ALGORITHM TO APPLY THE BEST WORST METHOD TO SYSTEMS ENGINEERING PROBLEMS CONCERNING CUSTOMER SATISFACTION, COST AND IMPLEMENTATION

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Abstract. *This paper presents a method that automatically addresses trade-offs between system engineering problems. A simple example is presented that considers cost, customer satisfaction, and ease of implementation. The software calculates optimal weights for each factor using the Best-Worst multi criteria decision-making method and calculates an overall score for each alternative with respect to calculated factors weights.*

Keywords: Systems engineering, Best-Worst, multi criteria decision-making, score, customer satisfaction, cost, implementation.

Introduction

Systems engineering is often considered as a multidisplinary field of science that involves engineering and management. It focuses on the design and management of complex systems.

The proposed software will assist decision makers to achieve the specific goals of their systems engineering project and increase the probability of success for their projects.

To achieve their goals, systems engineers need to make a decision from a number of choices available, which may include cost, ease of implementation and customer satisfaction targets while fulfilling the scope relating to each of the problems' tasks. See the trade off triangle in Fig.1

In the trade-off triangle, the competing criteria of cost, ease of implementation, and customer satisfaction are the independent variables and scope is the dependent variable in this trade-off [4]. See Fig. 1. Then, if the customer satisfaction needs to be increased, cost and / or ease of implementation should be increased to achieve system requirements.

If ease of implementation was increased then customer satisfaction and cost would increase to achieve system requirements.

Also if cost needed to be reduced then customer satisfaction and / or ease of implementation should be reduced to achieve system requirements.

This leads to some important systems engineering decisions, since systems engineering is concerned with the design and management of a system.

A multi-criteria decision tool can aid a systems engineer in making a suitable choice.

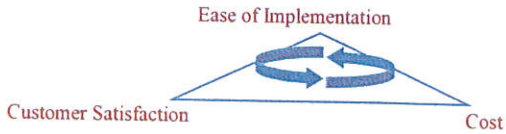

Fig.1.The Trade-off constraint triangle

Software described here helps systems engineers to set a preference for each criterion according to the current state of the system. This is demonstrated in two examples in the paper.

Since systems' cost, ease of implementation and customer satisfaction states change during the planning phase, the decision makers can revisit the software and change the average preference of the criteria in order to cope with these changes.

The software calculates new criteria weights and the overall score of alternatives according to the new inputs from the decision makers.

$V_i = \sum W_j P_{ij}$ For j from 1 to n (5)

Where:

W_j : The optimal weight of criterion i
V_i: Overall value of alternative i
P_{ij}: Score of alternative i with respect of criterion j

Proposed software

The software was written in Visual basic .net (Vb.net) within Microsoft Visual Studio 2012. Microsoft Visual Studio is an integrated development environment used to develop computer programs for Microsoft Windows. Vb.net is popular because of its ease of use. It is not case sensitive, has straight-forward symbols and a relatively simple user interface [25].

The software calculates the optimal weights of three criteria using the Best-Worst method and then calculates the overall score of the alternatives.

When the decision makers sets the Best Criterion and Worst Criterion from Cost, ease of implementation and customer satisfaction using the Track-Bars shown in Fig. 2, the software assigns these values to variables declared in the code as Best, and Worst.

Then the decision makers enters the values of the best other vector and the other worst vector using the six boxes shown in the top left of Fig. 2. and clicks the Calculate Optimal Criteria Weights button shown in the mid-left of Fig. 2.

The software checks for consistency:

If the comparisons are consistent then a consistency ratio is set to zero, optimal criteria weights are calculated, then optimal criteria weights and consistency ratio is displayed in the boxes shown at the bottom left of Fig. 2.

If the comparisons are not consistent then the software calculates a consistency ratio.
The software calculates the optimal criteria weights taking into consideration ζ.

Displays optimal criteria weights and the value of ζ in the boxes shown at the bottom left of Fig. 3.

Then the decision makers enters the average score of each alternative with respect to each criterion in the fifteen boxes shown at the top right of Fig 4 & 5 and clicks the Calculate button shown on mid-right of Fig. 4 & 5 the software calculates the overall score of each alternative using the optimal criteria weights of the Best-Worst method, and displays the results in the five boxes shown at the bottom right of Fig. 4 & 5.

