International Journal of Knowledge and Systems Science
Volume 15 • Issue 1

Fuzzy QFD for LCC Strategic Decisions in Thailand:
A Case Study of Nok Air and COVID-19 Recovery

Piyanee Akkawuttiwanich, International Academy of Aviation Industry, Thailand*

Pisal Yenradee, Sirindhorn International Institute of Technology, Thailand

https://orcid.org/0000-0001-8220-520X

Narudh Cheramakara, International Academy of Aviation Industry, Thailand

https://orcid.org/0000-0001-9148-3383

ABSTRACT

This study focuses on the impact of the Covid-19 crisis on low-cost carriers (LCCs), particularly in comparison to full-service airlines (FSAs). With a target segment of price-sensitive leisure travelers, LCCs have been significantly affected. The objective of this paper is to analyze customer requirements for Thai LCCs during the Covid-19 recovery period and identify strategic improvement decisions accordingly. Nok Air, a well-established LCC in Thailand, is used as a case study. The proposed fuzzy QFD approach is employed to prioritize customer requirements, suggest strategic decisions, and enhance operational practices for the airline's recovery. Key findings include positioning as a premium LCC, offering premium services, increasing ancillary revenue, and improving aircraft utilization. This research is the first to apply fuzzy QFD to prioritize strategic decisions for managing LCCs during the Covid-19 recovery, aiming to enhance customer satisfaction and performance ratings set by the management team.

KEYWORDS

Aviation Industry, Covid-19, Customer Requirement, Fuzzy QFD, Low-Cost Carrier, Strategic Decisions, Thailand

INTRODUCTION

Since the liberalization of the Thai aviation industry in 2001, the country has witnessed significant growth until the COVID-19 outbreak. Before the spread of the coronavirus, there was a projection of robust growth in the aviation industry from the development of global trade, the increase in the transportation of air cargo, and the excessive demand of the tourism economy (Dube et al., 2021). Soon after the realization that COVID-19 was a global concern, the government around the world announced the closure of countries, imposed travel restrictions, and enforced a policy of national lockdowns. The virus spread to more than 200 countries, causing outrageous panic among the world's

DOI: 10.4018/IJKSS.333900

*Corresponding Author

citizens as there was no vaccine or proper medical treatment back to date (Warnock-Smith et al., 2021). No previous pandemics caused a substantial impact for a prolonged period as COVID-19 has. Because travel and tourism are viewed as a major transmission pathway among infected people, the airline industry has been particularly hard hit by the pandemic. The sector was under pressure from various shocks, resulting in the collapse of airlines, a shortage of liquidations, and bankruptcies. Now, as the world adapts to living with the virus, it is imperative to examine the recovery or post-pandemic period for the aviation industry. As we embark on the path of recovery, it is evident that the aviation industry is confronting a changed landscape shaped by the long-lasting consequences of the pandemic. Air travel, which was previously considered a potential means of disease transmission, will remain under the influence of evolving travel patterns, stringent health and safety measures, and the shifting preferences of a more vigilant and health-conscious traveler demographic.

In the aftermath of the 2001 deregulation of the aviation market in Thailand, the industry witnessed heightened competition from low-cost carriers (LCCs), also referred to as low-cost airlines (LCAs). Both terms are used interchangeably within the aviation sector and describe airlines that prioritize a cost-efficient business model, aiming to provide passengers with affordable travel options. In 2017, LCAs played a significant role in Thailand, contributing to 47% of the total passenger traffic. Notably, they tripled their capacity in terms of available seat kilometers (ASK) on domestic routes between 2014 and 2017 (CAPA, 2018). However, with the LCCs' reliance on lower-cost customer segmentation, the earlier assessment showed that the pandemic's impact on the LCCs was immense due to the reduction of leisure travel and price-sensitive customers (Kam et al., 2022). Although the airline industry is opening up, how the airlines can realign their business in the 'new normal' era in more sustainable ways is still a significant challenge. The complexities of managing the LCCs during a COVID-19 recovery period are:

1. There are several business and operational factors for the LCCs to consider; without a systematic approach, the airlines cannot prioritize the customers' real needs.
2. There is an interrelationship between customers' requirements and the airlines' strategic decisions as the operational practices; without some methodology, the airlines cannot implement the proper strategy to respond to the customers' needs.

For these reasons, this paper proposes a systematic fuzzy quality function deployment (QFD) approach to evaluate the strategic decision of LCCs in Thailand to meet customers' requirements during a COVID-19 recovery period. A QFD is a customer-driven quality management system that ensures customer needs are integrated into the production process of product development. The QFD method has been successfully applied across the industry, including in product development, quality management, engineering decision-making, supplier selection, and strategic management in logistics and aviation (Weber et al., 2013; Bulut et al., 2016.) A house of quality (HOQ) analysis is fundamental and of strategic importance in the QFD process, as the customer needs are identified, the company's competitive priorities are incorporated, and the requirements are then converted into appropriate measures to fulfill the needs. The QFD method is therefore considered suitable for this analysis, and this paper is the first to apply the QFD method to manage the effect of the pandemic.

The objectives of this paper are:

1. To identify and prioritize the strategic decisions regarding the airline's operational practices to LCCs in Thailand to meet customers' requirements during a COVID-19 recovery period.
2. To demonstrate the application of a fuzzy QFD method in the aviation industry to manage strategic decisions.

In this paper, we demonstrate the application of the fuzzy QFD approach through a case study of Nok Airlines, a long-established and well-known LCC in Thailand. The customers' requirements during a pandemic recovery period are known as the "what" and airlines' competitive strategies are regarded as the "how". The fuzzy triangular numbers are used to capture the uncertainty of human linguistic judgments.

The paper is organized as follows. Section 2 presents a literature review focusing on previous publications on airline management and LCCs, and current policies and practices responding to COVID-19. Section 3 explains the fundamentals of QFD and industrial applications. Section 4 demonstrates the proposed methodology. Section 5 discusses the results. The conclusion is described in section 6.

LITERATURE REVIEW

Previous Works on Airline Management and LCCs

During the years leading up to the COVID-19 pandemic, the aviation industry reported the highest growth in terms of revenue. This was not only the result of global economic and income growth but also the market liberalization that resulted in increased supply and fare wars. This makes the airline industry a highly challenging environment. The literature review gathered from 2000 to 2018 by Dozic (2019) revealed that the problems in the aviation industry are distinguished into four areas: airlines, aircraft, airports, and air traffic management. According to the reviewed papers on airline management, various specific objectives and themes are investigated. Previous research papers focused on:

- An airline's service quality (Del Chiappa et al., 2016; Pandey, 2016; and Gao et al., 2018).
- Flight schedule planning (Cacchiani & González, 2016).
- Flight selection and aircraft routing (Jamili, 2017; Kenan et al., 2018; Cacchiani & González, 2020).
- Fleet assignment (González, 2014).
- Airline network planning (Cadarso & Celis, 2017; Hausladen & Schosser, 2020).
- The competition in the airline industry (Flores-Fillol, 2009).

The entrance and dominance of LCCs had a profound impact on the global market share. In Thailand, the introduction of LCCs began with One-Two-GO in December 2003, followed by Thai AirAsia in February 2004, Nok Air in July 2004, and Thai Smile in 2009 (Charoensettasilp & Wu, 2013). In 2017, the Airport Authority of Thailand reported that LCCs contributed to 47% of total passenger traffic and tripled ASK on Thailand's domestic routes (CAPA, 2018).

The significant growth in LCC traffic necessitated research efforts to understand the specific requirements and challenges faced by these carriers. As depicted in Table 1, systematic literature reviews have identified objectives, research methods, application areas, and considerations related to pandemic situations, reflecting the evolving landscape of the airline industry.

Passengers and Airlines' Response to COVID-19

When the World Health Organization declared COVID-19 a global pandemic, it caused a sudden decline in air transportation and airlines faced an indefinite future to regain customers. International travel restrictions, the contraction of economic activities, and changes in transportation behavior hinder the restoration of the aviation industry (OECD, 2020). The study by Gudmundsson et al., (2021) revealed that the passenger level will recover in about 2.4 years, with a minimum of two years and a maximum of six years. ICAO (2021) reported a 60% reduction in air passengers for both domestic and international in 2020 due to entry restrictions, lockdowns, and a decrease in willingness to travel.

