Staff Planning Optimization Case Study - Final Report

Business Objective:

An insurance company InsurePlus wants to find the optimal number of staff that they need for their insurance application approval process for the calendar year 2021.
The objective is to optimize the total cost for the application approval process by distributing the right number of applications between the FTEs and the vendors while meeting the monthly demand for each state at the same time.

Mathematical Model of the Optimization Problem (Question-1):

- **Sets & Indexes:** In this problem statement there are two indexes & they are:
  - State, $s \in state$
  - Month, $m \in month$

- **Parameters:** Below are the parameters given in the problem statement:
  - $\text{demand}_{s,m}$ - Number of applications expected for 2021
  - $\text{FTE\_monthlySalary}_{s,m}$ - Average Monthly Salary Per Staff
  - $\text{unitOutSourceCost}_{s,m}$ - Cost per application for Vendor
  - $\text{staffAvPer}_{s,m}$ - Average availability of an FTE
  - $\text{FTE\_serviceRate}_{s,m}$ - Number of insurance applications that can be processed by an FTE per month with 100% availability

- **Decision Variables:** Below are the decision variables which will be tuned to perform the optimization
  - Total number of FTE utilization per State per Month

    $MonthlyFTE_{s,m}$ where $s \in state, m \in month$

  - Total number of applications to be outsourced per State per Month

    $MonthlyOutsource_{s,m}$ where $s \in state, m \in month$

- **Objective Function:**
  To minimize the total cost of processing all the applications as projected by the Demand

$$\min \left[\sum_{s,m} \text{MonthlyFTE}_{s,m} * \text{FTE\_monthlySalary}_{s,m} + \sum_{s,m} \text{MonthlyOutsource}_{s,m} * \text{unitOutSourceCost}_{s,m} \right]$$

where $s \in state$ and $m \in month$

- **Constraints:**
  - All the applications (as per the demand) need to be processed every Month for each State
    - $\text{MonthlyFTE}_{s,m} * \text{staffAvPer}_{s,m} * \text{FTE\_serviceRate}_{s,m} + \text{MonthlyOutsource}_{s,m} = \text{demand}_{s,m} \quad \forall s \in state, m \in month$
  - Regulatory restriction on maximum applications to be outsourced for State A
    - $\text{MonthlyOutsource}_{A,m} \leq \text{demand}_{A,m} * 0.3 \quad \forall m \in month$
  - Regulatory restriction on maximum applications to be outsourced for State B
    - $\text{MonthlyOutsource}_{B,m} \leq \text{demand}_{B,m} * 0.4 \quad \forall m \in month$

Pyomo Modelling & Solving the Optimization Problem (Question-2):

The mathematical model has been converted to the below Pyomo models:

- Created the required Python data structures below for **Indexes** & **Parameters**:

```
# Defining Indexes
BankLoc = demandData['State'].unique()
BankLoc = BankLoc.tolist()

Month = demandData['Month'].unique()
Month = Month.tolist()
```

```
# Defining Parameters for Demand
demand = demandData.set_index(['State','Month'])['Demand'].to_dict()
```

```
# Defining Parameters for Cost
FTE_monthlySalary = cost.set_index(['State','Month'])['MonthlySalary'].to_dict()
unitOutSourceCost = cost.set_index(['State','Month'])['UnitOutSourceCost'].to_dict()
```

```
# Defining Parameters for Staff Availability
staffAvPer = staffAv.set_index(['State','Month'])['StaffAvPer'].to_dict()
staffAvPer_LB = staffAv.set_index(['State','Month'])['LB'].to_dict()
staffAvPer_UB = staffAv.set_index(['State','Month'])['UB'].to_dict()
```

```
# Defining Parameters for FTE service Rate
FTE_serviceRate = serviceRate['MgAppServedPerMonth'][0]
```

- Created the Pyomo Model object:

```
# Creating a model instance
model = ConcreteModel()
```

