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OPTIMIZATION OF SERVQUAL-QFD-LED SERVICE QUALITY DESIGN PARAMETERS USING TAGUCHI'S DESIGN OF EXPERIMENTS APPROACH: AN EMPIRICAL STUDY OF HOSPITALS IN DELHI-NCR

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Abstract
This paper proposes a dynamic approach to identifying and translating the customer needs and expectations into the quality characteristics using quality function deployment (QFD) and set of factors that influence consumers' perception of service quality are also identified with the help of SERVQUAL model. The integration of SERVQUAL and QFD has led to the identification of critical to service quality parameters and the parameters are further optimized using Taguchi's Design of experiments approach to obtain a more customer centric and robust service design.

Purpose – This paper proposes a dynamic approach to identifying and translating the customer needs and expectations into the quality characteristics in a healthcare setting. The study describes how an existing approach of SERVQUAL and QFD integration can be applied for measuring the service quality gaps in the healthcare setting and then identifying and optimizing the service quality design parameters for a more customer centric and robust service design. The robustness of design parameters is ensured using Taguchi methods.

Design/methodology/approach – Quality function deployment (QFD) is a powerful technique to identify and prioritize customer needs and linking them to technical requirements, whereas the service quality model-SERVQUAL represents the unique characteristics of services and is a structured approach to assess the set of factors that influence consumers' perception of service quality. The Taguchi Methods used in the study enable the conduct of experiments under various control conditions and provide optimum solution. To evaluate service quality of hospitals, a self-completion questionnaire was developed from the SERVQUAL instrument and distributed using convenience sampling technique to the patients in Delhi-NCR based hospitals to determine their perceptions of service quality. Thus, the SERVQUAL-QFD integration has led to the identification of critical to healthcare service quality characteristics and applying Taguchi design of experiments to find the optimum design parameters.

Findings – From the results of the QFD application, it is seen that competency and skills of doctors have attained the highest score, followed by other parameters like waiting time for treatment, attitude of doctors and finally, availability of desired modern machines and equipment obtaining the lowest score among others. The Taguchi's optimization approach adopted in this paper makes use of signal-to-noise ratio technique to minimize the sensitivity of a control characteristic to the noise factors and selecting optimal levels of design parameters. Thus, the present analysis indicates the significance of competency and skills of doctors for a better customer satisfaction score in hospitals along with waiting time which plays a significant role in securing customer faith.

Managerial and Practical Implications- The potentials and antecedents of using SERVQUAL-QFD led findings and learnings from a practical application of Taguchi's design of experiments approach can be used to improve various physiological processes in the hospitals. The research study is a first attempt to apply this integrated approach to a service sector and thus offers practical and applied knowledge useful to both academicians and practitioners.

Originality/value – This original contribution is two-fold. Firstly, the customer requirements/voice of customer data and the related hospital requirements are identified to analyze the gaps in service quality using SERVQUAL-QFD approach. Secondly, the gaps have been used as an opportunity to improve customer satisfaction and optimize potential service design parameters using Taguchi method. The proposed approach is expected to develop more robust and accurate results for process-based problems rather than classical approaches.

Key Words: Quality function deployment (QFD), SERVQUAL, Taguchi method, Healthcare, Orthogonal arrays (OA), Signal-to-noise ratio, Analysis of variance (ANOVA), Response surface regression.
Paper Type: Research Paper

1. Introduction

The SERVQUAL is multi-item scale for assessment of customer perceptions of service quality in various industry and cross-cultural contexts. The measures of reliability and factor structures indicate that the final 22-item scale and its five dimensions have sound and stable psychometric properties (Parasuraman et al., 1988) and has been described as the most popular, promising and standardized scale to conceptualize and measure service quality. Attributes with large negative gaps in SERVQUAL model represents dissatisfactions and lead to opportunities for improving them. Many researches have been conducted to identify and bridge the service quality gaps across various industries by using a well-designed questionnaire incorporating use of likert scale to get the customer responses (F. Buttle, 1995).

A well-known tool to obtain customer wants and to fill service quality gaps is quality function deployment (QFD). The applications of QFD in healthcare is a niche area and gaining much importance. Research in this area is also consistently increasing (Einspruch et al., 1996; Radharamanan et al., 1996; Lim and Tang, 2000; Dijkstra and van der Bij, 2002; Akao and Chaplin, 2003; Chou, 2004; Hallberg et al., 1999; Lim et al., 1999; Gonza´lez et al., 2006; Moores, 2006; Simons et al., 2008; Liu et al., 2009; Kuo et al., 2011).

Applying QFD in healthcare may be slightly different from its applications in other industries. Berry and Bendapudi (2007) described healthcare as a rare service that people need but do not necessarily want. In a healthcare setting, it is important to distinguish between "needs" and "wants." The difficulty of defining the "product" in healthcare sector limits the scope of QFD in such sectors. (Omachonu and Barach, 2005).

