BAMS 508 Final Project Report:

Optimal Staff Allocation

Due Feb 13th, 2021

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Executive Summary

Project Scope Statement

Project Blueprint will deliver an optimization model suitable for the needs of a clinic or laboratory that maintain regular profitable operations while providing COVID testing services for travelers before their flights. Assumptions for business context and needs are made based on online research to create a more realistic scenario. Analytics tools including Excel and Python will be used to estimate profitability, optimize staffing plans, and make operational decisions. This project will assist an eye care clinic in maintaining the provision of services and overcoming unanticipated changes in the volatile business environment.

Project Context and Business Need

The clinic needs to maintain the profitability of its current services and reduce the overload of the healthcare system during the COVID-19 pandemic. To satisfy these needs, the model is very flexible with changes in many business factors, including customer inflow and appointment cancelations. At its roots, the eye clinic is a profit and private institution that requires profitability and sustainability to remain competitive in the healthcare market. Therefore, the project will ensure the optimization model will provide the clinic the most resilient path based on the needs of the institution during the pandemic.

Model Design and Pragmatic Purpose

The two models (a Customer Estimation model and a Staff Allocation model) built using Excel Optimization are complementary to each other. The Customer Estimation model analyzes the variation in customer inflow and makes a prediction of the clinic's revenue based on the historical data. The Staff Allocation model minimizes staffing costs and outputs a staff shift arrangement automatically based on employee's willingness to work and several scheduling and resource constraints. The bar charts and CDF graphs generated using Python code visualize the Poisson Distribution of the customer inflow. Moreover, the user guide in Excel spreadsheet will guide a user such as a clinic manager to forecast and input parameters to generate a staff assignment plan and control over uncertainties in the operation process.

The reason we chose to build models for COVID-19 diagnostic testing is to solve the most serious problem in the world today. The combined model helps to solve the current healthcare overload and profitability problems. Our expectation is to make the model widely applicable and the web app publicly available to relieve the overload of current healthcare system. The pragmatic purpose is to facilitate more supportive and caring work conditions and environment for the frontline medical workers and to ensure the continuous operation of institutions that provide COVID testing services.

1. Introduction

COVID Testing has become a significant operation item for many clinics around Canada ever since the pandemic hit the country in early 2020. Such dramatic change created challenges of staffing and profitability for individual clinics that provide COVID testing in addition to their routine services. For instance, clinic managers should consider how to schedule shifts to maximize COVID testing, maintain original services acceptance capability, and at the same time meet social distancing requirements. To form up such schedules, many factors need to be taken into consideration, such as: shift numbers, protective supplies allocation, maximum consecutive days a nurse can be scheduled (to reduce the probability of infection).

Within the study, we hypothetically constructed a clinic (usually schedule two dayshifts, Mon - Sat) whose regular service is eye examination (including cataract surgery) and started to add international flight pre-departure COVID testing to its service catalog (night shifts on Mon/Wed/Friday) since 2020. Besides, such tests also need people to come to the clinic in person for registration form filling 2-3 days before the testing, which challenges the clinic's acceptance capacity under social-distancing requirements.

Our study targets facilitating clinic managers to set up a weekly staffing schedule using Excel optimization. Our team focused on linking a clinic's operating profitability with customer flows, staffing plans and resource allocation. Therefore, operating cost and revenue are considered, as profit equals to revenue minus cost. The final goal is to build up a model maximizing services revenue, keeping low operating costs while meeting or balancing constraints (hard & soft).

Setting up models minimizing costs and maximizing revenue ensures the sustainability and profitability of the clinic. To achieve the goal, we built up two models with Excel Solver: Customer Estimation model for customer flow and revenue estimation; and Staff Allocation model for shift assignment.

The Customer Estimation model used Poisson distribution to grant the manager a view of possible regular customer flows in the coming week and let the manager choose the probability (under x% there will be less than y visitors) he/she wants the staffing plan to support. Such regular customer estimation then gives us a maximum revenue estimation: summation of customers/ shift * service price for all shifts. Then the model helps manager optimize the COVID testing and registration form filling schedule after considering serving its usual clients. After this, we can get the max revenue from COVID testing: tests/week * test price. To achieve such ideal revenue, enough staff need to be scheduled, as staff shortage causing long waiting time will either drive away clients or prolong the process finally reducing revenue. Thus, the model established a mapping relation between the possible customer flow and minimum staffing requirement for each shift.

