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Optimal Demographic Factors of Passenger Satisfaction in Upcoming Airport Cities using The Design Of Experiments

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ABSTRACT

Conventionally, the concept of design has a prominent role in engineering applications. It brings innovations in organizations and industries through its process. Also, most of the design processes are frequently verified statistically and experimentally. Over the years, Design of Experiments (DoE) has gained significant application in diverse industries and research firms as a mathematical method and also as a multipurpose applied statistical feature/tool. It is used in numerous ways like process design, process development, design input comparisons, and process optimization. Hence, DoE is a powerful instrument for any organization for the growth and expansion of its business. And one of the means of a firm's growth (public or private) is customer satisfaction. Simply said, customer satisfaction refers to the identification and fulfillment of customer's requirements or needs as per their specifications. In this regard, this study aims to explore a unique application of DoE concerning passenger satisfaction of their travel to the nearest airport city. First, adding air transportation mode to any tier 2 and tier 3 cities in India requires an important decision concerning the passenger satisfaction of existing travel modes/types. In other words, it refers to generating an optimum combination of those who travel to the nearest airport city, i.e., passenger demographics whose responses serve as inputs for the study. The responses were collected on multiple factors concerning the satisfaction scale. On analysis, these factors & optimal inputs for responses revealed interesting insights into the plan and design of services accordingly. In this regard, the paper aims to get the optimal

combination of responses by constructing a factorial design and also conduct a response optimization experiment for a factorial design..

1. Introduction

Design of experiments (DOE):

In general, experiments are conducted in controlled environments and conditions to get the results of an unknown effect, or sometimes it's for forming a hypothesis or explaining the known effects. The common phenomenon in experiments is to find which inputs are showing significant impact or effect on the dependent variable or the process output and which inputs are optimum for the desired output. Proposed by Ronald Fisher in 1935, the basic principle of the experiment's design is to find the cause and effect relationship, i.e., the relationship between the dependent, independent variable. It is a systematic mathematical method and statistical tool for optimizing the outputs based on the process inputs.

The major three aspects of DOE are factors, levels, and response. The following descriptions give a better idea.

Factors: Factors or inputs or independent variables for the study. These factors are considered under the controlled environment according to the process design. Another thing is uncontrolled factors that are kept constant throughout the study for finding their effect on the process.

Levels: Levels are the settings of the individual factor or variable. Experiments will be conducted by keeping some of the factors and changing other factors to get the desired output.

Response: Response is an output of the experiments. The responses are impacted or influenced by the input levels.

Blocking: Sometimes unexpected or unwanted or unnecessary variations make an impact or influence the process and output. To avoid such, blocking will be used.

Replications: It means replicating and running one more time to calculate the process's estimated random error.

Interactions: Also known as combination. A combination of two or more inputs has much influence on the response.

Randomization: It is assigning interactions or experiments to random groups or individuals.

Customer Satisfaction: Customer satisfaction is the customer's judgment or opinion by consuming the product or service as per their requirements and fulfillment *(Deneke Dana 2016)*. Encounter satisfaction and cumulative satisfaction are the two levels of satisfaction. Cumulative satisfaction is judgmental, and it comes from not a single experience with the same experiences with many encounters. Whereas encounter satisfaction is a one time experience without multiple occurrences.

Customer satisfaction is one of the key metrics for any business unit or organization. It tells about where the business stands today. There are several ways to measure a customer's fulfillment. It can be done with the researchers' questionnaire as surveys, direct feedback of customers to the business or organization, and the organization itself going for the customers' satisfaction levels on their product or service usage. Satisfaction levels of the end-user bring new insights that are hidden for the growth causing factor.
*(B. Manikandan 2016)*The measurement of satisfaction has several dimensions of the customer or organization. For the passenger, the measurement will be according to transportation and their circumstances. It will be economical, comfort, safety, information, time, frequency of services, cleanliness, availability, and many factors or dimensions.

