Failure Modes and Effects Analysis in A Hyper-mart Store

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Abstract

Service systems should be designed for the realization of customer processes and achieving the service performance. An effective service system should be designed to prevent the failures from occurring and reduce the risk of service failures. In this regard, Failure Modes and Effects Analysis (FMEA) is a systemized group of activities that intent to recognize and evaluate the potential failure of a product or service, identify actions that could eliminate or reduce the likelihood of the potential failure occurrence and document the entire process. This paper applies the FMEA in a hyper-mart store in southern Taiwan from the viewpoints of preventing the failure from occurring and reducing the risk of failures before the service is delivered. Results show that “Unstable supply of goods/merchandise”, “Air-conditioning malfunction”, “No goods/merchandise on designated shelf of the sales floor”, “Slowness of cashier speed”, “Warranty/repair failure in timeliness, items, charge”, “Nonconforming quality of goods/merchandise”, and “Unable to find first line server in the sales floor” are the seven most critical potential failure modes in the research hyper-mart store. Some managerial implications are also provided.

Key words: Service System; Failure Modes and Effects Analysis; Risk Priority Number; Hyper-mart Store.

1. Introduction

Service Industry has been a dominating role in the developed and developing countries in the past two decades. Service industries often provide social/personal services, transportation, finance, advertising, repair, distribution, or communication support for manufacturing industries (Ma et al. [1]). By all accounts, more than half of the developed countries’ gross domestic product (GDP) is in the service sector (Pilat [2]; Menor et al. [3]). Specifically, according to the Department of Statistics, Ministry of Economic Affairs, R.O.C. [4], service related industries in Taiwan account about seventy percent of the country’s total GDP.

Concurrent to the economic growth, the globalization of services and rapid technological progress, afforded by information and communication technology, are increasing the pressures for service firms to compete on new offerings (Menor et al. [3]). The management
of new service development has become an important competitive concern in many service industries (Fitzsimmons and Fitzsimmons [5]). In the mean time, the service assurance and service quality should be emphasized and improved to upgrade the service abilities on the existing offerings.

To establish competitive advantage for either new or existing offerings, service design is an upstream management from the origin. The idea of service design is to design high quality into the service system from the outset, to consider and respond to customers’ expectations in designing each element of the service (Edvardsson [6]). The goal of service design can be described in terms of attracting and keeping customers who are satisfied, loyal and speak well of the company, but who are also profitable. Thus, the service sector aims at optimally allocate the limited resources in designing the service system that can satisfy customers’ needs and accrue high productivity for the service firms.

Moreover, economic development and the change in the standards of living have caused changes in human consumption patterns. Human needs are satisfied with not only physical goods but also services (Ma et al. [1]). Therefore, from the service organization’s perspective, designing a service means defining an appropriate mix of physical and non-physical components (Goldstein et al. [7]) and the service systems should be designed for the realization of customer processes and achieving the service performance. In this regard, most of the existing research considered the effects of process factors, such as customers, employees, and suppliers, to the service results (Ma et al. [1]; Brentani [8]). Others suggested the role of service concept, in service design and development, to define the how and what of service design and help linking the customer needs and an organization’s strategic intent (Edvardsson [6]; Goldstein et al. [7]). Though existing research proposed the paradigm model for designing service systems, an effective service system should also be designed to prevent the occurrence of and reduce the risk of service failures.

2. Service Failures

A Service failure occurs when customers’ expectations are not met (Mueller et al. [9]; Weber and Sparks [10]). Similar to service quality and satisfaction, it is customers’ perception that determines whether a service failure occurred even if the companies with the best strategic plans and the tightest quality control procedures and the service has been performed according to the blueprint established by the service provider (Goldstein et al. [7]; Weber and Sparks [10]). That is, though, zero defects is the desired objective for most firms, it is unlikely organizations will achieve this goal. This is particularly true of service industries where the multi-dimensional nature of the service encounter creates an environment where service failure is almost inevitable (Mueller et al. [9]).

