Case 3:

Salmones Puyuhuapi

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Question 1

Perez was assigned a difficult task to assign each bin to one or more of the five total products within the plant's limited resources of 2 shifts. The current harvest anticipates a yield of 900,000 salmon over the next two weeks, with an immediate intake of 42,000 fish expected for processing today. Given the best practices mandate to process all fish on the day of arrival, we have a significant operational task at hand.

The model facilitates optimal decision-making by mapping each bin to the most lucrative processing option based on current prices and expected yields. This ensures that we maximize profit while adhering to the weight distribution of the incoming salmon and minimizing the waste. Given the constraints of a two-shift system, the allocation of bins to final product categories must be carefully balanced to ensure feasibility.

Objective Function: *max(Profit)*:

$$max\left(\sum_{i=1}^{27}\sum_{j=1}^{5}\left(LW_iP_{ij}x_{ij}\right).Y_j - \left(LW_iPC_jx_{ij}\right)\right)$$

Where,

LW_i = Live Weight in bin i

P_{ij} = Price per kg in bin i processed as product j

x_{ij} = Number of fishes in bin *i* processed as product *j*

Y_j = Yield for product j

PC_j = Production cost for product j

With the model's objective as maximizing the above function, we get an optimal solution where the revenue, cost, profit, and weight metrics for each product type are as below:

	Whole Fresh	Whole Frozen	Fillet Fresh	Fillet Frozen	Portion Frozen	Total
Revenue ($)	141,569	-	77,664	175,389	191,266	**585,888**
Cost ($)	20,844	-	11,326	19,484	37,328	**88,982**
Live weight (kgs)	52,046	-	26,525	53,235	48,794	**180,600**
Profit ($)	120,724	-	66,338	155,905	153,938	**496,905**
Finished weight (kgs)	46,321	-	16,180	32,474	21,957	**116,932**

The optimal solution results in total revenue of **$585.9k** and the operation cost of **$89k** providing us with the optimal maximized profit of **$496.9k**. The constraints applied to the model considered the limited freezer capacity, fileting machine capacity, skilled-trimming workers' capacity, and the portioning machine capacity (*Further detail available in **appendix** under **constraints** section*).

Additional constraint (*mentioned below*) applied here was to make sure all the fish that weighed under 2.5 kgs were sold as Enteros.

$$\sum_{i=1}^{5}\sum_{j} x_{ij} = 0\,; where\ j = 3,4,5\ (filetes\ \&\ portions)$$

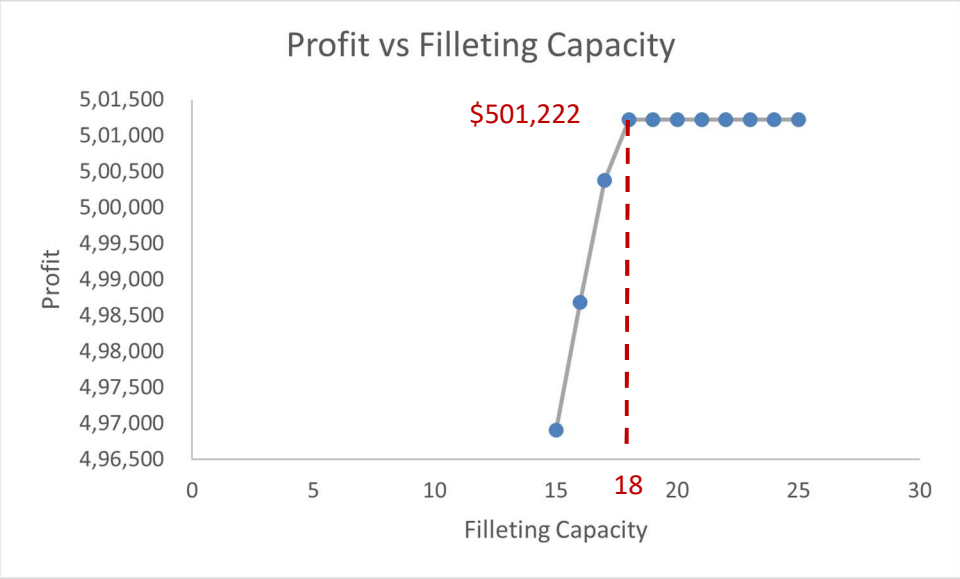
Bin	Whole Fresh	Whole Frozen	Fillet Fresh	Fillet Frozen	Portion Frozen
1	0.00	-	-	-	-
2	0.03	-	-	-	-
3	0.19	-	-	-	-
4	1.10	-	-	-	-
5	5.35	-	-	-	-
6	22.18	-	-	-	-
7	78.46	-	-	-	-
8	-	-	236.98	-	-
9	-	-	611.21	-	-
10	1,346.06	-	-	-	-
11	2,531.36	-	-	-	-
12	4,065.00	-	-	-	-
13	1,896.89	-	3,677.47	-	-
14	-	-	2,170.86	-	4,356.85
15	-	-	-	-	6,527.71
16	3,253.37	-	-	2,320.99	-
17	-	-	-	4,065.00	-
18	-	-	-	2,531.36	-
19	-	-	-	1,346.06	-
20	-	-	-	611.21	-
21	-	-	-	-	236.98
22	-	-	-	-	78.46
23	-	-	-	22.18	-
24	-	-	-	5.35	-
25	-	-	-	1.10	-
26	-	-	-	0.19	-
27	-	-	-	0.03	-