- Defined the decision variables, objective function & constraints:

```
# Decision variables
# FTE Work Force
model.MonthlyFTE = Var(BankLoc, Month, domain=NonNegativeReals)

# No. of applications outsourced
model.MonthlyOutsource = Var(BankLoc, Month, domain=NonNegativeIntegers)
```

```
# Defining Objective Function

def obj_rule(model):
    return(sum(model.MonthlyFTE[i,j]*FTE_monthlySalary[i,j] for i in BankLoc for j in Month) +
           sum(model.MonthlyOutsource[i,j]*unitOutSourceCost[i,j] for i in BankLoc for j in Month))

model.value = Objective(rule=obj_rule, sense=minimize)
```

```
# Defining Constraints

# Demand Constraint
def fulfill_demand(model,i,j):
    return (model.MonthlyFTE[i,j]*staffAvPer[i,j]*FTE_serviceRate + model.MonthlyOutsource[i,j]) == demand[i,j]

model.match_demand = Constraint(BankLoc,Month,rule=fulfill_demand)
```

```
# Regulatory Constraint for outsourced applications for State A

def reg_restrict_state_A(model,j):
    return (model.MonthlyOutsource['A',j] <= demand['A',j]*0.3)

model.reg_state_A = Constraint(Month,rule=reg_restrict_state_A)


# Regulatory Constraint for outsourced applications for State B

def reg_restrict_state_B(model,j):
    return (model.MonthlyOutsource['B',j] <= demand['B',j]*0.4)

model.reg_state_B = Constraint(Month,rule=reg_restrict_state_B)
```

- Solved the above Pyomo model for optimization with GLPK solver & obtained the minimized value of our objective function (which is the total cost)

```
# Invoking the solver
result = SolverFactory('glpk').solve(model)
```

```
# Print the value of the objective function
model.value()
```

```
17962336.448769882
```

- Below is the final output showing the optimized value of staff required (FTEs & Outsourced_Applications) for each state & each month

Index_#	State	Month	Demand	Staff_Availability	FTEs	Outsourced_Applications
0	A	Jan	5240	0.81	161.728395	0
1	A	Feb	4878	0.76	160.460526	0
2	A	Mar	5942	0.75	198.066667	0
3	A	Apr	2297	0.8	71.78125	0
4	A	May	1992	0.78	63.846154	0
5	A	Jun	2275	0.73	77.910959	0
6	A	Jul	5334	0.68	137.279412	1600
7	A	Aug	3371	0.76	110.888158	0
8	A	Sep	3759	0.81	116.018519	0
9	A	Oct	3529	0.73	120.856164	0

10	A	Nov	4284	0.68	110.257353	1285
11	A	Dec	5183	0.65	139.576923	1554
12	B	Jan	4927	0.81	152.067901	0
13	B	Feb	2628	0.76	51.875	1051
14	B	Mar	2974	0.75	59.5	1189
15	B	Apr	2338	0.8	73.0625	0
16	B	May	4020	0.78	128.846154	0
17	B	Jun	3147	0.73	64.691781	1258
18	B	Jul	4271	0.68	94.227941	1708
19	B	Aug	2620	0.76	51.710526	1048
20	B	Sep	4517	0.81	139.41358	0
21	B	Oct	4155	0.73	85.376712	1662
22	B	Nov	3137	0.68	69.227941	1254
23	B	Dec	4227	0.65	97.576923	1690
24	C	Jan	1162	0.81	35.864198	0
25	C	Feb	1967	0.76	64.703947	0
26	C	Mar	1898	0.75	63.266667	0
27	C	Apr	2261	0.8	70.65625	0
28	C	May	2030	0.78	65.064103	0
29	C	Jun	1642	0.73	56.232877	0
30	C	Jul	2489	0.68	0	2489
31	C	Aug	2496	0.76	82.105263	0
32	C	Sep	922	0.81	28.45679	0
33	C	Oct	2421	0.73	82.910959	0
34	C	Nov	963	0.68	0	963
35	C	Dec	1998	0.65	0	1998

- Below are a few stats which can be inferred from this optimized solution that we have obtained:
  - Minimum cost to process all the applications
    - ⇨ $ 17.9 Million
  - Percentage of Outsourced Applications *(Total Applications Outsources / Total Demand)*
    - ⇨ 18.31%
  - Average Cost per Application *(Total Cost / Total Demand)*
    - ⇨ $ 158.55

Solving the Optimization Problem in Pyomo with Worst Case & Best Case Analysis (Question-3):

1. Worst Case Analysis:

The same optimization problem has been solved again by changing the FTE Availability for the worst case scenario. Below are the results obtained after solving this optimization problem in Pyomo.

