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Optimal Alternate Path Model for Road Transportation Routing System Using a Web-Enabled Geographic Information System

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Abstract:
Background:*Road transportation is central to everyday life, but is often hampered by traffic congestion in developing countries. This paper proposes a routing system that promises to reduce traffic congestion on the road by constantly suggesting the optimal alternate routes to motorists while considering the condition of the road segments.*
Materials and Methods:*The optimal alternate route is computed by the system based on the digitized map and the geographic information system of the city that are stored in the database. Secondary data for the research was obtained from Lagos state ministry of transportation.*
Results:*The experimental results show that out of every 10 samples, the proposed approach differs only in two cases. On inspecting each case, it was observed that the approach reported in this work differs from the existing approach whenever there is a bad road segment. The consideration of the bad segment by the reported approach accounts for the optimal routing. It was also observed that the computational time for determining the shortest route was much lower using the proposed approach.*
Conclusion: *The results show that computation based on shortest distance alone does not guarantee fastest arrivals. Parameters such as state of the road and road congestion contribute immensely.*
Keywords: *Geographic Information System, Dijkstra Algorithm, Alternate Path, Transportation, A* search Algorithm.*

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I. Introduction

A Geographic Information System (GIS) is a system that digitally represents spatial areas which may be jurisdictional, purpose-oriented, or application-oriented (Abousaeidi*et al.*, 2016). GIS is generally used in planning applications and specifically in transportation in areas such as analysis of traffic volumes, road design and so on (Al-Enazi, 2016). Transportation is the movement of people, goods and services from one location to another. Road networks often facilitate this movement (Khan and Ather, 2018). The importance of transportation cannot be overemphasized; it is a key necessity for development, as it allows production and consumption of products to occur simultaneously at different locations. Major cities are characterized by high population, rapid urbanization as well as high volume of vehicular movement which often results in traffic congestion (Ranya*et al.*, 2016). A major problem in transportation planning and routing is finding the shortest route between two locations in a road network. Recently, GIS techniques have been used with great results and have proven to be more environmentally helpful than conventional techniques (Oyedepo*et al.*, 2019).

This paper outlines the findings of an empirical study of the development in road transportation models in developing nations like Nigeria. The aim of this work is to trace the current development in road transportation models as well as to authenticate the strengths and weaknesses of each as reported in literature so as to know where road transport models need further support for the purpose of reducing traffic congestions to the barest minimum.

The area of transportation has been widely researched so as to overcome the problems of traffic congestion on road networks. Ogunbodede (2008) carried out an analysis of rural and urban settlement, which clearly indicated that Nigeria has a very high urbanization rate and which has led to many problems including traffic congestion. To ameliorate the problem of transportation the construction of more motor-able roads, and private participation in the provision of transport services was proposed. However, it is easier and faster to provide transport services than to construct roads. Provision of more transport services without a corresponding expansion of road networks has caused more congestion on the roads instead of alleviating transportation problems. The imbalance that follows the implementation of this proposed solution has failed to solve transportation problems. Ogunbodede (2006) proposed a computerized approach for dealing with traffic congestion. Akure in Nigeria was used as case study to carry out an on-the-spot analysis of the road congestion problems. Topological maps of Akure were used to create a spatial database which provided functionality for executing certain queries which include locations of T-junctions, determining the size of the city, and determining buffered zones that are prone to congestion based on periodic data collected. GIS software was used to digitize hard-copy maps and represent geographical objects. However, the approach lacks sufficient intelligence to manipulate the database for optimal result as the spatial data are displayed just the way they are stored in the database; no algorithms that can take intelligent decisions based on some alternate paths.

Koshak (2006) proposed a web-based GIS approach to overcome the flaws inherent in the conventional approach being used to reduce traffic congestion during the yearly Hajj in Mecca when people converge to observe the Islamic pilgrimage. In the conventional approach, hard copies of maps are distributed to local authorities before each Hajj season. This approach is prone to many problems which include the time and human resources expended in physically distributing the plans to the authorities, and cost of reprinting and redistributing plans when changes occur. To overcome these, a Web-based GIS capable of processing soft copy maps was used. This approach makes the distribution of the traffic plan easier, wider, and cheaper because the web-interface offers both static and interactive maps that can be used by different local authorities and pilgrims. Though this approach mitigated traffic congestion during Hajj, it neither carries out computations nor makes decisions based on dynamic data, and hence provides no information other than the knowledge stored in the database.

