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Measuring the readability performance (RP) of aircraft maintenance technical orders by fuzzy MCDM method and RP index

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Abstract With the development of the global economy and the ease of air transportation, extra emphasis has been placed on flight safety. There are precise specifications and procedures in the operation and maintenance of aircraft. Human errors and mechanical disorders are two key factors of flight safety. The maintenance personnel need to follow an outlined procedure to avoid human errors and ensure flight safety. Readability of aircraft maintenance technical orders can affect the quality and reliability of aircraft maintenance. To ensure the editing quality of technical orders, controlling/monitoring the number of unreadable sentences is important and necessary. In this study, the number of unreadable sentences found in a technical order was used as the measure of readability performance (RP) as well as a readability performance index was provided to evaluate whether the RP of individual readability characteristics of technical orders was adequate. Different readability characteristics make different grade of RP loss. Based on fuzzy multiple criteria decision-making (Fuzzy MCDM) approaches, we investigated the expert opinions to rank and calculate the weights of all readability characteristics. At the same time, we proposed the upper limits of unreadable sentences according the weights of individual readability characteristics. In this paper, the technical orders issued by Taiwan Aerospace Industrial Development Corporation was used as an example to evaluate the readability of the technical orders and total RP losses for individual readability characteristics. Finally, an improved way of editing quality for technical orders was recommended.

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1 Introduction

With the development of global economy and the ease of air transportation, extra emphasis has been placed on flight safety. Two fundamental factors, human error and mechanical disorders, have been identified (IATA Safety Report (Jet) 2001). Mechanical disorders arise from the quality of parts and maintenance techniques. Consequently, all airplane manufacturers and maintenance plants place a high priority on production quality and maintenance to reduce accidents due to mechanical disorders (Lyonnet 1998). Precise specifications for the quality of airplane parts have been specified from the early design stage. Only high reliability components and redundant designs can be certified for use. The International Air Transport Association (IATA) reviewed causes of aircraft maintenance error and servicing disorders, and found that most accidents occurred when maintenance personnel failed to detect the components that were out of order or failed to do proper maintenance. Sometimes the repair or the replacement of failed components was not done or there were human errors in doing the maintenance (IATA Safety Report (Jet) 2001). Every aircraft manufacturer describes precisely in their integrated logistic support how to maintain their airplanes. These documents guarantee the necessary logistic support under the lowest life cycle cost. Logistic support analysis concentrates on exploring the maintenance strategy where it can be categorized into five maintenance tasks: localization, isolation, access, alignment and checkout (Jones 1999). Qualified maintenance personnel have to execute the five maintenance tasks according to the technical orders issued by the aircraft manufacturer. By following the well-editing technical orders precisely, human errors should be reduced.

The procedures outlined in the aircraft maintenance technical orders should thoroughly cover all the systems in the aircraft and in a manner which allows the maintenance personnel to comprehend the content and thus perform the tasks correctly. Maintenance personnel may not have the technical background of a system designer as well as system designers are not always good technical writers, so the readability of the technical orders is critical. Norman (1988) proposed a mental model shown as Fig. 1. He discussed the relationship between designers and users by using a designer's model and a user's model, and meanwhile, recommended the system designers should take the practical situation of maintenance tasks into consideration and be aware of the maintenance personnel's level in addition to the writing quality of technical orders. In other words, a user-centered concept should be introduced to the editors of technical orders with the aim of reducing human errors and improving flight safety.

However, the editing of technical orders is different from that of common literature in general. A good technical order should consist of text with a high readability such as correct sequences of sentences, proper semantics and syntax, and appropriate examples and illustrations, to ensure that qualified maintenance personnel can efficiently and correctly perform their tasks. The quality and reliability of aircraft maintenance is dependent upon well designed and written technical orders. When an aircraft manufacturer develops a new model of aircraft, the technical orders for that aircraft will be developed. As long as the airplane is in use, the technical orders will be continuously updated, revised, and rewritten to ensure higher quality and readability performance (RP). By doing so, the maintenance personnel

