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Transportation Algorithm: Awareness and Usage among Production, Operations and Logistics Managers in Rivers State, Nigeria

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ABSTRACT: *This study explored the level of awareness and use of transportation algorithms among Production, Operations and Logistics Managers in Rivers State, Nigeria. The study employed a survey-based quasi-experimental research design. Thirty manufacturing and logics enterprises in the Trans-Amadi Industrial Area of Rivers were surveyed using a structured questionnaire. Copies of the questionnaire were administered to 53 managers. A total of 41 valid responses were collected were used for data analysis. The research used means to gauge the degree of awareness and usage. According to the findings, very few managers have ever heard of transportation algorithms. Many managers are aware of transportation algorithms but have never used them. Furthermore, an average number of production and operations managers use transportation algorithms only occasionally, while the majority of them do not use transportation algorithms on a regular basis. This implies that while managers are cognizant of transportation algorithms, they are hesitant to use them. As a result, the research suggests that manufacturing, operations, and logistics companies raise consciousness about the benefits of transportation algorithms through education initiatives and the formation of communities of practise. Firms should also educate managers on the use of transportation algorithms and make it obligatory whenever they move products from origin to destination. This is, as to the best of the researcher's knowledge, the first study on the degree of awareness and usage of Transportation Algorithms among Production, Operations, and Logistics Managers in Rivers State, Nigeria.*

KEYWORDS: transportation algorithm, awareness, usage

INTRODUCTION

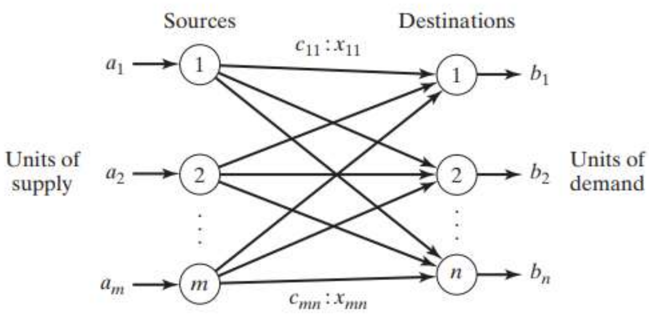
Given the complex, heterogeneous nature of transportation and supply chain management (SCM) in various industries (Stüve et al., 2022), the use of algorithms has been receiving widespread attention. Transportation management, with the aid of algorithms, for the distribution of long-haul goods plays an important role in reducing costs and time, and increasing customer satisfaction (Tavakkolimoghaddam et al., 2022; Dan & Liu, 2023). Gupta et al., (2022) also submit that transportation algorithms are deployed to minimize total transportation cost and inventory cost by determining optimal routes. Similarly, Huq et al.

(2010) averred a significant portion of the potential inefficiencies associated with supply chain management (SCM) costs can be attributed to wasteful practises such as inefficient transportation. This underscores the need of managers to be aware of transportation algorithms or scheduling methods and deploy them for the improvement of companies' fortunes. Various models have been advanced on how to minimize transportation cost. Such methods include; (i) Northwest Corner method (ii) Minimum cost method, and (iii) Vogel's approximation method. However, whereas these models are frequently cited in production and operations management literature, there appears to be lack of awareness and application of these models among production and operations managers in Rivers State, Nigeria. To this end, this study sought to investigate the extent of managers' awareness and usage of these models in the discharges of their functions.

LITERATURE REVIEW

Transportation algorithm is a special type of networks problems that for shipping a commodity from source (e.g., factories or supply side) to destinations (e.g., warehouse or demand side) (Taha, 2019). It is a linear programming stemmed from a network structure consisting of a finite number of nodes and arcs attached to them. The objective of transportation problem is to determine the shipping schedule that minimizes the total shipping cost while satisfying the demand and supply limit. If transportation time is minimized, transportation cost comes down naturally.

Figure 1 shows the nature of a transportation model:



Source: Taha, H. (2019). *Operations research: an introduction*. (10th Edition). Pearson India.