- Optimal number of staff required (FTEs & Outsourced_Applications) for each state & each month

Index_#	State	Month	Demand	Staff_Availability_LB	FTEs	Outsourced_Applications
0	A	Jan	5240	0.7	187.142857	0
1	A	Feb	4878	0.65	131.346154	1463
2	A	Mar	5942	0.7	212.214286	0
3	A	Apr	2297	0.75	76.566667	0

4	A	May	1992	0.7	71.142857	0
5	A	Jun	2275	0.65	61.269231	682
6	A	Jul	5334	0.6	155.583333	1600
7	A	Aug	3371	0.65	90.769231	1011
8	A	Sep	3759	0.7	134.25	0
9	A	Oct	3529	0.65	95.038462	1058
10	A	Nov	4284	0.6	124.958333	1285
11	A	Dec	5183	0.6	151.208333	1554
12	B	Jan	4927	0.7	105.607143	1970
13	B	Feb	2628	0.65	60.653846	1051
14	B	Mar	2974	0.7	63.75	1189
15	B	Apr	2338	0.75	46.766667	935
16	B	May	4020	0.7	86.142857	1608
17	B	Jun	3147	0.65	72.653846	1258
18	B	Jul	4271	0.6	106.791667	1708
19	B	Aug	2620	0.65	60.461538	1048
20	B	Sep	4517	0.7	96.821429	1806
21	B	Oct	4155	0.65	95.884615	1662
22	B	Nov	3137	0.6	78.458333	1254
23	B	Dec	4227	0.6	105.708333	1690
24	C	Jan	1162	0.7	41.5	0
25	C	Feb	1967	0.65	0	1967
26	C	Mar	1898	0.7	67.785714	0
27	C	Apr	2261	0.75	75.366667	0
28	C	May	2030	0.7	72.5	0
29	C	Jun	1642	0.65	0	1642
30	C	Jul	2489	0.6	0	2489
31	C	Aug	2496	0.65	0	2496
32	C	Sep	922	0.7	32.928571	0
33	C	Oct	2421	0.65	0	2421
34	C	Nov	963	0.6	0	963
35	C	Dec	1998	0.6	0	1998

- Below are a few stats which can be inferred from this optimized solution that we have obtained:
    - Minimum cost to process all the applications
        - ⇨ $ 19.6 Million
    - Percentage of Outsourced Applications *(Total Applications Outsources / Total Demand)*
        - ⇨ 35.14%
    - Average Cost per Application *(Total Cost / Total Demand)*
        - ⇨ $ 173.00

2. <u>Best Case Analysis:</u>

The same optimization problem has been solved again by changing the FTE Availability for the best case scenario. Below are the results obtained after solving this optimization problem in Pyomo.

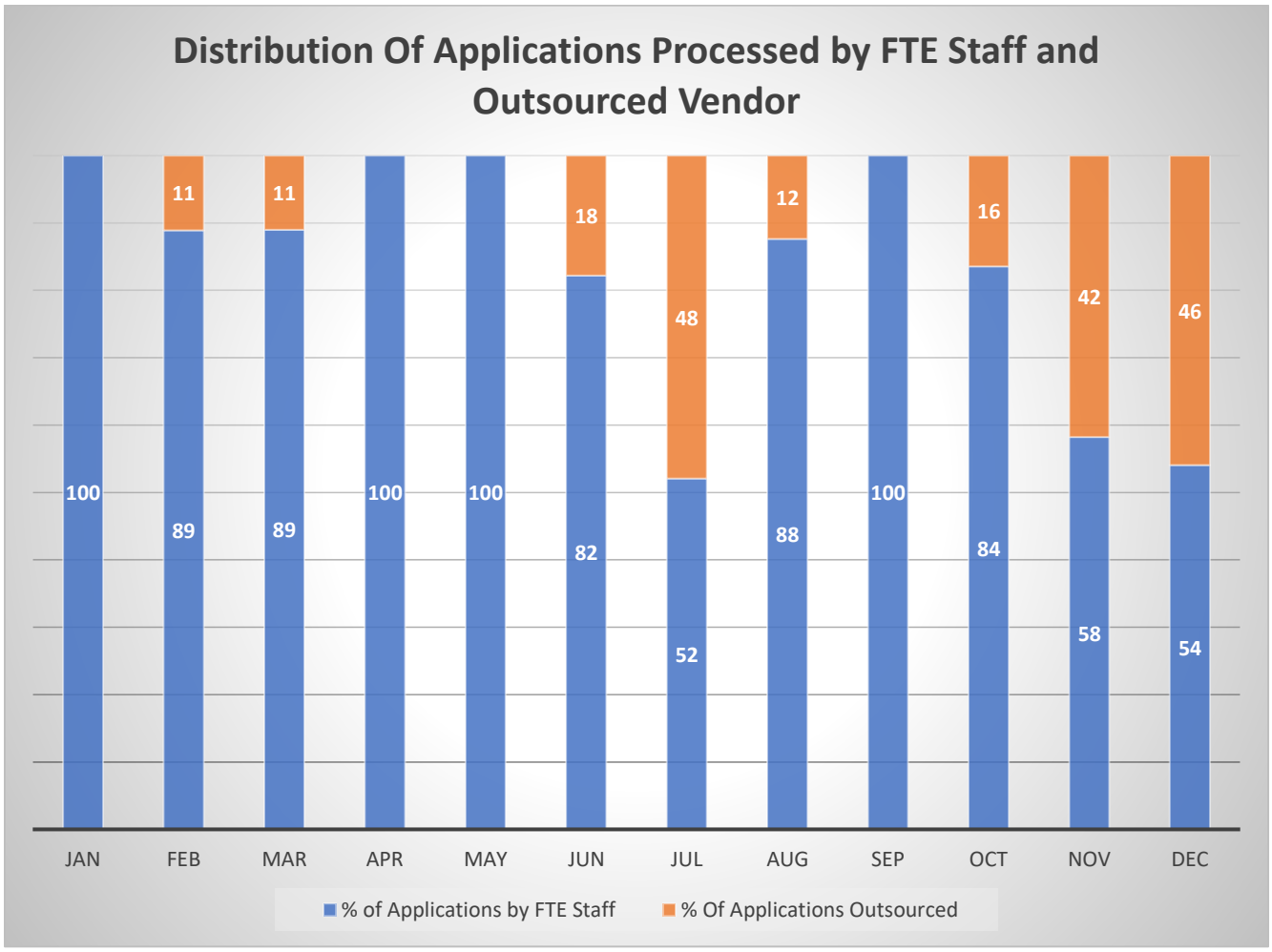
- Optimal number of staff required (FTEs & Outsourced_Applications) for each state & each month

