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OPTIMAL NETWORK PLAN FOR TRICYCLE TOWN SERVICE USING ALL-OR-NOTHING TECHNIQUE

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ABSTRACT

Sincethe state of traffic management technologies in many Nigerian towns can still be seen to be operating at a primitive level, this paper seeks to suggest modern operational models in traffic management such as All-**or-Nothing Assignment Technique incorporatingDijkstra's Algorithm to find shortest links and associated link flow volumes of commercial tricycles that ply the metropolitan routes in Minna Town. Minimum paths were identified to ease good movement and reduce cost for the commercial tricyclists.**

Keywords: All-or-Nothing, Dijkstra'sAlgorithm, Traffic Management, Assignment Technique, Transportation Model.

1.0 INTRODUCTION

Traffic Assignment is the process of allocating given set of origin-destination pair to the existing suitable road network based on specific traveler's route choice criteria. The route choice criteria is the travel impedance of the transportation network to be minimized for a given origin-destination pair. However, due to congestion on particular route on particular period, route choice does not only depend on the shortest path but also departure time and reliability of link of network. Therefore, planners need to focus on the optimal path rather than shortest path.

The simplest route choice and assignment method is **All-or-Nothing** assignment. This method assumes that there are no congestion effects, that all drivers consider the same attributes for route choice and that they perceive and weigh them in the same way.Historically all trips between two zones were assigned to the route having the minimum travel time, regardless of the available capacity; this is termed an "all-or-nothing" assignment. Such an approach is still used for identifying travel desire corridors as an initial step in locating new and improved transportation facilities. For most transit assignments the all-or-nothing approach is still used since there are rarely closely competing transit routes in an efficiently designed transit system. The following are the basic assumptions made in All-or-nothing assignment?

i. Travel time is a fixed input, equal to free flow travel time and it does not vary depending on the congestion on a link.
ii. Unlimited number of vehicles can be assigned to a link

Similarly, the all-or-nothing approach is used for assigning high occupancy vehicle trip assignments. The absence of congestion effects means that link cost are fixed; the assumption that all drivers perceive the same costs means that every driver from **i** to **j** must choose the same route. Therefore, all drivers are assigned to one route between **i** and **j** and no driver is assigned to other less attractive routes. These assumptions are probably reasonable in sparse and uncongested networks where there are few alternative routes and they are very different in cost.

The assignment algorithm itself is the procedure that loads the matrix '*T*' to the shortest path trees and produces the flows $\mathbf{V}_{A,B}$ on links (between nodes A and B). All load algorithms start with an initialization stage, in this case making all $\mathbf{V}_{A,B}$ =

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0 and then apply one of two basic variations: pair-by-pair methods and once-through approaches.

1.1 The Problem Situation

Although there have been technological improvements in almost all fields, the state of traffic management technologies in many Nigerian townscan still be seen to be operating at a primitive level. As a result of increasing vehicular movement, there is need for overall future development of our cities so that transport infrastructure, of which road traffic is a very important part, should be made state-of-the-art.

1.2 Objectives of the Study

The objective of this work was toidentify the shortest path and their related tricycle volumes between the major areas (Origins – Destinations) in Minna town using all-or-nothing assignment technique incorporating Dijkstra's algorithm.

1.3 Literature Review

1.3.1 Traffic Assignment

The process of allocating given set of trip interchanges to the specified transportation system is usually referred to as traffic assignment. The fundamental aim of the traffic assignment process is to reproduceon the transportation system, the pattern of vehicular movements which would be observed when thetravel demand represented by the trip matrix, or matrices, to be assigned is satisfied. Generally, Traffic Assignment Procedures seek to achieve the following:

1. **Estimate the volume of traffic on the links of the network and possibly the turning movements atintersections;**
2. **Furnish estimates of travel costs between trip origins and destinations for use in trip distribution;**
3. **Obtain aggregate network measures, e.g. total vehicular flows, total distance covered by thevehicle, total system travel time;**
4. **Estimate zone-to-zone travel costs(times) for a given level of demand;**
5. **Obtain reasonable link flows and to identify heavily congested links;**
6. **Estimate the routes used between each Origin to Destination (O-D) pair;**
7. **Analyze which O-D pairs that uses a particular link or path and**
8. **Obtain turning movements for the design of future junctions** (Tom, 2008).

