Project 3.9

Manufacturing a Box

Introduction

In the past, artisans who produced one item at a time built most products. Today, industry uses **mass production** to build many of the same items more efficiently. *Assembly lines* can benefit mass production. An assembly line is an arrangement of machines, tools, and workers that build a product in steps. Each station of the line is equipped to perform a specific task. Assembly-line production can usually manufacture a product in less time and at lower cost. Mass production can also improve the **quality** of the product.

What is quality? How is quality determined? Some would say that the product designer determines quality. The designer creates specifications. Those specifications dictate the quality of the product. However, poor manufacturing processes may also affect the quality of a final product. The use of inferior materials or components can also reduce quality.

Quality control, or QC, is a system used to verify the quality of a product. By testing important product features and comparing the resulting **data** to the previously established specifications, you can identify product defects. *Quality assurance*, QA, attempts to adjust the manufacturing process to improve and stabilize the quality of the product. We use **statistics** to help us determine and control quality. This is often the responsibility of quality control engineers.

In this project, you will work in teams to design, test, and improve a manufacturing process to build boxes. Collectively you will build a box for each student in your class. As part of the process, you will test the quality of the boxes using statistics. Note that your box will become part of your design for Problem 8.2 Automata Design Challenge. Quality matters!

Equipment

- Sand Paper (180 grit)
- Student Box Kit
- Quick-dry Tacky Glue
- Computer with spreadsheet capabilities
- Protractor
- Ruler or Dial Caliper
- Stopwatch
- Miter Box (Optional)
- Saw (Optional)

- MDF (Optional)
- Student Resource 3.9.SR Testing Trueness Squareness

Resources

[Introduction to Manufacturing Processes]

[Testing Trueness and Squareness]

[Project 3.9 Manufacturing a Box Checklists and Rubric]

Procedure

1. In your PLTW Engineering Notebook, hand sketch a scaled multiview drawing of an open box that is 4 in. x 4 1/2 in. x 5 in. (outside **dimensions**). The box drawing should show individual parts for assembly from the provided materials. That is, use a separate part for each side of the box and detail the connections at the corners. Use the thickness of the box material provided by your teacher. Remember that dimensions are nominal. That means that you can vary slightly the actual height, width, OR length dimension of the physical product from the nominal dimensions shown on the drawing, if using slightly different dimensions improves efficiency.

2. As a team, come to consensus on the specifications that you will use for your manufacturing process. That is, select a technical drawing created by a team member, or create a new technical drawing, which you will use when you manufacture boxes. You will compare the boxes you produce to this specification to determine the effectiveness of the manufacturing process.

3. As a class, develop two quality control standards that can be **measured** using a dial **caliper**, ruler, or protractor. Consider features that are most important to the aesthetics, function, and/or structural integrity of the box. Think about quality standards related to the box having square corners and being the correct size. Each standard may apply during an intermediate step of the process or to the final boxes. Refer to 3.9 SR TestingTruenessSquareness. Document these quality control standards in your PLTW Engineering Notebook.

4. As a team, design a manufacturing process flow diagram that details steps in your assembly line to produce one box for each student on your team. Document each step of the design process for your manufacturing process flow in your notebook.

5. Work with your team to estimate the cost of goods to make a single box. Use a Cost of Goods (COG) chart similar to the chart shown, and document calculations in your notebook. Remember to consider the number of boxes your assembly line will construct and pay close attention to **units**.

   Cost of Goods (COG)

Material or Service	Unit Cost	Quantity	Total

			Cost
Box Kit - 1 piece 1/4" × 4" × 4 1/2" wood - 2 pieces 1/4" × 4" × 5" wood - 2 pieces 1/4" × 4" × 4" wood	$4.25		
Student Time (research your state minimum wage per hour and write in)	State minimum wage: $________ /hour		
Teacher Consultation Time	$0.65/minute		
Testing Time	$0.12/second		
Fine for misrepresenting COG	Amount over real COG x 150%		

- What is your estimated COG for a single box?
- Based on the estimated COG, what revisions can be made to your manufacturing process flow to reduce the cost by reducing time or materials?

6. Have your teacher approve your manufacturing process flow before you move on to the next step. Your teacher should initial and date your process flow chart in your notebook.
7. Set up the assembly line to build one prototype box.
8. When all supplies and team members are ready, start the stopwatch and construct one box through the assembly-line process. Members of the team should document the test in their PLTW Engineering Notebooks, and when not directly involved in the manufacturing process, they should note flaws and mistakes. Include suggestions for process improvement. Stop the clock when the box is complete. Record the time it took to construct one box in your notebook. Be sure to specifically describe the quantity that you are recording. "Time to manufacture ONE box per the above process flow = ______."

   Estimate the time required to construct all the boxes. Remember that multiple workers can each work on separate boxes while the assembly line is running. Justify your estimate in a few sentences in your notebook.
9. As a team, assess the quality of the prototype based on the quality control standards you developed in step 3. Identify, discuss, and record (in your notebooks) the steps in the assembly line that resulted in an inefficient use of time or poor quality construction.
10. Devise and document in your notebook a plan to improve the process to address each inefficiency or quality issue.
11. Update your manufacturing process flow to reflect your planned improvements to the assembly line. Have your teacher approve and initial your revised process flow before you move on to the next step.
12. Set up the assembly line for mass production. After all supplies and team members are set up,

start the stopwatch and manufacture all the boxes. Stop the clock when the last box is complete. Record the time in your notebook.

13. Using your quality control standards determined in step 3, perform a quality inspection of all the assembled boxes. Document your results in your PLTW Engineering Notebook. As a class, compare and contrast manufacturing processes. What worked well? What needed improvement? Document your thoughts in your notebook.

14. Using a dial caliper, measure and record the length, width, and height of the boxes that your group produced. Collect this data for all the boxes constructed in your class.

15. Using a spreadsheet application, analyze one dimension (length, width, or height) of the class data by performing a statistical analysis of the data to determine each of the following:

    - Mean
    - Median
    - Mode
    - Range
    - Sample Standard Deviation

    Insert your data and analysis into your engineering notebook.

16. Create a **histogram** to represent the data. Use five to seven **class intervals** (bin values). Be sure to label your axes and define units, where appropriate. Insert your histogram into your engineering notebook.

17. Does your data appear to be **normally distributed**? Answer the question and justify your answer in your engineering notebook.

18. Compare your class data for the measurement under investigation to data from another class section for the same measurement (provided by your teacher). Describe any differences you see in the shape, center, and the spread of the distributions in your engineering notebook.

19. Share your data analysis and your assessment of the quality related to the measurement under investigation with your class. Based on the statistical analysis of each of the three dimensions (length, width, and height), is one dimension more difficult to maintain in the manufacturing process than the others? Justify your answer. Why do you think this is true?

20. (Optional) Use the data to calculate the lower-quartile median and upper-quartile median for each class **data set.** Create a box plot for each data set. What conclusions can you draw by comparing the box plots?

21. Revise your manufacturing process flow, as appropriate, to reflect recent findings. Create a final manufacturing process flow in your engineering notebook.

Conclusion Questions

1. Did you meet your estimated time to complete all the boxes? Why or why not?
2. List two advantages and two disadvantages of assembly-line manufacturing.
3. How does quality control and quality assurance fit into the design process of the product?
4. How can statistics of a product's dimensions be used to assess the quality of the product?
5. Did you class produce boxes more accurately than the comparison class? Explain your answer.
6. Did you class produce boxes that are more precise than the comparison class? Explain your answer.