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A New Approach to Solving Transportation Problems: The Middle Cell Method

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Abstract: *This study centers on another method of solving transportation problems called the Middle Cell method (MCM). This is achieved by finding the optimal basic feasible solution through allocating as many units as possible equal to the minimum cost between available supply and demand through the center of the transportation table. Results from the numerical examples showed that the Middle-Cell method was optimal (especially when the rows and columns are not equal having an even number of rows and an odd number of columns or vice versa). When compared with other transportation techniques, the Middle cell method does better than the North-West corner method (NWCM), the North-East Corner method (NECM), the South-West Corner method (SWCM) and the South-East Corner method (SECM). Finally, this new approach competes favourably with the Least Cost method (LCM).*

Keywords:,*Transportation, challenges, model, most suitable, Middle cell method,*

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1.0 Introduction

The transportation model in linear programming problems involves moving goods from diverse starting points called the origin to diverse end points called the destination bearing in mind the constraints of availability and supply. In most real-life situations, the availability of goods may be greater or less than the demand (In an unbalanced Problem) or the availability of goods may be equal to the demand (in a balanced Problem)

The earliest proponent of transportation problem formulation was the one done by (Hitchcook, 1941) to solve the basic business problem while (Dantzig, 1951) applied the notion of Linear programming in solving the transportation model. Since the introduction of simplex-based techniques in finding the initial basic feasible solution of transportation problems, many researchers have developed other procedures of finding the initial basic feasible solution. Ary and Syarifuddin (2011) contrasted the northwest-corner technique and the stepping-stone method with the foundation tree approach to solving transportation problems. The foundation tree technique was based on the theory that any vital possible solution to a transportation problem is a spanning tree of the underlying graph. As a result, the basis is represented as a rooted spanning tree for each iteration, with an arc and its flow representing the basic variable and node potential representing the simplex multiplier (dual variable). The northwest-corner method and the stepping-stone method with the basis tree approach have the same outcome. Lakshmi and Pallavi (2015), developed a new approach to finding the initial basic feasible solution from the bottom left-hand corner cell of the transportation table called the South West Corner rule. The result of this method competed favourably with the northwest corner method. Sharma and Bhadane (2016) developed an alternative method to the northwest corner method for solving the transportation problem. They used a

Statistical tool called Coefficient of Range to justify the result of their outcome. It was also observed that the initial basic feasible solution was obtained comparatively in less number of iterations. So, they conclude that the coefficient of range (CoR) can be used for finding the initial basic feasible solution (IBFS). Palaniyappa (2017) developed a method of an optimal solution by finding the initial basic feasible solution from the top right-hand corner cell of the transportation table called the Northeast corner method.

Ndayiragije (2017) made a comparison of finding the initial basic feasible solution from the top left-hand corner cell of the transportation table called the Northwest corner method (NWCM) and finding the initial basic feasible solution from the bottom left-hand corner cell of the transportation table called the Southwest corner method (SWCM), also a comparison of finding the initial basic feasible solution from top right-hand corner cell of the transportation table called Northeast corner method (NECM) and finding the initial basic feasible solution from bottom right -hand corner cell of the transportation table called the (SECM). The outcome revealed that the SECM and NWCM always have the same necessary effective solution, but the SECM and NECM do not.

Seethalakshmy and Srinivasan (2019) recommended a technique in which the maximum value is marked for the maximization type both row-wise and column-wise, and the minimum value is marked for the minimization type both row-wise and column-wise and the greatest maximum value is allocated. The method provided the best result with less number of iterations.

Mallia et al (2021) outlined the basic rudiments of a transportation problem and the challenges faced in using the simplex approach to solve the transportation problem. They noted that the simplex method takes a lot of time to solve the transportation problem and when the transportation problem is put into the format of linear programming, the transportation matrix is a unitary matrix whose determinant is one.

This study is to find the optimal basic feasible solution to a transportation problem by allocating as many units as possible equal to the minimum between available supply and demand through the center of the transportation table called the middle cell technique.

2.0 The Literature Review of Some Transportation Methods

2.1 Northwest corner method (NWCM)

To find the initial basic feasible solution to a transportation problem, first use the simplex method. This was first proposed by (Dantzig, 1951) and was named the Northwest Corner method by Charnes and Cooper (1954). The Northwest corner method procedure is as follows

(i) Set up a transportation problem in a tabular form, (ii) Select the upper left corner cell of the table and allocate the maximum possible units between the supply and demand requirements. During allocation, the transportation cost is completely discarded (not taken into consideration). (iii) Eliminate the row or column that is fully exhausted for supply or demand. (iv) Repeat steps (ii) and (iii) until all the supply and demand values are zero. (v) Obtain the initial basic feasible solution.

