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Optimization of A Car Rental Fleet To Fulfill The Demand

[1]Dhruval Patel, [2]Ankit Patel, [3]Dhruv Patel
[1]Operation Manager (Master of Engineering Management Master of Manufacturing Management),
[2,3]MEMEM Student
[1]Birring Holdings-Sydney, [2,3]University of Technology Sydney, Ultimo, Australia

Abstract- Inventory for the car rental business is the cars, that they have on the base. The availability of the cars for rent is essential to achieve desired profit. There are different factors, which affects the car rental operation. however, the most significant factor is the fleet design and the combination of the cars in the fleet. if the fleet is designed in the proper way than car rental business can mitigate the problem of shortage of booked cars and earn great profit. Therefore, the primary aim of this research work is to optimize the combination of the cars on the fleet and providing new constraints for the pool fleet system, which will improve the car rental operations.

In this research work, the most significant models of the cars have been identified with help of data analysis. Afterwards, the fleet has been optimized with the help of robust design methodology considering fleet as a product and cars as an affecting variable. L9 orthogonal array has been used to generate the data for some combinations in the fleet, and as per the objective of the study, to reduce the shortage of cars, “Smaller is better” signal to noise ratio has been used. The optimization process suggests, with the optimized combination the shortage of cars can be reduced from 55-60 cars per day to 7-8 cars per day. And the profit can be increased by $700000 per year.

Keywords: Car rental, Car rental supply chain, Fleet management, Optimization, Taguchi methodology, Design of experimental.

I. INTRODUCTION

The car rental industry is facing the evolution from past few years due to the evolving trends which directly or indirectly influence the car rental industry’s dynamics. Earlier car rental business was operated on-airport location only. However, from past few years car rental industry is having off-airport locations as well. This expansion in a short period of time desires in detailed research work, development and execution of advanced tactics. As per the new business models of huge car rent companies, they have a primary fleet (Pool Fleet) where they store the cars at the on-airport locations, from where off-airport locations can pull the cars to their off-airport locations. Nevertheless, due to pulling process there will be critical situation at the pool fleet as they will face the shortage of base cars to rent. This situation force administration to allocate a higher model of the car with the price of the base model.

This kind of problem is not a big issue for off-airport locations, as they have very few bookings compared to on-airport locations. At the on-airport location due to unorganized combination of the fleet, they allocate 100-150 higher model cars a day with price of base model. The cost of forced allocation may consequence losing of $2500-$3500 of potential profit[1]. Thus, this research work is focused on the optimizing the car rental fleet to reduce the shortage of cars by which, car rental industry does not have to comprise on their potential profit gain.

The solution to this problem is to provide optimized fleet to a car rental industry. The optimization of fleet is very crucial task. In this research work, fleet has been taken as a product and different class of the cars as a variable to modify the fleet with robust design. The process of optimization requires rigorous data analysis. There are quite a few models analytical and mathematical models which can be modified and used to optimize the fleet of car rental business. Development of such model needs historical data of demand (bookings) and the supply (allocation of cars) with details of shortage of cars are needed [2]. However, collecting the data at vast level and analyzing them is complex. But, while taking fleet as product design of experiments through Taguchi can save valuable time and can make the optimization process easier. To accomplish robust combination of the fleet using Taguchi, data for only few specific days with specific combination in the fleet is required.

The structure of this paper is having, in-depth state of the art literature review in the section 2. The following section is having the knowledge of car rental operations. The section 4, explains the research aim, objective and the research problem for this work. Section 5 and 6 are having Taguchi methodology for fleet as a product and experimental calculations respectively. Section 7 is discussion about the obtained results of the optimization process. The last section of this process is the conclusion.

II. LITERATURE REVIEW

As per the research done by Economics Intelligence Unit [3], there are major two business market for the car rental companies. First one is for the car rental companies with on-airport and off-airport locations aiming to serve corporate clients as well as leisure clients. The second market segment is country-side small car rental businesses aiming only leisure clients. However, the problem of fleet management and shortage of cars are associated with the major car rental companies having the pool fleet system. Thus, the focus of this research is on the car rental business operating with the interlinked pool fleet.

