ADVANCING INDUSTRIAL ENGINEERING IN NIGERIA THROUGH TEACHING, RESEARCH AND INNOVATION

A BOOK OF READING

Edited By
Ayodeji E. Oluleye
Victor O. Oladokun
Olusegun G. Akanbi

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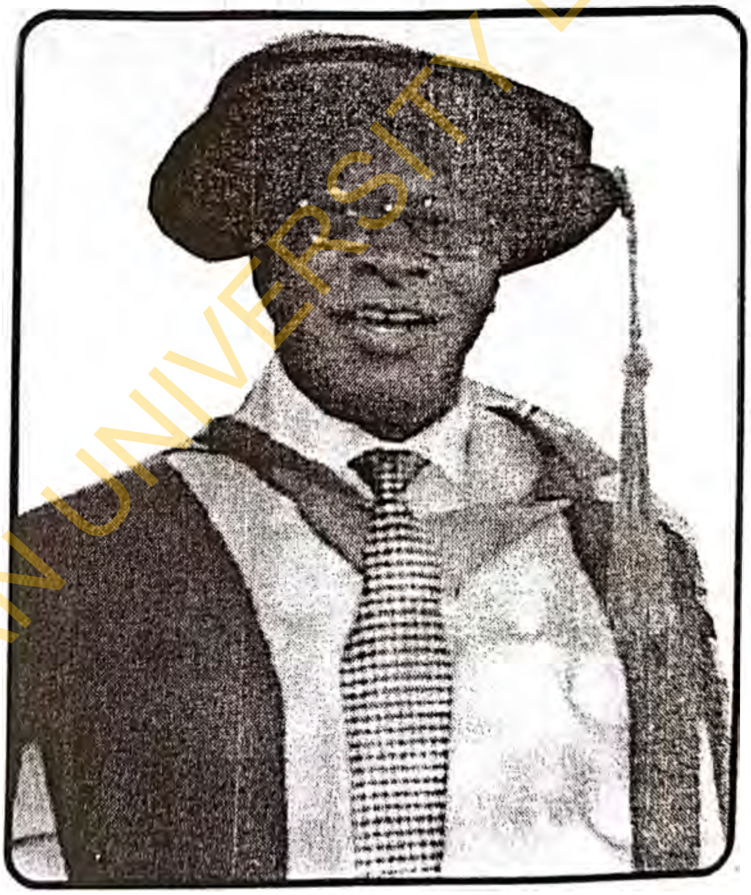
(A Festchrift in honour of Professor O. E Charles-Owaba)



Professor O. E. Charles-Owaba

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FOREWORD

It gives me great pleasure writing the foreword to this book. The book was written in recognition of the immense contributions of one of Nigeria's foremost industrial engineers, respected teacher, mentor, and lover of youth – Professor Oliver Charles-Owaba.

His commitment to the teaching and learning process, passionate pursuit of research and demonstration of excellence has prompted his colleagues and mentees to write this book titled – Advancing Industrial Engineering in Nigeria through Teaching, Research and Innovation (A Festschrift in honour of Professor O. E Charles-Owaba) as a mark of honour, respect and recognition for his personality and achievements.

Professor Charles-Owaba has written scores of articles and books while also consulting for a medley of organisations. He has served as external examiner to various programmes in the tertiary educational system. The topics presented in the book cover the areas of Production/Manufacturing Engineering, Ergonomics/Human Factors Engineering, Systems Engineering, Engineering Management, Operations Research and Policy. They present the review of the literature, extension of theories and real-life applications. These should find good use in the drive for national development.

Based on the above, and the collection of expertise in the various fields, the book is a fitting contribution to the corpus of knowledge in industrial engineering. It is indeed a befitting gift in honour of erudite Professor Charles-Owaba.

I strongly recommend this book to everyone who is interested in how work systems can be made more productive and profitable. It represents a resourceful compilation to honour a man who has spent the last forty years building up several generations of industrial engineers who are part of the process to put Nigeria in the rightful seat in the comity of nations. Congratulations to Professor Charles-Owaba, his colleagues and mentees for this festschrift.

