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Strategic planning for addressing the multi-option parameters for sustainable decision-making in multi-objective solid transportation problem

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Abstract

This study focuses on the multi-option multi-objective solid transportation problem (MOMOSTP). Multi-option parameters describe the problem parameters, such as the objective function's cost coefficients. The primary aim of this research is to convert the multi-option structure of cost coefficients in the objective function of the transportation problem

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(TP) into a singular option format, with the goal of minimizing total costs. In this study, we provide a novel heuristic technique for the given issue. Furthermore, we demonstrate the effectiveness of our suggested strategy by the use of a ranking approach.

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Keywords: *Solid transportation problem, Multi-choice multi-objective programming, Ranking, Goal programming.*

1. Introduction

The transportation problem, a distinct category of linear programming problem (LPP), entails the movement of goods from several origins to multiple destinations with the objective of minimizing total transportation costs. It is sometimes referred to as the Hitchcock [1] problem.

The solid transportation problem (STP) is a more complex variant of the classical transportation problem (TP). Unlike a TP, which only addresses source and destination restrictions, the STP addresses three different kinds of constraints. The additional limitation mostly arises from the various methods of transportation. The study offers a solution to a difficult transportation problem in which the quotient of two linear functions is the goal function [2]. In this study, we have included the MCMOSTP into our analysis, whereby we have taken into account the transportation problem parameters as being of the multi-option type. When faced with transportation criteria such as cost, supply, or demand, decision makers may have confusion in selecting the appropriate choice when several options are available, as opposed to a single option. In this particular context, the examination of the transportation issue gives rise to a novel avenue known as the MCMOSTP. Chang (year) introduced a multi-option objective programming methodology as a solution to mathematical programming. In the following year, Chang [3, 4] presented an alternative formulation of a multi-option goal programming (GP) technique.

A multi-option linear programming issue was transformed in a study by Biswal and Acharya [5]. More precisely, their concentration was on translating the phrases on the right-hand side of the restrictions, making sure that they also meet the requirements of the multiple-option or target criterion. In a recently proposed multi-option goal programming formulation, the use of a novel conic scalarizing function allows for increased flexibility, efficiency, and reliability in the decision-making process [6]. In the same year, Joshi [7] undertook an investigation into fractional transportation difficulties within the context of neutrosophic scenarios. This included considering objective function coefficients, needs, and availabilities that were purely speculative in nature. The study presents a novel approach to address a complex multi-objective linear fractional transportation problem by using rough set theory [8].

Notations	
• $\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}}$: Volume of shipment from the $\tilde{\imath}^{th}$supply source to the $\tilde{\jmath}^{th}$demand destination via the $\tilde{k}^{th}$ mode of transportation • $\mathcal{L}_{\tilde{\jmath}\tilde{k}}$: Supply • $\mathcal{M}_{\tilde{k}\tilde{\imath}}$: Demand • $\mathcal{N}_{\tilde{\imath}\tilde{\jmath}}$: Conveyance	• Z_t^U: Maximum value of t^{th} objective functions • Z_t^L: Minimum value of t^{th} objective functions • Z_t: t^{th} objective functions • $C^r_{\tilde{\imath}\tilde{\jmath}\tilde{k}}(t)$: Unit multi-option cost in the t^{th} objective function • Z_t^*: Ideal value • w_t: Weight

2. Mathematical models

The mathematical models of MCMOSTP and proposed approach is defined as follows:

We use Biswal's [5] approach to convert multi-option into single option.

