DATA AND BUSINESS ANALYTICS COURSE

Simulation Model for Mobile Cleaning Teams at Changi Airside to Aid Manpower Optimization

Team 13

FINAL REPORT | DECEMBER 2020

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The Team

Changi Airport Group (CAG) is the manager of Singapore Changi Airport, a leading air hub in Asia.

CAG performs the key functions of airport operations, air hub development, retail and commercial activities, infrastructure development and airport emergency services.[1]

1: https://www.linkedin.com/company/changiairportgroup/

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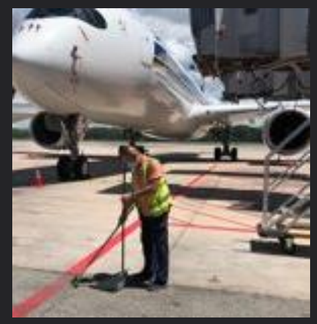
Problem Statement

A gradual ramp up of flights is expected as COVID restrictions are slowly being lifted.
There is a need to create a model to optimize the amount of manpower resources needed to :

1. Respond to and clear the FOD (Foreign object debris) bins or smart bins at the airside.
2. Perform sweeping and litter picking at the aircraft stands and airside roadways.

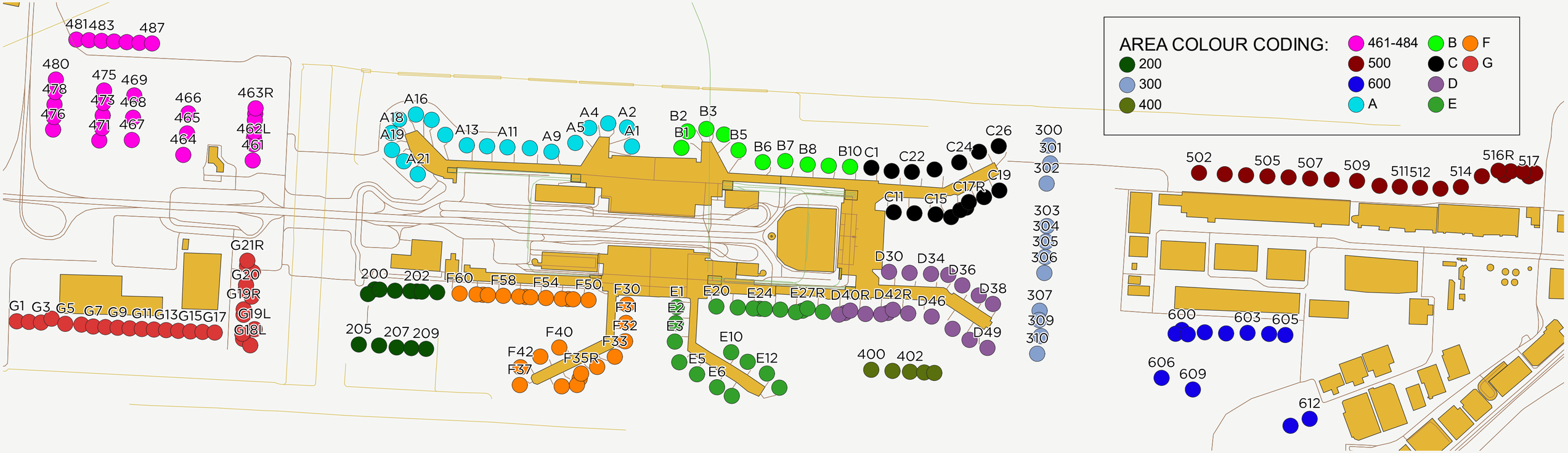
Phase 1 : Assess the current allocation of cleaning teams per shift to evaluate whether it is optimal.
Phase 2 : Optimize the number of teams required per shift by considering the new implementation of smart bins.