Major car rental companies like Hertz, Avis, Budget car rental and Europe car rental work nation-wide, and they have separated the market in metro region. This metro region for a car rental company has one or two on-airport locations where they have pool fleet. And other off-airport locations are linked with the pool fleet from where, they pull the cars for their rental business. As per the Pachon, Iakovou [4], in the integrated pool fleet, when off-airport business units pull the cars from the main fleet, there will be shortage of the cars at the pool fleet. His research suggests that, pulling those cars back encompasses significant capital and time which cannot be cover with the short-term rentals.

As per Geraghty and Johnson [5], the primary problem associated with the car rental operations is the pulling of the cars from main fleet to the other outlets, as this create the uneven combination in the fleet. And they suggested that, pulling those cars back to pool fleet after other locations are not in the need of those cars, is time consuming and will not work as per the supply and demand models. In contradiction, George and Xia [6] suggested, all the car rental outlets should have their own fleet to overcome the logistic of pulling cars. However, this requires a lot of investment of money to create separate fleet for each location. Xu and Lim [7]analyzed the car rental operations and the behavior of the pool fleet system and compared it with the behavior of the separate fleet system and concluded that, the pool fleet system is better. Xu & Lim (2007) added that, the pool fleet system will have problem of the shortage of cars for the pool fleet. To overcome the issue, they generated a unique neural computing based car sharing program to analyze the demand and supply. However, there are very few researchers who did research by focusing on the management hold cars and the cars with the service holds. Hertz, Schindl [8] studied the fleet with the service and management hold cars and they found out, around 16-18% of the cars in the fleet are having either service hold or management hold.

To reduce the cost of pulling the cars and optimizing the time of delivery, supply chain analysis of the fleet is the must (Carroll & Grimes 1995). As per their research, dynamic fleet can be analyzed by the dynamic programming algorithm. Their results with single time period were good compared to the multiple time period. Godfrey and Powell [9]used the neural computing algorithm to study the pool fleet and its logistics and concluded; each outlet should have minimum numbers of base cars in their fleet, as pulling of the cars is complex task. However, outlets can pull some unique cars as per the requirement and can sent them back after the rental.

The mathematical algorithms are complex and time consuming, instead of that grey relation analysis can be prove better. Grey relation analysis focus on the most significant variables and its consequence on the system, thus it can be more accurate and the time saving. Jaillet, Ahuja [10]tried to optimize the networking and the fleet of the car rental business with the help of the network flow analysis and soft computing techniques.

Coy, Golden [11]tried to optimize the fleet with the help of design of experiments. He stated that, the use of DOE is very helpful to reduce the shortage of the cars. He stated that, DOE is powerful method to reduce the shortage of the cars in the system and less time consuming. However, he took cars as a product. So, in his research work, he was dealing with number of products in the system. As per Johnson and Mena [12], to decrease the absence ofcars, fleet should have proper combination and numbers of cars which will reduce the negative influence of absence of basic models of the cars in the fleet.

Moreover, as per the national fleet auditor of a major car rental business suggest that, all the research work done by most of the researchers are on the pulling of the cars from the fleet and the logistics of the fleet. But, as per his review, if the fleet is having proper combination of the cars and if that limit can be fixed on the pulling, there will be drastic change in the shortage of the cars and car rental business can make higher profit. So, this research work will focus on the fleet optimization with proper combination of the base cars. This will become a robust design problem and design of experiments via Taguchi is the effective way to tackle the robust product design problem considering fleet as product and cars as its variables (Pardo et al. 2016).

III. CAR RENTAL OPERATIONS

For a car rental industry, cars are their inventory and they invest a lot of capital in their inventory. Most of the car rental business have centralized pool fleet from where other locations pull cars as per the requirement. And that's results into the shortage of cars at the pool fleet business center.

The car rental business is having very complex operations, if those operations are not integrated to each other than it may cause negative impact on the business. As shown in the figure, the pool fleet for this research work is having the constraint; system will not allow any other location to pull cars from the fleet if there are only 1000 cars. However, out of those 1000 cars, there are cars which needs service and cannot be rented. A car can be used 10000 kilometers after service and after that it requires service again. Data analysis indicated that, customers drive a car for 200 kilometers a day, which indicates a car requires service after 7th or 8th week. So, out of the 1000 available cars, 1/7th are not available due to the service hold, which indicates there are only 850 cars available on the fleet. to illustrate the problem in depth, if there are 500 booking on Monday and 350 cars are coming back on Monday, then at the end of business day fleet will have 600 cars to rent for the next business day. This designates the dynamic behavior of the fleet. Thus, a fleet with proper combination of the each models of the cars is very essential for car rental business [13].

