DAO1704 Decision Analytics Using Spreadsheets

Stimulation Team Project Assignment

Group 4

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1.Introduction To Business Case

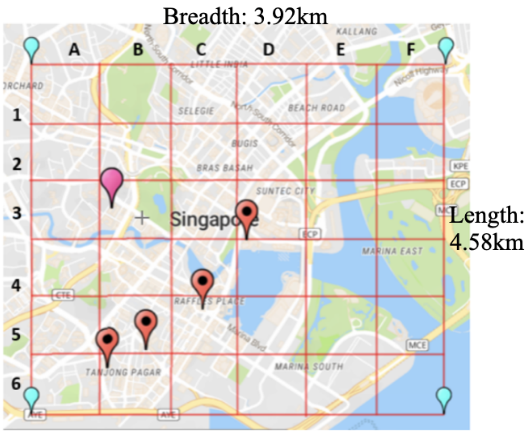

Figure 1 : Map of CBD

- Locations of existing charging station in CBD

- Possible locations for new charging stations

	A	B	C	D	E	F
1	3	2	3	4	5	
2	2	1	2	3	4	5
3	1	0	1	2	3	4
4	2	1	2			5
5	3	2	3	4	5	6
6	4	3	4	5	6	

Figure 2: Map of CBD with grids

Legend: Green: Initial Charging Station
Yellow: Customers Destinations
White: Water Body (No Demand)

*Numbers indicated are the number of grids (distance) from the charging stations to customers destinations

1.1 Business Problem

BlueSG is Singapore's first 24/7 electric car-sharing service currently with 530 Blue cars and 253 charging stations. Each BlueSG customer ends their ride by docking the car in a BlueSG charging station. Every morning, there is a high influx of BlueSG cars into the Central Business District (CBD) area as consumers drive BlueSG cars from housing estates to the CBD area for work, resulting in a shortage in the number of charging stations in the CBD. Currently, there is only 1 charging station in CBD. Mr Franck Vitte, the CEO of BlueSG, wishes to find out if it is profitable to increase the number of charging stations in the CBD to resolve the problem of a shortage of charging stations, and if so, where to optimally place them so as to maximise BlueSG profits for the year. Thus, he has approached BlueSG's market research team to evaluate the optimal number and location of charging stations in the CBD.

The research team has mapped out CBD into a rectangle (Refer to Fig. 1) and divided it into 36 identical boxes with the area of CBD at 17.95 km^2. Each box has a length and breadth of 0.76 km and 0.65 km respectively. Out of the 36 boxes, 4 boxes are assumed to have no demand as they are ≥80% covered by water: D4, E4, F1, F6 (Refer to Fig. 2). The location of the current sole charging station in the CBD area has been accurately pinpointed out in pink as seen in Fig 1. It is assumed that the number of cars available to the CBD is 188 (based on the customer to car ratio of 1:1.2 on the original mean demand of customers in CBD).

When sourcing plots of land to build the new charging stations, the research team narrowed it down to 4 possible locations: B5, B6, C5 and D3 (Refer to Fig. 2). The research team also decided to split CBD into different zones and simulated different scenarios of charging stations within respective zones to find the optimal placement of charging stations. Each zone must have at least one new charging station and the charging stations must not be in boxes that are right next to each other as they are considered to be too close for that scenario to be considered.It is assumed that customers will not cross zones and only dock their car off at the charging station within the same zone as their destination.

The research team estimated the following variables affecting BlueSG's potential demand. The data is as follows:

Distance from charging point to destination	Probability of demand with distance from box	Additional travelling time
0	1	0
1	1	2.5
2	0.9	5
3	0.7	7.5
4	0.4	10
5	0.2	12.5
>5	0	15

Figure 3: Probability Distribution Table

- **Demand for cars in each box,** $\overline{x}$

The demand for cars in each box, $\overline{x}$, is assumed to be identical and independent of one another. It is also assumed to follow a normal distribution with a mean, $\overline{x} = 8$ and standard deviation, σ, of 4. The distance from a customer's charging station to their destination will affect the demand of BlueSG cars. The additional travelling time is the time the customers take to arrive at their destination after docking the car at the charging station. As the distance of the customer destination's box from the charging station increases, both the demand and standard deviation of that particular box decreases (Refer to Fig. 3). In general, the closer the boxes are to their respective charging stations, the higher the mean demand for cars in that particular box.