To compensate and alleviate the effects of the service failure, researches on service failure recovery strategies and actions were proposed in many literatures (Goldstein et al. [7]; Mueller et al. [9]; Hocutt and Stone [11]; Mattila and Patterson [12]; Maxham [13]; Miller et
Whereas, Halstead et al. [17] mentioned that nothing is better than performing a service to a customer’s satisfaction the first time, nothing is worse than failing to detect a problem or failing to obtain information from a dissatisfied customer. Thus, a systematic approach that could identify and prioritize the potential service failure modes with the corresponding risks during the service design stage is very important and needed.

In this aspect, Failure Modes and Effects Analysis (FMEA) is a systemized group of activities that intent to recognize and evaluate the potential failure of a product or process, identify actions that could eliminate or reduce the likelihood of the potential failure occurrence and document the entire process (Johnson [18]). It improves operational performance of the production cycles and reduces their overall risk level. FMEA is a tool widely used in the automobile, aerospace, aviation, chemical, and electronics industries to identify, prioritize, and eliminate known potential failures, problems, and errors from systems under design before the product is released (Rhee and Ishii [19]). Literatures regarding to the FMEA in service industries are not widely found, with few on medical surgery, health related industries, organizational artifacts, or nuclear power plant (Guimarães and Lapa [20]; Guimarães and Lapa [21]; Busby et al. [22]; Hollick and Nelson [23]; Monti et al. [24]; Radermacher et al. [25]; Scipioni et al. [26]; Tellefsen [27]).

3. Research Goals

This paper applies the FMEA in a chain hyper-mart store in southern Taiwan from the viewpoints of preventing the failure from occurring and reducing the risk of failures before the service is delivered. The service system of the hyper-mart store is decomposed into four sub-systems: service facility, pre-service, in-service, and post-service. Each sub-system involves several sub-processes or activities. In the FMEA procedures, first, the potential failure modes for each sub-process/activity are explored and listed by interviewing the managers of the selected store and analyzing the service blueprint for the hyper-mart store. The required data of severity rating (S), occurrence rating (O), and detection rating (D) are, then, collected by a questionnaire survey on the employees and managers of the selected store. Finally, the Risk Priority Number (RPN) for each corresponding failure mode is computed. The RPN’s are used to determine the risk of potential failures and prioritize the needed preventive actions and resource allocations before the service is delivered.

4. Failure Modes and Effects Analysis

Failure Modes and Effects Analysis (FMEA) is a reliability-analysis tool widely used in the manufacturing sectors, such as automotive, aerospace, and electronics industries, to identify, prioritize, and eliminate known potential failures, problems, and errors from systems under design before the product is released (Rhee and Ishii [19]; Nakajima et al. [28]; Price and Taylor [29]; Sankar and Prabhu [30]; Scipioni et al. [31]; Teoh and Case [32]; Teoh and
Case [33]; Xu et al. [34]). FMEA is intended to provide information for making risk management decisions (Pillay and Wang [35]). The goal of FMEA is to predict how and where systems, that were designed to detect errors and alert staff, might fail. It is an important method of preventive quality assurance (Wirth et al. [36]). If the potential effects of the errors are intolerable, action is taken to eliminate the possibility of errors or to minimize their consequences (Cohen [37]).

The FMEA procedures, shown in Figure 1, involve ten steps as described below (Johnson [18]; Pillay and Wang [35]). And a FMEA tabular form can be shown as Table 1 (Cotnareanu [38]; Lore [39]; Vandenbrande [40]).

1. Review the process: Develop a good understanding of what the system is supposed to do when it is operating properly. Use blueprints, schematics and flow charts to identify components and relations among components. Identify operational and environmental stresses that can affect the system.

2. Determine potential failure modes: Look at each component of the product/service and identify ways it could potentially fail.

3. List potential effects of each failure mode: List the potential effects of each failure next to the failure. If a failure has more than one effect, list each in a separate row.