1.3.2 Stochastic Traffic Assignment Technique.

Stochastic technique emphasizes on the variability in driver's perceptions of costs and composite measure. They seek to minimize (distance, travel time and generalized costs). This assignment assumes the route choice is based on perceived travel times or costs rather than measured link travel time or costs.The travel times perceived by motorist are assumed to be random variable. (Sheffi,1985). Therefore, this technique needs to consider second-best routes (in terms of engineering or modeled costs or time); this generatesadditional problems as the number of alternative second-best routes between each pair may be extremely large. Stochastic models deal with probability distribution of flow state and/or the expected flow state rather than the flow evolution trajectory (He *et al.*, 2013).

1.3.3 Capacity Restraint Method

Capacity Restraint Method is resultant of improvementof All-Or-Nothing (AON) Assignment which also takes capacity of linkinto consideration. The capacity restraint procedure explicitly recognizes that as traffic flow of network increases from certain point the speed of traffic decreases. Capacity restraint is used in trip assignment by loadingthe network and adjusts assumed link speeds after each loading to reflect volume/capacity restraints. This loadings and adjustments are done incrementally untilbalance is obtained between speed, volume and capacity.The Bureau of Public Roads (BPR) (1996) technique is most suitable techniques to load the traffic on the network. α and β value for each link may change from region to regioneven it changes from one area type to other, as well asfrom one link to another (Pulugurtha *et al.*, 2010). However, it is very difficult to determine the efficient value of α and β for each corridor. It also does not capturethe driver behavior as well as dynamic characteristics(speed, travel time and flow) of traffic flow. It is applicable to highly continuous traffic (He *et al.*, 2013).

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1.3.4 Incremental Traffic Assignment

Incremental Assignment is a process in which proportions of total demand are assigned in steps based onAON assignment. After each step link traveltimes are recalculated based on link volumes. When there are many increments used, the flow may look like an equilibrium assignment; however, this methoddoes not yield an equilibrium solution. Consequently,there will be inconsistencies between link volumes andtravel times that can lead to errors in evaluation measures.Incremental assignment model assumes that eachtrip maker chooses a path so as to minimize his/hertravel time in addition that the travel time on the links during the assignment is constant. One could then update the travel times and repeat the process till all the trips are assigned a single trip to the road network assuming thatthe travel time on links during the assignment is constant.One could then update the travel times and repeatthe process till all the trips are assigned. However, thisprocedure is not practical as any network would typicallyhave a very large number of trips. Incremental assignmentmodels therefore try to approximate this idealprocess by dividing the total number of trips into fewsmaller parts and assign each part assuming a constantlink travel time.

1.3.5 User Equilibrium Traffic Assignment

Traffic equilibrium model are commonly in use for the prediction of traffic patterns on transportation networks that are subject to congestion phenomena. User equilibrium assignment is based on Wardrop's first principles which states that "the traveler time between a specified origin and destination of all used routes is equal or less than the travel time that would be experiencedby any unused route" (Wardrop, 1952). User equilibrium assignment takes congestions into consideration. However,user equilibrium can only be achieved in artificial small virtually uncongested networks; for highly congested transportation network, equilibrium can only be closely estimated. The model does not include traffic control as a variable and further it has certain assumptions those are unrealistic in nature such as each driver want to choose the path between their origin and their destinations with the least travel time, drivers have perfect knowledge of link travel time. Peeta and Mahmassani (1995) obtained the UE conditions for the time-dependent case by generalizing the Wardrop's UE condition. According to this extension, for each O-D pair (i,j), and every departure interval τ , the travel times on all used paths are equal and minimal and the travel times on all unused paths are greater than the travel times on the used paths. These conditions can be succinctly represented by the following equations:

$$r_{ijk}^{\tau}(T_{ijk}^{\tau} - \theta_{ij}^{\tau}) = 0 \qquad \forall i, j, k, \tau. \qquad (2.1a)$$

$$(T_{ijk}^{\tau} - \theta_{ij}^{\tau}) \geq 0 \qquad \forall i, j, k, \tau. \qquad (2.1b)$$

Where r_i^{τ} refers to the number of vehicles traveling on the k^th path between origin i and destination j is departing at time τ, T_i^{τ} refers to the travel time experienced by these vehicles and θ^{r}_{ij} refers to the minimum path travel times from origin i to destination j for the departure interval τ. Hence if $r_i^{\tau}{}_k > 0$ then $T_i^{\tau} = \theta_i^{\tau}$ and if $r_i^{\tau} = 0$ then $T_i^{\tau} > \theta_i^{\tau}$

This section described models and formulations where each user tried to minimize his experience or instantaneous travel time.