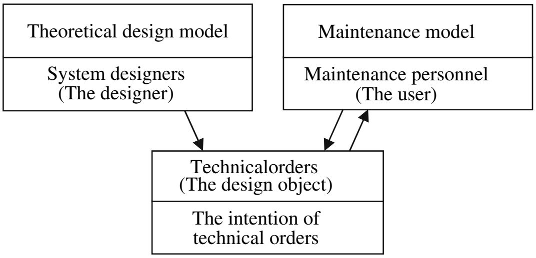

Fig. 1 Norman's mental model (1988) applied to the editing of aircraft maintenance technical orders

will be able to do their jobs correctly without accidents due to human error. For this reason, the development of technical orders is a continuous job.

Currently, most of the technical orders for aircraft maintenance are provided in a printed document. According to known human factors and design recommendations, information should contain the following characteristics (Sanders and Mc Cormick 1993). Visibility is the quality of a character or symbol that makes it visible separately from its surroundings. Legibility is defined as the attribute of alphanumeric characters that makes it possible for each one to be identifiable from others. Legibility depends on such features as stroke width, form of characters, contrast, and illumination. Readability is the recognition of the information contained in the material when it is represented by alphanumeric characters in meaningful groupings, such as words, sentences, or continuous text as defined by Sanders and Mc Cormick (1993). After decades of improvement in printing, technical orders now produced by aircraft manufacturers have a much higher visibility and are much more legible in terms of types of fonts, sizes and layouts. Therefore, this study examines the remaining characteristic, the readability of technical orders and a user-centered design concept is used to assess the editing quality of technical orders.

In order to adequately edit technical orders, the editors should refer to related literature reviews such as Broadbent (1977), Clark and Chase (1972), Chapanis (1965), Mayer (1997) and Kammann (1975) followed the user-centered concept. Among the authors, the first has practical experience in airplane manufacture for 20 years. He synthesized other theories and proposed six readability characteristics for guidelines in writing of technical orders. Besides, sentences that have wrong characters, incorrect punctuation mark, unclear meaning or inconsistent use of phrases and so forth will be categorized as 7th readability characteristic of unreadable sentences—referring to as 'Others'. They were displayed and shown in Table 1. Sentences that did not meet any one of these characteristics were classified as unreadable sentences in this paper.

When a large number of unreadable sentences appear in a technical order, maintenance personnel will have difficulty in understanding it and easily make mistakes. Obviously, the larger the number of unreadable sentences implies that the larger the RP loss of technical orders. In this paper, the technical orders issued by Taiwan Aerospace Industrial Development Corporation will be used as an illustrative example. Thus, we utilized a readability performance index (RPI) to assess whether the number of unreadable sentences meets the requirement. In addition, different types of unreadable sentences also make different grade of RP loss. That is, the importance of different readability characteristics is different. Based on fuzzy multiple criteria decision-making (Fuzzy MCDM) approaches, we will investigate the expert opinions to rank and calculate the weights of all readability characteristics. The values were defined and represented by triangular fuzzy number. The experts used fuzzy numbers to express their preferences and we employed fuzzy arithmetic mean to compute the weights

Table 1 Seven readability characteristics

Readability characteristics	Illustration
1. Type of sentences	The sentences written in an affirmative and active style are more easily understood and take less time to comprehend (Clark and Chase 1972)
2. Order of sentences	The order of sentences should mirror the order of operations to facilitate comprehension
3. Use semantic first and then syntactic	A semantic style means that the meaning of the sentence should be conveyed, based on the knowledge of the reader. With a syntactic style, the arrangement of the vocabulary in the sentences is stressed
4. Use simple sentences	Simple terse sentences are preferable because they require less additional resources to understand. (Chapanis, 1965)
5. Add instruction examples	Adequate examples must be provided. Mayer (1997) has proposed that a better design guideline usually incorporates several forms of instruction to be used in combination
6. Offer realistic graphics	For increasing comprehension, realistic graphics should be included in manuals. Kammann (1975) found that readers using text manuals without graphics had only two thirds of the desired comprehension levels
7. Others	Sentences that have wrong characters, incorrect punctuation mark, unclear meaning or inconsistent use of phrases and so forth will be categorized as 'Others'

and fuzzy ranking of all readability characteristics. Next, we can multiply the number of unreadable sentences with the corresponding weight for individual readability characteristic to obtain a total RP loss. Finally, an improved way of editing quality for technical orders was recommended.

