Dynamic intuitionistic fuzzy multi-attribute aftersales performance evaluation

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Abstract Aftersales services are crucial for gaining a competitive advantage, since they enhance long-term profitability and sustainability. Aftersales service performance evaluation is necessary to understand current problems and develop new strategies. Multi-period evaluations are required for revealing these performances. Moreover, performance appraisal results usually involve uncertainty and fuzziness. In this study, a dynamic intuitionistic fuzzy multi-attribute aftersales performance evaluation method is used to measure the performance of an electronics company. A sensitivity analysis is conducted to examine the robustness of the results.

Keywords Dynamic intuitionistic · Fuzzy · Performance evaluation · Aftersales · Multi-criteria

Introduction

Aftersales services include various activities that start after the purchasing of the product or service and continue during the usage of the product or service [3,9,36]. Aftersales services provide a competitive advantage by enabling companies to differentiate the product or service and increase the revenue by sale of spare parts. Therefore, aftersales services are considered as the linkage between customers and the company [9]. Customer preferences and an initial selection of customers differ based on the provided products or services and the additional services after purchasing the product or service [25,44]. Maintaining customer satisfaction, improving the quality, providing well-maintained relationships with customers, increasing customer satisfaction and loyalty, and enhancing competitive advantage are the main objectives of aftersales services [3,14,36].

Performance evaluation is the key to a successful aftersales service system. To have a comprehensive aftersales performance evaluation system, the evaluation process should involve both objective and subjective performance evaluation criteria collected at different periods. The nature of aftersales performance evaluation criteria usually consists of uncertainty and vagueness. Fuzzy sets are perfect tools for dealing with the vagueness and uncertainty. Intuitionistic fuzzy sets are the fuzzy sets that enable defining both membership and non-membership values. This definition enables a better representation of ambiguity and vagueness to inherit in performance criteria. Therefore, in this study, a dynamic intuitionistic fuzzy multi-attribute decision-making method is used for dealing with this fuzzy multi-stage evaluation process. To the best of our knowledge, this study is the first paper that develops an aftersales performance appraisal system using dynamic intuitionistic fuzzy sets. It also provides a sensitivity framework for better understanding the evaluations and checking the robustness of the results.

The rest of this paper is organized as follows: section “Aftersales performance” summarizes aftersales performance evaluation systems in the literature. Section “Dynamic intuitionistic fuzzy multi-attribute decision-making” presents basic concepts of the dynamic intuitionistic fuzzy sets. In the section “Aftersales Service Performance Measurement”, aftersales service performance of an electronics company is measured. The last section concludes the paper and gives some perspectives.
**Aftersales performance**

Installation, training, routine maintenance, emergency repair, spare parts supply, and software services are primary activities in the aftersales services [39]. These services also include transport or delivery, installation, user training, documentation, advice by helpdesk, technical advice, maintenance and repair, online report, warranty, spare part delivery, recycling, and upgrades [12, 13, 16, 32, 36]. In addition to these lists of activities, aftersales services include call center operations, home visiting services, and claim handling services [1].

Measurement of performance in aftersales services is quite important to understand current problems and develop strategies. Gaiardelli et al. [15] claim that literature has limited well-prepared performance measurement systems for aftersales services and develop performance measurement system for aftersales services. According to this study, there should be various levels of analysis depending on the purposes. Moreover, there should be a combination of financial and non-financial dimensions, long-term and short-term decisions, tangible and intangible features, and measures of the efficiency and effectiveness.

According to Baileyt et al. [6], the flexibility of services, the reliability of company and personnel, and expectations of customers about the service have an influence on the customer satisfaction. Matzler et al. [27] claim that reliability and friendliness of personnel affect customer satisfaction. Birgelen et al. [7] reveal that customization, flexibility, recovery, and spontaneous customer delight affect customer satisfaction by influencing from technological developments. The evaluation system includes four different levels of business, process, activity, and development and innovation [15]. At the business level, the overall performance of aftersales services is measured by operating profit, Return on Investment (ROI), and Return on Assets (ROA) for services based on the revenue and cost. At the process level, performance measurement is done based on the customer satisfaction, flexibility, and productivity. Flexibility evaluates the satisfaction level of customer expectations from the external and internal point of view. External point of view reflects customers view, while the internal point of view is about the company itself. Ahn and Sohn [1] determine all of the activities in the aftersales services necessitate usage easiness, reaching speed, technical skills, management speed, assurance, and politeness for having satisfied customers. Sadeghi and Hanzaei [34] claim that accessibility, convenience, accuracy, security, usefulness, and brand image affect the customer satisfaction. Krishnan and Hari [24] statistically show that cost of attracting a new customer for purchasing product or service of the company is ten times larger than the cost of keeping an existing customer. Satisfied customers tend to share their experiences with other people. According to [23], customer satisfaction has the essential meaning for companies as a tool for reaching important aspects. Customer satisfaction has importance due to both financial and operational advantages. Customer satisfaction is affected by various attributes, and it is important regarding having loyal customers, increasing long-term financial performance, profitability, and market share of the companies [35]. Customer satisfaction is crucial to the success of businesses in both economic and strategic aspects.