1.3.6 System Optimum Assignment

Wardrop also proposed an alternative way of assigning traffic in to a network and this is usually refers to as Wardrop's second principle which states that under equilibrium conditions traffic should be arranged in congested networks in such a way that the total cost (all trips) is minimized. In contrast with the first principle of Wardrop, that endeavors to model the behaviour of individual drivers.The second principle is oriented to the organization of traffic to minimize travel cost and therefore to achieve an optimum social equilibrium (Willumsen, 2000). Althoughthe latter is often held to be more descriptive of travelers behavior in traffic networks, System Optimum (SO) Assignment is also highly useful: it forms a key component of many first best pricing models, it provides a lower bound on network congestion, provides indications for how networks should be improved, and is applicable in

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network problems where the routed assetscan be centrally controlled. However, SO traffic assignment assumes deterministic networks conditions including a fixed capacity on every link. In reality, incidents, weather, and other phenomenaresult in considerable variability in roadway capacityand system congestion.

1.3.7 All-or-Nothing Assignment

The simplest route choice and assignment method is All-or-Nothing Assignment. This method assumes that there are no congestion effects, that all are no congestion effects, that all drivers consider the same attributes for route choice and that they perceive and weigh them in the same way. According to Tom (2008), trips from any origin zone to any destination zone are loaded onto a single, minimum cost, path between them. Also, traffic on links is assigned without consideration of whether or not there is adequate capacity or heavy congestion; travel time is a fixed input and does not vary depending on the congestion on a link. However, this model may be reasonable in sparse and uncongested networks where there are few alternative routes and they have a large difference in travel cost. This model may also be used to identify the desired path: the path which the drivers would like to travel in the absence of congestion. In fact, this model's most important practical application is that it acts as a building block for other types of assignment techniques. It has a limitation that it ignores the fact that link travel time is a functionof link volume and when there is congestion or that multiple paths are used to carry traffic.

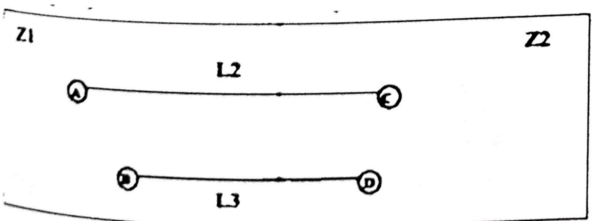

Fig1: Pictorial Sense of All-or-Nothing Technique

According to Fig1, if the cost of route AC is higher between the 2 routes, all the trips between zone Z1 and zone Z2 is assigned to route BD

1.3.8 Dijkstra's Algorithm

Dutch computer scientist EdsgerDijkstra in 1959 published a graph search algorithm that solves the single source shortest path problem for a graph with nonnegative edge path costs, which also produces a shortest path tree. However, an equivalent algorithm was also published in 1957, developed by EdwardF.Moore (Ravindra, 1993). The algorithm finds the path with lowest cost path (shortest, quickest) from specific node to all nodes in a network. It can be also used to find costs of shortest paths from a single vertex to a single destination vertex by stopping the algorithm once the shortest path to the desired destination vertex has been determined.

Dijkstra's algorithm is designed to determine the shortest routes between the source node and every other node in the network. The steps to be followed are listed below:

Let u_j be the shortest distance from source node 1 to a node I, and let us define $d_{ij} (\geq 0)$ as the arc length (i,j). Then the algorithm defines thelabel of an immediately succeeding node j as

$(u_j, i) = (u_j + d_{ij}, i)$, $d_{ij} \geq 0$

The label for the starting node is (0,--), indicating that the node is the starting node. Node labels in Dijkstra's algorithm are of two types; temporary and permanent. A temporary label is modified if a shorter route to a node can be identified, if there is no other alternative route the temporary label is changed to permanent.

