SALMONES PUYUHUAPI PRODUCTION PLANNING

Team 7 Case 2: MGMT 573

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Introduction

Salmones Puyuhuapi (SP) is preparing to process 42,000 fish, and Commercial Manager Eliza Perez has less than four hours to develop the most profitable mix of whole fish (“enteros”), fillets, and portions (“porciones”). She must optimize production while considering machine capacity, labor, and freezer space constraints. She has to choose between **5 different products**; enteros fresh, enteros frozen, fillets fresh, fillets frozen and portions frozen.

This report addresses **three key questions**. First, it examines how a linear programming model can help maximize profits while staying within operational limits. Second, it evaluates the impact of renting an additional freezer with a 20,000-pound capacity on both profits and the production plan, including determining the breakeven rental price. Third, it considers a simpler production approach suggested by the CEO, where fish are sorted by weight into different product types.

The goal is to recommend a practical and profitable production plan that makes the best use of SP’s resources while meeting customer demand.

Question 1

Objective: Devise a production plan to maximize profits. Profits = Revenue - Cost

Variables: 5 types of products for 25 bins = 25 x 5 = 125 production variables.

Modeling decisions: Constraints

- Fileting capacity was calculated as 15 fish * 60 minutes * 2 shifts * 16 hours = **28800 fish.**
- Trimming was calculated as 16 hours * 7-hour shift * 10 filetes per minute * 60 minutes = **67200 filetes.**
- Portioning capacity was calculated as 16 hours * 1400 filetes per hour / 2 = **11200 filetes** (assuming a 16-hour day rather than 24 hours) and that the quantity of filetes were divided into 2 portions.
- Freezing capacity is 60000 * 2 freezers working converted in Kg as **54431.0844 kg.**

Modeling Decisions & assumptions

- Prioritize frozen products due to higher profitability and lower production costs (e.g., $3.50 per kg for frozen enteros versus $3.20 per kg for fresh).
- Variables selected represent the number of fish in each bin. 25 bins each had one of the 5 types of fish resulting in a total of 125 bins.
- Total Fish in Bin is Fixed: All fish is assigned, no fish is left unprocessed.
- Revenue and costs are calculated considering the yield percentage of the Enteros and the Filetes but not for the Porciones. This is because the price and cost for Porciones is given as per live weight unlike Filetes and Enteros which is given as per finished kg.

Impacts

- Final profit of **$474,315.93** while minimizing costs. Optimizing the product mix maximizes profit while respecting operational limits. All 42,000 fish are processed given the available capacities.
- Balancing constraints ensure efficient utilization of the plant's resources (filleting machines, freezing capacity, and labor).

Limitations of the model

- This model assumes linearity, but this may not be true as costs and yields may not be proportional

- The model relies on divisibility. In practice, fractions of fish do not exist.
- Static capacity constraints, e.g., trimming, are fixed for a single day. The model does not account for dynamic changes such as shift lengths or worker variability
- Quality variability (e.g., color, fat content) affects prices and processing yields but is not modeled. Lower-quality fish might require rework or downgrading, impacting profitability.

Question 2

If Perez decides to rent a temporary freezer with a 20,000-pound daily capacity, the additional freezing capacity will significantly impact both profitability and the production plan. Currently, the freezer capacity is the bottleneck, limited to 120,000 pounds per day due to only two functioning tunnel freezers. The shadow price for freezer capacity is $0.40 per pound, indicating that for every additional pound of capacity, the profit would increase by **$0.40**, provided this increase remains within the allowable range. However, on looking at the sensitivity report, we see that an increase of 20000 lb or **9071.85 kg** is not within the allowable range of increment which is only **6174.08 kg** Therefore, increasing the RHS of the freezing capacity constraint will change the optimal solution and the solution structure in a way not covered in the sensitivity report. Thus, we generated a parameter analysis report to see how the solution change does as we increase the RHS by 20000 lb. We find that at a freezing capacity of 140000lb (20000 increase), the optimal profit increases to **$478255.78** which is an increase of **$3628.74** from the original solution.

However, on looking at the sensitivity report, we find that this increase in freezing capacity matches the insight from sensitivity report. The shadow price for the freezing capacity constraint is 0.4. Thus, the increase in optimal profit = 0.4 x 20000 lb in kg = 0.4 x 9071.8474 = **$3628.74.**

Therefore, the **rental price of the freezer should be lesser than $3628.74** in order to be lucrative. If the rental cost exceeds this amount or is equal to this amount then the additional profit from increased capacity would not offset the cost of renting, making the investment unprofitable.

This increase in capacity would allow the production plan to prioritize freezing more products, such as frozen filetes and enteros, which have higher selling prices and lower production costs compared to their fresh alternatives. Towards the increased profit of **$478255.78, the proportion of frozen enteros and filetes increases with the added freezing capacity till no fresh enteros are produced.**

Limitations:

- The model assumes that all additional 20,000 lb of freezing capacity will be fully utilized in production
- Increasing freezing capacity could create bottlenecks in other production areas (e.g., labor availability, packaging, transportation).