Despite these findings, the recovery period remains unclear because no one knows how long the virus spread will continue. As COVID-19 persists, rebuilding customer confidence in using airlines in terms of air travel safety measures is the key to recovering the demand for air travel (Lamb et al., 2020). Several publications have conducted studies on the impacts and response strategies to protect people's health in the post-COVID-19 period. Several critical aspects have been explored in recent literature. These include the evolving role of variants of concern in aviation, the implications of vaccine certificates, and considerations regarding network, fleet, and pricing economies (Sun et al., 2022). Additionally, studies have investigated scenario methodologies to establish trusted aviation in the future (Michelmann et al., 2023); proposed frameworks for airline demand recovery as diseases evolve (Tirtha et al., 2023); and put forth operational strategies for pandemic-free air travel (Tabares, 2021), passenger safety (Naboush & Alnimer, 2020), aircraft turnaround procedures (Schultz et al., 2020), point-to-point long-haul flight business model (Bauer et al., 2020), seat assignment with social distancing (Salari et al., 2020), and passenger flow management (Dabachine et al., 2020; Tuchen et al., 2020). Several methods have also been adopted, such as neural networks and Monte Carlo simulation (Truong, 2021). Linden (2021) introduced a three-step process to embrace uncertainty in crisis; sensing, seizing, and transforming. Sun et al., (2021) proposed research topics to overcome the problem using data, disease-specific models, and verification in natural environments. The role of government is also crucial for the future development of the aviation industry (Abate et al., 2020). Country-specific policies to respond to COVID-19 are also investigated in the USA (Hotle & Mumbower, 2021; Monmousseau et al., 2021; Brown & Kline, 2020), Australia (Tisdall & Zhang, 2020), Korea (Kim & Sohn, 2020), China (Li et al., 2021), and Japan (Kam et al., 2022).

Research Gap

From the systematic literature review as shown in Table 1, even though several studies and methods have been conducted during COVID-19, none of the research mentions systematic approaches that can identify the requirements of customers and relate such requirements to the airline's strategic decision during the COVID-19 recovery period. Also, among the ups and downs of LCCs due to the pandemic, no study explores the specific requirements of LCCs in terms of airlines' operational planning during the catastrophic situation. The case of Thailand has also not yet been explored. This paper will accommodate this existing gap in the literature.

THE FUZZY QFD METHOD

QFD belongs to the sphere of quality management, originating in Japan in 1972, as a structured methodology to transform the voice of the customer into engineering characteristics (EC) for new products and services. The method involves developing a planning matrix as a house, known as the HOQ, which is the hub of the whole QFD method. This construction enables us to proceed from the customer's requirement to the design specification (Partovi & Corredoira, 2002). The original procedure is explained in the following steps (Hauser & Clausing, 1998.) and the HOQ construction for the implementation of QFD is illustrated in Figure 1.

Step 1: Customer requirements, or "whats," must be identified. This is usually referred to as customer attributes (CA) in a "whats" area.

Step 2: Technical measures called "hows" or ECs are obtained according to the firm's products and services by expert discussion.

Step 3: The relationship matrix relates the contribution of each "what" and "how". This is typically expressed as a fuzzy degree of interaction.

Step 4: The correlation matrix measures the relationship of each "how" to show how much they affect each other.

Table 1. Related research for airline management and planning before, during, and after COVID-19

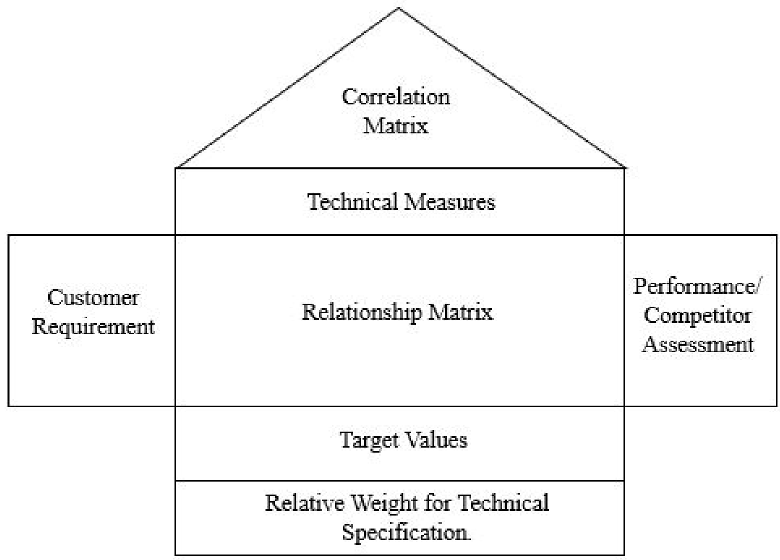
Related works	Objective functions										Methods								Application Areas				Situations		
	Service quality improvement	Flight scheduling	Flight selection and aircraft routing	Fleet assignment	Network planning	Airport facilities improvement	COVID-19 impact analysis.	Measures after COVID-19	Strategic management decisions	Airlines operations improvement	QFD	Fuzzy Logic	MILP and optimization	Benders' decomposition	Heuristics	Case Study	Archival data	Others	Airline Network	Airport	Airline Planning	Airline operations	Pre-COVID-19	During COVID-19	Recovery after COVID-19
Weber et al., 2013)	✓										✓									✓			✓		
Del Chiappa et al., (2016)	✓											✓								✓			✓		
Pandey (2020)	✓					✓			✓		✓	✓								✓			✓		
Bulut et al., (2016)	✓									✓	✓									✓			✓		
Cacchiani & González, (2016)			✓										✓								✓		✓		
Jamili, (2017)			✓										✓								✓		✓		
Kenan et al., (2018)		✓		✓														✓					✓		
Cacchiani & González, (2020)		✓													✓						✓		✓		
Gao et al., (2018)					✓													✓	✓				✓		
González, (2014)				✓														✓				✓	✓		
Cadarso & Celis, (2017)					✓								✓						✓				✓		
Hausladen & Schosser, (2020)					✓													✓	✓				✓		

continued on following page

Table 1. Continued

Related works	Objective functions										Methods								Application Areas				Situations		
	Service quality improvement	Flight scheduling	Flight selection and aircraft routing	Fleet assignment	Network planning	Airport facilities improvement	COVID-19 impact analysis.	Measures after COVID-19	Strategic management decisions	Airlines operations improvement	QFD	Fuzzy Logic	MILP and optimization	Benders' decomposition	Heuristics	Case Study	Archival data	Others	Airline Network	Airport	Airline Planning	Airline operations	Pre-COVID-19	During COVID-19	Recovery after COVID-19
Kam et al., (2022)							✓									✓					✓			✓	
Hotle & Mumbower, (2021)					✓		✓										✓				✓			✓	
Tisdall & Zhang, (2020)							✓									✓					✓			✓	
Dube et al., (2021)								✓		✓							✓		✓						✓
Li et al., (2021)							✓									✓			✓					✓	
Scarpin et al., (2022)							✓											✓	✓					✓	
Monmousseau et al., (2021)								✓										✓			✓			✓	
Kim & Sohn, (2020)							✓		✓							✓						✓		✓	
Maneenop & Kotcharin (2020)							✓											✓			✓			✓	
Warnock-Smith et al., (2021)							✓									✓					✓			✓	
Truong, (2021)								✓										✓			✓				✓
This study	✓							✓	✓	✓	✓					✓						✓			✓

Figure 1. The HOQ analysis for the implementation of QFD



Step 5: The performance and competitor assessment is computed by normalization of the sum of products which consists of the weight of customer requirements and the relationship value.

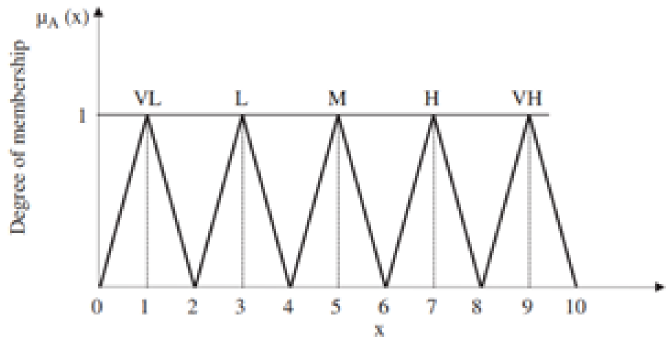
Step 6: The target values are identified by an expert group as a result of the performance and competitor weight. Obtaining targets is a judgmental process that is figured by the available capacity and facilities.

When a human decision is imprecise, the evaluation or opinion is usually expressed in linguistic terms. In dealing with this type of uncertainty, fuzzy set theory (FST) is introduced to capture the human thought process. FST involves sets with elements that have the degree of the membership values in $\left[0,1\right]$ where it has the minimum and maximum degrees of membership, and all the intermediate values indicate a degree of "partial" membership (Zadeh, 1965). There are various types of fuzzy numbers, and this paper uses a triangular fuzzy number (TFN) as it is a fuzzy form that is easy to manage and common in literature (Karsak, 2004). The TFN is represented by triplets of $A=\left(x^L,x^\alpha,x^R\right)$, where x^L and x^R denote the lower and upper limits and x^α shows the closest fit. Figure 2 illustrates the linguistic representation of the TFN.

For example, let $U=\left\{VL,L,M,H,VH\right\}$ be a linguistic representation of human opinions, where VL = very low, L = low, M = medium, H =high, and VH = very high, A TFN is expressed as follows. The human assessment of VL contains a fuzzy set of (0,1,2) where $x^L=0$, $x^\alpha=1$, and $x^R=2$.