Figure 1 depicts *m* sources and *n* destinations, each portrayed by a node. The arcs indicate the paths that connect the sources and destinations. Arc *(i, j)* connecting source i to destination *j* conveys two items of data: the transportation cost per unit, *cij*, and the quantity shipped, *xij*. The supply at source *i* is denoted by *ai*, and the demand at destination *j* is represented by *bj*. The model's objective is to minimise total transportation costs while satisfying all supply and demand constraints (Taha, 2019).

The basic steps of the transportation algorithm include:

Step 1. Determine an initial feasible solution, then proceed to step 2.

Step 2. Use the optimality condition to figure out which of the non-basic variables is the one to enter. If the condition for optimality is met, stop. If not, move on to step 3.

Step 3. Utilize the feasibility condition to identify the leaving variable among the current set of basic variables and to determine the new basic solution. Return to the second stage.

Demonstrating Each of the Methods

Nimibofa Transport Company ships finished goods from three factories (A_1, A_2 and A_3, respectively) to four warehouses (B_1, B_2, B_3, and B_4, respectively). The factories (supplier points) have daily vehicle-load outputs (supply) of 30, 45 and 25, respectively; while the warehouses (consumer points) have daily customer needs of 20, 20, 10 and 50 vehicle-loads respectively. The supplier and the consumer together with the unit transportation costs per vehicle-load haulage charges on different routes are given in Table 1. The unit transportation costs, *cij* are in thousands of naira. The model seeks the minimum cost shipping schedule between the factories and the warehouses, using: (i). LCM (ii). NWCR and (iii). VAM.

Table 1: Nimibofa Transportation Model

Supplier	**Consumer**				**Supply**
	B_1	B_2	B_3	B_4	
A_1	9	8	13	12	30
A_2	7	11	8	15	45
A_3	6	5	14	10	25
Customer needs	**20**	**20**	**10**	**50**	**100** / **100**

Solution Using the Northwest-Corner Method.

According to Taha (2019), this method starts at the northwest-corner cell (route) of the tableau (variable X_{11}). Taha (2019) outlines the following steps:

Step 1. Allocate as much as possible to the selected cell, and adjust the associated amounts of supply and demand by subtracting the allocated amount.

Step 2. Cross out the row or column with zero supply or demand to indicate that no further assignments can be made in that 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 (column).

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Step 3. 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. Go to step 1.

A necessary condition for solving the problem is that the total supply of suppliers should be equal to the total needs of consumers. The total supply of suppliers: 30 + 45+ 25 = 100 units. The total needs of consumers: 20 + 20 + 10 + 50 = 100 units. Hence, the total supply of suppliers equals the total needs of consumers. Also, the number of used routes = number of suppliers + number of consumers - 1. Therefore, if there is a situation where it is necessary to exclude a column and a row at the same time, one will be excluded. The process starts by filling the table from the upper left corner and gradually moving to the lower right corner. From the North-West to South-East.

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	? 9	8	13	12	30
A_2	7	11	8	15	45
A_3	6	5	14	10	25
Customer needs	20	20	10	50	

20 = min { 20, 30 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	20 9	? 8	13	12	30 10
A_2	7	11	8	15	45
A_3	6	5	14	10	25
Customer needs	20 No	20	10	50	

10 = min { 20, 10 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	20 9	10 8	13	12	30 10 No
A_2	7	? 11	8	15	45
A_3	6	5	14	10	25
Customer needs	20 No	20 10	10	50	

10 = min { 10, 45 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	20 9	10 8	13	12	30 10 No
A_2	7	10 11	? 8	15	45 35
A_3	6	5	14	10	25
Customer needs	20 No	20 10 No	10	50	

10 = min { 10, 35 }

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Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	20 9	10 8	13	12	30 10 No
A_2	7	10 11	10 8	? 15	45 35 25
A_3	6	5	14	10	25
Customer needs	20 No	20 10 No	10 No	50	

25 = min { 50, 25 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	20 9	10 8	13	12	30 10 No
A_2	7	10 11	10 8	25 15	45 35 25 No
A_3	6	5	14	? 10	25
Customer needs	20 No	20 10 No	10 No	50 25	

25 = min { 25, 25 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	20 9	10 8	13	12	30 10 No
A_2	7	10 11	10 8	25 15	45 35 25 No
A_3	6	5	14	25 10	25 No
Customer needs	20 No	20 10 No	10 No	50 25 No	

Total Cost of delivery for initial solution = (20*9) + (10*8) + (10*11) + (10*8) + (25*15) + (25*10) = 180 + 80 + 110 + 80 + 375 + 250 = 1,075

Solution Using the Least-cost Method.