Furthermore, every increment of one box between the charging station and the destination results in a 2.5 minutes increase in the travelling time to the destination for the customers. In the model, all the distances from charging station to destination that are more than 5 would be assumed to have a fixed additional travelling time of 15 minutes.

- **Effect of weather on the demand of cars in each box:**

Singapore has a tropical climate. The team has found out that the weather also affects the demand for BlueSg cars. The team has classified the weather on any day to be either rainy or non-rainy. The team has also deduced the weather to follow a binomial distribution with probability of a rainy day, p, 0.4 while the probability of a non-rainy day to be 0.6. They also assumed that these probabilities are constant throughout the year. Based on a customers' survey that the research team conducted, customers would not prefer to be outdoors when it is raining, hence the $\overline{x}$ decreases by 30%. On non-rainy days, demand is unaffected by the weather.

- **Costs and Revenue in Model:**

The team has estimated the different costs associated with building and maintaining charging stations. The variable costs of constructing each new charging station would include the cost of installation and maintenance of each charging station (including labour cost) with no fixed cost involved. The cost of installing one charging station is estimated to be $450/month, while the maintenance of each charging station (including labour cost) is estimated to be $30/month. The team has estimated the total revenue earned per person to be $22.75/month. It is assumed that all BlueSG users subscribe to a basic monthly membership of $8/month with a rental fee of $0.33/min and each BlueSG users' time usage of car to be identical of 45 mins.

