PROFIT MAXIMIZATION FOR AN Airbnb HOST

Ankit Pushpam

David Liu

Pavrithra Anbalagan

Sayali Peshwe

Summary

In this Project, we present an optimization model aimed at maximizing profit for an Airbnb host who is an independent property owner in Manhattan. Our model aids the host in deciding whether to make a listing or not for a particular property every month. The model estimates an optimal maximized profit for an entire year, which is the best possible earning achieved through a particular combination of property listings for every month of the year.

In accordance with our project objectives, we rummaged through the public data available on the internet, which had information about Airbnb property listings, the price per night for each property, number of bedrooms, property types, neighborhood etc. We have incorporated multiple expenses a host might bear while listing the property on Airbnb domain. We have also incorporated the legal challenges a host might face by carefully understanding the specific city laws. Based on all our collected data, we have proposed a profit maximizing model which can aid a host in deciding whether or not to list the property on Airbnb during particular months.

Our optimization model utilizes Microsoft Excel coupled with the GRG Nonlinear Solver and Solver Table add-ins to determine an optimal solution. We used the sensitivity analysis to investigate the model's constraints and their relationships, such as investigating the effects of a varying yearly Airbnb hosting budget on the optimal profit, as well as observing the changes in expenses and earnings corresponding to the size of a booking party. We then conclude by sharing our recommendations with the host regarding what we discovered through our optimization model and sensitivity analyses to be the best practices for maximizing profit. Due to the lack of reliable data on the internet, we experienced some difficulties throughout the process of building our model; hence, creating a universal

optimization model for Airbnb hosts in New York is far beyond our reach. However, with proper insider data and time, it is certainly possible.

The Company

In the current project, we have considered Airbnb as our choice of enterprise. Airbnb is a shorthand for Air Beds & Breakfast. It is an online marketplace that connects the property owners with prospective travelers/visitors in search of affordable short-term accommodation with a home-like experience. This exciting business idea was conceived when its founders put up an air mattress in their living room and turned it into a bed and breakfast space to cope with the expensive housing rents in San Francisco.

Airbnb, the company, does not own the properties that are listed out on their domains published on website or the mobile app. It acts as mediator between the host (typically the owner of the property) and the guest (a person in search for short-term accommodation). The company earnings are in the form of commission for each successful booking by a guest. It attracts a wide range of crowd from active travelers, businessmen to families. It not only assists guests but also provide a source of income for the host.

The Problem

Even though Airbnb provides an exciting opportunity for a host to earn income, it does not always make hosting travelers a profitable affair. There are multiple factors that control the amount of income a particular host can earn from his respective properties listed on Airbnb. Each time a host plans to list his property on the Airbnb domain, he is charged non-refundable commission charges. Additionally, if the property listed on the Airbnb domain is booked within 14 days of the posting date, the host would not be charged any taxes on the amount earned from the bookings.

However, if the listing is booked beyond the 14 days window, any income earned by the host shall be deemed taxable and host would have to pay appropriate taxes accordingly. All the above are can be considered as fixed expenses that a host has to bear when he decides to list his property on the Airbnb domain. Apart from these fixed expenses, there can be multiple incidental expenses related to maintenance, utilities, internet, cleaning services and other facilities the host decides to provide to the guests. These factors influence the decision making of the host on whether to proceed with a property listing or not.

With this motivation, in the current project, we plan to explore an option of utilizing Airbnb as a potential source of income for the specific property owner with a host ID of 33906660 who owns 4 private rooms in an apartment home in Manhattan, namely: A Slice of Harlem, Harlem Living, Harlem Oasis, and Harlem Vacation. We would like to maximize the annual profits for the above host while factoring in the fixed and incidental expenses. Using our Optimization Model, we help the host with deciding whether a property must be listed in a particular month or not. Furthermore, we will also conduct a sensitivity analysis on the host's budget for handling Airbnb expenses and see whether he can achieve a higher return with the budget he has on hand. Lastly, we will investigate the money saved or money lost from booked, under-capacity Airbnb properties.

Data Collection

The data of the property owner for this project was gathered from a sample excel dataset available in Tableau Public website as *Airbnb Listings in New York City* under Public Data. The scope of this project only focuses on the Airbnb host with ID 33906660 from the sample data who has been the property owner since May 21, 2015. The price that gets charged for a listing depends on the property owner and this was decided based on the average market prices of the area. The estimated number of days that each of the listings would be occupied per month was approximated

from the website *AllTheRooms.Analytics* for *Average Airbnb Occupancy Rates by cities*. Occupancy rates are the proportion of days in a month for which a property has bookings, and it's one of the most important key performance indicators for any vacation rental owner or property manager. As shown in below figure, we see the average occupancy rates throughout the year for New York.

Figure 1

According to Airbnb policies, in order to partner as a host, there is a mandatory commission fee that the host must pay to Airbnb which comprises of 3% of each booking price of each property that covers costs of processing payments. The *properties information* table below shows the price per night stay which was available from the excel dataset. The number of guests for each property is approximated based on the given data on available beds for each private room.