2.2 Least-cost method (LCM)

The minimum-cost approach focuses on the lowest approaches to obtain a better answer. The approach begins by assigning as much to the cell with the lowest unit cost as feasible. The fulfilled row or column is then crossed off, and the supply and demand quantities are modified accordingly. See Imam et al (2009). If both a row and a column are satisfied at the same time, only one is crossed out, and the same procedure as in the northwest corner technique is followed. Then, select the uncrossed-out cell with the lowest unit cost and repeat until only one row or column is left uncrossed out.

2.3 South-East corner method (SECM)

This approach (Srinivan, 2010) is achieved by finding the initial basic feasible solution from the bottom right-hand corner cell of the transportation table called the South-East

Corner Method (SECM). The SECM procedures are as follows

Step 1: Sketch the transportation problem table and attest that the problem is balanced.

Step 2: From the bottom right corner of the table, take $s_{mn} = \min(l_m, k_n)$.

Step 3: If $s_{mn} = l_m$, then the row *m* is deleted. Replace k_n by $k_n - l_m$. If $s_{mn} = k_n$, then column *n* is deleted. Replace l_m by $k_n - l_m$.

Step 4: If $l_m = k_n$, then $s_{mn} = l_m = k_n$, then the row *m* and the column *n* are deleted. We have a degenerate basic feasible solution.

Step 5: A new matrix of order (m-1) multiplied by *n*, or *m* multiplied by (n - 1) are reduced matrices. Repeat steps 1-3 till all quantities are exhausted.

2.4 Northeast corner method (NECM)

This method was proposed by (Sudirga, 2009) by finding the initial basic feasible solution from the top right-hand corner cell of the transportation table. The procedure is as follows

i) From the top right corner of the transportable table, starts at the cell (route) of the tableau (Variable s_{in}). Allocate as much as possible to the selected cell and adjust the associated amounts of supply and demand by subtracting the allocated amount. ii) Cross out the row or column with zero supply or demand to indicate that no further assignments can be made in the row or column. If both a row and a column net to zero simultaneously cross out one only and leave a zero supply (demand in the uncrossed-out row or column). If exactly one row or column is left uncrossed out or below if exactly one row or column is left uncrossed out, stop. Otherwise, move to the cell to the right if a column has just been crossed out or below if a row has been crossed out.

3.0 Methodology

3.1 Mathematical Formulation

Assume a commodity must be carried from m origins to n destinations. The supply is l_i in source *i* and the demand is k_j in destination *j*. C_{ij} denotes the unit cost of transportation from source *i* to destination j. The challenge is to carry the item from its origin to its destination at the lowest possible cost. Let S_{ij} represent the quantity of the item carried from the source (supply) *i* to the destination (demand) *j*. The goal is to minimize the overall shipping cost, C, by determining the values of the mn variables S_{ij} (i = 1, 2,..., *m*;j = 1, 2,..., *n*).. The linear programming (LP) formulation for the transportation problem is

$$\min imize \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} S_{ij}$$

$$S.t \quad \sum_{j=1}^{n} S_{ij} \le l_i \quad \forall_i = 1, \Lambda, m$$

$$\sum S_{ij} \ge k_j \quad \forall_j = 1, \Lambda, n$$

$$S_{ij} \ge 0$$

Table 1: General transportation table

Source	**D1**	**D2**	**…**	**Dj**	**…**	**Supply**
A_1	$C_{11}\ S_{11}$	$C_{12}\ S_{12}$	…	$C_{1j}\ S_{1j}$	…	l_{1n}
A_2	$C_{21}\ S_{21}$	$C_{22}\ S_{22}$	…	$C_{2j}\ S_{2j}$	…	l_{2n}
.						
.						
.						
A_m	$C_{m1}\ S_{m1}$	$C_{m2}\ S_{m2}$	…	$C_{mj}\ S_{mj}$	…	l_{mn}
Destination	k_1	k_2	…	k_j	…	

The above calculation assumes that total supply equals total demand to create basic feasible solutions to balanced transportation problems.

3.2 The Middle Cell Method

The following procedures are involved in the middle cell approach to transportation problems:

Step 1: Draw a transportation problem table and verify that the problem is balanced.

Step 2: Identify the middle cell (mid-point) of a transportation table and select it.

