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Quality and Reliability Engineering in Service Industry: A Proposed Alternative Improvement Framework

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Abstract. Quality and reliability engineering technique are widely used as improvement tools in manufacturing industries, involving the design experiments, quality function deployment (QFD), and survival analysis, focuses on improving the lifecycle of products. However, started at early last decade, some researches in improving the service lifecycle in some service industry consider to implements design of experiment in service industry, followed by other tools such as QFD, and the reliability engineering tools. This research proposed alternatives incorporated quality and reliability engineering methods in evaluating and improving the lifecycle of service. Starting with evaluating the weaknesses of service using SERVQUAL method, finding the improvement plan by implementing QFD, designing the robust service design using Taguchi designed experiment methods, and then implementing survival analysis for ensuring the reliability of designed services. This framework has successfully implemented in designing and evaluating existing airport service system with some recommendation generated in.

Keywords: Service life cycle, SERVQUAL, QFD, Taguchi robust design, survival analysis

1. Introduction

Continuous improvement in service industry has important role in raising up customer satisfaction and the way to keep the service deployed excellently. Some research shows that the service design proposed by various method become critical point, not because of its outstanding solution, but things that are more important are how to keep the service life cycle longer, i.e. keeping customer satisfaction survive over time. In addition, evaluation of deployed service design needs more comprehensive by considering innovative tools to strength the improvement path.

Starting by measuring gaps between expected and perceived service, the SERVQUAL method proposed by [1] and [2] perfectly identifies service attributes that should be improved. The negative gaps opens the opportunity for improvement at corresponding SERVQUAL attributes. Once the improvement plan found, the QFD (quality function deployment) helps the service provider in generating solution alternatives with some weighting calculation for selecting the best ones. (see [3] and [4]). The combination between SERVQUAL and QFD for service improvement has successfully implemented in various business field.

Otherwise, regardless of evaluating deployed service using SERVQUAL, some researcher proposed to design the service directly, especially for new type of services. Engineering tools for designing service includes kansei method [5], and robust taguchi design ([6] and [7]) commonly mentioned as robust quality engineering [8]. These methods focus on generating treatment in service refer to what the customer has desired, including the emotional aspect.



Once the service design has deployed and re-visiting service evaluation process, periodical SERVQUAL based survey still performed by service provider in order to get the feedback and re-evaluate the negative gaps. Of course, those gaps in every SERVQUAL survey taken would gives dynamic responses from customers since every survey samples different respondent. This tends to the continuous change in every time service provider proposed the improvement plan, in other words, the service design that recently been deployed but must be replaced with new ones in only short term period. Otherwise, service provides has not get enough information when the service design should been replaced with the new one, or how long the deployed service felt unsatisfied by customers in certain period. If a deployed service still gives satisfaction for customer, service provider should not rashly replace it. This problem can be solved by implementing reliability-engineering concept in evaluating how long a deployed service will gradually tends to un-satisfaction of customers.

The aim of this research is proposing alternative method for continuing the improvement and sustaining the service deployment in the term of service lifecycle. First, starting by evaluating existing service, then generate the improvement plan, followed by designing the robust service design by using quality engineering tools, finished by predicting how long the designed service will remain satisfy the customer by adopting reliability engineering principles, and then back to first step above.

2. Literature review

In this paper, quality and reliability methods are proposed to implement, capturing the dynamic of customer satisfaction with SERVQUAL, then improve it by using hard engineering tools.

2.1. SERVQUAL and QFD

Many research implement the integration of SERVQUAL and QFD in evaluating and improving service, as in [3] and [4]. This method simply measure five gaps for evaluating service performance, including gaps between perceived and expected attributes based on SERVQUAL dimensions [1]. Figure 1 shows the SERVQUAL model.

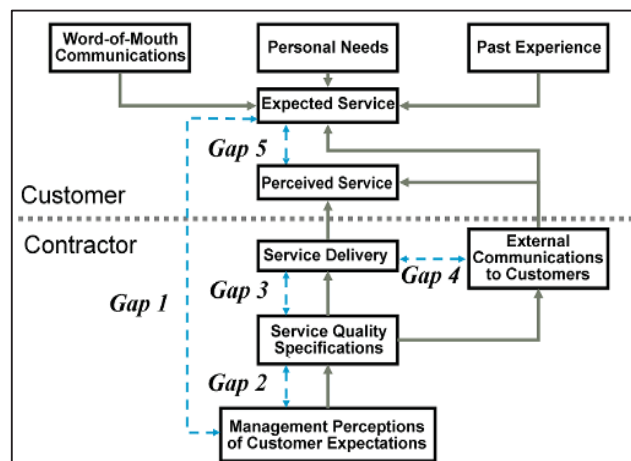


Figure 1. SERVQUAL gaps, calculating by difference between expected and perceived service (taken from [1])

Negative gaps represents unfulfilled customer expectation tends to unsatisfactory. The QFD then take place accommodating those negative gaps (as “what” part), and translate it to the house of quality then generating the alternative solutions (in “how” part). Weighting process between “what” and “how” part in QFD calculates the relationship between gaps and solution, and prioritize them.