Professor Godwin Ovuworie
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CHAPTER 15

Comparison of Compromise Constraint Bi-objective LP Method and Three Traditional Weighted Criteria Methods

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1. INTRODUCTION

Engineering and management decision situations with more than one criterion have been encountered with increasing frequency (Adeyeye&Charles-Owaba, 2008; Adeyeye&Oyawale, 2010a; Biswas *et al*, 2020; Zizovic, Miljkovic, &Marinkovic, 2020). In multi-criteria decisions, cases where the criteria conflict with each other are more common. In such situations gain in one criterion leads to loss in one or more of the other criteria. Due to conflict among the criteria, it is impossible to find a point at which all the criteria would assume their optimum values simultaneously. Consequently, there is no common optimal solution. What we have is a compromise solution(s). Since the criteria remain in conflict over the decision space, the analysist often elicits and incorporates the preferences of the Decision Maker (DM) in the model such that the DM gets the best compromise solution.

The criteria are often of varying degree of importance to the DM. Hence preference elicitation is very important in multicriteria optimisation. The preferences of the DM are often expressed as weights to reflect the relative importance of the criteria. The set of weights is often referred to as preference indices or preference structure. The preference structure is very important because the compromise solution obtained often vary from one set of preference structure to another. There are three possible situations in the case of a priori articulation of DM opinion concerning the relative importance of the various criteria. The DM may be satisfied with the compromise solution obtained with his preferencestructure and may not bother himself/herself about other feasible solutions that may exist. In other instance, the DM may have interest in the trade-off options available to him/her. In that case, the problem is solved repeatedly with different preference structures. In this manner, the DM learns about available trade-off options and is able to know how much he/she has to give up in one or more criterion/criteria to gain improvement in one or more of the remaining criteria. He is then able to intelligently select the most preferred solution from the candidate solutions. In some other instances, the DM may want the analyst to present the Pareto optimal solutions to him/her for evaluation after which the most preferred solution is picked. Pareto optimal solutions are often generated using the weights elicited from the DM(Adeyeye&Oyawale, 2010a, b; Adeyeye, Odu& Charles-Owaba, 2015; Zizovic, *et al*, 2020; Navarro, Penades-Pla, Martinez-Munoz, Rempling, &Yepes, 2020; Aiello, *et al*, 2020; Wang, Parhi, Rangaiah, & Jana, 2020).

Many methods have been proposed for solving multicriteria optimisation problems. Among the methods are the linear combination of objective functions or weighted-sum scalarization (WSS) method in which criteria are normalised and combined before performing optimisation of the combined objective (Adeyeye&Oyawale, 2010a;Adeyeye& Charles-Owaba, 2012; Oktal, Yaman, & Kasımbeyli, 2020 & Erozan &Calıskan, 2020). Nonpre-emptiveGoal Programming (NGP) is a distance-function approach which uses a certain target point in the decision space which represents the most desired values for the several criteria as a key element in modelling the problem (Adeyeye& Charles-Owaba, 2008; Adeyeye&Oyawale, 2010b;Bakhtavar, Prabatha, Karunathilake, Sadiq, &Hewage, 2020). Compromise Programming (CP) is another distance-function approach for which the target point is a utopian point usually not feasible which corresponds to the ideal value of each criterion (Adeyeye&Oyawale, 2010b;Adeyeye& Allu, 2017; Salman *et al*, 2020 and Canales,Jurasz, Beluco, &Kies, 2020). Adulbhan andTabucanon, (1977, 1979) and Chen, Wiecek, and Zhang (1998) observed that in multicriteria LP problems, the linear combination of objective functions method is very simplistic and sometimes fail to give the real compromise.

