Production Optimization Classroom Simulation

Abstract

This exercise has been prepared by an Operations Management instructor for use in the classroom. Within the exercise are instructions for the instructor, instructions for the class, printable materials, and a printable worksheet for students to perform their calculations.

Description

Students work in groups to optimize production and minimize waste in a simulated glass-cutting operation. The purpose of this assignment is for students to gain an understanding of what optimization software accomplishes in production processes within operations management. This assignment could be used in operations management, manufacturing management, engineering, cost accounting, or management information courses to provide an intuitive approach to understanding optimization software and the integration of such software into hardware performing automated tasks.

Skills

Students will be learning **how to:**

1) Calculate waste/scrap rates,
2) Plan batch and mixed product production processes,
3) Optimize materials use to minimize waste.

Knowledge

Students will be learning **about:**

1) Optimization logic,
2) Cost of material waste,
3) Production planning.

Materials/Equipment

- Scissors,
- Printed Worksheets (provided below),
    - Glass Blanks with the square footage (actually square inches, so 1:12 scale)
    - Shapes with square footage (actually square inches, so 1:12 scale)
- Calculator,
- Pen or pencil.

Preparation

- Print a set of worksheets (provided below) for each group of students.
- Complete the exercise yourself to make sure you understand what the students will be doing.
- Arrange desks in small groups.

Instruction before the exercise

1. Offer a mini-lecture on optimization technology and its use in your subject area and/or,
2. Show a video of a window factory operation that includes Computer Numerical Control (CNC) glass cutting such as this one https://www.youtube.com/watch?v=5R9IbPy2JX0, pointing out the mention of optimization (at 1m 56s in this video).

Implementing the exercise

Divide the students into groups of (ideally 3-4 students each), assigning each group a workstation. If groups are larger, appoint a group leader who is not allowed to touch anything, only to instruct, and/or a record keeper who is allowed to write and ask questions only (this role is good for a student who is reticent to participate in group activities for some reason).

Step 1 - Explain that the goal is minimize waste of glass from the 24 sq ft 4' x 6' glass sheet blanks (represented by the large squares printed alone with 24 centered, representing the square footage of the glass blanks.

- Have the students cut out the shapes from worksheet pages 7-10 (included below)

  Option: These can be cut out ahead of time to speed up the process; Student workers are helpful, here.
- Instruct the students to determine how many blank sheets of glass will be required for each shape, assuming that all of one shape must be cut before starting the next shape with a blank sheet of glass – representing batch production AAAA BBBB CCCC.
- Ask students to calculate and record the scrap rate for each blank sheet of glass.
- Then to calculate and record the total scrap rate for this production mix using the batch method.

Discussion

- Ask the students how they might be able to reduce the scrap rate.
- It is likely that a student will suggest cutting more than one shape out of the same glass blank. This is a teachable moment. They are suggesting mixed product production, e.g. ACCB ABAB ABCA.
- A student might also suggest larger sheets of glass blanks. Explain that the glass sheet size is determined by the glass manufacturer and by transportation limitations, so this would be very expensive if it is possible at all. Proceed with the assumption that the glass sheet size will not change for now.

Step 2 - Now tell the students they may get creative in organizing all the shapes together in any combination in order to use the least number of sheets of glass blanks.

This is where the exercise gets interesting and the 'aha' moments should begin! -

- Instruct the students to determine how many sheets of glass would be required to produce all of the needed shapes in any order – simulating their attempt at intuitive manual optimization.
  a. It is likely students will ask questions about tolerances – distance between shapes; The beauty of using hypothetical glass for this exercise is that there is no space between straight cuts and thus no waste and no tolerance needed.

b. It is likely that students will ask about the orientation of the shapes – can the triangle be upside down, etc. You can explain that if this were a special application glass (mirrored, polarized, etc.) that might be a concern, but for windows the glass is unidirectional.
c. A student might realize that some pieces of glass would be useable later for smaller or differently sized windows and that a partial sheet of glass is quite useable. You could:
    i. Keep it simple and tell them all leftover glass is unusable and will be discarded at no cost and no value.
    ii. Give them a minimum useable scrap piece. In this case, they would need to discount the scrap rate for those pieces, for example to calculate half the piece as scrap and half as useable inventory.
    iii. Give them a salvage price for small pieces. This simulates the sale of scrap pieces to another company making a different product.
    iv. Give them a price for disposal, so a cost but no value.
d. Have the students calculate the new scrap rate as they calculated the scrap rate before.
e. Have the students re-calculate the scrap rate using any of the criteria you created above in steps c.i-c.iv.
f. Have the students compare the scrap rate using the batch method to the optimized method, calculating the percent reduction in scrap.
g. Give the students a $12 glass cost per square foot and have them calculate the savings and percent savings using the optimization method.
h. Ask the students if they think they have found the absolute best way to optimize cutting, how long their manual intuitive optimization took, and how long they think it would have taken the optimization software within the CNC glass-cutting machine at the window factory.