Preprocessing of Data

1. **Changi Aerodrome Map:** Plotted in QGIS, the different sectors (color coded) given the geographic coordinates. Calculate the linear distance between each stand (bin) represented by the dots on the map below using QGis Distance Matrix function



Preprocessing of Data

2. Flight Volume Data: Sorting and cleaning up of flight volume data using SQLite and Excel.

i) Flight Volume Data provided by client

	DATE	TIME	AIBT_FINAL	SHIFT	SIBT	FLIGHTO	NATURE	FLIGHT_I	AIRCRAF	AIRCRAFT	TERMINA	PARKING	GATE
319	2019-06-07	14:55	2019-06-07 14:55	1	6/7/2019 15:00	O	PAX			B8338	1	C17L	C17L
320	2019-06-07	15:17	2019-06-07 15:17	1	6/7/2019 15:30	O	PAX			9VJSQ	1	D49	D49
321	2019-06-07	15:32	2019-06-07 15:32	1	6/7/2019 15:50	O	PAX			9VJSV	1	C25	C25
322	2019-06-07	15:42	2019-06-07 15:42	1	6/7/2019 15:35	O	PAX			PHBVO	1	D42	D42
323	2019-06-07	15:49	2019-06-07 15:49	1	6/7/2019 15:45	O	PAX			9VJSB	1	D35	D35
324	2019-06-07	15:56	2019-06-07 15:56	1	6/7/2019 15:45	O	PAX			FGZNE	1	C15	C15
325	2019-06-07	15:59	2019-06-07 15:59	1	6/7/2019 16:25	O	PAX			B5948	1	D36	D36
326	2019-06-07	16:01	2019-06-07 16:01	1	6/7/2019 15:45	O	PAX				1	D32	D32

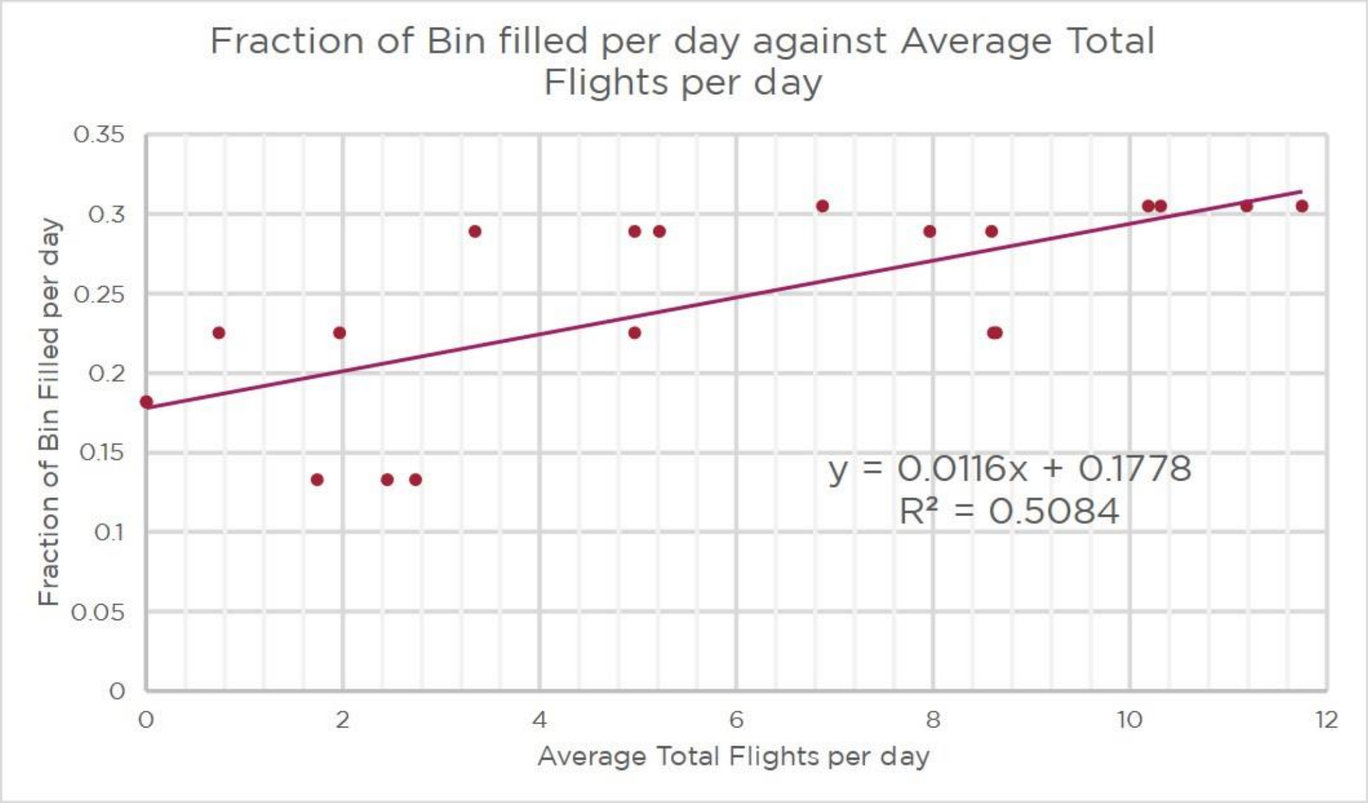
ii) Number of flights for each area allocation per day