- The model prioritizes frozen fish due to their higher per-kilogram price, as evident in the table, with a particular focus on Portion and Fillet frozen products because they command the highest prices.
- Additionally, we suggest processing Whole fish only as fresh, as our freezing capacity is fully utilized by the Fillet and Portion categories which provide higher margins as compared to Whole frozen fish.
- Despite the premium price of fresh Fillet fish, we opt for Whole fresh fish due to limitations in our filleting machinery's capacity.

In conclusion, Elisa Perez should follow this production plan to maximize the profit and minimize the wastage.

Question 2

In Question 1, we identified that the maximum profit achievable under current constraints is limited by the filleting capacity of our processing plant. Presently, the plant has the capability to fillet 28,800 out of the 42,000 fish received daily, with the filleting machines operating at a capacity of 15 fish per minute. To evaluate the potential for profit enhancement, a parameter analysis was conducted, examining the effects of incrementally increasing the filleting capacity from 15 fish per minute to 25 fish per minute while keeping the objective function the same.



The analysis revealed that profit improvements are observed with an increase in filleting capacity up to 18 fish per minute, beyond which profit plateaus due to the onset of limitations imposed by the portioning process. Consequently, the maximum attainable profit through enhancement of filleting capacity alone is identified as **$501.2k**.

Exploration of methods to augment filleting capacity highlighted two primary strategies:

- Upgrading the existing filleting machinery to enhance its capacity.
- Addition of new filleting machines.

Currently, the facility operates with two filleting machines. It was determined that the introduction of a third machine could elevate profits to the peak of **$501.2k**, while further additions would not yield additional benefits due to the bottleneck created by the portioning capacity.

The feasibility of these strategies for increasing filleting capacity, alongside the generated profit increase to **$501.2k**, was assessed. This assessment considers not only the potential for profit augmentation but also considers the practicality of upgrading existing machinery and the financial implications of acquiring additional filleting machines.

Another opportunity to maximize profit is to improve the freezer capacity (*further expanded upon under question 3*). The plant is expected to *receive 900,000 fish over the next two weeks which is 64,000 fish per day on average* assuming the plant is operating on all days of the week. It's going to be crucial for the plant to implement upgrades wherever possible across the board to be able to process the entire harvest coming in, and primarily the freezer capacity to maximize profit as frozen products bring in the highest margins.