The least-cost method identifies a more suitable starting point by focusing on the most affordable routes. It allocates the maximum amount to the cell with the lowest unit cost (ties are broken arbitrarily). The satisfied row or column is then crossed out, and the supply and demand quantities are adjusted accordingly. Similar to the northwest-corner method, if both a row and a column are satisfied at the same time, only one is crossed out. Next, choose the uncrossed cell with the lowest unit cost and repeat the procedure until exactly one row or column remains uncrossed (Taha, 2019).

First of all, the routes with the lowest cost of delivery are selected.

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Supplier	Consumer B_1	B_2	B_3	B_4	Supply
A_1	9	8	13	12	30
A_2	7	11	8	15	45
A_3	6	? 5	14	10	25
Customer needs	20	20	10	50	

20 = min { 20, 25 }

Supplier	Consumer B_1	B_2	B_3	B_4	Supply
A_1	9	8	13	12	30
A_2	7	11	8	15	45
A_3	? 6	20 5	14	10	25 5
Customer needs	20	20 No	10	50	

5 = min { 20, 5 }

Supplier	Consumer B_1	B_2	B_3	B_4	Supply
A_1	9	8	13	12	30
A_2	? 7	11	8	15	45
A_3	5 6	20 5	14	10	25 5 No
Customer needs	20 15	20 No	10	50	

15 = min { 15, 45 }

Supplier	Consumer B_1	B_2	B_3	B_4	Supply
A_1	9	8	13	12	30
A_2	15 7	11	? 8	15	45 30
A_3	5 6	20 5	14	10	25 5 No
Customer needs	20 15 No	20 No	10	50	

10 = min { 10, 30 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	9	8	13	? 12	30
A_2	15 7	11	10 8	15	45 30 20
A_3	5 6	20 5	14	10	25 5 No
Customer needs	20 15 No	20 No	10 No	50	

30 = min { 50, 30 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	9	8	13	30 12	30 No
A_2	15 7	11	10 8	? 15	45 30 20
A_3	5 6	20 5	14	10	25 5 No
Customer needs	20 15 No	20 No	10 No	50 20	

20 = min { 20, 20 }

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	9	8	13	30 12	30 No
A_2	15 7	11	10 8	20 15	45 30 20 No
A_3	5 6	20 5	14	10	25 5 No
Customer needs	20 15 No	20 No	10 No	50 20 No	

Total Cost of delivery for initial feasible solution = (30*12) + (15*7) + (10*8) + (20*15) + (5*6) + (20*5) = 360 + 105 + 80 + 300 + 30 + 100 = 975

Solution Using Vogel's Approximation Method (VAM).

VAM is an enhanced variant of the least-cost method that typically, but not always, yields superior starting solutions. Taha (2019) outlines the following steps:

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Step 1. For each row (column), calculate a penalty measure by subtracting the lowest unit cost in the row (column) from the next lowest unit cost in the same row (column). This penalty represents the opportunity lost if the lowest unit cost cell is not selected.

Step 2. Identify the row or column with the highest penalty, breaking ties arbitrarily. Assign as much as possible to the variable with the lowest unit cost in the chosen row or column. Adjust the supply and demand and cross out the satisfied column or row. In the event that both a row and a column are satisfied at the same time, only one is crossed out, and the remaining row (column) is assigned a zero supply (demand).

Step 3.

(a) If there is a single uncrossed row or column with nil supply or demand, the process is terminated.

(b) If there is still an uncrossed row (column) with a positive supply (demand), the basic variables in that row (column) should be determined using the least cost technique. Stop.

(c) If all uncrossed rows and columns have (remaining) zero supply and demand, use the least-cost method to determine the zero basic variables. Stop.

(d) If not, proceed to Step 1.