DATE	SHIFT	TotalArea_A	TotalArea_B	TotalArea_C	TotalArea_D	TotalArea_E	TotalArea_F	TotalArea_T4G	TotalArea_T4	TotalArea_200	TotalArea_200_2	TotalArea_300	TotalArea_500	TotalArea_600	TotalArea_461_4
1/6/2019	1	51	27	49	35	53	54	51	54	0	5	0	0	1	2
2/6/2019	1	53	29	53	35	50	50	49	52	0	5	0	0	3	2
3/6/2019	1	53	28	45	39	58	57	49	52	0	4	0	0	1	2
4/6/2019	1	49	28	49	43	52	49	51	54	0	4	0	0	2	2
5/6/2019	1	48	27	50	41	47	55	50	54	0	6	0	0	1	3
6/6/2019	1	55	28	47	39	48	58	52	56	0	5	0	0	1	3

Regression Modelling

Smart Bin Trial Data: Finding the best relationship between average total flights per day and fraction of bin filled given smart bin trial data

Results: Linear Model is the best fit based on R^2 value and randomly distributed residuals



Optimization Model 🎯

1st Phase:

Without smart bins to track the rate of bins filling up.

2nd Phase:

Adding in of smart bins, which allow us to track the rate of bins filling up and using our regression model to predict the rate of bins filling up based on flight volume.

Tool Used:

Excel, GRG Nonlinear, Data Solver

Optimization Model

Objective Function:

Minimize the number of Teams for each shift such that the excess time left of their working hours per pair is minimum

Current Allocation of Teams (in pairs):
Shift 1 (8am to 5pm): 6 Teams
Shift 2 (5pm to 11pm): 4 Teams
Shift 3 (11pm to 8am): 2 Teams

Decision Variable:

1 represents the area is **allocated** to the team
0 represents the area is **not allocated** to the team

Area Allocation & Solver

	A	B	C	D	E	F	200-209	300	400-404	500	600	461-484	G	
Shift 1 Pair 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shift 1 Pair 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shift 1 Pair 3	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Shift 1 Pair 4	0	0	0	0	0	0	0	0	1	1	1	1	0	1
Shift 1 Pair 5	0	0	1	1	1	0	0	1	0	0	0	0	0	1
Shift 1 Pair 6	1	1	0	0	0	1	1	0	0	0	0	0	0	1
Shift 2 Pair 1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Shift 2 Pair 2	0	0	0	0	0	0	0	1	1	1	1	0	0	1
Shift 2 Pair 3	0	0	1	0	1	1	0	0	0	0	0	0	0	1
Shift 2 Pair 4	1	1	0	1	0	0	1	0	0	0	0	0	0	1
Shift 3 Pair 1	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Shift 3 Pair 2	1	1	1	1	1	1	1	1	1	1	1	0	0	1
													Solver	10

Constraint

Optimization Model 🎯

Constraints:

Each area checked once per round of check by each shift, which also depends if the area is initially opened (1) or closed (0).

Constraint

Solver	10

	A	B	C	D	E	F	200-209	300	400-404	500	600	461-484	G
Shift 1 Area	1	1	1	1	1	1	1	1	1	1	1	1	1
Open/Close	1	1	1	1	1	1	1	1	1	1	1	1	1
Shift 2 Area	1	1	1	1	1	1	1	1	1	1	1	1	1
Open/Close	1	1	1	1	1	1	1	1	1	1	1	1	1
Shift 3 Area	1	1	1	1	1	1	1	1	1	1	1	1	1
Open/Close	1	1	1	1	1	1	1	1	1	1	1	1	1

Optimization Model 🎯

Input Parameters:

Adjustable Parameters (for client):

1. Number of stands or bins opened
2. Monthly Flight Volume
3. Number of rounds (checks) by each team during each shift
4. Checking and Clearing Timings per bin
5. Total (Includes non-working) Hours per shift
6. Working Hours per shift