Various aspects of service quality in healthcare industry have been researched upon. In this context, Rao et al. (2006) researched upon patient's perceptions of quality at public health facilities. The authors found that the doctor's behavior had the largest effect on general patient satisfaction followed by the medicine availability. Further, to bring innovativeness in service quality, quality engineering principles and practices can be followed as the goal of quality engineering is to design quality in every product and process. The two quality engineering methodologies, viz., QFD and Taguchi originated in Japan, are considered as the best synergy a company can use to improve its products and processes. As mentioned above, QFD systematically translates the customer's needs and desires into the voice of engineer data and Taguchi method determines the optimum values of service quality design parameter.

The quadratic loss function is at the core of Taguchi methods. It can be used to quantify and model the loss to the society and establishes a relationship between cost and variability. Thus, the performance and parameters of the design of medical applications can be easily integrated with the quality loss function. For instance, when the performance of a diagnostic test deviates from its ideal, the misclassification rate of patients increase. The loss functions are used to reflect the economic loss associated with variation and deviations from the ideal value of a process characteristic (Leung and Spiring, 2004, Taner and Antony, 2000), e.g. the loss of a customer due to the length of patient's stay in hospital due to misdiagnosis (Rinderer, 1996), hence the diagnostic cost, patient care costs, emotional and financial damages, variations in operating environments such as temperature, humidity conditions, machine settings and various other intrinsic and extrinsic service aspects influences the quality of healthcare services and their cost. This necessitates the designing of a robust process and accurate diagnostic tests that lead to minimum loss to the society. The signal-to-noise (S/N) ratio in Taguchi methods optimizes the process parameter and keeps the mean value of the signal closer to

the target by detecting control factors and neglecting the impact of uncontrollable factors. The larger the S/N, the less the total rate of misclassification and the smaller the quality loss. Thus signal-to-noise ratio is the functional way of incorporating Taguchi's quality loss function into experimentation (Lofthouse, T. ,1999). The S/N measures quality in terms of performance; whereas the quality loss function measures it in terms of cost. This connection between quadratic loss and Taguchi's S/N leads to a general principle for choosing performance measures in parameter design (Taner and Antony, 2004).
Each of these methods has their particular focus in the design stage of a product or process, but together they form a complete and balanced methodology to support a robust design.
This paper proposes a dynamic approach to identify and optimize service quality design parameters using integrated SERVQUAL-QFD and Taguchi based approaches. The proposed framework includes identifying the SERVQUAL variables, measuring the gaps and generating the customer wants and hospital requirements using QFD approach and subsequently applying Taguchi's method to optimize the service quality design parameters for getting more customer centric and robust service design parameters. The concept was applied to a group of private hospitals in Delhi-NCR region and relevant data was collected from these hospitals to evaluate the services offered and devise a set of optimum service quality characteristics.

2. Literature review

According to Hardie et. al (1993), quality has many different definitions and there is no universally acceptable definition of quality. However, the authors attributed it to the elusive/subjective nature of quality and the context in which different measures are applied to define the term "quality". In this context, Ghobadian A. et al. (1994) have defined **Quality** in service organizations as a measure of the extent to which the service delivered meets the customer's expectations. Service quality is, therefore, conceptualized as the consumer's perception about the level of services in terms of quality. Generally, service quality is assumed to be the difference between customer expectations and perceptions when received by the customer. Hence, service quality depicts the quality of a service or services subsequent upon comparing the customer expectations with the perceptions by virtue of actual services delivered to them. Any difference between the two is referred to as a gap. Service quality is an important and particularly relevant construct in virtually all service businesses (Voss et al., 2004). It is a powerful concept because of its strong relationship with customer satisfaction (Cronin and Taylor, 1992) and quality of life (Dagger & Sweeney, 2007).
SERVQUAL is one of the most powerful measurement tools for identifying the customer service levels for any organization The most recent version of SERVQUAL scale was developed by Parasuraman et al., (1988) which consisted of five components of reliability, tangibles, responsiveness, assurance and empathy with 22 items. The main purpose of the SERVQUAL is to measure the result of customers' expectation and perception in relation to various kinds of services. Several researches have established the significant relationship between the perception of service quality and customer satisfaction in sectors like healthcare, public sector, automobile and mobile service sectors (Cronin & Taylor, 1992; Agus A. et al., 2007, Izogo et al., 2014 and Samen et al., 2013). In respect of healthcare sector, a patients' perception about healthcare service quality is an important element of healthcare evaluation (Labarere et al., 2001; Iversen et al., 2012). Evaluating service quality from patient's perspective is important for several reasons. Firstly, service quality has a relationship with issues such as patient satisfaction, willingness to re-use the services, complying with physician prescription, etc. (Gasquet et al., 2004; Arab et al., 2012; Alrubaiee and Alkaa'ida, 2011). Secondly, patient feedback is an integral part of many accreditation and evaluation programs related to healthcare services.
Quality in healthcare services includes technical (clinical) and functional (non-clinical) quality. The clinical quality focuses on the skills, accuracy of procedures and medical diagnosis while the

