Advanced Manufacturing & Prototyping Integrated to Unlock Potential

EXPRESSIONS AND EQUATIONS

Data-Driven Decision Making

POWER PAYOFF

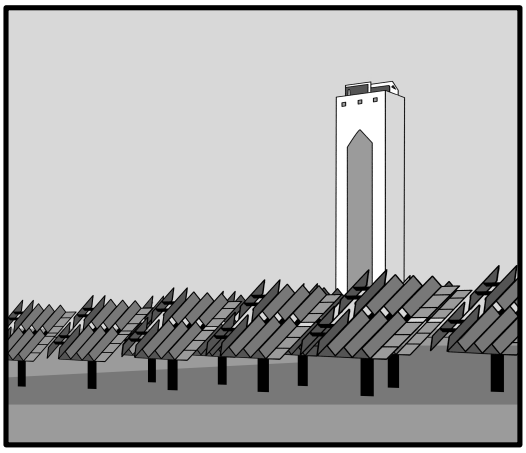
Power Finance Challenge

Fall 2018

8DMM

SECTION 1 – FINANCING THE SOLAR-THERMAL POWER PLANT

1.1 INTRODUCTION



The city of Solville has decided to build a new solar-thermal power plant. The city council is excited that the plant will produce clean energy to sell to customers. However, the plant will be very expensive to build. Mayor Whartenburger is worried whether the city will be able to afford it. Engineers have told the mayor and city council that they need to think about different costs when making their decision. They also need to think about the money that will be earned once the power plant starts selling electricity. If the power plant costs more to run than the amount of money it earns, it will go broke and need to shut down. On the other hand, if the plant makes more money than it spends, the city will make a profit.

In order to build the plant, the city will need to borrow money, which they will pay back over time when the plant starts to sell electricity. They will not be able to build anything else new until the power plant is fully paid for and is making a profit. The citizens of Solville have voted that the next big project will be to build a skate park, so everyone is eager to pay off the power plant loan as quickly as possible.

THE CHALLENGE

Your team has been hired by Mayor Whartenburger and the Chief Financial Officer of the city because you are engineers who understand both power plant construction and finance. You will make recommendations about which insulation materials to use when building the power plant. To help the mayor and council make their decision, you will need to collect evidence and decide which things are most and least important, and how to balance priorities.

1.2 ADD TO YOUR UNDERSTANDING: MAKING FINANCIAL DECISIONS

In order to make a sound financial decision for the city, you need to understand all the factors that will influence the city's financial planning. Four main factors are particularly important:

Part 1 of 4 – Expenses: The total amount of money it will cost you to provide the products or services.

In this case, the expenses are the amount it will cost the city of Solville to build and operate the power plant. The city of Solville's total expenses will include what it costs to build the power plant at the beginning (the ***start-up expense***), and how much it costs to run it each year (the ***yearly operating expenses***).

Discuss these questions as a class:

1. What are some examples of expenses that will be required to build the power plant?
2. The plant costs money to operate. What does the plant need to spend money on every year in order to run smoothly?

The city of Solville will need to borrow all the money from the bank to build the power plant. For this situation, the start-up expense is the amount of the **bank loan**. If you choose to use more expensive materials when building the power plant, the start-up expenses will be higher and the city will need to borrow more money. However, a power plant made with more expensive insulation materials might power more homes and increase the amount of money the plant makes after it is running. These competing priorities are called **trade-offs.**

Discuss these questions as a class:

1. What are examples of trade-offs that you need to make in your life?

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Part 2 of 4 – Revenue: The amount of money you earn by selling goods or services

For the Power Finance Challenge, the revenue is the money the city earns by selling power to people in order to power their homes and to charge their electronic devices. On average, each home pays $1,000 per year for electric power.

Discuss these questions as a class:

1. If the power company sells power to 50 homes, how much money will they earn as revenue?
2. If the power company sell power to 125 homes, how much money will they earn as revenue?