2 Fuzzy set theory

Fuzzy set theory was first introduced by Zadeh (1965) to provide a means for representing uncertainties and dealing with problems under a vague environment. It has been successfully applied in various fields such as control system, image processing, signal processing, mechanical engineering, finance analysis, operation research, management science and so forth (Mendel 1995; Langari and Zadeh 1995). Let X denote a universal set. Then a fuzzy set $\tilde{A}$ of X is defined by its membership function $f_{\tilde{A}} : X \to [0, 1]$, which assigns to each element $x \in X$ a real number $f_{\tilde{A}}(x)$ in the interval [0, 1], where the value of $f_{\tilde{A}}(x)$ at x represents the grade of membership of x in $\tilde{A}$. Thus, the nearer the value of $f_{\tilde{A}}(x)$ is unity, the higher the grade of membership of x in $\tilde{A}$. A fuzzy set $\tilde{A}$ can usually be written as $\tilde{A} = \{(x, f_{\tilde{A}}(x) | x \in X)\}$.

2.1 Triangular fuzzy number and linguistic variables

Since a fuzzy number is convex and normal, it can be considered to be a generalization of the interval of confidence (Kaufmann and Gupta 1991). Suppose that the membership function of a fuzzy number A is defined as following

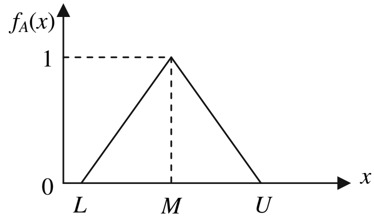

Fig. 2 The membership function of triangular fuzzy number A

Table 2 The scaling values for triangular fuzzy numbers of linguistic variables

The values of linguistic variables	Triangular fuzzy numbers
Very important (VI)	(0.75, 1, 1)
Important (I)	(0.5, 0.75, 1)
Ordinary (O)	(0.25, 0.5, 0.75)
Unimportant (U)	(0, 0.25, 0.5)
Very unimportant (VU)	(0, 0, 0.25)

$$f_A(x) = \begin{cases} (x - L)/(M - L), & L \le x \le M \\ (x - U)/(M - U), & M \le x \le U \\ 0, & \text{otherwise} \end{cases}, \tag{1}$$

then A is so-called triangular fuzzy number, where $-\infty < L \le M \le U < \infty$. It can also be denoted by $A = (L, M, U)$ and the membership function is illustrated in Fig. 2.

Based on Zadeh's extension principle (1975, 1976), let $A_1 = (L_1, M_1, U_1)$ and $A_2 = (L_2, M_2, U_2)$, some basic operations on triangular fuzzy numbers that will be used in this study were displayed as following:

$$(1) \quad A_1 \oplus A_2 = (L_1 + L_2, M_1 + M_2, U_3 + U_3), \tag{2}$$

$$(2) \quad k \otimes A = (kL, kM, kU), k \ge 0, k \in R, \tag{3}$$

$$A_1 \otimes A_2 \cong (L_1L_2, M_1M_2, U_3U_3), \text{ if } L_1 \ge 0, \; L_2 \ge 0. \tag{4}$$

Linguistic variables are variables whose values (interpretation) are not numbers but words or sentences in a natural or artificial language (Zadeh 1975–1976). The concept of linguistic variable is very useful to treat situations that are too ill-defined or too complicated to be appropriately described in traditional quantitative expressions (Zadeh 1975–1976). In this study, we investigate the expert opinions (or linguistic variables) to rank and calculate the relative importance (or weight) of all criteria (or readability characteristics) and its value are defined and represented by triangular fuzzy number as Table 2. The rationale for using triangular fuzzy number is that its arithmetic operation is more complete, especially in fuzzy multiplication.