According to Adeyeye and Charles-Owaba (2012), this drawback could be due to the lack of sensitivity of the linear combination of objective functions.The Compromise Constraint Bicriteria LP (CCBLP) method was proposed to overcome the limitation of combination of objective functions method for bicriteria case (Adulbhan&Tabucanon, 1977 & 1979). The CCBLP hasnot gained much popularity apart from few applications probably due to lack of evidence on its efficacy (Adulbhan&Tabucanon, 1979;Adeyeye and Charles-Owaba, 2012). The DMs desire to know the relative merits of these approaches so that under any given decision situations they can be properly guided in making the choice of the method that best meet their needs. Since preference indices are often used to determine the best compromise solution, generate the Pareto optimal solutions and carry out trade-off analysis, the sensitivity of any multicriteria method to changes in weight structure could be a good approach of evaluating the usefulness of the method. In this study, the earlier work of Adeyeye and Charles-Owaba (2012) is extended by comparing the CCBLP method with three commonly used traditional weighted criteria methods, namely; WSS, NGP and CP on their sensitivities to changes in the weight structure for bicriteria LP problem.

2. BRIEF DESCRIPTION OF THE FOUR METHODS

In this section, the Compromise Constraint Bicriteria Linear Programming (CCBLP) and three traditional methods, namely, Weighted-sum Scalarisation, Nonpre-emptive Goal Programming (NGP) and Compromise Programming (CP) are briefly described.

2.1 Weighted-sum Scalarisation (WSS)

Consider a bicriteria problem, with criterion functions $f_1(x) = \sum_{j\in J} c_{1j}x_j$ and $f_2(x) = \sum_{j\in J} c_{2j}x_j$, respectively and $g_t(x)$ is the constraint function of t^{th}constraint while b_t is the righthand side of the t^{th} constraint. The elicited weights that reflect the relative importance of criteria are $w_1,\ w_2 > 0$ and $w_1 + w_2 = 1$. The weighted-sum or linear combination of objective functions is given by;

$$Maximise, F = f_1^N(x) + f_2^N(x)$$

$Subject\ to;$ (1)

$$g_t \ \leq, =, \geq \ b_t, t = 1, 2, \dots, T$$

Where $f_1^N(x) = \left(w_1 \middle/ \sqrt{\sum_{j \in J} c_{1j}^2} \right) f_1(x)$ and $f_2^N(x) = \left(w_2 \middle/ \sqrt{\sum_{j \in J} c_{2j}^2} \right) f_2(x)$ also the respective coefficients of criteria 1 and 2 are $c_{1j}^2\ and\ c_{2j}^2$.

2.2 Compromise Constraint Bicriteria LP

The CCBLP is a modification of the weighted-sum approach. The objectives are normalised and combined into one. Next, the compromise constraint is derived and added to the structural constraints of the problem. The compromise constraint is expressed as;

$$\left(w_1 \middle/ \sqrt{\sum_{j \in J} c_{1j}^2} \right) (f_1(x) - f_1^*) + \left(w_2 \middle/ \sqrt{\sum_{j \in J} c_{2j}^2} \right) (f_2(x) - f_2^*) = 0 \quad (2)$$

The combined criteria or any of the original criterion may be used as the criterion to be optimised subject to the compromise and structural constraints as shown below.

Maximise (any one of the three criterion

$$f_1(x) = \sum_{j \in J} c_{1j} x_j$$

$$f_2(x) = \sum_{j \in J} c_{2j} x_j,$$

$$F = \left({w_1}\Big/{\sqrt{\sum_{j\in J} c_{1j}^2}} \right) f_1(x) + \left({w_2}\Big/{\sqrt{\sum_{j\in J} c_{2j}^2}} \right) f_2(x)$$

Subject to;
(3)

$$\left({w_1}\Big/{\sqrt{\sum_{j\in J} c_{1j}^2}} \right) (f_1(x) - f_1^*) + \left({w_2}\Big/{\sqrt{\sum_{j\in J} c_{2j}^2}} \right) (f_2(x) - f_2^*) = 0$$

$$g_t \ \leq, =, \geq \ b_t, t = 1, 2, \ldots, T$$

Where f_1^* and f_2^* are the respective ideal values of criterion 1 and 2 when optimized individually.

