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SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES

Preprints of the IFAC/IFORS/IIASA/TIMS Workshop

Warsaw, Poland

June 24-26, 1992

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VOLUME 1:

Names of first authors: **A-K**

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SUPPORT SYSTEMS FOR DECISION AND NEGOTIATION PROCESSES
Preprints, IFAC/IFORS/IIASA/TIMS Workshop, June 24-26, 1992, Warsaw, Poland

PREFERENCE ELICITATION IN RELIABILITY ENGINEERING

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Abstract: In recent years the literature has shown an increasing interest in preference elicitation, dealing mainly with principles and procedures for eliciting preferences from Decision Makers (DMs). However, extensive application of these procedures has yet to be undertaken. The purpose of this study is to investigate the results of the multiattribute utility function in Reliability Engineering. The paper presents details of result obtained in a particular application in a maintenance planning problem.

Keywords: Preference Elicitation, Multiattribute Utility Function, Reliability Engineering, Maintenance, Maintainability, Availability.

1. Introduction

Preference elicitation is established by utility function of von Neuman and Morgenstern (see classical reference Luce and Raiffa, 1957). The preference structure of the DM on the consequences (outcomes or payoffs) should be consistent with a set of axioms. Among these axioms: a preference shall be transitive, there is continuity, substitutibility and monotonicity. From the set of axioms is shown that numbers can be assigned to the consequences.

Problems in maintenance decision making generally involve one or both of the following state of nature (Raiffa, 1970): Reliability and Maintainability of the system. The first is represented by the variable Time Between Failure (TBF) in repairable systems or Time To Failure (TTF) in non-repairable systems. The second is represented by the Time To Repair (TTR). The consequences are in most problems related to Availability and Cost. Hwang et al (1979) considered three consequences or criteria: Cost, Availability and Reliability (lower-bound).

The decision problem presented in Almeida and Souza (forthcoming) is analysed in this paper considering preference elicitation aspects of the multiattribute utility function. In that problem two attributes are considered: Availability represented by the variable Interruption Time (TI) and Cost of the maintenance strategy to be adopted (C).

Results in preference elicitation may differ depending on several variables related to the typical behaviour of the DMs in the environment studied. Cultural aspects and the context analysed can have a considerable influence on the results. Vincke (1981) carried out an investigation conducted in France, Switzerland and Belgium, concerning people's preferences about a particular decision problem. He suggested that the same investigation could be conducted in Anglo-Saxon countries, with different expected results, arising from differences in attitude in utility theory.

This paper presents results of multiattribute utility function elicitation conducted in a particular context related to maintenance decision making concerned with complex systems, presenting also a specific procedure for the general problem found in this context.

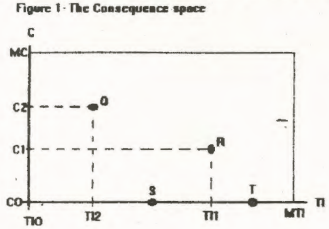
2. The Main Result

The elicitation procedure applied to obtain the multiattribute utility function U(TI,C) is based on the approach and derivations proposed in Keeney and Raiffa (1976) for multiattribute preferences under uncertainty. This procedure consists in a dialogue between the analyst and the Decision Maker (DM). Results obtained in a practical application are presented illustrating the procedure, which is implemented through a dialogue developed in five stages.

2.1. Introducing the terminology and ideas

The consequence space of the problem, which is shown in Figure 1, is make clear for the DM. The consequence Q represents (TI2,C2), and R represents (TI1,C1). The directions in which the preferred values of TI and C increase should be understood.

Figure 1 - The Consequence space



The region corresponding to the consequence space is limited to as small a region as possible, to simplify the task of elicitation. The maximum and minimum values of C are determined according to estimations that can be assumed. The minimum value for TI is TI=0, the most desirable result. The maximum value for TI is established according to the admissibility in the context studied; that is, if TI>0 it could increase up to such an undesired amount MTI that, in the context studied further increases become irrelevant. After this value the unidimensional utility function U(TI) is assimptotical, so that for any TI>MTI, then U(TI)≅U(MTI).

In the practical application mentioned above, the DM considered that for the specific context analysed, for TI>,–24 hours, any value of TI is equally undesirable, so the range of TI is [0,24]. For C, the cost estimation was obtained such that the maximum cost per unit time for the action space defined would be less than 0.69 monetary units (for the context studied), and for the minimum value was taken to be C=0.

This step is concluded by checking the DM's understanding of the representation in Figure 1, asking about his preferences over several combinations of (TI,C), and verifying his decision that, for example, TI2 should be preferred to TI1.

2.2. Identifying relevant independence assumptions.

This procedure was applied to the DM facing a specific problem with the general characteristics presented above. The same problem was presented to eight other DMs involved in the same context in the same organization. Results show that five DMs had a structure of preferences such that their utility function for TI and C satisfied the additive independence condition. Three of them had a structure of preference such that a utility independence condition was found for one of the variables. One of them had no pattern of independence condition. The two most common cases are presented here, giving more details for the additive utility function shown below, which may be applied when TI and C are additive independent.

$$U(TI,C) = Kt.U(TI) + KcU(C) \qquad (1)$$

where Kt and Kc are positive scaling constants, with Kt>0, Kc>0, and Kt+Kc=1.

The additive independence is verified by asking the DM about his preferences between the lotteries L(A,B) and L(C,D), which are illustrated in Figure 2. The four points A,B,C and D, in the consequence space, correspond to a combination of (TI,C), established by an arbitrarily chosen value of TI (say Ti=24), and C (say C=500) for any TI' and C'.