**Service quality (SQ)**

Service quality is another important attribute of aftersales services performance. Service quality is the comparison of expected performance level of services with perceived performance of services. Parasuraman et al. [28] develop SERVQUAL dimensions and state that there are ten dimensions affecting service quality as reliability, responsiveness, competence, access, courtesy, communication, credibility, security, understanding the customer, and tangibles. Parasuraman et al. [29] decrease these ten factors to five as reliability, responsiveness, security, understanding the customer, and tangibles.
Financial success (FS)

The financial success of aftersales services is mainly determined based on the calculations of profit, cash flow, ROI, and ROA of companies regarding the costs and revenue [15]. It is one of the main goals of companies and departments. Most of the elements have small or large effects on the financial success.

Perceived service value (PSV)

Perceived service value determines the value of product and service based on the perception of customers. According to [20], perceived service value is defined by comparing inputs and outputs of a service where inputs include attributes related to the customers and outputs include attributes related to the aftersales service of the company. It is the comparison of benefits from the service and sacrifices of customers to get this service such as price, time, and effort [33].

Customer retention (CR)

Customer retention is keeping customers to purchase products and services of companies. According to Lindgreen et al. [26], attracting a new customer is ten times more expensive than keeping an existing customer. Therefore, companies give importance to customer retention instead of trying to get new customers. Customer retention provides an increase in the revenue of the companies, because retained customers increase the quantity of sold products [8,30]. Griffin [17] states that a little increase in customer retention provides as much as 25% increase in the profits. Thus, retained customers are important, since they tend to spend more money for the company and share their experiences.

Repurchase (RP)

Repurchase is keeping purchasing the products and services offered by the company. It is about the satisfaction level of customers and customer retention of companies. If customers are satisfied with the aftersales services of companies, they tend to stay as a customer of the same company, and keep buying other products and aftersales services of the company [18].

Brand loyalty (BL)

Brand loyalty is an emotional relationship between customers and company. Anderson and Srinivasan [2] declare that dissatisfied customers highly tend to go to competitors. Thus, customer satisfaction affects the brand loyalty of customers and brand loyalty leads to customer retention.

Recommendation (RC)

Recommendation is the advice of customers to other customers on the products and services of a company [31]. It has a significant impact on the customer behaviors. Most of the customers start purchasing activities based on the recommendations of previous customers of the company.

Brand image (BI)

Brand image is the current perception of customers on a company. It is the position of the company in their customers’ minds. This intangible and inimitable element of the company is one of the most important attributes for aftersales performance and customer satisfaction. Brand image is affected by reliability, professionalism, and innovativeness of company, having a social contribution and giving value to the customers [38].

Dynamic intuitionistic fuzzy multi-attribute decision-making

Intuitionistic fuzzy sets are the fuzzy sets that consider both the membership and non-membership values for defining fuzziness in a system. The sum of membership and non-membership values of an intuitionistic fuzzy set is less than or equal to one [4,5]. In the literature, they are widely used to represent fuzziness in different areas [21,42,43], Onar et al. (2015, 2016).

Preliminaries

Definition 1 An intuitionistic fuzzy set in a given set $X (X \neq \emptyset)$ is an object $I$ given by

$$I = \{(x, \mu_{I}(x), v_{I}(x)) ; x \in X\}, \quad (1)$$

where $\mu_{I} : X \rightarrow [0,1]$ and $v_{I} : X \rightarrow [0,1]$ satisfy the condition

$$0 \leq \mu_{I}(x) + v_{I}(x) \leq 1,$$

for every $x \in X$ where $\mu_{I}(x)$ is the membership value and $v_{I}(x)$ is the non-membership value of intuitionistic fuzzy set $I$.

