Risk Mitigation at Call Centers

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Introduction

- Since 1980, the United States has experienced **218** weather and climate disasters.

- In 2017, across the U.S. there were **15** weather and climate events that resulted in material and financial losses that exceeded **$1 billion** each

- The annual average of climate disasters has **doubled** in the last five years.

Image adapted from 2017 Weather and Climate Disasters in the US. (https://www.ncdc.noaa.gov/billions/)

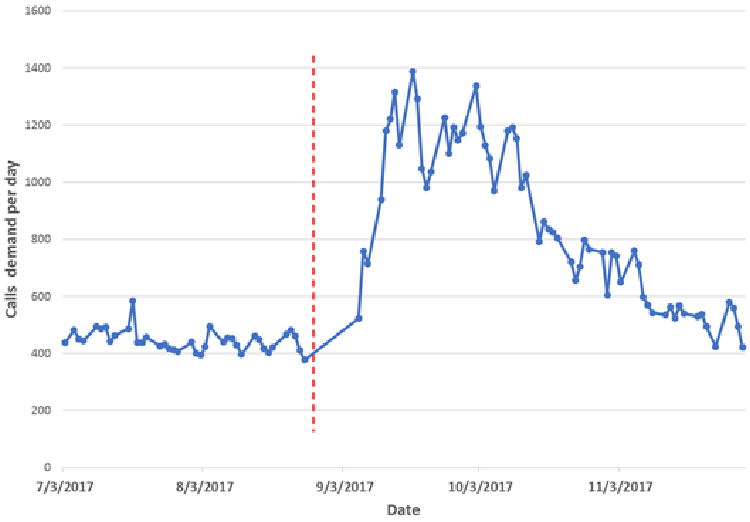
Photo: Hurricane Harvey 2017

The Company

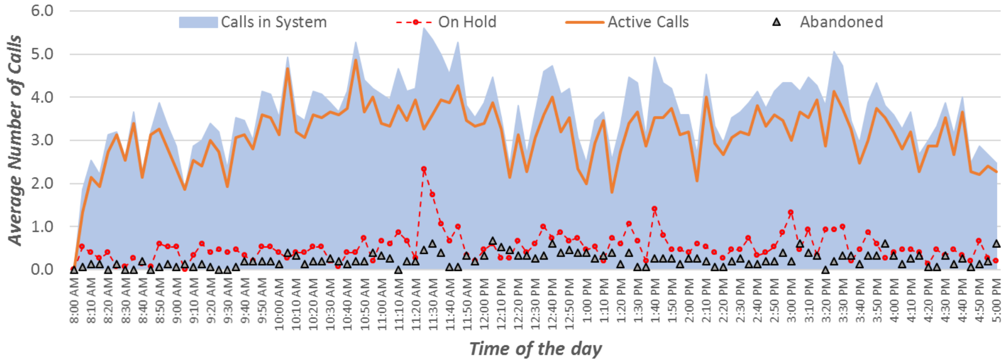
- Manages an operation that helps sellers connect with buyers of product A through ecommerce site
- Over **150 physical locations** across the US, where Company X conducts **storage**, **distribution** and **call center** operations relating to the transfer of product A
- Call center operation handles inbound and outbound calls
- Target Service Level Agreement (**SLA**) to respond to **incoming calls** in under **60 seconds**

Motivation

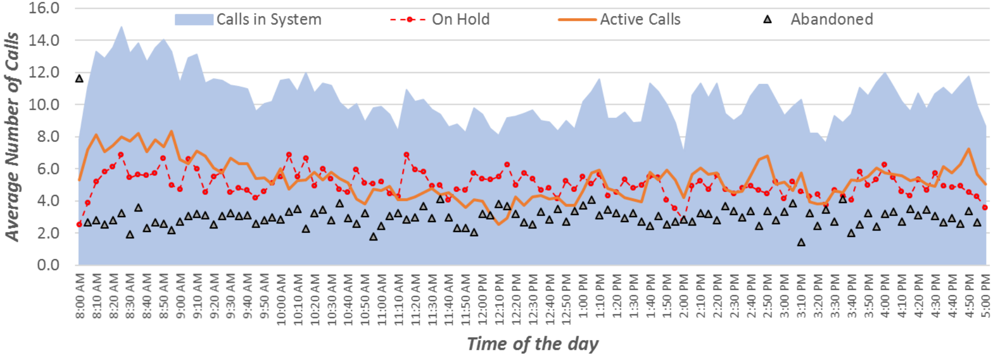
How can a company **leverage resources** from a network of **call centers** to accommodate during a disruption, such as a **climate catastrophe event**?