Research on fuzzy QFD has received incredible attention and has been used not only in product development but also in other fields. For example, Kamvysi et al., 2023 introduced a QFD for orchestrating and aligning quality for effective service strategy planning using a 3-phased QFD framework. Wu et al., 2018 adopted a QFD together with ANP to integrate the service value and service recovery in the hospitality industry. Cui et al., 2021 proposed innovative strategies incorporating QFD, Dematel, and interval-valued intuitionistic fuzzy multi-objective optimization ratio analysis for green supply chain management. A QFD approach to improve maritime supply chain resilience is also studied by Lam et al., 2016. For the aviation industry, QFD has successfully applied as follows. Pandey (2020) evaluated the strategic design parameters of the airport to meet service expectations.

Figure 2. Linguistic representation of the TFN



Bulut et al., (2016) proposed a multilayer QFD to compromise the requirements of both airlines and passengers at Kansai International Airport. Wang (2007) improved the service quality of air cargo in China airlines using QFD. Weber et al., (2013) applied QFD as the primary tool to assess the levels of quality in the Brazilian air market. Furthermore, this methodology is also successfully applied in other industries area such as part deployment (Chen & Weng, 2006, Liu, 2009), material selection (Mayyas et al., 2011), supplier selection (Amin & Razmi, 2009), service provider selection (Liao & Kao, 2014, Wang, 2015), lean and agility (Bottani, 2009, Zarei et al., 2011), and supply chain performance evaluation (Akkawuttiwanich & Yenradee, 2018).

From the literature review based on the application of fuzzy QFD in the aviation industry, this paper shows the potential benefits of extending the fuzzy QFD method to accommodate the customers' needs and to identify airlines' strategic decisions during the current COVID-19 recovery situation.

THE PROPOSED METHODOLOGY

The fuzzy QFD method to evaluate the strategic decisions of LCC to meet customers' expectations is described using eight steps as illustrated in Figure 3.

Indexes and Variables

The related indexes and variables are defined as follows:

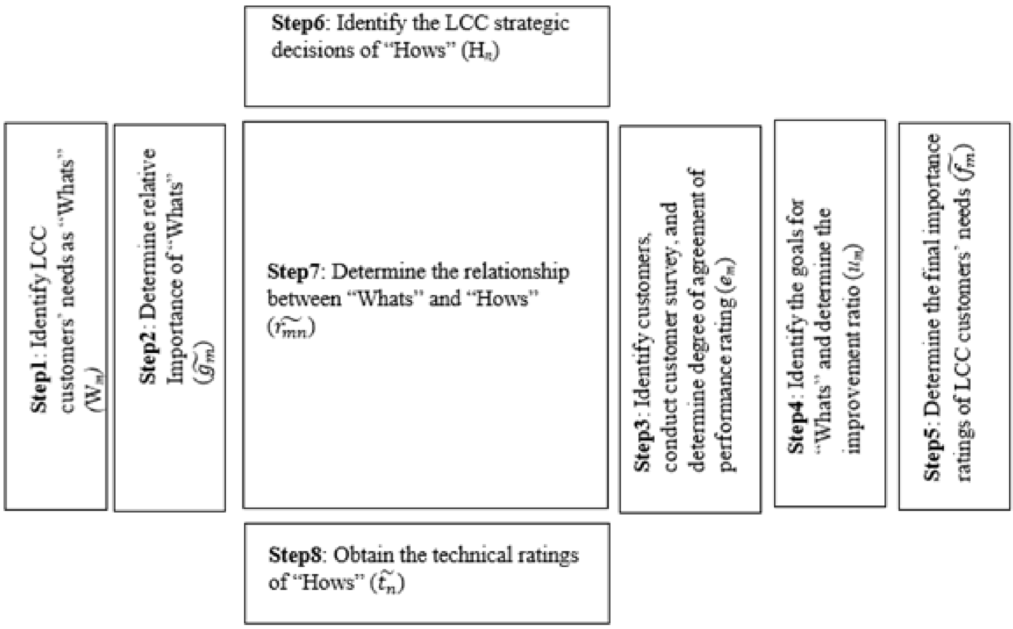
Indexes

- m index of CAs or "whats" ($m = 1, 2, \ldots M$)
- d index of decision makers ($d = 1, 2, \ldots D$)
- l index of customer groups ($l = 1, 2, \ldots L$)
- k index of customer respondents in group l ($k = 1, 2, \ldots K_l$)
- n index of strategic decisions "hows" ($n = 1, 2, \ldots N$)

Names

- W_m Customer attribute m
- H_n Strategic decision n

Figure 3. Fuzzy QFD approach to evaluate the strategic decisions of LCC



Variables

- $\widetilde{g}_{md}$ Relative importance rating of customer attribute *m* rated by decision maker *d*
- $\widetilde{g}_{m}$ Average relative importance rating of customer attribute *m* from all decision makers
- x_{mlk} Performance rating of customer attribute *m* rated by respondent *k* of customer group *l*
- x_{ml} Average performance rating of customer attribute *m* rated by all respondents in customer group *l*
- $EN\left(W_m\right)$ The entropy of performance rating from all customer groups of customer attribute *m*
- e_m Degree of agreement of performance rating from all customer groups of customer attribute *m*
- K_l Number of respondents in customer group *l*
- $\overline{x}_m$ Average performance rating of customer attribute *m* from all customer groups
- a_m Goal of average performance rating of customer attribute *m*
- u_m Improvement ratio on the performance rating of customer attribute *m*
- $\widetilde{f}_m$ Final importance rating of customer attribute *m*
- f_m^{max} Maximum final importance rating under the optimistic scenario of customer attribute *m*
- $\widetilde{f'}_m$ Scaled final importance rating of customer attribute *m*
- $\widetilde{r}_{mn}$ Relationship between customer attribute *m* and strategic decision *n*
- $\widetilde{t}_n$ Technical rating of strategic decisions *n*
- t_n^{max} A maximum technical rating under the optimistic scenario of strategic decision *n*
- $\widetilde{t'}_n$ Scaled technical rating of strategic decision *n*

Step One: Identifying LCC CAs During the COVID-19 Recovery Period as “Whats”

The requirement of customers is primarily obtained from previous literature reviews and interviews with academics and practitioners in the aviation industry. Initially, 25 CAs (W_1 to W_{25}) under five dimensions of general factors, services, air safety measures, price and promotion, and personnel were identified as shown in Table 2.

Step Two: Determine the Relative Importance Ratings of CAs

CAs typically have different degrees of importance, and it is normal for the airlines to emphasize a high priority of “whats”. In this paper, the relative importance rating is determined by decision makers (DMs), which are top managers from departments in Nok Air. Each DM established the level of importance of the “whats” by using a linguistic variable, where they are translated into a TFN as shown in Table 3. For each customer need W_m, each DM rates the relative importance $\widetilde{g}_{md}$. Then

Table 2. Identification of LCC CAs During the COVID-19 Recovery Period

Dimensions	CAs (W_m)	Whats	Dimensions	CAs (W_m)	Whats
General Factor	W_1	Aircraft type	Service	W_{14}	Baggage claim at the destination airport
	W_2	Frequent flyer program		W_{15}	Comfort
	W_3	Network routing		W_{16}	Free seat selection
	W_4	Flight frequency	Air safety measures	W_{17}	Cleanliness and sanitation of aircraft
	W_5	Overall airlines’ services		W_{18}	COVID-19 prevention policy
	W_6	Alliance with other airlines	Price and Promotion	W_{19}	Fare
Service	W_7	On-time departure and arrival		W_{20}	Worthiness
	W_8	Overall Reputation		W_{21}	Promotion and marketing
	W_9	Ground services	Personnel	W_{22}	The appearance of flight crews
	W_{10}	Free water		W_{23}	Courtesy of ground staff
	W_{11}	Check-in experience		W_{24}	Courtesy of flight attendants
	W_{12}	Aircraft boarding experience		W_{25}	Airline communication method with passengers
	W_{13}	Ticket distribution channel			

Table 3. A TFN for each linguistic variable

Linguistic variables	TFN	Likert Scale
Strongly disagree	(0, 1, 2)	1
Disagree	(1, 2, 3)	2
Neutral	(2, 3, 4)	3
Agree	(3, 4, 5)	4
Strongly agree	(4, 5, 6)	5

the average relative importance $\widetilde{g_m}$ is computed by Equation 1. Since the $\widetilde{g_{md}}$ is expressed by a TFN, then the calculated $\widetilde{g_m}$ is also a TFN.

$$\widetilde{g_m} = \frac{\left(\widetilde{g_{m1}} + \widetilde{g_{m2}} + \ldots + \widetilde{g_{md}}\right)}{D}, \forall m \tag{1}$$

Step Three: Identify Customer Groups, Conduct a Customer Survey, and Determine a Degree of Agreement of Performance Ratings From Different Customer Groups (e_m)

Knowing the preferences of customers in different segments is essential for the company to gain competitiveness over the competitors. In this step, a customer questionnaire survey is conducted to collect customer opinions on the performance of Nok Air to satisfy customers' needs. Customers are divided into segments based on age ranges since customers of different ages may have different opinions. Respondents are randomly selected from LCC customers.