Numerical examples

Applying BWM to system engineering.

Example 1: During a planning phase of a system, decision makers needed to outsource suppliers for system parts. The main concern for decision makers was customer satisfaction, the system was on budget, and ease of implantation was not a major concern.

Using the five steps of the BWM described in Section II to evaluate optimal criteria weights and the overall score of suppliers to choose the best supplier for this task.

1.The decision makers defined a set of criteria:

C_{Cost}: Cost
C_{EI}: Ease of Implementation
C_{CS}: Customer Satisfaction

2. Set the Best criterion and the worst criterion:

$C_{CS} = C_{Best}$
$C_{EI} = C_{Worst}$

3. Determined the preference of the Best criterion to all other criteria. (See table I)

The Best Criterion was C_{CS}

C_{Best} to $C_{CS} = 1$

4. Determined the preference of all other criteria to the Worst criterion. (See Table II)

The Worst criteria was C_{EI}

C_{EI} to $C_{Worst} = 1$

From Tables I & II:

$a_{EI,EI} = a_{Worst, Worst} = 1$,
$a_{cost, cost} = 1$,
$a_{CS,CS} = a_{Best, Best} = 1$,
$a_{cost,EI} = a_{cost, Worst} = 4$,
$a_{CS,EI} = a_{Best, Worst} = 8$,
$a_{CS, cost} = a_{Best, cost} = 2$

Resulting in Matrix A: $\begin{pmatrix} 1 & a_{EI, cost} & a_{EI,CS} \\ 4 & 1 & a_{cost,CS} \\ 8 & 2 & 1 \end{pmatrix}$

Calculate: aEI,cost , $a_{EI,CS}$ and $a_{cost,CS}$

According to [5] for all secondary comparisons:
$a_{best, i} X a_{i, j} = a_{best, j}$ (6)

$a_{i, j} X a_{j, worst} = a_{i, worst}$ (7)