Before Catastrophe Event*



After Catastrophe Event**



Increase in calls

141%

Waiting Time

32 sec → **143 sec**

Drop Calls

4.3% → **28.9%**

**Data Source: Three weeks of data before climate event*

***Data Source: Three weeks of data after climate event*

Methodology

Data Collection

- Historical Call Logs
  - 1 Year of Past Data
- Known Adverse Events
  - e.g. Hurricane
- Sites' Geographic Information
  - 154 Centers

Service Level Agreement

- 95% Hold Time < 60s

Statistical Analysis (Descriptive)

- Descriptive Statistics
  - Mean, Standard Deviation, Median, IQR(Interquartile Range)
  - Classification of centers
- Probability Distribution
- Correlation Analysis
  - Relationship between holding time and the number of incoming calls

Demand Forecasting (Predictive)

- Exponential Smoothing

Capacity Analysis (Descriptive)

- Queueing Theory

Resource Allocation/ Optimization (Prescriptive)

- Interactive script in R

Service Profile (Insights)

- General Service Level Profiles
  - Histograms + Box Plots
  - Hold Time
- Significant Difference between Normal Operations and Anomaly Events
- Weekly Aggregation for Baseline

Forecasting Model

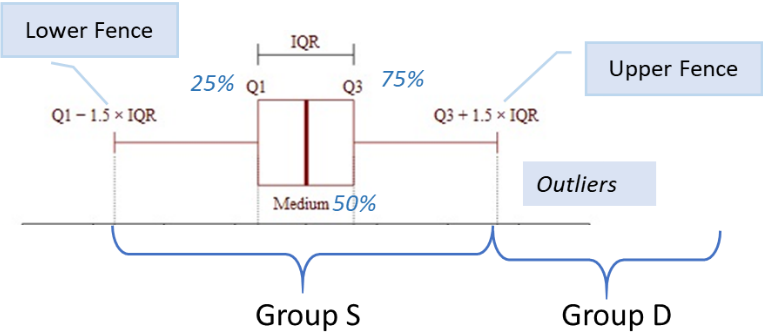
- Demand Forecasting Model
- Models of Normal Operation
- By Site and Region

Optimization Model

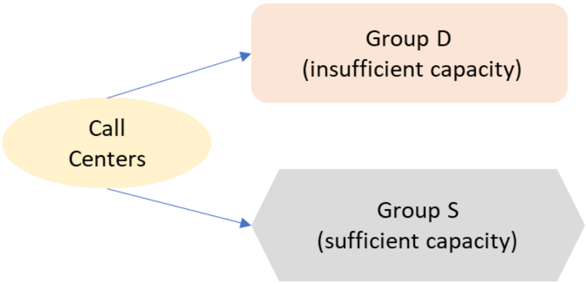
- An Interactive model
- Easy to use for internal customer to take decisions under a high-pressure environment
- Fast response (within 4 mins)

Methodology

Statistical Analysis & Classification



IQR: Interquartile Range



Optimization Model

$$Min \quad \sum_{i=1}^{M}\sum_{j=1}^{N} c_{ij} * X_{ij} + \sum_{i=1}^{M}\sum_{j=1}^{N}\sum_{k=1}^{T} s_{ijk} * Y_{ijk}$$

Objective Function

s.t.