Suppose L groups of customers are identified, denoted as C_1, C_2, …, C_L. Then k^{th} customer of each group rates the performance (ability) of Nok Air to satisfy his/her need according to the customer attribute m as x_{mlk}. Note that x_{mlk} is a crisp number. The average performance rating x_{ml} from the customer segment l for customer attribute m is calculated by Equation 2, where K_l is the number of respondents in customer group l. The company's performance rating is expressed by $M \times L$ matrix, called a customer comparison matrix, shown in Equation 3:

$$x_{ml} = \left(x_{ml1} + x_{ml2} + \ldots + x_{mlk}\right) / K_l \, , \, \forall m, l \tag{2}$$

$$X = \begin{bmatrix} x_{11} & \cdots & x_{1L} \\ \vdots & \ddots & \vdots \\ x_{M1} & \cdots & x_{ML} \end{bmatrix} \tag{3}$$

This step not only collects customer opinions but also determines a degree of agreement of opinions among customer groups based on an entropy concept (Chan & Wu, 2005). When opinions from all customer groups have a low degree of variation or high entropy, the collected opinions from the survey are highly precise or highly reliable, and more weight should be given to the collected opinions.

Entropy is a measure of variations that is represented by a discrete probability distribution p_1, p_2,.., p_L, and is computed by Equation 4:

$$EN\left(p_1, p_2, .., p_L\right) = -\varnothing_L \sum_{l=1}^{L} p_l ln(p_l) \tag{4}$$

$\varnothing_L = 1 / \ln\left(L\right)$ is a normalization constant to guarantee that the value of entropy is between 0 and 1. The larger entropy implies smaller variations among the group.

For the m^{th} row of the matrix X that includes the performance ratings of the CAs m from all customer groups ($x_{m1}, x_{m2}, .., x_{ml}$), the entropy is computed by Equation 5. Note that $x_{ml} / \sum_{l=1}^{L} x_{ml}$ can be considered a probability:

$$EN\left(W_m\right) = -\varnothing_L \sum_{l=1}^{L} \left(x_{ml} / \sum_{l=1}^{L} x_{ml} \right) ln \left(x_{ml} / \sum_{l=1}^{L} x_{ml} \right), \forall m \quad (5)$$

The larger $EN\left(W_m\right)$ means a smaller variation among the x_{ml}. If the performance ratings from all customer groups are equal, $EN\left(W_m\right)$ equals to the maximum value of 1. $EN\left(W_m\right)$ is normalized to e_m by Equation 6. e_m is a degree of agreement between customer responses from all customer groups that reflects the weight of data precision. When e_m is relatively high, the performance ratings from customers are more precise and reliable, resulting in more weight that should be given to the customer opinions on the customer attribute m:

$$e_m = \frac{EN\left(W_m\right)}{\sum_{m=1}^{M} EN\left(W_m\right)} \ , \forall m \quad (6)$$

Step Four: Identify the Goals For “Whats” and Determine the Improvement Ratio

Based on the performance ratings of customer attribute m rated by respondents in customer segment l (x_{ml}), the average performance rating of customer attribute m from all customer groups ($\overline{x}_m$) is calculated by Equation 7:

$$\overline{x}_m = \frac{\left(x_{m1} + x_{m2} + \ldots + x_{mL}\right)}{L} \ , \forall m \quad (7)$$

Once the average performance rating of customer attribute m from all customer groups ($\overline{x}_m$) is determined, the DMs carefully set the goal of the average performance rating of customer attribute m (a_m). In the QFD process, the establishment of improvement goals (a_m) is a pivotal step. Typically, these goals are determined by a group of company executives or consultants. These objectives must be set at a level significantly higher than the current average performance rating ($\overline{x}_m$). This goal-setting process is both competitive and realistic, representing a highly strategic activity that involves careful consideration and input from relevant management stakeholders. (Chan & Wu, 2005). If the DMs feel that $\overline{x}_m$ perceived by customers is relatively low it reflects a need for significant improvement. On the other hand, the goal may be set slightly higher or equal to the $\overline{x}_m$ when it is sufficiently high to ensure that the current average performance is maintained.

The improvement ratio on performance of customer attribute m (u_m) is calculated by Equation 8. The relatively high value of u_m indicates that the average performance rating of customer attribute m should be significantly improved:

$$u_m = \frac{a_m}{\bar{x}_m} \quad ,\forall m \tag{8}$$

Step Five: Determine the Final Importance Ratings of CAs

The final importance ratings of customer attribute *m* are expressed as vector $\widetilde{f_m} = \left\{\widetilde{f_1},..,\widetilde{f_M}\right\}$ and are determined jointly by the average relative importance rating $\widetilde{g_m}$, the degree of agreement of performance rating e_m, and the improvement ratio u_m, as presented by Equation 9. Based on Equation 9, the final importance rating of customer attribute *m* is high when the relative importance, degree of agreement of performance rating from all customer groups, and improvement ratio of customer attribute *m* are relatively high:

$$\widetilde{f_m} = \widetilde{g_m} \times e_m \times u_m \quad ,\forall m \tag{9}$$

$$\widetilde{f'_m} = \widetilde{f_m} \,/\, f_m^{max} \quad ,\forall m \tag{10}$$

As $\widetilde{g_m}$ is a set of TFN, the resulting $\widetilde{f_m}$ is also a set of TFN. The $\widetilde{f_m}$ is scaled for ease of comparison. The scaled rating ($\widetilde{f'_m}$) is obtained by dividing all ratings by the maximum rating under an optimistic scenario (f_m^{max}), using Equation 10, which would yield a maximum value of 1.

Step Six: Identify the LCC Strategic Decisions as a List of Operational Practices During a COVID-19 Recovery Period as "Hows"

Once the customer needs are revealed, the airline's expert team that contributed directly to the strategic and operational planning develops a set of strategic decisions or "hows" that are practicable to LCC during a COVID-19 recovery period. A literature review was provided as a reference and a semi-structured interview was conducted to derive the strategic decisions of nine "hows" as shown in Table 4. A set of nine strategic decisions is developed and is denoted by H_1, H_2,.., *and* H_9.

Step Seven: Determine the Relationship Between "Whats" and "Hows"

This is the critical step in the HOQ analysis, where the relationship between each "what" and "how" is established by analyzing to what extent each "how" can technically relate to or influence each "what". In this paper, DMs from departments of Nok Air were asked to express their opinions about the degree of correlation between each pair of "what-how" using linguistic variables in Table 3. As the relationships were determined by empirical judgment, it is more appropriate to represent this information set by a TFN. Let the relationship between each customer need W_m and the strategic decisions H_n be determined by r_{mn}, the relationship matrix is in Equation 11:

$$\tilde{R} = \begin{bmatrix} \widetilde{r_{11}} & \cdots & \widetilde{r_{1N}} \\ \vdots & \ddots & \vdots \\ \widetilde{r_{M1}} & \cdots & \widetilde{r_{MN}} \end{bmatrix} \tag{11}$$

Table 4. Suggested strategic decisions in response to COVID-19

Topic	Hows	Strategic decisions	Description
Revenue	H_1	Fleet strategy	Use the Q400 NextGen aircraft, a fuel-efficient turboprop, to increase the flight frequency, and add unique routes that are operatable only at Nok Air, such as Fly'n'Ferry or Fly'n'Ride.
	H_2	Airport utilization	Increase airport utilization in terms of aircraft turnaround and optimum slot scheduling.
	H_3	Ancillaries revenue	Increase ancillaries (non-airfare revenue) such as premium seat selection, in-flight service, Nok Flexi, insurance, and pet carriage service.
Cost	H_4	Contract renegotiation	Renegotiate the contract with suppliers, such as debt restructuring and suspending the aircraft's lease to reduce costs.
	H_5	Aircraft utilization	Increase aircraft utilization with regional flights and shorter airplane turn-times to reduce the unit cost.
Services	H_6	Premium LCC	Nok Air positions itself as a premium LCC with competitive airfare but offers a service beyond expectation, such as free water, free 7 kg carry-on, and broader seats to increase revenue per available seat kilometers.
	H_7	Improve e-platform	Improve all electronic platforms (Nok Air application) to offer the most convenient way to book and manage the trip with only one touch.
Finance	H_8	Capital injection	More capital injection to prevent the collapse of the airlines.
Administration	H_9	Restructuring organization	Restructure the organization to create a leaner business during COVID-19, such as a leave without-pay policy and keeping a minimum wage for a pilot.