2.2 The fuzzy weights and defuzzification for fuzzy MCDM

In this paper, the experts will supply information about the issues for each criterion (or readability characteristic) and also about the importance of the criteria (or readability characteristics) with respect to RP. Suppose we investigate m experts, then the opinions (or linguistic variables) of all experts are transformed into triangular fuzzy numbers and synthesized as fuzzy arithmetic mean

$$Fw_j = (a_j, b_j, c_j),\ 0 < a_j \leq b_j \leq c_j < 1, \quad j = 1, 2, \ldots, k; \tag{5}$$

where $t_j = \sum_{i=1}^{m} t_{ji}/m,\ t \in \{a, b, c\}$, t_{ji} represents the importance (or weight) that ith expert assigns to jth criterion (or readability characteristic). Fuzzy arithmetic means cannot be ranked since they are not crisp values. Thus, we employ the fuzzy ranking methods, referring to as 'defuzzification', to obtain non-fuzzy values. In general, there are the following methods: min-max method (Chen 1985), mean of maximal (MOM), center of area (COA) and α-cut method (Zhau and Govind (1991), Teng and Tzeng (1996), Tang and Tzeng (1999)). Since COA method is an easy and efficient method, thus, we employ it to calculate non-fuzzy weights for all criteria in this paper. It is defined as below.

$$w_j = [(c_j - a_j) + (b_j - a_j)]/3 + a_j, \quad j = 1, 2, \ldots, k. \tag{6}$$

3 Measurement of readability performance

The editing quality of technical orders reflects the quality of aircraft maintenance. Unreadable sentences indicate a lower readability, which will adversely affect the aircraft maintenance and flying safety. Assuming N_j represents the number of unreadable sentences for jth readability characteristic (or jth criterion). Clearly, N_j is a random variable for jth criterion since the number of unreadable sentences is uncertain. Based on Montgomery (2002), because the number of unreadable sentences is similar to the number of product defects, thus, N_j conforms to a *Non-homogeneous Poisson Distribution* (Ross 1985). The probability function is defined as below.

$$P(N_j = n_j) = \frac{e^{-\lambda_j} \lambda_j^{n_j}}{n_j!}, \quad n_j = 0, 1, 2, 3, \ldots, \quad j = 1, 2, \ldots, 6, \tag{7}$$

where j represents jth readability characteristic, λ_j is the mean and variance of the number of unreadable sentences for jth criterion (i.e., $\lambda_j = E(N_j)$ and $\lambda_j = \mathrm{Var}(N_j)$). Besides, different types of unreadable sentences (or readability characteristics) will make different grade of RP loss. Assuming X_{ji} represents the RP loss of ith unreadable sentence for jth criterion. Thus, X_{ji} is a random variable for a continuous measurement. Total RP loss of unreadable sentences for jth criterion ($L_j = \sum_{i=1}^{n_j} X_{ji}$) will conform to *Compound Poisson Distribution*(Ross 1985). Hence, the mean of total RP loss of unreadable sentences for jth criterion is $E(L_j) = \mu_j \times \lambda_j$, where $\mu_j = E(X_{ji})$ represents the average of RP loss of unit unreadable sentence for jth criterion. Obviously, if we want to reduce $E(L_j)$, the reduction of λ_j is important and necessary. Since the evaluation of μ_j is not trivial, we employ the weight (w_j) of jth criterion to estimate μ_j in this paper. That is to say, $E(L_j) \approx w_j \times \lambda_j$ is used to evaluate the mean of total RP loss of unreadable sentences for jth criterion. A main issue, how to assess whether the number of unreadable sentences for different readability characteristics is qualified, will be studied. In addition, as described by preceding section, seven readability characteristics are criteria for evaluating RP of technical orders. Thus, the weights of readability characteristics are also important factors affecting RP in this study. Total RP loss of unreadable sentences for jth criterion can be estimated. The detail discussions are presented in the following subsections.