4. Assign a severity rating for each effect: Categorize the hazard level (severity) of each failure mode. Give each effect its own severity rating (traditionally from 1 to 10, with 10 being the most severe).

5. Assign an occurrence rating for each failure mode: Identify operational and/or environmental stresses that increase the likelihood of the failure mode. Using this information to estimate the probability or determine how likely it is for a failure to occur and assign an appropriate rating (traditionally from 1 to 10, with 10 being the most likely).

6. Assign a detection rating for each failure mode and effect: List all controls currently in place to prevent each effect of a failure from occurring and assign a detection rating for each item (traditionally from 1 to 10, with 10 being a low likelihood of detection).

7. Calculate Risk Priority Number (RPN) for each effect: the RPN is calculated as the multiplication of the severity rating, the occurrence rating, and the detection rating.

8. Prioritize the failure modes for action: Determine if action needs to be taken depending on the RPN and decide which items need to be worked on right away.

9. Take action to eliminate or reduce the high risk failure modes: Develop recommendations to enhance the system performance. These fall into two categories. Preventive actions are taken to avoid a failure situation whereas compensatory actions to minimize losses in the event that a failure occurs.

10. Calculate the resulting RPN as the failure modes are reduced or eliminated: Recalculate the RPN for each failure mode after completing the initial corrective actions. Decide if enough actions are taken or go through another set of FMEA.

5. FMEA in the Hyper-mart Example and Discussions

To perform the FMEA systematically, the service system of hyper-mart store is decomposed into four sub-systems: service facility, prior-service, in-service, and post-service. Each sub-system involves several sub-processes or activities. Among those, service facility
involves sales floor facility, sales floor security, and sales floor surroundings. Prior-service involves incoming goods/merchandise activity and inventory activity. In-service involves customer choose/purchase flow and cashier flow. Post-service involves post-sale activity and warranty. The potential failure modes for each sub-process/activity are then explored and listed by interviewing the managers of the research store and analyzing the service blueprint for the hyper-mart store. In this regard, twenty three potential failure modes, in total, are structurally listed for further analysis.

To compute the risk priority number (RPN) that differentiate the effect of each potential failure modes, the required data of severity rating, occurrence rating, and detection rating are collected by a questionnaire survey. This survey was assisted by a chain hyper-mart store, which has four branch stores in southern Taiwan (We will call it T-store in the rest of the paper). By prior contact with the T-store and having their approvals, one hundred questionnaires were sent to the employees and the managers of the T-store. Among those, 6 are executive managers, 16 are middle/floor managers, and 78 are first-line servers. The respondents were asked to rate the degree of severity, the probability of occurrence, and the degree of detection ability for each failure modes. In the questionnaire, a five-scaled rating from 1 to 5 is used for each failure mode. That is, for the severity rating, 1 means the least severe it is if the corresponding failure mode occurs and 5 means the most severe; for the occurrence rating, 1 means the least likely it is for the corresponding failure mode to occur and 5 means the most likely; for the detection rating, 1 means that the store has the highest degree of control ability to prevent the corresponding failure mode from occurring and 5 means the lowest degree of control ability.

The severity rating, the occurrence rating, and the detection rating for each failure mode in the FMEA analysis were computed by the arithmetic average of the surveyed data and shown on the fourth, the fifth, and the sixth columns, respectively, of Table 2. And the Risk priority number (RPN) for each failure mode was computed as Equation (1) and shown on the right-most column of Table 2.

\[
RPN = \text{Severity rating} \times \text{Occurrence rating} \times \text{Detection rating}
\] (1)

The higher the RPN is the more preventive action needed for the failure mode from occurring is. In order to identify the more critical failure modes, these RPN values are ordered, from lowest to highest value, to find the third quartile \(Q_3\) as the reference value.

\[
Q_3 = \left[ \frac{(n+1)}{4} \times 3 \right] \text{ ranked value}
\] (2)

where, \(Q_3\) = third quartile value and represents that 25% of the RPN values are higher than the third quartile.