This revenue is <u>all</u> of the money coming into the power plant. Economists call this the **gross yearly revenue**. The formula for the gross yearly revenue (in dollars) earned by the power plant is:

Gross Yearly Revenue ($) = Number of houses powered X $1,000

Unfortunately, the city of Solville cannot use all the gross yearly revenue to pay for other things. As we discussed, it takes money each year to operate the power plant. An important financial term is the **net yearly revenue**, which is the amount of money the city can spend on other things. The formula for the net yearly revenue (in dollars) earned by the power plant is:

Net Yearly Revenue ($) = Gross Yearly Revenue ($) – Yearly Operating Expenses ($)

In this challenge, you will use a computer simulation to collect data about the number of houses that the power plant can power under different conditions. You will use this data to help determine how much gross and net yearly revenue the city can earn, and how quickly Solville can pay back their loan. That information will help you decide which insulation materials to use during construction.

Part 3 of 4 – Profit: The amount of money you earn after all expenses have been paid

The profit is found by subtracting all your expenses from your revenues. If the result is a positive number, then you are making a profit and can use that money to buy other things. Until the bank loan is paid off, all of the net yearly revenue earned by the Solville power plant needs to be paid to the bank. Once that loan is paid off, Solville will make a profit from selling electricity. Then, the city can build the skate park that the citizens of Solville requested. The quicker that happens, the more pleased everyone will be.

Part 4 of 4 – Break-Even Point: The point in time when you have spent the same amount of money as you have earned

The **total expenses,** or **cumulative expense,** is all the money that has been paid since the beginning. It is calculated by adding the start-up expenses to all the yearly operating expenses that have been spent since the power plant began running.

The **total revenue,** or **cumulative revenue,** is all the money that has been earned since the beginning. You find this by adding up all the gross yearly revenue numbers.

The **break-even point** is when your total expenses is equal to your total revenues. After that time, you will make a profit.

Discuss this question as a class:

1. If your class decided to run a snack stand at one of your school events, how would you determine the break-even point?

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1.3 POWERING THE CITY INVESTIGATION

Your team will need to collect data about the power plant to help Mayor Whartenburger and the city's Chief Financial Officer make a good, informed decision about their power plant. In particular, you will need to test how many houses the plant can power using different types of insulation materials and determine what the start-up expenses and yearly operating expenses will be. In the end, you will need to determine how long it will take for the city to break-even and be able to make a profit. You will use a **computer simulation** to collect this data because the power plant has not been built yet. An advantage of using a computer simulation is that it can help calculate the financial information your team needs to help you make your decision.

In this investigation, you will gather the following data from the simulation.

1. The number of houses powered by the plant.

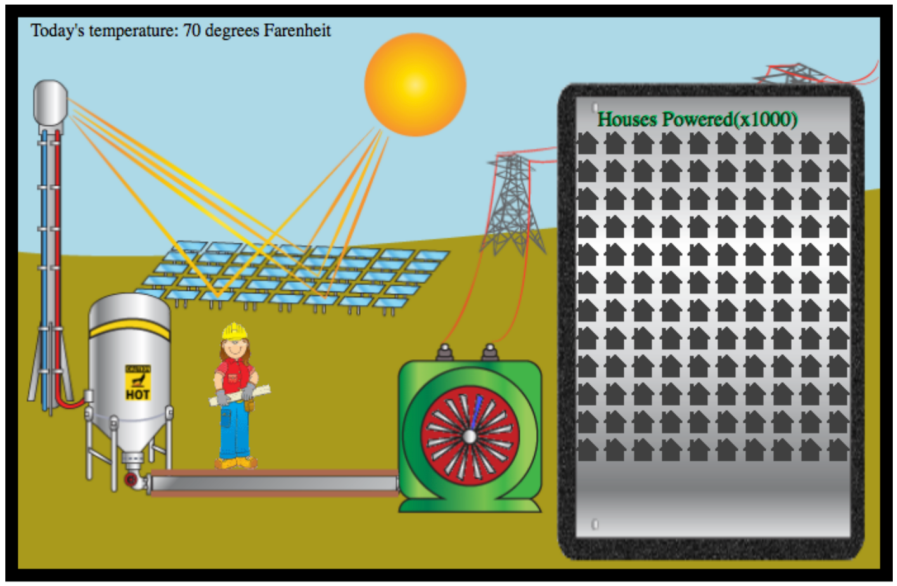
   Using the simulation, you can change the type of insulation material and the material thickness. Based on the what you select, the simulator will predict the number of houses the plant can power.
2. The start-up expenses for the power plan for each insulation material.