Poisson distribution and stochastic process optimization techniques are used to take full account of the randomness for objective function and constraints and reflects the 'best guessing' for probabilities of different events. For instance, some flights may be canceled due to airplane companies' commitment to safety, in such case the manager needs to forecast and input a probability of flight cancellation, and the uncertainty will be reflected in the minimum staffing requirement for each shift as well. And also, the manager can schedule testing appointments to the least busy shifts by predicting the probability of different customer flow of a week based on the historical data.

The Staff Allocation model covers the consideration of staffing and administration (personal protective supplies) costs that are associated with staffing plans. In this part, we mainly utilized assignment optimization techniques. The concerns for the health and safety of both customers and staff are reflected on the Excel optimization spreadsheets. For example, staff who conduct COVID testing on the night shifts are not allowed to work on the next shift. Each staff must wear masks and gloves, sanitized suit. After balancing all hard and soft constraints, an optimized staffing assignment plan will be generated to reflect the max profit.

2. Model Description

Customer Estimation model:
There are four major parts in the model, and this model has a lot to do the with manager's subjectivity because the estimate for some parameters is to be pre-determined by the manager. We present the general logic/steps for the manager to use this worksheet (User Guide in Excel). An important note is that the steps to be illustrated are sequential and a latter step will always depend on the previous ones.

Daytime customer estimation**:** How many customers are likely to visit our clinic at each daytime shift and how could we arrange staff to at least cover the lower bound probability of those coming customers? The Poisson model is designed to estimate the probability of customer numbers for each of the 2*6=12 shifts in a week. Assume the parameter for the Poisson model is λ-ij (to be determined by the manager, discussed later) which represents the mean number of customers y-ij coming at day i shift j. Mathematically, if a random variable X follows a Poisson distribution with parameter lambda, then the PMF (probability mass function) can be defined as:

$$P(X = k) = \frac{\lambda^k}{k!} e^{-\lambda}, k = 0, 1, \cdots$$

This formula gives probabilities for each discrete integer value for y-ij. In plain language, this model estimates the probability that K customers will come for regular eye examination on day i shift j.

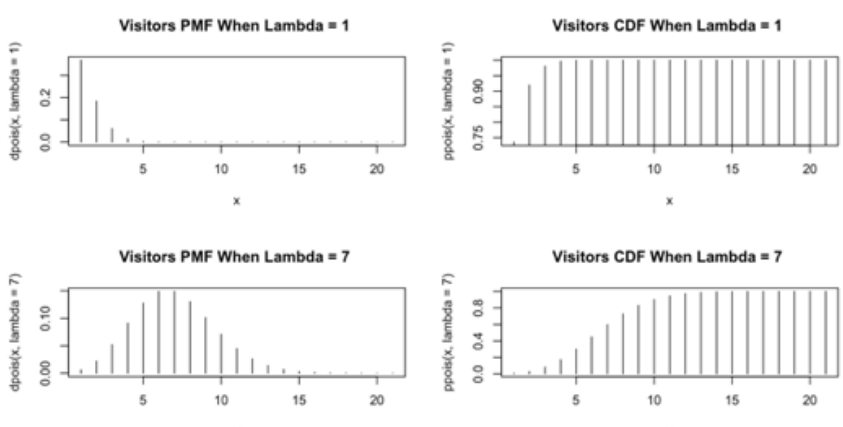

Figure 1

By choosing the probability (under x% there will be less than y visitors) manager wants the staffing plan to support, he/she would set the maximum daytime eye exam/surgery customer estimation.

Nighttime COVID-test customer arrangement: Based on the daytime customer flow estimation, we set up an Excel solver to optimize the schedule of COVID testing and registration form filling, which needs to meet both government minimum request (20 tests per week) and social-distancing health requirement (<=10 persons per shift).