Table 1

Properties Information		
Property Name	Price (Per Night)	# of Guests
A Slice of Harlem	80	2
Harlem living	69	1
Harlem Oasis	74	2
Harlem Vacation	74	2

The budget of $5,000 was roughly determined as a believable amount that an Airbnb host might set aside for necessary and unexpected expenses. The *Expenses table* below shows the type of expenses the host may encounter per month or throughout the year while listing his properties. In this host's case, these include cleaning costs by a third-party cleaning service called *'TaskRabbit'* which, on average, charges $45 /hour of cleaning according to their website. The property also includes high-speed internet service from the internet provider '*Spectrum'* which is a 12 month contract for $49 a month as found on their respective website. The other utilities per month such as Electricity, Heating, Cooling, Water and Garbage are an average expense estimate from *numbeo.com*'s cost of living in Now York for each month.

Table 2

Expenses	
Type	Cost
Cleaning Cost (TaskRabbit) per hour *	45
Internet (Spectrum) per Month	49
Utilities (Electricity, Heating, Cooling, Water, Garbage) Per Month	40

All the monthly tables (for instance, for January as below) shows whether each of the properties should be listed, their expenses and revenues. The 'List (Yes/No)' column values are decision variables.

Table 3

JANUARY				
Properties	**List (Yes/No) Decision Var.**	**Total Days Rented**	**Monthly Booking Earnings**	**Monthly Utility Expenses**
A Slice of Harlem	0	0	0	0
Harlem living	1	9	621	12
Harlem Oasis	0	0	0	0
Harlem Vacation	0	0	0	0
Internet Expense	**Cleaning Expense (4x a Month)**	**Total Commission Fee**	**Total Expenses**	**Total Earnings - Expenses & Comm. Fee**
49	**90**	18.63	151	451.37

The *constraints table* below shows the constraints that were considered for model optimization. The Maximum expense of $5000 is, again, roughly determined as a believable amount that an Airbnb host might set aside for necessary and unexpected expenses. According to the New York State Multiple Dwelling Law, it is illegal to rent out a property that is listed under Airbnb for less than 30 days unless the host is residing in the apartment at the same time. Based on this law, the second constraint for our model was formulated as to rent out each property of the host for 31 days or more.

Table 4

Constraints			
Maximum Expense	5056.8	<=	5000
Minimum Rent Days (At least one property in Apartment)	162	>=	31

The taxes for the host under Airbnb was calculated as per the IRS rules. According to IRS rules, anyone who earns more than $400 on any home-sharing platform needs to report that income for taxes. Federal, state, and self-employment taxes might have to be paid. Net income determines the taxes, and net income equals earnings after deductions. Assuming only the tax brackets of Married Filing Jointly -Taxable income, we see the taxes for the host in NY would fall in any of the below tax bracket.

Table 5

Taxes for Host (2019)		
Taxable Income	**Rate**	**Estimated Taxed Amount**
0 to $19400	10	1940
$19401 to $78950	12	1832.3424
$78951 to $168400	22	0
$168401 to $321450	24	0
$321451 to $408200	32	0
$408201 to $612350	35	0
$612351 and up	37	0
	Total Tax	3772.3424

Data Analysis

The Predicted Monthly Occupation Rate table shows the approximate occupied days for each month which was calculated by the product of *Occupancy Rate for 2018-2019* and *Number of Days in each month.* The commission fee is calculated as the 3% of the each booking price for each property. Regarding expenses, the cleaning cost per hour is $45. Each room is estimated to have 30 mins of cleaning service. Hence, each room has a cleaning cost of $45/2 which amounts to $22.5. The high-speed internet charge per month is the monthly subscription of $49 that is a part of a 12 month contract. The other utilities per month such as Electricity, Heating, Cooling, Water and Garbage are an average expense estimate from *numbeo.com*'s cost of living in Now York for each month. The total expenses for a year in the below table are calculated by the sum of total expenses per month throughout the year. The total days each property was rented throughout the year was calculated as the sum of the total days rented out each month throughout the year for each property.

Table 6

Total Figures	
Total Expenses	5056.8
Total Days Rented - A Slice of Harlem	153
Total Days Rented - Harlem Living	162
Total Days Rented - Harlem Oasis	111
Total Days Rented - Harlem Vacation	126

For a specific month of various monthly expenses, the List (Yes/No) variable is the decision variable which is a binary value to say if the property is rented out or not for that month, based on which total days rented out for the specific month was calculated as the product of *List (Yes/No)* decision variable for that month and the *approx. occupied days* for that specific month from the *Predicted Monthly Occupation Rate* Table. The *Monthly Booking Earnings* was calculated as the product of the total days rented out for that specific month and the price per night stay for that specific property. The monthly utilities expenses are calculated as the product of the number of guests and estimated utilities cost per month. The cleaning cost (table 7) is calculated by first determining how many rooms will be rented out each month. For each property room rented out, we assume that it will take 30 minutes to clean which we estimate to cost approximately $45/2 for each room. However many rooms are rented out, the host will order cleaning services for each of those rooms for the remainder of the month, which would equate to the total cost of cleaning service for each of the rooms multiplied by 4. This is done purely to remain conservative about the cleaning cost because our data lack the details that would tell us exactly which date a guest will arrive, when they will leave, or when the next booking party will arrive. Hence, it is appropriate to simply assume that the rooms will be cleaned at least once a week for a month, assuming there are rooms booked for the month. The total commission fee is calculated as the product of 3% of the sum of total monthly booking earnings. The total monthly expenses are calculated as the sum of total expenses incurred for each property for that specific month, internet expense and cleaning

expense. The total earnings per month is calculated as the difference of sum of the total monthly booking earnings for each property, total expense and total commission fees for that specific month. The Net Profit without tax is calculated as the sum of all the total earnings per month throughout the year.

