MMCS Oil Refinery Model

Introduction and Model Formulation

The purpose of this assignment is to develop an optimal operating policy for an oil refinery with three distillation columns (labeled A, B, and C) and a blender. It is possible to operate each distillation column continuously, i.e., 24 hours per day. The distillation columns take in crude oil and split it into butane, tar, unblended fractions, and waste.

Butane and tar can be sold as finished products, and fractions 1, 2, and 3 can be blended to produce petrol, kerosene, and diesel. It is company policy to try not to produce more than the demand of these products: if there is any excess output of butane, tar, or the unblended fractions, it must be disposed of at a cost. All waste must be disposed of at a cost as well.

This problem is modeled using Xpress-MP software. The optimal policy is calculated by finding the number of hours each column should operate in order to maximize profit. Details are available in the attached Mosel file.

Results for Part 1

Total profit is maximized when columns A and B are operated for 24 hours continuously, and column C is operated for 4.29 hours. It makes sense that demand is fulfilled first from columns A and B, which are run for the maximum amount of time, and then from column C, as it is the most expensive. This yields a profit of £765,398 per day.

Demands for butane, petrol, diesel, and tar are met (and not exceeded), but there is a shortage of 331.63 tons of kerosene. If this amount is produced, the cost of disposing of the additional waste of the other materials more than offsets the profit earned by meeting the demand for kerosene. These results can be seen in the following table.

	Quantity Manufactured	Demand	Shortage
Butane	3000.00	3000.00	0.00
Petrol	2000.00	2000.00	0.00
Kerosene	1168.37	1500.00	-331.63
Diesel	1750.00	1750.00	0.00
Tar	500.00	500.00	0.00

Changes to the Model for Part 2

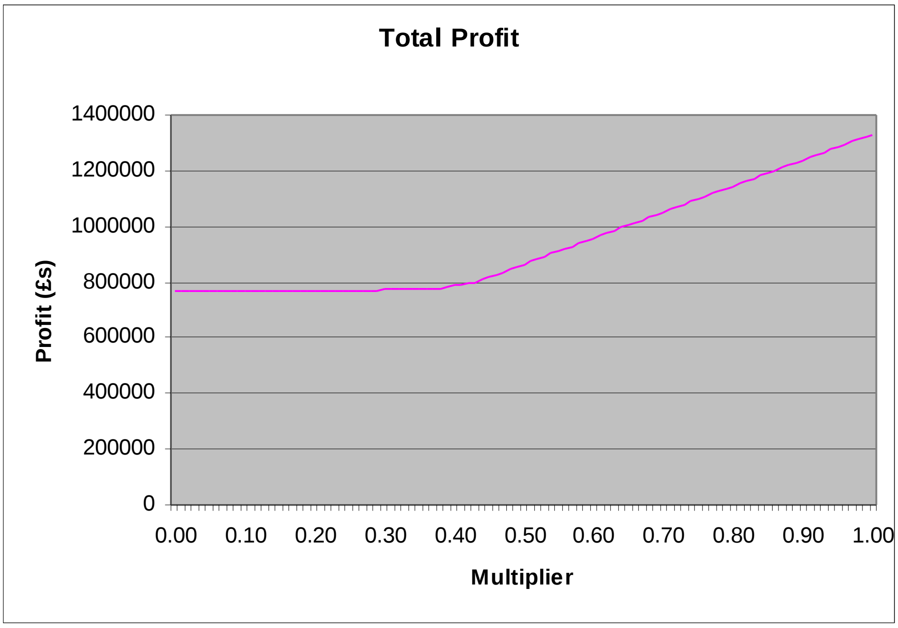
In the second part of this assignment, the company is able to sell any excess production for a price that is a discounted multiple of the normal sale price. The multiplier for this discounted sale price is varied from 0.00 to 0.99 in increments of 0.01. At the lower extreme, i.e., using a multiplier of 0.00, the only difference between this model and the one used for part 1 is that it is possible to give away any excess production without having to pay to dispose of it. At the upper extreme, i.e., using a multiplier of 0.99 (selling excess for 99% of the normal price), excess production is sold for the same price as the production used to meet the demand. In any case, there are still disposal costs for unused unblended fractions and waste.

Results for Part 2

Total profit increases with the multiplier, starting at £766,085 with a multiplier of 0.00 and increasing up to £1,322,360 with a multiplier of 0.99. Initially the optimal operating policy for the distillation columns is the same as before: 24 hours each for columns A and B and 4.29 hours for column C. This remains optimal until the multiplier is 0.23, at which point the usage of column C increases to 7.06 hours. When the multiplier is 0.38, the usage of column C increases to 14.26 hours. When the multiplier is 0.44 or greater, all three columns are operated for 24 hours continuously. This is shown in the table below.