1.4 Definition of Terms

i. **Capacity Restraint:** the volume loading process is constrained by the capacity of the link.
ii. **Free Flow Speed:** speed under no congestion.
iii. **Free Flow Travel Time:** travel time under no congestion.
iv. **Level of Service:** a qualitative measure describing the operation conditions.
v. **Link:** An element of a transportation network that connects two nodes. A section of roadway or a bus route could be modeled as a link.
vi. **Nodes:** Nodes are points at which links terminate. Links may terminate at destinations or at intersections with other links.
vii. **Trip Assignment:** "loading the network" volumes are assigned to links.

i. **Path Finding:** finding the path with the minimum impedance.
ii. **Path Loading:** loading vehicles to links comprising a path.
iii. **Routes in Network**: Pathways through a network. Routes are composed of links and nodes.

2.0 MATERIALS AND METHODS

2.1 All-or-Nothing Assignment Technique

All-or-Nothing method for solving conventional transportation forecasting in Minna as a case study was demonstrated. This survey was carried out using a tricycle. The various data needed to work with this model were:

i. Estimated number of motor vehicles between zones.
ii. Available trips between zones and travel times to each route.
iii. Decision criteria by which users will select route.

2.2Dijkstra's Algorithm

The algorithm follows Step 0 and Step I in obtaining solution as follows:

Step 0: Label the source node (node 1) with a permanent entity (0,-). Set i=1.

Step I: (a) Compute the temporary labels (u_j+d_{ij},i) for each node j that can be accessed or reached from node I, provided it is not permanently labeled. If node j is already labeled with (u_j,k) through another node k and if $u_i+d_{ij}<u_j$, replace(u_j,k) with (u_i+d_{ij},i).

(b) If all nodes have permanent labels, stop. Otherwise, select the label (u_r,s) having the shortest distance $(=u_r)$ among all the temporary labels (break ties arbitrarily). Set i =r and repeat step i.

2.3 Raw Data Collected

This survey was carried out in Minna - **a city with an estimated population of 304,113 people according to 2007 Census. It is located in west central Nigeria. It is the capital city of Niger State, one of Nigeria's 36 Federal States. The state is connected to neighboring cities such as Kebbi, Kaduna, Illorin and Abuja by road. Abuja, the capital of the country, is only 150 km away. Minna is also connected by railroad to both Kaduna in the north and Ilorin in the south. The city hosts one of the Federal Universities of Technology. The road networks of Seven (7) major Areasof the city** were considered for this study based on heaviest traffic flow. The Areaswhich constituted the nodes are defined in Table 1. Data on link arrays and distribution network are presented in Tables 2 and 3 respectively.

Table 1: Defining Nodes used on the Network.

Node	Name of Node (Town or Area)
1	Kpakungu
2	Central (Kure) Market
3	Maikunkele
4	Tunga
5	Mobil
6	Bosso
7	Maitumbi

Table 2: Data on Link array (Direct Link Table)

From/to	1	2	3	4	5	6	7
1	-	6	-	16	-	-	-
2	6	-	18	-	8	12	-
3	-	18	-	-	-	15	-
4	16	-	-	-	8	-	14
5	-	8	-	8	-	10	17
6	-	12	15	-	10	-	-
7	-	-	-	14	17	-	-

Source

	5		0		0	0	0
5	100	50	25	175	0	175	125
6	150	10	75	200	50	0	75
7	100	125	175	100	175	200	0

Source: The data were collected primarily by counting the number of Tricycles at the O-D zones

Note: The Distribution Table (Table 3) contains the volume of Tricycle flow from one zone to another in a particular time. For example, in 1 hour, 50 Tricycles were counted as they moved from zone 1 to zone 2. 75 Tricycles were counted from zone 1 to zone

3.0 RESULTS AND DISCUSSION

First of all, we shall obtain the shortest paths between the links using Dijkstra's algorithm before applying All-or-Nothing Technique to this problem. The network for the formulated problem is seen in Fig 1. The iterations of ofDijkstra's algorithm begin from iteration 0 to find the shortest paths from node 1 to all other nodes in the network.