Flight cancelation estimate: Based on previous daytime customer estimate and nighttime COVID test arrangement, the flight cancelation probability (input by the manager) is applied to calculate the expected customer numbers after considering the conditions. For instance, assume x regular customers estimated for day shifts, y customers are scheduled for form-filling during the day, z customers are scheduled for COVID - testing during the night shift, after applying the probability of flight cancelation, the customer number changed as below:

	Regular customers estimated for day shifts	Customers scheduled for form-filling	Customers scheduled for COVID - testing
Original number	x	y	z
Applied cancel probability (p)	x	y*(1-p) + 0*p	z*(1-p) + 0*p
Example: original No.	5	5	7
Example: after applied p (0.6)	5	5*0.4 + 0*0.6 = 2	7*0.4 + 0*0.6 = 3 (2.8)

Figure 2

Customer estimate and minimum staff requirement mapping: with the customer estimates from the previous three parts, the model then translates the customer flow into the minimum staff requirement for each shift and each position, with a pre-defined mapping relation as below:

Staff Demand / Mappinng					
Day shift	Visitors/shift	receptionist	doctor	nurse	cleaning staff
Exam	1 person	1	1	1	1
	2 person	1	1	1	1
	3 person	1	1	2	1
	4 person	1	1	2	1
	5 person	1	1	2	2
	6 person	2	2	2	2
	7 person	2	2	3	2
	8 person	2	2	3	2
	9 person	2	2	3	2
	10 person	2	2	3	2

Figure 3

Finally, two outcomes are generated by the model:

- Minimum staff requirement for each shift, position, day – > a constraint in staff allocation model.
- The maximum estimated revenue: summation of regular customers / shift * service price for all shifts + tests/week * test price –> objective function in the staff allocation model. (We also assume the pricing for eye examination is $50, surgery is $3500 and COVID testing is $500. 60% regular customers are for eye exams and 40% are for eye surgeries. COVID test revenue depends on the maximized COVID test numbers for the week.)

		Minimum Request			
		receptionist	doctor	nurse	cleaning staff
Monday	Shift1	2	1	1	1
Monday	Shift2	1	1	2	2
Monday	Shift3	1	0	3	2
Tuesday	Shift1	2	1	2	1
Tuesday	Shift2	2	2	3	2
Wednesday	Shift1	2	1	2	1
Wednesday	Shift2	1	1	2	2
Wednesday	Shift3	1	0	3	2
Thursday	Shift1	2	1	2	1
Thursday	Shift2	2	2	3	2
Friday	Shift1	2	1	2	2
Friday	Shift2	2	2	3	2
Friday	Shift3	1	0	3	2
Saturday	Shift1	2	2	3	2
Saturday	Shift2	2	2	3	2
Sunday	Shift3	1			

Revenue	Eye exam & Surgury	98670
	Covid-test	14500
	Total	113170

Figure 4

Staff Allocation model:
Since the max revenue estimate is an output from the Customer Estimation model, this model focuses more on minimizing cost, in order to maximize the profit. And there are two types of cost concerned in the model: staffing cost and necessity supply cost.

In our model, we assume eye examinations and form filing for COVID tests are conducted during two dayshifts (dayshift 1from 12:00 to 15:00 and dayshift 2 from 15:00 to 18:00) and COVID testing is conducted during the night shift on Monday, Wednesday, and Friday (from 23:30 to 02:30 next day), while night shift on Sunday (from 23:30 to 02:30 next day) is used to summarize the performance for the previous week and prepare paperwork for the next week and therefore only 1 receptionist is required.

For staffing cost, the model takes into account the hourly wages of 18 employees in total, including 4 receptionists, 6 nurses, 4 doctors, and 4 cleaning staff in the clinic. Some constraints are considered: max working hour willingness per shift per person; no night – morning shift constraint, minimum staff requirement per shift per position (output from Customer Estimation model).

For necessity supply cost, we assume each staff must wear masks and gloves, sanitized suit. For health reasons, a person will consume one mask ($1/unit) and a pair of gloves ($2/pair) for each shift, and a sanitized suit ($20/unit) per day. Therefore, the cost for necessity is a soft constraint: in order to minimize cost, the optimal solution will seek to schedule the same person for as many shifts as possible for the same day, which is also an intended outcome.

The Excel solver takes into account both costs, estimated weekly revenue from the Customer Estimation model and generate the optimized staffing plan and max profit estimate as below (example):

Max Revenue Estimate:	$113,170
(-) Staffing & Supply Cost:	15,754
(=) Max Profit Estimate:	$ 97,416

Figure 5

Note: As we have maximum 16*18 = 288 decision variables in the optimal staff allocation model, OpenSolver was used in this model.

2.1 Decision variables

There are four types of data captured in the decision variables: whether a specific worker is scheduled to work on a specific shift (binary), whether a specific worker is scheduled to work on a specific day (binary), and numbers of customers assigned to fill out registration forms for COVID testing during day shifts (integer) and numbers of eye exam / surgery customers estimated for each day shift (integer). The first two are for the Staff Allocation model, and the last two are for the Customer Estimation model.