Table 7

Cleaning Expense (4x a Month)
90

Lastly, to calculate the optimal profit, the tax rates and margins in table 8 are used to calculate exactly how much tax needs to be paid, given that we know the profit before tax. This calculated amount is then subtracted from the objective function, which will yield us the optimal solution.

Table 8

Taxes for Host (2019)		
Taxable Income	**Rate**	**Estimated Taxed Amount**
0 to $19400	10	1940
$19401 to $78950	12	1832.3424
$78951 to $168400	22	0
$168401 to $321450	24	0
$321451 to $408200	32	0
$408201 to $612350	35	0
$612351 and up	37	0
	Total Tax	3772.3424

Table 9

Net Profit without Tax	34670.52	
Objective Function	30898.1776	<-------- Optimal Profit
Objective Function for Calculating Over-Budgeting	30898.1776	

Constraints			
Maximum Expense	5056.8	<=	5000
Minimum Rent Days (At least one property in Apartr	162	>=	31

Optimization Modeling

After completing the data collection, we are ready to build our model. Below you will see our model's decision variables, inputs, objective function, and constraints.

To complete this model, we have the following decision variables:

<table>
<tr><th>Decision Variables
(Variable is binary = 0 or 1)</th><th colspan="2">Definition</th></tr>
<tr><td rowspan="5">B_{pm}</td><td rowspan="4">Properties
p = (1,2,3,4)</td><td>1 = A Slice of Harlem</td></tr>
<tr><td>2 = Harlem Living</td></tr>
<tr><td>3 = Harlem Oasis</td></tr>
<tr><td>4 = Harlem Vacation</td></tr>
<tr><td>Months
m = (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12)</td><td>1 = Jan
2 = Feb
3 = Mar
4 = Apr
5 = May
6 = Jun
7 = Jul
8 = Aug
9 = Sep
10 = Oct
11 = Nov
12 = Dec</td></tr>
</table>

Following are the inputs for the model:

1. Appr. Occupied Days is one of the inputs which is calculated based on the Occupancy Rate 2018-2019 multiplied by Number of Days for each month

Month	**Occupancy Rate** R_m Months m = (1, 2, 3, 4, 5, 6, 7, 8, 9, 10 , 11, 12)	**Appr. Occupied Days (Rounded)** D_m Months m = (1, 2, 3, 4, 5, 6, 7, 8, 9, 10 , 11, 12)
January	0.3	9
February	0.36	10
March	0.43	13
April	0.5	15
May	0.54	17
June	0.54	16
July	0.48	15
August	0.49	15
September	0.56	17
October	0.55	17
November	0.47	14
December	0.44	14

2. Expenses

Type	Variable	Cost
Cleaning Cost (TaskRabbit) per Hour	C	45
Internet (Spectrum) per Month	I	49
Utilities (Electricity, Heating, Cooling, Water, Garbage) Per Month Per Guest	U	40

3. Property Price (Per Night)

Property Name	Price Per Night Variables P_p $p = (1,2,3,4)$	Price (Per Night)
A Slice of Harlem	P_1	80
Harlem living	P_2	69
Harlem Oasis	P_3	74
Harlem Vacation	P_4	74

4. Number of Guest

Property Name	Variable G_p $p = (1,2,3,4)$	Number of Guests
A Slice of Harlem	G_1	2
Harlem living	G_2	1
Harlem Oasis	G_3	2
Harlem Vacation	G_4	2

5. Commission Fee (total booking price)

Fee Type	Variable	
Commission Fee (total booking price)	F	0.03

6. **Applicable for host (2019)**

Taxes for Host (2019)		
Taxable Income	**Rate**	**Estimated Taxed Amount**
0 to $19400	10	1940
$19401 to $78950	12	1599.0072
$78951 to $168400	22	0
$168401 to $321450	24	0
$321451 to $408200	32	0
$408201 to $612350	35	0
$612351 and up	37	0
	Total Tax	-3539.0072

Our objective in this study, as stated earlier, is to maximize the profit. Here is the

Objective function:

Objective Function	Definition
$\sum_{m=1}^{12}(\sum_{p=1}^{4} B_{pm}D_mP_p - F(\sum_{p=1}^{4} B_{pm}D_mP_p) - (\sum_{p=1}^{4} B_{pm}G_pR_mU + I + C((\sum_{p=1}^{4} B_{pm})/2))) -3539.0072$	Maximize his total year's profit with his Airbnb properties

For this model, we will have the following constraints:

Constraint	Equation	Explanation
Total Expense	X1 <= 5000	Maximum total expense
Rent Days	X2 <= 172	Minimum Rent Days (Any properties in Apartment)
Binary	B_{pm}	Either the listed property can be occupied or not.
Non-negativity	$B_{pm > 0}$	The binary variable cannot be less than 0.

With our model constructed, we set out to solve the model with Excel's Solver. We used the GRG Nonlinear function to get our optimized solution.

Results and Analysis

To reiterate, the purpose of this model is to help the host decide during which months he should make listings on Airbnb for his 4 private room properties in order to maximize profit. Furthermore, the model must consider a couple constraints in order to arrive at a proper optimal profit solution: 1) the host has a budget of $5,000.00 for the entire year's monthly expenses, and 2) New York law requires that the host rent out his property, or any one of his private room listings, for more than 30 days combined in a year. In addition to finding the optimal solution, performing sensitivity analysis on the model may yield useful information regarding ways to further increase the host's profit earning potential.