Iteration 0 Assign the permanent label (0,--) to node 1

Table 4: Iteration 1; nodes 2 and 4 can be reached from node 1. Thus the list of labeled nodes (temporary and permanent) becomes

Node	Label (time, node)	Status
1	(0, -)	Permanent
2	(0+6,1)=(6,1)	Temporary
4	(0+16,1)=(16,1)	Temporary
TOTAL NODE ASSIGNED	3	

For the 2 temporary labels (6,1) and (16,1), node 2 yields the shortest path or distance (u_2=6). Thus the status of node 2 is changed to permanent.

Table 5: Iteration 2; nodes 3, 5 and 6 can be accessed from node 2. The list of the labeled nodes become

Node	Label	Status
1	(0, -)	Permanent
2	(6, 1)	Permanent
3	(6+18, 2) = (24, 2)	Temporary
4	(16, 1)	Temporary
5	(6+8, 2) =(14, 2)	Temporary
6	(6+12, 2) =(18, 2)	Temporary
TOTAL NODE ASSIGNED	6	

For the 3 temporary labels (24, 2), (14, 2) and (18, 2); node 5 yields the smallest. Thus, the status of node 5 is changed to permanent because it is the shortest path from node 2 (u_5=14)

Table 6: Iteration 3; nodes 4, 6 and 7 are accessible from node 5. Hence the list of labels become

Node	Label	Status
1	(0, -)	Permanent
2	(6,1)	Permanent
3	(24,2)	Temporary
4	(14 + 8,5) = (22, 5)	Temporary
5	(14, 2)	Permanent
6	(14+10, 5) = (24, 5)	Temporary
7	(14+17, 5) = (31, 5)	Temporary
TOTAL NODE ASSIGNED	7	

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Source: The data were collected primarily by counting the number of Tricycles at the O-D zones

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Node	Label	Status
1	(0, -)	Permanent
2	(6,1)	Permanent
3	(24,2)	Permanent
4	(16, 1)	Permanent
5	(14, 2)	Permanent
6	(18, 2)	Permanent
7	(30, 4)	Permanent
TOTAL ASSIGNED NODE	7	

The computations of the iterations can be more easily seen on the network in Fig 2.