Decision variables
x_hijk *= is a binary variable indicating if worker* ***i*** *from a specific position* ***h*** *is scheduled to work on day* ***j*** *in shift* ***k*** *(for Staff Allocation model)*
y_hij *= is a binary variable indicating if worker* ***i*** *from a specific position* ***h*** *is scheduled to work on day* ***j*** *(for Staff Allocation model)*
z_ij *= is an integer variable assigned number of customers to fill out registration forms on day* ***i*** *and shift* ***j*** *(for Customer Estimation model)*
e_ij *= is an integer variable estimated number of eye exam and surgery customers day* ***i*** *and shift* ***j*** *(for Customer Estimation model, automated from Poisson distribution)*

We used numbers to assign each worker in a specific position as worker #1, #2, #3, #4, #5, #6.

The binary variables x_hijk is used to suggest if worker i from a specific position h is scheduled to work on day j within a week in shift k, where h=receptionist, nurse, doctor, cleaning staff, i=1,2,3,4,5,6 (maximum i=4 for receptionist, doctor, and cleaning staff), j=1,2,3,4,5,6,7 (1=Monday, 2=Tuesday, etc.), k=1,2,3 (1 and 2 indicate day shift 1 and day shift 2 respectively and 3 indicates night shift). For example, x_r111 suggests receptionist #1 is scheduled to work on day shift 1 on Monday.

The binary variables y_hij is used to suggest if worker i from a specific position h is scheduled to work on day j within a week, where h=receptionist, nurse, doctor, cleaning staff, i =1,2,3,4,5,6 (maximum i=4 for receptionist, doctor, and cleaning staff), j =1,2,3,4,5,6,7 (1=Monday, 2=Tuesday, etc.), this variable is particularly set to control the sanitized suit usage (one unit per person per day, will discuss further in constraint part).

Since appointments for form filling are flexible, we can assign customers to fill out forms according to our optimal schedule and estimated visitors, preferably during non-busy hours. Therefore, the decision variable z_ij is used to indicate the optimal number of customers we should assign for form filling in each shift; and the decision variable e_ij is used to indicate the number of eye exam / surgery customers estimated for each day shift. In which, i = 1,2,3,4,5,6,7 (1=Monday, 2=Tuesday, etc.) and j = 1,2 (1 = day shift 1, 2 = day shift 2).

2.2 Objective

The final goal of the project is to build up models reflecting max profit, namely, max services revenue, lowest operating cost, while meeting or balancing constraints (hard & soft).
Since we have two models and two corresponding Excel Solvers, we listed two objective functions as below:

Staff Allocation model:
Objective: Maximize Profit = Revenue – Cost

Objective formula: *Predicted Profit = PRE + PRC – SC – NC*

Where,

<u>Predicted revenue from eye exam and surgery (PRE)</u>= predicted number of customers request eye exam and surgery(0.6*$50 + 0.4* $3500)*

predicted number of customers request eye exam and surgery are from Customer Estimation model: summation of qpois (p, lambda) over all day shifts, where p is the manager input probability, lambda = history average customer number per day per shift.

*<u>Predicted revenue from COVID testing (PRC)</u> = predicted number of customers request COVID testing * $500*

predicted number of customers request are from Customer Estimation model: see next objective formula.

<u>Staffing cost (SC)</u> = $\sum_{h=4}^{h=1}\sum_{i=6}^{i=1}\sum_{j=7}^{j=1}\sum_{k=3}^{k=1}(x_{hijk} * hourly\ wage * 3)$
Since doctors do not work on night shifts, we used M (9999) as the hourly wage on such shifts for doctors, to make sure no shift assignment will be made.

<u>Necessity cost (NC)</u> =
$\sum_{h=4}^{h=1}\sum_{i=6}^{i=1}\sum_{j=7}^{j=1}\sum_{k=3}^{k=1}(x_{hijk} * (\$1 + \$2)) + \sum_{h=4}^{h=1}\sum_{i=6}^{i=1}\sum_{j=7}^{j=1} y_{hij} * (\$20))$

Customer Estimation model:
Objective: Maximize Total Covid Test Times

Objective formula: *Total Covid Test Times =* $\sum_{i=7}^{i=1}\sum_{j=2}^{j=1} z\_ij$

We try to set up a model maximizing profit (total revenue – total cost), so we mainly concerned about the two aspects as below:

Total costs:
We considered staffing and administration (sanitizing, appointment cancelation, staff COVID testing. etc) costs as main operating costs which are associated with staffing plans. In this part we will utilize assignment optimization techniques.
In addition, since COVID testing is also subject to many uncertainties, such as ad hoc flight cancelation, etc., stochastic process optimization techniques are also used to reflect possibilities and 'best guessing'.
We also consider regular supply for necessity as part of the cost, which will be discusses later in constraint 2.3.5.

