CONCEPT SELECTION AND EVALUATION USING LINEAR PHYSICAL PROGRAMMING.

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Abstract

Much interest has been recently developed to generative processes in design. The purpose of this paper is to focus on the drawbacks of typical decision matrix construction, as well as the limitation of possible alternatives. In this paper, linear physical programming (LPP) is purposed as an alternative to typical construction of decision matrix. The use of LPP overcomes the main drawback of this typical construction. LPP method is used for concept selection as well as parameter selection. In this paper LPP based approach for concept selection is purposed. An example is provided to explain how the method works.

Keywords: MCDM, LPP, CRANK HOOK.

Introduction

The purpose of conceptual design selection is to choose the best or most desirable design concept among several options for the subsequent detailed design stage. As the concept design has a great

influence on the cost, robustness, reliability, manufacturability and development time of final products and hence on the total cost, therefore it is crucial for designer to use effective method or tool to select the best design alternative approach among the several. Depending upon whether evaluation criteria can be quantified or not, the linear physical programming model is used.

The decision matrix is one of the most popular evaluation method in engineering design. The main drawback of this method is, i) some potentially optimal concept never receive the best score and ii) the decision maker has to specify a set of weights which are meaningless. To overcome this shortcoming, In this paper linear physical programming (LPP) method is used for concept selection purpose amongst the other.

Research Methodology

Brief overview of LPP and of its formulation in an optimization setting are provided below. Under the physical programming paradigm, the decision maker express his or her preferences for each criteria using four different classes (1S 2S 3S or 4S). These classes are defined as follows; smaller is better(1S), larger is better(2S), value is better(3S), and range is better(4S).each class consist of two cases, hard and soft, depending upon the sharpness of the preference. Figure 1

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depicts these different classes. On the horizontal axis the value of criteria, g_p , while the class function are used to map the criteria into real, positive, and dimensionless parameters, which are then minimized. Such a mapping ensures that the different criteria, with different criteria, with different physical meanings, are mapped to a common scale.

Class function have several important properties such as: i) they are non negative, continuous, piecewise linear, and convex, and ii) the value of the class function, Z_p, at given range intersection (say desirable tolerable) is the same for all class type. The physical programming problem is always of the minimization type, regardless of which class is being considered.
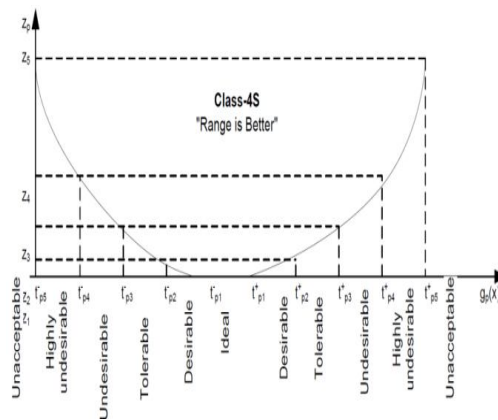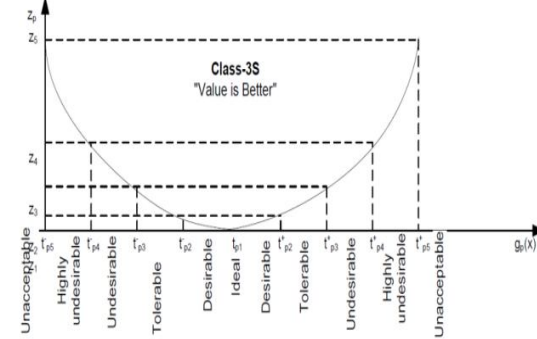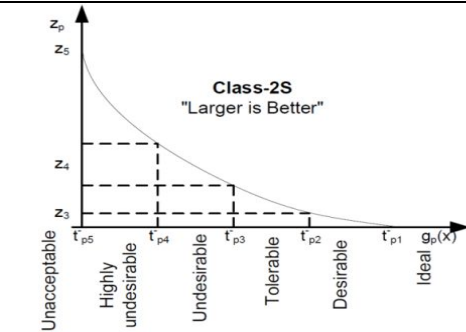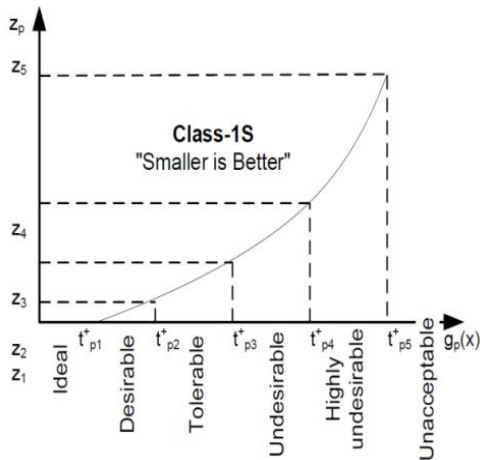

Fig1. Class function of the pth design criteria.

