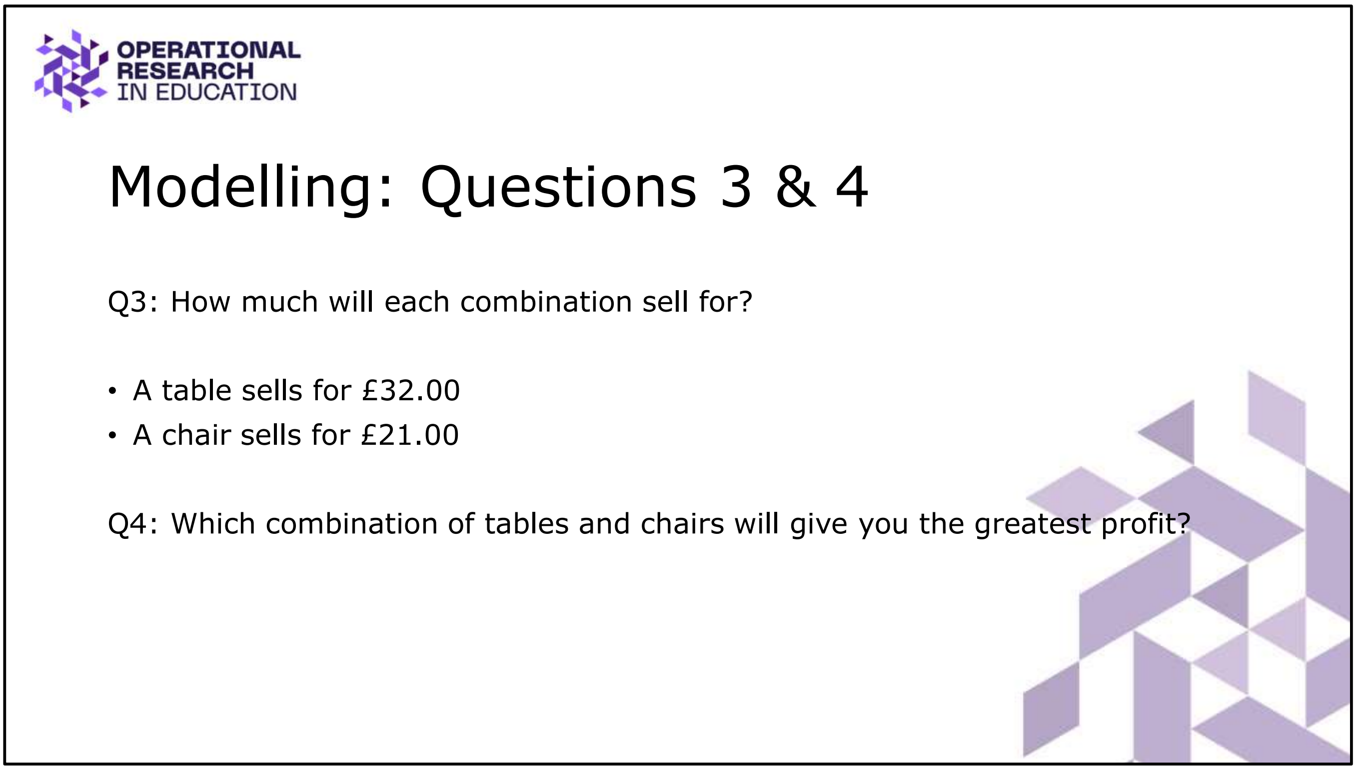
OPERATIONAL RESEARCH IN EDUCATION

Modelling: Question 2

Q2: How much will it cost to produce the tables and chairs that you have just made?