Index_#	State	Month	Demand	Staff_Availability_UB	FTEs	Outsourced_Applications
0	A	Jan	5240	0.9	145.555556	0
1	A	Feb	4878	0.85	143.470588	0
2	A	Mar	5942	0.8	185.6875	0
3	A	Apr	2297	0.85	67.558824	0
4	A	May	1992	0.85	58.588235	0
5	A	Jun	2275	0.8	71.09375	0
6	A	Jul	5334	0.75	177.8	0
7	A	Aug	3371	0.85	99.147059	0
8	A	Sep	3759	0.9	104.416667	0
9	A	Oct	3529	0.8	110.28125	0
10	A	Nov	4284	0.75	142.8	0
11	A	Dec	5183	0.7	185.107143	0
12	B	Jan	4927	0.9	136.861111	0
13	B	Feb	2628	0.85	77.294118	0
14	B	Mar	2974	0.8	92.9375	0
15	B	Apr	2338	0.85	68.764706	0
16	B	May	4020	0.85	118.235294	0
17	B	Jun	3147	0.8	98.34375	0
18	B	Jul	4271	0.75	85.433333	1708
19	B	Aug	2620	0.85	77.058824	0
20	B	Sep	4517	0.9	125.472222	0
21	B	Oct	4155	0.8	129.84375	0
22	B	Nov	3137	0.75	62.766667	1254
23	B	Dec	4227	0.7	90.607143	1690
24	C	Jan	1162	0.9	32.277778	0
25	C	Feb	1967	0.85	57.852941	0
26	C	Mar	1898	0.8	59.3125	0
27	C	Apr	2261	0.85	66.5	0
28	C	May	2030	0.85	59.705882	0
29	C	Jun	1642	0.8	51.3125	0
30	C	Jul	2489	0.75	82.966667	0
31	C	Aug	2496	0.85	73.411765	0
32	C	Sep	922	0.9	25.611111	0
33	C	Oct	2421	0.8	75.65625	0
34	C	Nov	963	0.75	32.1	0
35	C	Dec	1998	0.7	71.357143	0