First Iteration

Supplier	**Consumer**				**Supply**
	B_1	B_2	B_3	B_4	
A_1	9	8	13	12	30
A_2	7	11	10 8	15	45
A_3	6	5	14	10	25
Customer needs	**20**	**20**	**10**	**50**	**100** **100**

Row penalties: (R1: 9-8 = 1); (R2: 8-1 = 1); (R3: 6-5 = 1)

Column penalties: (C1: 7-6 = 1); (C2: 8-5 = 3); (C3: 13-8 = 5); (C4: 12-10 = 2)

Decision: C4 is the pivot column since it has the highest penalty. Cell A_2 - B_3 chosen since it has the least cost.

Second Iteration

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	9	8	X 13	12	30
A_2	20 7	11	10 8	15	45
A_3	6	5	X 14	10	25
Customer needs	**20**	**20**	**10**	**50**	**100** / **100**

Row penalties: (R1: 9-8 = 1); (R2: 11-7 = 4); (R3: 6-5 = 1)

Column penalties: (C1: 7-6 = 1); (C2: 8-5 = 3); (C4: 12-10 = 2)

Decision: R2 is the pivot row since it has the highest penalty. Cell A_2 - B_1 chosen since it has the least cost

Third Iteration

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	X 9	X 8	X 13	12	30
A_2	20 7	X 11	10 8	15	45
A_3	X 6	20 5	X 14	10	25
Customer needs	**20**	**20**	**10**	**50**	**100** / **100**

Row penalties: (R1: 12-8 = 4); (R2: 15-11 = 4); (R3: 10-5 = 5)

Column penalties: (C2: 8-5 = 3); (C4: 12-10 = 2)

Decision: R3 is the pivot row since it has the highest penalty. Cell A_3 - B_2 chosen since it has the least cost.

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Fourth Iteration

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	x 9	x 8	x 13	12	30
A_2	20 7	x 11	10 8	15 15	45
A_3	x 6	20 5	x 14	10	25
Customer needs	**20**	**20**	**10**	**50**	**100** / **100**

Row penalties: (R1: 12-0 = 12); (R2: 15-0 = 15); (R3: 10-0 = 10)

Column penalties: (C4: 12-10 = 2)

Decision: R2 is the pivot row since it has the highest penalty. Cell A_2 - B_4 chosen since it is the only cell left on row 2

Fifth Iteration

Supplier	Consumer				Supply
	B_1	B_2	B_3	B_4	
A_1	x 9	x 8	x 13	30 12	30
A_2	20 7	x 11	10 8	15 15	45
A_3	x 6	20 5	x 14	10	25
Customer needs	**20**	**20**	**10**	**50**	**100** / **100**

Row penalties: (R1: 12-0 = 12); (R3: 10-0 = 10)

Column penalties: (C4: 12-10 = 2)

Decision: R1 is the pivot row since it has the highest penalty. Cell A_1 - B_4 chosen since it is the only cell left on row one.

Sixth Iteration

Supplier	Consumer								Supply
	B_1		B_2		B_3		B_4		
A_1	x	9	x	8	x	13	30	12	30
A_2	20	7	x	11	10	8	15	15	45
A_3	x	6	20	5	x	14	5	10	25
Customer needs	**20**		**20**		**10**		**50**		**100** / **100**

Cell A_3 - B_4 is allocated with 5 units as the only cell left, in order to balance the model.

Minimum Total Cost of delivery = (30*12) + (20*7) + (10*8) + (15*15) + (20*5) + (5*10) = 360 + 140 + 80 + 225 + 100 + 50 = 955

A comparison of the methods shows that Vogel's Approximation Method gave the optimal solution with the minimum total cost. The second preferred method is the Least Cost Method, while the least preferred is the North-West Corner Method.

Assessment of Awareness and Usage of Transportation Algorithms

Research Design

I adopted the quasi-experimental research design (Leedy & Ormrod, 2019) whereby a cross-sectional survey was conducted to collect data from respondents at a snap-shot (LoBiondo-Wood & Haber, 2022).