Total maximum revenues:
We estimated the maximum revenue from the estimated eye exam/surgery revenue and COVID test revenue. Here we assume 60% regular customers are for eye exams and 40% are for eye surgeries. COVID test revenue depends on the maximized COVID test numbers for the week. By building the Customer Estimation model and assuming we are not allowed to cancel any service appointments, we assume revenue are fixed dependent on estimated customer flow when solving the Staff Estimation model.

2.3 Constraints

The optimal model developed has the following constraints:

1. Minimum staff for each shift should fulfill minimum request. (Staff Allocation model)
2. Decision variables should be binary decision. (Staff Allocation model)
3. Scheduling hour should be less than individual willingness. (Staff Allocation model)
4. No consecutive night-day or day-night shift. (Staff Allocation model)
5. Minimize staff number per day. (Staff Allocation model)
6. No greater than 10 customers per shift, minimum 3 customers to be scheduled to each night shift. (Customer Estimation model)
7. Weekly COVID tests should be greater than 20. (Customer Estimation model)

2.3.1 Minimum staff for each shift should fulfill minimum request (hard constraint, Staff Allocation model)

Since COVID tests are required before boarding, canceling customer' testing appointments due to staff shortage is not allowed in our model. In order to maximize revenue, we assume that the clinic should not cancel any eye examination and surgery since they generate high profit margin. The optimal schedule should ensure we have enough staff to serve every customer. As a result, total number of workers in each position should be greater than or equal to the minimum requests that were simulated in the poison distribution model.

Each shift should fulfill the minimum request predicted from the Customer Estimate Model

$\sum_{i=6}^{i=1} x\_hijk \geq$ *minimum request predicted in the daily visitor worksheet for each shift (k), each type of position (h), and each day (j) (maximum i=4 when h=receptionist, doctor, cleaning staff)*

2.3.2 Scheduling decision variables should be binary decision (hard constraint, Staff Allocation model) and COVID test form-filling decision variables should be integer (hard constraint, Customer Estimation model)

Scheduling decisions indicate binary variables whether a specific worker is scheduled and therefore can only be 0 or 1, where 0 and 1 indicate the worker is not scheduled and scheduled respectively. While the COVID test form-filling decision variable should be integers.

x_hijk *= binary (0 or 1)*
y_hij **=** *binary (0 or 1)*
z_ij **=** *integer*
e_ij **=** *integer*

2.3.3 Scheduling hours should less than individual willingness of work hours per day (hard constraint, Staff Allocation model)

To maximize employee satisfaction, we accommodate individual needs and ask employees to fill their willingness of work hours they prefer for each day in a week before scheduling. As a result, actual scheduling hours for each employee for a specific day should be limited to the maximum hours they prefer.

Scheduling hours should less than individual willingness of work hours per day

$\sum_{k=3}^{k=1} x\text{-}hijk \quad \leq$ *maximum willingness of work hours per day for each type of position (h), each worker (i), and each day (j)*

2.3.4 No night-day shift (hard constraint, Staff Allocation model)

Considering workers' health during this sensitive time, night-day shift is not allowed in our model. For example, if a worker was scheduled a night shift on Monday, he or she would not be able to work in day shift 1 on Tuesday. As indicated in the formula below, the sum of binary variables for a night shift and day shift 1 on the next day should be less or equal to 1, indicating a worker can only work on a night shift or day shift 1 on the next day, avoiding night-day shift.

No night-day shift

$$x\_hij3 + x\_hi(j+1)1 \leq 1$$

2.3.5 Minimize staff number per day (soft constraint, objective function, Staff Allocation model)

We assume that masks and gloves are consumed based on number of shifts, and sanitized suits are based on the number of people work on each day, so by adding the costs to objective function, a soft constraint is formed up: whether schedule a person to a shift should be subject to whether to schedule a person on that day, and Excel Solver will try to minimize number of people working on the same day.