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functional quality refers to the way health services are provided to the patients (Alhassan R.K. et al., 2015). As stated above, quality function deployment (QFD) is employed for translating customer needs and expectations into the quality characteristics. Technical requirements to meet specified customer expectations can also be extracted using QFD. Although QFD was originally developed for new product or service development, its capabilities of identifying customer needs and discovering new market opportunities (Hunt and Xavier, 2003) makes it best suited for any kind of research study. In this context, Akao et al. (2003) described a transformative method in which QFD has been used as a tool to meet true customer needs and to improve the product development process. Puga-Leal and Pereira (2007) also suggested a model by integrating SERVQUAL and QFD to translate customer expectations into specification limits in services. They use the SERVQUAL 3-column model and were able to create the real performance distribution by defining the zone of tolerance/desired service level with the perceived performance of customers. Thus, the integration of SERVQUAL and QFD can provide important insights into the significant customer wants and the relevant technical knowhow to fulfill all such requirements.

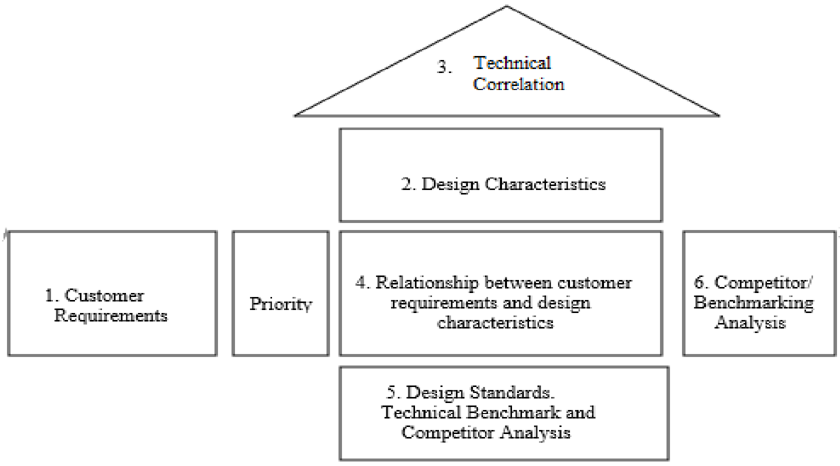

Figure 1- House of quality

The notion of robust service design is incomplete without considering the Taguchi’s way of conducting experiments and analyzing the response variable in the light of various measures such as ANOVA, signal-to-noise ratio, prediction of optimum parameters etc. Taguchi methods have created revolutionary momentum for the use of experimental design in various sectors and Taguchi methods have been successfully applied and proven in many industrial and commercial applications. Wimalin S. and James D.T. (2005) made a novel contribution in the manufacturing sector by describing Neural Network based Taguchi approach using historical data to gain process understanding and identify significant factors for optimization of manufacturing processes. These techniques can be used to optimize processes without expensive and time-consuming experimentation.

Thus, the Taguchi method for experimental design is a powerful optimization technique for improving process performance, yield and productivity (Antony et al., 2001; Taguchi et al., 2005; Ghosh et al., 2019). Kumar and Otero et al. (1996) suggested an optimal combination for QFD “hows” using Taguchi method for designing the services for the customers and also determined the optimum service design parameters similar to the factors in an experimental design application. Taner et al. (2007) applied the Taguchi’s experimental design approach in healthcare sector to improve the quality of medical images.

Another important component of the Taguchi method is the signal-to-noise ratio (SNR), which is a measurement scale used in the communication industry for nearly a century. Shoemaker and Kackar (1991) explained Taguchi's signal-to-noise ratios in detail and discussed their role in parameter

design. Taguchi generalized the concept of the SNR to other industries also for evaluation of products and processes.
In healthcare sector, Taguchi method can be used to measure the dissatisfaction level of patients when performance departs from the ideal. A higher SNR indicates higher quality (Hadiyat M.A. et al., 2013). The quality characteristics in Taguchi method can be categorized into the three following types: the smaller the better, the nominal the best, and the larger the better. The larger the better signal-to-noise ratio would be used in this paper, since the objective is to maximize customer response.
The signal-to-noise (S/N) ratio is calculated for each factor level combination. The formula for the larger-is-better S/N ratio using base 10 log is:
$S/N = -10*\log(\Sigma(1/Y^2)/n)$
where Y = responses for the given factor level combination and n = number of responses in the factor level combination.
In this research, the Taguchi method has been used for identifying robust service design parameters consequent upon SERVQUAL-QFD analysis. The customer responses for various combinations of factors and their levels are gathered in order to find the optimum combination of the same. The voice of customer data and technical requirements are obtained with the help of SERVQUAL-QFD analysis. The gaps have been determined subjectively and are considered as factors with two levels for each factor. The results have been analyzed using Taguchi's design of experiments approach using signal-to-noise ratio and orthogonal arrays to optimize various service quality parameters.