- A square brick costs £3.00
- A rectangular brick costs £5.00

Student Worksheet Question 2

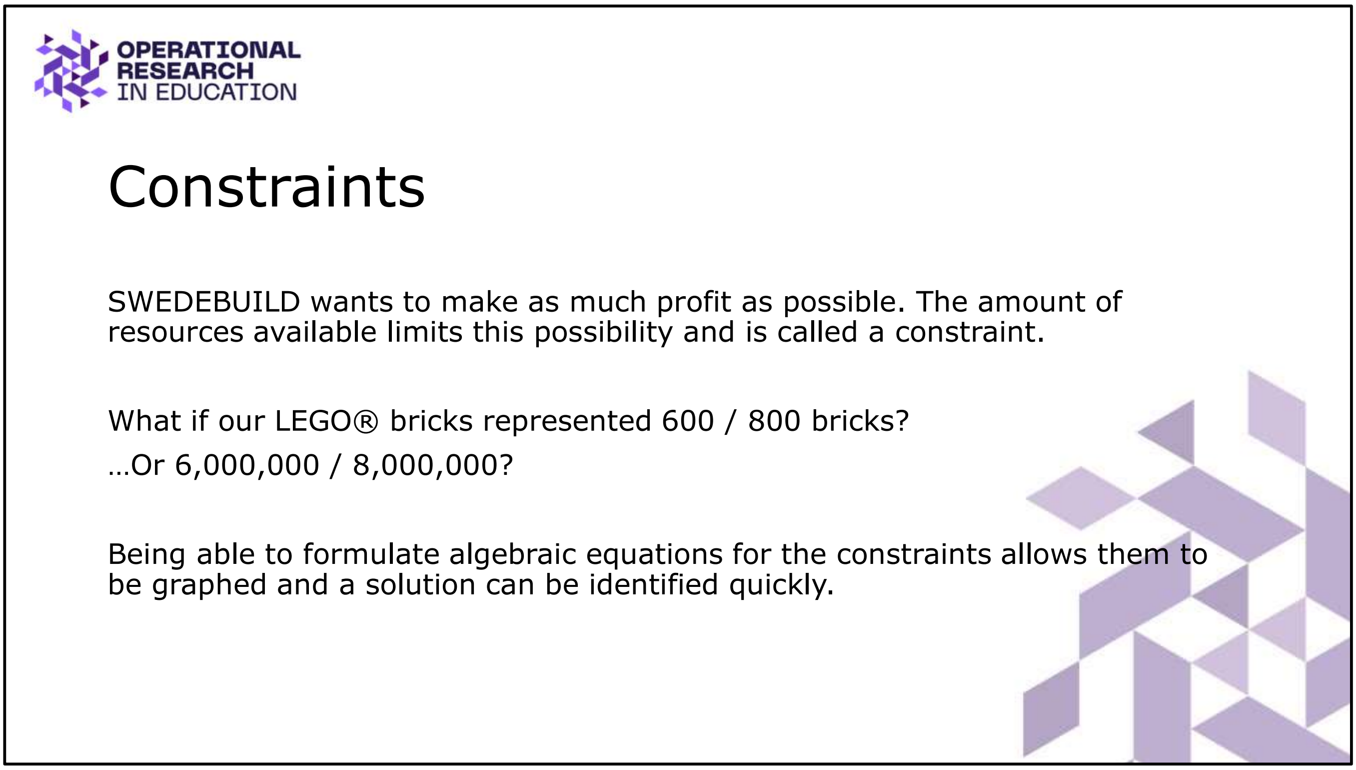


Student Worksheet Question 3

Student Worksheet Question 4

Students should find that the best answer is to build 2 tables and 2 chairs.

Students may argue to deduct the cost of the left over bricks from the profit. For some businesses this may be the case, whereas other businesses are able to use the left over materials. Either option will not change the most profitable combination.