Question 3

The production plan makes sense given the freezing, machining, and skilled trim workers constraints for the supply of fish. Upon deeper inspection of the production cost and revenue brought in the five products, we see that processing the fish as frozen products (whole frozen, fillet

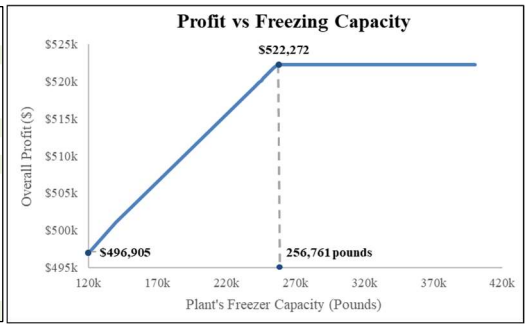
frozen and portions frozen) is more lucrative i.e., bringing in higher profit. However, the number of frozen fish processed is limited because of the limited freezing capacity available for 2 freezers, each working at freezing 60,000 pounds (27,215.5 kgs) per day.

With the current total freezing capacity of the plant, we are limited to processing only 120,000 pounds (54,431 kgs) per day. This brings in a profit of **$496.9k** (production cost: $89k, revenue: $585.9k). To check the impact of freezer constraints we check the optimal production plan without having to account for the freezer constraints and get a production plan that processes all the fish into frozen products. It selects the highest number of fish to be processed as frozen fillets due to its high yield (61%) and secondly as frozen portions due to its high margin and the remaining fish as frozen whole fish. It is also in line with Perez's inclination towards processing as many frozen products as possible due to its high-profit margins. The new production plan generates a revenue of **$604.93k** for a production cost of **$82.66k** and hence generates a profit of **$522.3k** which is a **$25.4k** (5.10%) increase over the plan with freezer capacity constraints.

Bin	Whole Fresh	Whole Frozen	Fillet Fresh	Fillet Frozen	Portion Frozen	Total fish processed in bin
1	-	0.00	-	-	-	0.00
2	-	0.03	-	-	-	0.03
3	-	0.19	-	-	-	0.19
4	-	1.10	-	-	-	1.10
5	-	5.35	-	-	-	5.35
6	-	22.18	-	-	-	22.18
7	-	78.46	-	-	-	78.46
8	-	-	-	236.98	-	236.98
9	-	-	-	611.21	-	611.21
10	-	1,346.06	-	-	-	1346.06
11	-	2,531.36	-	-	-	2531.36
12	-	4,065.00	-	-	-	4065.00
13	-	5,150.26	-	424.10	-	5574.36
14	-	-	-	1,855.43	4,672.29	6527.71
15	-	-	-	-	6,527.71	6527.71
16	-	-	-	5,574.36	-	5574.36
17	-	-	-	4,065.00	-	4065.00
18	-	-	-	2,531.36	-	2531.36
19	-	-	-	1,346.06	-	1346.06
20	-	-	-	611.21	-	611.21
21	-	-	-	236.98	-	236.98
22	-	-	-	78.46	-	78.46
23	-	-	-	22.18	-	22.18
24	-	-	-	5.35	-	5.35
25	-	-	-	1.10	-	1.10
26	-	-	-	0.19	-	0.19
27	-	-	-	0.03	-	0.03
Total number of fish ->	**-**	***13,200.00***	**-**	***17,600.00***	***11,200.00***	***42,000.00***
Revenue ($)	-	147,146.17	-	268,364.97	189,417.54	604,928.68
Cost ($)	-	15,612.21	-	30,062.31	36,982.46	82,656.97
Live weight (kgs)	-	50,119.44	-	82,137.45	48,343.08	180,599.97
Profit ($)	**-**	***131,533.97***	**-**	***238,302.66***	***152,435.08***	***522,271.71***
Finished weight (kgs)	-	44,606.30	-	50,103.84	21,754.39	116,464.53

Intuitively, the freezer capacity should have an impact on the production plan only as long as the finished weight of the total fish processed is more than the freezer capacity. And this can be confirmed by the constant profit of **$522.3k** post 256,761 pounds, which is the weight in finished pounds for the consignment of 42,000 fish frozen as various products.