2. Literature review

(B. Manikandan & Dr.T. Vanniarajan, 2016) They conducted an empirical study on the service quality in public buses using Structural equation modeling. The authors collected responses from 626 passengers who traveled in public buses and asked for responses on a Likert scale. The study's main features are network, cleanliness, service planning, comfort, safety network, and safety studied from various published papers. The study results are like service quality factors that have a major effect/influence on passenger satisfaction are network & service planning. Finally, I delivered a model using the SPSS statistical tool and used mean and standard deviation to understand the characteristic factors or variables.
(Deneke Dana, Million Nane, Mebratu Belete, Teshome Ergado & Teferi Labiso,2016). The authors surveyed both service quality and satisfaction of the passengers in public transportation. The paper's major objective is to evaluate passenger satisfaction and service quality using descriptive research design, data collected from primary sources. Primary data collected through a questionnaire of probability sampling. The two dimensions of data were collected on the Likert scale of the positive statements. The study results are majorly concerning passenger handling and lack of physical facilities leading to higher dissatisfaction. The tool used for the study is SPSS, and descriptive analysis is used for finding the insights.
(Tomas Macaka, Olga Regnerova a & Stefan Toth.2014). The applied design of experiments to find the optimal factors which are influencing consumer behavior for particular products. They prepared one questionnaire for collecting data of consumers online of 246 responses. This particular study's research design is a quasi-experimental, prepared hypothesis and performed the testings using ANOVA and chi-sq test conducted in SPSS. The results are identified using a response optimizer after fitting the regression model. The key finding is to provide insights about the products to current consumers.
(Vikas K. Jain & Durward K. Sobek II, 2006). The authors had an idea to understand how the process impacts the design outcome. For processing, the data collected from student projects on the design experiment and by interviews with the experiments, and those are processed with artificial neural

networks, for analyzing the data used virtual designed experiments. The study's outcome is to get higher satisfaction by generating ideas at the conceptual stage and clear problem definition.

3. Research Gap

There are some relevant studies identified then reviewed for the present study. Some of the reviewed studies are mentioned below for reference. The research gap is identified from previous studies, i.e., they have considered and linked the design of experiments for the process of designing the surveys and analyzing consumer behavior or consumer satisfaction influencing factors, and studies are not identified related to both analyzing the passenger satisfaction and finding the optimal inputs for responses (independent variables) of the passenger's demographics on their satisfaction levels those who travel to nearest airport city.

4. Research Objectives

- To study the passenger satisfaction levels of demographic factors of responded passengers.
- To determine the optimal responses (independent variables) of the passenger's demographics on their satisfaction levels.

5. Research design

This present study used the descriptive statistical analytical method, factorial design, and response optimization experiment for factorial design. The research variables were then identified based on the literature review in the descriptive research method. The research variables and independent variables are the keys to analytics. In the present study, all steps included are data collection, processing, analyzing the result, and conclusion.

The following are the steps to perform the design of experiments and response optimization.

- Define problem
- Determine objectives
- Determine response(s) and factors
- Design experiment(s)
- Experiment and collect data
- Analyze data
- Interpret results
- Verify predicted results
- Conduct response optimization
- Find the desired solution with the targeting.

Population and Sample size:

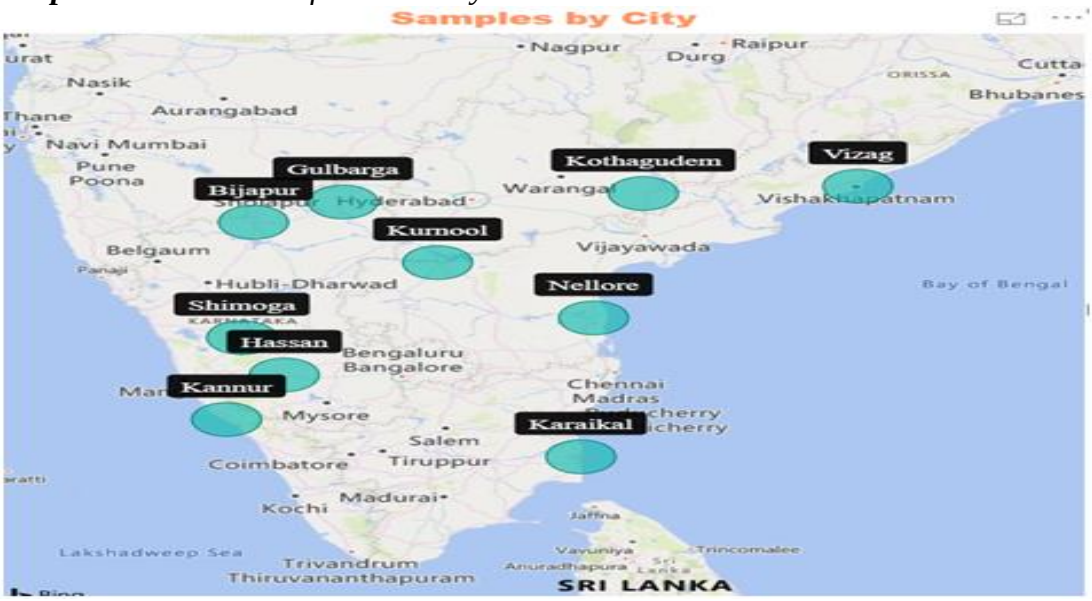
Here, this study's population is from passengers of tier 2 & tier 3 cities where the airport is not there, and new airports proposed by the government to India with special reference to South India. The sample from the population is