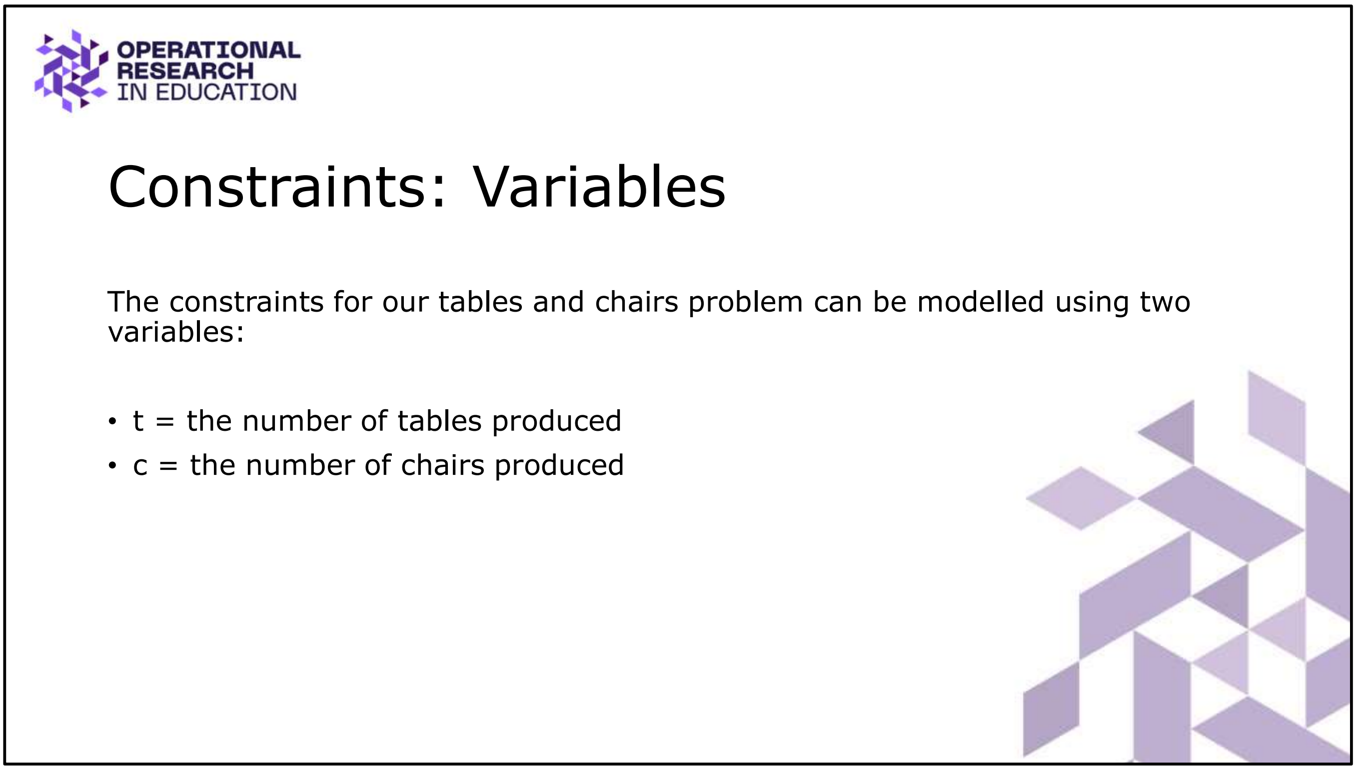


This type of maths is used by many businesses and organisations to determine a way to achieve the best possible outcome. This may be to minimise expenditure or maximise profit.

For us, and SWEDEBUILD, the goal is to make as much profit as possible (by selling as many tables and chairs as possible). The number of resources available (in this case, Lego bricks) limits this possibility and is therefore our constraint.

In this problem, it's very easy to work out the best solution as there are only a small amount of resources and the problem was simplified in order to be modelled. Explain to the students that the six rectangle Lego bricks and eight square Lego bricks could represent 600/800 bricks, 6 million/8 million bricks, or more. With that many raw materials available, it would take too long to find the best solution by working through all of the possible answers.

Being able to formulate algebraic expressions for the resource constraints allows them to be graphed. The solution to the problem can then be found on the graph, in much less time than modelling all of the solutions.



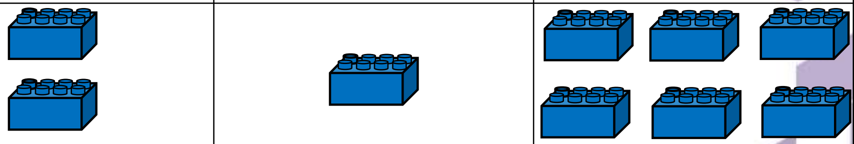
Students are asked to write inequalities for the constraints on the next slide.

OPERATIONAL RESEARCH IN EDUCATION

Constraints: Rectangular Bricks

- Q5: Write an inequality that links the number of tables and chairs to the number of rectangular bricks

No. rectangular bricks used		Total no. rectangular bricks available
Tables (t)	Chairs (c)	
2	1	6



Student Worksheet Question 5

Equation for rectangular Lego bricks constraint

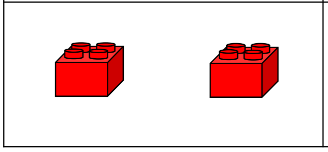
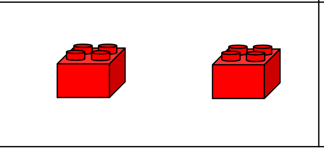
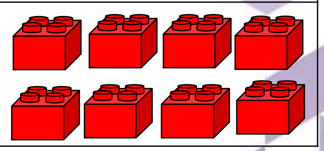
$2t + c \leq 6$

Where
2 = no. rectangular bricks needed to produce a table
t = no. tables produced
(1= no. rectangular bricks needed to produce a chair)
c = no. chairs produced
6 = no. rectangular bricks available

OPERATIONAL RESEARCH IN EDUCATION

Constraints: Square Bricks

Q6: Write an inequality that links the number of tables and chairs to the number of square bricks used

No. square bricks used		Total no. square bricks available
Tables (t)	Chairs (c)	
2	2	8
		

