Minimizing Food Waste for *Tacofino* with an Optimized Purchasing Schedule

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Abstract

This paper describes a scheduling project that we undertook for *Tacofino's* inventory purchasing schedule. Our goal was to provide the management of Tacofino with a model that uses their menu and daily demand forecasts to determine when fresh ingredients should be bought so as to minimize the total amount of food that is wasted. After solving, we obtained a minimum total weekly waste of 73.28 lbs. While a good foundation, we believe that further work and improvements are required to make our model a more reliable tool for planning.

1 Introduction

Tacofino is a Vancouver restaurant that specializes in Baja-style tacos. Its menu includes items such as Fish Tacos, Burritos, Tortilla Soup, and Tuna Ta-takos. Apart from ensuring the quality, freshness, and affordability of their products, Jason Sussman and Kaeli Robinsong, the owners of Tacofino, are also committed to reducing the environmental impact of their business [2].

Figure 1. Tacofino's fish tacos

Figure 2. Robinsong and Sussman

Food in landfills represents one of the largest sources of greenhouse gas emissions, so environmentally conscious restaurants like Tacofino try to minimize the total amount of food that they throw away [1]. The problem they face is that they buy ingredients with the intention of using them to prepare dishes, but before they can be used these ingredients expire. If fresh ingredients never expired or had a long shelf-life like dry ingredients, then they could be stored for however long they needed to be until they could be used. In this case the problem would be a matter of deciding what to stock based on a maximum capacity.

But in reality fresh ingredients expire, and they expire fast relative to dry ingredients. So as soon as a fresh ingredient is bought, there is only a short window of time within which the ingredient may be used. Ideally all ingredients that are bought will be used within this window of time. This involves overlapping this window of time with another timeframe in which the amount demanded of that ingredient is guaranteed to be at least the amount had.

Most restaurant managers plan when to purchase ingredients based on their experience and what has worked in the past. When dealing with only a few ingredients, this strategy for coordinating the window of time in which the ingredient *can* be used with a timeframe in which all of the ingredient *will* be used may be quite effective. Not very much is wasted, and the manager's judgement proves to be quite efficient. However with more than just a few ingredients to consider, this becomes hard to keep track of and the purchasing plans become more susceptible to error. With more time and experience, a restaurant owner's sense of how much to buy and when may continue to get better. However we hope to improve on this strategy by designing a LP model that can be used to make these decisions more precisely.

1.1 Scope of Project

The method we develop is generalizable over any smaller scale restaurant, however here we only consider Tacofino specifically. Given the software we had available for this project, we only considered the purchasing schedule for three of the ingredients needed to make fish tacos. These ingredients are cod, tortilla, and tomato. The addition of each ingredients introduced too many constraints and became unsolvable with Excel. Given the appropriate software and adequate time, we believe that we could generate a schedule for all the ingredients Tacofino uses. Furthermore, because of computational limitations we only generate a purchasing schedule for one week of Tacofino's operations. Given adequate software and enough time we would be able to generate a schedule for much longer lengths of time, (e.g. for the whole year). Whether or not we could achieve this would depend on whether we had access to the demand forecast for the length of time in question.

2 Data

We obtained the list of ingredients included in Tacofino's fish taco from their menu. The sample demand schedule for each day was obtained by talking to an employee at *Tacofino*. Although they did not provide us with exact figures for the number of customers they receive each day, they provided us with estimates for the number of customers they receive on each day of the week. They gave us a range for each day and we calculated the median of each range to obtain the following demand schedule

Day	Number of Customers
Monday	70
Tuesday	70
Wednesday	79
Thursday	88
Friday	115
Saturday	150
Sunday	107

Figure 3. Weekly demand schedule

From this we were able to derive the daily demand for each ingredient.