Step Eight: Obtain the Technical Ratings of "Hows"

The HOQ analysis is completed by calculating the technical rating $\widetilde{t_n}$ using the final importance rating $\widetilde{f_m}$ and the "what-how" relationship $\widetilde{r_{mn}}$. The simple additive weighting method is used to derive these ratings according to Equation 12. $\widetilde{f_m}$ and $\widetilde{r_{mn}}$ are TFNs, therefore, they comprise three numbers under pessimistic, most likely, and optimistic scenarios. To multiply two TFNs, the corresponding values under the same scenario are multiplied:

$$\widetilde{t_n} = \sum_{m=1}^{M} \widetilde{f_m} \times \widetilde{r_{mn}} \quad ,\forall n \tag{12}$$

$$\widetilde{t'_n} = \widetilde{t_n} \, / t_n^{max} \quad ,\forall n \tag{13}$$

The fuzzy technical ratings $\widetilde{t_n}$ are also scaled to $\widetilde{t'_n}$ for comparison purposes using Equation 13. These ratings indicate the importance of the strategic decisions ("hows") to satisfy customer needs ("whats") and are the main outputs of the proposed methodology. The highest technical rating of strategic decision *n* means that the company should give the highest priority to implementing the strategic decision *n* during a COVID-19 recovery period.

RESULTS AND DISCUSSION

Based on the proposed systematic fuzzy QFD method, after LCC CAs have been identified from Table 2, the relative importance of 25 CAs is evaluated and ranked by the top management of Nok Air, who are the commercial officer, operating officer, and financial officer. According to the organization chart, they are the big three officers of Nok Air. These three DMs use a linguistic scale for their judgments and then the judgments are converted to TFNs. Figure 4 indicates the degree of importance of W_m as perceived by the airlines' DMs, and these are the results of Step 2 in the proposed methodology. From these rankings, the first 15 ranks, which consist of 16 W_m, are selected for the customer survey (see Figure 5). These 16 CAs contribute to more than 70% of the total values of importance.

Progressing to the third step, a questionnaire survey is conducted with the following question: "Based on your experiences with the services of Nok Air in comparison to services of other LCCs, are you satisfied with the service of Nok Air for customer attribute *m*?"

The respondents give the performance ratings following the linguistic variable and 5-point Likert scale as shown in Table 3. The survey got responses from 249 respondents who are air travelers of LCCs. They are classified into four groups of age ranges 20–30, 31–40, 41–50, and 51–60. These customer segments are classified as *C1* to *C4*. The number of respondents in customer

Figure 4. Relative importance of 25 W_m based on airlines' DMs perception

WHATs (W_m)	Relative Importance Ratings $\tilde{g}_{md}$ Decision makers (*d*) *d* = 1	*d* = 2	*d* = 3	Average relative importance rating $\tilde{g}_m$	Ranking
W_1	[1,2,3]	[2,3,4]	[2,3,4]	[1.7,2.7,3.7]	22
W_2	[3,4,5]	[1,2,3]	[3,4,5]	[2.3,3.3,4.3]	18
W_3	[2,3,4]	[2,3,4]	[3,4,5]	[2.3,3.3,4.3]	18
W_4	[3,4,5]	[4,5,6]	[4,5,6]	[3.7,4.7,5.7]	3
W_5	[4,5,6]	[4,5,6]	[3,4,5]	[3.7,4.7,5.7]	3
W_6	[0,1,2]	[2,3,4]	[2,3,4]	[1.0,2.0,3.0]	24
W_7	[3,4,5]	[4,5,6]	[4,5,6]	[3.7,4.7,5.7]	3
W_8	[3,4,5]	[3,4,5]	[4,5,6]	[3.3,4.3,5.3]	7
W_9	[3,4,5]	[3,4,5]	[2,3,4]	[2.7,3.7,4.7]	15
W_{10}	[1,2,3]	[1,2,3]	[2,3,4]	[1.0,2.0,3.0]	24
W_{11}	[3,4,5]	[3,4,5]	[3,4,5]	[3.0,4.0,5.0]	9
W_{12}	[2,3,4]	[3,4,5]	[2,3,4]	[2.3,3.3,4.3]	18
W_{13}	[3,4,5]	[4,5,6]	[3,4,5]	[3.3,4.3,5.3]	7
W_{14}	[1,2,3]	[0,1,2]	[3,4,5]	[1.3,2.3,3.3]	23
W_{15}	[3,4,5]	[3,4,5]	[3,4,5]	[3.0,4.0,5.0]	9
W_{16}	[3,4,5]	[3,4,5]	[3,4,5]	[3.0,4.0,5.0]	9
W_{17}	[3,4,5]	[3,4,5]	[3,4,5]	[3.0,4.0,5.0]	9
W_{18}	[3,4,5]	[3,4,5]	[2,3,4]	[2.7,3.7,4.7]	15
W_{19}	[4,5,6]	[4,5,6]	[4,5,6]	[4.0,5.0,6.0]	1
W_{20}	[4,5,6]	[4,5,6]	[4,5,6]	[4.0,5.0,6.0]	1
W_{21}	[3,4,5]	[4,5,6]	[4,5,6]	[3.7,4.7,5.7]	3
W_{22}	[2,3,4]	[2,3,4]	[2,3,4]	[2.0,3.0,4.0]	21
W_{23}	[2,3,4]	[2,3,4]	[3,4,5]	[2.3,3.3,4.3]	15
W_{24}	[3,4,5]	[3,4,5]	[3,4,5]	[3.0,4.0,5.0]	9
W_{25}	[3,4,5]	[3,4,5]	[3,4,5]	[3.0,4.0,5.0]	9

Figure 5. Sixteen CAs (W_m) with the highest relative importance ratings

WHATS (W_m)	Description	Ranking
W_4	Flight Frequency	3
W_5	Overall airlines' services	3
W_7	On-time departure and arrival	3
W_8	Overall Reputation	7
W_9	Ground services	15
W_{11}	Check-in experience	9
W_{13}	Ticket distribution channel	7
W_{15}	Comfort	9
W_{16}	Free seat selection	9
W_{17}	Cleanliness and sanitation of aircraft	9
W_{18}	Covid-19 prevention policy	15
W_{19}	Fare	1
W_{20}	Worthliness	1
W_{21}	Promotion and marketing	3
W_{24}	Courtesy of flight attendants	9
W_{25}	Airline communication method with passengers	9

groups 1 to 4 (K_l) are 70, 86, 18, and 75, respectively. The k^{th} respondent in customer group l evaluated the performance ratings of customer attribute m (x_{mlk}) of Nok Air. Then the average value of x_{mlk} is computed as x_{ml} using Equation 2. The values of x_{ml} are presented in Figure 6. The entropy $EN\left(W_m\right)$ is calculated by Equation 5 and is converted to the degree of agreement of performance rating from all customer groups of customer attribute m (e_m) as shown in Figure 6, which are the results of Step 3.

A numerical example for calculating e_m is given as follows: The average performance ratings from customer group l for customer attribute 1 (x_{1l}) are 4.3077, 4.2188, 4.0000, and 4.0714. Then,

Figure 6. Performance ratings, degree of agreement of performance ratings, goals, and improvement ratios

WHATs (W_m)	Average performance rating (x_{ml}) C1 x_{m1}	C2 x_{m2}	C3 x_{m3}	C4 x_{m4}	Entropy $EN(W_m)$	Degree of agreement of performance rating e_m	Average performance rating $\overline{x_m}$	Goals of average performance rating a_m	Improvement Ratio u_m
W_4	4.3077	4.2188	4.0000	4.0714	0.999695	0.062501	4.1495	5	1.2050
W_5	4.3462	4.2500	4.1429	4.2143	0.999892	0.062514	4.2383	5	1.1797
W_7	4.5385	4.2500	4.4286	4.2857	0.999750	0.062505	4.3757	5	1.1427
W_8	4.3846	4.2188	4.2857	4.1786	0.999880	0.062513	4.2669	5	1.1718
W_9	3.8462	3.6875	4.1429	4.0000	0.999321	0.062478	3.9191	4	1.0206
W_{11}	4.0769	3.7188	4.2857	3.9643	0.999059	0.062462	4.0114	5	1.2464
W_{13}	4.0769	4.0313	4.1429	3.8929	0.999813	0.062509	4.0360	5	1.2389
W_{15}	4.2692	3.9375	4.1429	4.1786	0.999687	0.062501	4.1320	5	1.2101
W_{16}	4.3462	4.1563	4.4286	4.2500	0.999796	0.062508	4.2952	5	1.1641
W_{17}	4.6923	4.3438	4.2857	4.2500	0.999428	0.062485	4.3929	6	1.3658
W_{18}	4.5769	4.5000	4.2857	4.4286	0.999789	0.062507	4.4478	6	1.3490
W_{19}	4.5000	4.3750	4.4286	4.2857	0.999886	0.062513	4.3973	6	1.3645
W_{20}	4.3462	4.1250	4.0000	4.0714	0.999650	0.062499	4.1356	5	1.2090
W_{21}	4.4231	4.4375	4.1429	4.2857	0.999724	0.062503	4.3223	5	1.1568
W_{24}	4.1154	4.1250	4.1429	4.0357	0.999964	0.062518	4.1047	5	1.2181
W_{25}	4.2692	4.2500	4.2857	3.8929	0.999441	0.062485	4.1745	5	1.1978
				SUM $EN(W_m)$	15.994775				