considered based on passengers who travel to the nearest airport city. The Sample size for the study can be calculated by the following full factorial design method.

Total Runs/ Samples =Levels Factors * Replications

The sample size 250 (5^3 * 2) per the general factorial design with 3 factors, 5 levels, and 2 replications. The data collection is for 10 selected cities, and each city required sample size is 25. The responses are collected according to the factorial randomized run order.

Graph:1 *Selected cities for the survey.*



Variables and Scale:

The research objectives considered factors as dependent variables are economics, frequency or services, time, comfort, information, and safety. The input factors or responses are what type of transportation they are using, monthly income, and how frequently they visit the airport city.

Passenger's satisfaction towards the current transportation modes collected on a 5 points rating scale is 1: Highly dissatisfied, 2: dissatisfied, 3: neutral, 4: satisfied, and 5: Highly Satisfied by using a Likert scale.

6. Data Analysis and Results

To decide whether a developed scale has internal consistency or not. The Cronbach's alpha test can do the reliability testing of any developed scale, and acceptable test results should be more than 0.60 and below are considered poor. The test results are as follows.

Table:1 *Reliability test results*

Reliability Statistics		**No.of items**
Cronbach's Alpha	0.970	18
Rule of Thumb	0.6	

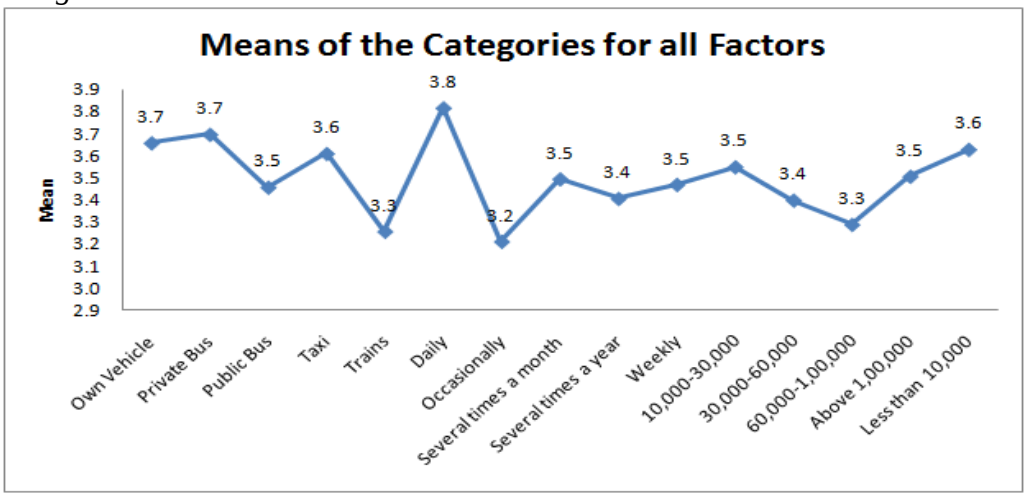
Source: Calculated from primary data

From the above table, it is understood that Cronbach's Alpha test static is 0.970, which is more than the required standards, i.e., 0.6. So, it is proved that the designed questionnaire has excellent internal consistency, so it is reliable for the study and can proceed with the analysis.