3. Framework and Methodology

To evaluate service quality of hospitals, a cross-sectional study was conducted in Delhi-NCR Region and around 500 patients were randomly selected from four private hospitals. Data were collected using a questionnaire with 30 variables depicting various aspects of service quality covering all five dimensions of SERVQUAL model.
The methodology included SERVQUAL-QFD integration and applying Taguchi design of experiments to find the optimum levels of factors with their levels. The research framework is shown in figure 3. Customer feedback is collected for various SERVQUAL dimensions and for designing QFD. QFD determines customer wants and technical requirements with weightage assigned to both as per customer specifications and organizational needs. Steps in implementing the framework is briefly explained below:

- Development of questionnaire as per SERVQUAL dimensions and other variables.
- Conducting survey
- Computation of customer gaps for each variable
- Mapping of SERVQUAL variables and technical constraints with the "whats" and "hows" components of QFD
- Prioritizing the customer needs and technical constraints.
- Deciding the factors and their levels of hospital service quality dimensions and assign them in the orthogonal array in Taguchi design
- Running the experiments with a suitable software
- Optimizing the responses using Taguchi method and finding the optimal combination of factors with their levels for a robust service design.

A robust service design is amenable to consider almost all the voice of customer data, thus reducing the number of customer complaints. It is possible to find variables with negative gaps in expectation and perception of customer responses and the negative gaps would constitute the "whats" component of QFD.

Industrial Engineering Journal
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Volume : 53, Issue 5, No.14, May : 2024

	Variables	Expectation	Perception	Customer Gaps
		E	P	P-E
1	Courtesy shown by the administration staff	4.50	2.93	-1.57
2	Availability of doctors throughout the OPD timings	4.85	2.84	-2.01
3	Competency and skills of doctors	4.90	2.88	-2.02
4	Friendly and caring attitude of Doctors	4.80	2.89	-1.91
5	Medical treatment received is fruitful	4.85	3.12	-1.73
6	Correct assessment of patient’s health condition by the Doctor	4.90	3.09	-1.81
7	Medical team promptly handles unforeseen/ unexpected complications arising in the process of medical treatment	4.89	3.06	-1.83
8	Ease of consulting with doctors (within a reasonable waiting time)	4.87	3.06	-1.81
9	Quality of food available in canteen is good	4.74	3.11	-1.63
10	Adequate information on website	4.70	3.02	-1.68

Table-1. Variables with negative gaps

4. Results and Discussion

The customer gaps were computed and 10 variables with negative gaps (unsatisfactory) were identified (Table-1). All negative gaps would then constitute the “whats” component of QFD and the gap values would be treated as their respective weights. A list of factors was then determined by considering the association between “hows” and “whats” in QFD and computing importance weights for critical “hows”. The factors with relatively higher weights in QFD matrix were selected for obtaining the optimum levels of these factors and lower weights were rejected due to having insignificant influence upon patients. In this way, four “hows” are generated. The relevant results are shown in Figure-2 and Table-2.

As mentioned above, these four factors are then assigned different levels to build an experimental design using L_{12} orthogonal array with each factor having two levels (interactions not assumed), as shown in Table-3. Taguchi’s design of experiments with ANOVA and signal-to-noise Ratio was then applied to get the optimal combination of factors at appropriate levels for a robust service design.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.14, May : 2024

Row	Max relationship value in row	Relative Weight	Weight Importance	Customer Requirements	Doctors attitude towards patients	Competency and skills of doctors	Competency and skills of Nursing Staff	Availability of desired modern machines and equipments	Behavior and attitude of staff	Quality of food	Waiting time for having treatment	Availability of all specialities	Hygeine and cleanliness of hospital	Website Management
				Column	1	2	3	4	5	6	7	8	9	10
				Direction of Improvement	▲	▲	▲	▲	▲	▲	▽	▲	▲	▲
1	9	9%	1.57	Courtesy shown by the administration staff					●		▽		▽	
2	9	11%	2.01	Availability of doctors throughout the OPD timings	○						●	○		
3	9	11%	2.02	Competency and skills of doctors	○	●						▽		
4	9	11%	1.91	Friendly and caring attitude of Doctors	●	○					●			
5	9	10%	1.73	Medical treatment received is fruitful	●	●	●	●	▽		○	○	▽	
6	9	10%	1.81	Correct assessment of patient's health condition by the Doctor	○	●		●				●		
7	9	10%	1.83	Medical team promptly handles unforeseen/ unexpected complications arising in the process of medical treatment		●	●	●	▽		●			
8	9	10%	1.81	Ease of consulting with doctors (within a reasonable waiting time)	●	●					●			▽
9	9	9%	1.63	Quality of food available in Canteen is good						●			●	
10	9	9%	1.68	Adequate information on Website										●
				Importance Rating Sum (Importance x Relationship)	370	492	178	269	98	82	416	164	100	94.1
				Relative Weight	16%	22%	8%	12%	4%	4%	18%	7%	4%	4%
				Max relationship value in Column	9	9	9	9	9	9	9	9	9	9