Multiplier	Total Profit	Operating Hours		
		Column A	Column B	Column C
0.00	£766,085	24.00	24.00	4.29
0.23	£768,159	24.00	24.00	7.06
0.38	£777,214	24.00	24.00	14.26
0.44	£808,436	24.00	24.00	24.00

As illustrated in the graph below, the slope of the total profit line changes at the aforementioned values of the multiplier. The most significant change in slope occurs when the multiplier is 0.44, which is when all columns are used continuously for the first time.



In terms of production, as before, the demand for kerosene is not met initially. However, excess tar is produced, because in this case it can be given away (sold for a price of £0) and its disposal will not cost anything. When the multiplier is increased to 0.23, all demands are met, and in addition to excess tar, the company also produces excess butane. As the multiplier continues to increase, it becomes profitable to produce excess of more products, and when the multiplier reaches 0.44 it is profitable to produce excess of everything but kerosene.

It is not lucrative to produce excess kerosene for any multiplier values from 0.00 to 0.99. In fact, when the multiplier is 0.62, production decreases to less than the demand, and petrol production increases still more. This shows that it is more profitable to produce more excess petrol than it is to meet the demand for kerosene. All distillation columns continue to operate continuously. Their optimal policy is not affected by this change in production, thus there is no change in the slope of the total profit line in the above graph.

Increases in production can be seen in the color-coded table below, where a pink cell represents production that exceeds demand, a green cell represents production that is equivalent to demand, and a white cell represents production that is less than demand.

Multiplier	Quantity Manufactured				
	Butane	Petrol	Kerosene	Diesel	Tar
0.00	3000.00	2000.00	1168.37	1750.00	1187.37
0.23	3262.54	2000.00	1500.00	1750.00	1256.46
0.38	3946.56	2000.00	1500.00	3478.05	1436.46
0.44	4872.00	3288.39	1500.00	4012.26	1680.00
0.62	4872.00	3313.85	1482.46	4011.69	1680.00

As production increases, the cost of disposal of waste materials changes at the same multiplier values as production does, but does not always increase. There is understandably no butane or tar to dispose of, as those are finished products that may be sold. The quantities of the unblended fractions that remain unused change with production, but for any multiplier greater than 0.37, there is no excess fraction 3, and for any multiplier greater than 0.61, there is no excess fraction 1. For any multiplier greater than or equal to 0.62, the company only has to dispose of waste from the distillation columns. This is shown in the following table.

Multiplier	Cost of Disposal						Total Cost
	Butane	Fraction 1	Fraction 2	Fraction 3	Tar	Waste	
0.00	£0.00	£30.29	£0.00	£259.28	£0.00	£2,507.37	£2,796.94
0.23	£0.00	£60.69	£0.00	£295.21	£0.00	£2,576.46	£2,932.36
0.38	£0.00	£96.69	£0.00	£0.00	£0.00	£2,756.46	£2,853.15
0.44	£0.00	£3.68	£0.00	£0.00	£0.00	£3,000.00	£3,003.68
0.62	£0.00	£0.00	£0.00	£0.00	£0.00	£3,000.00	£3,000.00

Conclusions and Recommendations

For part 1, the optimal policy is to operate columns A and B for 24 hours and column C for 4.29 hours. This will yield the company a profit of £765,398 per day and meet all demands except that for kerosene.

For part 2, the optimal policy depends on the real value for which the company can sell excess production, with higher discounted multipliers yielding higher profits. If they can sell excess for up to 23% of the normal price, the optimal policy stays the same as it is in part 1. If the discounted price ranges from 23% to 37% of the normal sale price, the number of hours for which column C is operated increases to 7.06; from 38% to 43%, 14.26 hours; and for any value 44% or greater, all three distillation columns will be used continuously.

However, the company likely has other considerations on which to base the optimal operating policy decision. They may want to reduce their disposal costs, in which case the highest amount of production would not be ideal, as it would also cost more to dispose of waste products. Also, if they plan aggressively around operating all three distillation columns continuously and one breaks, they will suffer losses. If, on the other hand, they plan more conservatively by not using column C continuously, it can serve as a backup in the case that there is a problem with column A or B.

With the assumption that the company's customers are happiest when their demand is met and the conservative approach of not using all three distillation columns continuously, the multiplier value should be between 0.23 and 0.43, which would suggest an optimal policy of operating columns A and B continuously and column C for either 7.06 or 14.26 hours, and yield a profit between £768,159 and £800,108.