IV. RESEARCH AIM & QUESTION

The primary research objective of this research study is "to achieve the optimized combination of the different class of the cars in the fleet to reduce the absence of the booked cars and increase the profit." To achieve the objective of this study, data analysis of the past bookings and applying DOE via Taguchi method is essential.

Firstly, by using cause and effect analysis, the most significant parameters can be selected as input parameters for the Taguchi approach. Secondly, after obtaining the input parameters and their levels, orthogonal array to be selected to collect the data for the shortage of the cars. And finally, performing the Taguchi optimization process to achieve the optimized fleet for the car rental business. These processes involved in the research work, are the sub-goals for this study.

From, the objective and the optimization process, the research question can be obtained as below.

- How the combination of the cars in the fleet affects the unavailability of the cars to rent or to the allocation process?
- What will be the optimized combination of the cars to reduce the shortage of cars and increase the profit?

V. TAGUCHI ROBUST DESIGN METHODOLOGY FOR FLEET AS A PRODUCT

Optimization of the combination of the affecting variable of any system can be obtain by the Taguchi robust design methodology. The optimization process using Taguchi method is divided into two different parts as shown in the figure-1.

Initiating steps like problem identification, brainstorming and experimental design are in the first part of the process. The second part comprise of experiment runs, analysis of the results and confirmation of the result [14].

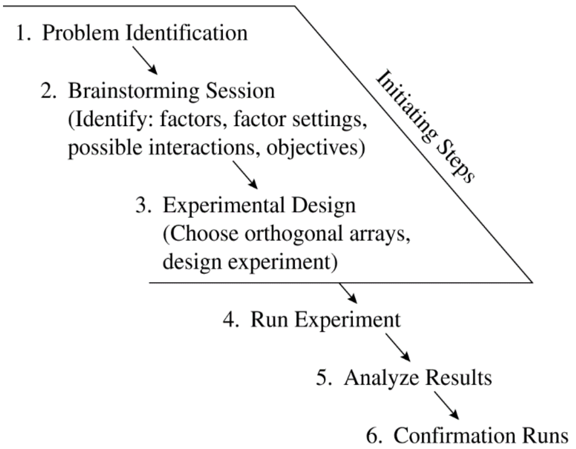


Figure-1 Taguchi robust design process via DOE[14]

The first phase of the Taguchi process is to identify the research aim and the problem which has been discussed above in the section-4. The second process of the research initiating step is to identify the most affecting parameters of the research work to further investigate them for the solution. For this research work, there are many affecting parameters, which affects the car rental operations and the fleet management. To identify the significant parameters, use of Ishikawa diagram can be used.

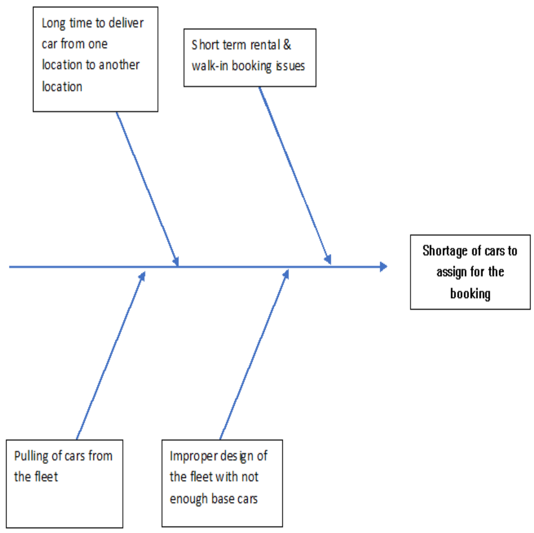


Figure-2 Ishikawa diagram

As per the Ishikawa diagram, there are four major factors which affects the supply and demand of the car rental business and result in the shortage of the cars. However, as per the national auditor of the Hertz car rental, if the fleet is optimized then there will be no longer problems related to the short-term rental or logistic from one location to the other. Therefore, the most significant parameter is the fleet design. As for this research work, the fleet is a product; the most significant variables will be the base car models in the fleet. Form the collected data of bookings, there are five major classifications of the cars in the car rental industry; hatchbacks, sedans, small SUVs, people mover, prestige and commercial vehicles. The data analysis suggests, there are very few cases of shortage of cars with people mover, prestige or commercial vehicles.