An approach for incorporating intelligence in transportation systems was proposed in Singh (2010), where the popular shortest path algorithms were modified to formulate a routing traffic in a large road network. The work aimed to plan a shortest route between a source and a destination as well as plan a next available shortest route when the current route is unusable. A system that provides different route finder options like shortest path finder, alternate path finder, and facility-based path finder, with underlying intelligence was built. This algorithm is a combination of A* search algorithm and Dijkstra's or Floyd Warshall's algorithms, computed on dynamic parameters like distance and travel time to reflect real-time information that would aid within-trip guidance. However, traffic congestion resulting from the condition of road segments was not taken into account.

This paper proposes an improved model for routing road transportation networks that will take conditions of the road network into consideration. Section 2 presents the improved road transportation model while section 3 presents the results and discussion. Conclusions were drawn in section 4. Data collected from Lagos state Ministry of Transportation were used to test the algorithm.

II. Materials And Methods

System Architecture: This section presents the architecture and algorithm of the proposed system. The architecture of the proposed system comprises the following four components: the web browser, web server, application server, and database. Any java-compatible web browser can be used. Tomcat Apache web server 6.0 is used in this experiment. The application server is responsible for executing the business rules. It comprises the GIS software for processing the maps and the knowledge base which makes decisions based on interpretations from the map. The database stores data such as geographical and spatial data as well as the attribute data that are used in this study. The postgreSQL 9.1 relational database software is used to store and execute queries with support from the postGIS 1.5 package to enable it act on spatial data. The architecture is presented in figure 1.