Optimal Solution for Airbnb Property Listings

Shown in the figure below (figure 2), the model has arrived at an estimated optimal profit of $30,457.85 using the GRG nonlinear solver, and given the constraints shown below along with a taxable amount of approximately $3,712.30 (figure 3). The total expense for this optimal solution is $4,954.80, and the longest combined number of days that any one of his private room properties will be rented out is 153 days long. Hence, as shown below, all constraints are satisfied.

Net Profit without Tax	34170.15		
Objective Function	30457.852	<-------- Optimal Profit	
Objective Function for Calculating Over-Budgeting	30457.852		
	Constraints		
Maximum Expense	4954.8	<=	5000
Minimum Rent Days (At least one property in Apartme	153	>=	31

Figure 2

Taxes for Host (2019)		
Taxable Income	Rate	Estimated Taxed Amount
0 to $19400	10	1940
$19401 to $78950	12	1772.298
$78951 to $168400	22	0
$168401 to $321450	24	0
$321451 to $408200	32	0
$408201 to $612350	35	0
$612351 and up	37	0
	Total Tax	3712.298

Figure 3

The binary decision variables indicating whether a property should be listed during a certain month are listed in the tables below (Table 10 – 21).

1) Table 10 indicates that the model has decided that no properties should be listed during the month of January, which will accrue a total expense of $49.00 from internet cost.

Table 10

JANUARY				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	0	0	0	0
Harlem living	0	0	0	0
Harlem Oasis	0	0	0	0
Harlem Vacation	0	0	0	0
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	0	0	49	-49

2) Table 11 indicates that the model has decided that no properties should be listed during the month of February, which will accrue a total expense of $49.00 from internet cost.

Table 11

FEBRUARY				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	0	0	0	0
Harlem living	0	0	0	0
Harlem Oasis	0	0	0	0
Harlem Vacation	0	0	0	0
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	0	0	49	-49

3) Table 12 indicates that Slice of Harlem and Harlem Living should be posted during March, which will have an estimated gain of $1598.29 with all earnings and expenses considered.

Table 12

MARCH				
Properties	**List (Yes/No) Decision Var.**	**Total Days Rented**	**Monthly Booking Earnings**	**Monthly Utility Expenses**
A Slice of Harlem	1	13	1040	34.4
Harlem living	1	13	897	17.2
Harlem Oasis	0	0	0	0
Harlem Vacation	0	0	0	0
Internet Expense	**Cleaning Expense (4x a Month)**	**Total Commission Fee**	**Total Expenses**	**Total Earnings - Expenses & Comm. Fee**
49	**180**	58.11	280.6	1598.29

4) Table 13 indicates that all four properties should be listed during the month of April. With all earnings and expenses considered, the total estimated profit is $3,772.35 for April.

Table 13

APRIL				
Properties	**List (Yes/No) Decision Var.**	**Total Days Rented**	**Monthly Booking Earnings**	**Monthly Utility Expenses**
A Slice of Harlem	1	15	1200	40
Harlem living	1	15	1035	20
Harlem Oasis	1	15	1110	40
Harlem Vacation	1	15	1110	40
Internet Expense	**Cleaning Expense (4x a Month)**	**Total Commission Fee**	**Total Expenses**	**Total Earnings - Expenses & Comm. Fee**
49	**360**	133.65	549	3772.35

5) Table 14 indicates that all four properties should be listed during the month of May. With all earnings and expenses considered, the total estimated profit is $4,337.33 for May.

Table 14

MAY				
Properties	**List (Yes/No) Decision Var.**	**Total Days Rented**	**Monthly Booking Earnings**	**Monthly Utility Expenses**
A Slice of Harlem	1	17	1360	43.2
Harlem living	1	17	1173	21.6
Harlem Oasis	1	17	1258	43.2
Harlem Vacation	1	17	1258	43.2
Internet Expense	**Cleaning Expense (4x a Month)**	**Total Commission Fee**	**Total Expenses**	**Total Earnings - Expenses & Comm. Fee**
49	**360**	151.47	560.2	4337.33

6) Table 15 indicates that all four properties should be listed for June. With all earnings and expenses considered, the total estimated profit is $4049.24.

Table 15

JUNE				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	16	1280	43.2
Harlem living	1	16	1104	21.6
Harlem Oasis	1	16	1184	43.2
Harlem Vacation	1	16	1184	43.2
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	360	142.56	560.2	4049.24

7) Table 16 indicates that all four properties should be listed for July. The total estimated profit for July is $3,777.95.

Table 16

JULY				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	15	1200	38.4
Harlem living	1	15	1035	19.2
Harlem Oasis	1	15	1110	38.4
Harlem Vacation	1	15	1110	38.4
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	360	133.65	543.4	3777.95

8) Table 17 indicates that A Slice of Harlem, Harlem Living, and Harlem Vacation should be listed for August with an estimated profit of $2,827.65.

Table 17

AUGUST				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	15	1200	39.2
Harlem living	1	15	1035	19.6
Harlem Oasis	0	0	0	0
Harlem Vacation	1	15	1110	39.2
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	270	100.35	417	2827.65

9) Table 18 indicates that all four properties should be listed during September. The total estimated profit would be $4,331.73.