Day	Cod	Tortilla	Tomato	Cabbage	Cilantro	Onion	Lime
Monday	35	4.2	43.4	30.8	7	9.1	6.3
Tuesday	35	4.2	43.4	30.8	7	9.1	6.3
Wednesday	39.5	4.74	48.98	34.76	7.9	10.27	7.11
Thursday	44	5.28	54.56	38.72	8.8	11.44	7.92
Friday	57.5	6.9	71.3	50.6	11.5	14.95	10.35
Saturday	75	9	93	66	15	19.5	13.5
Sunday	53.5	6.42	66.34	47.08	10.7	13.91	9.63

Figure 4. Daily demand schedule (lbs)

Our cost data for each ingredient is based on *Superstore*'s listed prices. The following table shows the cost per pound of each ingredient.

Ingredient	$/lb
cod	10.43
cabbage	0.97
cilantro	0.85
tortilla	3.60
tomato	1.46
onion	1.97
lime	2.00

Figure 5. Cost of each ingredient

Our expiry date information comes from the two websites www.fda.gov and www.eatbydate.com [3][4]. The average length of time until expiry for each of the ingredients is listed in the following table.

Ingredient	Days
cod	2
cabbage	7
cilantro	3
tortilla	2
tomato	5
onion	5
lime	5

Figure 6. Days until expiry for each ingredient

3 Methodology

In the following section we describe our linear programming model. The output will be a schedule of when and how much of each ingredient to buy each day of the week. The model we describe here is for seven ingredients over the span of one week.

3.1 Indices

We have the following indices for days:

$i =$ the day we buy ingredient
$t =$ the days on and after we bought ingredient (i.e. day that keeps track of our inventory)

where i and t are integers such that $1 \leq i, t \leq 7$ and $i \leq t$.

We use the j to index the ingredient where $1 \leq j \leq 7$.

3.2 Known Parameters

c_j : cost per pound of ingredient j

D_{tj} : the expected demand for ingredient j each day t

E_j : number of days that ingredient j is usable

C : minimum total cost of order required to get a delivery

3.3 Variables

We have a binary variable for each day

$$z_i = \begin{cases} 1 \text{ if ingredients are bought on day } i \\ 0 \text{ otherwise} \end{cases}$$

We have continuous variables for the amount of ingredient j that is bought on each day i

$$x_{tij} = \begin{cases} x_{tij} \geq 0 \text{ if } t = i \\ x_{tij} = 0 \text{ if } t \neq i \end{cases}$$

We have continuous variables representing the level of inventory of ingredient j at the end of day t that was bought on day i

$$\text{Level of inventory at day end} = I_{t,i,j}$$

for $i \leq t$.

We have continuous variables for the amount of ingredient j that was used on the t^{th} day that had been bought on day i

$$u_{t,i,j} \text{ where } \sum_i u_{t,i,j} = D_{tj}$$

.
and D_{tj} is the total demand for ingredient j for day t and $i \leq t \leq (i + E_j)$.

3.4 Objective

Our goal is to minimize the total amount of each ingredient that is wasted throughout the week. This is a matter of minimizing the sum of all the $w_{t,i,j}$ terms where $w_{t,i,j}$ is the amount of ingredient j bought on day i that is thrown out on day t.

For each ingredient we will need to keep track of the amount of the ingredient that is used and the amount that is expired. Amounts of the ingredient bought on different days will have different expiry dates, so we need to be able to keep the amounts remaining from each day separate.

But we will also need to keep track of the daily inventory balance which depends on the amount that was bought on a particular day, the amount that carried over from previous days, the amount that was used each day, and the amount that is no longer usable. The formula for the amount that the purchase of ingredient j on day i contributes to the inventory balance of ingredient j at the end of day t is

$$I_{t,i,j} = x_{t,i,j} + I_{t-1,i,j} - u_{t,i,j} - w_{t,i,j}$$

.
In other words, this formula shows the t^{th} day inventory of ingredient j purchased on day i. We obtain this expression since the level of inventory at the end of day t *from* the purchase on day i should be the amount of inventory carried over from the previous day that was purchased on day, i ($I_{t-1,i.j}$), less the amount used on day t from the portion purchased on day i, ($u_{t,i,j}$), less the amount now expired from the purchase on day i, ($w_{t,i,j}$). The $x_{t,i,j}$ is 0 unless $t = i$ in which case the amount purchased on that day should be added as well.