Step 3 - Tell the students that they can actually (as they likely earlier suggested) purchase larger sheets of glass, but the glass would have to be custom ordered for $2 more per square foot.

- Hand out the 40 sq ft sheets of glass.
- Have the students manually optimize again to determine the scrap rate for the entire order (no need to calculate individually this time).
- Then instruct the students to calculate the percent savings of using the $14 per sq ft 40 sq ft sheets of glass instead of the $12 per square foot 24 sq ft sheets of glass.

Further Customization

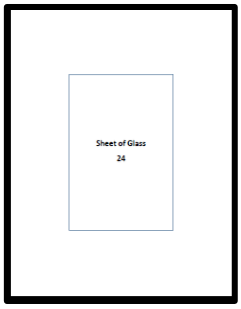
Using the basic methodology of this exercise, it can be adapted to larger scale using poster board, for example and can be made more complex by introducing shapes that are more intricate and further varying the glass blank size, product costs, etc. On the other hand, it can be simplified by using less pieces per shape or fewer shapes.

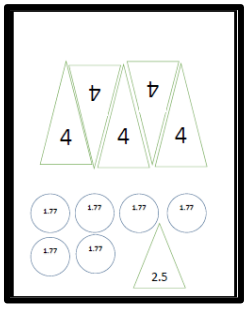
Feel free to reach out with suggestions for improvement or adaptation and with questions about implementation. – Author

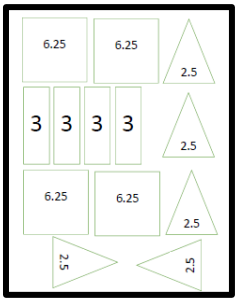
Optimization Simulation – CNC Glass Cutting

You should have:

- 8 sheets of glass
- Scissors
- 2 sheets of window shapes
- Calculator
- Pencil







Step 1 – Simulations batch production

- Cut out the Window Shapes and group them by size and shape.
- Determine how many standard 4' x 6' = 24 sq ft sheets of glass will be needed if each sheet of glass is used for only one shape and size of shape (e.g. circles from one sheet, large triangles from a second, small triangles from a third, etc. - This simulates batch production
- Calculate the scrap rate for this set of production runs using batch production:

Shape	Square Footage Number in the shape	Number of shapes	Glass Used For products	Sheets of glass consumed	Square Footage	Glass consumed	Waste	Scrap Rate
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =

	Total	Total	– =	/ x 100 =

Step 2 – Simulates mixed product production with manual optimization

- Cut out the Window Shapes and group them by size and shape.
- Determine how many 4’ x 6’ = 24 sq ft sheets of glass will be needed if all shapes are produced using as few sheets of glass as possible. Get creative with the shape placement, but don’t overlap the shapes. - This simulates optimization to reduce waste
- Calculate the scrap rate for this set of production runs using optimization:

Shape	Square Footage Number in the shape	Number of shapes	Glass Used For products	Sheets of glass consumed	Square Footage	Glass consumed	Waste	Scrap Rate
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	Total			Total			– =	/ x 100 =

Step 3- Calculate the % savings using the optimization method assuming a cost of $12 per square foot of glass.

Step 4 – Simulates mixed product production with manual optimization with special order of larger sheets of glass.