   Different insulation materials cost different amounts, so the simulation allows you to change the one you use, and predict the costs.
3. The annual operating expenses for the plant, for each insulation material.

First, Mayor Whartenburger wants you to report the data if you built the plant using 5 cm of Adobe insulation to ensure that you and your team know how to use the simulation. You will test other materials later.

Use the experimental procedure on the following page to collect your data. You can access the computer simulation at the link and password provided by your teacher. The simulation should look like the screen shot on the next page.

8DMM Power Finance Challenge



Investigating Finances

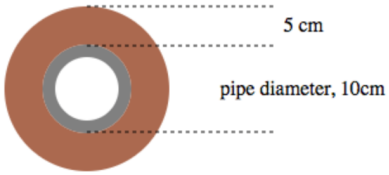
Choose insulation type: Adobe

Choose insulation amount (cm): 5

Startup expense($): calculate

Annual operating expense($): calculate

Connect the Power | Calculate Expense



1. Generator Capacity | 2. Testing Insulation | 3. Financial Calculations

Procedure:

1. Go to the web address and enter the password your teacher has provided.
2. Click on button 3: 3. Financial Calculations on the simulation.
3. On the top right, choose your insulation type by clicking on the arrow and selecting Adobe.
4. On the top right, choose your insulation amount, by clicking on the arrow and selecting 5 cm.
5. Click on the button Connect the Power. This will start the simulation.
6. On your *Financial Planning Sheet #1*, record the number of homes that can be powered using 5 cm of Adobe as your insulator in table 1. Each house icon in the grid represents 1,000 homes. Remember to multiply the number of house icons that are lit up in the grid by 1,000 to get the actual number of houses.
7. Click on the button Calculate Expense
8. On your *Financial Planning Sheet #1*, record the start-up expense and the annual operating expense in table 1.

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9. Use the data you collected from the simulation to calculate the gross and net yearly revenues. The formulas are provided below. Record the revenues in Table 1 on your *Financial Planning Sheet #1.*

Gross Yearly Revenue

Since on average each house pays $1,000 per year for power, you calculate your total annual revenue using this formula:

Gross Yearly Revenue ($) = Number of houses powered X $1,000

Net Yearly Revenue

This is the amount of money you have left from your gross yearly revenue after you pay for the costs of running the power plant for the year. Until the loan is paid off, this money will go to the bank. After that, this money will be Solville's profit.

Net Yearly Revenue = Gross Yearly Revenue – Yearly Operating Expenses

1.4 SOLVILLE'S FINANCIAL STATEMENT

You now have enough data to predict how long it will take Solville to pay back the bank loan and begin making a profit. Years ago, you would have been required to do the calculations by hand. Instead, you will instead use a computer spreadsheet to help with these calculations, just like current professionals do.

Procedure:

1. Open the *Solville Financial Statement* spreadsheet provided by your teacher.
2. Follow along with the class to enter the following data into the *Solville Financial Statement:*
    a. Insulation Material – Adobe
    b. Insulation Thickness – 5
    c. Number of Homes Powered – The number that you determined using the simulation (92,000).

3. Use the numbers that you computed and recorded in Table 1 on *Financial Planning Sheet #1* to enter the following data into the *Solville Financial Statement:*

    a. Enter the start-up expenses

    b. Enter the gross yearly revenue

    c. Enter the yearly operating expenses

    d. Enter the net yearly revenue

Discuss these questions as a class:

1. Why is the gross yearly revenue the same for every year on the statement?

2. When will the city make a yearly profit first? What had to happen first in order for the city to make a profit?

3. Is the total cumulative revenue increasing? Is it constant? Why?

4. When did the city break-even? Can you determine exactly when the break-even point occurred?

1.5 FINDING THE BREAK-EVEN POINT BY GRAPHING LINES

The *Solville Financial Statement* revealed which year the break-even point occurred. In this section, you will now determine this break-even point with more accuracy using mathematical equations and a coordinate graph. You will do this by first generating ordered pairs, then determining the **equation of the line** for both the total, or cumulative, revenue and the total, or cumulative, expenses. Graphing these lines will show you when the total revenue is equal to the total expenses.