Minimize staff number per day (by minimizing sanitized suit costs)

$$x_{hij1} \leq y_{hij}$$
$$x_{hij2} \leq y_{hij}$$
$$x_{hij3} \leq y_{hij}$$

Since x and y are all binary variables, if y = 1, x can be 1 or 0, if y = 0 then x = 0, by setting constraints as below on y, we can control the number of people working on the same day.

Weekly supply costs =

$$\sum_{h=4}^{h=1}\sum_{i=6}^{i=1}\sum_{j=7}^{j=1}\sum_{k=3}^{k=1}(x_{hijk} * (\$1 + \$2)) + \sum_{h=4}^{h=1}\sum_{i=6}^{i=1}\sum_{j=7}^{j=1} y_{hij} * (\$20))$$

2.3.6 No greater than 10 customers per shift, minimum 3 customers to be scheduled to each night shift. (Customer Estimation model)

To avoid staffing shortage and ensure sufficient workers in the clinic, the number of total customers (including those customers for form filling and regular eye service) in a specific shift should be less than the maximum capacity of the clinic, which is 10 customers in this case.

In addition, we set up the minimum total customers in each night shift be greater than or equal to 3 to balance out customers for COVID testing on Monday, Wednesday, and Friday, to avoid waste of resources and increase related costs for empty shift.

Here we assume Mon + Tue form filling customers are for Wednesday test; Wed + Thu are for Friday test; Fri + Sat are for Monday test; and this Monday tests are estimated based on the number of form-filling people of the same week.

$$z\_ij + e\_ij \leq 10, \text{for each shift } j \text{ on each day } i$$
$$3 \leq \sum_{i=2}^{i=1} z\_ij \leq 10, \text{for each } i$$
$$3 \leq \sum_{i=4}^{i=3} z\_ij \leq 10, \text{for each } i$$
$$3 \leq \sum_{i=6}^{i=5} z\_ij \leq 10, \text{for each } i$$

2.3.7 Weekly COVID tests should be greater than 20. (Customer Estimation model)

Besides the profit side, there is also public health aspect for COVID testing. According to government regulation, each clinic should fulfill the minimum test requirement, which is 20 tests in this case. As a result, we come up with a constraint that ensure the summation of customers who come for COVID testing (as indicated from the number of customers for form filling) should be greater than 20.

$$\sum_{i=7}^{i=1} \sum_{j=2}^{j=1} z_{ij} \geq 20, \text{ for each i, j}$$

2.4 Assumption
In order to achieve a feasible solution, the model was built with the following assumptions:

2.4.1 No full-time worker within the clinic
We assume that there are no full-time workers in our clinic, every of our staff members are part-time workers, to allow flexibilities. We assume that, on our staff's side, only their willingness length to work have an impact on the final schedule; in other words, we don't count the interactions between two employees (swapping shift/asking for leave/resign) and we also exclude any unexpected accidents. In the example data, we assume that within each type of staff, everyone has the same willingness length to work.

2.4.2 Anticipated demand is based on historical data
It is also assumed that historical data that were input in the Customer Estimation model was based on manager's previous experience. Based on the fact that customer flow is uncertain and different from week to week, we expect the manager to update the new historical data every week to better forecast for customer base and scheduling accordingly for the following week to achieve minimum staffing and administration cost.

2.4.3 Other Assumptions
- Canceling customer appointment is not allowed
- No over-time worker and no over-time pay
- Necessities are sufficient from regular supplier
- Workers are guaranteed to work as long as working hours less than their willingness
- The maximum capacity for each shift is 10 customers
- Health department from the government requires minimum of 20 COVID testings for each clinic per week

3. Discussion and Result Analysis
Maximum revenue estimate is based on the income from eye exam/surgery operations and COVID tests. For the former, we firstly used Poisson distribution to calculate the cumulative probability distribution of possible visitors' numbers (1-10), and let manager choose the probability (under x% there will be less than y visitors) he/she wants the staffing plan to support and flight cancelation rate (COVID test cancel). Such that we obtain max eye exam/surgery visitors that the plan can cover, then we assume 60% come for exams ($50/time) and 40% are for surgery ($3,500/time). Thus, we calculate the max revenue from eye services. For COVID test, we used solver to maximize the total tests the clinic can do after considering serving its usual clients, and we multiply the tests number by $500 to get the max revenue from COVID test.