2.2. Taguchi robust design

The Taguchi robust design has widely used in hard engineering, especially in selecting best combination of machining parameter to maximize or minimize the desired responses. Many researches successfully adopted Taguchi method, and the results have been confirmed for improvement methods options in the field of quality engineering (see [8] and [9]), including some Taguchi model modifications [10]. Based

on design experiments method in service by [11], Taguchi simplifies the procedures and number of experiment run by adopting orthogonal array experiment design and transforming experiment responses to the signal-to-noise ratio (SNR) characteristic. There are three types of SNR for optimizing the responses [8]; larger the better (as used in this paper), nominal the best, and smaller the better

$$SNR = -10 \log \left[\frac{1}{n} \sum_{i=1}^n \frac{1}{y_i^2} \right] \quad (1)$$

Ignoring the complex mathematical and statistical assumptions, Taguchi method accepted by practical users in many factories, including Service Company. [6] and [7] initiates to use Taguchi method in designing the service deployed to customers. Factors in Taguchi treated as service design attributes being improved, with the factors levels represents alternatives for solutions (see [12]). Treating factor level as solution alternatives, the experiment conducted by confirming the design to the customers. The customer's answer assumed as data responses in Taguchi, then optimizes it by using Taguchi's response table and graph. The selected factor level as optimization result then applied and adopted by service provider as new service design

2.3. Survival analysis

Survival analysis or commonly mentioned as reliability analysis, often used for predicting lifetime of an electrical or mechanical based component [13]. Implementation of this method started by conducting reliability experiment i.e. measuring the lifetime of component from firstly started until failure condition reached, then these data are fitted to certain statistical probability density function. Lifetime prediction stated as probability of survival in certain continuous time, explained below;

- Measure the survival or reliability data t (age of components, based on reliability experiment)
- Fit the data to probability density function (PDF) $f(t)$, the most appropriate PDF then selected for failure prediction
- The fitted PDF then used for predicting time to reach the failure condition and mean time to failure (MTTF). This prediction is stated as reliability function $R(t)$, where

$$R(t) = P(t > T) = 1 - F(t) \quad (2)$$

$$F(t) = \int_0^t f(t) dt \quad (3)$$

$$MTTF = E(t) = \int_0^{\infty} R(t) dt = \int_0^{\infty} t f(t) dt \quad (4)$$

Treating age of component t before failure as customer satisfaction before unsatisfactory condition, [14] and [15] have performing this survival analysis applied to customer satisfaction. Then, completing those both paper, [16] even was fitting Bayesian mixture probability density function for combining satisfaction variables with duration of customer being experience the service. Those research shows that the survival analysis as part of reliability engineering has successfully applied to evaluate of service duration before "failure"; in this case, failure represents customer unsatisfactory.

3. Proposed framework

Incorporating the SERVQUAL, QFD, Taguchi robust design, and survival analysis becomes framework for improving service deployed to customers, started from identifying step, improving, designing, and evaluating. These steps form the cycle or continuous improvement in terms of service lifecycle. Figure 2 shows this cycle, and explained below;

- Creating questionnaire, based on SERVQUAL attributes and dimensions to evaluate existing service deployed to customer. Questions includes the expected and perceived attributes answered by respondent, and the difference between them represents customer gap (fifth gap)
- Calculate the customer's gap. All negative attributes gaps will lead for next improvement.
- The Quality Function Deployment (QFD) take place in accommodating all negative gaps, store in in the "what" part, then generating solution as the "how" part works in QFD. This steps

produce the improvement plans, and QFD will weights and prioritizes it for selecting critical solutions related to most negative gaps

4. Selected improvement plan then forms the factors in Taguchi design. Each factor consists of two levels, i.e. options for each factor to be deployed in service design. Taguchi method require each factor levels (options) must be mutually exclusive without some overlap in it.
5. Designing the deployed service, by using optimized Taguchi robust design. All the factors and their levels assigned to Taguchi's orthogonal array, as if it an experimental design. Conducting experiment by creating questionnaire consist of all combination of factors levels, refer to orthogonal array provided before. Respondent will answer the questionnaire; this activity represent the perception of customer in order to involve them in designing the service.