2.3 Nonpre-emptive Goal Programming (NGP)

The bicriteria model may be transformed to a GP model by assigning targets to each criterion. In some cases, a priori determination of goal may not be easy. Arbitrary setting of targets may lead to computation dominated or suboptimal solution. Hence, the potentials provided by the objectives are explored by solving them individually and using their optimum values as the target levels. The GP method seeks to minimise the distance between the desired aspiration levels and the compromise solutionobtained according to the preference structure.The general NGP model is given as;

$$Minimise, \qquad a = \sum_i w_i(d_i^+ + d_i^-)$$

$Subject\ to$;
(4)

$$f_i(x) + d_i^- - d_i^+ = f_i^*, \quad i = 1, 2, \ldots I$$

$$g_t \ \leq, =, \geq \ b_t, t = 1, 2, \ldots, T$$

Where $d_i^-, d_i^+ \geq 0$ $and d_i^- \times d_i^+ = 0, \forall i$

2.4 Compromise Programming (CP)

Compromise Programming (CP) has received a lot of attention since it was proposed by Zeleny (1973, 1974). The best compromise solution is identified as the solution that give the shortest distance to a utopian point where all the criteria simultaneously reach their ideal values. The utopian point is not practically attainable but is usually used as a base point. First, the ideal (i.e. the best or anchor) values, (f_i^*) and anti-ideal (worst or nadir) values, (f_i^{**}) are computed for each criterion and are often used for the construction of pay-off matrix. Next, the distance function $(f_i^* - f_i(x))$between the outcome/achievement of each criterion and its ideal/optimum value is defined. This distance gives the degree of closeness of the outcome/achievement of the criterion to its ideal. The distance is usually normalised for dimensional consistency. The normalised distance is given by;

$$D_{ni} = \left(\frac{(f_i^* - f_i(x))}{(f_i^* - f_i^{**})}\right), \forall i \qquad (5)$$

The combined distance (D_p) for all the criteria which expresses the closeness of the solution of the problem to the utopia is expressed as;

$$D_p = \left[\sum_{i \in I} \left(w_i \frac{(f_i^* - f_i(x))}{(f_i^* - f_i^{**})}\right)^p\right]^{1/p} \qquad (6)$$

Where, p is a metric and real number belonging to the closed interval$[0, \infty]$. The value of$p = 1$, when the distances are of equal concern to the DM and $p = \infty$if only the largest distance is of concern. Observe, that all other solutions fall between the solutions obtained by solving the CP model with $p = 1$ and $p = \infty$. For instance, if the DM weighs the distances in proportion to their magnitude, then, $p = 2$ and the resulting model is solved to obtain the compromise solution. The general CP problem is as presented below;

$$\text{Minimise, } D_p = \left[\sum_{i\in I}\left(w_i \frac{(f_i^* - f_i(x))}{(f_i^* - f_i^{**})}\right)^p\right]^{1/p}$$

Subject to: (7)

$$g_t \le, =, \ge b_t, t = 1, 2, \dots, T$$

When only the largest distance(L) counts, then,$p = \infty$,and the problem becomes a min-max problem. The model is stated as;

$$\text{Minimise, } D_\infty = L$$

Subject to:

$$\left(w_i \frac{(f_i^* - f_i(x))}{(f_i^* - f_i^{**})}\right) \le L, \ \forall i \qquad (7)$$

$$g_t \le, =, \ge b_t, t = 1, 2, \dots, T$$

3. EXPERIMENTAL

A bicriteria production planning problem from literature is used (Adeyeye and Charles-Owaba, 2008). The two criteria considered are (i) minimisation of production cost (ii) maximisation of capacity utilisation of production facilities. Cost minimisation criterion was converted to maximising criterion by multiplying by -1. The major production facilities with their respective capacities and cost of processing one unit of materials are presented in Table 1. The model developed by Adeyeye and Charles-Owaba (2008) were used for the experiment see Eq. 8. The problem was solved using the WSS, CCBLP, NGP and CP methods. For WSS method, the normal forms of the criteria were combined into one objective and solved using the existing constraints of the problem. In the case of CCBLP, apart from adding the normal forms of the criteria, the compromise constraint was derived and added to the structural constraints of the problem before solving it. In the case of the NGP and CP, the two criteria were solved individually to determine their ideal and anti-ideal values. For the NGP, the ideal values were set as the target while in the case of CP, the ideal and anti-ideal values were used for the computation of normalised distances.