$\sum_{l=1}^{4} x_{1l}$ is 16.5979 and $x_{1l} / \sum_{l=1}^{L} x_{1l}$ are 0.2595, 0.2542, 0.2410, 0.2453. The entropy of customer attribute W_1 is:

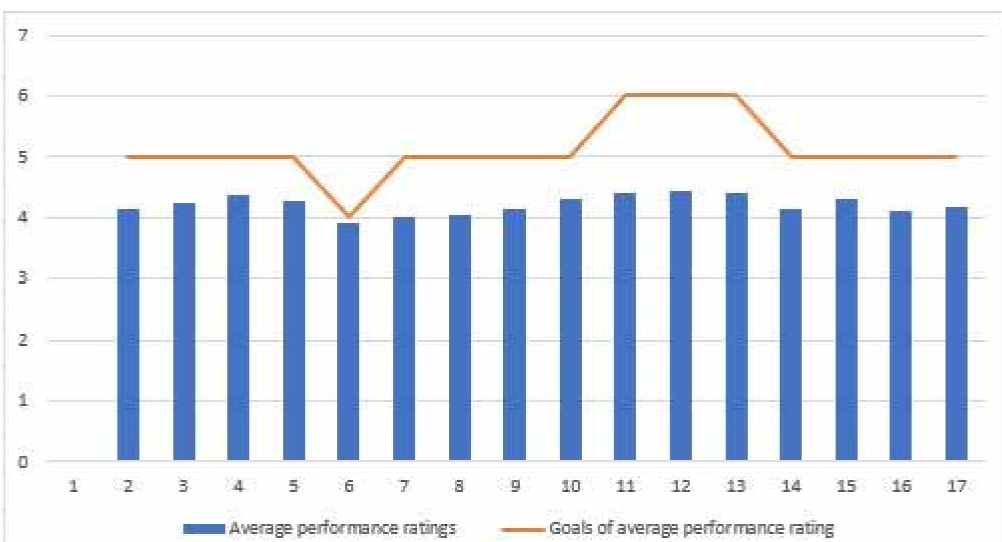
$$EN\left(W_1\right) = -\left[0.2595\ln\left(0.2595\right) + 0.2542\ln\left(0.2542\right) + 0.2410\ln\left(0.2410\right) + 0.2453\ln\left(0.2453\right)\right] / \ln\left(4\right)$$
$= 0.999695$

From all CAs, $\sum_{m=1}^{M} EN\left(W_m\right) = 15.994775$, therefore, $e_1 = 0.999695 / 15.994775 = 0.062501.$

In Figure 6, the values of e_m in Column 6 range from 0.062462 to 0.062518, which are only slightly different. This indicates that the opinions on performance ratings from the four customer groups are very similar.

In Step 4, the average performance rating from all customer groups of customer attribute *m*, $\overline{x_m}$, are calculated from x_{ml} to identify the goals for "whats" and to determine the improvement ratios which are presented in Figure 6. A brainstorming session among invited researchers and consultants of Nok Air was organized to determine the goal of average performance rating of customer attribute *m*, a_m. Finally, the improvement ratio on the performance rating of customer attribute *m*, u_m is calculated using Equation 8 and is presented in Figure 6. Figure 7 shows a relationship between the average performance ratings from all customer groups ($\overline{x_m}$) and their goals (a_m). It is seen that the average performance ratings perceived by all customer groups varied from the minimum of 3.9191 (W_9: ground services) to the maximum of 4.4478 (W_{18}: COVID-19 prevention policy). In Figure 7, although the average performance ratings of customer attribute W_9 (ground services) is the lowest, it almost achieves the goal. Thus, the improvement ratio of this customer attribute is close to 1.0 (see Figure 6), which indicates that it does not need improvement. On the other hand, the average performance ratings of cleanliness and sanitation of aircraft, COVID-19 prevention policy, and competitive airfare are the top three, however, they are significantly lower than the goals (a_m). Thus,

Figure 7. Average performance ratings from all customer groups ($\overline{x_m}$) and their goals (a_m)



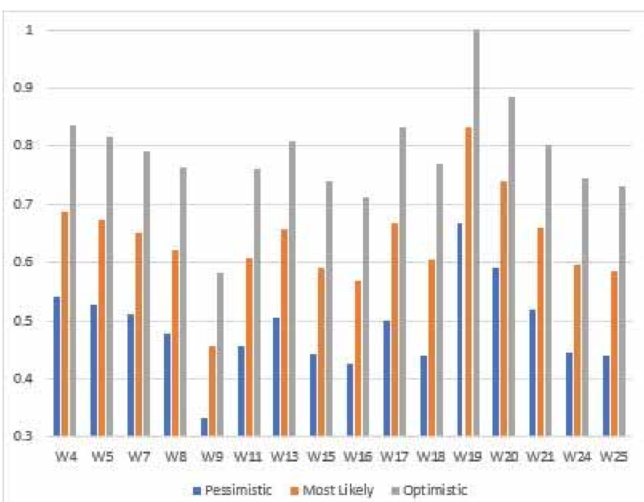
the improvement ratios of customer attributes W_{17}, W_{18}, and W_{19} are significantly higher than 1.0 and are the highest among all CAs. This indicates that there is a strong need to improve the average performance ratings perceived by the customers for CAs W_{17}, W_{18}, and W_{19}.

For Step 5, the final importance ratings of customer attribute m, $\widetilde{f_m}$, are determined as the main output related to "whats" which represents the voice of customers in the QFD process. They are affected by the relative importance ratings, degree of agreement of performance ratings, and improvement ratio. The scaled final importance ratings of customer attribute m, $\widetilde{f'_m}$, are calculated by Equation 10 where $f_m^{max} = 0.512$, which is the highest optimistic value of $\widetilde{f_m}$. The values of $\widetilde{f_m}$, $\widetilde{f'_m}$, and their ranking are presented in Figure 8. The customer attribute W_{19}, competitive airfare, has the first rank since the improvement ratio and the relative importance ratings are very high. This indicates that Nok Air has the highest priority to improve this customer attribute. The scaled final importance ratings of customer attribute m, $\widetilde{f'_m}$, are presented graphically under three fuzzy scenarios in Figure 9. It is very useful for the top management of Nok Air to visualize the priority to improve the performance of each customer attribute. It clearly shows the degree of priority and the degree of

Figure 8. Final importance ratings of 16 W_m

WHATs (W_m)		Average relative Importance Ratings $\widetilde{g_m}$	Degree of agreement of performance rating e_m	Improvement Ratio u_m	Final Importance Rating $\widetilde{f_m}$	Scaled Final Importance Rating $\widetilde{f'_m}$	Ranking
W_4	Flight Frequency	[3.7,4.7,5.7]	0.062501	1.2050	[0.277,0.352,0.428]	[0.541,0.687,0.835]	3
W_5	Overall airlines' services	[3.7,4.7,5.7]	0.062514	1.1797	[0.271,0.345,0.419]	[0.529,0.673,0.818]	4
W_7	On-time departure and arrival	[3.7,4.7,5.7]	0.062505	1.1427	[0.263,0.334,0.405]	[0.513,0.652,0.792]	8
W_8	Overall Reputation	[3.3,4.3,5.3]	0.062513	1.1718	[0.245,0.318,0.392]	[0.479,0.621,0.765]	9
W_9	Ground services	[2.7,3.7,4.7]	0.062478	1.0206	[0.171,0.234,0.298]	[0.333,0.457,0.582]	16
W_{11}	Check-in experience	[3.0,4.0,5.0]	0.062462	1.2464	[0.234,0.312,0.39]	[0.457,0.609,0.761]	10
W_{13}	Ticket distribution channel	[3.3,4.3,5.3]	0.062509	1.2389	[0.259,0.336,0.414]	[0.506,0.656,0.809]	7
W_{15}	Comfort	[3.0,4.0,5.0]	0.062501	1.2101	[0.227,0.303,0.379]	[0.444,0.592,0.739]	13
W_{16}	Free seat selection	[3.0,4.0,5.0]	0.062508	1.1641	[0.219,0.292,0.364]	[0.427,0.569,0.711]	15
W_{17}	Cleanliness and sanitation of aircraft	[3.0,4.0,5.0]	0.062485	1.3658	[0.257,0.342,0.427]	[0.501,0.668,0.834]	5
W_{18}	Covid-19 prevention policy	[2.7,3.7,4.7]	0.062507	1.3490	[0.226,0.31,0.394]	[0.44,0.605,0.77]	11
W_{19}	Fare	[4.0,5.0,6.0]	0.062513	1.3645	[0.342,0.427,0.512]	[0.667,0.834,1]	1
W_{20}	Worthiness	[4.0,5.0,6.0]	0.062499	1.2090	[0.303,0.378,0.454]	[0.591,0.739,0.886]	2
W_{21}	Promotion and marketing	[3.7,4.7,5.7]	0.062503	1.1568	[0.266,0.338,0.41]	[0.519,0.66,0.802]	6
W_{24}	Courtesy of flight attendants	[3.0,4.0,5.0]	0.062518	1.2181	[0.229,0.305,0.381]	[0.447,0.596,0.745]	12
W_{25}	Airline communication method with passengers	[3.0,4.0,5.0]	0.062485	1.1978	[0.225,0.3,0.375]	[0.439,0.585,0.732]	14

Figure 9. Scaled final importance ratings under fuzzy scenarios of CAs W_m



uncertainty of priority since the relative importance ratings obtained from top executives are uncertain and handled by fuzzy numbers. Figure 9 clearly shows that the management team should give priority to improving the performance of fare, worthiness, flight frequency, overall airlines' services, cleanliness and sanitization of aircraft, and frequent flyer programs.