Part 1 of 2 – Determine the Equations of the Lines

Procedure:

1. Locate the total cumulative revenue and total expenses columns in the *Solville Financial Statement* spreadsheet.

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2. Using numbers from the financial statement, fill in the total cumulative revenue and total cumulative expenses for Years 0-3 in table 2 on your *Financial Planning Sheet #1*. Year 1 has been completed as an example for you.
3. Complete table 2 on your *Financial Planning Sheet #1* by creating ordered pairs for the total expenses data using the ordered pair form: (year, total expenses).
4. Create ordered pairs for the total revenue data using the ordered pair form: (year, total revenue).
5. At the bottom of the *Financial Planning Sheet #1***,** use the data from Table 2 to determine the **slope (m),** the **y-intercept (b),** and the **slope intercept equation** for both the total expenses and total revenue lines.

Part 2 of 2 – Graph the Lines for Total Expenses and Total Revenue

Procedure:

6. On your *Break-even Graph* student sheet, graph the total expenses equation of a line, using a red "X" to graph the points and including the year 0 intercept. Draw the line.
7. On your *Break-even Graph* student sheet, graph the total revenue equation of a line, using a black "O" to graph the points and including the year 0 intercept. Draw the line.
8. Determine the break-even point for the power plant, when the total expenses equals the total expenses. Record this number at the bottom of your *Break-even Graph* student sheet.

You have now determined the break-even point for Solville's power plant if the plant is built using 5 cm of Adobe as the insulation material.

Discuss these questions as a class:

1. What is the total revenue at year 0?
2. What are the total expenses at year 0?
3. What point on the graph shows the break-even point?
4. Is this break-even point more precise than the break-even point you generated from the *Solville Financial Statement* spreadsheet?

SECTION 2 – PLANT DESIGN INVESTIGATION

2.1 DETERMINING BREAK-EVEN USING A SYSTEM OF EQUATIONS

You have now determined the break-even point using a spreadsheet and a graph. Although these methods are useful, they can be time consuming and inaccurate. In your role as advisor to the city of Solville, you want to be able to determine the break-even point quickly and accurately. This is best done using a mathematical process known as solving the problem using a **system of equations**.

When you have two or more equations with the same set of unknowns, you can use a s**ystem of equations** approach to find where the equations share a common value. In this challenge, the common value is the Solville power plant's financial break-even point. In other words, it is the point where Solville will start to make a profit.

Your teacher will instruct you on how to use the System of Equations mathematical technique. Practice the systems of equations method to find the exact break-even point for the Adobe-insulated power plant.

Procedure:

1. Locate the equations of a line that you determined for total revenue and total expense that are located at the bottom of your *Financial Planning Sheet #1*.
2. Transfer these equations to your *Break-even System of Equation* student sheet.
3. Use the system of equations method to identify the exact break-even point and record that number.

Discuss these questions as a class:

1. Does this method provide a more exact determination of the break-even point? What is that point?
2. Did everyone in the class have the exact same break-even point? Was that the case with the spreadsheet or the line graph?

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2.2 DETERMINING WORKABLE PLANT DESIGNS

You determined that a power plant insulated with Adobe can break-even and become profitable for the city of Solville. Another important criterion for this power plant is that it needs to be able to provide power to all the 120,000 homes in the city. If it can provide power to more houses than there are in Solville, the city can sell the power to a neighboring town.

Discuss these questions as a class:

1. Did the power plant constructed using 5 cm of Adobe create enough power for the city of Solville?

2. If the power plant can power 150,000 homes, how much extra money can Solville earn per year? Assume that each home purchases $1,000 in electricity per year.

Your team's next task is to determine which power plant designs can produce enough power for a city of 120,000 homes and how much each will cost.

Procedure:

1. Use the simulation to test each insulation material and each thickness to determine whether a power plant built using that insulation material is able to power 120,000 homes. Refer to section 1.3 to use the same procedure. Record all your data on your *Financial Planning Sheet #2*.
    a. If a design cannot produce enough power, discard that choice.
    b. For combinations of insulation material and thickness that can power 120,000+ homes, record all the information provided by the simulation in table 1 on your *Financial Planning Sheet #2*.
2. Complete table 1 on your *Financial Planning Sheet #2* by calculating the gross yearly revenue and net yearly revenue for each plant design.

Discuss these questions as a class:

1. Which power plant designs can provide enough power for the city? Each design is a combination of insulation and thickness.