\(n = \text{number of RPN values in the data set (in this example, } n=23).\)
From Equation (2), the \( Q_3 \) falls in the 18\(^{th} \) ranked value, 23.28. Those RPN values higher than \( Q_3 \), by priority order from the highest, are “Unstable supply of goods/merchandise”, “Air-conditioning malfunction”, “No goods/merchandise on designated shelf of the sales floor”, “Slowness of cashier speed”, “Warranty/repair failure in timeliness, items, charge”, and “Nonconforming quality of goods/merchandise”. In addition, because the RPN for the failure mode of “Unable to find first line server in the sales floor” is 23.27, which is also close to the \( Q_3 \). It also needs some preventive actions in advance. Therefore, these seven failure modes represent the most critical failure modes in the T-store. Thus, the preventive action for these failure modes from occurring should be the top focus in the service design stage of the T-store. In the mean time, the service recovery strategy and actions regarding to these failure modes should also attain the most attention and should be planned in advance in order to restore the service, immediately, if they do occur.

6. Conclusion

A Service failure occurs when customers’ expectations are not met. It is very important for the service provider to identify the potential service failures and take the required action in advance to prevent the failure from occurring. In addition, each type of service failure has different degree of effect and risk to the service performance and the service results. Therefore, prioritizing potential service failure modes is needed in order to take the preventive actions under the limited resource of the service company. In this regard, the FMEA is a systematic method that can be used to predict how and where service system might fail. The FMEA is designed to detect errors and alert staff to take preventive actions. It is an important method of preventive quality assurance.

This paper applies the FMEA in a hyper-mart store (T-store) in southern Taiwan from the viewpoints of preventing the failure from occurring and reducing the risk of failures before the service is delivered. The results show that the seven most critical failure modes in the T-store are: “Unstable supply of goods/merchandise”, “Air-conditioning malfunction”, “No goods/merchandise on designated shelf of the sales floor”, “Slowness of cashier speed”, “Warranty failure in timeliness, items, charge”, “Nonconforming quality of goods/merchandise”, and “Unable to find first line server in the sales floor”.

The research provides the T-store in understanding the potential service failure modes as well as knowing how and where to take the preventive actions for its service system. This would not only improve the service effectiveness of the T-store but also ensure the preventive quality assurance of the service system. The results can also provide other hyper-mart stores and other service industries an approach to arriving ideal service design and achieving customer satisfaction by preventive service quality assurance.
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References


**Author’s Vitae**

Pao-Tiao Chuang is a Professor at the Department of Asia-Pacific Industrial and Business Management, National University of Kaohsiung, Taiwan. He received his B.S. degree in Industrial Engineering from Chung Yuan Christian University, Chung-Li, Taiwan, in 1984, and both M.S. and Ph.D. degrees from the Department of Industrial Engineering, University of Texas at Arlington, Texas, USA, in 1988 and 1992, respectively. His research interests include quality management, supply chain management, and operations management. He is a member of ACME and permanent members of both the Chinese Institute of Industrial Engineers and the Chinese Society for Quality. He holds the Certificate of National Examination for Professionals and Technical Personnel in the category of Industrial Engineer, High Examination held by the Ministry of Examination, Taiwan.
Figure 1. FMEA Procedures

Table 1. Headings of a FMEA Form

<table>
<thead>
<tr>
<th>Subprocess/Function</th>
<th>Potential Failure Mode</th>
<th>Potential Effects of Failure</th>
<th>Severity Rating</th>
<th>Potential Causes of Failure</th>
<th>Occurrence Rating</th>
<th>Current Process Control</th>
<th>Detection Rating</th>
<th>Risk Priority Number (RPN)</th>
<th>Recommended Action(s)</th>
<th>Person responsible/Target completion date</th>
<th>Actions Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2. FMEA in the Hyper-mart Store Example