Student Worksheet Question 6

Equation for square Lego bricks constraint

$2t + 2c \leq 8$

Where

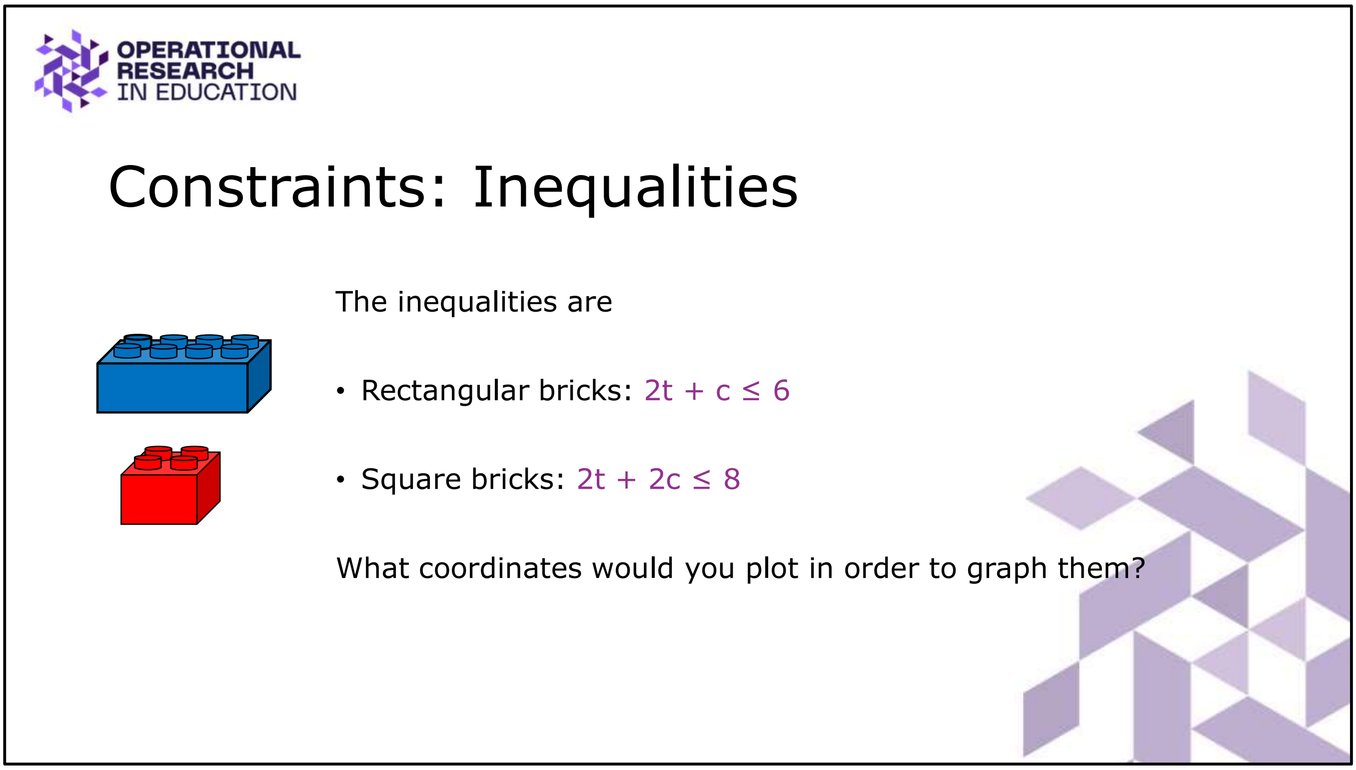
(1st) 2 = no. square bricks needed to produce a table

t = no. tables produced

(2nd) 2= no. square bricks needed to produce a chair

c = no. chairs produced

6 = no. square bricks available



In order to plot the equations on a graph, the students can solve them as equalities. This will give them two points to plot before drawing a straight line through them. These equations are an $ax + by = c$ variation of $y = mx + c$.

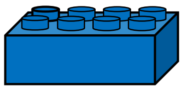
OPERATIONAL RESEARCH IN EDUCATION

Solving the inequalities: 2t+c=6

For rectangular bricks, 2t + c = 6

First, solve for c. If t = 0, what does c = ? Then solve for t when c=0

2t	**+**	**c**	**=**	**6**
0	**+**	**?**	**=**	**6**
2(?)	**+**	**0**	**=**	**6**



Students should set **t = 0** and solve to find the value of **c**. Then, set **c = 0** and solve to find the value of **t** for the rectangular and square Lego bricks.

Answers (in purple) appear on next slide.