Relationships/Weights: Strong (●)/9, Medium (○)/3, Weak (▽)/1

Figure 2. Association between "Hows" and "Whats" in QFD

	Variables	QFD Relative Weight
1	Doctors attitude towards patients	16%
2	Competency and skills of doctors	22%
3	Availability of desired modern machines and equipments	12%
4	Waiting time for having treatment	18%

Table 2. Improvement Plan

Taguchi method makes use of orthogonal arrays (OA) to enable the study of a large number of factors with smaller number of experimental runs. The use of OA significantly reduces the number of experimental runs without compromising validity of experiments thus reducing costs and time. Using minitab software (version 19), the appropriate orthogonal array (OA) for our experiment was L_{12} having 4 factors and 2 levels as presented in Table-4 below.

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.14, May : 2024

Taguchi Factors	"Hows" in the QFD	Level-1	Level-2
A	Doctors attitude towards patients	Spending very limited time with patients	Highly Supportive
B	Competency and skills of doctors	Moderate	Excellent
C	Availability of desired modern machines and equipment	Partially Available	Infrastructure at par with global standards
D	Waiting time for having treatment	Standard	Low

Table-3. Taguchi Factors and Levels

In order to collect patient/customer responses, a Taguchi experiment with 12 runs was conducted with the design used as L_{12} orthogonal array. Responses taken from the customers were their perceptions for each level combination. For example, in the first run, customers were asked to gives their perception if the hospital would deploy Level-1 with the four factors mentioned above:

Factor	***Level-1***
A	*Spending very limited time with patients*
B	*Moderate*
C	*Partially Available*
D	*Standard*

Customers were asked to use a likert scale while filling the questionnaire representing what their perception is about the entire service design. The optimization approach adopted in this research used the signal-to-noise ratio to identify those control factors that reduce variability. The signal-to-noise ratio measures the changes in response variable relative to the nominal or target value under different noise conditions. This section mentions different parameters that were chosen for conducting the experiments.

Run	A	B	C	D	Avg. Patient Response
1	1	1	1	1	1.12
2	1	1	1	1	1.12
3	1	1	2	2	1.60
4	1	2	1	2	4.32
5	1	2	2	1	4.32
6	1	2	2	2	4.75
7	2	1	2	2	1.78
8	2	1	2	1	1.78
9	2	1	1	2	1.58
10	2	2	2	1	4.80
11	2	2	1	2	4.80
12	2	2	1	1	4.60

Table-4. L_{12} Orthogonal Array

Final responses from customers forming a completed Taguchi L_{12} orthogonal array are shown in Table-4. As part of standard Taguchi's analysis, the response table and graphics are then created to find optimal responses. Section 4.1 shows optimal combination of factors at appropriate level to get the optimized customer responses.

4.1 Discussion on MINITAB Output

The analysis of variance (ANOVA) and S/N ratio were evaluated to determine the effect of each selected factor on the optimization criteria. For these analyses, the Minitab-19 software was utilized. The results of the ANOVA for determination of significant factors are shown in Section 4.1.1 and 4.1.2. In general, the F values indicate the importance of these variables in the Taguchi's Orthogonal array analysis.

4.1.1. Linear Model Analysis: SN ratios versus A, B, C, D

Estimated Model Coefficients for SN ratios

Term	Coef	SE Coef	T	P
Constant	8.3389	0.1574	52.973	0.000
A 1	-0.7435	0.1574	-4.723	0.003
B 1	-4.9041	0.1574	-31.153	0.000
C 1	-0.6556	0.1574	-4.165	0.006
D 1	-0.4831	0.1574	-3.069	0.022

Model Summary

S	R-Sq	R-Sq(adj)
0.5101	99.39%	98.98%

Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	0.211	5.805	5.805	22.31	0.003
B	1	246.508	252.523	252.523	970.52	0.000
C	1	3.780	4.514	4.514	17.35	0.006
D	1	2.451	2.451	2.451	9.42	0.022
Residual Error	6	1.561	1.561	0.260		
Total	10	254.511				

4.1.2 Linear Model Analysis: Means versus A, B, C, D

Estimated Model Coefficients for Means

Term	Coef	SE Coef	T	P
Constant	3.04548	0.03233	94.201	0.000
A 1	-0.17786	0.03233	-5.501	0.002
B 1	-1.55286	0.03233	-48.032	0.000
C 1	-0.12619	0.03233	-3.903	0.008
D 1	-0.09286	0.03233	-2.872	0.028