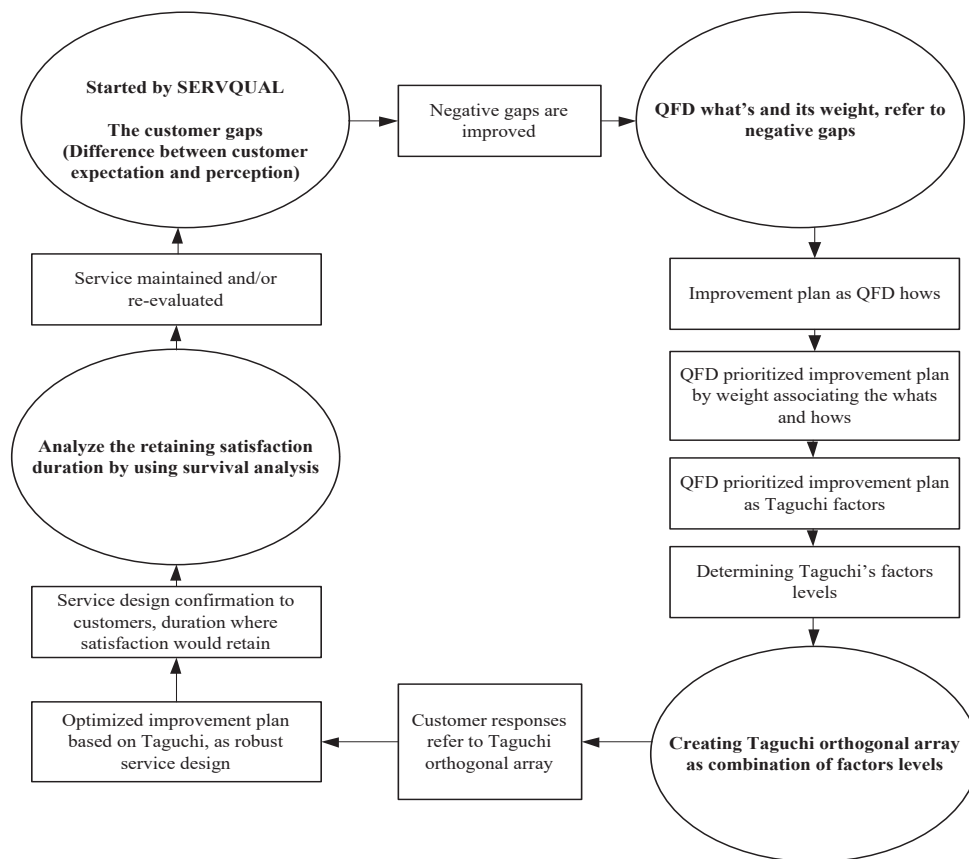


Figure 2. Framework for service continuous improvement (modified form [12] and [16])

6. Optimized improvement plan. Analyzing Taguchi experiment data, transforming it to Taguchi's S/N ratio, and finding the best combination of service design option, based on what customer has answered and confirmed. Optimization process uses Taguchi's response graph and table
7. Selected improvement plan as result of Taguchi then deployed to customers. Service provider execute this step as part of their tasks, this plan plays the role as new service design.
8. Along with deployed new improvement plan, service provides evaluate the robustness of it, by using simple two points questionnaire, i.e.; how satisfy the customer with this designed service, and how long customer has been experiencing this designed service. The interaction between both questions are then measured and produced the survival data.

9. Survival data then captured by modeling them with statistical probability distribution. The best fitted probability distribution then uses for predicting the duration of being “failure”, i.e. the unsatisfactory condition of customer.
10. Once the failure condition reached, service provider should re-evaluate the deployed service design, by re-survey the customer based on SERVQUAL attributes and dimension. Then, these steps return to step 1 above.

4. Result and discussion

The framework in Figure 2, has been implemented in a case study where the object is airport service provider in Abdul Rahman Saleh airport, Malang, Indonesia (airport code MLG). Regularly, MLG airport services the passengers before and after they take the flight. Considering that MLG airport is small airport only for domestic flight, the service provider still treats the customer well and periodically improve the service. Follows steps above, result of improvement framework explained in this sub part.