Constraints

Office on the web Frame		Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
B91	Filleting capacity Enteros	28800	0.926920196	28800	5150.036001	424.3241113
B92	Trimming capacity Enteros	28800	0	67200	1E+100	38400
B93	Portioning machine Enteros	0	0	11200	1E+100	11200
G55	Bin 1 D	0.00373492	2.253169832	0.00373492	1E+100	0.00373492
G56	Bin 2 D	0.029134723	2.526078764	0.029134723	1E+100	0.029134723
G74	Bin 20 D	611.209033	13.52801542	611.209033	424.3241113	611.209033
G75	Bin 21 D	236.981035	14.0580102	236.981035	424.3241113	236.981035
G76	Bin 22 D	78.45568049	14.58811272	78.45568049	424.3241113	78.45568049
G77	Bin 23 D	22.17723261	16.21233098	22.17723261	424.3241113	22.17723261
G78	Bin 24 D	5.35236863	16.7788481	5.35236863	424.3241113	5.35236863
G79	Bin 25 D	1.102865313	17.34551857	1.102865313	424.3241113	1.102865313
E90	Freezing Cap Filetes Frozen	54431.0844	0.4	54431.0844	6174.081137	10555.20033

Rental Price
3628.73896

Question 3

To simplify the production plan as requested by Correa, Correa (the CEO) wants lightest fish to be processed as enteros (fresh, frozen, or a combination), the heaviest fish be processed as porciones (frozen), and the remaining fish be processed as filetes (fresh, frozen, or a combination). To achieve this hierarchy in weights, we came up with a set of linking and logical constraints guided by introducing **3** new binary variables for all **25 bins = 25 x 3 = 75 binary variables**.
→Y(E), Y(F), Y(P): indícate 1 if Enteros/Filetes/Porciones are produced and 0 otherwise.

Assumptions

- Processing Order Hierachy (According to weights)
- Total Fish in Bin is Fixed: All fish is assigned, no fish is left unprocessed.
- Each bin can only have one type of fish: Enteros, Filetes or Porciones. Cannot have a mix. This can be modelled as: Y(E)+Y(F)+Y(P) = 1 for all 25 bins.

1. **Linking Constraints (Connecting Binary & Production Variables)** (Formula in Appendix)

- Enteros Constraints: If a bin is assigned to Enteros, it must have fish in Enteros Fresh/Frozen. Other categories (Filetes & Porciones) must be zero.
  →(Enteros_Fresh + Enteros_Frozen) – y(E) × (TotalFishinBin) ≤ 0
  →(Filetes_Fresh+Filetes_Frozen+Porciones_Frozen)≤(1−y(E))×(TotalFishinBin)

- Filetes Constraints: If a bin is assigned to Filetes, it must have fish in Filetes Fresh/Frozen. Other categories (Enteros & Porciones) must be zero.
  →(Filetes_Fresh + Filetes_Frozeni) − y(F) × (TotalFishinBin) ≤ 0
  →(Enteros_Fresh+Enteros_Frozen+Porciones_Frozen) ≤ (1−y(F))×(TotalFishinBin)

- Porciones Constraints: If a bin is assigned to Porciones, it must have fish in Porciones Frozen. Other categories (Enteros & Filetes) must be zero.
  →Porciones_Frozeni−y_Porcionesi×(TotalFishinBin)≤0
  →(Enteros_Freshi+Enteros_Frozeni+Filetes_Freshi+Filetes_Frozeni)≤(1−y(P)
  ×(TotalFishinBin)

2. **Logical Constraints: Bin Processing Order & Hierarchy Restrictions** (Formula in Appendix)

- If a bin is processed as Filetes or Porciones, the next bin cannot be processed as Enteros.
- If a bin is processed as Porciones, the next bin cannot be processed as Filetes.

We could successfully simplify the production plan as the CEO wanted. According to our plan:

Bin 1 - 13	Enteros Fresh
Bin 14 - 15	Combination of Filetes Fresh & Frozen
Bin 16 – 25	Filetes Frozen

We observe that similar to Question 1, we still do not produce any “porciones” at all. Our Optimal Profit with this Production plan is **$473,136.42** which is lesser than the optimal profit of Question 1 by a small amount of $1490.62. This may be due to the fact that we are trying constraint the bins into only producing a specific type of product. However, the model in Q1 also more or less had bins producing only one type of product hence the profit does not decrease much. Here is a picture of the production plan simplified.

Enteros Fresh	Enteros Frozen	Filetes Fresh	Filetes Frozen	Porciones Frozen
0.00373492	0	0	0	0
0.029134723	0	0	0	0
0.194007062	0	0	0	0
1.102865313	0	0	0	0
5.35236863	0	0	0	0
22.17723261	0	0	0	0
78.45568049	0	0	0	0
236.981035	0	0	0	0
611.209033	0	0	0	0
1346.06471	0	0	0	0
2531.355898	0	0	0	0
4065.000591	0	0	0	0
5574.360112	0	0	0	0
0	0	1941.475291	4586.237856	0
0	0	6527.713148	0	0
0	0	0	5574.360112	0
0	0	0	4065.000591	0
0	0	0	2531.355898	0
0	0	0	1346.06471	0
0	0	0	611.209033	0
0	0	0	236.981035	0
0	0	0	78.45568049	0
0	0	0	22.17723261	0
0	0	0	5.35236863	0
0	0	0	1.102865313	0

Observations: We observe that the model of Q1 and Q3 both do not produce any Porciones fish. This might be due to the fact that even though the price is high, the cost of producing the Porciones is also equally high.