Standard Mathematical Model	**Proposed Model**
Minimize $Z_t = \sum_{\tilde{\imath}=1}^{m}\sum_{\tilde{\jmath}=1}^{n}\sum_{\tilde{k}=1}^{l} C^r_{\tilde{\imath}\tilde{\jmath}\tilde{k}}(t)\,\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}}$ Subject to $\sum_{\tilde{\imath}=1}^{m}\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} = \mathcal{L}_{\tilde{\jmath}\tilde{k}},\ \sum_{\tilde{\jmath}=1}^{n}\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} = \mathcal{M}_{\tilde{k}\tilde{\imath}}$, $\sum_{\tilde{k}=1}^{l}\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} = \mathcal{N}_{\tilde{\imath}\tilde{\jmath}}, \sum_{\tilde{\jmath}=1}^{n}\mathcal{L}_{\tilde{\jmath}\tilde{k}} = \sum_{\tilde{\imath}=1}^{m}\mathcal{M}_{\tilde{k}\tilde{\imath}}$, $\sum_{\tilde{k}=1}^{l}\mathcal{M}_{\tilde{k}\tilde{\imath}} = \sum_{\tilde{\jmath}=1}^{n}\mathcal{N}_{\tilde{\imath}\tilde{\jmath}}, \sum_{\tilde{\imath}=1}^{m}\mathcal{N}_{\tilde{\imath}\tilde{\jmath}} = \sum_{\tilde{k}=1}^{l}\mathcal{L}_{\tilde{\jmath}\tilde{k}}$, $\sum_{\tilde{\jmath}=1}^{n}\sum_{\tilde{k}=1}^{l}\mathcal{L}_{\tilde{\jmath}\tilde{k}} = \sum_{\tilde{k}=1}^{l}\sum_{\tilde{\imath}=1}^{m}\mathcal{M}_{\tilde{k}\tilde{\imath}} = \sum_{\tilde{\imath}=1}^{m}\sum_{\tilde{\jmath}=1}^{n}\mathcal{N}_{\tilde{\imath}\tilde{\jmath}}$, $\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} \geq 0, \forall\ \tilde{\imath},\tilde{\jmath},\tilde{k}$. Where $C^r_{\tilde{\imath}\tilde{\jmath}\tilde{k}}(t) = (C^1_{\tilde{\imath}\tilde{\jmath}\tilde{k}}, C^2_{\tilde{\imath}\tilde{\jmath}\tilde{k}}, \dots, C^R_{\tilde{\imath}\tilde{\jmath}\tilde{k}})$, $r = 1,2,\dots,R$.	Minimize $\sum_{t=1}^{K}\left(\frac{w_t}{Z_t^*}\right)Z_t$ Subject to $Z_t = (Z_t^U + Z_t^L)/2$, $\sum_{\tilde{\imath}=1}^{m}\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} = \mathcal{L}_{\tilde{\jmath}\tilde{k}},\ \sum_{\tilde{\jmath}=1}^{n}\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} = \mathcal{M}_{\tilde{k}\tilde{\imath}}$, $\sum_{\tilde{k}=1}^{l}\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} = \mathcal{N}_{\tilde{\imath}\tilde{\jmath}}, \sum_{\tilde{\jmath}=1}^{n}\mathcal{L}_{\tilde{\jmath}\tilde{k}} = \sum_{\tilde{\imath}=1}^{m}\mathcal{M}_{\tilde{k}\tilde{\imath}}$, $\sum_{\tilde{k}=1}^{l}\mathcal{M}_{\tilde{k}\tilde{\imath}} = \sum_{\tilde{\jmath}=1}^{n}\mathcal{N}_{\tilde{\imath}\tilde{\jmath}}, \sum_{\tilde{\imath}=1}^{m}\mathcal{N}_{\tilde{\imath}\tilde{\jmath}} = \sum_{\tilde{k}=1}^{l}\mathcal{L}_{\tilde{\jmath}\tilde{k}}$, $\sum_{\tilde{\jmath}=1}^{n}\sum_{\tilde{k}=1}^{l}\mathcal{L}_{\tilde{\jmath}\tilde{k}} = \sum_{\tilde{k}=1}^{l}\sum_{\tilde{\imath}=1}^{m}\mathcal{M}_{\tilde{k}\tilde{\imath}} = \sum_{\tilde{\imath}=1}^{m}\sum_{\tilde{\jmath}=1}^{n}\mathcal{N}_{\tilde{\imath}\tilde{\jmath}}$, $\chi_{\tilde{\imath}\tilde{\jmath}\tilde{k}} \geq 0, \forall\ \tilde{\imath},\tilde{\jmath},\tilde{k}$. $\sum_{t=1}^{K} w_t \geq 1, t = 1,2,\dots,K$.