3.1 Measurement for the number of unreadable sentences

Prevention is better than cure. When unreadable sentences appear on technical orders, the loss generally cannot be avoided. Aircraft manufacturers can set up the upper limit (U_j) of the number of unreadable sentences according to the weights of different readability characteristics, their experience, external competitive environment and so forth. The lager the weight of readability characteristic implies that the lager the unit RP loss. Vice versus, the unit RP loss is smaller. Therefore, if the weight of readability characteristic is lager, then U_j will be set to be smaller. Suppose the upper limit of total number of unreadable sentences per 100 pages is set up as U_T and the average number of pages in some volumes of technical order is $100v$ (For example, 500 pages, then $v = 5$), then the upper limit of the number of unreadable sentences for jth readability characteristic (U_j) can be defined as following

$$U_j = \frac{1/w_j}{\sum_{j=1}^{7} (1/w_j)} \times U_T \times v, \tag{8}$$

where w_j is the weight of jth readability characteristic and v is a multiple of 100.

We mimic the index in Wu et al. (2004), and then revise it to be a RPI defined as below.

$$R_j = \frac{\lambda_j}{U_j} \times 100\%, \quad j = 1, 2, \ldots, 7. \tag{9}$$

Obviously, when the mean of the number of unreadable sentences is equal to the upper limit of the number of unreadable sentences (i.e., $\lambda_j = U_j$), then the RPI $= 100\%$. It represents that the number of unreadable sentences for jth readability characteristic has fully loaded. As $\lambda_j > U_j$, then the RPI $> 100\%$. It represents that the number of unreadable sentences for jth readability characteristic has overloaded. As $\lambda_j < U_j$, then the RPI $< 100\%$. It represents that the number of unreadable sentences for jth readability characteristic is under tolerable limitation. Hence, R_j is an increasing function of λ_j. The larger the R_j, the worse the RP is. Vice versus, the better the RP is.

Suppose an aircraft manufacturer requests R_j does not exceed r_j, a hypothesis testing (i.e., $H_0 : R_j \leq r_j$ versus $H_1 : R_j > r_j$) will be used to judge whether the number of unreadable sentences for jth readability characteristic meets requirements. Since λ_j are generally unknown, they must be estimated. Let N_{ji} represents the number of the ith sample of unreadable sentences for jth readability characteristics, then $(N_{j1}, N_{j2}, \ldots, N_{jn})$ is a random sample with mean and variance of λ_j. If the sample mean of the number of unreadable sentences for jth readability characteristics $\overline{N}_j$ is used to estimate λ_j, the intuitive estimator of index R_j can be written as

$$\hat{R}_j = \frac{\overline{N}_j}{U_j}, \tag{10}$$

where $\overline{N_j} = \sum_{i=1}^{n} N_{ji}/n$, $j = 1, 2, \ldots, 7$. Since $\hat{R}_j$ is a best estimator of R_j (Wu et al. 2004), we have

$$\mathrm{Var}(\hat{R}_j) = R_j/(7U_j). \tag{11}$$

By using $\hat{R}_j$ as a test statistic of R_j, the rejection region can be expressed as $\{\hat{R}_j | \hat{R}_j > C_0\}$. Under the specified significance level α, the critical value (C_0) can be calculated as follows:

$$P(\hat{R}_j > C_0 | R_j = r_j) = \alpha. \tag{12}$$

Since $E(\hat{R}_j) = R_j$ and $\mathrm{Var}(\hat{R}_j) = R_j/(7U_j)$, thus, we have

$$Z = \frac{\sqrt{7U_j}(\hat{R}_j - R_j)}{\sqrt{R_j}}. \tag{13}$$

The random variable Z is approximated to standard normal distribution according to the central limit theorem when sample size n is quite large. Thus, Eq. 12 can be represented as

$$P\left(Z > \frac{\sqrt{7U_j}(C_0 - r_j)}{\sqrt{r_j}}\right) = \alpha. \tag{14}$$

Based on the above equation, C_0 value can be derived as following:

$$C_0 = r_j + Z_\alpha\sqrt{\frac{r_j}{7U_j}}, \tag{15}$$

where Z_α is the upper αth quantile of standard normal distribution.