Descriptive Analysis:

The first objective of the study is to analyze the satisfaction levels of three factors. Those factors are monthly income, type of transportation, and how frequently they travel to the nearest airport city. As mentioned above, each factor has five levels as categories. The respondents were asked to mark their satisfaction levels for the 18 dependent variables according to the demographic categories. Working the factorial design needs one dependent variable that takes the 18 dependent variables designed on multiple considerations.

Graph:2 *Mean satisfaction levels of the passengers according to their categories.*



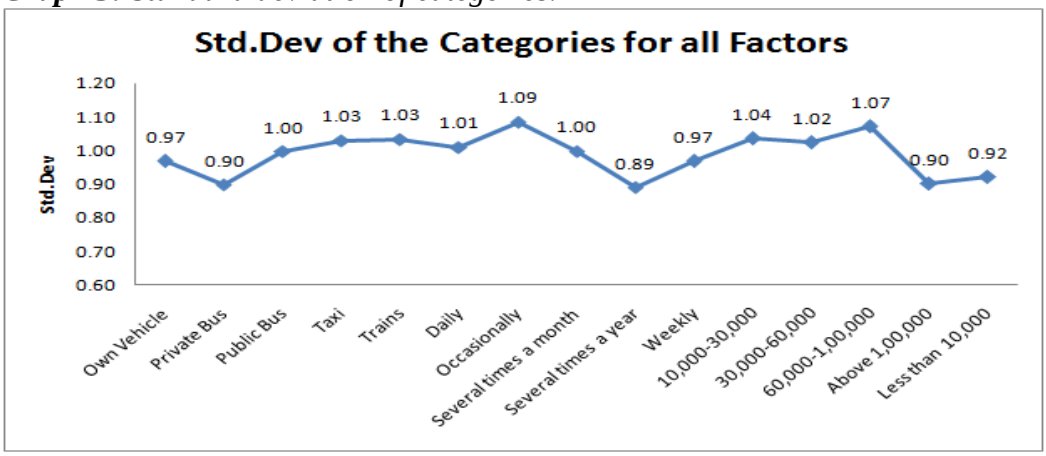
Source: Calculated from primary data

From the above graph, it is understood that passengers have less mean value for the transportation type- trains category than other transportation types, i.e., 3.3. Overall, the mean is between 3 & 4, i.e., 3.5, which means that the passengers' satisfaction is neutral and satisfied.

For the factor - frequency of travel, those who occasionally travel to the airport city express the less mean value than other categories, i.e.,3.2 and as overall mean value is between the 3 & 4 which means that satisfaction of the passengers is between the neutral and satisfaction.

For the factor - Income level, those who have the income level 60k to 1 Lakh are expressing the less mean value compared to other categories, i.e.,3.3 and as overall mean value is in between the 3 & 4 which means that the satisfaction of the passengers is between the neutral and satisfaction.

Graph 3: *Standard deviation of categories.*

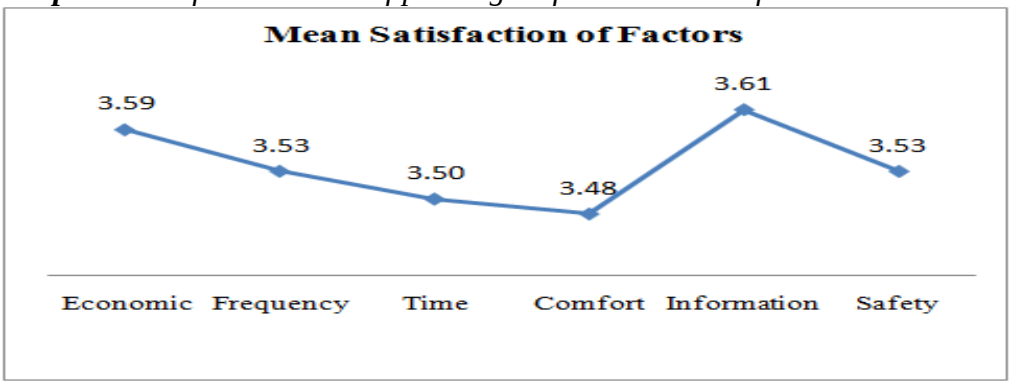


Source: Calculated from primary data

The above graph can understand how the group means vary with the overall mean, i.e., standard deviation. The range of standard deviation for all overall categories is between 0.89 and 1.02, which means the individual's mean satisfaction level doesn't vary from all passengers who travel to the nearest airport city. So, the study results are found that almost all the respondents are having similar kinds of satisfaction for the mentioned things in the questionnaire.