For rectangular Lego bricks, **2t + c = 6**

OPERATIONAL RESEARCH IN EDUCATION

Solving the inequalities: 2t+c=6

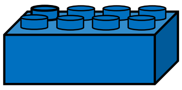
For rectangular bricks, $2t + c = 6$

First, solve for c. If $t = 0$, what does $c = ?$ Then solve for t when $c=0$

$$2t + c = 6$$

$$0 + 6 = 6$$

$$2(3) + 0 = 6$$

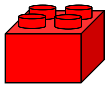


Solving the Inequalities: 2t+2c=8

For square bricks, 2t + 2c = 8

First, solve for c. If t = 0, what does c = ? Then solve for t when c=0

2t	**+**	**2c**	**=**	**8**
0	**+**	**2(?)**	**=**	**8**
2(?)	**+**	**0**	**=**	**8**



Students should set **t = 0** and solve to find the value of **c**. Then, set **c = 0** and solve to find the value of **t** for the rectangular and square Lego bricks.

Answers (in purple) appear on next slide.

For square Lego bricks, **2t + 2c = 8**

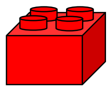
OPERATIONAL RESEARCH IN EDUCATION

Solving the Inequalities: 2t+2c=8

For square bricks, 2t + 2c = 8

First, solve for c. If t = 0, what does c = ? Then solve for t when c=0

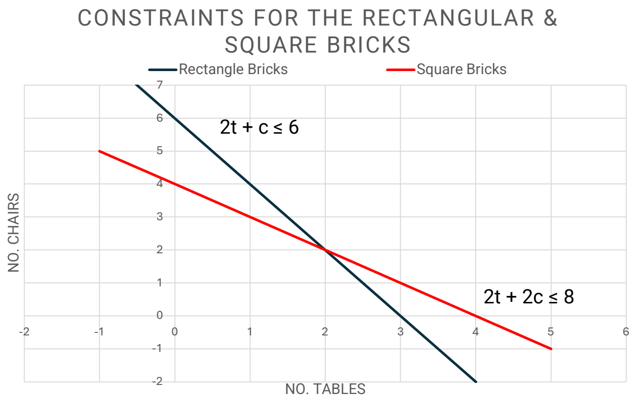
2t	**+**	**2c**	**=**	**8**
0	**+**	**2(4)**	**=**	**8**
2(4)	**+**	**0**	**=**	**8**



OPERATIONAL RESEARCH IN EDUCATION

Graphing the Equation: Question 7

- Q7: Plot the constraint inequalities on the same graph



Student Worksheet Question 7

When the students draw their graphs, ask them to include negative numbers on their axes and ask them to draw their line beyond the points they have plotted. They should label their lines with the equations.

Answer: Graph appears on click.

Considering that the equations are ‘less than or equal to’, ask the students which side of the lines they think the possible solutions will lie. If they’re not sure, ask them to move on to Question 8, which will provide the answer.

OPERATIONAL RESEARCH IN EDUCATION

Graphing the Equation: Questions 8-10

Q8: Can you plot the points on the graph that represent the different combinations of tables and chairs that you worked out in Question 3?

Q9: Could negative numbers form part of the solution?

Q10: Write a report for the production manager of SWEDEBUILD. This should explain your recommendations to the company and how you came to those conclusions.

Student Worksheet Question 8

Students can link the table of results from Question 1 to their graph by plotting the points for the combinations of tables and chairs they identified. Answer on next slide.

Student Worksheet Question 9

Encourage students to discuss whether negative numbers could be possible solutions.

Answer: The plotted combinations of tables and chairs indicates that the feasible region lies below the lines (equal to or less than). A negative number of tables and chairs cannot be produced and so this provides further boundaries for the feasible region.

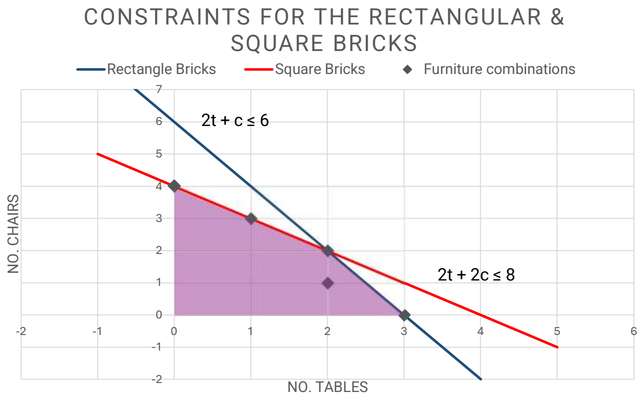
Student Worksheet Question 10 (Extension Task)

This can be set as homework or a follow up task. It can also be approached as a plenary/summary discussion.