Using physical programming, the decision maker can express his or her preference associated with each criteria in a more detailed, quantitative, and qualitative way than when using weight based methods. The criteria values are categorized according to their degrees of desirability as seen in fig 1 consider, for example the class 1S. the preference ranges are :

Ideal range	$(gp \leq t+p1)$
Desirable range	$(t+p1 \leq gp \leq t+p2)$
Tolerable range	$(t+p2 \leq gp \leq t+p3)$
Undesirable range	$(t+p3 \leq gp \leq t+p4)$
Highly Undesirable range	$(t+p4 \leq gp \leq t+p5)$
Unacceptable range	$(gp \leq t+p5)$

The quantities t^{+}_{p1} through t^{+}_{p5} represents physically meaningful constants, referred to as target value that express the decision makers preferences associated with the pth generic design criteria.

The rest of paper is organized as follows. Section 2 gives an overview of the LPP model for design alternatives. An example is solved to understand the whole procedure of LPP method.

Mathematical representation of LPP

The LPP based model for concept selection and decision making can be mathematically expressed as follows,

$$\text{Min } J = \sum_{p=1}^{n_s} \sum_{S=2}^{5} (w^{-}_{ps} d^{-}_{ps} + w^{+}_{ps} d^{+}_{ps})$$

Where, d^{-}_{ps} and d^{+}_{ps} denotes respectively the negative and positive deviations of the criteria value $g_p(x)$ from its target values $t^{-}_{p,s-1}$ and $t^{+}_{p,s-1}$. The magnitude of preference function's to satisfy the OVO- rule is mathematically represented as follow.

Let $\mathcal{Z}_s = Z_s - Z_{s-1}$ $(2 \leq s \leq 5)$ and $\mathcal{Z}_S = \beta (n_s-1) \mathcal{Z}_{S-1}$ $(3 \leq S \leq 5, n_S>1, \beta>1)$

Where, n_s denotes no of soft criteria, and β is used as a convexity parameter.

The length of the sth criteria is defined as,

$\text{t}^{+}_{ps} = t^{+}_{ps} - t^{+}_{p(s-1)}$ and $\text{t}^{-}_{ps} = t^{-}_{ps} - t^{-}_{p(s-1)}$ $(2 \leq s \leq 5)$.

The slope value of the class function are, $w^{+}_{ps} = \mathcal{Z}_s / t^{+}_{ps}$ and $w^{-}_{ps} = \mathcal{Z}_s / t^{-}_{ps}$

$(2 \leq s \leq 5)$.

These slop changes from range to range and from criteria to criteria

Let ,

$w^{+}_{ps} = w^{+}_{ps} - w^{+}_{p(s-1)}$, $w^{-}_{ps} = w^{-}_{ps} - w^{-}_{p(s-1)}$ and $w^{-}_{ps} = w^{+}_{ps} = 0$

Once the slops are know the convexity requirement can be verified through the relation,

$W_{min} = \min_{p, s} (w^{+}_{ps}, w^{-}_{ps,}) > 0$.

When convexity satisfied certain demands, the weights can be determine. And by using equation first we can calculate the total score. The lower value of total score, the better the better the design scheme is.

Case study: A heavy crank hook, for use in supporting ladles filled with molten metal steel as they transported through the steel mill, is being designed. Two crane hooks are needed for each steel ladle. These large, heavy components are usually made to order in steel mill machine shop when one is damaged and needs to be replaced. Three concept have been purposed: 1)

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Built up from flame cut steel plates, welded together,   2) Built up from flame cut steel

Design criteria		Ideal	Satisfied	Tolerable	Unsatisfied	Highly unsatisfied
	Class	t_{p1}	t_{p2}	t_{p3}	t_{p4}	t_{p5}
Material cost	1-s	40	50	60	70	80
Mfg cost	1-s	2000	2300	2600	2900	3200
Reparability	1-s	20	40	60	80	100

plates, riveted together, 3) A cast steel hook,

Figure.1 crank hook.

Table.1 Design criteria values for hook.

Table.2 Desirable ranges of each criteria.
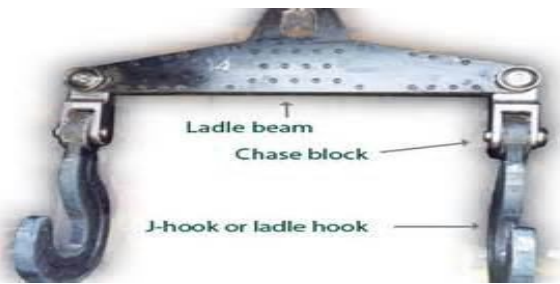
Table.3 evaluation results of each scheme.

Built up plates	Welded	Riveted	Cast
Total score	16.6	10	116.6
Rank	2	1	3

Built up plates	Welded	Riveted	Cast
Material cost	60	60	50
Manufacturing cost	2500	2100	3000
Reparability	40	25	60

As the score of riveted plate is less hence the riveted hook is the best for application.

Conclusion:

In this paper, the drawbacks of the typically constructed decision matrix for concept selection were discussed. A new Linear Physical Programming (LPP) based approach to formulate the decision matrix is presented. This new approach allows a designer to obtain solutions on the non-convex regions of the Pareto frontier. LPP also avoids the need to specify physically meaningless weights and ratings. We presented examples that showed the

effectiveness of the new LPP approach to concept selection.

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