Table 18

SEPTEMBER				
Properties	List (Yes/No)	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	17	1360	44.8
Harlem living	1	17	1173	22.4
Harlem Oasis	1	17	1258	44.8
Harlem Vacation	1	17	1258	44.8
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	360	151.47	565.8	4331.73

10) Table 19 indicates that all four properties should be listed during October, which would have a total estimated profit of $4,334.53.

Table 19

OCTOBER				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	17	1360	44
Harlem living	1	17	1173	22
Harlem Oasis	1	17	1258	44
Harlem Vacation	1	17	1258	44
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	360	151.47	563	4334.53

11) Table 20 indicates that only A Slice of Harlem and Harlem living should be posted during November, which will have a total estimated profit of $1738.02.

Table 20

NOVEMBER				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	14	1120	37.6
Harlem living	1	14	966	18.8
Harlem Oasis	0	0	0	0
Harlem Vacation	0	0	0	0
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	180	62.58	285.4	1738.02

12) Table 21 indicates that all properties should be posted during December, which will have an estimated profit of $3501.06.

Table 21

DECEMBER				
Properties	List (Yes/No) Decision Var.	Total Days Rented	Monthly Booking Earnings	Monthly Utility Expenses
A Slice of Harlem	1	14	1120	35.2
Harlem living	1	14	966	17.6
Harlem Oasis	1	14	1036	35.2
Harlem Vacation	1	14	1036	35.2
Internet Expense	Cleaning Expense (4x a Month)	Total Commission Fee	Total Expenses	Total Earnings - Expenses & Comm. Fee
49	360	124.74	532.2	3501.06

Predicted Monthly Occupation Rate			
Month	Occupancy Rate 2018-2019	Number of Days	Appr. Occupied Days (Rounded)
January	0.3	31	9
February	0.36	28	10
March	0.43	31	13
April	0.5	30	15
May	0.54	31	17
June	0.54	30	16
July	0.48	31	15
August	0.49	31	15
September	0.56	30	17
October	0.55	31	17
November	0.47	30	14
December	0.44	31	14

Figure 4

Notably, January and February are the only two months that were not assigned any property listings. Looking at figure 4, January and February are clearly the months with the two lowest rate of occupancy. Since occupancy rate affects how much gross earnings can be earned in a given month, it would be logical to assume that months with low occupancy rates would be less desirable for the optimal solution. Hence, having low occupancy rates were likely the reasons for the exclusion of January and February from the optimization model. Regardless, this optimization solution shows that it can still be economically viable to accept losses in profit during certain months with low occupancy rates, as long as the money is spent mostly on months with large returns (i.e. months with high occupancy rates).

One-Way Sensitivity Analysis of Budget Size

Even though the host's yearly budget for Airbnb expenses is $5,000, the money earned from guest bookings can plausibly be used to pay off expenses of the same year. Obviously, the money used to pay off expenses will be subtracted from the overall year's profit, but there is a chance for money to be gained, which may offset the amount spent on expenses. A one-way analysis table, shown below (figure 5), is used to investigate the gain/loss in profit from going over-budget.

Oneway analysis for Solver model in Airbnb Maxed Profit (Max Guest) worksheet

Budget Constraint (cell G39) values along side, output cell(s) along top

	Optimal Profit	Total Expense	Slice of Harlem	Harlem Living	Harlem Oasis	Harlem Vacation	Data for chart
	B100	K36	K37	K38	K39	K40	B100
4000	24898.1792	4082	140	140	67	96	24898.18
4500	27459.9296	4472.8	140	140	97	112	27459.93
5000	30457.852	4954.8	153	153	111	126	30457.85
5500	33083.8264	5463.6	153	153	140	153	33083.83
6000	34923.6376	5925.200002	172	163	153	153	34923.64
6500	36786.95839	6492.800004	172	172	172	172	36786.96
7000	36786.95839	6492.800004	172	172	172	172	36786.96
7500	36786.95839	6492.800004	172	172	172	172	36786.96
8000	36786.95839	6492.800004	172	172	172	172	36786.96
8500	36786.95839	6492.800004	172	172	172	172	36786.96
9000	36786.95839	6492.800004	172	172	172	172	36786.96
9500	36786.95839	6492.800004	172	172	172	172	36786.96
10000	36786.95839	6492.800004	172	172	172	172	36786.96

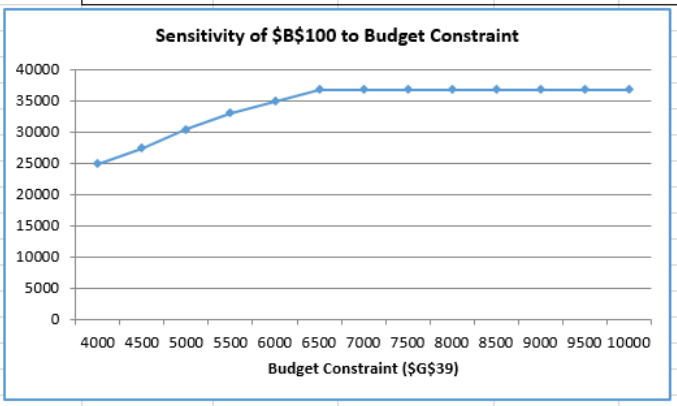


Figure 5

This one-way analysis sets the budget constraint, or the maximum total expense, from $4,000 to $10,000 in increments of $500, and the optimal profit would be calculated as the budget continues

to increase incrementally. For any amount of total expense calculated above $5000, the amount would be subtracted from the optimal profit, indicating that some of the profit made during the year was spent on Airbnb expenses. Optimal profit calculated from a budget constraint set below $5,000 would not be affected because any expense below $5,000 is not cutting into the year's profit. Shown above in figure 5, the optimal profit increases from a net profit of approximately $24,898 to $36,787 before the profit becomes insensitive to any further increases in the budget.