As per the chosen significant parameters, hatchback falls in class A & H, sedan falls in class S & D and, small SUV falls in class G & I in the nomination of the car rental industry. The data analysis of the past suggests that, for class A & H the bookings range from 18-29%. While for class S & D and, G & I bookings range between the 12-22% each. So, from the booking range the slot has been divided into the three parts ranging 5% each. The table-1 shows the detailed factors and their levels.

Table-1 variables and levels

Level	Hatchback	Sedan	Small SUV
1	16% to 20%	11% to 15%	11% to 15%
2	21% to 25%	16% to 20%	16% to 20%
3	26% to 30%	21% to 25%	21% to 25%

As we have three affecting variables with three levels each, the orthogonal array for this research work will be L_9 orthogonal array.

Once the orthogonal array has been finalised, the next step is to identify the signal to noise ratio for the optimization process. In signal to noise ratio, signals are the beneficial factors and the noise is the waste or undesirable factors. There three kind of S/N ratios, which can be used as per the objective of the study [15].

1. Larger is good,
2. Medium is good,
3. Smaller is good.

As per the objective of this study and the aim, the smaller is better S/N ratio will be applicable for this research work. As, the aim suggests reducing the unavailability of the cars on the base.

S/N Ratio (Smaller is better) = $\mathbf{-10\log_{10}\sum_i \frac{{y_i}^2}{n}}$**[16],**

Where, n= number of trails and,
y=the response value.

VI. TAGUCHI CALCULATIONS

From, the collected data of the shortage of the cars, we can calculate the S/N ratio for each of the combination.

S/N ratio calculations

- S/N_1 $= -10\log_{10}\sum_i \frac{{y_i}^2}{n}$
  $= \mathbf{-10\log_{10}((98+86+102)^2/3)}$
  = -39.6069
- S/N_2 $= -10\log_{10}\sum_i \frac{{y_i}^2}{n}$
  $= \mathbf{-10\log_{10}((92+88+84)^2/3)}$
  = -38.8956
- S/N_3 $= -10\log_{10}\sum_i \frac{{y_i}^2}{n}$
  $= \mathbf{-10\log_{10}((86+78+92)^2/3)}$
  = -38.6419
- S/N_4 $= -10\log_{10}\sum_i \frac{{y_i}^2}{n}$
  $= \mathbf{-10\log_{10}((98+86+84)^2/3)}$
  = -39.0410
- S/N_5 $= -10\log_{10}\sum_i \frac{{y_i}^2}{n}$
  $= \mathbf{-10\log_{10}((58+55+61)^2/3)}$
  = -35.2763
- S/N_6 $= -10\log_{10}\sum_i \frac{{y_i}^2}{n}$

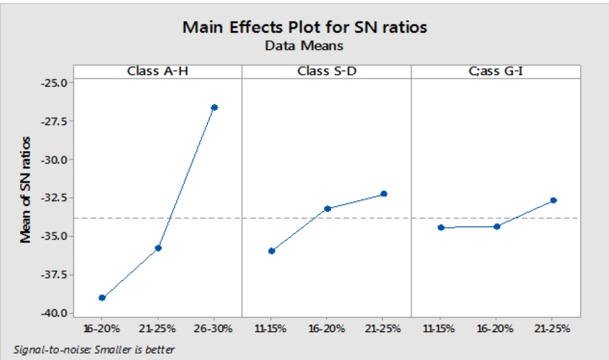
$= -10\log_{10}((42+50+42)^2/3)$
$= -33.0305$

- $S/N_7 = -10\log_{10}\sum_i \frac{y_i^2}{n}$
  $= -10\log_{10}((26+32+30)^2/3)$
  $= -29.3785$
- $S/N_8 = -10\log_{10}\sum_i \frac{y_i^2}{n}$
  $= -10\log_{10}((16+19+21)^2/3)$
  $= -25.4736$
- $S/N_9 = -10\log_{10}\sum_i \frac{y_i^2}{n}$
  $= -10\log_{10}((16+17+21)^2/3)$
  $= -25.1676$