From the proposed methodology in Step 6, to identify the LCC strategic decisions as a set of operational practices, a team with three DMs (DM_1, DM_2, and DM_3) under a chief operations officer (COO) of Nok Air is requested to provide opinions on the relationships between the CAs, "what" and strategic decisions, "hows". These DMs are experts in Nok Air who clearly understand the details of nine strategic decisions, H_n, and how the strategic decisions affect the CAs, W_m. Then, the degree of relationship obtained from the three DMs is expressed by the Likert scale as a result of Step 7, as shown in Figure 10. The degree of relationship in the Likert scale is converted to the corresponding TFNs according to Table 3. Finally, the average values of TFNs from three DMs ($\widetilde{r_{mn}}$) are determined and presented in Figure 11.

Based on the linguistic variables and the corresponding TFNs presented in Table 3, the TFNs that are higher than or equal to (3, 4, 5) are considered relatively strong relationships. The relationships ($\widetilde{r_{mn}}$) that are relatively strong, are highlighted in Figure 11. Some examples are provided to show that the relationships in Figure 11 are reasonable. The strategic decision to use Q400 NextGen aircraft should significantly increase the CA flight frequency. The strategic decision of premium LCC should

Figure 10. DMs' opinion on the relationship between "whats" and "hows" expressed in a likert scale

Hows / Whats	H_1			H_2			H_3			H_4			H_5			H_6			H_7			H_8			H_9		
	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3
W_4	5	5	5	5	5	4	4	3	3	4	3	1	5	5	5	1	2	1	1	1	1	1	1	2	1	3	3
W_5	4	5	3	2	2	3	4	4	5	3	2	1	2	4	4	5	5	4	3	4	4	2	3	2	2	2	2
W_7	2	3	3	2	4	3	1	1	1	1	1	1	5	4	4	1	3	4	2	2	2	2	3	2	2	1	2
W_8	1	1	3	1	1	3	2	1	1	1	3	3	1	1	1	4	4	3	4	3	3	3	4	3	3	2	2
W_9	1	1	1	1	1	1	3	3	4	3	2	2	2	3	2	5	4	4	3	3	3	1	1	1	2	3	3
W_{11}	3	2	1	1	2	2	2	4	4	1	1	1	2	2	3	5	4	4	5	5	5	1	1	1	2	3	3
W_{13}	1	1	1	1	2	1	5	5	3	3	4	1	3	3	4	3	4	3	5	5	5	2	1	1	1	1	1
W_{15}	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	5	5	5	1	2	2	1	1	1	3	3	3
W_{16}	1	1	1	1	1	1	3	1	1	1	1	1	1	1	1	5	5	4	1	2	2	1	1	1	2	3	2
W_{17}	1	1	1	1	1	1	2	3	3	1	1	1	3	3	3	1	3	3	1	1	1	1	1	1	1	1	1
W_{18}	1	1	1	1	1	1	4	2	1	1	1	1	1	1	1	1	4	4	1	1	1	1	1	1	1	1	1
W_{19}	5	5	3	5	3	3	4	5	5	3	3	2	5	3	4	5	5	3	1	2	2	2	3	2	1	1	2
W_{20}	4	4	3	4	4	3	3	3	3	1	3	1	4	3	4	5	5	4	1	1	1	2	2	2	1	1	2
W_{21}	2	3	1	2	5	4	3	3	3	1	1	1	4	2	2	5	5	4	5	4	4	2	3	3	1	1	1
W_{24}	3	5	3	3	1	1	5	5	5	1	1	1	1	1	1	5	3	5	1	2	1	1	1	1	1	2	1
W_{25}	1	1	1	1	1	1	5	5	5	1	1	1	1	2	1	1	1	1	2	3	3	1	1	1	1	1	1

Figure 11. Fuzzy relationship between "Whats" and "Hows" ($\widetilde{r_{mn}}$)

Hows / Whats	H_1	H_2	H_3	H_4	H_5	H_6	H_7	H_8	H_9
W_4	[4,5,6]	[3.67,4.67,5.67]	[2.34,3.34,4.34]	[1.67,2.67,3.67]	[4,5,6]	[0.34,1.34,2.34]	[0,1,2]	[0.34,1.34,2.34]	[1.34,2.34,3.34]
W_5	[3,4,5]	[1.34,2.34,3.34]	[3.34,4.34,5.34]	[1,2,3]	[2.34,3.34,4.34]	[3.67,4.67,5.67]	[2.67,3.67,4.67]	[1.34,2.34,3.34]	[1,2,3]
W_7	[1.67,2.67,3.67]	[2,3,4]	[0,1,2]	[0,1,2]	[3.34,4.34,5.34]	[1.67,2.67,3.67]	[1,2,3]	[1.34,2.34,3.34]	[0.67,1.67,2.67]
W_8	[0.67,1.67,2.67]	[0.67,1.67,2.67]	[0.34,1.34,2.34]	[1.34,2.34,3.34]	[0,1,2]	[2.67,3.67,4.67]	[2.34,3.34,4.34]	[2.34,3.34,4.34]	[1.34,2.34,3.34]
W_9	[0,1,2]	[0,1,2]	[2.34,3.34,4.34]	[1.34,2.34,3.34]	[1.34,2.34,3.34]	[3.34,4.34,5.34]	[2,3,4]	[0,1,2]	[1.67,2.67,3.67]
W_{11}	[1,2,3]	[0.67,1.67,2.67]	[2.34,3.34,4.34]	[0,1,2]	[1.34,2.34,3.34]	[3.34,4.34,5.34]	[4,5,6]	[0,1,2]	[1.67,2.67,3.67]
W_{13}	[0,1,2]	[0.34,1.34,2.34]	[3.34,4.34,5.34]	[1.67,2.67,3.67]	[2.34,3.34,4.34]	[2.34,3.34,4.34]	[4,5,6]	[0.34,1.34,2.34]	[0,1,2]
W_{15}	[1,2,3]	[0,1,2]	[0,1,2]	[0,1,2]	[1,2,3]	[4,5,6]	[0.67,1.67,2.67]	[0,1,2]	[2,3,4]
W_{16}	[0,1,2]	[0,1,2]	[0.67,1.67,2.67]	[0,1,2]	[0,1,2]	[3.67,4.67,5.67]	[0.67,1.67,2.67]	[0,1,2]	[1.34,2.34,3.34]
W_{17}	[0,1,2]	[0,1,2]	[1.67,2.67,3.67]	[0,1,2]	[2,3,4]	[1.34,2.34,3.34]	[0,1,2]	[0,1,2]	[0,1,2]
W_{18}	[0,1,2]	[0,1,2]	[1.34,2.34,3.34]	[0,1,2]	[0,1,2]	[2,3,4]	[0,1,2]	[0,1,2]	[0,1,2]
W_{19}	[3.34,4.34,5.34]	[2.67,3.67,4.67]	[3.67,4.67,5.67]	[1.67,2.67,3.67]	[3,4,5]	[3.34,4.34,5.34]	[0.67,1.67,2.67]	[1.34,2.34,3.34]	[0.34,1.34,2.34]
W_{20}	[2.67,3.67,4.67]	[2.67,3.67,4.67]	[2,3,4]	[0.67,1.67,2.67]	[2.67,3.67,4.67]	[3.67,4.67,5.67]	[0,1,2]	[1,2,3]	[0.34,1.34,2.34]
W_{21}	[1,2,3]	[2.67,3.67,4.67]	[2,3,4]	[0,1,2]	[1.67,2.67,3.67]	[3.67,4.67,5.67]	[3.34,4.34,5.34]	[1.67,2.67,3.67]	[0,1,2]
W_{24}	[2.67,3.67,4.67]	[0.67,1.67,2.67]	[4,5,6]	[0,1,2]	[0,1,2]	[3.34,4.34,5.34]	[0.34,1.34,2.34]	[0,1,2]	[0.34,1.34,2.34]
W_{25}	[0,1,2]	[0,1,2]	[4,5,6]	[0,1,2]	[0.34,1.34,2.34]	[0,1,2]	[1.67,2.67,3.67]	[0,1,2]	[0,1,2]

improve the CA overall airlines' services and courtesy of flight attendants. The strategic decision to improve the e-platform should help improve check-in experience and aircraft boarding experience.

