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Procedia Engineering 17 (2011) 440 – 445

Procedia Engineering

www.elsevier.com/locate/procedia

The 2nd International Symposium on Aircraft Airworthiness (ISAA 2011)

Application of Expert Judgment Method in the Aircraft Wiring Risk Assessment

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Abstract

The FAA has developed a risk assessment means for the electrical wiring interconnection system, in which expert judgment plays an important role. However, the huge number of complex judgment will lead to high probability that the experts make the wrong choice. An evaluation and validation of the expert judgment before using the data is necessary. This paper discusses and reviews the evaluation method for the expert judgment from the two aspects: the validation of each expert judgment and the coefficient of agreement as a group, and gets certain feedbacks though an application of the method in a Chinese aircraft type.

Keywords: Paired comparison, Expert judgment, EWIS, Aircraft wiring risk assessment.

1. Introduction

In modern aircraft, components of airborne systems are often distributed in different location in the aircraft, and are connected by the Electrical Wire Interconnect System (EWIS). In FAR25(Amdt-125), FAA made some regulation changes to FAR§25.1309, there has been added an airworthiness sub-item which is introduced by FAR§25.1709. EWIS, especially for risk assessment, is becoming a challenge for both aircraft manufacturer and authorities, of EWIS.

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1877-7058 © 2011 Published by Elsevier Ltd.
doi:10.1016/j.proeng.2011.10.053

In recent years, FAA has developed a risk assessment tool for the EWIS, to assess the reliability of the EWIS, of which, wire is a major component. The reliability of wire is relative to the wire properties, the located wire zonal environment, bundle of wires .

It's impossible to make a wire failure rate function by usual statistical techniques, because the number of different environments, the combinations of wire properties and zonal environments that realistically occur on aircraft is innumerable.

Thus FAA's research is leading to use Expert Judgment Method(EJM) in risk analysis. The paired comparison method is often used to combine several experts' judgment about the relative probabilities (or rates of occurrence) of certain events. It's one of the most effective methods to scale an ambiguous quantity in the sensory evaluation. The paired comparison method is relatively easier to compare and choose one from two samples than to choose directly.

However, when a large number of samples exist, the huge number of comparison will still lead to high probability that the experts make the wrong choice. It's necessary to evaluate and validate the expert judgment before using the data.

This paper reviews EJM in the aircraft wiring risk assessment, and apply EJM in an ongoing Chinese aircraft type EWIS design to illustrate how to use EJM in wiring risk assessment for showing compliance of FAR§25.1709(d).

2. Paired comparison method for aircraft wiring risk assessment

Paired comparison is used to combine experts' judgment about the relative probabilities of certain failure modes[1,3].. With this approach, experts need to compare n items pairwise, and indicate their preference for one or the other item[2], The NEL [4]model is an adopted from the Bradley-Terry model, which can indicate which component or environment is more likely to produce an earlier failure though experts' comparison of n components or environments pairwise.

According to FAA's guideline the aircraft wiring risk assessment based on the paired comparison method will consist of four steps[2]:

(i) Select certain failure environments to compare via paired comparison. For one of the environments selected there should also be a reasonable amount of existing failure data. Conduct the paired comparison with the candidate environments. The result of the paired comparison will be transformed to a set of failure rate estimates obtained to within proportionality constant by the NEL model.

(ii) Given the failure rate estimates obtained using (i), obtain the parameters estimates of the failure rate function based on the regression analysis.

(iii) Obtain a failure rate estimate from the candidate failure environment for which there exists significant exposure time and failure data.

(iv) By comparing the failure rate estimate for the failure environment selected in (iii) to the failure rate estimate using the paired comparison and regression results in i and ii, the constant of proportionality for all failure rate estimates can be estimated.

Once the estimates for the parameters are obtained, the complete failure rate function may be determined. The failure rate for any environment can be reckoned by the function. The focus of this paper will be just on step (i).

3. Application of ejm in risk assessment

3.1. Select experts and environments.

In application case, the wire failure condition includes two modes: failing to ground and failing to open. In order to acquire the sufficient data, 14 experts are asked to judge the failure rate of 17 environments using the paired comparison method.

The 14 experts are selected from engineers from aircraft design offices and manufactures, engineers from wire manufactures, engineers from airline maintenance department, professors from university.

There are 17 environments[8] which are selected from the real typical compartment environments of aircraft type under study, with considering the factors as: wire gauge, conductor type, insulation type, splices, bundle size, bundle protection, curvature of bundle, bundle orientation, ops/main traffic, Ops temp/Alt, vibration, exposure to corrosive fluid, and exposure to conductive fluid.

With 17 typical compartment environments, 136 paired comparison question form for each failure mode are built. The experts would judge which one can more easily lead to the wire failure between the two environments in every question form.

The question format sample is as follows:

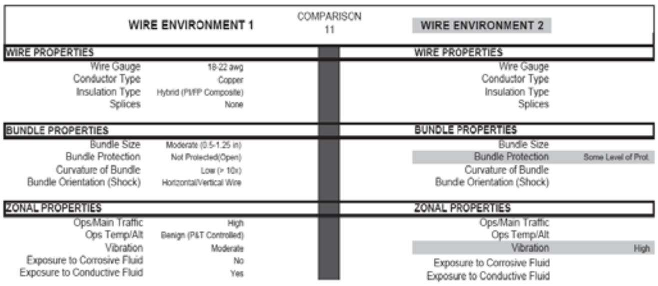

Fig.1 Paired comparison question format

3.2. Review of nel model

The first evaluation aspect for the expert choices is analyzing the number of circular triads. It is a means to check if each expert is answering the question with realizing the true fact or just assuming the answers.