Various weight structures were used to perform experiment to see the response/sensitivity of the CCBLP and the other three traditional approaches to the changes in the weight structure (see Table 2). The total production costs and capacity utilisation of each production facility was determined. The utilisation of production facilities was computed using the production facilities capacity constraints in Eq. 8. For instance, the respective capacity utilisation of PMV1 and ST3 are $\left(\frac{x_{111}+x_{211}+x_{311}}{9{,}600} \times 100\%\right)$ and $\left(\frac{y_{23}}{20{,}000} \times 100\%\right)$. The utilisation of the remaining facilitieswas computed in similar manner. In this study, the deviations were weighed equally, hence the D_1 distance metric is used to identify the solution that is closest to the utopian and the corresponding preference structure. The D_1 distance metric in its discrete form is mathematically expressed for bicriteria decision situation as $D_1 = w_1 \left|\frac{f_1^* - f_1(x)}{f_1^* - f_1^{**}}\right| + w_2 \left|\frac{f_2^* - f_2(x)}{f_2^* - f_2^{**}}\right|$

Table 1: Facilities Capacities and Processing Costs

Stage of Production	Facility Name	Capacity kg/month	Processing cost per unit
Premix	Premix Vessel 1 (PMV1)	9,600	2.00
	Premix Vessel 2 (PMV2)	14,400	1.20
	Premix Vessel 3 (PMV3)	24,000	1.00
Processing	Processing Vessel 1 (PLT1)	25,000	2.00
	Processing Vessel 2 (PLT2)	25,000	1.80
	Processing Vessel 3 (PLT3)	40,000	1.40

	Processing Vessel 4 (PLT4)	30,000	1.60
Storage	Storage 1 (ST1)	80,000	0.30
	Storage 2 (ST2)	45,000	0.45
	Storage 3 (ST3)	20,000	0.20

$$Minimise, Cost = 2x_{111} + 2x_{211} + 2x_{311} + 1.2x_{121} + 1.2x_{221} + 1.2x_{321} + x_{131} + x_{231} + x_{331} + 2y_{12} + 2x_{412} + 2x_{512} + 2x_{612} + 2x_{712} + 1.8y_{22} + 1.8x_{422} + 1.8x_{522} + 1.8x_{622} + 1.8x_{722} + 1.4y_{32} + 1.4x_{432} + 1.4x_{532} + 1.4x_{632} + 1.4x_{732} + +1.6y_{42} + 1.6x_{442} + 1.6x_{542} + 1.6x_{642} + 1.6x_{742} + 0.3y_{13} + 0.45y_{23} + 0.20y_{33}$$

Maximise, $Capacity\ Utilisation$

$$= 4.17x_{111} + 4.17x_{211} + 4.17x_{311} + 2.78x_{121} + 2.78x_{221} + 2.78x_{321} + 1.67x_{131} + 1.67x_{231} + 1.67x_{331} + 1.6y_{12} + 1.6x_{412} + 1.6x_{512} + 1.6x_{612} + 1.6x_{712} + 1.6y_{22} + 1.6x_{422} + 1.6x_{522} + 1.6x_{622} + 1.6x_{722} + y_{32} + x_{432} + x_{532} + x_{632} + x_{732} + 1.33y_{42} + 1.33x_{442} + 1.33x_{542} + 1.33x_{642} + 1.33x_{742} + 0.5y_{13} + 0.89y_{23} + 2y_{33}$$

Subject to: (8)

Production facilities capacity constraint

$$x_{111} + x_{211} + x_{311} \leq 9{,}600 \qquad (PMV1)$$

$$x_{121} + x_{221} + x_{321} \leq 14{,}400 \qquad (PMV2)$$

$$x_{131} + x_{231} + x_{331} \leq 24{,}000 \qquad (PMV3)$$

$$y_{12} + x_{412} + x_{512} + x_{612} + x_{712} \leq 25{,}000 \qquad (PLT1)$$

$$\boldsymbol{y_{22} + x_{422} + x_{522} + x_{622} + x_{722} \leq 25,000} \qquad (\boldsymbol{PLT2})$$