The satisfaction of passengers:

Graph 4: *Satisfaction levels of passengers for the selected factors.*



Source: Calculated from primary data

The above graph shows that comfort-related factors are close to neutral, followed by time, frequency, safety, economic, and information-related factors. It means that passengers are in the stage where they can't get completely satisfied or dissatisfied.

Design Of Experiments (DOE):

By considering all other external factors as a constant and under controlled environment for the study and finding customer satisfaction predictions. There are 250 runs (5^3 * 2) needed to collect responses from passengers.

For the prediction of satisfaction levels, simple linear regression is used in the full factorial design. The equation of the factorial design is :

Average of satisfaction = f(Monthly income, Type of transportation, Frequency of travel)

Table 2: *Factorial design format*

Factors	**Levels**				
Monthly Income	Less than 10,000	10,000-30,000	30,000-60,000	60,000-1,00,000	Above 1,00,000
Transportation type	Private Bus	Trains	Taxi	Own Vehicle	Public Bus
Frequency of travel	Daily	Weekly	Several times a month.	Several times a year	Occasionally

Source: Calculated from primary data

Table 3: *Analysis of Variance results.*

Following are the results by analyzing the full factorial design with replicates:

Analysis of Variance					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	124	78.269	0.6312	0.94	0.000
Linear	12	10.333	0.8611	1.29	0.000
Monthly Income	4	3.524	0.8809	1.32	0.000
Transportation Type	4	4.611	1.1528	1.72	0.000
Frequency of travel	4	2.198	0.5495	0.82	0.000
2-Way Interactions	48	31.484	0.6559	0.98	0.000
Monthly Income*Transportation Type	16	4.243	0.2652	0.4	0.173
Monthly Income*Frequency of travel	16	13.909	0.8693	1.3	0.000
Transportation Type*Frequency	16	13.332	0.8332	1.24	0.000
3-Way Interactions	64	36.452	0.5696	0.85	0.011
Monthly Income*Transportation * Type * Frequency	64	36.452	0.5696	0.85	0.011
Error	125	83.689	0.6695		
Total	249	161.958			

Source: Calculated from primary data

The above table shows the variance analysis (ANOVA) summary of the main factor effects and their interactions. To find the weather factors having significant effects or not. As the results explain for the model, the p-value is 0.000 at a 5 % level of significance. It means that data groups have significant differences among them. For linear effects, the p-value is 0.000. For 2-way interactions and 3-way interactions, the p-value is 0.000, which is less than a 5% significance level. It shows that there is a statistically significant difference among the factors means and group means.

Table: 4 *Fitness of the model and its predictability*.

Model Summary			
S	R-sq	R-sq(adj)	R-sq(pred)
1.20431	78.42%	75.01%	73.67%

Source: Calculated from primary data

The above model summary clarifies the effect of independent variables on the dependent variable and explains the relationship's strength. From the above table, the R-Square value is 78.42% and greater than 70%, which means that the independent variables can bring variation in the dependent, i.e., the satisfaction of current transportation modes/types. Another value is R-sq adjusted is 75%, which means inputs are accountable for 75% variation in output, i.e., satisfaction level. The two values indicate the fitness of the model according to the data points. Final value is predicted R-squared value is very close to the R-sq & adj R-sq values i.e 73.67%. It explains the overfitting of the data, and in this model, there is no problem of overfitting, and this model has sufficient predictability.

The model's coefficients are significant at the 5 % level of significance, and some are not significant. There is no multicollinearity in the data and auto-correction. The VIF (variable inflation factors) values are in the range of 1-5, which means inputs don't correlate. If VIF values are ranging from 5-10, then model coefficients are not sufficiently derived. Some of the coefficients are having negatives & some the positives so, they have negative relationships with the dependent variable, and some have positive relations. Here the coefficients table is not used due to the next steps involved in using the model for response optimization for factorial design. The above model is fit and adequate for optimizing responses and interpretations of the results.