Definition 2 A dynamic intuitionistic fuzzy variable that has a time dimension can be defined as $I(t) = (\mu_{I(t)}, v_{I(t)}, \pi_{I(t)})$, where $t$ is a time variable [40]:

$$\mu_{a(t)} + v_{a(t)} \leq 1, \pi_{a(t)} = 1 - \mu_{a(t)} - v_{a(t)} \quad (2)$$
Table 1 Intuitionistic fuzzy decision matrix collected at four quarters

|   | CS | SQ | FS | PSV | CR | RP | BL | RC | BI |
|---|----|----|----|-----|----|----|----|----|----|
| t1 | (0.8, 0.1, 0.1) | (0.8, 0.1, 0.1) | (0.4, 0.5, 0.1) | (0.9, 0.1, 0.0) | (0.7, 0.2, 0.1) | (0.5, 0.2, 0.3) | (0.7, 0.2, 0.1) | (0.3, 0.1, 0.6) | (0.5, 0.3, 0.2) |
| t2 | (0.9, 0.1, 0.0) | (0.8, 0.1, 0.1) | (0.4, 0.2, 0.4) | (0.9, 0.1, 0.0) | (0.8, 0.1, 0.1) | (0.5, 0.3, 0.2) | (0.6, 0.2, 0.2) | (0.7, 0.1, 0.2) | (0.3, 0.1, 0.6) |
| t3 | (0.1, 0.7, 0.2) | (0.1, 0.7, 0.2) | (0.8, 0.2, 0.0) | (0.5, 0.2, 0.3) | (0.6, 0.4, 0.0) | (0.6, 0.2, 0.2) | (0.7, 0.2, 0.1) | (0.9, 0.1, 0.0) | (0.4, 0.4, 0.2) |
| t4 | (0.3, 0.6, 0.1) | (0.8, 0.1, 0.1) | (0.1, 0.6, 0.3) | (0.9, 0.1, 0.0) | (0.7, 0.2, 0.1) | (0.7, 0.2, 0.1) | (0.5, 0.4, 0.1) | (0.8, 0.2, 0.0) | (0.4, 0.4, 0.2) |

where \( \mu_{\tilde{I}(t)} \in [0, 1] \) is the membership value, \( v_{\tilde{I}(t)} \in [0, 1] \) is the non-membership value, and \( \pi_{a(t)} \in [0, 1] \) is the hesitancy value of dynamic intuitionistic fuzzy variable \( I(t) \).

**Definition 3** \( \tilde{I}(t_1), \tilde{I}(t_2), \ldots, \tilde{I}(t_n) \) are the intuitionistic fuzzy numbers collected at \( n \) different periods [8].

**Definition 4** Let \( \tilde{I}(t_1) = (\mu_{\tilde{I}(t_1)}, v_{\tilde{I}(t_1)}, \pi_{\tilde{I}(t_1)}) \) and \( \tilde{I}(t_2) = (\mu_{\tilde{I}(t_2)}, v_{\tilde{I}(t_2)}, \pi_{\tilde{I}(t_2)}) \) be the values of intuitionistic fuzzy variable \( I(t) \) taking \( t = t_1, t_2 \).

Then,

\[
\tilde{I}(t_1) \oplus \tilde{I}(t_2) = (\mu_{\tilde{I}(t_1)} + \mu_{\tilde{I}(t_2)} - \mu_{\tilde{I}(t_1)} \mu_{\tilde{I}(t_2)}), \\
v_{\tilde{I}(t_1)} v_{\tilde{I}(t_2)} \left( 1 - \mu_{\tilde{I}(t_1)} \right) + \left( 1 - \mu_{\tilde{I}(t_2)} \right) - v_{\tilde{I}(t_1)} v_{\tilde{I}(t_2)} \\
\lambda \tilde{I}(t_1) = (1 - (1 - \mu_{\tilde{I}(t_1)})^\lambda, \\
\lambda v_{\tilde{I}(t_1)}^\lambda - v_{\tilde{I}(t_1)}^\lambda, \quad \lambda > 0
\]

where \( \lambda \) is a scalar.

**Definition 5** Let \( t_k \) denote the \( k \)th period and \( \omega_k \) is the weight at the \( t_k \)th period, where \( t = t_1, t_2, \ldots, t_n \) and \( \omega(t) = (\omega(t_1), \omega(t_2), \ldots, \omega(t_n)) \) istheweightvector with \((t_n) \in [0, 1] \), \( \sum_{k=1}^{n} \omega(t_k) = 1 \).