We can then say that the expression for the total inventory of ingredient j at the end of day t is

$$I_{t,j} = \sum_i I_{t,i,j}$$

.
Rearranging the formula we can get an expression for the amount of waste on day t for the portion of the ingredient j that was bought on day i

$$w_{t,i,j} = x_{t,i,j} + I_{t-1,i,j} - I_{t,i,j} - u_{t,i,j}$$

.
So the total waste function for day t is

$$w_t = \sum_{i,j} w_{t,i,j}$$

.
and the total waste function for the entire week for the ingredient in question is

$$\sum_t w_t = \sum_{t,i,j} w_{t,i,j} = \sum_{t,i,j}(x_{t,i,j} + I_{t-1,i,j} - I_{t,i,j} - u_{t,i,j})$$

.
making our objective function

$$min \sum_t w_t$$

3.5 Constraints

1. t, i, j integers
   $1 \leq t, i, j \leq 7$
2. z_{ij} binary
3. $x_{t,i,j},\ I_{t,i,j},\ u_{t,i,j},\ w_{t,i,j} \geq 0$
4. $I_{t,i,j} = x_{t,i,j} + I_{t-1,i,j} - u_{t,i,j} - w_{t,i,j}$ (for $i \leq t < i + E_j$)
5. $\sum_j c_j x_{t,i,j} \geq C z_{ij}$
6. $x_{t,i,j} \leq (\sum_{tj} D_{tj}) z_{tij}$
7. $\sum_i u_{t,i,j} = D_{tj}$
8. $x_{tij} \geq \sum_t u_{tij}$ for each i and j

3.6 Assumptions

1. Demand is known and it is fixed.
2. The fixed cost for a delivery is high and Tacofino is not willing to pay this fixed cost (i.e Tacofino's operations are relatively small enough in scale that the fixed cost represents too large a percentage of their total expenses). However the distribution company offers free delivery under the condition that the total amount of goods ordered on a given day is more than \$500. So the management of Tacofino must meet a minimum purchase threshold in order to purchase more ingredients on a given day.

3. Left over ingredients at the end of the week will not be carried over to the next week. They will contribute to total weekly waste.

4. There is always enough storage space available.

5. All fresh ingredients are provided from one distributor.

6. Deliveries can occur on any day of the week.

3.7 Limitations

The model we developed does not accommodate for ingredients being carried over from one week to the next. To avoid this problem we could make the length of time over which the purchasing schedule is determined longer. The length of the run should be planned so that it ends during a holiday or some time when leftovers could not have been used anyway. As mentioned earlier, we believe this is a possible extension to our model and would only require having the appropriate demand forecast for the length of time in question.

4 Implementation

4.1 Software

To solve our problem we used Excel and the Simplex LP solver. Because of this, we had to consider less ingredients when we ran the problem since there were too many variables and constraints for Excel to handle. Instead we ran it with three of the ingredients: cod, tortilla, and tomato. This proved to be manageable for Excel's solver and we obtained a optimal solution with all constraints being met.

4.2 Results

Initially we ran our program with a minimum daily cost constraint. In other words, the total cost of a delivery on a given day had to exceed \$500. However the solution suggested that we *only* buy extra cod to meet this constraint while for all the other ingredients we only bought the amount we needed. So the total waste at the end of the week was composed of only cod. We determined that this was happening because cod was the most expensive ingredient and would yield that lowest amount of waste while meeting the cost constraint. Because of this, the amount of wasted ingredients depended on the cost of the ingredient rather than the scheduling of purchases.

So we amended our model by changing this constraint from a minimum cost to a minimum weight. In order for a purchase to be made on a given day, it had to meet a minimum total weight requirement of 220 pounds. We obtained a solution with the waste of ingredients more evenly spread out and the waste was not being determined by the relative cost of the ingredients.