Limitations

The model does not include capacity constraint for each bin or capacity constraint for each type of product. The models of Q1 and Q3 do not take into consideration the demand of each product type.

Recommendations

- Integer variables may be used to enforce whole-fish allocation, though this increases computational complexity.
- Scenario Analysis to test the model against variable harvest sizes, demand shifts, or machine downtime to assess robustness.
- Include demand coefficients to better model the production plan to increase profits.

Solution Structure

Variables: X_{ij} , Y_{ij}

X_{ij} :- No. of fishes produced in bin (i) in product (j)

Y_{ij} :- Binary variables for Enteros, Fillets, Portions

$Y_{ij} = 1$; if Bin (i) produces E, F or P

$Y_{ij} = 0$; otherwise

Objective function

Maximize Profit = Revenue of 42000 fish − Cost of 42000 fish

Revenue :

For Enteros & Fillets: Live weight (kg) x yield x Price per finished kg * X_{ij}

$= (X_{1,1} \times 89\% \times 2 \times 1.63) + (X_{12} \times 89\% \times 2.3 \times 1.63) \ldots \ldots$

$\ldots \ldots (X_{25,4} \times 61\% \times 5.7 \times 6.37)$.

For Porciones : Live weight (kg) x Price per live kg x X_{ij}

$= (X_{15} \times 6.37 \times 0) \ldots \ldots (X_{25,5} \times 6.37 \times 3.98)$

Cost

For Enteros & Fillets: Live weight (kg) x yield x Cost per finished kg x X_{ij}

$= (X_{11} \times 89\% \times 0.45 \times 1.63) \ldots \ldots (X_{25,4} \times 45\% \times 0.6 \times 6.37)$

For Porciones : Live weight (kg) x Cost per live kg x X_{ij}

$= (X_{15} \times 1.7 \times 1.63) \ldots \ldots (X_{25,5}, 1.7, 6.37)$

Constraints

→ Filleting Capacity : 15 fish × 60 mins × 2shifts × 16 hours.

Filleting only for Fillets, and Porciones.

$$\sum_{i=1}^{25}\sum_{j=3}^{5} x_{ij} \le 28800 \text{ fish}.$$

→ Trimming Capacity -

16 hours × 7hrshift × 10 filets/min × 60 mins = 67 200 filetes

Trimming only for fillets and Porciones.

$$\sum_{i=1}^{25}\sum_{j=3}^{5} x_{ij} \le 67200 \text{ filetes + Porciones.}$$

→ Portioning Capacity

16 hours × 1400 filetes/hr / 2 = 11200 filetes

Portioning only for Porciones.

$$\sum_{i=1}^{25} x_{i,5} \le 11200$$

→ Freezing Capacity

60000 lb × 2 freezers / 2.2 = 54431.0844 kg

Freezing for all types of fish.

$$\sum_{i=1}^{25}\sum_{j=1}^{5} x_{ij} < 54431.08$$

→ Maximum Fishes in Bin Constraint

$$\sum_{j=1}^{5} x_1 \le 0.0037 + \sum_{j=1}^{5} x_2 \le 0.029 \ldots\ldots \sum_{j=1}^{5} x_{25} \le 1.10$$

→ All $x_{ij} \ge 0$: Non Negativity.

→ y_{ij} — Binary.

→ Linking Constraints.

For Bin 1: If $y_{11} = 1$ (Produces Enteros)

only enteros → $x_{11} + x_{12} \le$ Total fish in Bin 1 $\times\ y_{11}$

others = 0 → $x_{13} + x_{14} + x_{15} \le$ Total fish in Bin 1 $(1 - y_{11})$.

→ If $y_{12} = 1$ (Bin 1 produces Fillets).

only Filetes: $x_{13} + x_{14} \le$ Total fish in Bin 1 $\times\ y_{12}$

others = 0: $x_{11} + x_{12} + x_{15} \le$ Total fish in Bin 1 $(1 - y_{12})$.

If $y_{13} = 1$ (Bin 1 produces Porciones).

only Porciones: $x_{13} \le$ Total fish in Bin 1 $\times\ y_{13}$

others = 0: $x_{11} + x_{12} + x_{13} + x_{14} \le$ Total fish in Bin 1 $\times\ y_{13}$.

Repeat same for all 24 Bins.

→ Logical constraints (Repeat same for all 23 bins).

- If filets / Porciones in Bin 1, then no Enteros in Bin 2.
  $y_{12} + y_{13} \le 1 - y_{21}$
- If Porciones in Bin 1, then no filets in Bin 2
  $y_{13} \le 1 - y_{22}$