Model Summary

S	R-Sq	R-Sq(adj)
0.1048	99.74%	99.57%

Industrial Engineering Journal
ISSN: 0970-2555
Volume : 53, Issue 5, No.14, May : 2024

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	1	0.0000	0.3321	0.3321	30.27	0.002
B	1	25.2328	25.3193	25.3193	2307.08	0.000
C	1	0.1400	0.1672	0.1672	15.24	0.008
D	1	0.0905	0.0905	0.0905	8.25	0.028
Residual Error	6	0.0658	0.0658	0.0110		
Total	10	25.5292				

4.1.3 Response Table for SN Ratios

Larger is better

Level	A	B	C	D
1	8.804	3.811	8.909	9.116
2	9.082	13.243	8.995	8.822
Delta	0.278	9.432	0.085	0.294
Rank	3	1	4	2

4.1.4 Response Table for Means

Level	A	B	C	D
1	3.222	1.572	3.284	3.324
2	3.223	4.598	3.172	3.138
Delta	0.001	3.026	0.112	0.186
Rank	4	1	3	2

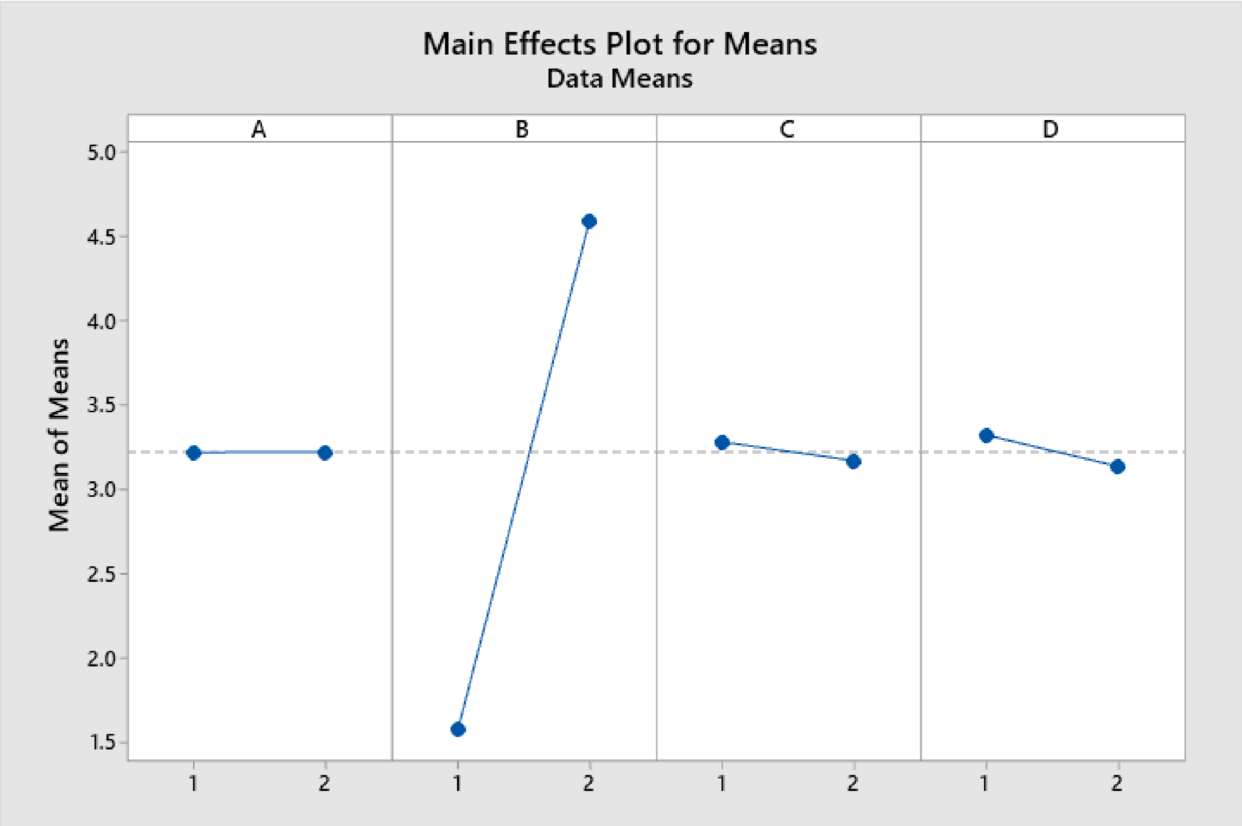

Figure 3. Main Effects Plot for Means

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Volume : 53, Issue 5, No.14, May : 2024