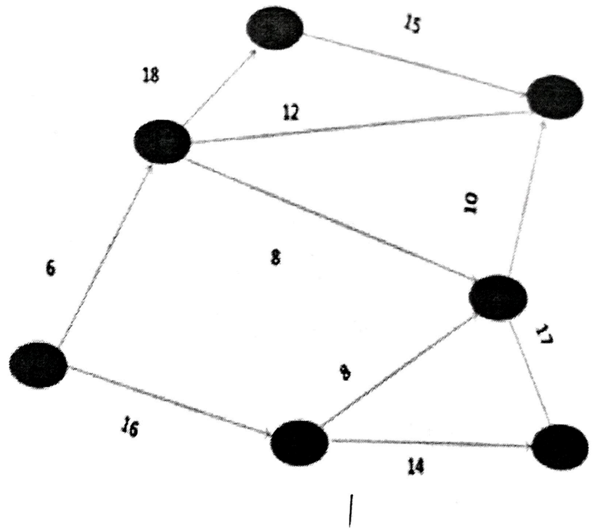


Fig 1: Road Network Analysis

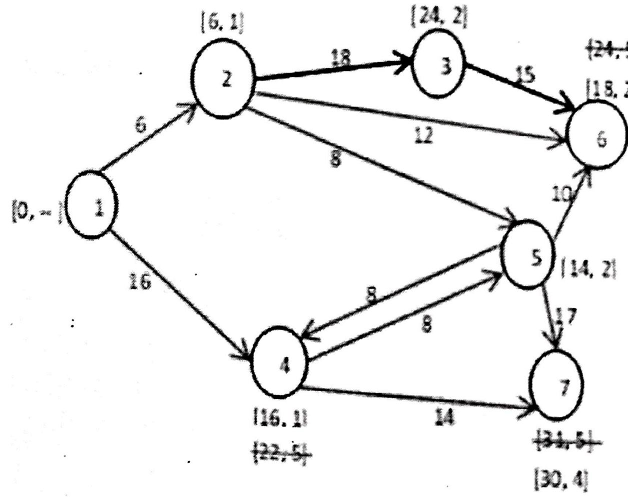


Fig 2: Dijkstra's Labeling Procedure

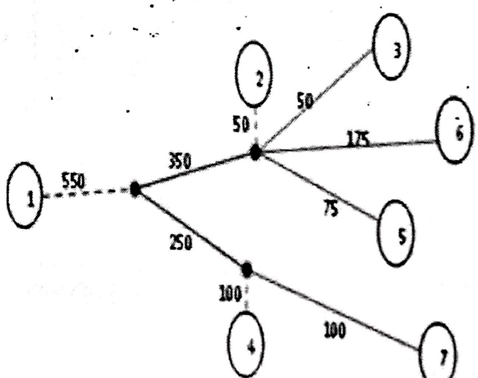
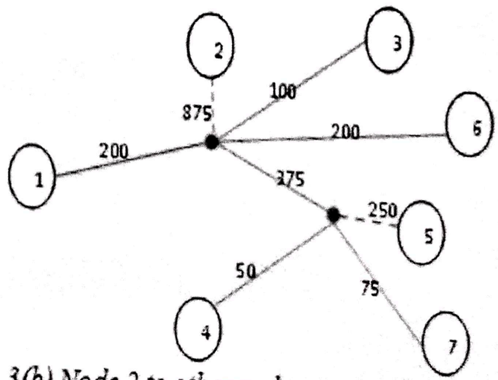


Fig 3(a) Node 1 to other nodes



3(b) Node 2 to other nodes

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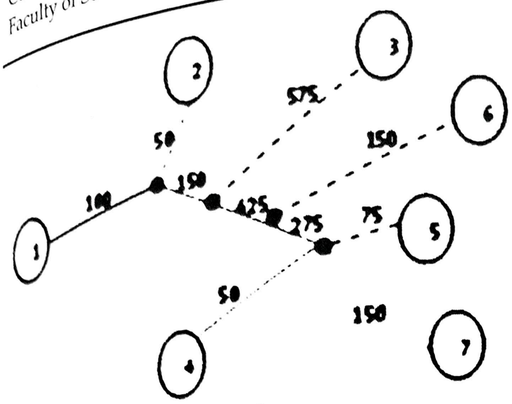
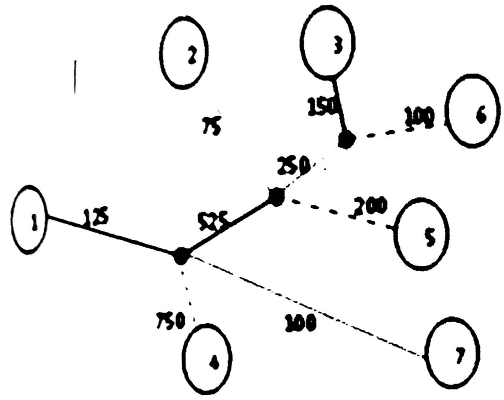
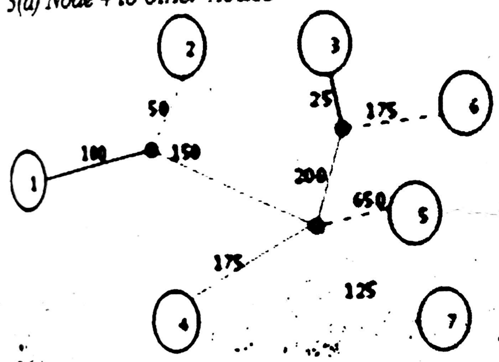