Overall Freezing Capacity			
in Pounds	in KGs	Profit	
120,000	54,431	$496,905	*2 Freezers at 60k pounds/day capacity each*
140,000	63,503	$501,052	
160,000	72,575	$504,716	
180,000	81,647	$508,345	
200,000	90,718	$511,973	*2 Freezers at 100k pounds/day capacity each*
220,000	99,790	$515,602	
240,000	108,862	$519,231	*4 Freezers at 60k pounds/day capacity each*
260,000	117,934	$522,272	
280,000	127,006	$522,272	
300,000	136,078	$522,272	
320,000	145,149	$522,272	
340,000	154,221	$522,272	
360,000	163,293	$522,272	
380,000	172,365	$522,272	
400,000	181,437	$522,272	*4 Freezers at 100k pounds/day capacity each*



The current freezer capacity caps our production plan at 120,000 pounds of finished fish products, which in turn limits our profit. To generate more profit, Salmones Puyuhuapi can work towards fixing the other two broken freezers. In that case, assuming the four freezers work at 60,000 pounds freezing capacity per day, we would be able to freeze up to 240,000 pounds of finished kgs of fish as frozen products which could help process almost the entire consignment.

While it's clear that the freezer capacity is limiting the profits that the plant can produce, the freezers should be improved or the non-functional freezers should be repaired as soon as possible to meet the demand that's expected to come over the coming two weeks.

Question 4

Salmones Puyuhuapi's production optimization plan adheres to CEO Osvaldo Correa's directive for a straightforward operational strategy. The simplicity of the plan is achieved by categorizing fish into three size-based product types: the smallest fish processed as enteros (whole fish), midsize as porciones (portions), and the largest as filetes (fillets). This categorization respects the plant's operational constraints while aiming to maximize profitability and efficiency.

To align with the CEO's directive, the following production allocation strategy is adopted:

- Enteros (Whole Fish): Bins 1-14, fish weighing less than 4.3 kilograms on average.
- Porciones (Portions): Bins 15-16, fish weighing between 4.3 and 4.7 kilograms on average.
- Filetes (Fillets): Bins 17-27, fish weighing more than 4.7 kilograms on average.

Due to operational constraints, including freezing, trimming, and filleting capacity limits, the plant processed only 41,098 out of the available 42,000 fish.

Below are the additional constraints that were used specifically to evaluate the above production allocation strategy.

$$\sum_{i=1}^{14} \sum_{j} x_{ij} = 0 \; ; where \; j = 3,4,5 \; (filetes \; \& \; portions)$$

$$\sum_{i=15}^{16} \sum_{j} x_{ij} = 0 \; ; where \; j = 1,2,3,4 \; (whole \; \& \; filetes)$$

$$\sum_{i=17}^{27} \sum_{j} x_{ij} = 0 \; ; where \; j = 1,2,5 \; (whole \; \& \; portions)$$

The optimized production plan results in revenue of $563.35k, cost of $87.1k and overall profit margin of **$476.25k**.

Other combinations of bins have been tried out to follow the allocation strategy mentioned above. However, all the combinations resulted in lower profits and more fish being left unprocessed.

Bins allocated			Total Harvest		**42000**
Enteros	**Porciones**	**Filetes**	**Profit**	**Fish processed**	**Wastage**
1-11	12-17	18-27	280,556	20,866	21,134
1-13	14-15	16-27	475,472	40,145	1,855
1-12	13-15	16-27	424,818	34,570	7,430
1-10	11-13	14-27	389,172	31,102	10,898
1-14	15-16	17-27	**476,253**	**41,098**	**902**
1-12	13-14	15-27	452,462	37,698	4,302

The shortfall of 902 unprocessed fish presents both a challenge and an opportunity. To address this, we'd like to suggest further uses for the unprocessed fish:

- *Process Optimization:* The unprocessed fish numbers can serve as a key input for future processing capacity expansion and optimization initiatives.
- *Alternative Markets or Products:* Exploring alternative markets or developing new products, such as pet food or fish meal, can provide a revenue stream for fish that do not fit the current processing plan.
- *Sustainability Practices:* Unprocessed fish could be used in initiatives aimed at sustainability, such as donation for community support or used in environmental programs.