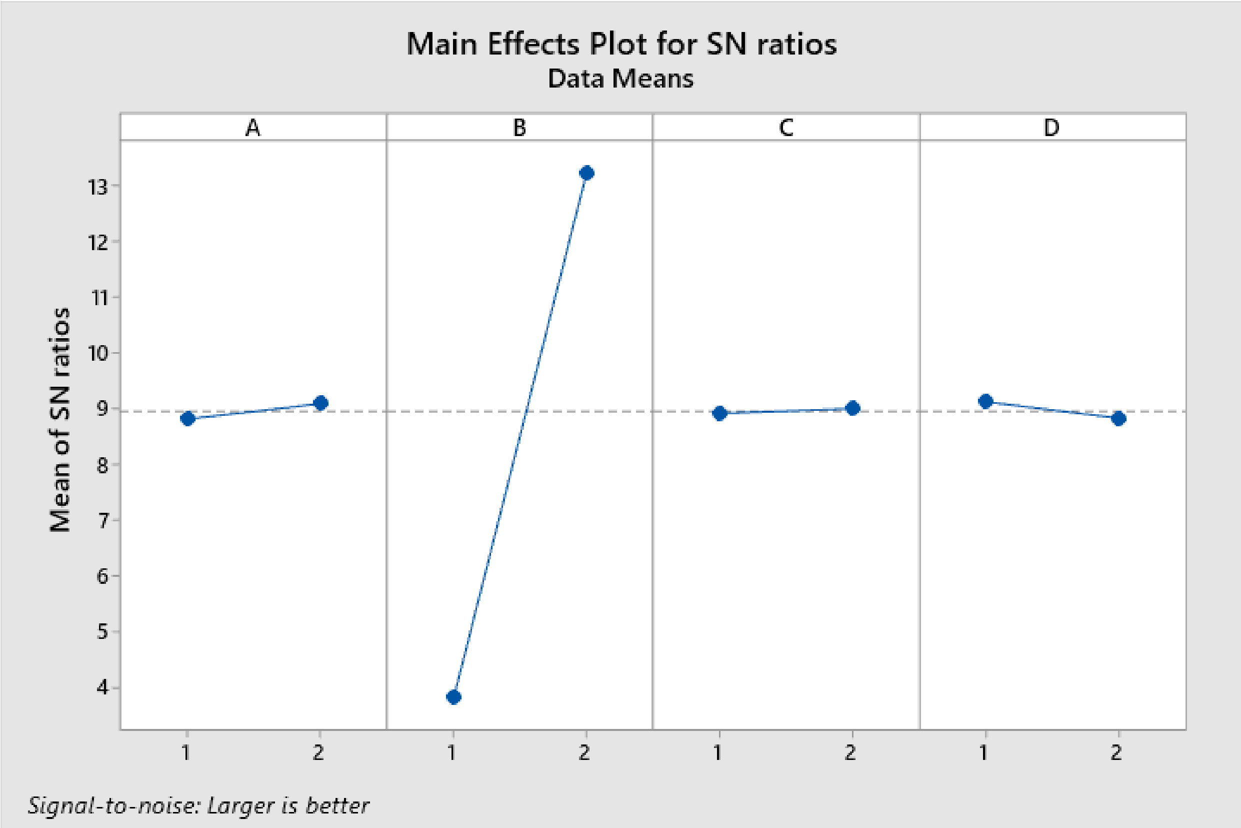

Figure 4. S/N Taguchi response graph

4.1.5 Prediction

S/N Ratio	Mean
15.0016	4.96667

5. Findings

The customer gaps were computed and 10 variables with negative gaps (unsatisfactory) were identified (Table-1). All negative gaps constituted the "whats" component of QFD and the gap values are treated as their respective weights. A list of factors was then determined by considering the association between "hows" and "whats" in QFD and computing importance weights for critical "hows". The factors with relatively higher weights in QFD matrix were selected for obtaining the optimum levels of these four factors and lower weights were rejected due to having insignificant influence upon patients (Table-2).

In the variance analysis for S/N ratios under Section 4.1.1, SS stands for sum of squares (factors) between groups and the sum of squares in the group (error). MS stands for sum of squares divided by the number of degrees of freedom of the mean square, F stands for test statistics, p stands for significance level. If p value is smaller, the influence is more significant. When the general P value is less than 0.05, it just means the factor has a significant effect. Thus, the factors which are less than 0.05 in the analysis of variance (for S/N ratios) are significant. Similar conclusion can be drawn with regard to section 4.1.2, where the factors A, B, C and D are significant.

The relative strength of a factor can be measured through its coefficient's absolute value. The largest coefficient factor has the largest impact on a given response characteristic. In Taguchi designs, the magnitude of the factor coefficient usually reflects the factor ranks in the response tables. The ranks

