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Calculus 1210
Pipeline Project

OBJECTIVE

I have been given the task to determine the best route for running the pipeline from the natural gas well to our refinery. We will first review the known costs, review three possible scenarios, and then determine what the best route will be based off my findings.

KNOWN COSTS

- The cost for labor and fees to run the pipeline strictly on BLM ground is $500,000 per mile.
- The cost to run the pipeline across private ground is $350,000 per mile for right-of-way fees in addition to the aforementioned $500,000 per mile.
- The cost to drill through mountainous territory is $1,200,000. This figure is to be added to the normal costs of the pipeline itself.
    - It must be noted that if we are to drill through the mountainous territory, the BLM requires an environmental impact study. This study is estimated to be $240,000 and will delay the project by four months which in turn will cost us $140,000 per month.

Now having reviewed the known costs, let us take a moment to analyze the cost of three individual routes:

BLM GROUND

This can be broken up into two different cases; we can either go around the private land remaining on BLM ground, or go directly through the mountain. We will first review the former.

Mountainous Detour

In order to avoid the mountain and private land we need to lay the pipe 3 miles west, then go 8 miles south, and lastly lay it 25 miles heading east to the refinery. This requires a total of 36 miles of pipeline. Recalling that pipeline strictly for BLM ground is $500,000 per mile we can determine the cost in this scenario.

$$B(x) = 500{,}000*x$$

Where ‘x’ equals the amount of pipeline required, and ‘B(x)’ equals the cost of laying pipeline only on BLM ground. So we have:

$$B(36) = 500{,}000*36 = \$18{,}000{,}000$$

Through Mountain

If we are to drill through the mountainous territory we then need to figure in the additional costs of the environmental study and loss of revenue over the 4 months. This gives us a new function which we will call M(x).

Let M(x) = 500,000*x +1,200,000 + 240,000 + 560,000

Where ‘x’ equals the amount of pipeline required, ‘$1,200,000’ is the cost of drilling through the mountain, ‘$240,000’ is the estimated cost of the environmental study, and ‘$560,000’ is the cost incurred due to the company being delayed for 4 months at a rate of $140,000 per month.

Assuming the mountainous territory is 22 miles, and then having to lay pipeline an additional 8 miles south to the refinery we then have a total of 30 miles of pipeline.

M(30) = 500,000*30 + 1,200,000 + 240,000 + 560,000 = $17,000,000

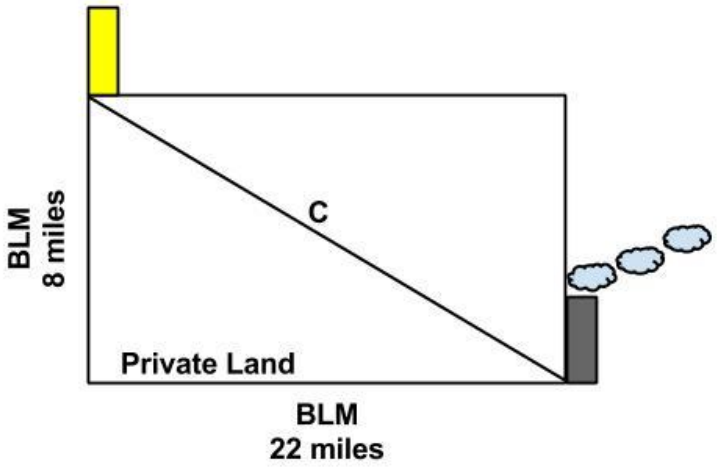
I wish I could say this were the best option, and stop boring you with number crunching. We do need to however look at a third option.

