Project Report:
Coffee Roastery Inventory Management

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I. Problem & System Description

As a coffee roaster, one of the core operations is roasting raw coffee beans into a finished product to be sold to customers and cafes. It is a very simple, yet demanding responsibility that requires daily management in order to satisfy demands, capacity, and constraints.

The Roaster is the primary tool used in this process and is the focus of the system. This process is the basis of two models: (1) Productive Capacity and (2) Replenishment. The goal of Model #1 is understanding the optimal amount of batches to produce satisfying demand, respecting constraints, and minimizing costs for the business. Model #2's goal is to find the ideal amount of bags to replenish the roastery to satisfy the same parameters.

The problem these models solve is the inefficient use of resources that increases the cost of operation. Through optimization, the ideal amount of ready to use (finished) beans and raw (input) unprocessed beans is found to minimize cost. Assumptions being made in this model consist of:

- Constant Demand, with incorporation of seasonal factor
- Constant Price
- Uniform Roast Time for all types of Origins
- Holding Cost for only Finished Goods

II. Key Data & Data Sources

Data collection looks at invoices from customers and are compiled into a collective table helping determine a demand forecast.

Data Preparation

Cafes are composed of wholesale customers and cafes that the roastery sells to, customers are categorized by name, while cafes are categorized by location. Sell type varies across three categories: Food & Beverage, Retail, and Wholesale. Coffee Type denotes the different origins and blends being produced for the cafes. Base unit assigns the amount of coffee to the sell type and coffee type in terms of pounds. These characteristics help create a demand forecast determining the amount of finished goods to be supplied per month based on the origins and blends over a six-month period. Multiplying the “Base Unit” column by the anticipated demand from months one to six yields the weight needed per month

Data Transformation

The next step condenses data by performing a SUMIF function. This adds together monthly observations with matching coffee types. However, there are two nuances that need to be accounted for to accurately meet demand: (1) Input weight and (2) Blend composition. In the invoice analysis, all orders use fully roasted coffee beans. Therefore, the amount of beans initially being analyzed which are “finished” needs to be multiplied by a coefficient of 18/15 or 1.2 to properly account for the “raw” input weight. Additionally, blend composition must reflect the constituent origins that go into making the blend. There are four blends to account for: Classic, Game Changer, Peachfield, and Lock & Key. This is accounted for by adding together the demand for the origin itself and the fractional demand attached to the blend. Subsequent tables translate pounds demanded into batches and bags. This is used as the basis for decision variables and constraints used in the production capacity model and inventory model.

III. Excel Model

There are two excel models used in the project. The first model is a production capacity model which calculates the optimized batch production satisfying demand and minimizes costs. The second excel model calculates bag replenishment satisfying demand and minimizes costs. These models are both inventory-based, but look at different sides of the process, providing a clearer picture of inputs and outputs of the roasting process. This helps increase business performance through optimizing production & replenishment, and minimizes cost structure.

Production Model

	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6
Roasting Inventory	42	22	41	96	95	67
Production	152	264	300	300	300	300
Demand	172	245	245	301	328	328
Ending Inventory	22	41	96	95	67	39
Labor Cost	$ 1,266.67	$ 2,200.00	$ 2,500.00	$ 2,500.00	$ 2,500.00	$ 2,500.00
Holding Cost	$2,774.00	$2,730.20	$5,971.40	$8,336.60	$7,066.40	$4,613.60
Cost per Batch	$87.60	$87.60	$87.60	$87.60	$87.60	$87.60
Total	$4,040.67	$4,930.20	$8,471.40	$10,836.60	$9,566.40	$7,113.60
Objective:	$44,958.87					