2. Analysis Of Results

2.1. Histogram

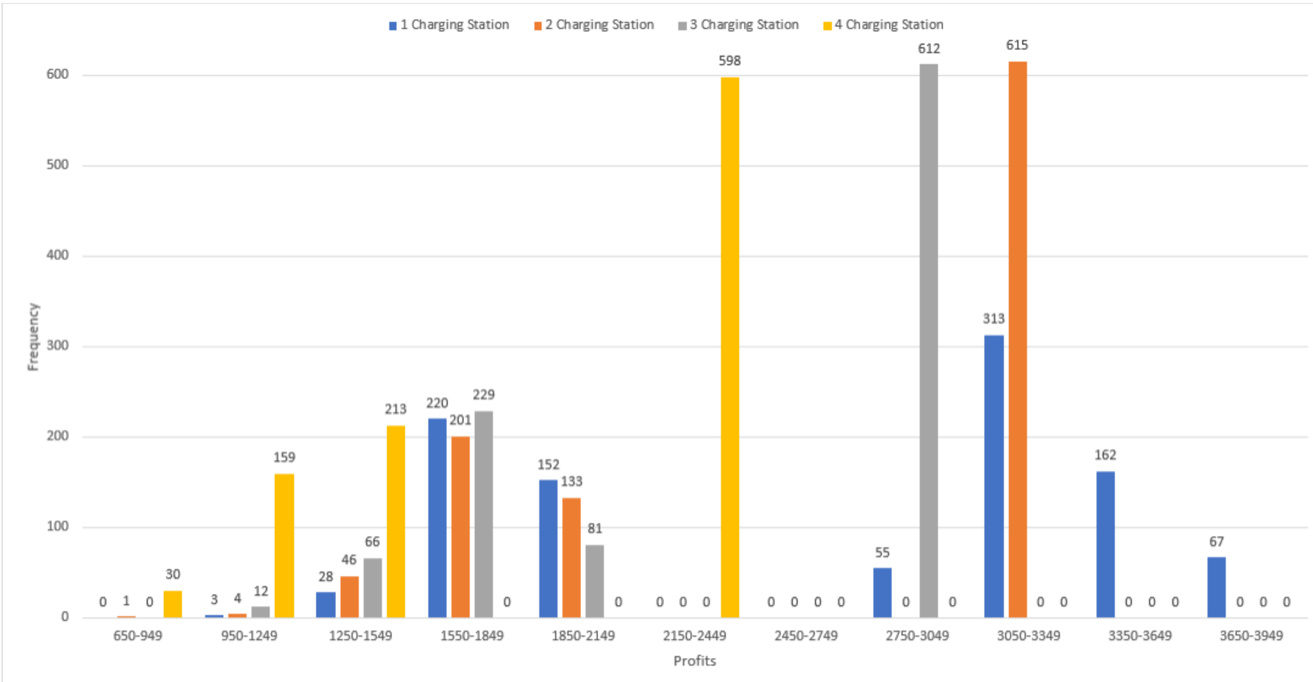

Figure 4: Frequency distribution of profits of various charging stations

We calculated the average profits and the frequency of profits in intervals of $300 for each of the different number of charging stations. With this two-pronged approach, it enhances the accuracy in deriving optimal profits (We used this same approach to find the optimal placement of 2 and 3 charging stations based on the different scenarios available). The highest average profits was $2,710.88, corresponding to 2 charging stations. The highest frequency of profits was 615, corresponding to the profit range of $3050 to $3349 for profits of 2 charging stations. Hence, we derived that the most optimal number of charging stations in the CBD is 2.

2.2. Sensitivity Analysis, Recommendations & Evaluations

Given that Mr Vitte is deciding on how many new charging stations to add to CBD, we will examine the various uncertainties and variables and how it affects the total profits.

2.2.1 Rainy day

From the sensitivity analysis, the probability of a rainy day, p, affects the profitability of building new charging stations. When $p <= 0.5$, having 2 charging stations will be most profitable. However, when $p >= 0.6$, 1 charging station is the most profitable model. Considering how Singapore's climate has 2 monsoons and 2 inter-monsoonal periods, p is not identical each month. Hence, it is highly inaccurate to assume that the value of p in each month is identical. Although it is possible that the yearly average $p \approx 0.4$, BlueSG might be making profits and losses in different months respectively throughout the year. Hence, the market research team should create a profit maximisation model with different p values for respective monsoon and inter-monsoonal seasons across the year to obtain more accurate profits per month.

2.2.2 Cars to Customers Ratio, CCR

From the sensitivity analysis, when CCR is 1.1:1 or 1:1, 1 charging station is most profitable. When 1.2:1 ≤ CCR ≤ 1.4:1, 2 charging stations is the most profitable. When CCR >1.5:1, 3 charging stations is the most profitable. With an increase in the number of charging stations from 1 to 3, there would be a higher chance of demand exceeding the number of cars available, hence leading to a need to increase CCR. However, 4 charging stations is least profitable regardless of the CCR. Hence, BlueSG has no incentive to have more than 3 charging stations. Based on the sensitivity analysis, BlueSG earns maximum profits when CCR ≥ 1.8:1. BlueSG should build 3 charging stations and assign a CCR of 1.8:1 as any more than that would be a waste of resources as there would be no increase in profit. However, this CCR may be too high and come at the expense of other customers outside of the CBD. Considering how BlueSG only has 530 cars in total currently, allocating more cars to CBD would result in a higher probability of other areas outside of the CBD in Singapore running out of cars. Hence, a sustainable increase in the CCR requires an increase in the total number of BlueSg cars in Singapore.

2.2.3 Mean Demand Per Box, $\overline{x}$

From the sensitivity analysis, having 2 charging stations in the CBD is the most profitable when $\overline{x} \geq 8$. When $\overline{x} \leq 7.5$, 1 charging station is the most profitable. However, in reality, $\overline{x}$ is not identical due to availability of public transport (e.g. MRT stations, bus interchanges) at different parts around the CBD. Furthermore, the mean demand of CBD would not be identical throughout the year due to holiday and working seasons, as it would dip during the former and peak during the latter. Hence, such assumptions are unrealistic and the research team should extract actual data of CBD customers to find the most accurate mean demand for each of the individual boxes within the CBD during the different months to obtain more accurate profits.