Table 2: The odd-number transportation table

	A	B	C	Demand
I	C_{11}	C_{12}	C_{13}	l_1
II	C_{21}	C_{22}	C_{23}	l_2
III	C_{31}	C_{32}	C_{33}	l_3
Destination	k_1	k_2	k_3	

The odd-numbered cells are situations where the number of rows and columns are odd numbers. In such a situation, it is easy to pick the center point cell when it is odd. For example, using the Table 2, C_{22} is the middle cell. So it will be selected. Then, the values of the destination k_2 and demand l_2 are considered. In that case, the less value will be attached to C_{22} until it is exhausted. For instance if $l_2 < k_2$, l_2 will be considered or vice versa

Suppose we have even-numbered cells of rows and columns, the cell with the least cost among the two cells at the center will be chosen,

Table 3: The even-number transportation table

	A	B	C	D	Demand
I	C_{11}	C_{12}	C_{13}	C_{14}	l_1
II	C_{21}	C_{22}	C_{23}	C_{24}	l_2
III	C_{31}	C_{32}	C_{33}	C_{34}	l_3
Destination	k_1	k_2	k_3	k_4	

For example, using information conained in Table 3, there are two cells (C_{22} and C_{23}) at the middle. The cell with the least cost will be selected as the middle cell. Then, the value of k_2 or l_2 will be considered:

If $l_2 < k_2$, l_2 or vice versa will be attached to C_{22} or C_{23} conversely, If $l_2 < k_3$, l_2 or vice versa will be attached to C_{22} or C_{23}

Step 3: Allocate to the cell the supply or demand that is high in value with the least cost.

Step 4: Allocate along the row as much as possible to the next adjacent feasible cell bearing in mind the supply or demand that is high in value with the least cost

Step 5: Repeat step 3 until all RIM requirements are met.

4.0 Results and Discussion

4.1 Numerical Example of Transportation Problem with Odd Cells

Consider a transportation scenario with three sources of supply (rows) and five places of demand (columns). The availability in the supply points are 60, 35 and 40, respectively and the demand requirements are 22, 45, 20, 18 and 30, respectively as shown in Table 4.

Table 4: Transportation Problem 1

	A	B	C	D	E	Supply
I	4	1	3	4	4	**60**
II	2	3	2	2	3	**35**
III	3	5	2	4	4	**40**
Demand	**22**	**45**	**20**	**18**	**30**	

Source: Sample transportation problem (Srinivasan, 2010)

The initial basic feasible solution of this transportation problem with an odd number of rows and columns are obtained using the middle cell method following the steps presented starting from the center (C_{23}) cell until all demand and supply are satisfied, as demonstrated in Table 5. The red characters are the steps for the middle cell method

Table 5: Transportation problem solution for middle cell method

	A	B	C	D	E	Supply
I		1 (45)7		4 (15) 6		**60**
II	2(15) 2		2(20) 1			**35**
III	3 (7) 3			4 (3) 5	4 (30) 4	**40**
Demand	**22**	**45**	**20**	**18**	**30**	

* red represents steps of middle cell method
MinZ =2*15+ 3*7 +1*45 + 2*20 + 4*15 + 4*3 + 4*30 = 328
The objective function value evaluated for the above transportation problem in Table 5 is 328.
Comparing the middle cell method (MCM) with other transportation methods as shown in Table 6 showed that the total minimum transportation cost of transportation problem with three supply sources (rows) and five demand points (columns) is a better method compared with NWCM and SECM and also NECM and SWCM.

Table 6: Comparison of Middle Cell Method Solution with other methods

	MCM	NWCM	LCM	NECM	SECM	SWCM
Allocations	$x_{12}=45$	$x_{11}=22$	$x_{12}=45$	$x_{13}=12$	$x_{11}=22$	$x_{13}=12$
	$x_{14}=15$	$x_{12}=38$	$x_{13}=15$	$x_{14}=18$	$x_{12}=38$	$x_{14}=18$
	$x_{21}=15$	$x_{22}=7$	$x_{21}=12$	$x_{15}=30$	$x_{22}=7$	$x_{15}=30$
	$x_{23}=20$	$x_{23}=20$	$x_{23}=5$	$x_{22}=27$	$x_{23}=20$	$x_{22}=27$
	$x_{31}=7$	$x_{24}=8$	$x_{24}=18$	$x_{23}=8$	$x_{24}=8$	$x_{23}=8$
	$x_{34}=3$	$x_{34}=10$	$x_{31}=10$	$x_{31}=22$	$x_{34}=10$	$x_{31}=22$
	$x_{35}=30$	$x_{35}=30$	$x_{35}=30$	$x_{32}=18$	$x_{35}=30$	$x_{32}=18$
Total Cost	328	363	**310**	481	363	481

Consider a transportation scenario with three sources of supply (rows) and three places of demand (columns). The availability in the supply points are 200, 400 and 200, respectively and the requirements are 120, 620 and 60 respectively. Table 7 shows the data including the unit cost of transportation.