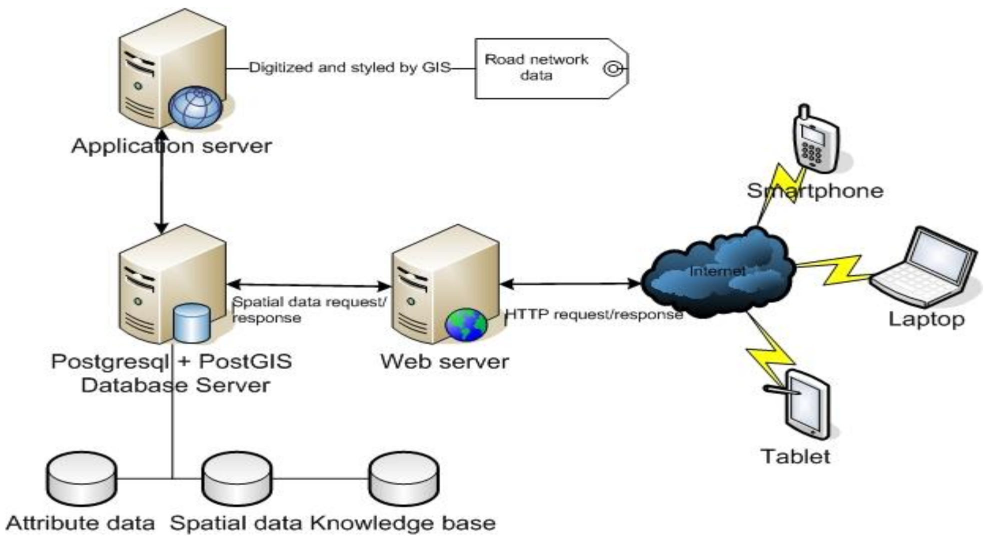

Figure 1: 4-tier Architecture of the Proposed GIS-system

The System Algorithm: This study uses dynamically changing values in real-time and takes factors such as the condition of road segments and traffic congestion into consideration when making alternate path computations.
In Alazab*et al.* (2011), the values of real-time traffic information gathered through GIS were utilized for achieving an optimal vehicle routing within a dynamically stochastic transportation network. Real-life traffic congestion data was collected, and analyzed. Results confirmed that the shortest path based on distance does not always guarantee the fastest arrival. Thus Dijkstra's algorithm was modified to take into account dynamic parameters as follows:
i) The cost (*Cij*) is directly proportional to the traffic congestion (*Tij*)between two nodes *i* and *j*,
ii) The cost (*Cij*) is directly proportional to the distance (*Dij*) between two nodes *i* and *j*,
iii) The cost (*Cij*) is inversely proportional to the vehicle speed (*Sij*) between two nodes *i* and *j*, and
iv) Lastly, the cost (*Cij*) is directly proportional to some constant factor or weight (*W*), which is assigned based on certain fixed parameters such as fuel charge, currency rate, etc. Hence, the cost (*Cij*) assigned to an arc connecting node *i* and *j* is given by the following equation: $C_{ij} = W (D_{ij} * T_{ij}) / S_{ij}$ (1)
The objective of Alazab*et al.* (2011)'s proposed algorithm was to find the shortest path that minimizes the total cost by calculating the dynamically changing cost *Cij* on each arc as given in the above equation as well as catering for the above mentioned dynamic constraints.
However, the condition of the road network was not considered in the work.
Hence, there is need for an improved model that will be able to take the condition of the road into consideration and suggest an optimal alternate path. This can be achieved by further fine-tuning the inference engine to improve on the decision making process that takes the condition of each alternate path into consideration.
The improved mathematical model is presented below.
Let the cost of reaching vertex v from vertex u be denoted byC_{uv}. The following are the parameters affecting C_{uv} and the relationships between them:

1) The cost (C_{uv}) is directly proportional to the distance (D_{uv}) between two vertices u and v,
2) The cost (C_{uv}) is directly proportional to the traffic congestion (T_{uv}) between two vertices u and v,
3) The cost (C_{uv}) is inversely proportional to the condition of the road segment (R_{uv}) between two vertices u and v,
4) Lastly, the cost (C_{uv}) is directly proportional to a constant weight (W), which is assigned based on certain fixed parameters like price of fuel, government policies, and so on.

Hence, the cost (C_{uv}) assigned to a segment connecting vertices *u* and *v* is given as:
$C_{uv} = W (D_{uv} * T_{uv}) / R_{uv}$ (2)
From the equation (2) above, it is evident that all the parameters except the condition (R_{uv}) of the road segment have positive relationships with the cost implying that an increase in the distance (D_{uv}) or traffic congestion (T_{uv}) on a segment, results in a corresponding increase in the cost (C_{uv}), while an increase in the condition R_{uv}(better condition of a road segment) results in a corresponding decrease in the cost (C_{uv}). All the parameters except the distance, are dynamic and this allows for the computation of dynamically changing costs for input into the Dijkstra's algorithms. The consideration of the alternate paths in this study therefore makes the distance dynamic. Depending on the condition of the road segment, the speed S_{ij} of the vehicle is assumed to be constant in this work. It is also assumed that vehicle engines are not switched off while in traffic jam.

Decision Making Process: The proposed system finds the optimal alternate path out of all alternatives which minimizes the cost of traversing all locations between the source and the destination. The problem is defined as follows:
Given*:*

1. A road network, G= (V, E) where G is a graph representing a city, V is the number of vertices, and E is the number of edges.
2. A Source vertex, s and a Destination vertex, t.

Find: the minimum *cost (s, t)*
The segment of the algorithm for decision making process is shown in Figure 2.

1 Start
2 Select Source node and Destination Node
3 Check in Database, if any direct path stored,
4 If yes, check if influential parameters are unchanged
5 If yes, retrieve and display the path and distance, go to 16
6 If no, go to 7
7 If no, Extract all path from Database and check whether if there is any sub path of *a*same source and destination nodes
8 If yes, check if influential parameters are unchanged
9 If yes, retrieve and display path and distance, go to 16
10 If no, go to 11
11 If no, Compute Path
12 Display path and distance
13 Check from all path in database whether this path is super path of any path
14 If yes, remove that path and insert this super path
15 If no, insert this path into database
16 End

Figure 2: Decision making process

III. Results

Implementation: The proposed system was developed using Java, JavaScript, and Java Server Pages (JSP) languages for the web application, Postgis 1.5 and PostgreSql 9.1 for the database system, Tomcat Apache 6.0 as the web server, and OPENLAYERS to interface between the web application and the GIS map source.

Secondary data was obtained from the Lagos State Ministry of Transportation for traffic counts and road survey experiments. This data served as input to the algorithm. For lack of space, Table 1 shows an excerpt of the secondary data collected from 7am to 7pm for one day, while Table 2 shows aggregated data based on Table 1 in that it shows the aggregate results of traffic counts from 7am to 12pm, 12pm to 4pm and 4pm to 7pm for each day. Figures 3 depicts graphical representations of Table 2, showing average values mapped against period of day.