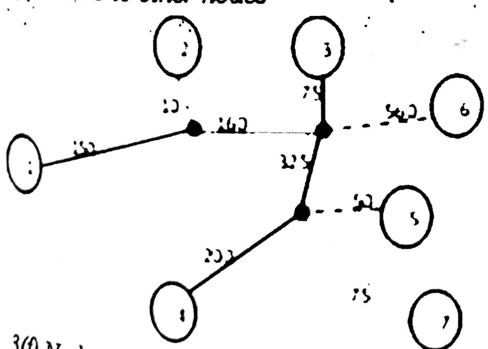
3(c) Node 3 to other nodes



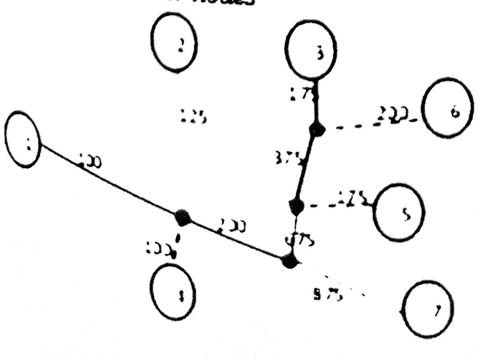
3(d) Node 4 to other nodes



3(e) Node 5 to other nodes



3(f) Node 6 to other nodes



3(g) Node 7 to other nodes

In applying All-or-Nothing technique, the Skim Trees in Fig 3a-g, which are the analysis from the data in Table 3 are used to obtain trip volumes between O-D nodes. A Skim Tree Shows Tricycle volume from a particular node to other nodes.

3.1 Discussion of Result

From Fig 2, the shortest route between node 1 and any other node on the network is determined by starting at the desired destination node and back-tracking through the nodes using the information given by the permanent labels. For example, the following sequence determines the shortest route from node 1 to node 6:

$$(1) \leftarrow [6,1] \leftarrow (2) \leftarrow [18,2] \leftarrow (6)$$

Thus, the desired route is $(1) \rightarrow (2) \rightarrow (6)$ with a total length of 18 minutes. See Table 8 for other routes.

From Fig 3, the average volume of Tricycles technically referred to as Total Trip Volume (TTV) at any given time from node 1 is 550. That of nodes 2, 3, 4, 5, 6 and 7 are 875, 575, 750, 650, 560 and 875 respectively (see Fig 3a-g).

In Fig 3a, 550 volumes can be observed from node 1: 350 of it goes into node 2 route out of which 50 stops at node 2 while 50, 175 and 75 respectively goes into nodes 3, 6 and 5. From the 200 volume that entered node 4 route, 100 stops at node 4 as the other 100 proceeds to node 7. This explanation of Fig 3a similarly follows to 3g.

Table 8: Recommended Routes Showing Travel Time and Tricycle Volumes

Nodes		Shortest Path	Travel Time (min)	Volume (per day)
From	**To**			
1	2	1-2	6	350
	3	1-2,2-3	24	50
	4	1-4	16	200
	5	1-2,2-5	14	75
	6	1-2,2-6	18	175
	7	1-4,4-7	26	100
2	1	2-1	6	200

	3	2-3	18	100
	4	2-5,5-4	16	50
	5	2-5	8	375
	6	2-6	12	200
	7	2-5,5-7	21	75
3	1	3-2,2-1	24	100
	2	3-2	18	50
	4	3-6,6-5,5-4	28	50
	5	3-6,6-5	20	275
	6	3-6	10	425
	7	3-6,6-5,5-7	38	150
4	1	4-1	16	125
	2	4-5,5-2	16	75
	3	4-5,5-6,6-3	28	150
	5	4-5	8	525
	6	4-5,5-6	18	250
	7	4-7	10	100
5	1	5-2,2-1	14	100
	2	5-2	8	150
	3	5-6,6-3	20	25
	4	5-4	8	175
	6	5-6	10	200
	7	5-7	13	125
6	1	6-2,2-1	18	150
	2	6-2	12	160
	3	6-3	10	75
	4	6-5,5-4	18	200
	5	6-5	10	325
	7	6-5,5-7	23	75
7	1	7-4,4-1	26	100
	2	7-5,5-2	21	125
	3	7-5,5-6,6-3	38	175
	4	7-4	10	200
	5	7-5	13	675
	6	7-5,5-6	23	375

4.0 CONCLUSION

Although this study was particularly on Tricycles in Minna, the methodology can be adopted in carrying out similar studies on other transportation means in other places; it should be noted that, this result cannot be generalized. The study provides useful insight/information to both present and future tricyclists and other road users on minimum link paths and link flow volumes in Minna town. We can conclude from the study that Bosso-Mobil route has easiest access routes to all the other routes in the city and most drivers ply the route. Link flow volumes have also shown the most populated based on the most visited places by passengers and the roads the drivers ply the most.

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