Table 1. SERVQUAL attributes and their negative gaps

| SERVQUAL ATRIBUTES | Negative Customer Gaps |
|--|------------------------|
| Public facilities look and cleanness | -0.41 |
| Waiting room layout and comfortable | -2.67 |
| Availability of mini store or mart | -1.27 |
| Communications facilities (Wi-Fi, free internet kiosk, etc.) | -0.54 |
| Sprightly entrance door officer | -0.85 |
| Willingness to prompted service from officer | -0.44 |
| Complete disability and woman facilities | -1.69 |
| Sufficient number of waiting seat | -1.14 |

4.1. SERVQUAL and QFD analysis

The questionnaire design accommodates the SERVQUAL dimensions and attributes similar to [1] with Likert scale answer. There are 20 attributes in 5 dimensions, measuring gap between expected and perceived service (customer gap). Table 1 shows attributes with negative customer gap, which should be improved by service provider. Assigning all negative gap attributes into house of quality in QFD (“what” part), service provider has generate solution alternatives as “how” part (see Figure 3). Calculating relationship weight between “what” and “how”, improvement plans (i.e. selected “how”) then chosen and assumes them as factors in Taguchi method. Only selected plans that should be confirmed to customers because of their critical perception considered to be assigned in Taguchi.

4.2. Taguchi robust design service

Factors in Taguchi method represent the improvement plan selected from QFD (see Table 2). Each factors divided into two levels improvement option, where the mutually exclusive between levels should be fulfilled; this will ensure there will be no overlaps in each solution option. Next, factors are assigned to orthogonal array design of experiment as shown in Table 3, consist of factor level combination that should be conducted. Additional survey to customers are conducted as well as carrying out Taguchi experiment, and customer answers for Taguchi questionnaire in Table 4 represent experiment responses. By calculating Taguchi S/N ratio as in table 5, optimized solution was reached. This result represents the new service design, i.e. grouped seat based on airline name, ergonomics non minimalist seat design equipped by electricity plug in it, and provide some minimart and vending machine at certain locations. This service design completes another improvement plan that are not selected in Taguchi. Next, service provider deploy the new service design obtained from Taguchi method. It should have more robustness to customer satisfaction because they are involved in the decision of new service design. Once the new service design deployed, service provider then evaluate the lifecycle of it, in other words, service provider conducting periodical survey where the questions lead to the data analyzed in survival analysis

| Relative Weight | Weight / Importance | Demanded Quality (a.k.a. "Customer Requirements" or "Whats") | Quality Characteristics (a.k.a. "Functional Requirements" or "Hows") | | | | | | | | | |
|---|---------------------|--|--|------------------------------------|--|-----------------------------|---|------------------------------------|---------------------------------------|---------------------------------------|---|-----------------------------|
| | | | maximizes waiting room layout | standardize the airport facilities | provide mini store for snack and beverages | speed up the check in queue | periodically evaluate officer's service | provide smartphone charger station | upgrade the facilities for disability | periodically maintain internet system | additional person for speeding up service | maximizes waiting room seat |
| 26.4 | 24.4 | Waiting room layout and comfortable | ⊕ | | ⊖ | | | | | | | ⊖ |
| 13.9 | 12.8 | Public facilities look and cleanness | | ⊖ | ⊖ | | | | ⊖ | | ⊖ | |
| 13.5 | 12.5 | Availability of mini store or mart | | | ⊖ | | | | | | | |
| 12.7 | 11.8 | Sprightly entrance door officer | | | | ⊖ | ⊖ | | | | ⊖ | |
| 11.1 | 10.3 | Complete disability and woman facilities | ⊖ | ⊖ | | | | ⊖ | ⊖ | | | |
| 7.7 | 7.1 | Sufficient number of waiting seat | ⊖ | ⊖ | | | | | ⊖ | | | ⊖ |
| 7.6 | 7.1 | Communications facilities | | ⊖ | | | | ⊖ | | ⊖ | | |
| 7.0 | 6.5 | Willingness to prompted service from officer | | | | | ⊖ | | | | ⊖ | |
| Max Relationship Value in Column | | | 9 | 9 | 9 | 3 | 9 | 9 | 9 | 9 | 9 | 9 |
| Weight / Importance | | | 340.0 | 271.2 | 242.6 | 38.2 | 177.6 | 123.0 | 164.9 | 68.7 | 184.2 | 306.7 |

Figure 3. The House of Quality in QFD analysis

Table 2. Taguchi robust design factors and levels

| Factor code | Taguchi Factors (Selected from QFD) | Mutually exclusive difference between factor levels | Level 1 (solution option 1) | Level 2 (solution option 2) |
|-------------|--|---|---|---|
| A | maximizes waiting room layout | seat layout | grouped seat based on airline name | additional seat by moving indoor garden outside waiting room |
| B | maximizes waiting room seat | Waiting room capacity and seat design | minimalist seat design, centralized electricity plug | ergonomics non minimalist seat design, equipped by electricity plug in it |
| C | provide mini store for snack and beverages | kiosk design | provide centralized minimart at 1st floor (check in room) | provide some minimart and vending machine at certain locations |