2. Which designs can provide extra power to sell?

2.3 CALCULATING BREAK-EVEN POINTS

An important part of Solville's decision in choosing a power plant design is how long it will be before the city begins to make a profit. You have learned that this will happen only after the city reaches the break-even point. The easiest way to determine the break-even point is by using the method of systems of equations.

All of the plant designs that you recorded in table 1 of *Financial Planning Sheet #2* can provide enough power for Solville's 120,000 homes. Your teacher will assign you or your group one specific insulation material and thickness combination. Your task will be to determine the break-even point for that design.

Procedure:

1. Record on your *Financial Planning Sheet #2* the insulation material and thickness that was assigned to you by your teacher.
2. Determine the equations of a line for total revenue and for total expenses. Record the slopes, intercepts, and equations on your *Financial Planning Sheet #2*.
3. Use the systems of equations method to determine the break-even point. Show your work.
4. When all teams are finished with steps 2 and 3, each team will share your results with the rest of the teams in your class. Record all results reported in table 2 on the back of *Financial Planning Sheet #2*.

You now have all the data you need to make an informed decision about which power plant you will recommend to Solville's mayor and Chief Financial Officer. But how can you make an informed decision from all these numbers?

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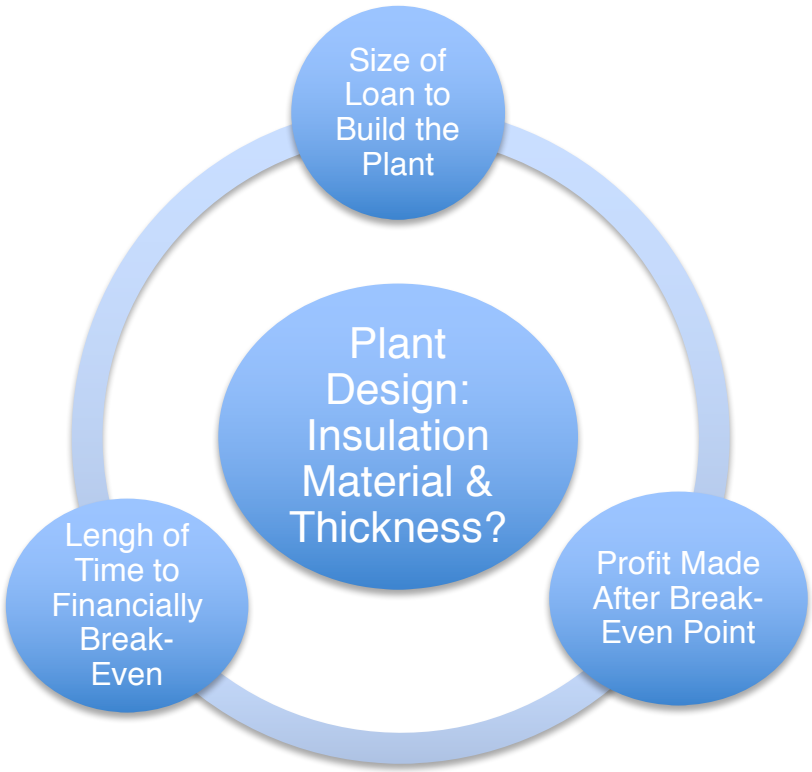
SECTION 3 – MAKING DECISIONS BASED ON DATA

3.1 UNDERSTANDING DECISION MAKING

How can all this information you gathered be used to make an informed recommendation about power plant design? There are different things to consider:

- The type of insulation material and its thickness determines how expensive the plant will be to build, and therefore how much money Solville needs to borrow.
- The amount of time it takes to financially break-even will affect how soon the city of Solville can make a profit and build a skate park.
- The plant design also determines whether Solville will be able to sell electricity to other towns, and therefore how much profit Solville will be able to make.

Below is a diagram of these factors. You will need to look at each one in detail to make a decision.



3.2 DECISION MAKING MATRIX

It is helpful to have all the information in one place in order to make an informed decision based on data. Then, you can easily compare the data for different options side-by-side. For this challenge, you will use a **decision making matrix** to compare your information.