3. Numerical example

Let's examine the multi-option two-objective solid transportation programming problem presented in Table 1.

Table 1
Matrix of costs for the solid transportation problem with multiple options and objectives

		$\tilde{\jmath} = 1$	$\tilde{\jmath} = 2$	$\tilde{\jmath} = 3$	
$\tilde{\imath} = 1$	$E_{11} = 10$	$Z_1 = \{6,8\}$, $Z_2 = \{4,7\}$	$\{5\},\{7\}$	$\{3,7\},\{1,2\}$	$B_{11} = 6$
	$E_{12} = 6$	$\{12,13\}$, $\{8,9\}$	$\{3,6\}$, $\{12,15\}$	$\{8,10\}$, $\{17,19\}$	$B_{21} = 9$
	$E_{13} = 9$	$\{6,8,10\}$, $\{15,17,19\}$	$\{20,21\}$, $\{23,24\}$	$\{15,16,17\}$, $\{12,15,19\}$	$B_{31} = 10$
$\tilde{\imath} = 2$	$E_{21} = 21$	$\{9,10,11\}$, $\{3,5,7\}$	$\{5,6,7,8\}$, $\{4,6,8,10\}$	$\{3,4\}$, $\{10,12\}$	$B_{12} = 13$
	$E_{22} = 10$	$\{4,5,6\}$, $\{11,13,15\}$	$\{14,15,16\}$, $\{8,9,11\}$	$\{18,19\}$, $\{6,7\}$	$B_{22} = 15$

	$B_{23} = 14$	{9,10}, {26,27}	{11},{29}	{12,14,16}, {6,9,12}	$B_{32} = 17$
$\tilde{\imath} = 3$	$E_{31} = 22$	{9},{19}	{2,3},{5,7}	{12},{15}	$B_{13} = 15$
	$E_{32} = 13$	{7,8}, {20,22}	{14},{22}	{11,12,13,14}, {7,9,11,13}	$B_{23} = 14$
	$E_{33} = 10$	{10,12}, {17,20}	{13,15,17,19}, {19,21,23,25}	{20,21,22}, {22,24,26}	$B_{33} = 18$
		$A_{11} = 15$	$A_{21} = 8$	$A_{31} = 11$	
		$A_{12} = 18$	$A_{22} = 12$	$A_{32} = 8$	
		$B_{13} = 20$	$A_{23} = 9$	$A_{33} = 16$	

4. Result and discussion

The mathematical programming model presented in section 2 is solved using LINGO 18.0 software; it is regarded as a non-linear programming problem. The most effective solution, as determined by the mathematical model, is:

$\boldsymbol{\chi_{131} = 6, \chi_{211} = 11, \chi_{221} = 2, \chi_{311} = 4, \chi_{321} = 6, \chi_{331} = 5, \chi_{122} = 6, \chi_{132} = 3, \chi_{212} = 10, \chi_{222} = 5, \chi_{312} = 8, \chi_{322} = 1, \chi_{332} = 5, \chi_{113} = 10, \chi_{223} = 3, \chi_{233} = 14, \chi_{313} = 10, \chi_{323} = 6, \chi_{333} = 2}$ where the other decision variables have a value of zero. The objective function has a minimum cost of $\mathbf{823}$ values of $\boldsymbol{Z_1}$. Similarly, for $\boldsymbol{Z_2}$, $\boldsymbol{\chi_{131} = 6, \chi_{211} = 11, \chi_{311} = 2, \chi_{321} = 8, \chi_{331} = 5, \chi_{112} = 6, \chi_{122} = 2, \chi_{132} = 1, \chi_{212} = 5, \chi_{222} = 10, \chi_{312} = 7, \chi_{332} = 7, \chi_{113} = 4, \chi_{123} = 4, \chi_{133} = 2, \chi_{213} = 3, \chi_{233} = 14, \chi_{313} = 13, \chi_{323} = 5}$, where the other decision variables have a value of zero. The objective function has a minimum cost of **1181**.