$$y_{32} + x_{432} + x_{532} + x_{632} + x_{732} \leq 40{,}000 \qquad (PLT3)$$

$$y_{32} + x_{432} + x_{532} + x_{632} + x_{732} \leq 30{,}000 \qquad (PLT4)$$

$$y_{13} \leq 80{,}000 \qquad (ST1) y_{23} \leq 80{,}000 \qquad (ST2)$$

$$y_{23} \leq 20{,}000 \qquad (ST3)$$

Firm's full capacity constraint

$$x_{111} + x_{211} + x_{311} + x_{121} + x_{221} + x_{321} + x_{131} + x_{231} + x_{331} = 48{,}000$$

Material proportions constraint

$$x_{111} - 0.1x_{311} = 0$$

$$x_{121} - 0.1x_{321} = 0$$

$$x_{131} - 0.1x_{331} = 0$$

$$x_{211} - 1.3x_{311} = 0$$

$$x_{221} - 1.3x_{321} = 0$$

$$x_{231} - 0.1x_{331} = 0$$

$$x_{422} - 0.0625y_{22} = 0$$

$$x_{432} - 0.0625y_{32} = 0$$

$$x_{442} - 0.0625y_{42} = 0$$

$$x_{512} - 0.01042y_{12} = 0$$

$$x_{522} - 0.01042y_{22} = 0$$

$$x_{532} - 0.01042y_{32} = 0$$

$$x_{542} - 0.01042y_{42} = 0$$

$$x_{612} - 0.96y_{12} = 0$$

$$x_{622} - 0.96y_{22} = 0$$

$$x_{632} - 0.96y_{32} = 0$$

$$x_{642} - 0.96y_{42} = 0$$

$$x_{712} - 0.0521y_{12} = 0$$

$$x_{722} - 0.0521y_{22} = 0$$

$$x_{732} - 0.0521y_{32} = 0$$

$$x_{742} - 0.0521y_{42} = 0$$

Material balance constraint

$$x_{111} + x_{211} + x_{311} + x_{121} + x_{221} + x_{321} + x_{131} + x_{231} + x_{331} - y_{12} - y_{22} - y_{32} - y_{42} = 0$$

$$y_{12} + x_{412} + x_{512} + x_{612} + x_{712} + y_{22} + x_{422} + x_{522} + x_{622} + x_{722} + y_{32} + x_{432} + x_{532} + x_{632} + x_{732} + y_{32} + x_{432} + x_{532} + x_{632} + x_{732} - y_{13} - y_{23} - y_{33} = 0$$

Table 2: Relative Importance of Criteria

S/N	Preference Structure
1	$w_1 = 0.25, w_2 = 0.75$
2	$w_1 = w_2 = 0.5$
3	$w_1 = 0.75, w_2 = 0.25$

4. RESULTS AND DISCUSSION

The summary of results of experiments with different preference structures are presented in Table 3 below. All the four methods have been able to assist the DM to determine the utilisation of the production facilities and the associated costs for the different weight structures. However, the usefulness of the various methods as tool for the DM in making intelligent trade-off decisions vary because of the difference in their sensitivity to relaxations in the objectives. The D_1-distanceswere not computed for the WSS, NGP and CP when $w_1 = 0.75$ and$w_2 = 0.25$ because their solutionsare identical to the ideal solution of the minimum cost objective (see Table 3). Their so called "best compromise solutions" could mislead DM because they did not reflect the relaxation provided by the DM. Only the CCBLP responded to the small relaxation in the costminimisation objectives with improved capacity utilisation of production facilities but with a decrease in the achievement of minimum cost objective. The utilisation of the least utilisedfacility improved from 0.18% to 20.32% while production cost increased by 1.8%. The increase in the utilisation of production facilities was achieved at the detriment of production cost because the objectives are in conflict.Also, when $w_1 = 0.25$ and$w_2 = 0.75$, the NGP and CCBLP responded to the relaxation in the capacity utilisation objective while that of WSS and CPare identical to the ideal solution of the maximisation of capacity utilisation objective. It is only in the case where the objectives are of equal importance ($w_1 = w_2 = 0.50$) to the DM that all the four approaches responded to the relaxations in the objectives. In terms of sensitivity of the approaches, WSS and CP were the least sensitive, followed by NGP while CCBLP is the most sensitive. In terms of the D_1-distances, the compromise solution provided by CCBLP is the closest to the utopia and the corresponding preference structure is $w_1 = 0.25,\ w_2 = 0.75$).