Fixed Parameters:

1. Travel time between each bin
2. Fraction of Bin Filled per day for each area (achieved using the regression model embedded in the Excel Sheet)

Optimization Model

SHIFT 1			Equation of regression
areas	Open=1/Closed=0	no. of stands/bins	Fraction of Bin per stand Filled per day
A	1	18	0.2706
B	1	10	0.2822
C	1	16	0.2938
D	1	19	0.259
E	1	21	0.2474
F	1	26	0.2358
200-209	1	13	0.201
300	1	11	0.201
400-404	1	4	0.1894
500	1	21	0.1894
600	1	12	0.201
461-484	1	30	0.1894
G	1	29	0.2242

1. Number of stands or bins opened, for Shift 1

Total Flights per area per month	A	B	C	D	E	F	200-209	300	400-404	500	600	461-484	T4G
Jan													
Feb													
Mar													
Apr													
May													
Jun	4345	2438	4117	3126	4030	4422	493	331	11	593	522	249	3213
Jul	4501	2522	4198	3242	4184	4596	477	402	4	604	538	242	3299
Aug	4482	2533	4162	3268	4131	4643	524	401	7	611	574	245	3253
Sep	4247	2523	4114	3015	4047	4429	492	433	3	596	536	238	3172
Oct	4382	2571	4409	3371	3952	4243	533	540	31	617	546	266	3251
Nov	4078	2488	4738	3839	3468	3722	524	627	34	630	565	238	3219
Dec	4246	2613	5000	4072	3640	3869	524	555	43	525	587	273	3383

2. Monthly Flight Volume (e.g. November 2019)

Optimization Model 🎯

Number of Rounds per day	
Shift 1	3
Shift 2	2
Shift 3	1

Check and Clear Timings	
check time (mins)	2
clear time (mins)	4

Hours per shift	
Shift 1	9
Shift 2	6
Shift 3	9

Sum should be 24 hours. Assumption that there are always workers 24 hours

Working Hours per shift	
Shift 1	8
Shift 2	5
Shift 3	8

3. Number of rounds (checks) by each team during each shift
4. Checking and Clearing Timings per bin
5. Total (Includes non-working) Hours per shift
6. Working Hours per shift

Optimization Model 🎯

Consolidated Timings (All Rounds)

	Shift 1	Shift 2	Shift 3
A	129.6865638	86.45770917	48.09965459
B	72.41394798	48.27596532	26.95998266
C	115.509973	77.00664865	43.20412433
D	134.9470803	89.9647202	49.9033601
E	150.2100872	100.1400581	55.26542906
F	182.6902874	121.7935249	67.02756246
200-209	90.31070602	60.20713735	32.71656867
300	78.33785213	52.22523476	28.32361738
400-404	27.8341533	18.5561022	10.0356511
500	146.7352566	97.82350442	52.88915221
600	89.16216681	59.44144454	32.13272227
461-484	212.5101489	141.6734326	76.5187163
G	198.5840008	132.3893339	72.69646695

Excess Timings (For Cleaning Tasks + Travel between Areas)

Timings needed per shift		Shift Working Hou	Excess(min)
x11	0	480	480
x12	0	480	480
x13	198.5840008	480	281.4159992
x14	476.2417256	480	3.758274356
x15	479.0049926	480	0.995007398
x16	475.1015051	480	4.898494864
x21	274.0627665	300	25.93723351
x22	228.0462859	300	71.95371408
x23	298.9402317	300	1.059768307
x24	284.905532	300	15.09446796
x31	149.2151832	480	330.7848168
x32	446.5578248	480	33.44217517