→ $a_{cost,CS} X a_{CS, cost} = a_{cost, cost}$

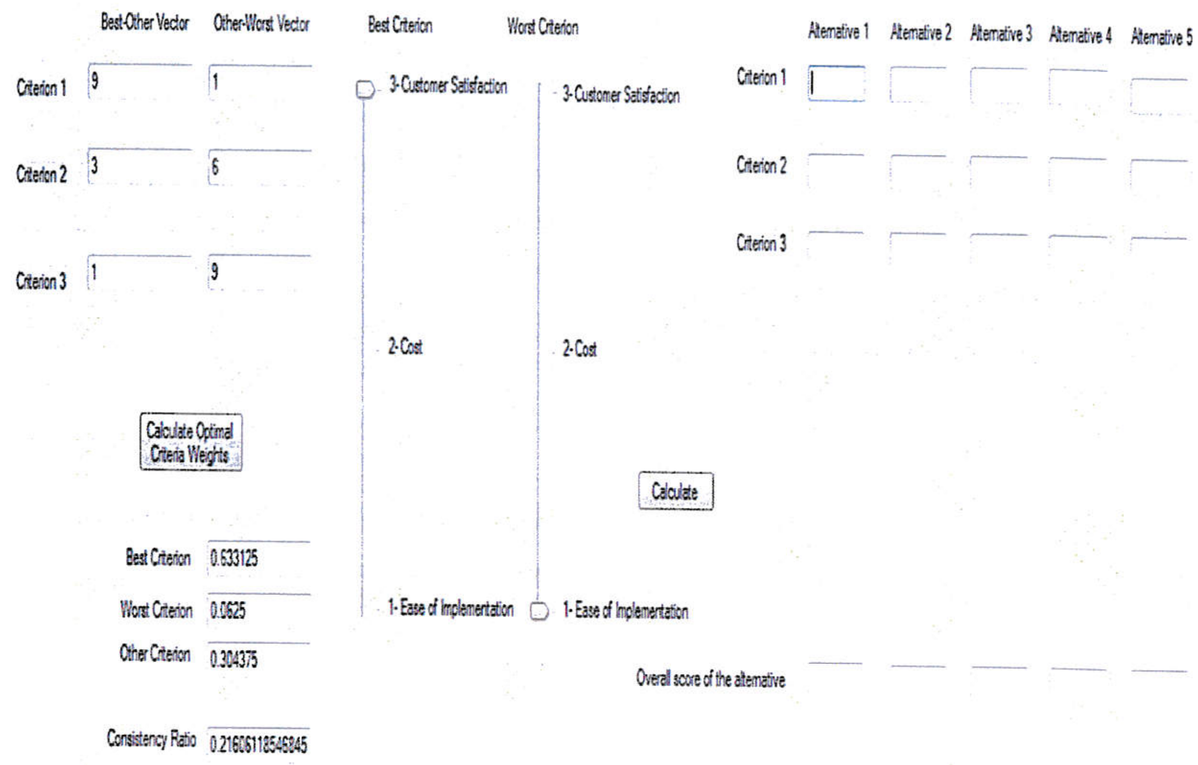

Fig. 3. Screen shot of the user interface for calculating the optimal criteria weights, showing the consistency ratio

Example 2: The idea from example 1 is reused for simplicity but some numbers are changed to make comparisons not fully consistent.

Using the five steps of the BWM to evaluate the criteria weights and the overall score of alternatives to choose the best contractor for this task.

1. The project manager defined a set of criteria:

C_{EI}: Ease of Implementation
C_{cost}: Cost
C_{CS}: Customer Satisfaction

2. Set the Best criterion and the Worst criterion:

$C_{CS} = C_{Best}$
$C_{EI} = C_{Worst}$

3. Determined the preference of Best criterion to all other criteria. (see Table III)

The Best Criterion was C_{CS}

C_{Best} to $C_{CS} = 1$

4. Determined the preference of all other criteria to Worst criterion, (see Table IV)

The Worst criteria was C_{EI}

C_{EI} to $C_{Worst} = 1$

Resulting in Matrix A: $\begin{pmatrix} 1 & a_{EI,cost} & a_{EI,CS} \\ 6 & 1 & a_{cost,CS} \\ 9 & 3 & 1 \end{pmatrix}$

Using (6), and (7) calculate

$a_{EI,\ cost} = 1/6$
$a_{EI,\ CS} = 1/9$
$a_{cost,\ CS} = 6/9 = 2/3$

So that Matrix A becomes: $\begin{pmatrix} 1 & 1/6 & 1/9 \\ 6 & 1 & 2/3 \\ 9 & 3 & 1 \end{pmatrix}$

Conduct consistency check using (1):

$a_{CS,\ cost}$ X $a_{cost,\ EI} = a_{CS,\ EI}$ ➔ 3 X 6 $\neq$ 9

Then the comparisons are not fully consistent

➔ $\xi \neq$ zero

According to Razaei [5]

Consistency Ratio = ζ / Consistency Index (8)

where ζ and the consistency index can be found from Table V & VI.