Appendix – Model Formulation

- ## Decision variables:

Count of fish: x_{ij} : Number of fishes in bin *i* processed as product *j*; *where*

i = 1,2,…,27 (Bins in which fishes are distributed based on weights)

j = 1,2,3,4,5 (Final processed products; Whole fresh, Whole frozen, Fillet fresh, Fillet frozen, Portion frozen respectively)

- ## Parameters

1) Price per finished kg from bin i and product j: P_{ij} ; *where i = 1,2,..,27, j = 1,2,…,5*
2) Live weight of fish from bin i in kgs: LW_i ; *where i = 1,2,..,27*
3) Yield when processed as Product j: Y_j ; *where j = 1,2,...,5*
4) Production cost when fish processed as Product j: PC_j ; *where j = 1,2,...,5*

- ## Constraints

1) **Demand – Supply constraint:** *Entire consignment of fish to be processed on the same day*
   Total number of fish processed as products: $\sum_{i=1}^{27}\sum_{j=1}^{5} x_{ij} \leq 42{,}000$

2) **Operational Capacity constraints**
   Fileting Capacity per day:
   Fileting machine capacity: 15 fish/min = 15 * 60 fish/hr = 900 fish/hr
   Number of hours the fileting machine can be run: 16 hrs
   Number of fileting machines: 2
   Maximum number of fish that can be fileted by 2 machines in 16 hours: 900 * 16 * 2 = 28,800

$$\sum_{i=1}^{27}\sum_{j} x_{ij} \leq 28{,}800 \; ; where \; j = 3{,}4{,}5$$

   Trimming Capacity per day:
   Trimming capacity: 10 fillets/min = 10 * 60 fillets/hr = 600 fillets/hr
   Number of hours each skilled trim worker works for: 7 hrs
   Number of skilled trim workers: 16
   Maximum number of fillets that can be trimmed by 16 workers in 7 hours: 600 * 7 * 16 = 67,200
   Number of filets per fish: 2

$$\sum_{i=1}^{27}\sum_{j} x_{ij} \,.\, 2 \leq 67{,}200 \; ; where \; j = 3{,}4{,}5$$

   Portion Machine Capacity per day:
   Portioning machine capacity: 1400 fillet/hr
   Number of hours the portioning machine can be run: 16 hrs
   Number of portioning machines: 1

Maximum number of fillets that can be portioned in 16 hours: 1400 * 16 = 22,400
Number of filets per fish: 2

$$\sum_{i=1}^{27} x_{i5} \,.\, 2 \leq 22{,}400$$

Freezing capacity per day:
Freezing capacity: 60,000 pounds/day = 60,000 * 0.453592 kgs/day = 27,215 kgs/day
Number of freezers: 2
Maximum kgs of fish that can be frozen by 2 freezers in 1 day: 27,215.52 * 2 = 54,431

$$\sum_{i=1}^{27} \sum_{j} LW_i \,.\, x_{ij} \,.\, Y_j \leq 54{,}431 \,;\, where\ j = 2{,}4{,}5\ (frozen)$$

3) **Non-Negative Constraints:**
Number of fish in bin *i* processed as product *j*: $x_{ij} >= 0$

- # Constants

As mentioned in the excel:

1) Fish Counts and Product Prices by Live Weight:

Exhibit 5. Fish Counts and Product Prices by Live Weight	
Number of fish	42,000
Average weight (kg)	4.3
Standard deviation	0.5
Bin increments	0.2
Whole yield	89%
Fillet yield	61%
Portion yield	45%