A decision matrix usually includes three categories or types of data. Two are things that you know. The other category are the things you tested for. In this case, you know:

1) The insulation material and thickness combinations that can power at least 120,000 homes
2) The different types of financial factors that are important in making your decision. In this case, these are:
    i. The start-up expense, also known as the size of the bank loan
    ii. How long it will take to break-even
    iii. How much profit the plant can make? After the loan is paid off, this is the same as the net yearly revenue.

Your *Decision Matrix* student sheet has these items pre-labeled on the matrix. The third type of data in the challenge, which you will fill into the boxes of the matrix, is the actual numbers for each plant design that you and your teammates determined.

Procedure:

1. Locate the data in Tables 1 and 2 from your *Financial Planning Sheet #2***.**
2. Transfer the numbers to complete the *Decision Matrix*.

3.3 CODING THE MATRIX

You are now ready to use the matrix to assist in the decision-making process. Using the directions below, you will use the matrix to code each square of the matrix as being good, medium/average, or bad. Using the usual convention, green is good, red is bad, and yellow is average.

1) Start-up Expenses – Bank loan, in millions of dollars

The size of a loan determines how risky the loan is. From a bank's point of view, risk is defined as the chance that the loan will not be paid back on time. If the loan request for the power plant is too big, then the bank will consider the loan to be very risky. In that case, the bank will charge Solville a lot of extra money for the risky loan. For this loan, the bank has decided that there are three levels of risk.

a. Low risk: Any amount less than or equal to $500 million is considered low risk. Solville will not be charged any extra fees to get this loan. Color the loan amounts on the matrix that are low risk with a green colored pencil.
b. Medium risk: Any amount between $500 million and $600 million is considered medium risk. The bank will add some extra fees to the cost of the loan. Color the loan amounts on the matrix that are medium risk with a yellow colored pencil.
c. High risk: Any amount over $600 million will require that Solville pay substantial extra fees for the loan. Color the loan amounts on the matrix that are high risk with a red colored pencil.

2) Time to Break-even

The Solville City Council has plans to revitalize the city once the power plant has reached the break-even point and is making a profit. That includes building the skate park. The sooner this occurs, the better.

a. Best timeline: Any amount of time less than or equal to 3.5 years is considered by Solville to be the best timeline. Color the best time to break-even data on the matrix with a green colored pencil.
b. Medium timeline: Any amount of time between 3.5 and 5 years will slow down the Soville revitalization. Color the medium/average time to break-even data on the matrix with a yellow colored pencil.
c. Worst timeline: Any amount of time greater than 5 years is considered by Solville to be very slow. Color the worst times to break-even data on the matrix with a red colored pencil.

3) Yearly Profit after Break-even

The Solville City Council's revitalization plan is dependent upon the city making a good yearly profit from the power plant. The City Council wants to invest money in infrastructure throughout the whole city but the amount of profit will determine how much they can do.

a. Whole city: Any amount greater than or equal to $160 million per year will give Solville enough money to fund project throughout the entire city. Color the yearly profit numbers in the matrix that are large enough to fund projects across the whole city with a green colored pencil.
b. Most of the city: Any amount between $100 and $160 million per year will provide enough money to fund project in most of the city. Color the yearly profit numbers on the matrix that are in this range with a yellow colored pencil.
c. Half of the city: Any amount less than $100 million will only allow for revitalization projects in half of the city of Solville. Color the yearly profit numbers on the matrix that profits only half the city with a red colored pencil.

3.4 MAKING YOUR RECOMMENDATION

Your job, as advisor to Mayor Whartenburger, is to recommend the type of insulation material and its thickness that should be used when building the city's solar thermal power plant. On your *Insulation Recommendation Sheet*, provide your recommendation of both the material and its thickness. Support your recommendation with the financial information that you gathered using the power plant financial simulation, that you calculated using system of equations and with a consideration of the local community.

Things to think about, and balance, as you make your decision:

1. How does the amount of the loan request impact whether Solville has to pay extra fees?
2. How does the amount of time to break-even impact the Solville revitalization plan?
3. How does the amount of profit impact how much revitalization the mayor and city council will be able to do?

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This curriculum is produced by Advanced Manufacturing & Prototyping Integrated to Unlock Potential (AMP-IT-UP) supported by National Science Foundation Award #1238089 through Georgia Institute of Technology's Center for Education Integrating Science, Mathematics, and Computing (CEISMC).

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