Table-2 S/N ratio calculations

Case	Hatchback	Sedan	Small SUV	S/N ratio
Case-1	16% to 20%	11% to 15%	21% to 25%	-39.6069
Case-2	16% to 20%	16% to 20%	16% to 20%	-38.8956
Case-3	16% to 20%	21% to 25%	11% to 15%	-38.6419
Case-4	21% to 25%	11% to 15%	16% to 20%	-39.0410
Case-5	21% to 25%	16% to 20%	11% to 15%	-35.2763
Case-6	21% to 25%	21% to 25%	21% to 25%	-33.0305
Case-7	26% to 30%	11% to 15%	11% to 15%	-29.3785
Case-8	26% to 30%	16% to 20%	21% to 25%	-25.4736
Case-9	26% to 30%	21% to 25%	16% to 20%	-25.1676

From, the above table it is clearly seen that, the highest value of the S/N ratio is for the case-9. However, from 3 factors and 3 variables, we can get total 27 different 27 combination cases. So, the optimized combination may be from the 9 tested combinations or from the 27 total combinations. So, to accomplish the combination having the optimized values MINITAB software can produce a graph of data means vs S/N ratios[17].



Graph-1 Data means vs S/N ratios

From the above graph, it can be observed that, for hatchbacks (Class A-H) fleet should have 26-30% cars. For sedans (Class S-D), fleet should have 21-25% cars on the base. For small SUVs (Class G-I), fleet should have 21-25% cars on the base. So, the optimized combination is Class A-H 26-30%, Class S-D 21-25% and Class G-I 21-25%.

VII. RESULT& DISCUSSION

Form the data analysis and the S/N calculations, 9 S/N ratios were calculated. However, the optimized S/N ratio was the not the one in the data recorded. From the graph-1 the optimized combination is Class A-H 26-30%, Class S-D 21-25% and Class G-I 21-25%.

For the optimized calculation, the value of S/N ratio will be -23.9876. as per the reverse calculation, it suggests that, there will be shortage of only 7.18 cars per day. This states that there will be shortage of 7-8 cars per day with this optimized combination in the fleet. Earlier, there was shortage of 59-65 cars per day, which can be reduced to 7-10 cars per day with the used of the optimized combination constraint on the pool fleet. This optimized combination can reduce the shortage of cars by 50, which can increase the profit by $40 (average rent of car per day) * 50 cars per day = $ 2000. Thus, this optimized profit can increase the potential profit of the car rental business by $700000 per year.

However, to achieve this, the pool fleet must change the constraint from 1000 cars to the optimized combination. Pool fleet must come up with a new constraint which will have minimum limit of total cars as 1000 excluding the service & management hold as well as, they need to add one constraint which is the combination of the cars on the fleet, if pool fleet is having more than 1000 cars on the fleet but only 30% of hatchback cars, than they will not let any other out let to pull hatchback cars to satisfy the optimized combination on the fleet.

CONCLUSION

There are different problems related to the car rental operations. However, mitigating the proper fleet design indirectly eliminate the problems related to the pulling of cars and the logistics connected with the supply & demand of the cars. The fleet design can be done by considering the fleet as a product and cars as a variable. The Taguchi robust design process is powerful tool to improve the any product design with affecting variables. For the fleet of a car rental industry, base models of the cars are the influencing parameters.

The optimized combination is not form the L_9 orthogonal array. This is the beauty of this process, by obtaining data for only 9 combinations; result can be calculated for all 27 possible combinations for 3 factors and 3 levels. This indicates, Taguchi process can save a lot of time and capital required for the optimization process. The optimized combination of the cars in the fleet should have 26-30% of hatchbacks, 21-25% of sedans and 21-25% of small SUVs. Rest of the 25-30% cars can be prestige cars, people movers and commercial cars. By using this combination, car rental industry can make up to $700000 more on their profit. The only limitation is, they must maintain this optimized combination in the pool fleet by changing the constraints in the system which allows the other outlets to pull the cars from the main pool fleet.

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