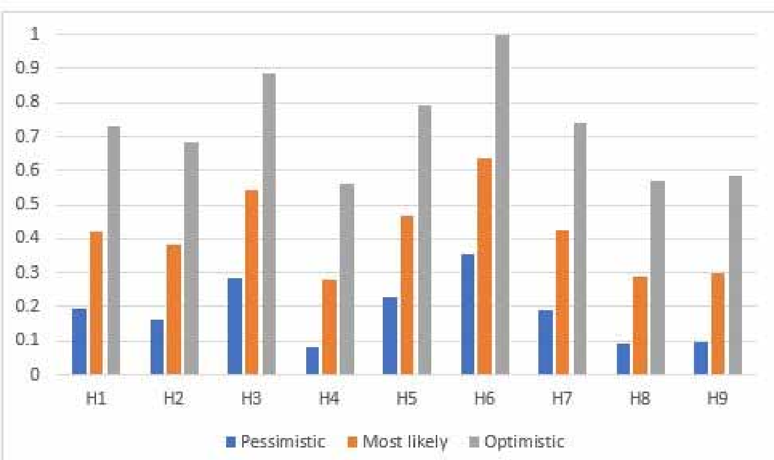
In the final step, the technical ratings $\tilde{t}_n$ and the scaled technical ratings $\tilde{t}'_n$ are computed by Equation 12 and Equation 13 respectively. $\tilde{t}_n$, $\tilde{t}'_n$, and their raking are presented in Figure 12. A graph of the scaled technical ratings under fuzzy scenarios is presented in Figure 13.

The final result of the proposed fuzzy QFD method is to determine the priority for implementing the strategic decisions H_n, which are interpreted from the values of the scaled technical ratings $\tilde{t}'_n$. The higher value of scaled technical ratings means higher priority. The graph in Figure 13 clearly shows that the top five strategic decisions that need to be implemented very soon during the COVID-19 recovery period are as follows: positioning itself as a premium LCC and offering premium services to all passengers; increasing ancillary revenue, such as advanced seat selection and pre-booked in-flight catering; utilizing more aircraft in terms of aircraft turnaround to reduce the unit cost; enhancing all the electronic platforms that can facilitate customers with seamless travel experience; and using the Q400 NextGen fleet to increase the flight frequency and monopoly route.

Figure 12. Fuzzy technical ratings of "Hows"

HOWs (H_n)	Description	Technical rating $\tilde{t}_n$ Fuzzy	Scaled technical rating $\tilde{t}'_n$ Fuzzy	Ranking
H_1	Fleet strategy	[5.796,12.616,21.875]	[0.195,0.423,0.733]	5
H_2	Airport utilization	[4.88,11.41,20.382]	[0.164,0.383,0.683]	6
H_3	Ancillaries revenue	[8.504,16.267,26.474]	[0.285,0.545,0.887]	2
H_4	Contract renegotiation	[2.486,8.404,16.762]	[0.084,0.282,0.562]	9
H_5	Aircraft utilization	[6.839,13.982,23.568]	[0.23,0.469,0.79]	3
H_6	Premium LCC	[10.604,19.009,29.862]	[0.356,0.637,1]	1
H_7	Improve e-platform	[5.724,12.67,22.062]	[0.192,0.425,0.739]	4
H_8	Capital injection	[2.66,8.599,16.979]	[0.09,0.288,0.569]	8
H_9	Restructuring organization	[2.849,8.947,17.484]	[0.096,0.3,0.586]	7

Figure 13. Scaled technical ratings under fuzzy scenarios of strategic decisions H_n



CONCLUSION AND FURTHER STUDIES

This section provides general conclusions, a summary of contributions, and recommendations for further studies.

Conclusion

The outbreak of COVID-19 has brought a significant shock to the world and has led to severe economic losses in the tourism and aviation industry, including LCCs in Thailand. The prospects for a sustainable recovery to the pre-pandemic conditions are still a considerable challenge. Further complications arose during the COVID-19 recovery period because customer requirements were unknown, and airlines could not execute the right strategies in response to the needs of the customers. This paper proposes the use of the fuzzy QFD approach, which is a systematic method, to prioritize the needs of the customers, relate such requirements to the airlines' strategies, and suggest the strategic decisions that the LCCs should accomplish to ensure the business survival during the recovery period. Nok Air, a leading LCC in Thailand, is chosen to demonstrate the application of the proposed method. In this study, the customers' needs are known as "whats", and the airlines' strategic decisions are known as "hows". The QFD process, by the construction of HOQ, prioritizes the needs and transforms those requirements into implementable actions. For Nok Air, the top priorities of "whats" are to improve the performance of CAs W_{19}- Fare, W_{20}- Worthiness, W_4- Flight frequency, W_5- Overall airlines' services, W_{17}- Cleanliness and sanitization of aircraft, and W_2- Frequent flyer program. The top priorities of strategic decisions or "hows" are H_6- Positioning itself as a premium LCC and offering premium services to all passengers, H_3- to increase the ancillary revenue such as advanced seat selection and pre-booked in-flight catering, H_5 – to utilize more aircraft in terms of aircraft turnaround to reduce the unit cost, H_7- to enhance all the electronic platforms that can facilitate customers with the seamless travel experience, and H_1- to apply the fleet strategy of using the Q400 NextGen fleet to increase the flight frequency and monopoly route.

Contributions

This study has a significant theoretical contribution related to the application of fuzzy QFD since it is the first research that applies the fuzzy QFD method to prioritize various strategic decisions for managing LCC during the COVID-19 recovery period to improve performance ratings perceived by customers toward the target performance set by the management team. There are previous works that applied the QFD method to improve airport operations or airline planning (not airline operations) before the COVID-19 period (not during the COVID-19 recovery period).

This study has many practical contributions to Nok Air and other LCCs as follows: First, the proposed fuzzy QFD method is more suitable to be applied to the real case of Nok Air since some variables are uncertain (for example, the relationship between CAs W_m and strategic decisions H_n) and DMs are unable to determine exact values of the variables. Additionally, the final results which are the scaled technical ratings of strategic decisions, $\widetilde{t'_n}$, are fuzzy numbers with three different values under pessimistic, most likely, and optimistic scenarios as shown in Fig. 5. The fuzzy numbers provide more information to DMs and also warn DMs about the degree of uncertainties of the results. Therefore, DMs should use the results as a guideline, which should be adapted based on emerging situations.

Second, the proposed method requires three DMs under the COO to systematically analyze and estimate relationships between CAs W_m and strategic decisions H_n so that they better and more accurately understand the relationships, which is very beneficial for further formulations of new strategic decisions.

Third, the proposed fuzzy QFD method is systematic, reasonable, and explainable. Therefore, the DMs under the COO have the confidence to present the method and to propose the priority of implementing the strategic decisions suggested from this method to the top management of Nok Air.

Finally, three top executives of Nok Air participated in this project by providing opinions related to the relative importance ratings. Therefore, they understand the concept of fuzzy QFD and also trust that the analysis results should be valid. The support from top executives should allow a smooth implementation of the proposed strategic decisions.

Limitations and Recommendations for Further Studies

This study has some limitations that require further studies. The limitations and further studies are simultaneously discussed as follows. First, the performance ratings of customer attribute *m* perceived by customer group *l*, x_{ml}, which are obtained from the customer survey are affected by the opinions on the quality of services of Nok Air at the time that the survey is conducted. These opinions are dynamic and may be changed when Nok Air starts implementing strategic decisions or when competitors of Nok Air change their strategies. Thus, the results of this study may be valid for the short term, not for the long term. In the long run, the proposed method should be re-conducted to collect up-to-date opinions from customers.

Second, the list of nine strategic decisions presented in Table 4 is obtained from the airline's expert team that contributed directly to the strategic and operational planning during the COVID-19 recovery period. It is expected that when the situation of Nok Air is completely recovered, some strategic decisions may be out-of-date and should be revised. When some new strategic decisions are formulated, a revision of the HOQ should be done and a new set of priorities for implementing the revised strategic decisions should be re-determined.

Third, this research is the first time that the fuzzy QFD is applied in Nok Air, therefore, the DMs from the office of the COO may not accurately understand the relationship between the strategic decisions and CAs. This may affect the accuracy of the priority of implementing strategic decisions to a certain extent. During the implementation of the strategic decisions, the DMs may better understand the relationship, and the revision of the calculation of the HOQ is recommended.

Finally, a technical competitive analysis, which compares the strategic decisions or "hows" of Nok Air with comparison to the strategic decisions of other LCCs is excluded from this study since the research team wants to focus on a particular case study of Nok Air only. Further studies may be conducted to include the technical competitive analysis with other LCCs.

FUNDING STATEMENT

This research was supported by the KMITL Research Fund [grant number xxxxxx].

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Pisal Yenradee is an Associate Professor with the School of Manufacturing Systems and Mechanical Engineering and Chairperson of Industrial Engineering Curriculum at Sirindhorn International Institute of Technology, Thammasat University, Thailand. His research interests include Production and Inventory control (P&IC) systems, JIT, MRP, and TOC, P&IC systems for Thai industries, P&IC in supply chain, Applied operations research, and Systems simulation.