$$Y_{ijk} \leq \frac{C_{ijk}}{D_{jk}} \qquad \forall_{ijk} \in I, J, K$$

Capacity Constraint

$$\sum_{i=1}^{M} Y_{ijk} \geq 1 \qquad \forall_{jk} \in J, K$$

Demand Constraint

$$\sum_{k=1}^{T} (-Q * X_{ij} + Y_{ijk}) \leq 0 \qquad \forall_{ij} \in I, J$$

Linking Constraint

$$X_{ij}, Y_{ijk} \in \{0,1\}$$

Binary Constraint

i serial number of location $i \in [1,154]$

j serial number of queue $j \in [1,5]$

k serial number of time slot $k \in [1,9]$

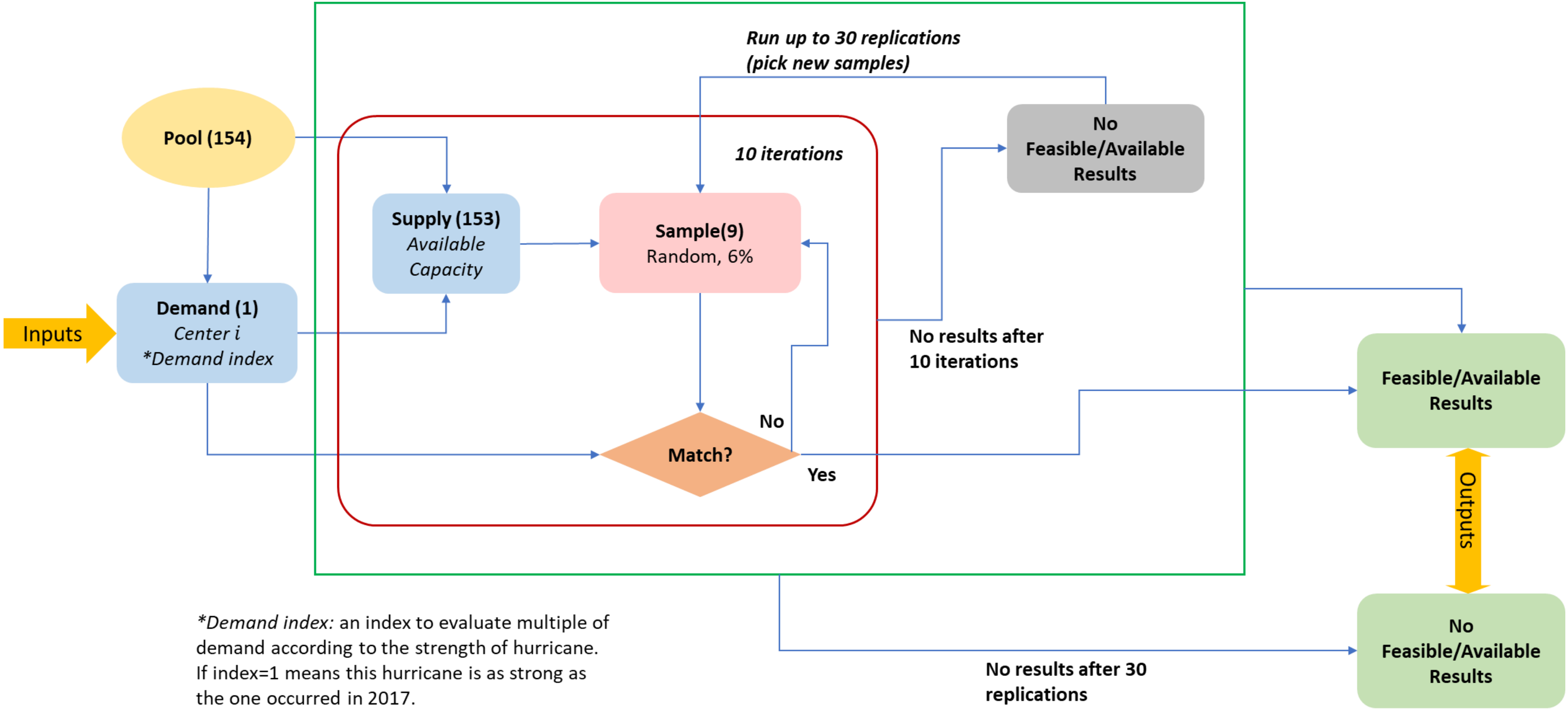
X_{ij} be recommended to reroute calls, =1; otherwise, =0 (supply side)