2.2.4 Rental Fee Per Minute, *r*

From the sensitivity analysis, it can be observed that when r increases, profit increases. When $0.23 \leq r < 0.33$, 1 charging station is most profitable. When $0.33 \leq r \leq 1.23$, 2 charging stations are most profitable. However, when $r > 1.23$, 3 charging stations are most profitable. 4 charging stations is the least profitable regardless of r, hence there is no incentive to have 4 charging stations. Thus, BlueSG should price at $r > 1.23$ and have 3 charging stations in order to reap the highest profits. However, the demand for BlueSg cars is price elastic due to the availability of substitutes (eg. ride-hailing services and public transport). Hence, the extent to which BlueSG can increase r is limited due to the price elasticity of demand (PED) of BlueSG cars. In reality, 3 charging stations with $r > 1.23$ may not be most profitable as the demand for BlueSG cars could have dipped with the increase in price as customers switch to other substitutes. Thus, the market research team needs to find the optimal r based on the PED of BlueSG cars and subsequently derive the most profitable number of charging stations for that r value.

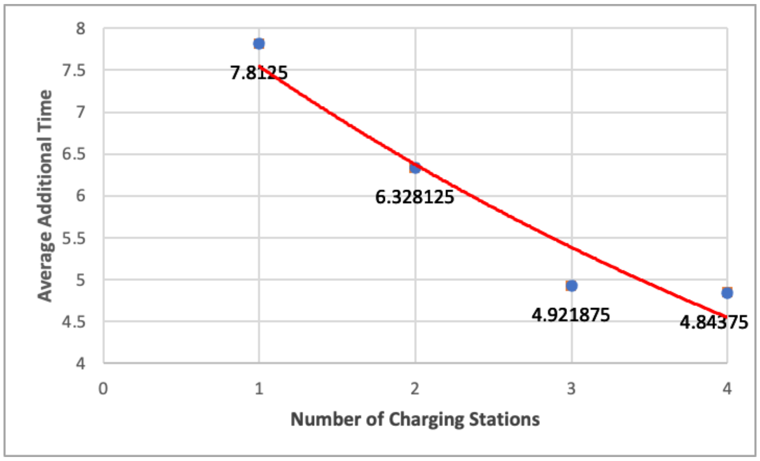

Figure 5: Average additional time of the different number of charging stations

Average Additional Time, *t*

As seen in Figure 5, the average additional time, *t,* taken by the customer to their destination decreases with an increase in the number of charging stations. By comparing the optimal profits for the different number of charging stations, BlueSG has no incentive to build 4 charging stations. However, using 2 charging stations (optimal) would not maximise customer's satisfaction as the added travel time is not kept to a minimum. If BlueSG considered the minimum additional travel time and built 4 charging stations, the mean demand per box would increase beyond 8 over time. This will allow BlueSG to attract more customers over time which will allow them to earn higher profits in the long run at the expense of their short run profits.

3.0 Conclusion and Evaluation

After simulating different numbers of charging stations as well as their different locations, we have come to the conclusion that the most optimal number of charging stations is 2 with the additional charging station being placed at C5. This is showcased at Scenario 3 of the tab "2 Charging Stations" in the Excel sheet.

We made certain assumptions in our model which are unrealistic.

We assumed that charging stations and customer destinations are in the middle of each box, however customers' destinations could be located at the corner of a box. This model could be improved by reducing the individual grid size as this would allow for a smaller margin of error with the actual customer destination being closer to the middle of a box.

Furthermore, in our model, there is also no cross-zoning of customers. In reality most customers would prefer to use the charging station that is the nearest to their destinations in order to save time, hence no cross-zoning may not be an ideal assumption.

It is also assumed that there is a fixed number of cars in the CBD which may not be the case as it could differ with the number of customers driving in and out of the CBD be it after or before work, or during their lunch hour.