Table 2
Comparison of solution of numerical example by goal programming (GP), revised multi-choice goal programming (RMCGP), conic scalarization [3, 4, 6], and proposed method

Weights	GP		RMCGP		Conic Scalarization		Proposed method		Ranking ($0 \leq r \leq 1$) [9]			
									GP	RMCGP	Conic	Proposed method
	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2	Z_1	Z_2				
0.1,0.9	891.9	1283	945	1283	945.0	1251.7	864	1187	0.30	0	0.18	0.75
0.2,0.8	945.0	1283	945	1283	903.1	1283.0	864	1187	0.00	0	0.24	0.75
0.3,0.7	945.0	1283	945	1283	945.0	1283.0	837	1203	0.00	0	0.00	0.84
0.4,0.6	945.0	1283	945	1283	893.2	1283.0	837	1203	0.00	0	0.30	0.84
0.5,0.5	939.7	1283	945	1283	893.6	1283.0	837	1203	0.03	0	0.30	0.84
0.6,0.4	945.0	1283	945	1283	925.0	1283.0	837	1203	0.00	0	0.12	0.84
0.7,0.3	945.0	1283	945	1283	929.0	1281.0	837	1203	0.00	0	0.10	0.84
0.8,0.2	870.5	1283	945	1283	905.0	1275.0	830	1232	0.40	0	0.25	0.71
0.9,0.1	945.0	1283	945	1283	938.9	1283.0	830	1232	0.00	0	0.04	0.71

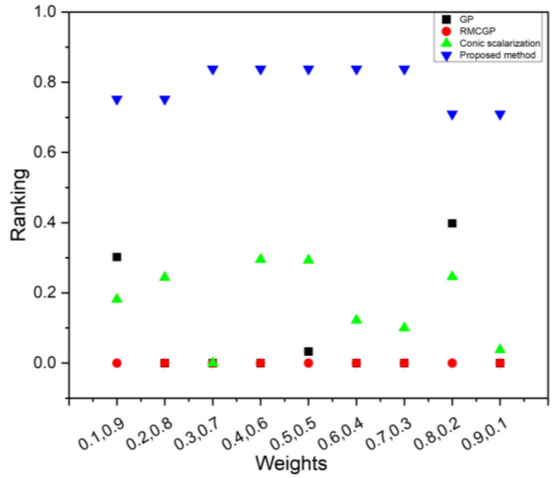

Figure 1
Comparative consistency between the GP, RMCGP, conic scalarization, and suggested method is shown graphically.

We can see that rank of proposed method is better than GP, RMCGP, conic scalarization (table 2). It may be compared to a competition, and our strategy is succeeding by being more in line with our intended result which is shown in Figure 1.

A diagram that contrasts conic scalarization, GP, RMCGP, and a suggested rank-based approach. The proposed method outperforms GP, RMCGP, and conic scalarization, indicating its superiority. The graph illustrates the proposed method's effectiveness in achieving desired outcomes, akin to leading in a race. It serves as a visual representation of the proposed method's proficiency in solving the solid transportation problem with two objectives.

5. Conclusion

This study aims to design a solution strategy for the MCMOSTP issue, taking into account the multi-choice cost parameter. For many real-world transportation situations, the cost coefficients of the objective function parameters may not be known beforehand for a number of unanticipated reasons. We compare our algorithm with previous algorithms [3,4,6] using LINGO 18.0. For future research, researcher can improve the algorithm for complex transportation scenarios for better compromise optimal solution.

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