Staffing and administration costs were calculated from the staffing plan. Hourly wage for each staff and purchase cost of each supply (mask/glove/sanitized suit) are used to calculate weekly labor and administration cost. The maximum profit is calculated using max revenue minus lowest costs. We used Open Solver to maximize the profit by changing the staffing plan to reach the optimal shift arrangement.

Below are comparisons of our two optimized staffing plans for a position:

<table>
<tr><td></td><td>A: Manager wants to cover 90% (poison CDF) scenarios of visitors and predict no flight cancelation (0%) (max customers)</td><td>B: Manager wants to cover 50% (poison CDF) scenarios of visitors and predict 50% flight cancelation probability (average customers)</td></tr>
<tr><td>Profit</td><td>$91,249</td><td>$53,979</td></tr>
<tr><td>Staff Assignment</td><td>
<table>
<tr><th colspan="2">Decision Variables</th><th>Scheduling Shift</th><th colspan="4">receptionist</th></tr>
<tr><th></th><th></th><th></th><th>receptionist1</th><th>receptionist2</th><th>receptionist3</th><th>receptionist4</th></tr>
<tr><td>Monday</td><td>Day</td><td>Monday 12:00-15:00</td><td>1</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>Monday</td><td>Day</td><td>Monday 15:00-18:00</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
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<tr><th colspan="2">Decision Variables</th><th>Scheduling Shift</th><th colspan="4">receptionist</th></tr>
<tr><th></th><th></th><th></th><th>receptionist1</th><th>receptionist2</th><th>receptionist3</th><th>receptionist4</th></tr>
<tr><td>Monday</td><td>Day</td><td>Monday 12:00-15:00</td><td>1</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>Monday</td><td>Day</td><td>Monday 15:00-18:00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Monday</td><td>Night</td><td>Monday 23:30- 1:30</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td>Tuesday</td><td>Day</td><td>Tuesday 12:00-15:00</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>Tuesday</td><td>Day</td><td>Tuesday 15:00-18:00</td><td>0</td><td>0</td><td>1</td><td>0</td></tr>
<tr><td>Wednesday</td><td>Day</td><td>Wednesday 12:00-15:00</td><td>1</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>Wednesday</td><td>Day</td><td>Wednesday 15:00-18:00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Wednesday</td><td>Night</td><td>Wednesday 23:30-1:30</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
<tr><td>Thursday</td><td>Day</td><td>Thursday 12:00-15:00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Thursday</td><td>Day</td><td>Thursday 15:00-18:00</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Friday</td><td>Day</td><td>Friday 12:00-15:00</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>Friday</td><td>Day</td><td>Friday 15:00-18:00</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>Friday</td><td>Night</td><td>Friday 23:30-1:30</td><td>1</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Saturday</td><td>Day</td><td>Saturday 12:00-15:00</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>Saturday</td><td>Day</td><td>Saturday 15:00-18:00</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>Sunday</td><td>Night</td><td>Sunday 23:30-2:30</td><td>0</td><td>0</td><td>0</td><td>1</td></tr>
</table>
</td></tr>
</table>

From the results, we can see that under scenario A (max customer#), most staff did not reach their maximum willingness, and this is especially true for doctors (it makes sense as doctors do not work for COVID tests and the total available doctors are the same as receptionists and cleaning staff). While this is a favorable situation for clinics as they have a big enough staff pool to hedge against the uncertainties brought by COVID, but it may not be desirable for staff as it means less income and difficulty to arrange personal schedule, if the situation continues staff may not want to retain. Under scenario B (average customer#), we can see that there is a receptionist only scheduled 2 shifts per week, and a doctor scheduled for only 1 shift. So, if such a clinic may consider to further adjust the schedule rules, for instance to divide staff into groups and schedule different groups in different weeks, so that it may allow more flexibility to staff to take jobs elsewhere.

In addition, we can see that due to our soft constraint: the use of sanitized suit per day depends on the number of people scheduled, optimized result tried to schedule the same person several shifts, this is also a desired outcome as it can help control the people flow in clinic and allow work continuity and flexibility to staff.

4. Conclusion, Limitation and Further Expansion

The optimization model built helps the clinic to maintain profitable operations while reducing the burden on Canada's healthcare system. Holding the percent of customer inflow that will be cover at XX% and the probability of flight cancelation at YY%, the model forecast the clinic will make $ZZZZZ in profit in a week. The real world is much more unpredictable and uncontrollable factors; other randomness and unexpected costs will incur in the operation and testing processes.