PRIVATE LAND (DIRECT ROUTE)

If were to take a direct route cutting through the privately owned land, and pay $350,000 per mile for right-of-way fees in addition to the $500,000 per mile we then up with the function:

P(x) = 850,000*x

Where ‘x’ equals the amount of pipeline required, $850,000 is the sum of $350,000 and $500,000 per one mile, and ‘P(x)’ is equal to the cost incurred. We first need to determine the length of pipeline required. Thankfully the great philosopher and mathematician, Pythagoras gave us a way to determine the amount. Take a second to look at the illustration below:



The yellow block illustrates the natural gas well while charcoal block illustrates the refinery. 'C' is the unknown. Using the Pythagorean Theorem (a^2 + b^2 = c^2) we then have:

$$8^2 + 22^2 = c^2$$
$$\Rightarrow\ c = \sqrt{548} = 23.41 \text{ miles}$$

So, we then have:

$$P(23.41) = 850{,}000*23.41 = \$19{,}898{,}500$$

ANALYSIS

Let's take one second to review the three totals:

- Mountain detour: $18,000,000 at 36 miles
- Through mountain: $17,000,000 at 30 miles
- Through private land: $19,898,500 at 23.41 miles

Even though it appears that the most cost effective route is to go through the mountain, we should be able to drive down the cost even further without having to delay the project for 4 months.

Using information from the first and third scenarios we can determine the optimal place to run the pipeline to minimize the cost. We can show this with the following cost function:

$$C(x) = 8.5(\sqrt{64 + x^2}) + 5(22 - x)$$

If we then take the derivative of the former function, we end up with:

$$C'(x) = \frac{17x}{\sqrt{64+x^2}} - 5 = 0$$

Solving for x:

$$\frac{17x}{\sqrt{64 + x^2}} = 5$$

$$\Rightarrow (17x = 5\left(\sqrt{64 + x^2}\right)^2$$

$$\Rightarrow 289x^2 = 1600 + 5x^2$$

$$\Rightarrow 264x^2 = 1600$$

$$\Rightarrow x^2 = 6.06$$

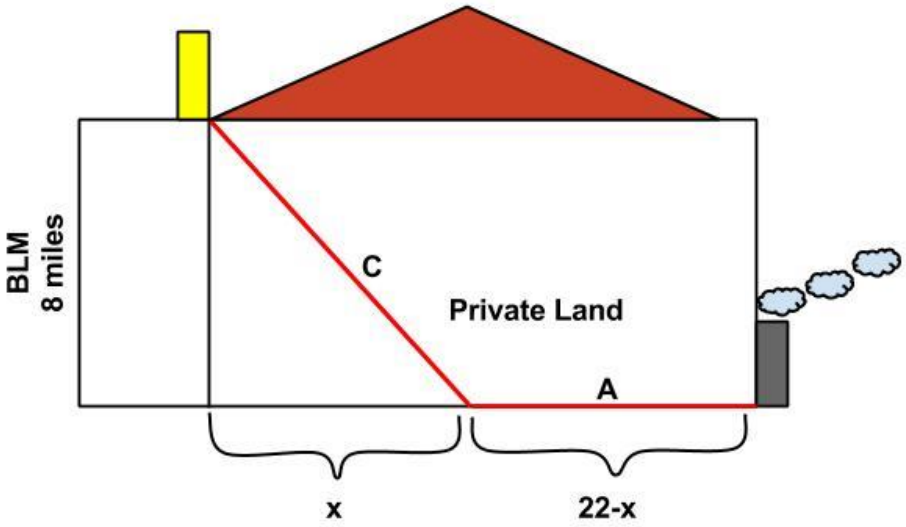
$$x = 2.46$$

Plugging 2.46 into the original cost function we can then find the optimal cost of the project:

$$C(2.46) = 8.5\left(\sqrt{64 + (2.46)^2}\right) + 5(22 - 2.46) = 168.76$$
$$168.76 * 100{,}000 = \$16{,}876{,}000$$

Using $\sqrt{64 + (2.46)^2}$ we can find the length of pipeline that must travel through private land which is 8.36 miles. Using $(22 - 2.46)$ we can the length of pipeline that will fall on BLM land which is 19.54 miles.

A path the pipeline may take is illustrated in red below:



So we have now determined laying pipeline across private land and BLM ground we can use 27.9 miles for a total of $16,876,000.

REFLECTION

I am the first to admit that I need more practice on my application skills, and this project was a great exercise in doing that. I do see calculus being a useful tool; however, other than the critical thinking skills I am unaware of how I will use it in CS. This opinion could quickly change due to the fact that I am not far in my major studies yet.