If $\hat{R}_j > C_0$, the number of unreadable sentences of jth readability characteristic is unqualified. The improvement actions of editing quality of technical orders should be taken. Vice versus, the number of unreadable sentences of jth readability characteristic is qualified.

3.2 Measurement for total readability performance loss

Different readability characteristics make different grade of RP loss. Thus, the estimation of importance of readability characteristics for technical orders is necessary. Since the RP loss of different readability characteristics is hard to measure, thus, we employ the weights of readability characteristics to evaluate the RP loss in this paper. The larger the weights of readability characteristics implies that the larger the RP loss of unreadable sentences. Multiple criteria decision-making (MCDM) approaches can deal with the problems in the presence of multiple but usually conflicting criteria and have been widely applied in many fields. In classical MCDM approaches, the measurement of weights of the criteria and the assessment of alternatives are crisp values. However, in practice, the available data such as linguistic rating used in decision-making problems are often imprecise and vague. Hence, we utilized the fuzzy MCDM approach to calculate the weights (w_j) of individual readability characteristics in order to estimate the unit RP loss of unreadable sentences (μ_j). Thus, the estimator of the mean ($E(L_j)$) of total RP loss can be defined as following

$$\overline{L}_j \approx w_j \times \overline{N}_j, \tag{16}$$

where w_j is the weight of jth readability characteristic and $\overline{N}_j$ is an estimator of λ_j.

4 A case study

In this section, the flow chart of case study can be shown as Fig. 3 and illustrated as following three parts, respectively.

4.1 Part (I): The calculation of weights

The experts (14 maintenance personnel and 2 editors) were selected and asked to evaluate the importance (or weights) of seven readability characteristics. Their opinions (or linguistic variables) were transformed into triangular fuzzy numbers according to Table 2. Next, these fuzzy numbers were synthesized as fuzzy arithmetic means (Fw_j) according to Eq. 5. Since they are not crisp values, they can not be ranked. Thus, based on Eq. 6, we employed COA method to calculate non-fuzzy weights for all readability characteristics and obtained crisp weights (w_j) shown as Table 3. Among them, 3th readability characteristic (i.e., use semantic first and then syntactic) is the most important ($w_3 = 0.8542$); 5th readability characteristic (i.e., add instruction examples) is second important ($w_5 = 0.7917$) and the rest may be deduced by analogy.

4.2 Part (II): The testing of unqualified readability characteristics

In this study, 35 volumes of technical orders issued by Taiwan Aerospace Industrial Development Corporation were used as material for the evaluation. The number of sentences (N_{ji}) that didnot follow the seven readability characteristics was recorded in Appendix. Furthermore, the average number of each type of unreadable sentences ($\overline{N}_j$) was obtained and shown as the bottom of Appendix and Table 3. To guarantee the editing quality, reliability of aircraft maintenance and flight safety, the upper limit for the number of unreadable sentences in each technical order unit (100 pages) was preset as 20 (i.e., $U_T = 20$) in this study. In other words, suppose that the number of unreadable sentences in a volume of technical orders with $100v$ pages exceed $20v$, the technical order has overloaded and shall not be used. Sample data showed the yield of technical orders merely reached 80% in the final column of Appendix. In other words, the editing quality of technical orders had still great improvement space in this case.

Since the average of the number of pages for each volume in Appendix is about 130 (i.e., $v = 1.30$) and w_j has been obtained in Part (I), thus, the upper limit of the number for jth readability characteristic (U_j) can be calculated and displayed in Table 3 according to Eq. 8. The assessment of RP of jth readability characteristic is presented as following:

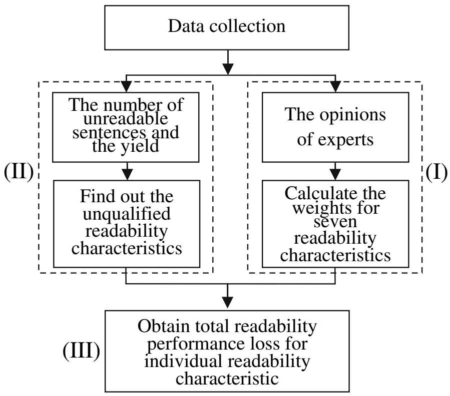

Fig. 3 The assessing procedure of readability performance

Table 3 Total readability performance loss of seven readability characteristics

Readability characteristics	Fw_j / (a_j, b_j, c_j)	w_j	U_j	$\overline{N}_j$	$\hat{R}_j$	C_0	$\bar{L}_j$	Percentage of $\bar{L}_j$
1. Type of sentences	(0.3281, 0.5781, 0.8281)	0.5781	2.8383	0.63	0.22	1.37	0.3642	0.0459
2. Order of sentences	(0.2188, 0.4688, 0.7188)	0.4688	3.5006	6.26	**1.79***	1.33	**2.9344**	**0.3694**
3. Use semantic first and then syntactic	(0.6563, 0.9063, 1.0000)	**0.8542**	1.9210	0.97	0.50	1.45	0.8285	0.1043
4. Use simple sentences	(0.1250, 0.3438, 0.5938)	0.3542	4.6331	4.94	1.07	1.29	**1.7496**	**0.2203**
5. Add instruction examples	(0.5781, 0.8281, 0.9688)	**0.7917**	2.0727	0.77	0.37	1.43	0.6096	0.0767
6. Offer realistic graphics	(0.4844, 0.7344, 0.9375)	0.7188	2.2830	0.29	0.13	1.41	0.2084	0.0262
7. Others	(0.0000, 0.1563, 0.4063)	0.1875	8.7514	6.66	0.76	1.21	1.2488	0.1572

Step 1: The values of all RPIs (r_j) and the significant level (α) were preset as 1.00 and 0.05, respectively.

Step 2: Based on U_j and $\overline{N}_j$ values in 4th and 5th column of Table 4, all estimators of $R_j(\hat{R}_j)$ were calculated and shown as 6th column of Table 3.

Step 3: The critical values (C_0) for all readability characteristics were obtained according to r_j, U_j and α. They were displayed in 7th column of Table 3.

Step 4: To determine whether the number of unreadable sentences of jth readability characteristic meets the requirements, we compared the testing statistic ($\hat{R}_j$) with the corresponding critical value (C_0) according to Sect. 3.1. The testing results revealed that the number of unreadable sentences of 2th readability characteristic (i.e., order of sentences) was unqualified (i.e., $\hat{R}_2 = 1.79 > C_0 = 1.33$) and the other readability characteristics were qualified.

4.3 Part (III): Total RP loss for individual readability characteristic

Based on Part (I) and (II), the estimated values ($\overline{L}_j$) of total RP loss of seven readability characteristics were calculated by Eq. 16 and shown in 8th column of Table 3. The results revealed that the total RP loss (i.e., $\overline{L}_j = 2.9344$) of 2th readability characteristic (i.e., order of sentences) was the largest; the total RP loss (i.e., $\overline{L}_j = 1.7496$) of 4th readability characteristic (i.e., use simple sentences) was secondary and so forth. Besides, the percentages of performance loss for all readability characteristics were displayed in the final column of Table 3.

As a result of preceding evaluation (Part I–III), we knew the number of unreadable sentences of "order of sentences" was unqualified and the other readability characteristics were qualified. The improvement actions of editing quality in "order of sentences" should be taken. In total RP loss, "order of sentences" was the largest and "use simple sentences" was secondary. Using 80/20 rule or Pareto's law, we know that the majority of quality problems are the result of relatively few causes (Foster 2001). Thus, the performance loss of "use simple sentences" should be reduced except for "order of sentences" to effectively improve the editing quality of technical orders since the cumulative percentage of total RP loss of the first two (i.e., "order of sentences" and "use simple sentences") in seven readability characteristics was 58.97%.