Y_{ijk} need to be reroute, =1; otherwise, =0 (demand side)

Q big number

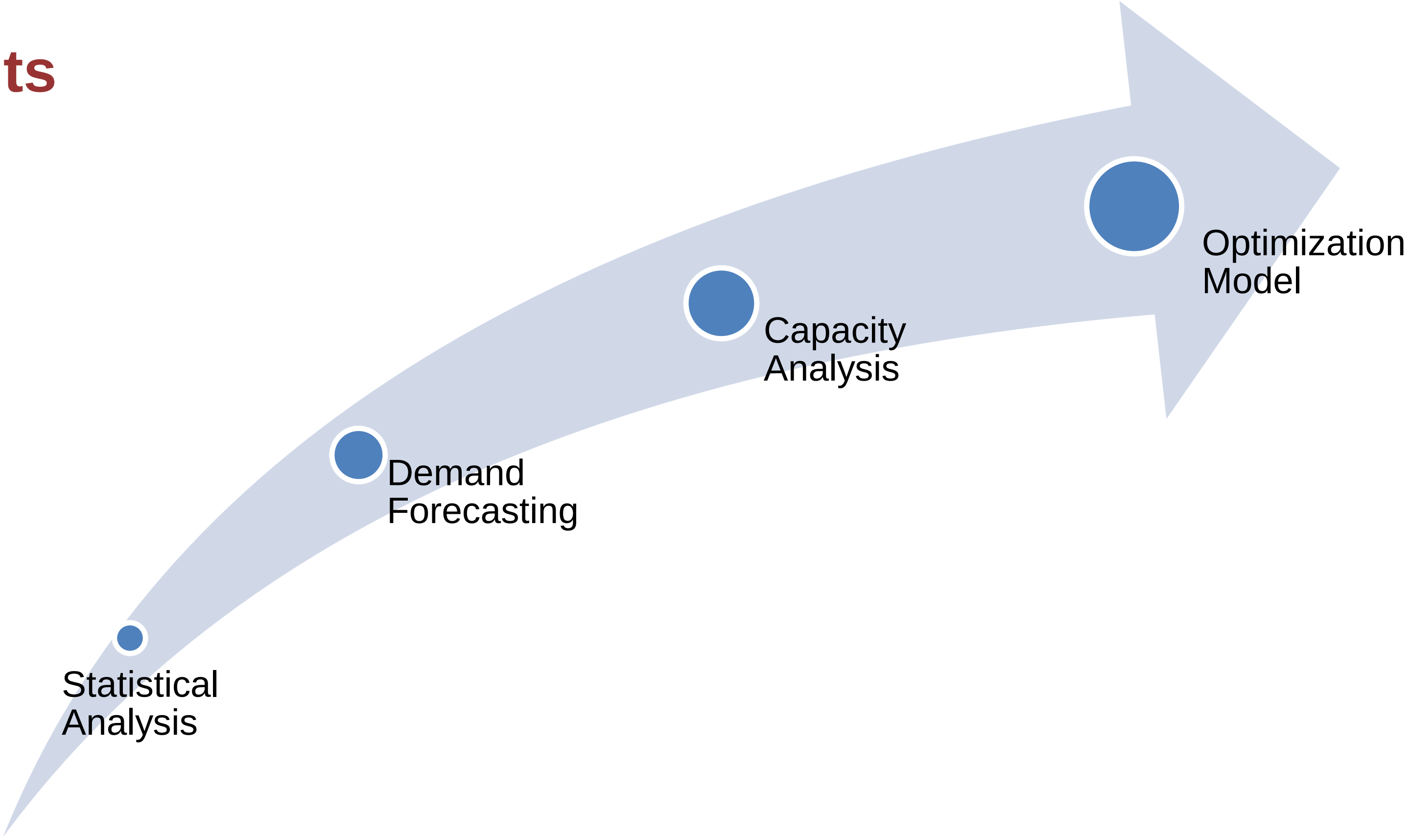
Methodology

Optimization Model

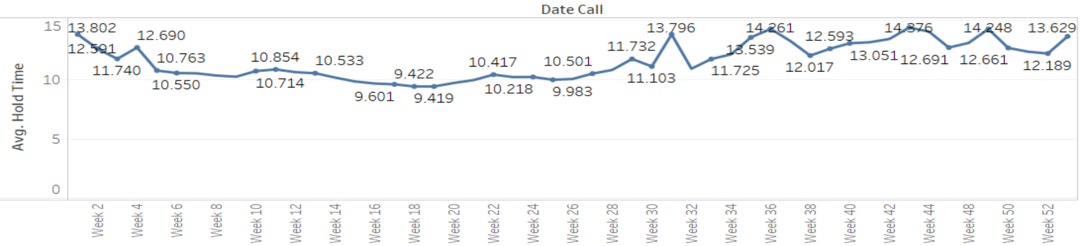


**Demand index:* an index to evaluate multiple of demand according to the strength of hurricane. If index=1 means this hurricane is as strong as the one occurred in 2017.

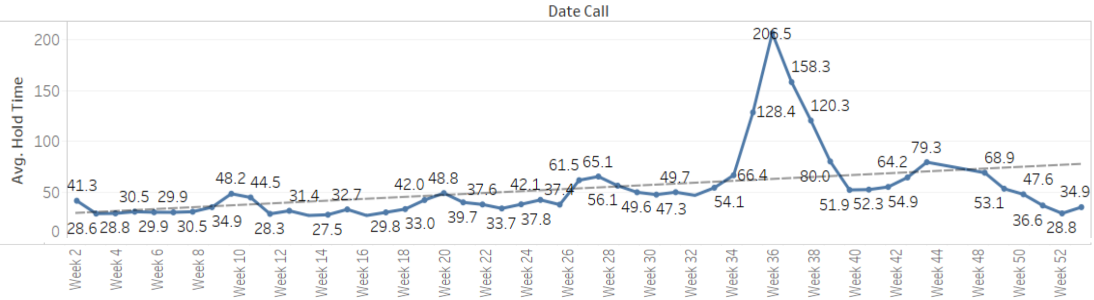
Results


Statistical Analysis
Demand Forecasting
Capacity Analysis
Optimization Model

Results – Statistical Analysis



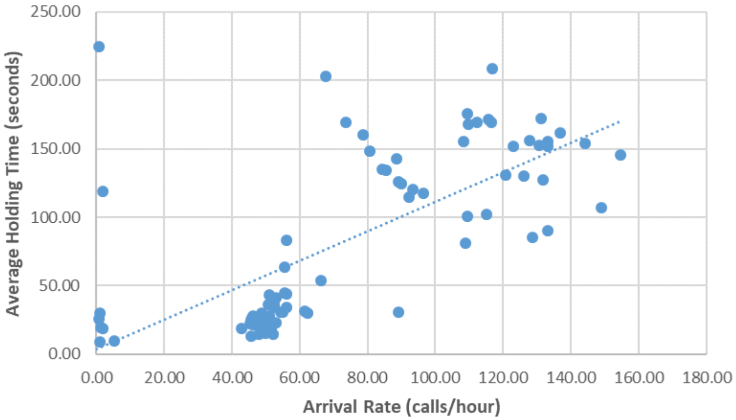
Call centers analysis with holding time lower than 24.5 seconds (Group S)



Call centers analysis with holding time greater than 24.5 seconds (Group D)

	Q1 (25%)	Q2 (50%)	Q3 (75%)	IQR (Q3-Q1)	Lower Fence (Q1-1.5*IQR)	Upper Fence (Q3+1.5*IQR)
Holding time	4	7	14	7	-6.5	24.5
Duration time	60	116	221	105	97.5	378.5
Total time	75	135	247	112	-93	415

Interquartile Range (IQR) analysis for all call centers



Relationship between call arrival rate and holding time (July to October 2017)

Results – Demand Forecasting

- Simple exponential smoothing
- Parameter alpha (α) that minimizes Root Mean Squared Error (RMSE) of call demand.