OPERATIONAL RESEARCH IN EDUCATION

Graphing the Equation

- Purple area: feasible region



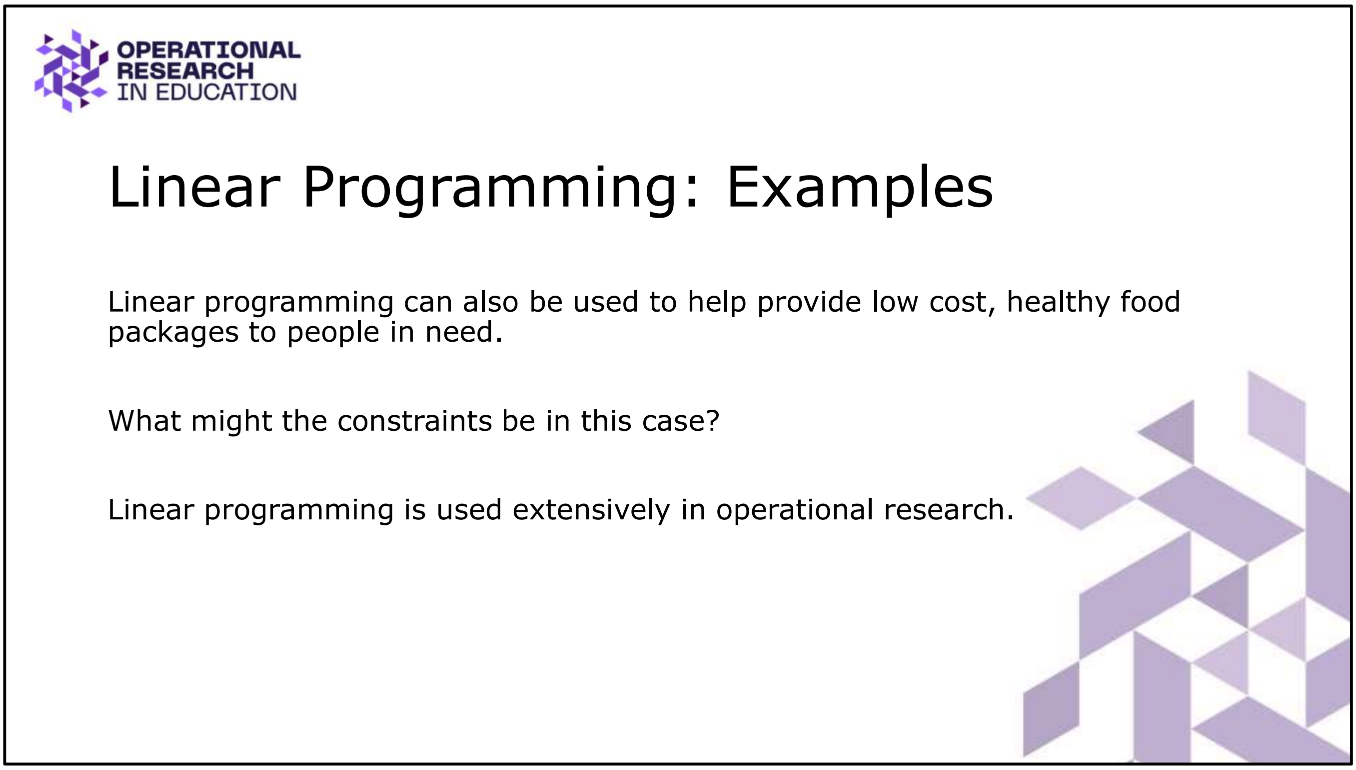
OPERATIONAL RESEARCH IN EDUCATION

Linear Programming

This type of maths is called linear programming.

Linear programming is concerned with finding the best solution (e.g. increase profit, reduce costs) from a set of constraints.

Linear programming has many uses.



Food banks and nutritionists can use linear programming to help assemble food packages.

Discussion question: what constraints might there be in assembling food packages? Answer: Dietary or cultural restrictions, nutrition, price limits (would it be cheaper to buy certain foods in bulk etc.)…

In order to optimise the food packages, data like food prices, nutrition information and potentially shelf life/seasonal availability would need to be taken into account.

As with SWEDEBUILD, people can optimise their use of a constrained or limited resource to maximise their output (which could be anything from profit to food packages).

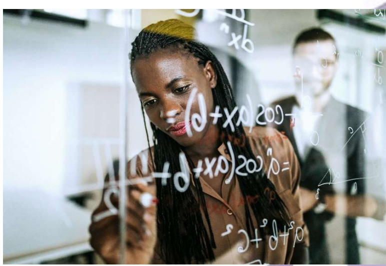
OPERATIONAL RESEARCH IN EDUCATION

Operational Research

Operational research (OR) is the application of mathematical methods and advanced analysis to improve decision-making

Or:

'The science of better decision-making'



Ask the students if they have heard of operational research. Often not many people have. (Text appears on click/moving forward).