									Price per Finished kg				Price/Live kg
Live Weight			Normal	Normal	Number of	Live	Price Category		Whole		Fillet		Portion
Bin	Min.	Max.	Cumulative	Density	Fish	Weight	Whole	Fillet	Fresh	Frozen	Fresh	Frozen	Frozen
1	1.5	1.7	0.00	0.00	0.0	1.61	A	A	$2.00	$2.30	$3.00	$3.20	$3.83
2	1.7	1.9	0.00	0.00	0.0	1.83	A	A	$2.00	$2.30	$3.00	$3.20	$3.84
3	1.9	2.1	0.00	0.00	0.2	2.03	A	A	$2.00	$2.30	$3.00	$3.20	$3.84
4	2.1	2.3	0.00	0.00	1.1	2.23	A	A	$2.00	$2.30	$3.00	$3.20	$3.85
5	2.3	2.5	0.00	0.00	5.4	2.42	B	A	$2.80	$3.10	$3.00	$3.20	$3.86
6	2.5	2.7	0.00	0.00	22.2	2.62	B	A	$2.80	$3.10	$3.00	$3.20	$3.86
7	2.7	2.9	0.00	0.02	78.5	2.82	B	A	$2.80	$3.10	$3.00	$3.20	$3.87
8	2.9	3.1	0.01	0.04	237.0	3.02	B	B	$2.80	$3.10	$4.80	$5.10	$3.88
9	3.1	3.3	0.02	0.11	611.2	3.21	B	B	$2.80	$3.10	$4.80	$5.10	$3.88
10	3.3	3.5	0.05	0.22	1,346.1	3.41	C	B	$3.00	$3.30	$4.80	$5.10	$3.89
11	3.5	3.7	0.12	0.39	2,531.4	3.61	C	B	$3.00	$3.30	$4.80	$5.10	$3.90
12	3.7	3.9	0.21	0.58	4,065.0	3.81	C	B	$3.00	$3.30	$4.80	$5.10	$3.90
13	3.9	4.1	0.34	0.74	5,574.4	4.00	C	B	$3.00	$3.30	$4.80	$5.10	$3.91
14	4.1	4.3	0.50	0.80	6,527.7	4.20	C	B	$3.00	$3.30	$4.80	$5.10	$3.91
15	4.3	4.5	0.66	0.74	6,527.7	4.40	C	B	$3.00	$3.30	$4.80	$5.10	$3.92
16	4.5	4.7	0.79	0.58	5,574.4	4.60	D	C	$3.20	$3.50	$5.00	$5.40	$3.93
17	4.7	4.9	0.88	0.39	4,065.0	4.79	D	C	$3.20	$3.50	$5.00	$5.40	$3.93
18	4.9	5.1	0.95	0.22	2,531.4	4.99	D	C	$3.20	$3.50	$5.00	$5.40	$3.94
19	5.1	5.3	0.98	0.11	1,346.1	5.19	D	C	$3.20	$3.50	$5.00	$5.40	$3.95
20	5.3	5.5	0.99	0.04	611.2	5.39	D	C	$3.20	$3.50	$5.00	$5.40	$3.95
21	5.5	5.7	1.00	0.02	237.0	5.58	D	C	$3.20	$3.50	$5.00	$5.40	$3.96
22	5.7	5.9	1.00	0.00	78.5	5.78	n/a	C	$0.00	$0.00	$5.00	$5.40	$3.96
23	5.9	6.1	1.00	0.00	22.2	5.98	n/a	D	$0.00	$0.00	$5.20	$5.70	$3.97
24	6.1	6.3	1.00	0.00	5.4	6.18	n/a	D	$0.00	$0.00	$5.20	$5.70	$3.98
25	6.3	6.5	1.00	0.00	1.1	6.37	n/a	D	$0.00	$0.00	$5.20	$5.70	$3.98
26	6.5	6.7	1.00	0.00	0.2	6.57	n/a	D	$0.00	$0.00	$5.20	$5.70	$3.99
27	6.7	6.9	1.00	0.00	0.0	6.77	n/a	D	$0.00	$0.00	$5.20	$5.70	$4.00
Totals or Average					***42,000.0***	***4.30***							

2) Historical Processing Costs (dollars per finished kg):

Product	Fresh	Frozen
Whole	$0.45	$0.35
Fillet	$0.70	$0.60
Portion		$1.70