Developing a model for production capacity looks at the output side of production. This starts with identifying the base units involved in the model. Since roasting uses batch production, batches will be used as the basis.. This is input into the “Demand” section of the model. Right above this will be the “Production” section, which is home to the decision variables being calculated by the solver model. Next, “Beginning” and “Ending" inventory is implemented. Beginning inventory for month 1 is going to be assumed in this situation, the amount is 5 bags worth of batches. Every month forward uses the ending inventory of the month prior as the beginning inventory. Ending inventory is a formula which adds together beginning inventory and production and subtracts demand. This is then dragged across the row for each month in the period. Next, monthly costs must be implemented, this is the basis for the model’s objective. There are two main costs associated with the model: (1) Labor and (2) Holding. Labor cost is found by multiplying the labor cost per minute by the batch time. This finds the cost of labor per batch, which is multiplied by the production variable for the month to find labor cost.

Holding cost is calculated by averaging the beginning and ending inventory and multiplying it by the average cost per batch. This model uses the average cost per batch because the productive model finds the total batch production required, not the specific, simplifying the model's calculations. With these two costs established a total cost can be found and summarized, this is the objective function of the model.

Moreover, constraints must be accounted for in the production process. There are three main constraints that need to be addressed: Time Capacity, Safety Stock, and Storage Capacity. Time capacity is based on available working minutes per month, which is 6,000 minutes. Safety stock applies to the ending inventory, and is determined by calculating 10% of the demand for that month. Storage capacity is storage available for finished beans on a monthly basis. With these foundational pieces laid out, a solver analysis can be created to optimize productive capacity, minimize the objective cost, and respect constraints imparted upon the system.

Replenishment Model

Guatemala										
		month 1	month2	month 3	month 4	month 5	month 6		Objective (Min):	$19,500.00
	Beg Inventory	10	10.00	10.00	10.00	10.00	7.00			
	Demand	4	6	6	6	7	7			
	End Inventory	6	4	4	4	3	0			
	Replenishment	4.00	6.00	6.00	6.00	4.00	0.00			
	Total Cost:	$3,000.00	$4,500.00	$4,500.00	$4,500.00	$3,000.00	$0.00			

Developing an Inventory model for replenishment looks at the input side of production. This starts by establishing bags as the base units since bags of coffee are typically ordered, not batches. Similarly to the production model, “Beginning Inventory”, “Demand”, and “End Inventory” is used. Beginning inventory is assumed to be 10 bags for every origin at the start of the period. Demand is based on the data collection table, and Ending inventory is calculated by subtracting Demand from Beginning Inventory. Then, the decision variable of “Replenishment” is inserted below these. Replenishment is determined by subtracting end inventory from the next period's demand, if this value is negative there is enough supply, however if the number is positive there is not enough supply and replenishment is needed. Total cost is calculated by multiplying the bag replenishment amount by the cost per bag for each respective origin. This makes up the objective function to be minimized. Constraints involved in the inventory model consist of: (1) Replenishment Minimum and Maximum, (2) Monthly Budget, and (3) Inventory Capacity. With these fundamentals laid out, a solver analysis can be created for the inventory model. This minimizes the objective cost, finds replenishment levels needed to satisfy demand, and respects inventory constraints. This process is repeated for every origin found at the roastery so a total cost can be found.

Both of these models depict the optimal Input and Output function related to the roasting process. This provides insight into what a Roastery's cost structure over a six-month period looks like given the amount of customers and cafes it provides to. Going a step further, sensitivity analysis can be conducted to understand where costs can be further minimized and where resources can be more efficiently allocated. This examines the relationship each variable has with the system, and enables decision-makers to experiment with the model in ways that reduce cost

IV. Discussion of Results

Below are the results of the Production & Replenishment model. First is the analysis of the production model and its sensitivity report which depicts two ways to minimise overall cost: (1) Labor time and (2) Safety Stock.