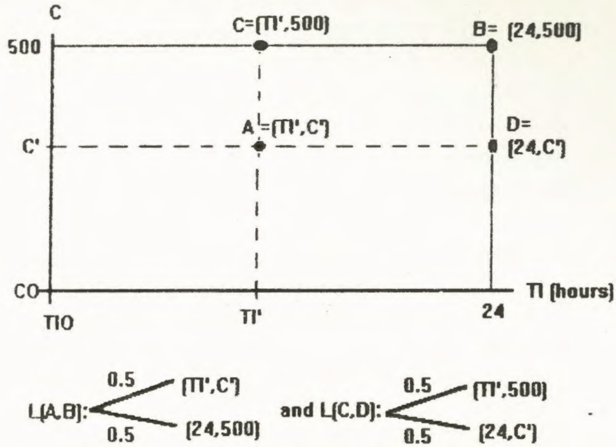
TI and C are additive independent if and only if the lotteries L(A,B) and L(C,D) are equally preferred by the DM, for all values of TI' and C'. If this condition is not accepted by the DM, another independence condition should be verified, by introducing the multilinear utility function:

$$U(TI,C) = Kt.U(TI) + Kc.U(C) + Ktc.U(TI).U(C) \qquad (2)$$

where, Kt, Kc, and Ktc are scaling constants, with Kt>0, Kc>0, and Kt+Kc+Ktc=0.

This function can be applied when the utility independence (UI) condition for one the variables is found in the structure of preferences of the DM. That is, either TI is UI of C or C is UI of TI. In this case the analyst should try one of these conditions and, if it is not found, then the analyst should try for the other variable. The following procedure illustrates the check if TI is utility independent of C.

Figure 2 - Verifing the additive independence condition



L[A,b] and L[C,D] are equally prefered by the DM

2.3. Elicitation of the conditional utility functions for TI and C

The utility functions U(TI) and U(C) correspond to a unidimensional utility function. Same procedure is applied for both variables as described below for TI.

The scaling for U(TI) and U(C) is defined to be (0,1). Then the utility values for the most and for the least desirable value of TI are: U(0)=1 and U(24)=0. The utility U(TI) for any TI is the probability p, whose equal preference is found between the consequence TI and a lottery whose TI=0 is obtained with probability p or TI=24 is obtained with probability 1-p. The analyst asks the DM about his preferences between any value of TI and the lottery above. For the probability p, where the lottery has TI as the certainty equivalent, then U(TI)=p. The final analytical expression for U(TI) is obtained applying a regression analysis over the points obtained.

For U(TI), the following values were assessed: U(0)=1; U(2)=0.81; U(4)=0.66; U(6)=0.56; U(8)=0.44; U(10)=0.37; U(12)=0.31; U(15)=0.22; U(18)=0.16; U(20)=0.13; U(22)=0.10; U(24)=0. A regression analysis was applied to these data and a good fit for U(TI), with the regression coefficient of determination (R^2) greater than 0.9, was found for the following analytical function U(TI)=exp[-0.1TI].

Similarly for U(C), the following values were obtained: U(0)=1; U(0.03) =0.89; U(0.07)=0.76; U(0.13)=0.61; U(0.17)=0.5; U(0.22)=0.44; U(0.29)=0.32; U(0.35)=0.27; U(0.39)=0.23; U(0.43)=0.19; U(0.53)=0.13; U(0.63)=0.09; U(0.69)=0. Similarly a regression analysis (R^2>0.9) shown the following function:U(C)=exp[-3.82.C]

2.4. Assessing the scaling constants

For both variables the scaling (0,1) is applied for the unidimensional utility functions. The same scaling is applied to the two-dimensional utility function U(TI,C), so that U(0,0)=1 and U(24,500)=0.

For the additive utility function U(0,500)=Kt, and U(0,500) is the probability p, whose equal preference is found between the consequence (0,500) and the following lottery, where the consequence (0,0) is obtained with probability p or the consequence (24,500) is obtained with probability 1-p. Then the analyst presents this lottery to the DM and finds the value of p for which there is equal preference. Finally the value of Kc is found using Kc=1-Kt. A similar procedure is applied for the multilinear utility function.

The results shown that the DM facing the problem has a structure of preferences with the additive independence condition, where the scaling constants gives to the utility function the form below:

$$U(TI,C) = 0.6.U(TI) + 0.4.U(C) \qquad (3)$$

2.5. Final consistency checking

There are several consistency checks which could be applied to verify possible errors in the elicitation procedure, allowing a reevaluation. The method applied here consists in paired comparisons of various consequences. That is, now the value of utility for any TI and C can be computed from the assessed function U(TI,C), the analyst might ask the DM about his preferences between (TI_1,C_1) and (TI_2,C_2) and check if the answer agrees with the utilities computed for both. Then the analyst might repeat this kind of check several times, and verify if it is necessary to make any reevaluation.

2.6. Conclusions and future work

The results above represent the first part of an investigation conducted in the particular context of maintenance decision making, which involves aspects of reliability engineering.

It has been observed that the success of the elicitation procedure depends greatly on the skills of the decision analyst and on the DM ability to express his preferences and his attitude towards risks. Further work is being conducted to consider other procedures in order to establish the most appropriate one for the skills of people in this context. One of the ideas to be explored includes the use of the DSS approach presented in Sprague and Watson (1989). This is part of a whole Information System currently being developed and outlined in Almeida et al (1991).

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