in a response table (Sections 4.1.3 and 4.1.4) identify which factors have the largest effect. Ranks 1 is given to the factor with the largest delta value. The factor with the second largest delta is given rank 2, and so on. Thus, in the response tables for signal-to-noise ratios and means, competency and skills of doctors (factor B) is ranked 1 and waiting time for having treatment (factor D) is ranked 2. However, different ranks are given to factors A and C in the response tables for signal-to-noise ratios and means. It can be easily inferred from the results that competency and skills of doctors are most important to maintain service quality in a hospital. Waiting time also plays a significant role in securing customer faith. However, the attitude of doctors towards patients and availability of desired modern equipment are other significant requirements of customers to achieve the desired service quality.
The study of factor levels in response table for signal-to-noise ratio (section 4.1.3) indicates the optimum level of factors for an improved service quality in healthcare, e.g. for a “larger is better” S/N ratio, level-2 has been found appropriate for factors A, B and C and level-1 is found appropriate for factor D. It is quite justifiable to say that results obtained from the analysis are quite close to the reality as every patient would seek for a highly skilled and supportive medical practitioner along with the availability of all the desired equipment and machines in the hospital premises itself for diagnostic purposes so that there is less patient wait in all sense and better satisfaction scores.
In the model summary table shown in section 4.1.4, S represents the deviation of data values from the fitted values. S is measured in the units of predicted variable. The lower the value of S, the better the model explains the response. R^2 is the percentage of variation in the response that is explained by the model and adjusted R^2 is the percentage of the variation in the response that is explained by the model and is adjusted for the number of predictors in the model relative to the number of units/observations. The higher the value of R^2, the better the model fits the observed data.
Finally, the output in section 4.1.5 shows the predicted values for the signal-to-noise ratio (S/N) and the mean that corresponds to the factor levels that have been selected. The S/N ratio is predicted to be 15.0016 and the mean is predicted to be approximately 4.97. The follow-up runs can be planned using these factor settings to test the accuracy of the model.
Thus, signal-to-noise ratio gives a sense of how close the performance of the variables under study is to the standard outcomes and practices in the field of study. While considering signal-to-noise ratios as a measure of variability, higher S/N ratios indicate lower levels of variability. The larger the S/N, the less the total rate of deviations from the standard and smaller the quality loss.

6. Conclusion

In healthcare, the patient needs and wants are different since the applications are patient-based and there is no product, but rather a service. The heterogeneity and intangibility of services in healthcare makes it rather more critical to define and understand the service process requirements. The overall improvement of efficiency in a non-commercial sector like healthcare can only be quantified in personal terms such as comfort levels, emotional & cognitive factors and waiting times. In this context, the present analysis very clearly indicates the significance of competency and skills levels of doctors for a better customer satisfaction score in a hospital. Waiting time also plays a significant role in securing customer faith. The framework for incorporating SERVQUAL-QFD-Taguchi has been successfully implemented in this paper. The study illustrates how an existing approach of SERVQUAL, QFD and Taguchi’s design of experiments integration can be applied to hospitals. The integrated approach systematically translates the customer's needs and desires into the voice of engineer data and Taguchi’s method determines the design's optimum parameter values. The integration of the three culminates into factors leading to the attributes of service quality that have a strategic significance on customer satisfaction and the need for qualified professionals in healthcare and how these are linked to the strategic service needs of patients.

Thus, Taguchi methods show immense potential in healthcare applications and is able to give more definitive evidence of process and outcome links. For instance, the use of Taguchi's orthogonal arrays significantly reduces the number of experimental runs without compromising the validity of experiments thus reducing costs and time. Further, Taguchi's signal-to-noise ratios give an idea of how close is the performance to the ideal. By optimizing the signal-to-noise ratio, quality-engineering activities can be aimed at identifying near-optimum levels of factors that help improve service quality due to prioritization of service requirements from the patient's viewpoint. Also, correlating technical requirements with customer satisfaction and the measurement of outcomes in terms of cost and quality gives a pertinent strategy to design service process matrix and makes this approach a powerful tool for healthcare sector.
As far as the research limitations are concerned then these are mainly derived from the quali-quantitative approach pertaining to SERVQUAL model in healthcare setting and the difficulty to map all the variables into various SERVQUAL dimensions as it may not fully represent the respondent's perception. SERVQUAL-QFD based approach may cause biases when compared to statistically validated protocols, particularly, with regard to the analysis of voice of customer data. The other limitation stems from the statistical literature that Taguchi's approach assumes absence of interactions in the experimental designs and would require a larger number of experiments to study the various control factors (Park J.K., 2001).
The research findings and limitations lead to a more guided way for future research. First, that the perceptions of key stakeholders could be obtained and analyzed in order to derive more meaningful insights. Such multiple sources of feedback on the delivery of services would provide a more comprehensive view of the service quality and the extent to which it permeates in service organizations. Secondly, the healthcare services are comprised of a number of distinct services and each of these services is different in terms of its cost to the customers and its operational requirements. The quality of services delivered in different healthcare settings are significantly affected by the cost of treatment, expertise of doctors, staff and other modern facilities and it, therefore requires further investigation to bridge the service quality gaps. Third, the subjectivity of services and interdependence of factors would require the inclusion of interactions in the experimental design and the researchers, practitioners in the field of optimization may come forward to address such issues and apply Taguchi's technique for the improvement of various parameters in different service processes.

6. References

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