α =0.21

Alpha (α)	*RMSE*
0.21	4.335632
0.2	4.336268
0.18	4.337819
0.19	4.339523
0.17	4.343181
0.16	4.344477
0.15	4.347776
0.22	4.34808
0.23	4.350566

Results – Capacity Analysis

Inputs: Waiting time (t_q^{ijk}) , coefficient of variation for interarrivals (CV_a^{ijk}), coefficient of variation of process time (CV_p^{ijk}), process time (t_p^{ijk}) and, number of parallel agents (m^{ijk})

Output: Maximum capacity for call arrivals (r_a^{ijk})

Location	Queue	Timeslot	Demand	Max. Capacity	Capacity Bandwidth
312	Queue 1	1	6	54	48
312	Queue 1	2	6	58	52
312	Queue 2	3	4	58	54
312	Queue 2	4	3	46	43
312	Queue 3	5	3	30	27
312	Queue 3	6	3	23	20
312	Queue 5	7	3	24	21
312	Queue 5	8	3	4	1
312	Queue 4	9	3	42	39

Results – Optimization Model

Inputs:

- ➔ Location to reroute calls for
- ➔ Demand Forecast
- ➔ Capacity Bandwidth

Output: Call rerouting assignments

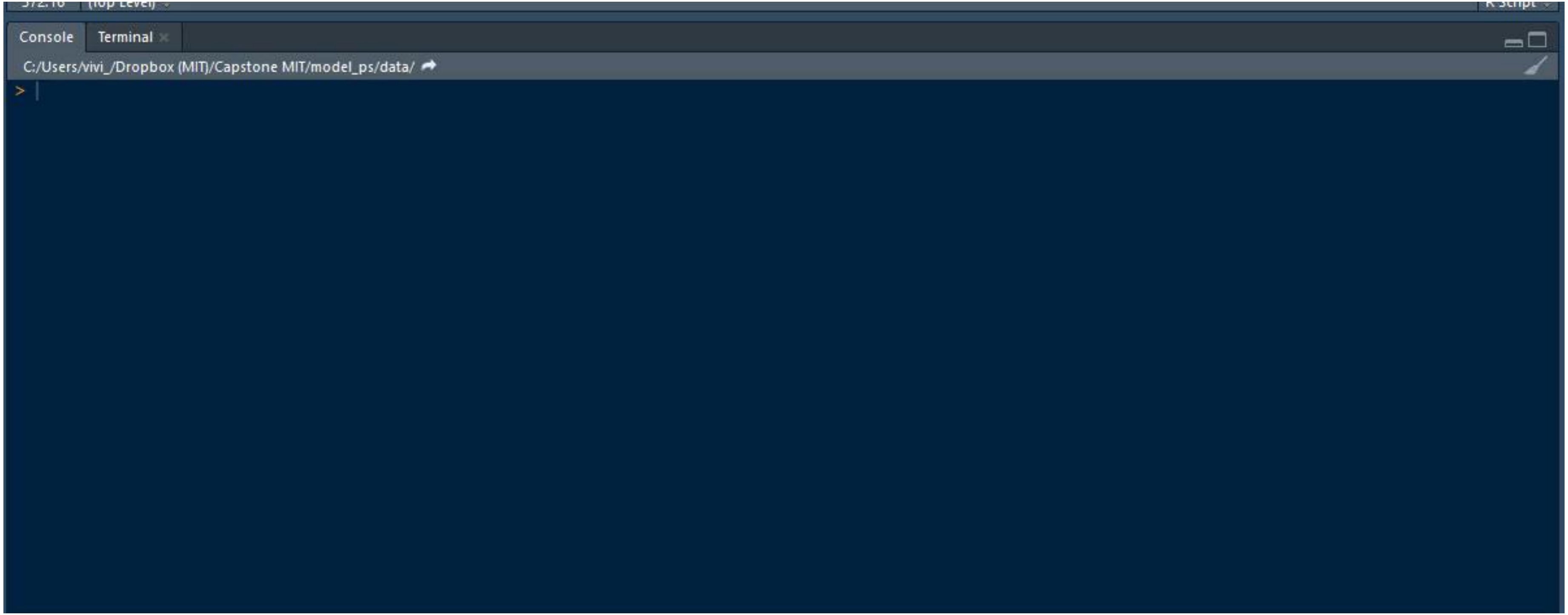
Solver: GLPK

Software: R

Queue Location "A"	Location to	Timeslots "A"
1	349	c("1", "3", "4", "6", "8", "9")
1	437	c("2", "5", "7")
2	365	c("1", "2", "3", "4", "5", "6", "7", "8", "9")
3	429	c("1", "3", "7", "8")
3	391	c("2", "4", "5", "6", "9")
4	447	c("1", "2", "3", "4", "5", "6", "7", "8", "9")
5	349	c("1", "3", "4", "6", "7", "9")
5	447	c("2", "5", "8")

Example of optimization output

Interactive Script in R



Discussion

- As the **number of locations** in the optimization **increases**, the **running time** of the model **increases** exponentially
- Random selection of locations with multiple iterations can help minimize the running time of the Mixed Integer Linear Programming (MILP) model
- Call rerouting framework can be applied in other scenarios such as outages and call center closures

Conclusion

- A sudden increase of demand affects the service level the company has with its customers