Population, Sample and Data Collection Procedure

The population of this study 53 operations/production managers of 30 manufacturing and logics firms at the Trans-Amadi Industrial Area of Rivers State. Moreover, these companies were selected because they have been in business for more than 15 years. Responses were solicited from these class of respondents because they best understand the constructs under investigation (Huber & Power, 1985). Due to the small size of the population, the study adopted a census. Primary data was collected from the respondents via structured questionnaire.

Questionnaire Design and Measurement

The questionnaire comprises sections A-B. Section A contains seven items pertaining to the demographic (personal) details of the respondents (e.g. gender, age, marital status). Section B comprises items on the awareness and usage of transportation algorithms. These items include: "I have never heard of it", "I am aware but never used it", "use it only sometimes", and "use it on regular basis" (Kampa & Patra, 2020).

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These questions were anchored on a four-point scale, where 1 = I have never heard of it, 2 = I am aware but never used it, 3 = Use it only sometimes, and 4 = Use it on regular basis.

Validity and Reliability of the Research Instrument

The questionnaire was shown to 5 logistic managers at Trans-Amadi industrial area of Port Harcourt, and two colleagues in operations management to face-validate it. The majority of the experts thought the items and overall layout of the instrument were clear, easy to understand, and appropriate (Bell et al., 2022). This study adopts the Cronbach's coefficient alpha (Cronbach, 1951; Nunnally & Bernstein, 1994) measure, which is the most common, and the best, index of internal consistency. The items exceeded an Alpha value (∝) of 0.7 (Nunnally & Bernstein, 1994).

Data Analysis Techniques

After retrieving and entering the data, I performed the following quantitative procedure: Firstly, with the aid of the IBM@SPSS version 28.0.1. I presented results on the demographic aspects of the respondents. Secondly, I presented univariate analysis output and the descriptive aspects (means and standard deviations). I also checked for normality of data distribution via skewness and kurtosis criteria.

RESULTS

Fieldwork, Data Cleaning and Demographic Report

The instrument was administered by hand to 53 target respondents. After 4 weeks a total of 41 copies of the questionnaire, which were all properly filled were retrieved, representing 77.4% response rate. The high response rate was traceable to various strategies we deployed, such as: sending several emails and making telephone calls, advancing gifts to some of the respondents and fostering an atmosphere of conviviality (Yu et al., 2017). No case of missing data was recorded. Hence all the responses were keyed into the IBM@SPSS version 28.0.1 for subsequent analysis. The demographic summary of the respondents is shown in table 4.1.

Table 4.1: Demographic Characteristics of the respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Gender	Male	36	87.8	87.8	87.8
	Female	5	12.2	12.2	100.0
	Total	**41**	**100.0**	**100.0**	
Age	20-35	6	14.6	14.6	14.6
	36-50	21	51.2	51.2	65.8
	51-above	14	34.2	34.2	100.0
	Total	**41**	**100.0**	**100.0**	
Marital Status	Single	6	14.6	14.6	14.6
	Married	28	68.3	68.3	82.9
	Separated	4	9.8	9.8	92.7
	Divorced	3	7.3	7.3	100
	Total	**41**	**100.0**	**100.0**	
Educational Qualification	WAEC-OND	0	0.00	0.00	0.00
	HND/Bachelor	23	56.1	56.1	56.1
	Masters above	18	43.9	43.9	100
	Total	**41**	**100.0**	**100.0**	

Source: Research Data (SPSS Output) 2023

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Table 4.1 shows that 36 respondents (87.8%) were males and 5 (12.2%) females. The manufacturing sector is male dominated. For age, respondents within 20-35 age brackets were the least with only 6 respondents (14.6%), while those who are 36 years to 50 years old were the highest with 21 (51.2%). Respondents who are 51 years old and above were 14, representing 34.2% of the total number of respondents. Hence, most of the managers in the industry are in mid-life ages. For marital status, 28 respondents (68.3%) were married, 6 (14.6%) were single, 4 (9.8%) were separated, while 3 (7.3%) was divorced. On highest level of educational attainment, 23 respondents (56.1%) have Higher National Diploma and Bachelor Degree, no respondent (0.00%) have The West African School Certificate and Ordinary National Diploma, while 18 respondents (43.9%) have Master Degree and above. Thus, a great number of managers in the sector are well educated.