Analysis of Production Model

The Roastery currently runs at a cost of $44,824.69. However, it is possible to decrease the cost further under the condition that Labor Time is increased to 6,200 minutes per month, (an addition of only 200 minutes to the Constraint Table: Time Capacity,) it can save around $6,000 from the total cost. The focus data of the sensitivity analysis is shadow price and allowable increase. With shadow prices being negative, any additional minutes to the associated months will drive costs downward marginally. The First month provides the least value with ($4.38) per additional minute while the last month provides the most value with ($17.52) per additional minute. The relationship between labor time and the model supports adding more time to later months in order to minimize cost and enable more efficient production in Months 4, 5, and 6. Going beyond the allowable increases provides an opportunity to cut costs down to $9,500, this is based on the allotted constraints:

- Month 1, 2, and 3 are constrained to 6,000 minutes
- Month 4 time constraints are increased by 200 minutes, resulting in 6,200 minutes
- Month 5 time constraints are increased by 300 minutes, resulting in 6,300 minutes
- Month 6 time constraints are increased by 400 minutes, resulting in 6,400 minutes

Increased labor time in later months saves money for the business, aligning with the roastery's objective of minimizing cost.

Another way to minimize cost is by removing safety stock. Currently, there is a 10% finished inventory minimum for each month. This adds to the holding cost affecting the objective cost function. The final objective cost is $27,496 with safety stock removed, saving an additional $17,328 compared to the original model. Every bag has an average cost of $730, so every bag removed saves this amount. The most money is saved towards the end because there is no anticipated demand after month 6. So putting a constraint on the end serves no purpose other than adding cost.

Analysis of Replenishment Model

The objective minimal cost to meet all replenishment demands is $89,249. The model cannot be minimized any further; however, operational planning can be enhanced in two ways: (1) Budgeting and (2) Capacity. Using the budget of Guatemala as an example, the total cost of replenishment comes out to $19,500. The initial allocated monthly budget is $6,000, adding up to $36,000 over the entire period. However, since the total cost is actually less than this, the sensitivity analysis shows how to strategically allocate the budget across the period to reduce it by $12,000. This analysis is useful in developing an appropriate budget strategy to meet the demand for future periods on a rolling budget basis. This means whatever is leftover in a month can be used for the next period.

Another way to maximize operational efficiency is by optimally allocating storage. The Replenishment model has a storage capacity of ten bags, however not all ten bags are needed for some origins. Using the capacity of Guatemala, analysis shows that months two through four can be reduced to six bags, and Months five and six can be reduced to seven bags. Month one remains ten. Capacity has an allowable increase of up to ten, meaning that as long as stock stays within the allowable limits, the cost remains optimal. Due to no associated holding costs of raw inputs, only finished outputs, a flexible way to allocate storage for each origin is demonstrated in the model

V. Conclusion

The coffee roastery inventory and production models developed in this project successfully minimize operational costs while meeting demand and adhering to constraints. These models optimized key processes, including batch production and replenishment planning, and revealed opportunities to reduce costs further through strategic adjustments.. These insights highlight the value of data-driven optimization in improving efficiency and supporting informed decision-making in the coffee roasting process.

Data Processing was the most complex part of the modeling process. Every step refines the data into a more interpretable form helping apply it to the parameters of the model. Ensuring data integrity be maintained during this process strengthens the validity of results, providing accurate solutions for business problems.

Looking at the limitations of the model, it would be interesting to implement more advanced forecasting techniques to the demand forecast based on historical data. The model in the project uses a simple naive approach to determine demand. Incorporating discounts on bulk pricing would be helpful in analyzing costs in larger quantities. Roast times for different roast profiles can be implemented into the labor constraints to determine how to schedule roasting optimally in a work week. All these additional considerations paint a more transparent picture of the roasting process

Building a cost-minimization model in Excel pulls from several skill sets helping execute more effective decision-making. This process provides lessons in Data Analysis, Managerial Science, and Business know-how. Learning to apply assumptions is critical when needing to simplify objectives. Using dynamic tools such as Solver provides insight in its use in business strategy. Overall, this project taught how to manage complex data and create a model that provides clear & practical results.