Response Optimization for Factorial Design:

Optimization for factorial design useful for finding the factor or variable settings that maximize or minimize or targeting the response or dependent variable. It is the next step of the design experiments.

Table: 5: Factor

Response Optimization - Multiple Response Prediction						
Target Satisfaction	Monthly Income	Transportation Type	Frequency of travel	Satisfaction Fit	Composite Desirability
1	Above 1,00,000	Public Bus	Several times a year	1.14	0.97
2	10,000-30,000	Trains	Weekly	2.11	0.96
3	Less than 10,000	Trains	Several times a year	3.02	0.99
4	30,000-60,000	Own Vehicle	Occasionally	3.97	0.99
5	10,000-30,000	Own Vehicle	Daily	4.64	0.93

ial Response output

Source: Calculated from primary data

The above table results are generated by designing the experiments response optimizer by giving the multiple target values. Sometimes if it's related, cost-related factors can minimize the target, and if it is yield-related can maximize the target. In this case, checking for the optimal responses for various satisfaction levels of passengers. The above table values are noted by giving all levels of satisfaction to the target each time. The satisfaction levels, as mentioned above 5: Highly satisfied, 4: Satisfied,3: Neutral, 2: Dissatisfied, and 1: Highly dissatisfied.

In the Design experiments for a response, optimization results can be validated by the composite desirability. It is the function, the weighted geometric mean of each factor desirability of the responses. The desirability function is to determine how much attention reaches the target value.

Composite desirability tells about how well a combination of independent variables reaches the objectives. It evaluated the optimization of the setting of a set of responses as overall. The values are range between 0 and 1. Where zero indicates the responses are out of the desired limits, and 1 indicates the perfect optimal setting.

For Target: 1 (Highly dissatisfied):

To find the optimal factor settings for the desired target is Highly dissatisfied. The composite desirability is 0.97, which is close to 1, which means factor settings or a combination of passenger's demographics are good for reaching the target, i.e., highly dissatisfied. Passengers who all belong to the monthly income group above 1 lakh, using public bus type of transportation and their frequency of travel is several times a year to the nearest airport city are the highly dissatisfied passengers with their travel factors.

For Target: 2 (Dissatisfied):

To find the optimal factor settings for the desired target is dissatisfied. The composite desirability is 0.96, which is close to 1, which means factor settings or a combination of passenger's demographics are good for reaching the target, i.e., dissatisfied. Passengers who all belong to the monthly income group 10,000 - 30,000, using train type of transportation and their frequency of travel are weekly to the nearest airport city are the dissatisfied passengers with their travel factors.

For Target: 3 (Neutral):

To find the optimal factor settings for the desired target is neutral. The composite desirability is 0.99, which close to 1, which means factor settings or a combination of passenger's demographics are good for reaching the target, i.e., neutral. Passengers who all belong to the monthly income group below 10,000 using train type of transportation and their frequency of travel several times a year to the nearest airport city are the neutral passengers with their travel factors, which means they are in between the satisfaction dissatisfaction.

For Target: 4 (Satisfied):

To find the optimal factor settings for the desired target is satisfied. The composite desirability is 0.99, which close to 1, which means factor settings or

a combination of passenger's demographics are good for reaching the target, i.e., satisfied. Passengers who all belong to the monthly income group 30,000 - 60,000 using their vehicle to travel. Their frequency of travel occasionally to the nearest airport city satisfies passengers with their travel factors.

For Target: 5 (Highly satisfied):

To find the optimal factor settings for the desired target is highly satisfying. The composite desirability is 0.93, which is close to 1, which means factor settings or a combination of passenger's demographics are good for reaching the target, i.e., satisfied. Passengers who all belong to the monthly income group 10,000 - 30,000 using their vehicle to travel and their frequency of travel daily to the nearest airport city are the highly satisfied passengers with their travel factors.