4.1 Limitations

The revenue and customer inflow are estimated based on historical data by using stochastic process optimization techniques involving Poisson Distribution. The model mainly focuses on minimizing the cost of staffing and necessities in the operation process; thus, revenue is not optimized. Also, staff could run short if the clinic had higher customer inflow in a week.

Most clinics and laboratories in Canada now are providing drive-through services for the sake of health and social distancing. The model does not consider the possibility of providing drive-through services and arranging a waiting line for cars.

Parameter estimates are dependent on decision-makers. The manager needs to input two probabilities for flight cancelation and variation in customer flow. Predicting flight cancelation could be relatively difficult for managers as flights are subject to weather conditions, local and destination health and safety policy, and airline companies' commitment to safety. It is very difficult for the manager to predict the cancelation probability one week earlier; the manager must be very conservative when making such predictions.

4.2 Ideas for Further Expansion

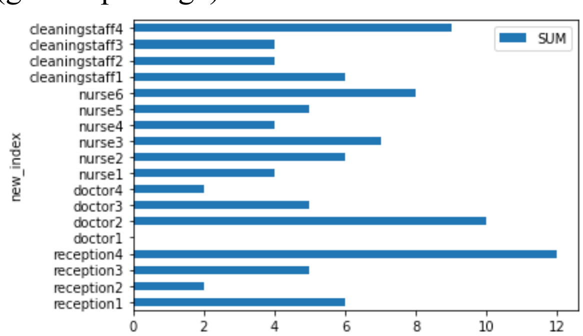
If the clinic offers drive-through service, the model should include the location and parking capacity of the clinic. The waiting line can not block the traffic and increase the number of potential safety problems. A constraint for queue length should be added to limit the maximum length of the waiting line. The time spends on each testing varies for vehicle appointments and for pedestrian appointments.

To be more realistic, every staff should take COVID diagnostic test regularly to avoid cross-infection especially for those who work during the night shift. In that case, the staff testing costs could be added to the objective function and influence our optimal solution value.

The entire model is expected to be developed into a web app with a UI with python code (which gives the model more expansion power) as the backend engine instead of Excel. The users (clinics and laboratories that provide COVID testing) can use the app by simply inputting staff number, shift number and length, and anticipation for different events of the week. Part of the python code is attached in the appendix section.

Staff Assignment Sample Output with Python (gurobi package):

new_index	Mon_s1	Mon_s2	Mon_s3	Tue_s1	Tue_s2	Wed_s1	Wed_s2	Wed_s3	Thu_s1	Thu_s2	Fri_s1	Fri_s2	Fri_s3	Sat_s1	Sat_s2	Sun_s3
reception1	S	-	S	-	-	S	-	S	-	-	S	-	S	-	-	-
reception2	-	-	-	-	-	-	-	-	-	-	S	S	-	-	-	-
reception3	-	-	-	-	S	-	-	-	S	S	-	-	-	S	S	-
reception4	S	S	-	S	S	S	S	-	S	S	-	S	-	S	S	S
doctor1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
doctor2	S	S	-	S	S	S	S	-	S	S	S	S	-	-	-	-
doctor3	-	-	-	-	S	-	-	-	-	S	-	S	-	S	S	-
doctor4	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-
nurse1	-	-	-	-	-	-	-	-	S	S	S	S	-	-	-	-
nurse2	-	-	-	S	S	-	-	-	S	S	-	-	-	S	S	-
nurse3	-	S	S	-	-	-	S	S	-	S	-	-	-	S	S	-
nurse4	-	-	-	S	S	-	-	-	-	-	-	S	S	-	-	-
nurse5	-	S	-	-	S	S	S	-	-	-	-	-	S	-	-	-
nurse6	S	-	S	-	-	S	-	S	-	-	S	S	-	S	S	-
cleaningstaff1	-	S	S	-	-	-	S	S	-	-	S	S	-	-	-	-
cleaningstaff2	-	-	-	-	-	-	-	-	-	-	S	S	-	S	S	-
cleaningstaff3	-	-	-	-	S	-	-	-	-	S	-	-	-	S	S	-
cleaningstaff4	S	S	-	S	S	S	S	-	S	S	-	-	S	-	-	-



APPENDIX:

1. BAMS 508 Final Project Model -Excel Model (including user guide)
2. Clinic Staff Assignment Code. ipynb (python code for staffing assignment model)