Table 1: Excerpt of data from traffic count experiment

MANUAL CLASSIFIED TRAFFIC COUNT SUMMARY

Highway:- Weather: Normal Date: 21-2-2011
Direction:- Inward/outward Maroko Number of lanes:- 3 Location: Before 1st Roundabout

DAY 1 HOUR	INWARD MAROKO										OUTWARD MAROKO									
							Trucks & Tankers										Trucks & Tankers			
	Motorcycle	Tricycle	Cars	SUVs, Pick-ups	Mini-buses (e.g danfo)	Big buses	2 & 3 Axles	4+ Axles	Other vehicles	TOTAL	Motorcycle	Tricycle	Cars	SUVs, Pick-ups	Mini-buses (e.g danfo)	Big buses	2 & 3 Axles	4+ Axles	Other vehicles	TOTAL
7:00-7:15	137	0	145	94	91	14	15	2	0	498	108	0	263	151	78	2	4	0	0	606
7:15-7:30	175	0	180	110	81	30	0	0	4	580	202	0	205	100	81	0	1	1	1	591
7:30-7:45	141	0	172	117	88	25	8	5	1	557	163	0	209	92	75	0	4	1	0	544
7:45-8:00	147	0	160	112	87	23	9	1	1	540	180	0	190	108	51	2	5	3	2	541
8:00-8:15	135	0	131	53	62	19	10	1	2	413	130	0	175	80	75	1	4	4	0	469
8:15-8:30	175	1	133	98	92	17	10	1	0	527	114	0	195	84	53	2	5	0	5	458
8:30-8:45	182	0	173	82	78	15	5	2	7	544	100	0	170	90	42	3	11	1	0	417
8:45-9:00	192	2	150	91	63	21	9	5	11	544	90	0	155	70	35	2	9	0	2	363
9:00-9:15	187	0	165	98	72	7	14	7	4	554	137	0	140	70	45	4	6	0	2	404
9:15-9:30	180	0	170	90	81	20	5	6	5	557	86	0	125	100	44	2	7	0	8	372
9:30-9:45	176	1	140	85	76	14	6	0	2	500	123	0	135	80	50	1	5	4	1	399
9:45-10:00	160	0	155	75	66	13	9	2	1	481	97	0	145	104	35	0	6	4	0	391
10:00-10:15	160	0	158	94	73	16	12	1	4	518	105	0	120	90	53	3	5	1	3	380
10:15-10:30	135	0	110	91	77	10	14	7	5	449	86	0	135	77	40	2	4	2	1	347
10:30-10:45	136	0	90	90	83	16	14	6	3	438	90	0	105	60	52	3	3	2	0	315
10:45-11:00	130	0	100	86	51	7	7	3	6	390	99	0	100	71	34	4	5	4	8	325
11:00-11:15	143	0	105	51	66	10	5	2	3	385	78	1	97	52	33	0	1	2	1	265
11:15-11:30	133	0	124	68	71	10	11	3	5	425	126	0	80	48	35	1	10	4	7	311
11:30-11:45	145	0	132	84	68	4	4	6	2	445	127	0	110	70	30	3	12	3	5	360
11:45-12:00	140	0	105	61	57	13	11	8	3	398	101	0	100	64	45	0	4	6	6	326
12:00-12:15pm	140	0	130	84	63	13	13	3	5	451	115	0	97	53	37	4	12	4	7	329
12:15-12:30	150	0	115	66	65	6	15	7	4	428	90	0	90	60	30	1	11	3	2	287
12:30-12:45	135	0	126	65	60	10	6	2	5	409	75	0	79	51	40	4	9	1	3	262
12:45-1:00	110	0	128	63	57	12	3	5	2	380	88	0	115	49	60	1	8	3	10	334