Dynamic intuitionistic fuzzy multi-attribute decision-making

Dynamic intuitionistic fuzzy multi-attribute decision-making method developed by [41] deals with the intuitionistic fuzzy values collected at different periods. The steps of this methodology are given as follows:

- Defining the attributes and evaluating alternatives for the problem.
- Evaluating each alternative \( i \) with respect to each attribute \( j \) using intuitionistic fuzzy numbers for each period \( t_k \):

\[
\tilde{I}_{ij}(t_k) = (\mu_{\tilde{I}_{ij}(t_k)}, v_{\tilde{I}_{ij}(t_k)}, \pi_{\tilde{I}_{ij}(t_k)})
\]

where \( \tilde{I}_{ij}(t_k) \) is the intuitionistic fuzzy evaluation for alternative \( i = 1, 2, \ldots, n \) and attribute \( j = 1, 2, \ldots, m \) at period \( t_k \).
Table 2 Complex intuitionistic fuzzy decision matrix

|   | CS         | SQ         | FS         | PSV        | CR         |
|---|------------|------------|------------|------------|------------|
| P1| (0.813, 0.1, 0.087) | (0.747, 0.152, 0.101) | (0.585, 0.211, 0.204) | (0.722, 0.132, 0.146) | (0.806, 0, 0.194) |
| P2| (0.466, 0.2, 0.334) | (0.73, 0.143, 0.127) | (0.516, 0.4, 0.084) | (0.73, 0.229, 0.041) | (0.529, 0.143, 0.328) |
| P3| (0.783, 0.14, 0.077) | (0.362, 0.464, 0.174) | (0.351, 0.504, 0.145) | (0.412, 0.325, 0.263) | (0.478, 0.316, 0.206) |
| P4| (0.439, 0.158, 0.403) | (0.727, 0, 0.273) | (0.401, 0.263, 0.336) | (0.543, 0.141, 0.316) | (0.654, 0, 0.346) |
| P5| (0.659, 0.135, 0.206) | (0.629, 0, 0.371) | (0.688, 0.255, 0.057) | (0.599, 0.263, 0.138) | (0.403, 0.204, 0.393) |

Table 3 Closeness coefficient

|   | \(\sum_{j=1}^{m} Y_j (1 - v_{ij})\) | \(\sum_{j=1}^{m} Y_j (1 + \pi_{ij})\) | Closeness coefficient |
|---|---------------------------------|---------------------------------|----------------------|
| P1| 0.864                           | 1.179                           | 0.733                |
| P2| 0.808                           | 1.204                           | 0.671                |
| P3| 0.741                           | 1.196                           | 0.620                |
| P4| 0.918                           | 1.296                           | 0.709                |
| P5| 0.847                           | 1.191                           | 0.711                |

- Calculating the weight vector for periods \(\omega(t) = (\omega(t_1), \omega(t_2), \ldots, \omega(t_p))\) using arithmetic series based method (Xu 2008) where the difference between \(\omega(t_k)\) and \(\omega(t_{k+1})\) is a constant \(c\):

\[
\omega(t_{k+1}) - \omega(t_k) = c, \quad \omega(t_k) = \eta + (k - 1)c
\]  

(6)

where when all the weights are equal, \(c = 0, \eta = \frac{1}{n}\), \(\omega(t_k) = \frac{1}{n}(k = 1, 2, \ldots, p)\),

when \(\omega(t_k)\) is a monotonically increasing sequence, \(c > 0\) then \(\omega(t_k) < \omega(t_{k+1})\), when \(\omega(t_k)\) is a monotonically decreasing sequence \(c < 0\) then \(\omega(t_k) > \omega(t_{k+1})\).

In this study, the weights are assumed to be equal.

- Aggregating the Intuitionistic numbers collected at different periods with dynamic weighted fuzzy averaging (DIFWA) operator [41].

\[
\text{DIFWA}_{\omega(t)} \left( \hat{I}_{t_1}, \hat{I}_{t_2}, \ldots, \hat{I}_{t_n} \right) = \left( 1 - \prod_{k=1}^{n} \left(1 - \mu \hat{I}_{t_k} \right)^{\omega(t_k)} \right) \prod_{k=1}^{n} v_{\hat{I}_{t_k}}^{\omega(t_k)},
\]

\[
\times \prod_{k=1}^{n} \left( 1 - \mu \hat{I}_{t_k} \right)^{\omega(t_k)} - \prod_{k=1}^{n} v_{\hat{I}_{t_k}}^{\omega(t_k)}. \quad (7)
\]

- Defining the intuitionistic fuzzy ideal \(Y^+ = (I_1^+, I_2^+, \ldots, I_m^+)\) and negative ideal solutions \(Y^- = (I_1^-, I_2^-, \ldots, I_m^-)\), where \(I_i^+ = (1, 0, 0)\) is the largest and \(I_i^- = (0, 0, 1)\) is the smallest Intuitionistic fuzzy numbers.