The answer on the slide can also be stated as "OR involves using maths to solve problems or make better decisions". It is a broad, slightly vague answer – that's because OR has lots of practical applications!

OR is used today by many businesses – shops, airlines, architects, hospitals, local government and central government (think Ministry of Defence, HMRC etc.)

There are some in depth examples of OR on the following slides. Feel free to include your own.

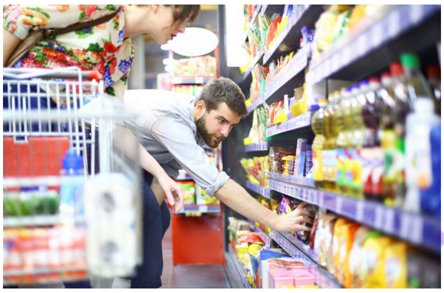
OPERATIONAL RESEARCH IN EDUCATION

OR in detail: Supermarkets

Understanding people's buying patterns

Determining the number of staff needed on checkout and when

Calculating order quantities and delivery times



Please feel free to paraphrase the below:

Supermarkets use teams of OR professionals to solve problems and make decisions, such as understanding consumer buying patterns, deciding how many staff they should allocate to a shift and calculating the optimal quantity and delivery times of their products.

Supermarket loyalty cards, like a Tesco's Clubcard, are a great example of OR in action. Loyalty cards let supermarkets track what their customers are buying, creating huge amounts of data for operational researchers to work with. They can use statistics to search for patterns in the data, attempting to predict how customers will behave in the future.

For example, the data might show that people buy lots of milk on a Saturday, in which case the supermarket would know to stock up on Friday evening. It might also show that lots of people shop at certain times, or on a particular day, so the store managers would know to have more staff members working at that time.

Most supermarkets also incorporate weather forecasting data, obtained from weather stations near each of their stores to optimise this further by making sure they have extra BBQ food in towns that are expecting sunny weekends.

It’s easy to see what a big impact OR has on making the right decisions for supermarkets – helping them keep customers happy and make profits!

OPERATIONAL RESEARCH IN EDUCATION

OR in detail: Airlines

Forecasting where people want to go and when

Setting the ticket prices

Simulating boarding the plane

Please feel free to paraphrase the below:

Operational researchers at places like British Airways are involved in a lot of decision-making.

When you book a holiday, OR has been used to decide where an airline will fly to and how much they charge you for your ticket, using customer buying patterns and forecasting to predict demand.

When you arrive at the airport, OR has been used to minimise queueing times, and simulations are used to model the flow of passengers through the terminal to ensure staff members and equipment are in the right places at the right time.

When you board the plane, OR has helped choose a boarding strategy and ensure your plane leaves on time. OR is even used to forecast how many passengers are likely to cancel their holiday!

Just like supermarkets, airlines rely heavily on OR to make better, more informed decisions that result in better outcomes for their business.

OR in detail: Healthcare

Moving people through waiting lists as quickly as possible

Using hospital resources as efficiently as possible

Increasing the number of transplant operations

Please feel free to paraphrase the below:

Some hospitals have dedicated OR teams to help with resource allocation – especially if they have multiple specialities. The OR staff allocate patients, equipment and surgical teams to operating theatres based on the urgency and specific requirements of each patient – some operations need specialist equipment and others do not and it's not very efficient to have a 'general' patient in a 'specialist' surgery.

The OR team have to set a schedule, which is made complicated by the fact that how long an operation takes can be hard to predict and an emergency patient might need immediate attention and throw off the rest of the rota!

OR researchers designed an algorithm to optimise kidney transplant surgery – imagine somebody needs a kidney transplant and their family member is willing to be a donor, but is incompatible. The algorithm identifies patients in this situation and matches them up so they can swap donors, and both patients receive the kidney that they need.

The surgery has to take place simultaneously to prevent anybody from backing out at the last minute, so the algorithm also has to take into account the nearest hospital with enough resources (theatres and surgical teams) to carry out the transplant when matching patients.