The initial basic feasible solution of this transportation problem with an equal odd number of rows and columns are obtained also using the middle cell method following the steps presented starting from the center (C_{22}) cell until all the demand and supply are met as shown in Table 8

Table 7: Transportation Problem 2

	A	B	C	Supply
I	5	9	16	**200**
II	1	2	6	**400**
III	2	8	7	**200**
Demand	**120**	**620**	**60**	

****Source: Sample transportation problem (Sudirga, 2009)**

Table: 8: Transportation problem solution for middle cell method

	A	B	C	Supply
I	5 (120) 4	9 (20) 3	16 (60) 5	**200**
II		2 (400) 1		**400**
III		8 (200) 2		**200**
Demand	**120**	**620**	**60**	

* red represents steps of middle cell method

MinZ = 5*120+ 9*20+ 2*400+ 8*200+ 16*60 = 4140

Comparing the middle cell method (MCM) with other transportation methods as shown in Table 9 showed that the total minimum transportation cost of moving goods with three supply sources (rows) and three demand points (columns) is a better method compared with LCM

Table 9: Comparison of middle cell method solution with other methods

	MCM	NWCM	LCM	SWCM	NECM	SECM
Allocations	$x_{11}=120$	$x_{11}=120$	$x_{12}=140$	$x_{12}=140$	$x_{12}=140$	$x_{11}=120$
	$x_{12}=20$	$x_{12}=80$	$x_{13}=60$	$x_{13}=60$	$x_{13}=60$	$x_{12}=80$
	$x_{13}=60$	$x_{22}=400$	$x_{21}=120$	$x_{22}=400$	$x_{22}=400$	$x_{22}=400$
	$x_{22}=400$	$x_{32}=140$	$x_{22}=280$	$x_{31}=120$	$x_{31}=120$	$x_{32}=140$
	$x_{32}=200$	$x_{33}=60$	$x_{32}=200$	$x_{32}=80$	$x_{32}=80$	$x_{33}=60$
Total Cost	4140	**3660**	4500	3900	3900	3660

4.2 Numerical Example of Transportation Problem with Even Cells

Consider a transportation problem with four sources (rows) and four demand points (columns). The availability in the supply points are 32, 45, 30 and 28, respectively and the demand requirements are 30, 35, 40 and 30 respectively. Table 10 displays the facts, including the transportation unit cost.

Table 10: Transportation problem 3

	A	B	C	D	Demand
I	4	1	3	4	**30**
II	2	**3**	**2**	2	**35**
III	3	**5**	**2**	4	**40**
IV	4	3	4	5	**30**
Supply	**32**	**45**	**30**	**28**	

The initial basic feasible solution of this transportation problem with an equal even number of rows and columns is obtained also using the middle cell method following the steps presented starting from the center (C_{33}) cell until all the demand and supply are met as shown in Table 11. C_{22}, C_{23}, C_{32} and C_{33} are the points for consideration for the middle point. C_{33} was considered because it is the cell with the least cost with high demand or supply.

Table: 11: Transportation problem solution for middle cell method

	A	B	C	D	Demand
I		1 (15) 6		4 (15) 5	**30**
II	2 (22) 3			2 (13) 4	**35**
III	3 (10) 2		2 (30) 1		**40**
IV		3 (30) 7			**30**
Supply	**32**	**45**	**30**	**28**	

MinZ= 2*22 +3*10 +1*15+ 3*30 +2*30+ 4*15+ 2*13 =325

Comparing the middle cell method (MCM) with other transportation methods as shown in Table 12 showed that the total transportation cost of with four supply sources (rows) and four demand points (columns) is a better method compared with NWCM and SECM and also NECM and SWCM.