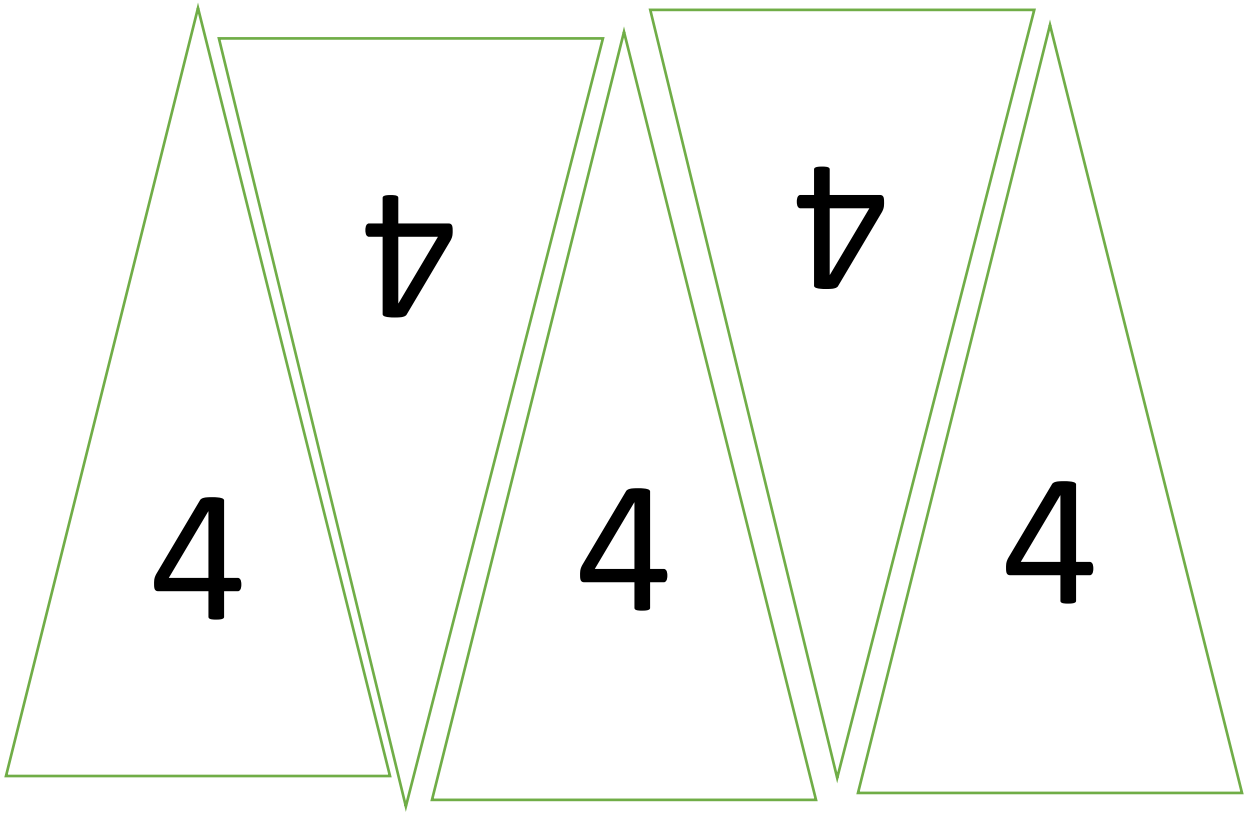
- Using the 5’ x 8’ = 40 sq ft sheets of glass, determine how many sheets of glass will be needed if all shapes are produced using as few sheets of glass as possible. Get creative with the shape placement, but don’t overlap the shapes. - This simulates optimization to reduce waste
- Calculate the scrap rate for this set of production runs using optimization with the custom large sheets of glass:

Shape	Square Footage Number in the shape	Number of shapes	Glass Used For products	Sheets of glass consumed	Square Footage	Glass consumed	Waste	Scrap Rate
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	sq ft x =			x	24 sq ft		– =	/ x 100 =
	Total				Total		– =	/ x 100 =

Step 3- Calculate the % savings using the optimization method assuming a cost of $14 per square foot of glass for the custom 5’ x 8’ = 40 sq ft custom ordered sheets of glass, compared to the $23 per square foot standard 4’ x 6’ = 24 sq ft sheets of glass.