<table>
<thead>
<tr>
<th>Sub-System</th>
<th>Sub-Process/Activity</th>
<th>Potential Failure Mode</th>
<th>Severity Rating (1—5)</th>
<th>Occurrence Rating (1—5)</th>
<th>Detection Rating (1—5)</th>
<th>Risk Priority Number (RPN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Insufficient parking space</td>
<td>2.93</td>
<td>2.42</td>
<td>3.01</td>
<td>21.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air-conditioning malfunction</td>
<td>3.10</td>
<td>2.65</td>
<td>3.09</td>
<td>25.38*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Escalator malfunction</td>
<td>2.58</td>
<td>2.00</td>
<td>2.77</td>
<td>14.29</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Shopping cart malfunction/damage/impair</td>
<td>2.40</td>
<td>2.01</td>
<td>3.03</td>
<td>14.62</td>
</tr>
<tr>
<td>Service Facility</td>
<td>Sales Floor Facility</td>
<td>Emergency, fire, and security alarm failure</td>
<td>2.85</td>
<td>1.91</td>
<td>3.01</td>
<td>16.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inappropriate streamline arrangement of sales floor</td>
<td>3.09</td>
<td>2.48</td>
<td>2.79</td>
<td>21.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unstable supply of goods/merchandise</td>
<td>3.54</td>
<td>3.00</td>
<td>2.57</td>
<td>27.29*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tardiness of incoming goods/merchandise</td>
<td>2.83</td>
<td>2.76</td>
<td>2.89</td>
<td>22.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incoming inspection failure of goods/merchandise</td>
<td>2.35</td>
<td>2.35</td>
<td>3.01</td>
<td>16.62</td>
</tr>
<tr>
<td>Prior-Service</td>
<td>Incoming Goods/ Merchandise Activity</td>
<td>Forecasting error of goods/merchandise</td>
<td>2.48</td>
<td>2.19</td>
<td>2.93</td>
<td>15.91</td>
</tr>
<tr>
<td></td>
<td>Warehousing and Inventory Activity</td>
<td>Inconsistency between actual and book inventories</td>
<td>2.32</td>
<td>2.18</td>
<td>2.84</td>
<td>14.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrong location of warehousing goods/merchandise</td>
<td>2.51</td>
<td>2.13</td>
<td>2.99</td>
<td>15.99</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No goods/merchandise on designated shelf of the sales floor</td>
<td>3.07</td>
<td>2.64</td>
<td>2.94</td>
<td>23.83*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nonconforming quality of goods/merchandise</td>
<td>3.29</td>
<td>2.67</td>
<td>2.65</td>
<td>23.28*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unable to find first line server in the sales floor</td>
<td>2.81</td>
<td>2.76</td>
<td>3.00</td>
<td>23.27*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bad service attitude of the first-line server</td>
<td>2.84</td>
<td>2.45</td>
<td>3.10</td>
<td>21.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrong price tag / price tag missing</td>
<td>2.68</td>
<td>2.50</td>
<td>2.78</td>
<td>18.63</td>
</tr>
<tr>
<td>In-Service</td>
<td>Customer Choose/ Purchase Flow</td>
<td>Slowness of cashier speed</td>
<td>2.94</td>
<td>2.74</td>
<td>2.94</td>
<td>23.68*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bad attitude of cashier server</td>
<td>2.96</td>
<td>2.51</td>
<td>2.87</td>
<td>21.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrong cashier amount of money</td>
<td>2.80</td>
<td>2.35</td>
<td>2.85</td>
<td>18.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Inappropriate complaints/liability adjustments</td>
<td>3.46</td>
<td>2.15</td>
<td>2.74</td>
<td>20.38</td>
</tr>
<tr>
<td></td>
<td>Post-Sale Activity</td>
<td>Inappropriate returned/refund policy</td>
<td>3.05</td>
<td>2.47</td>
<td>2.91</td>
<td>21.92</td>
</tr>
<tr>
<td></td>
<td>Warranty</td>
<td>Warranty/repair failure in timeliness, items, charge</td>
<td>2.89</td>
<td>2.65</td>
<td>3.05</td>
<td>23.36*</td>
</tr>
</tbody>
</table>

*: the most critical failure modes