1:00-1:15	115	0	130	95	81	15	9	2	5	452	110	0	80	63	45	1	13	4	9	325
1:15-1:30	133	0	120	94	62	7	9	6	2	433	137	0	90	50	35	2	15	8	6	343
1:30-1:45	105	0	122	79	60	9	8	4	5	392	113	0	125	77	44	0	12	5	5	381
1:45-2:00	95	0	140	87	74	14	10	3	2	425	127	1	233	69	37	3	10	4	7	491
2:00-2:15	95	0	130	94	77	13	11	7	10	437	125	0	170	56	34	2	6	1	3	397
2:15-2:30	90	0	150	91	73	18	16	4	5	447	133	0	120	63	23	3	14	5	7	368
2:30-2:45	130	0	160	93	79	15	8	5	3	493	110	0	105	40	22	2	9	3	3	294
2:45-3:00	90	0	151	90	65	19	11	5	6	437	130	0	100	40	29	3	6	4	3	315
3:00-3:15	137	0	160	85	66	11	10	5	7	481	121	0	90	46	21	5	7	1	4	295
3:15-3:30	160	0	195	51	45	17	13	5	7	493	82	0	83	82	40	2	4	2	7	302
3:30-3:45	150	0	150	90	51	18	18	5	4	486	110	0	75	60	39	1	4	3	12	304
3:45-4:00	140	0	180	44	38	16	4	4	2	428	102	0	60	59	45	5	5	1	4	281
4:00-4:15	135	0	140	33	42	11	12	5	3	381	94	0	70	42	33	3	2	1	5	250
4:15-4:30	157	1	165	68	72	17	16	3	2	501	101	0	105	61	49	5	3	1	6	331
4:30-4:45	157	0	135	93	51	23	9	2	3	473	87	0	90	60	30	2	4	2	2	277
4:45-5:00	102	0	135	60	65	12	3	5	3	385	105	0	75	57	32	3	2	2	4	280
5:00-5:15	135	0	140	83	52	16	11	2	1	440	77	0	55	62	26	33	5	5		263
5:15-5:30	128	0	150	109	44	11	6	2	0	450	43	0	63	69	35	2	7	3	2	224
5:30-5:45	105	0	180	99	53	13	6	2	2	460	36	0	60	52	29	3	3	1	1	185
5:45-6:00	115	0	175	88	69	11	6	0	1	465	32	0	53	60	43	2	3	1	0	194
6:00-6:15	120	0	220	98	81	19	6	4	1	549	67	0	72	56	36	4	4	2	2	243
6:15-6:30	117	0	185	75	52	10	4	4	6	453	85	0	80	40	24	3	3	0	1	236
6:30-6:45	111	0	223	101	63	18	3	1	1	521	76	0	69	54	31	2	1	0	1	234
6:45-7:00	125	0	210	95	57	14	1	1	1	504	30	0	70	43	34	1	4	0	2	184
TOTAL	6591	5	7143	4003	3200	692	425	171	167	22397	4943	2	5528	3235	1969	137	297	112	170	16393

Table 2: Aggregated traffic count values over a period of seven (7) days, with three periods per day

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total	Average
Morning (7am – 12pm)	8184	8119	10617	14395	15025	9512	5837	71689	10241.29
Afternoon(12pm - 4pm)	5308	6179	6156	7008	8996	6053	5426	45126	6446.57
Evening (4pm – 7pm)	2651	3670	4227	4563	3221	3771	2489	24592	3513.14
Total	16143	17968	21000	25966	24849	19336	13752	-----	-----
Average S	5381	5989.33	7000	8655.33	8283	6445.33	4584	-----	-----

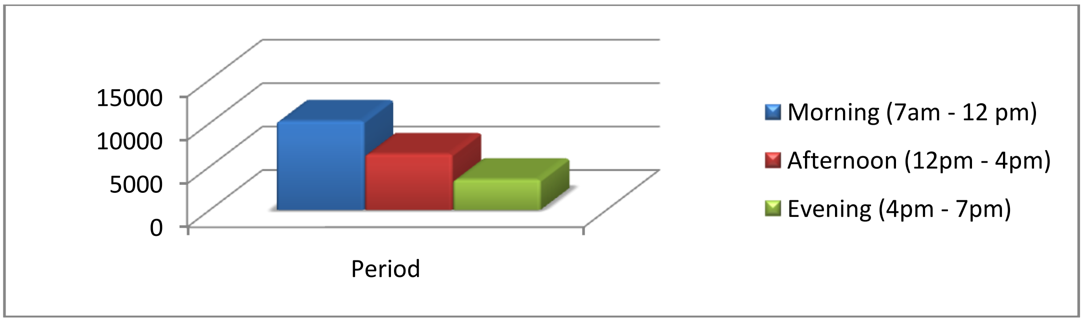

Figure 3: Chart showing average periodic traffic count values

IV. Discussion

The following experiments were carried out:

i. Executing shortest route query using normal computation of algorithms vs. Executing optimal route query using the modified algorithm.