Table 3: Results of Simulation with Different Preference Structure

Facility Name	$w_1 = 1$	$w_1 = 0.75, w_2 = 0.25$				$w_1 = w_2 = 0.50,$				$w_1 = 0.25, w_2 = 0.75$				$w_2 = 1$
	Ideal Cost $f_1(x)$	WSS	NGP	CCBLP	CP	WSS	NGP	CCBLP	CP	WSS	NGP	CCBLP	CP	Ideal $f_2(x)$ Capacity utilisation
PM 1	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PM 2	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PM 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100
PP 1	20.32	20.32	20.32	20.32	20.32	20.32	20.32	25.20	20.32	100	100	58.40	100	100
PP 2	100	100	100	100	100	100	100	100	100	100	100	100	100	100

PP 3	100	100	100	100	100	100	100	97	100	50.20	100	76.20	50.20	50.20
PP 4	100	100	100	100	100	100	100	100	100	100	33.60	100	100	100
ST 1	100	100	100	66.80	100	43.90	43.90	43.90	43.90	43.90	43.90	43.90	43.90	43.90
ST 2	0.18	0.18	0.18	59.10	0.18	100	100	100	100	100	100	100	100	100
ST 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cost (₦)	2.48×10^5	2.48×10^5	2.48×10^5	2.52×10^5	2.48×10^5	2.54×10^5	2.54×10^5	2.55×10^5	2.54×10^5	2.67×10^5	2.62×10^5	2.60×10^5	2.67×10^5	2.67×10^5
Distance Metric (L_1)				0.337		0.388	0.388	0.391	0.388		0.366	0.326		
Increase In Cost (%)		0.0	0.0	1.8		2.7	2.7	3.0	2.7	7.5	5.9	5.0	7.5	7.5

The feasible solution space defined by the constraint sets determines the sensitivity of the methods to the changes in the preference structure. In the case of WSS, NGP and CP, the compromise solution is limited to the vertices of the solution space. Such solutions could be misleading because in some cases the real best compromise solution may be in other parts of the solution space other than the vertices. This could be the reason why WSS and CP were giving identical solutions for all the cases studied. The addition of goal constraints to the NGP model changes the feasible solution space of the bicriteria problem by introducing new vertices and eliminating some of the existing vertices. This could be the reason why the solution of the NGP was different from that of WSS and CP for $w_1 = 0.25$ and$w_2 = 0.75$.It is possible that the NGP picks one of the new vertices introduced by the goal constraints. Once the goal constraints are added to the structural constraints, the feasible region for the problem has been defined and does not change with relaxations in the criteria and the solutions are limited to the vertices. In the case of CCBLP, the preference indices are used to derive the compromise constraint which is added to the original constraint set and it forces the criteria to settle on a common point on any part of the boundary of the solution space. The CCBLP is able to identify the real compromise solution because it is not limited to the vertices of the constraint set. Although the CCBLP approach is the most sensitive to changes in preference structure, its application is limited to bicriteria case whereas WSS, NGP and CP can handle more than two objectives. The CP approach has a means of incorporating the concerns of the DM over the deviations through the use of the topological metric, $p$which is a real number belonging to the closed interval $[0, \infty]$. The choice of which of the approaches the DM should use in a given situation depends on the number of criteria, sensitivity to relaxations in the criteria and the concerns of the DM on the deviation from utopian solution among others.

5. CONCLUSION

Simulation with different preference structures showed that CCBLP is the most sensitive to the changes in the preference structures and gives the real compromise solution. It is able to identify the real compromise anywhere on the boundary of the feasible region either on the vertices on not. The CCBLP is limited to bicriteria while WSS, NGP and CP can handle more than two criteria. This provide a guide for Decision Maker on the choice of method to use for his decision problem.

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