From the parameters, for a round of check we sum up

i) Clearing time per bin based on the fullness of the bin

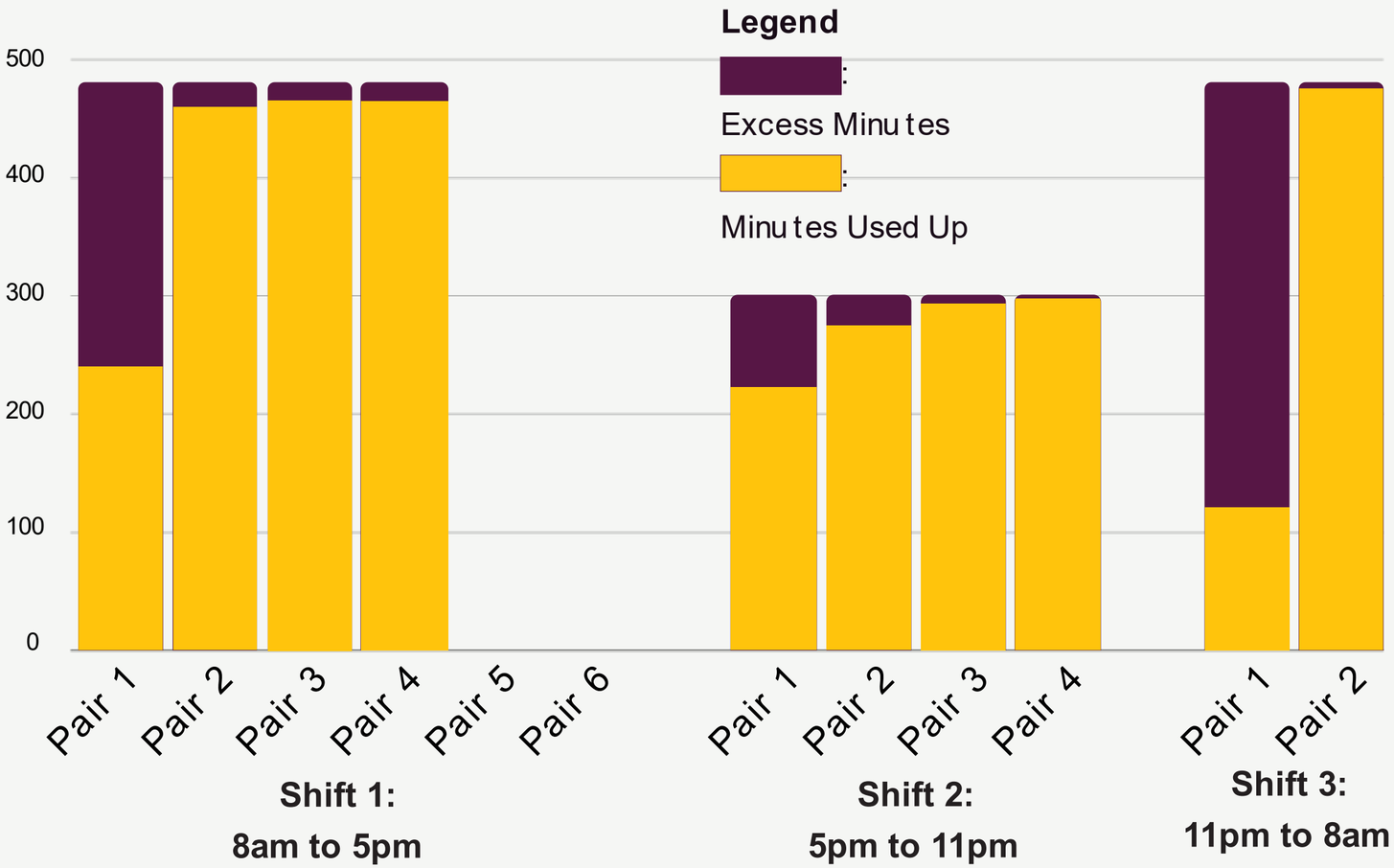
ii) Checking time per bin

iii) Travel time between each bin for allocated area.

Then we calculate for timings for all rounds instead of 1, resulting in **Consolidated Timings**, together with the area allocation in the decision variable will affect the timing needed per shift for each pair of worker, and the **excess timings.**

Results of Model

Optimal, Minimum Number of Teams (For November 2019):



Result

Optimal No. of Teams	
Shift 1	4
Shift 2	4
Shift 3	2

Analysis:

Client can indeed **reduce the number of workers** needed based on the flight volume data for the month.

If there is forecasted data for the coming months flight volume, the number of workers needed can be decided prior to each month.

Minimizes manpower costs for the company.

Limitations of Model

1. **Limited** number of points for regression modelling of the average flight volume per day and the fraction of bin filled per day. Only **20 data points** were available for modelling.

2. QGIS Distance Matrix: Calculates **Linear Distances**. However, the travelling path between stands may not be linear which would differ the travelling time calculated.

3. Does not take into the account that if the flight volume is very high, **more than** the current number of teams is required.