- Calculating the closeness coefficient of each alternative using Eq. (8) and selecting the alternative with the highest closeness coefficient:

\[
C_i = \frac{\sum_{j=1}^{m} w_j (1 - v_{ij})}{\sum_{j=1}^{m} w_j (1 + \pi_{ij})}, \quad (8)
\]

where \(i = 1, 2, \ldots, n\) and \(w_j\) is the weight of the \(j\)th attribute.

Aftersales service performance measurement

An electronics company that outsources its aftersales services wants to measure the performance of the aftersales provider companies. The company has five different aftersales providers. These aftersales providers’ performance can be measured by the attributes Customer Satisfaction (CS), Service Quality (SQ), Financial Success (FS), Perceived Service Value (PSV), Customer Retention (CR), Repurchase (RP), Brand Loyalty (BL), Recommendation (RC), and Brand Image (BI). A group of three managers evaluated five different aftersales providers. The managers discuss their evaluations and achieve final compromise evaluations collectively. The performances of the aftersales service providing companies are evaluated at four periods. Table 1 shows the compromised intuitionistic fuzzy decision matrix collected at these four periods.

The newer periods have a bigger impact on the performance evaluation. Therefore, the weights of periods are determined by the arithmetic series. The weight of the
Fig. 1 Sensitivity analysis

periods are defined as follows: $\omega (t_1) = 0.1; \omega (t_2) = 0.2; \omega (t_3) = 0.3; \omega (t_4) = 0.4$. Using Eq. (7), the intuitionistic fuzzy evaluations given in Table 1 are aggregated into complex intuitionistic fuzzy decision matrix (Table 2).
All the attributes have the same importance. Using Eq. (8), the closeness coefficient of each alternative is calculated (Table 3).

P1 has the highest performance, whereas the P3 aftersales services provider has the lowest performance. The managers of the study revealed that they are satisfied with the results.

To reveal the robustness of the results, a one at a time sensitivity analysis is conducted. Figure 1 shows the results of the sensitivity analysis. In this analysis, the weights of the attributes are changed, and the change in the closeness coefficient is measured.

The performances of aftersales companies are changing depending on the weights of the attributes. The performances are highly responsive to the change in the attributes. Currently, P1 shows the highest performance among aftersales provider companies mainly due to its performance on Customer Satisfaction, Perceived Service Value, and Customer Retention criteria. However, P5 becomes the leading aftersales provider when the importance of Financial Success is higher than 0.4, or the importance of Recommendation is greater than 0.2 or the importance of Brand Loyalty is greater than 0.3. P4 becomes the highest performing aftersales provider when Service Quality is almost only performance criteria or when the importance of repurchase is higher than 0.4. P2 becomes the leading aftersales provider when the brand image is more important than 0.5.

Conclusion

In this study, the performances of aftersales performance providers of an electronics company are measured with a dynamic aftersales performance measurement system. Customer Satisfaction (CS), Service Quality (SQ), Financial Success (FS), Perceived Service Value (PSV), Customer Retention (CR), Repurchase (RP), Brand Loyalty (BL), Recommendation (RC), and Brand Image (BI) are the main factors for the measurement process. The evaluations are collected at four different periods. These intuitionistic fuzzy evaluations are aggregated with the dynamic intuitionistic fuzzy multi-attribute decision-making method. The first provider shows the highest performance, whereas the third provider has the worst performance. The performance scores of the providers change when the weights of attributes are changed.

In this study, a new dynamic performance evaluation system is developed. This proposed performance evaluation system uses intuitionistic fuzzy sets for evaluating the performance of aftersales companies. Since intuitionistic fuzzy sets use both membership and non-membership values, they provide a more realistic approach for revealing the evaluations of decision makers. The method also enables collecting information at various times and aggregating them without losing information. The decision makers are satisfied with the results and willing to use the method in the future. The developed sensitivity analysis framework provides a better understanding of the results. Other companies that deal with aftersales providers can use the proposed method.

For further research, instead of the intuitionistic fuzzy sets, other extensions of fuzzy sets such as interval-valued intuitionistic fuzzy sets, Pythagorean fuzzy sets, or triangular intuitionistic fuzzy sets can be used.

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