The total amount of waste over the week was 73.28 lbs, and the purchase schedule was as follows:

	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Cod	75	0	84	0	57.5	146.82	0
Tortilla	8.4	0	16.92	0	9	6.42	0
Tomato	136.6	0	119.08	0	153.5	66.76	0

Figure 7. Purchase schedule for the week (lbs)

More specifically, 18.32 lbs of cod was wasted, 0 lbs of tortilla was wasted, and 54.96 lbs of tomato was wasted. Most of the waste came from the last day that ingredients were being purchased. For example, the 54.96 lbs of tomato that became waste were still fresh by the end of the week and could have been used the next day had the model allowed for the use of ingredients beyond the seven days of the week. This suggest that a longer time frame of consideration could potentially accommodate a more efficient purchasing schedule.

4.3 Sensitivity Analysis

From studying the solutions, we could see that the waste was mostly generated as a result of the lower bound constraint since this constraint was binding for all the non-zero purchase days. This meant that most of the waste in our model was created because the quantities had to reach the minimum required weight for a purchase.

When altering our upper bound for the total weight of a purchase on a given day, we noticed that while the objective function value remained the constant, the values of the variables, and hence the composition of the total waste in terms of the three types of waste, kept changing. This indicated the existence of several optimal solutions or multiple optima. Because we knew that there were alternative ways of reaching the optimal value we got for the objective function, we were able to draw on secondary preferences when it came to choosing the optimal solution. We knew that we did not want a solution that advised us to go with a schedule that wasted mostly cod. So we spent some time changing the value of the upper bound and re-running Solver until we found our final solution – a solution which did not favour cod as the main source of waste.

In fact we added a constraint that ensured that cod only represented 25% or less of the total waste. Our reluctance to admit cod as the predominantly wasted ingredient stemmed from the fact that the production of cod and other livestock has a larger negative impact on the environment than vegetables. So from this perspective, minimizing the amount of cod wasted should be prioritized over tortilla or tomato.

Not having enough time and technical issues caused us not to be able to do a full sensitivity analysis on the demand and other parameters. Given more time and the right resources we could accomplish this and provide a more in depth analysis of the stability of our solution under fluctuations in demand.

4.4 Extensions

There are several ways we believe that we could improve our model. Firstly, adding more ingredients to the mix would produce a more accurate and fuller picture of the business's purchasing schedule.

Secondly, all the quantities of ingredients that we work with in our model are given in pounds. It would be good to include constraints that say that certain ingredients can only be bought in certain quantities (i.e. milk can only be bought in crates of four 4L jugs). This is more realistic since it is not likely that only could buy milk by the pound. This would amount to changing our x_{tij} variables to instead being integer variables are multiplied by the size of a bundle of an ingredient. So for instance, it milk comes in crates of four 4L jugs, we would have the integer variable x_m with weight $(4\text{x}4L)$.

Thirdly, since the purpose of our project is to minimize waste from an environmental perspective, but many businesses are not interested in protecting the environment but rather cutting costs of their operations, we could come up with a way to link the goal of minimizing waste with minimizing cost. This would provide the business with incentives to minimize their waste. If there were a law in place that charged businesses money for throwing out a certain amount of waste, we could incorporate this in our model. And although this is not a current reality for businesses, this is a definite possibility in the future. So starting to think about this now and preparing could be helpful to businesses concerned with generating profits.

Fourthly, we considered possible applications of the framework of our model to other industries. The idea of scheduling the start of some processes knowing the length of time it last for could be used for other scheduling problems involving varying lengths of items to be scheduled.

5 Summary

It is not certain whether or not an average restaurant the size of Tacofino wastes 73 lbs a week. We had interviewed several restaurant owners, but they refused to provide with us a quantitative measure of the amount of food that their restaurant wastes every week. But given the number of ingredients used in the implementation of our model, and the length of the timeframe we considered, we do not believe that the solution and we obtained would be something ready for Tacofino to use.

Furthermore, we assumed that all the ingredients used were fresh and that none were frozen or served in some other way in which the standard of freshness did not need to be so stringent. It is probable that there other techniques, including those just mentioned, that are used by restaurants to cut down on total waste. But we did not consider these factors within the scope of our project.

Given more time we would change our assumptions to better reflect the factors in play for Tacofino's decision making. Furthermore, we would learn to use better software with larger variable and constraint capability so that we could consider more ingredients at once and extend the timeframe of our solution over more than one week.

References

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