Table 3. Orthogonal array as designed experiment

| Trial No. | Factors | | | Customers Response Mean | S/N ratio (larger he better) | Larger the better S/N ratio = $-10 \log \left[\frac{1}{n} \sum_{i=1}^n \frac{1}{y^2} \right]$ |
|-----------|------------------|---|---|-------------------------------|------------------------------------|--|
| | A | B | C | | | |
| | <i>Column no</i> | | | | | |
| | 1 | 2 | 3 | | | |
| 1 | 1 | 1 | 1 | 2.57 | 4.9576 | |
| 2 | 1 | 2 | 2 | 4.10 | 11.5353 | |
| 3 | 2 | 1 | 2 | 2.67 | 5.3917 | |
| 4 | 2 | 2 | 1 | 3.83 | 10.7788 | |

4.3. Survival analysis

Last steps in this proposes framework, evaluating the service lifecycle by adapting survival analysis, by measuring time or duration of customer being experienced the service until unsatisfied condition (See Table 6). Unsatisfied has been reached when customer answer second question in scale 1 to 5; otherwise, scale 6 to 10 represent satisfied condition. Duration of being unsatisfied then measured in years, as the customers could distinguish their satisfaction level by years of service experience.

Table 4. Taguchi questionnaire design

| According to your expected service, please rate these service option combinations from 1 (unwanted) until 5 (most wanted) | | | | |
|---|--|---|--|------------------------------|
| Treatment number | A: Waiting room layout | B: Waiting room seats | C: Mini stores | Your response (scale 1 to 5) |
| Treatment 1 | L1: grouped seat based on airline name | L1: minimalist seat design, centralized electricity plug | L1: provide centralized minimart at 1st floor (check in room) | |
| Treatment 2 | L1: grouped seat based on airline name | L2: ergonomics non minimalist seat design, equipped by electricity plug in it | L2: provide some minimart and vending machine at certain locations | |
| Treatment 3 | L2: additional seat by moving indoor garden outside waiting room | L1: minimalist seat design, centralized electricity plug | provide some minimart and vending machine at certain locations | |
| Treatment 4 | L2: additional seat by moving indoor garden outside waiting room | L2: ergonomics non minimalist seat design, equipped by electricity plug in it | L1: provide centralized minimart at 1st floor (check in room) | |

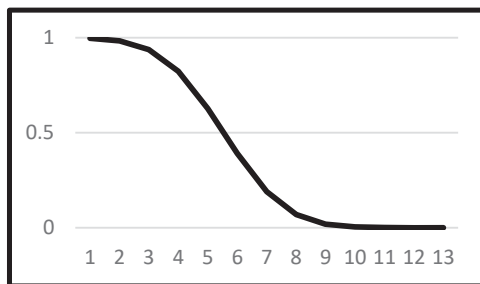
Table 5. Taguchi optimization result

| Level | Factors | | |
|------------|---------|----------|---------|
| | A | B | C |
| 1 | 8.246** | 5.175 | 7.868 |
| 2 | 8.085 | 11.157** | 8.463** |
| difference | 0.161 | 5.982 | 0.595 |
| Rank | 3 | 1 | 2 |

** selected factor level combination being deployed

Table 6. Survival analysis questionnaire

| According to your experience for this service, please answer these questions numerically | | | | | | | | | | |
|--|--|--|--|-------------|---|---|---|---|---|----------------------|
| How long you have been experiencing this service (in years) | | | | years | | | | | | |
| How satisfy are you at current day | | | | unsatisfied | 1 | 2 | 3 | 4 | 5 | 6 7 8 9 10 satisfied |

**Figure 4.** Survival function. $R(t)$ as Y axis, duration (years) as X axis. $R(t)$ represent probability of service being survive at certain period t

Fitting probability distribution for duration data, normal distribution selected as best fitted, so prediction of service lifecycle before unsatisfied condition are based on this, as in (5) and (6).

$$f(t) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right] \quad (5)$$

$$R(t) = \int_t^{\infty} f(t)dt \quad (6)$$

Mean time to failure in (4) are calculated, average duration of being fall down into unsatisfied is around 5.541 years. Continuing with graphing the survival function $R(t)$ as in Figure 4, recommendation for next new improved service design should be taken by service provider at the around fifth years after current service has been deployed.

5. Conclusion

This proposed framework has successfully implemented with case study. Existing airport service has evaluated, and new service design has generated for ensuring customer satisfaction still in high condition until certain period where some re-evaluation and re-designing should be performed. Once the customer satisfaction fails into “failure” condition, then this framework could be re-implemented continuously.

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