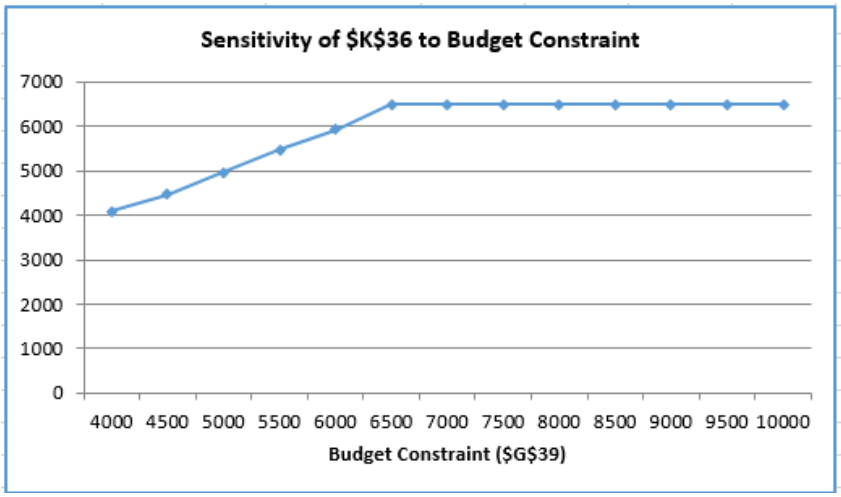


Figure 6

In figure 6, it is shown that the total expense also plateaus and becomes insensitive to the increasing budget at around the same maximum budget step as the optimal profit. This can be explained in figure 5, shown in the last four columns, as the total number of days rented for each of the four properties have reached their estimated maximum for the year, which is 172 days according to the occupancy rates for each month (see figure 4 in the "**Appr. Occupied Days (Rounded)**" column. Add up all days in the column). This means that adding any more money to the year's maximum budget above $6,492.80 will not yield any further benefits, because $6,492.80 is enough to cover all predicted expenses for all 4 properties in each month for the entire year. $6,492.80 is a

$1,492.80 increase from the original budget of $5,000. In addition, the optimal profit increases from $30,457.85 to $36,787, which is a $6,329.11 increase in profit.

Two-Way Sensitivity Analysis of Varying Guest Room Capacity

The host owns four private room properties, 3 of which – A slice of Harlem, Harlem Oasis, and Harlem Vacation – can accommodate 2 guests. However, it may not always be the case that these rooms are fully occupied, or booked by a party of two. A two-way analysis is performed to investigate the effect of under-capacity rooms on profit and expenses. This is done by manipulating the number of guests for each 2 guest rooms to be accommodated by either only 1 or 2 guests, and then calculating the optimal profits and expenses for each combination.