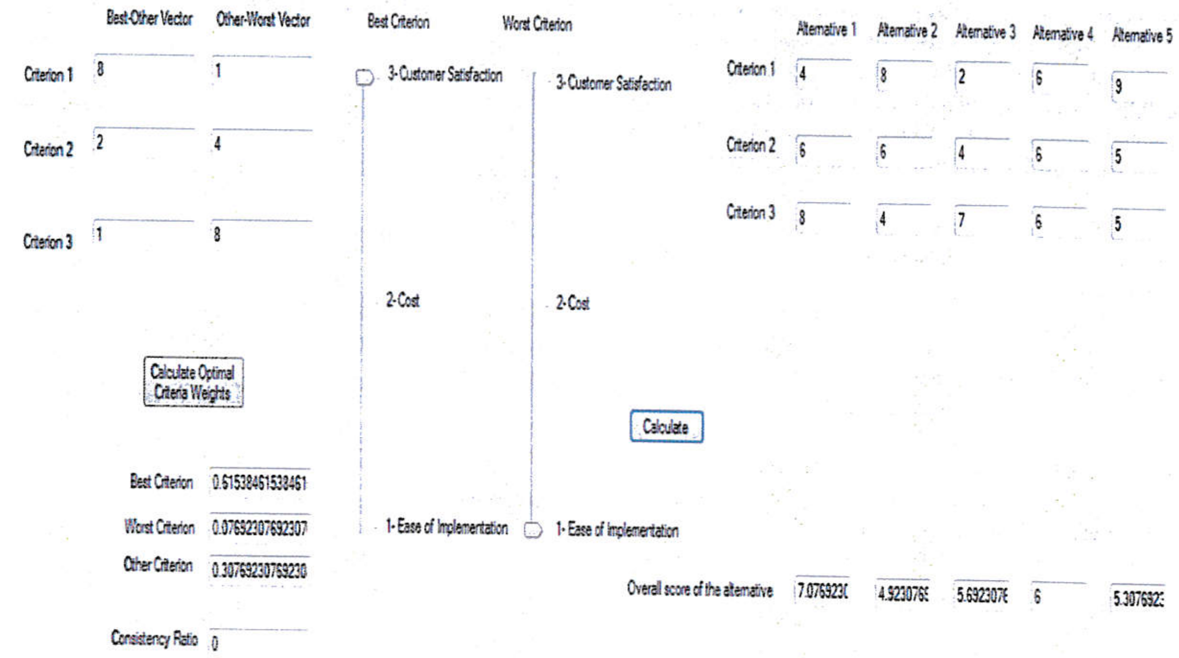

Fig. 4. Screen shot of the user interface for calculating overall score of alternatives

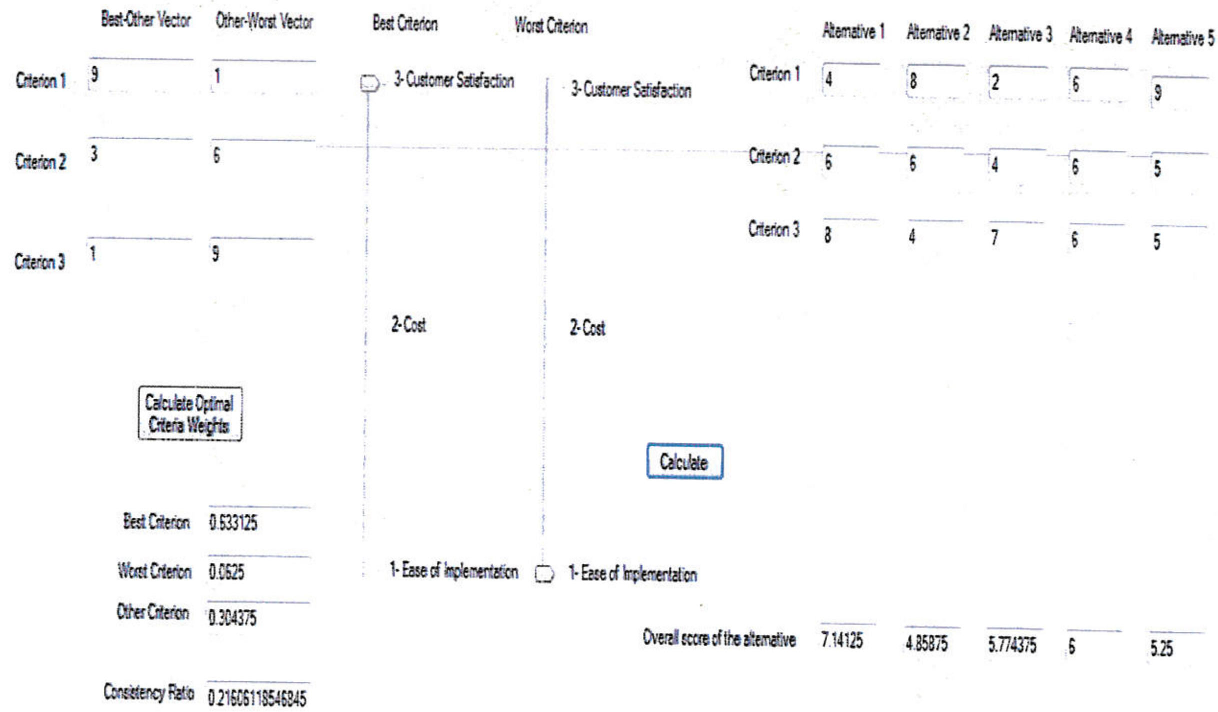

Fig. 5. Screen shot of the user interface for calculating overall score of alternatives, showing the effect of non-consistent comparisons on the overall scores of the alternatives

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