5 Conclusions

A well-edited maintenance technical order should provide proper readability levels. Unreadable sentences will adversely affect the aircraft maintenance and flying safety. Therefore, to ensure the editing quality of technical orders, controlling/monitoring the number of unreadable sentences is important and necessary. In this paper we proposed an equation for setting U_j and utilized the estimator of RPI($\hat{R}_j$) to assess whether the number of unreadable sentences for different readability characteristics was qualified. In addition, unreadable sentences were divided into seven types according to readability characteristics. These seven readability characteristics were criteria for evaluating RP of technical orders. Their weights (w_j) were calculated by utilizing the opinions of experts along with fuzzy MCDM approaches. Thus, multiplying w_j by $\hat{R}_j$, total RP losses for jth readability characteristics were estimated. Finally, a case study was used as an example to evaluate whether the editing of the aircraft maintenance technical orders reached the required quality levels. Sample data showed the yield of technical orders merely reached 80% in Appendix. In other words, the editing quality of technical orders had still great improvement space in this case. The further assessing results revealed that "order of sentences" was unqualified in the number of unreadable sentences. In total RP loss, "order of sentences" was the largest and "use simple sentences" was secondary. Hence, "order of sentences" and "use simple sentences" has first and second priority in the improvement of editing quality of technical orders, respectively. In a word, this paper provided an assessing procedure for solving the problems of editing quality of aircraft maintenance technical orders. The techniques and methods proposed by this paper can be sufficiently applied in the evaluation of editing quality for other fields. Besides, the improvement processes of editing quality were not discussed in this study. It will be an interesting issue in the future.

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Appendix The number of the unreadable sentences for seven readability characteristics

Volume	No. of pages	Readability characteristics							Total	$v * U_T$	Overloaded
		Type of sentences	Order of sentences	Use semantic first and then syntactic	Use simple sentences	Add instruction examples	Offer realistic graphics	Others			
1	118	1	2	0	2	1	0	5	11	23.6	
2	90	0	11	0	5	0	0	3	19	18	*
3	164	0	15	2	9	0	0	6	32	32.8	
4	138	0	7	1	7	1	1	11	28	27.6	*
5	172	0	10	1	9	0	0	7	27	34.4	
6	258	0	11	2	6	1	1	16	37	51.6	
7	94	1	6	0	4	0	0	6	17	18.8	
8	90	1	4	1	3	1	0	4	14	18	
9	90	0	5	0	1	1	0	5	12	18	
10	212	2	8	2	10	2	2	12	38	42.4	
11	50	0	3	0	2	0	0	4	9	10	
12	44	0	3	0	1	0	0	3	7	8.8	
13	498	4	18	5	16	4	2	19	68	99.6	
14	36	0	2	1	2	0	0	3	8	7.2	*
15	88	0	4	0	5	1	0	4	14	17.6	
16	74	0	4	0	3	0	0	4	11	14.8	
17	36	0	2	0	1	0	0	1	4	7.2	
18	142	1	4	2	10	2	0	11	30	28.4	*
19	241	3	8	3	8	3	1	12	38	48.2	
20	134	1	8	0	7	0	0	5	21	26.8	
21	82	1	6	1	4	0	0	4	16	16.4	
22	216	3	13	4	11	1	1	12	45	43.2	*
23	119	1	9	0	8	1	1	5	25	23.8	*
24	112	0	7	1	9	0	0	7	24	22.4	*
25	28	0	2	0	0	0	0	2	4	5.6	
26	84	1	4	0	3	3	0	4	15	16.8	
27	116	2	4	2	3	0	0	7	18	23.2	
28	100	0	6	0	4	0	0	7	17	20	
29	124	0	9	1	1	1	0	6	18	24.8	
30	118	0	4	0	2	0	0	7	13	23.6	
31	222	0	6	2	6	2	1	9	26	44.4	
32	128	0	2	1	4	0	0	5	12	25.6	
33	78	0	3	0	2	1	0	6	12	15.6	
34	130	0	7	2	2	0	0	5	16	26	
35	127	0	2	0	3	1	0	6	12	25.4	
Total	4553	22	219	34	173	27	10	233	Yield % = 28/35 = 80%		
Average	130	0.63	6.26	0.97	4.94	0.77	0.29	6.66			

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