A Slice of Harlem = 2

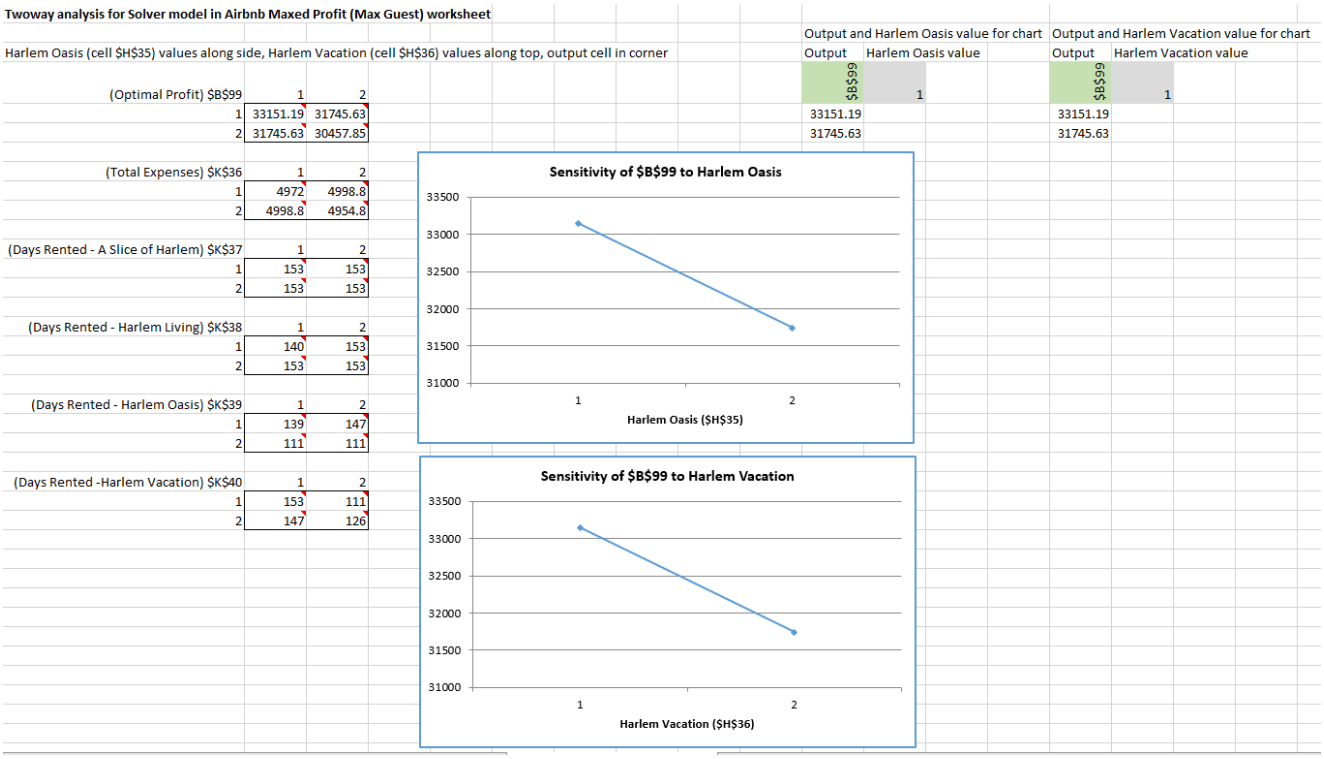


Figure 7

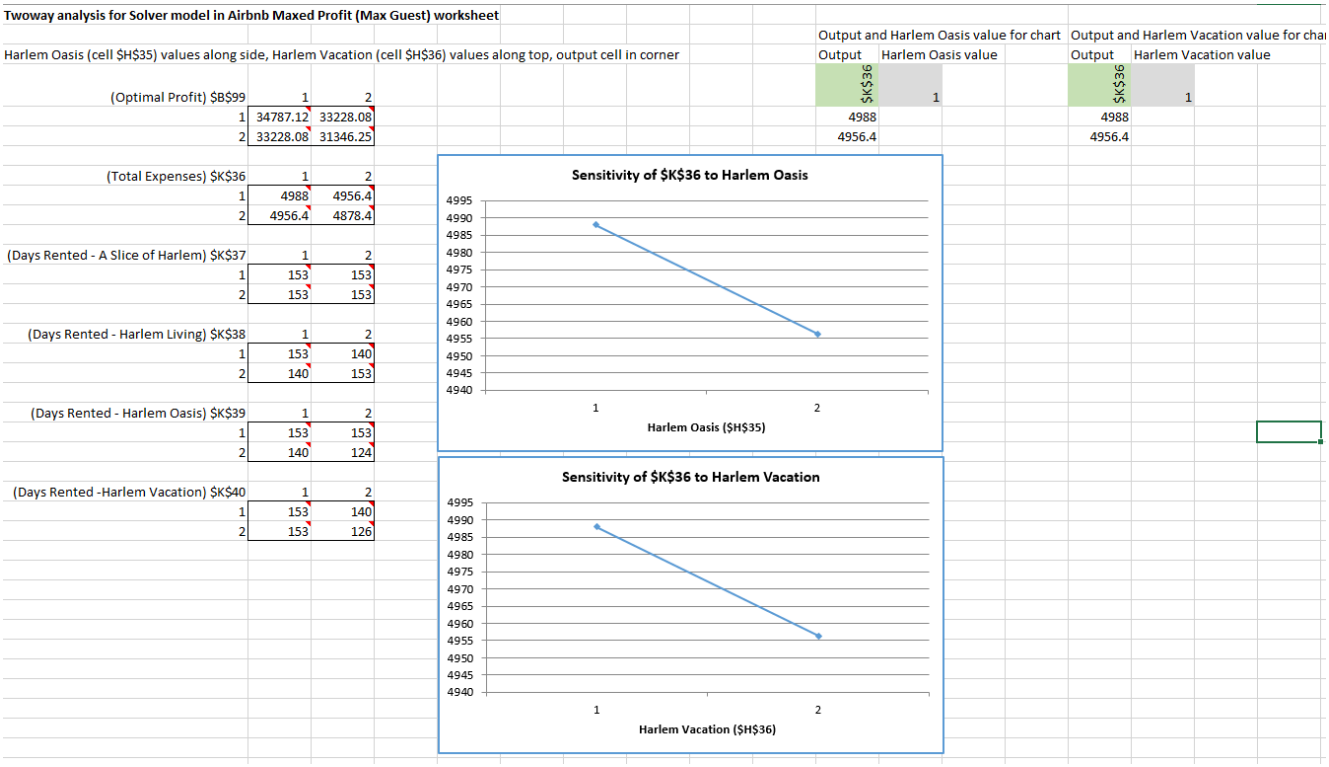
Properties Information		
Property Name	Price (Per Night)	# of Guests
A Slice of Harlem	80	2
Harlem living	69	1
Harlem Oasis	74	2
Harlem Vacation	74	2

Figure 8

Figure 7 shows the expense and optimal profit assuming that the **# of Guests** values for "A Slice of Harlem" and "Harlem Living" in figure 8 are 2 and 1, respectively. "Harlem Oasis" and "Harlem Vacation" are input variables in a two-way analysis where their ranges are from 1 to 2, with increments of 1. When both "Harlem Oasis" and "Harlem Vacation" are 1 and 1, the optimal profit is at its highest at $33,151.19, whereas the expense is at its highest as well at $4,972. When both input variables are either 1 and 2 or 2 and 1, the profit and expense are at their second highest at

$31,745.63 and $4998.80, respectively. Lastly, when both input variables are 2 and 2, the profit and expense are at their lowest at $30,457.85 and $4954.80, respectively.