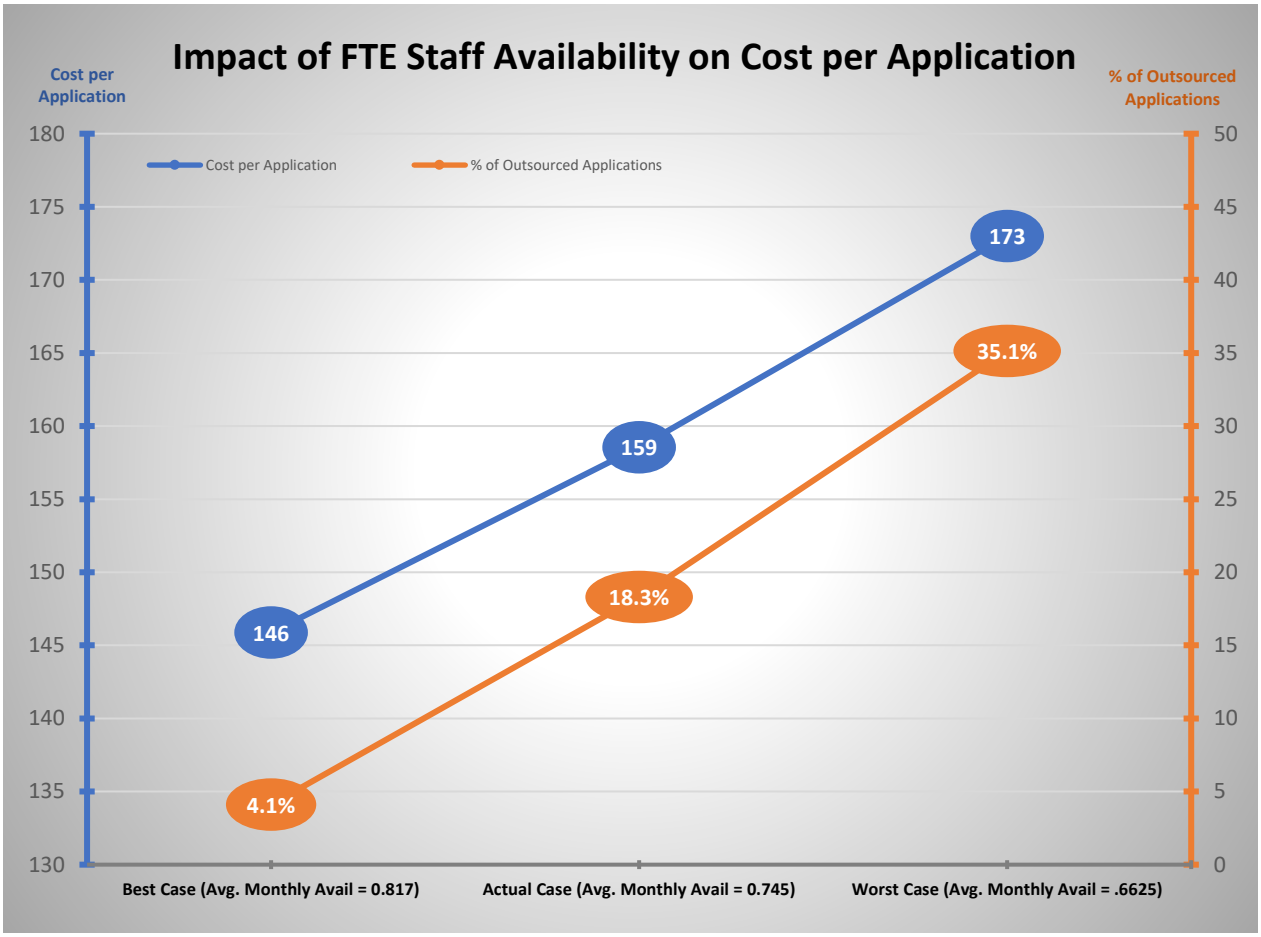
- Below are a few stats which can be inferred from this optimized solution that we have obtained:
  - Minimum cost to process all the applications
    - ⇨ $ 16.5 Million
  - Percentage of Outsourced Applications *(Total Applications Outsources / Total Demand)*
    - ⇨ 4.11%
  - Average Cost per Application *(Total Cost / Total Demand)*
    - ⇨ $ 145.88

Visualizations on the Optimized Solutions (Question-4):

- The below visualization shows the percentage share of total applications processed by FTE Staff & Outsourced Vendor.



- The below visualization represents the impact of FTE Staff availability on Cost per Application & percentage of Outsourced applications for the three scenarios that we had solved.



INSIGHTS:

- ⇨ Cost per Application increase as the FTE staff availability decrease -> With the decrease in FTE staff availability, more applications need to be outsourced to the vendor (in order to fulfill the demand) which eventually increases the total cost for the company & therefore, the cost per application goes up.