OPERATIONAL RESEARCH IN EDUCATION

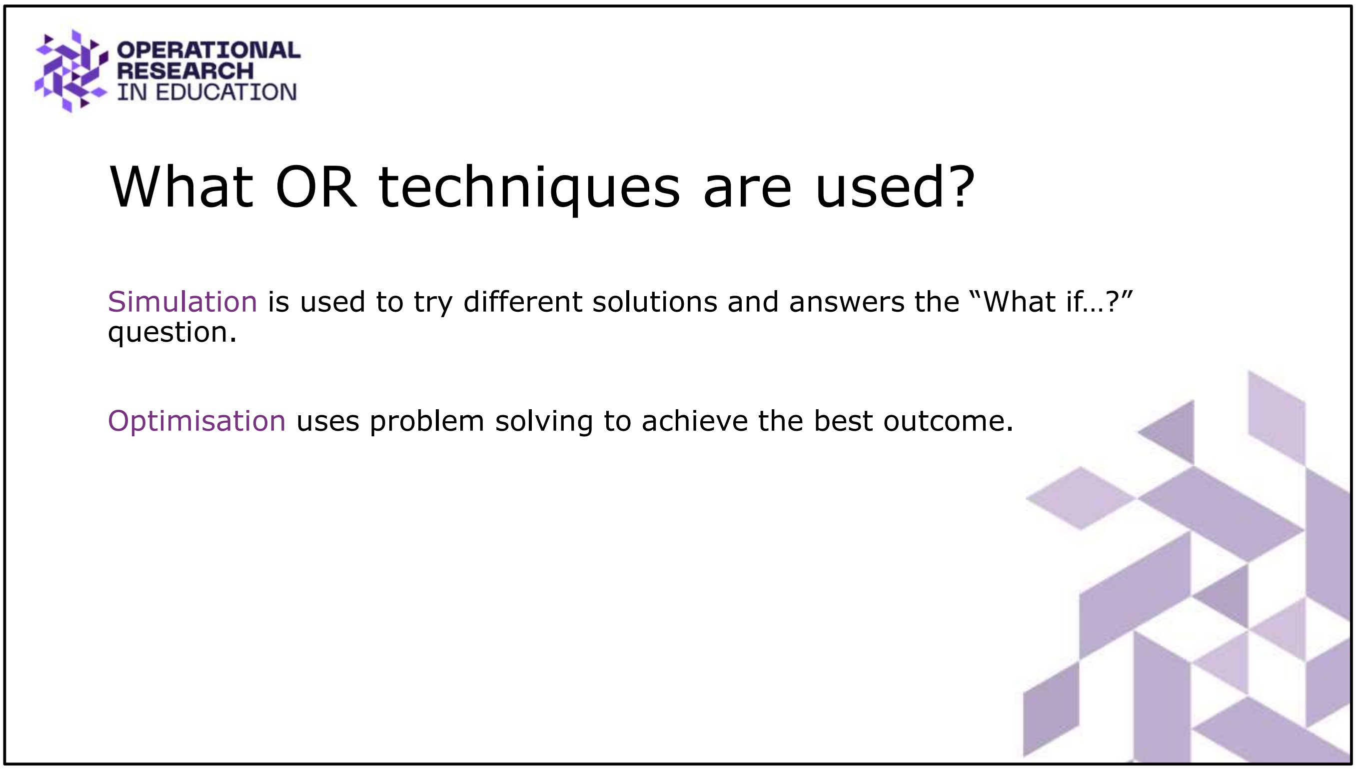
When is OR used?

When a decision is complex or it's unclear what the main problem is

When you don't know how well things are working or think they could work better

Decision-making and problem-solving in business can be complicated and messy.
It may not be clear what the main problem is, what the outcome of different actions may be or how well things are currently working, and there may be lots of different factors to consider.

For example, if things don't go well when businesses make big changes, they might upset customers, slow down production or create a need for extra staff training. Any of these could have a negative impact on the business. OR can help to reduce the chances of this happening.



Some commonly used OR techniques include:

Optimisation – depending on what variable is most important (manufacturing something quickly, or maximising profit?), optimisation will find the best use of limited resources.

Simulation – this modelling tool is fantastic when there are a lot of different ways to solve a problem as you can try lots of different solutions until you find the best one. It also allows something to be tested in a safe way, for example, organisations like the NHS have to be careful when making changes as lives could be at risk!

Also many more techniques – including algorithms, modelling etc.

Non-exhaustive list of businesses that use OR. Please note they are not endorsed by The OR Society but are designed to show the variety of careers in OR. Feel free to use your own examples if relevant.

OPERATIONAL RESEARCH IN EDUCATION

Interested?

Next steps:

- Maths GCSE and A Level
- Further Maths and Computer Science are highly beneficial
- Obtain a good classification in a STEM degree
- A master's degree in OR is often desirable, although not always essential

Depending on the age of the audience this may or may not be relevant.

Not many universities offer OR degrees, although some offer maths and OR degrees or similar. OR is often a module in a maths or business studies degree and can be hard to find on its own.

STEM degrees (science, technology, engineering and maths) show a skill set and analytical way of thinking that is often beneficial to people working in OR and are a good alternative to an (often elusive) OR degree.

OPERATIONAL RESEARCH IN EDUCATION

Find out more

www.theorsociety.com

Careers information, OR news and information on free student membership (available for people aged 16+) can be found on our website.