A circular triad means that the expert's suggestion violates the transitivity property, for example, that E_1 is more severe than E_2, E_2 is more severe than E_3, and E_3 is more severe than E_1 , then this is a circular triad.

It is normal for a few circular triads exist in result, when experts compare a huge number of events. The number of circular triads in expert r's preferences, is given [2,5]by

$$c(r) = \frac{n(n^2-1)}{24} - \frac{1}{2}\sum_{i=1}^{n}\left(N_r(i) - \frac{1}{2}(n-1)\right)^2 \qquad (1)$$

Experts are asked 136 paired comparisons as to which environment is more severe.

the following statistic [2,6] formula is used to perform a standard one-tailed hypothesis test for comparing n items in a random fashion:

$$c'(r)=\frac{n(n-1)(n-2)}{(n-4)^2}+(\frac{8}{n-4})\times\left[(\frac{1}{4})\binom{n}{3}-c(r)+\frac{1}{2}\right] \tag{2}$$

when n>7, this statistic has approximately a chi-squared distribution with $((n(n-1)(n-2))/(n-4)^2$ degrees of freedom. If the null hypothesis for any expert cannot be rejected at the 5% level of significance, the expert should be dropped from the analysis.

In addition, the agreement of the experts as a group can be statistically tested .the following coefficient of agreement formula can be used to test the hypothesis that all agreements of experts are due to chance.

$$u=\frac{2\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n}\binom{N(i,j)}{2}}{\binom{e}{2}\binom{n}{2}}-1 \tag{3}$$

Where N(i,j) represent the number of times some expert ranked Ei more severe than Ej.

For large values of n and e, the following formula[2,6,7] which under the null hypothesis that all agreements of experts is due to chance, has approximately a chi squared distribution with $\binom{n}{2}e(e-1)/(e-2)^2$ degrees of freedom.

$$u'=\frac{4\left[\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n}\binom{N(i,j)}{2}-\frac{1}{2}\binom{e}{2}\binom{n}{2}(\frac{e-3}{e-2})\right]}{e-2} \tag{4}$$

For statistics the one-tailed hypothesis that all agreements are due to chance should be rejected at the 5% level of significance in order for us to have confidence in the expert estimates[2].

3.3. Analyze the circular triads with nel model

First of all, the judgment is evaluated by the equation (1) to get the number of circular triads for each expert. The purpose is to see if he/she is specifying a true preference structure in his/her answers or just assigning answers in a random fashion. The results are as follows:

Table 1 Circular triads numbers of comparison

Fail to ground		**Fail to open**	
Expert NO.	Circular triads	Expert NO.	Circular triads
Exp 1	1	Exp 1	7
Exp 2	28	Exp 2	28
Exp 3	26	Exp 3	9
Exp 4	50.5	Exp 4	48.5
Exp 5	10	Exp 5	9
Exp 6	1	Exp 6	7
Exp 7	2	Exp 7	9

Exp 8	22	Exp 8	22
Exp 9	42.5	Exp 9	17
Exp 10	17	Exp 10	9
Exp 11	63	Exp 11	36
Exp 12	17	Exp 12	20
Exp 13	5	Exp 13	11
Exp 14	1	Exp 14	5

According to the equation (2), for the condition of n=17 and e=14, the circular triads of each expert should be not more than 150. Otherwise, the expert should be dropped. Actually, the evaluation results show that all the experts meet the requirement.

Secondly, the coefficient of agreement of the experts as a group is tested by the equation (3) and (4). The results are as follows:

Table 2 The coefficient of agreement

Fail to ground		**Fail to open**	
u	0.4486	u	0.5189
u'	1.0932e+003	u'	1.2379e+003
df	172	df	172

Thus we can conclude that it's an extremely improbable result if the preferences were allotted at random and the observed value of u is significant.

3.4. Evaluate experts judgment result

In this project , the analysis of result shows that all experts' judgment are valid, and all the coefficients of agreement are qualified, which means the data of these expert judgment can be used for failure rate estimates.

4. Conclusions

This paper apply the expert judgment method in the an ongoing Chinese aircraft type EWIS design to illustrate how to use EJM in wiring risk assessment evaluation method. It can be used to conduct other aircraft wiring risk assessment based on the expert judgment well.

However, with this method it can find out if each expert is specifying a true preference structure in his/her answers or just assigning answers in a random fashion[2], but it can not exactly check if the judgment of expert is accurate. It is very important to build an optimized paired comparison question format to help experts to do judgment more objectively and reduce the deviation of result from the true property.

References

[1] Thurstone L. A law of comparative judgment. Psychol Rev1927;34:273﹣86.

[2] Thomas A. M, William G. L, Armin B, A paired comparison experiment for gathering expert judgment for an aircraft wiring risk assessment. Reliability Engineering and System Safety 93 (2008) 722﹣731.

[3] Bradley R, Terry M. Rank analysis of incomplete block design. Biometrica 1952;39:334﹣45.

[4] Cooke RM. Experts in uncertainty: opinion and subjective probability in science. New York, NY: Oxford University Press; 1991.

[5] David HA. The method of paired comparison. London: Charles Griffin & Co. Ltd.; 1963.

[6] Kendall M. Rank correlation methods. London: Charles Griffin & Co. Ltd; 1962.

[7] Moffat B.G., Failure mechanisms of legacy aircraft wiring and interconnects, Dielectrics and Electrical Insulation, 2008.

[8]RTCA DO-160F, Environmental Conditions and Test Procedures for Airborne Equipment, 2007.