Table: 6 *The following table shows the top 5 optimum settings for a response to the desired target values.*

Target - 1 (Highly Dissatisfied)					**Target - 2 (Dissatisfied)**				
Response Optimization - Multiple Response Prediction					**Response Optimization - Multiple Response Prediction**				
MI	**TT**	**FT**	**SF**	**CD**	**MI**	**TT**	**FT**	**SF**	**CD**
Above 1,00,000	Public Bus	Several times a year	1.14	0.97	10,000-30,000	Trains	Weekly	2.11	0.96
10,000-30,000	Private Bus	Several times a year	1.17	0.96	Above 1,00,000	Trains	Several times a year	2.17	0.94
60,000-1,00,000	Trains	Several times a month	1.28	0.93	30,000-60,000	Taxi	Several times a year	1.86	0.93
30,000-60,000	Own Vehicle	Several times a year	1.42	0.9	< 10,000	Own Vehicle	Several times a year	2.22	0.93
30,000-60,000	Trains	Weekly	1.44	0.89	Above 1,00,000	Taxi	Daily	2.22	0.93
Target - 3 (Neutral)					**Target - 4 (Satisfied)**				
Less than 10,000	Trains	Several times a year	3.03	0.99	30,000-60,000	Own Vehicle	Occasionally	3.97	0.99
10,000-30,000	Own Vehicle	Occasionally	3.06	0.97	< 10,000	Public Bus	Occasionally	3.94	0.99
10,000-30,000	Taxi	Several times a month	3.08	0.96	< 10,000	Trains	Several times a month	3.94	0.99
Above 1,00,000	Public Bus	Several times a month	3.08	0.96	60,000-1,00,000	Trains	Several times a year	3.89	0.97
60,000-1,00,000	Public Bus	Several times a month	2.86	0.95	< 10,000	Private Bus	Occasionally	4.03	0.97
Target - 1 (Highly Satisfied)									

10,000-30,000	Own Vehicle	Daily	4.64	0.93	MI: Monthly Income
30,000-60,000	Own Vehicle	Weekly	4.53	0.91	TT: Transportation Type
Less than 10,000	Taxi	Daily	4.5	0.9	FT: Frequency of travel
Less than 10,000	Taxi	Weekly	4.47	0.89	SF: Satisfaction Fit
30,000-60,000	Taxi	Several times a month	4.47	0.89	CD: Composite Desirability

Source: Calculated from primary data

In the above table, the top 5 optimum combinations are responses loaded. Adding a table is used to find relevant optimum factor settings after the best combination as per the response target. And the remaining combinations are not many optimum setting factors for the study.

For highly dissatisfied response targets: There are no passengers related to less than 10,000 income, who use a taxi, and who occasionally travel to the nearest airport city.

For dissatisfied response target: There are no passengers related to who uses a private and public bus and occasionally travel to the nearest airport city.

For neutral response target: There are no passengers who travel daily to the nearest airport city.

For a satisfied response target: There are no passengers related to 10,000 - 30,000 income, who use a taxi, and who travel daily and weekly to the nearest airport city.

For highly satisfied response targets: There are no passengers related to, who use the public bus, private bus, and trains, and who travel occasionally and several times in a year to the nearest airport city.

7. Conclusion

As per the paper's objectives, they have identified the key factors or variables used for measuring the satisfaction of the customer (or) passenger. Using the design of experiments created a data collection sheet with the randomized two replicates with five levels and three factors. The selected demographic factors are monthly income, frequency of travel to the air city, and transportation type, using them as independent variables for the model. The dependent variable took the average of the passenger satisfaction factors. The model is analyzed and it is fitted for the next steps. The overall satisfaction of the passengers between the neutral and satisfied. This means passengers require improvements in all the factors to meet their satisfaction levels on their travel, and it shows there is scope for acceptance of new journey which might fulfill their

requirements. The research needs to carry further to find the expectations of the passengers on upcoming airlines.

The second main objective is to find the optimal factor settings of demographics for the response's satisfaction levels. Out of 125 combinations, 25 are the best optimal factor settings for the output i.e. level of satisfaction. The remaining 100 combinations are also expressed their satisfaction then these are not much optimal according to the target values of the responses. The results reveal exciting insights into the plan and design of services, i.e., adding new transportation modes accordingly. There is scope for further research in the same field by adding some independent variables other than demographics to understand the passenger satisfaction levels in detail.

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