Univariate Analysis

I used univariate analysis to determine the means and standard deviations of the observed variables, therefore estimating the prevalence of the awareness/usage of the transportation algorithms by managers. IBM@SPSS version 28.0.1 was used for the univariate analysis. Low, medium, and high thresholds were used to observe the levels of manifestation of the variables in the firms. On a five-point scale, the following equation provided the basis for these classifications: interval length = (highest weight minus lowest weight)/ (three levels) = (5-1)/3 =1.33, as shown in Table 3.3.

Table 3.3: Scale on Relative Importance of the Mean

Level of Effect	**Mean**
Not Sufficient	2.33 and <
Moderate	2.34 to 3.67
High	3.68 to 5.00

Moreover, data concerning the transportation algorithms were analysed in terms of skweness and kurtosis. In the case of normality assumptions, if skewness and kurtosis values of each variable are divided by the corresponding Standard Errors (S.E), and the outputs fall within -2 and +2, it means there is no serious violation of normality (Gravetter & Wallnau, 2016; George & Mallery, 2019). Table 4.2 shows that output for univariate analysis and test for normality.

Table 4.2 Descriptive statistics on the Latent Variables

Transportation Algorithms	N	Mean	Std. Deviation	Skewness (S_k)		Kurtosis (Ku)	
	Stat.	Stat.	Stat.	Stat.	Std. Error	Stat.	Std. Error
I have never heard of them (NHD)	41	2.28	.593	2.317	1.983	-.292	.193
I am aware but never used them (ANU)	41	3.73	.655	1.447	.730	-2.070	1.105
Use it only sometimes (UOS)	41	3.41	.601	-2.294	1.192	-1.223	.880
Use them on regular basis (URB)	41	2.20	.477	1.996	1.230	2.112	1.068
NHD: $\alpha = 0.73$; ANU: $\alpha = 0.70$; UOS: $\alpha = 0.79$; URB: $\alpha = 0.88$							

Source: SPSS Computation from Data, 2023

Table 4.2 shows that, for normality, all the variables are reasonably acceptable with the largest values being 2.317 and 2.112 for skewness and kurtosis, respectively. Also, table 4.2 shows that the respondents did not sufficiently agree that they have never heard of transportation algorithms (*M* = 2.28, *SD* = 0.593). Respondents highly agreed that they are aware of transportation algorithms but never used them (*M* = 3.87, *SD* = 0.655). Moreover, the production and operations managers moderately agreed that the use transportation algorithms only sometimes (*M* = 3.41, *SD* = 0.601), while most of them did not sufficiently agree that the use transportation algorithms on regular basis (*M* = 2.20, *SD* = 0.477). All items also scored satisfactory levels of reliability, between 0.70 (I am aware but never used them - ANU) and 0.88 (Use them on regular basis - URB).

CONCLUSION AND RECOMMENDATION

Due to the complex, heterogeneous nature of transportation and supply chain management (SCM) in various industries (Stüve et al., 2022), managers have sought for ways to create place utility for customers, and reduce transportation time and cost through the use of algorithms (Gupta et al., 2022; Tavakkolimoghaddam et al., 2022; Dan & Liu, 2023). Classical transportation algorithms include; (i) Northwest Corner method (ii) Minimum cost method, and (iii) Vogel's approximation method. Although these models are frequently referenced in the production and operations management publications, it appears that production and operations managers in Rivers State, Nigeria are not familiar with or making use of them. Thus, the purpose of this research was to inquire into the awareness and application of such models by managers in carrying out their duties. The study deployed means to calibrate the level of awareness and usage. Results indicated that very few managers have never heard of transportation algorithms. Quite a large number of the managers are aware of transportation algorithms but never used them. In addition, an average number of the production and operations managers use transportation algorithms only sometimes; while most of them did not sufficiently use transportation algorithms on regular basis. This means that managers are aware of transportation algorithms but are reluctant to deploy them.

The study therefore recommends that production, operations and logistics firms should create more awareness on the benefit of transportation algorithms by carrying out sensitization programmes and building communities of practice. The firms should also train managers on the use on transportation algorithms and make it mandatory whenever they are to transport goods from sources to assigned destinations.

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