A Slice of Harlem = 1



Twoway analysis for Solver model in Airbnb Maxed Profit (Max Guest) worksheet

Harlem Oasis (cell H35) values along side, Harlem Vacation (cell H36) values along top, output cell in corner

(Optimal Profit) B99	1	2
1	34787.12	33228.08
2	33228.08	31346.25

(Total Expenses) K36	1	2
1	4988	4956.4
2	4956.4	4878.4

(Days Rented - A Slice of Harlem) K37	1	2
1	153	153
2	153	153

(Days Rented - Harlem Living) K38	1	2
1	153	140
2	140	153

(Days Rented - Harlem Oasis) K39	1	2
1	153	153
2	140	124

(Days Rented -Harlem Vacation) K40	1	2
1	153	140
2	153	126

Output and Harlem Oasis value for chart

Output	Harlem Oasis value
K36	1
4988	
4956.4	

Output and Harlem Vacation value for cha

Output	Harlem Vacation value
K36	1
4988	
4956.4	

Figure 9

Figure 9 shows the expense and optimal profit assuming that the **# of Guests** values for "A Slice of Harlem" and "Harlem Living" in figure 8 are 1 and 1, respectively. Once again, "Harlem Oasis" and "Harlem Vacation" are input variables in a two-way analysis where their ranges are from 1 to 2, with increments of 1. When both "Harlem Oasis" and "Harlem Vacation" are 1 and 1, the optimal profit and expense are at their highest at $34,787.12 and $4,988. When both input variables are either 1 and 2 or 2 and 1, the profit and expense are at their second highest at $33,228.08 and $4,956.40, respectively. Lastly, when both input variables are 2 and 2, the profit and expense are at their lowest at $31,346.25 and $4878.40, respectively.

The above two-way analyses shows that there is a trend in which higher optimal profits and expenses correlate with less guests occupying each private room properties. A reasonable explanation for this trend would be that having less guests reduces the utility bills.

Conclusion

Through this project, we have succeeded in creating an optimization model that provides the basic ground works for making rough estimations in regards to identifying the optimal steps in order to get started with hosting Airbnb properties, as well as knowing when to post listings on the Airbnb site to maximize potential profits and minimize expenses.

Using a GRG Nonlinear solver, a one-way solver table, and a two-way solver table, we as a team were able to identify plausible solutions for maximizing the host's potential profits using his four available properties. Using our GRG Nonlinear solver solution, which identified the optimal property listing combinations for each month of the year in order to obtain the maximum profit, we recommend that the host start by ranking the months with the highest occupancy rates in New York and prioritize the listing of properties for those months. Recall that our optimal solution registered property listings for each month of the year except for January and February, which had the lowest occupancy rates of all the months.

Assuming that the host is not strictly holding on to a budget of $5,000, we would recommend that he go over his allotted budget by at least $1,492.80, as our one-way sensitivity analysis had discovered that $6,492.80 is the exact amount needed to fully fund all expenses for the entire year; doing so would increase profit by $6,329.11.

Lastly, we would recommend that the host should try to decrease full occupancy of his private rooms. It is shown in our two-way sensitivity tables that basically any decrease in the

occupancy of any of the 2-guest private rooms has resulted in a decrease in expenditures. Another suggestion would simply be to change the maximum occupancy for each of the rooms to 1 guest instead of 2 guests, but we are not yet sure whether that would lead to other unwanted negative feedbacks, such as having a lowered occupancy rate per month.

Although we were able to accomplish our goal of creating an optimization model, our model is still somewhat limited. This can definitely be attributed to the lack of solid and reliable data that are available on the internet (i.e. inconsistent data between different websites, unreliable sources, etc.), and an overall difficulty in finding any source of substantial database data to mine and analyze. The model itself could have definitely been improved if there were more direct and less ambiguous data. For instance, the purpose of our model was to estimate the occupancy rate of Airbnb properties, but our available data only allowed an ambiguous estimation of Airbnb property occupancy rate with a flat percentage value for each month. Possible future improvements for our model would be to gather first hand data, which would allow a more accurate grasp of the day to day occupancy rate, as well as the range of occupancy between the more and the less popular property owners.

Bibliography

1. "Average Airbnb Occupancy Rates By City | AllTheRooms." *AllTheRooms Analytics*, www.alltherooms.com/analytics/average-airbnb-occupancy-rates-by-city/. Accessed 10 May 2020.
2. Charter Communications. "Internet Services - High Speed Internet Service Provider | Spectrum." *Spectrum.Com*, 2017, www.spectrum.com/internet. Accessed 10 May 2020.
3. Inc, TaskRabbit. "TaskRabbit Connects You to Safe and Reliable Help in Your Neighborhood." *TaskRabbit*, www.taskrabbit.com/tasks/r/recommendations?job_draft_guid=6505a1ec-2e62-4a97-b74c-6b7a46833d68&uuid=5b33c10d-5170-48d9-a7b3-98b28d7ca2c9. Accessed 10 May 2020.
4. "Inside Airbnb: New York City. Adding Data to the Debate." *Inside Airbnb*, insideairbnb.com/new-york-city/. Accessed 10 May 2020.