Table 12: Comparison of middle cell method solution with other methods

	MCM	NWCM	LCM	NECM	SECM	SWCM
Allocations	$x_{12}=15$	$x_{11}=30$	$x_{12}=45$	$x_{13}=2$	$x_{11}=30$	$x_{13}=2$
	$x_{14}=15$	$x_{21}=2$	$x_{13}=15$	$x_{14}=28$	$x_{21}=2$	$x_{14}=28$
	$x_{21}=22$	$x_{22}=33$	$x_{21}=12$	$x_{22}=7$	$x_{22}=33$	$x_{22}=7$
	$x_{24}=13$	$x_{32}=12$	$x_{23}=5$	$x_{23}=28$	$x_{32}=12$	$x_{23}=28$
	$x_{31}=10$	$x_{33}=28$	$x_{24}=18$	$x_{31}=2$	$x_{33}=28$	$x_{31}=2$
	$x_{33}=30$	$x_{43}=2$	$x_{31}=10$	$x_{32}=38$	$x_{43}=2$	$x_{32}=38$
	$x_{42}=30$	$x_{44}=28$	$x_{35}=30$	$x_{41}=30$	$x_{44}=28$	$x_{41}=30$
	325	487	**310**	435	487	435

4.3 Numerical Example of Transportation Problem with Odd and Even Cells

Consider the following transportation problem: it has three supply sources (rows) and four demand places (columns). The availability in the supply points are 25, 30 and 50, respectively and the demand requirements are 20, 40, 30 and 15 respectively. Table 13 shows the data including the unit cost of transportation.

Table 13: Transportation Problem 4

	A	B	C	D	Supply
I	6	10	15	20	**25**
II	32	8	12	16	**30**
III	4	14	11	30	**50**
Demand	**20**	**40**	**30**	**15**	

Source: Sample transportation problem: Mallia, et al (2021)

The initial basic feasible solution of this transportation problem with an even number of rows and odd columns or vice versa is obtained also using the middle cell method following the steps presented starting from the center (C_{22}) cell until all the demand and supply are met as shown in Table 14. C_{22} and C_{23} are the points for consideration for the middle point. C_{22} was considered because it is the cell with the least cost with high demand or supply.

Table: 14: Transportation Problem Solution for Middle Cell Method

	A	B	C	D	Supply
I	6 (15) 3	10 (10) 2			**25**
II		8 (30) 1			**30**
III	4 (5) 4		11 (30) 5	30 (15) 6	**50**
Demand	**20**	**40**	**30**	**15**	

* red represents steps of middle cell method

MinZ= 6*15 +10*10 +8*30+ 4*5 + 11*30 + 30*15 = 1230

Comparing the middle cell method (MCM) with other transportation methods as shown in Table 15 showed that the total minimum transportation cost with three supply sources (rows) and four demand points (columns) is a better method compared with NWCM and SECM and also NECM and SWCM. The MCM has the same minimum cost as the LCM

Table 15: Comparison of middle cell method solution with other methods

	MCM	**NWCM**	**LCM**	**NECM**	**SECM**	**SWCM**
Allocations	$x_{11}=15$	$x_{11}=20$	$x_{11}=15$	$x_{13}=10$	$x_{11}=20$	$x_{13}=10$
	$x_{12}=10$	$x_{12}=5$	$x_{12}=10$	$x_{14}=15$	$x_{12}=5$	$x_{14}=15$
	$x_{22}=30$	$x_{22}=30$	$x_{22}=30$	$x_{22}=10$	$x_{22}=30$	$x_{22}=10$
	$x_{31}=5$	$x_{32}=5$	$x_{31}=5$	$x_{23}=20$	$x_{32}=5$	$x_{23}=20$
	$x_{33}=30$	$x_{33}=30$	$x_{33}=30$	$x_{31}=20$	$x_{33}=30$	$x_{31}=20$
	$x_{34}=15$	$x_{34}=15$	$x_{34}=15$	$x_{32}=30$	$x_{34}=15$	$x_{32}=30$
	1230	1260	**1230**	1270	1260	1270

5.0 Conclusion

This study has presented an alternate method to the other methods of solving transportation problems called the Middle cell method. This is achieved by finding the optimal basic feasible solution by allocating as many units as possible equal to the minimum cost between available supply and demand through the center of the transportation table. Results from the numerical examples showed that the middle cell method is optimal especially when the rows and columns are not equal, especially in cases of transportation tables having even rows and odd columns or vice versa. When compared with transportation techniques, the middle cell method performs better than the North-West Corner method, North-East Corner method, South-West Corner method and South-East Corner method. Finally, this alternate method competes favorably with the Least cost method.

5.0 References

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Compliance with Ethical Standards Declarations

The authors declare that they have no conflict of interest.

Data availability

All data used in this study will be readily available to the public.

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data Public.

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Conceptualization of the tittle, design ofresearch objectives and development as well as result interpretations was done by Nwanya J.C while Njoku K.N.C developed the literature and reserch methods.