- Optimization model helps on **minimizing** the **risk** of losing a customer due to bad service during a catastrophe event

- Implementing the proposed framework will lead to quicker **response times**, better **customer service** and higher **customer satisfaction**

Future Work

- Interactive dashboard using “Shiny Apps” package or Matplotlib

- Utility development

- Integration with ERP system

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Appendix A - Queueing Theory Equations

$$t_q = \left(\frac{CV_a^2 + CV_p^2}{2}\right)\left(\frac{u^{\sqrt{2(m+1)}-1}}{m(1-u)}\right)t_p$$

$$u = \frac{r_a * t_p}{m}$$

Notation	Definition	Unit
r_a^{ijk}	Rate of call arrival at location *i* in queue *j* for timeslot *k*	calls/ time
t_a^{ijk}	Mean time between arrivals at location *i* in queue *j* for timeslot *k*	time/call
CV_a^{ijk}	Coefficient of variation of interarrivals at location *i* in queue *j* for timeslot *k*	
m^{ijk}	Number of parallel agents at location *i* in queue *j* for timeslot *k*	
r_p^{ijk}	Rate or capacity at location *i* in queue *j* for timeslot *k*	calls/time
t_p^{ijk}	Mean effective process time at location *i* in queue *j* for timeslot *k*	time/call
CV_p^{ijk}	Coefficient of variation of process time at location *i* in queue *j* for timeslot *k*	

Notation	Definition	Unit
t_q^{ijk}	Expected waiting time at location *i* in queue *j* for timeslot *k*	time
CT^{ijk}	Expected time in system $(t_q^{ijk} + t_p^{ijk})$ for a call at location *i* in queue *j* for timeslot *k*	time
WIP^{ijk}	Average calls in process at location *i* in queue *j* for timeslot *k*	calls
WIP_q^{ijk}	Average work in process in queue at location *i* in queue *j* for timeslot *k*	calls
u^{ijk}	Utilization of the server $(r_a^{ijk} + r_p^{ijk})$ at location *i* in queue *j* for timeslot *k*	calls/time