Sheet of Glass

24



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6.25


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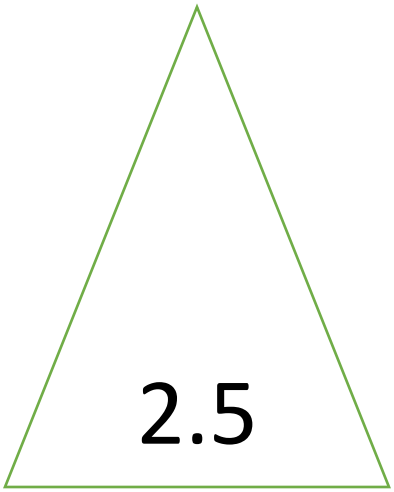
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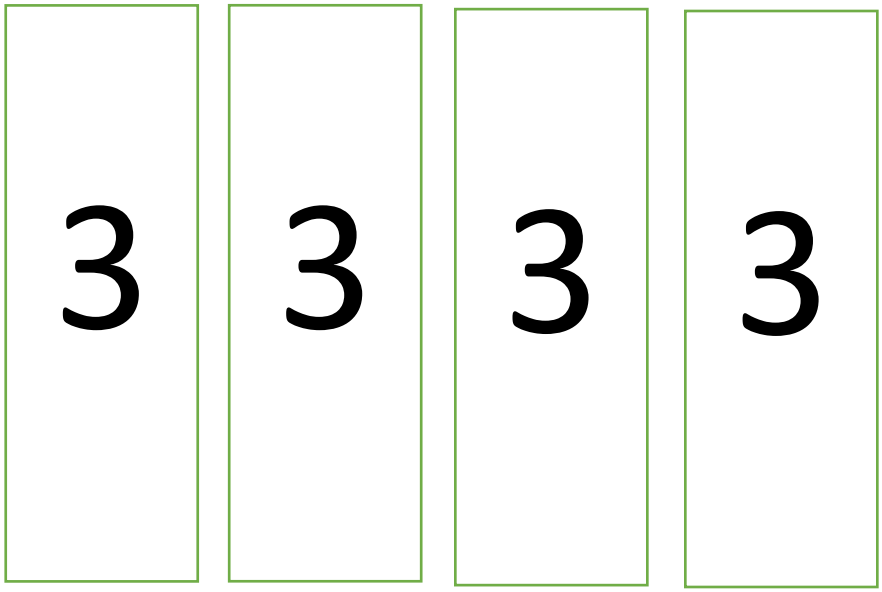
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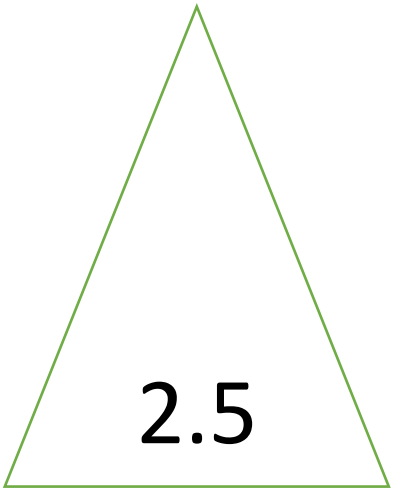
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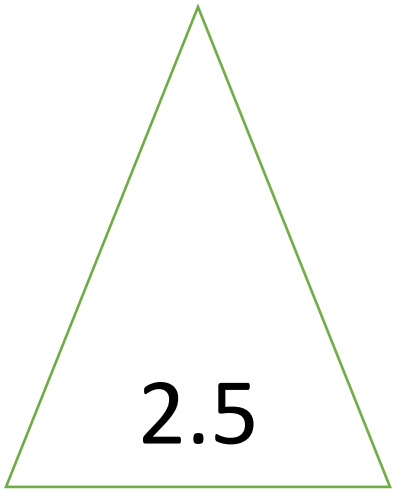
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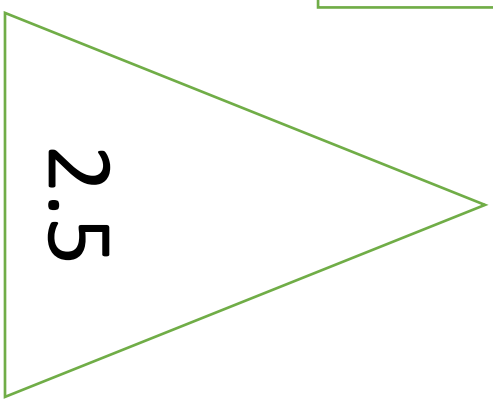
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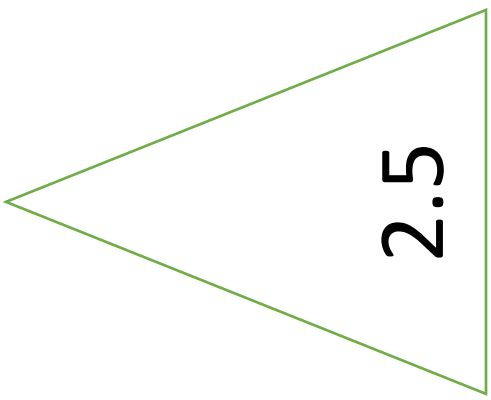
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Optional step 3 round with 5’ x 8’ glass sheets. Print six per group.