Finding the shortest route in a normal approach requires executing the algorithm every time a route query is executed while finding the optimal route using the proposed approach involves the following steps:

a) If shortest path table in database does not have bad road segments, store source, destination and path into the database and follow the road.

b) If shortest path table in database had bad road segment.

- Traverse all database paths,
- For each path, check for the road with the best road segment and check column and if the node in the destination column match the chosen source and destination nodes. If so, extract the path string.
- If path is not found in the database and parameters remain unchanged, then there exists no path between the source and destination nodes.

The total time taken for computing shortest route using the normal approach and the proposed approach is as follows:

Normal computation time = Computation time for query by executing algorithm

Computation time using the proposed approach =
- Database access time + client/server latency (if found),
- Database access time + searching time + execution time for algorithm + storing time (if not found)

To prove the correctness of this analysis, the shortest paths between 100 random source and destination nodes were computed. The computation time/speed for the proposed approach and the shortest path approach respectively are shown in table 3 and table 4. Figure 5 shows the comparison of the two different approaches when executing route queries.

Table 3: Computational time for 100 randomly selected queries using the proposed approach

Query #	Computational time (s)
0	31.2
20	1.2
40	1.1
60	1.1
80	1.3
100	1.2

Table 4: Computational time for 100 randomly selected queries using normal approach

Query #	Computational time (s)
0	30
20	32
40	31
60	29
80	31
100	30

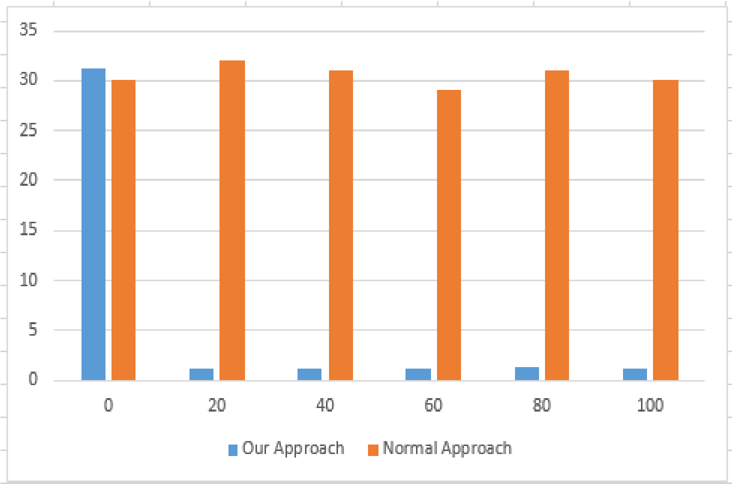

Figure 5: Clustered Column Chat showing computational time for the proposed approach vs. normal approach.

Computing shortest paths using a static algorithm based on distance alone may not always yield the correct solution as other factors may influence the cost of paths. Here, the results of computations based on static Dijkstra's algorithm were compared with the results of computations based on the modified dynamic algorithm. Shortest paths were computed, first using a static implementation of dijkstra's algorithm, then using the modified algorithm. Ten (10) queries were chosen at random to be executed each time and the outputs are recorded to observe if there is a correlation in results. The outcomes of the queries executed (using the static Dijkstra implementation vs. the modified algorithm) shows that the output is the same eight times out of ten thus they only differed on two events. To show how the values differ from one approach to another, a value of "1" was assigned when the outputs are the same, and a value of "0" otherwise as shown in Table 5. A graph of the output value against the query number is plotted as shown in Figure 6. Note that a "drop" in values at queries #3 and #8 represent queries with different results. On further investigation into these queries, it was observed that the output obtained using the modified algorithm was influenced by the additional parameters such as the condition of the road thus revealing that the static computation based on shortest distance alone does not guarantee the fastest arrival.

Table 5: Comparison of static Dijkstra's algorithm vs. the modified algorithm

Query #	Output	Value
1	Same	1
2	Same	1
3	Different	0
4	Same	1
5	Same	1
6	Same	1
7	Same	1
8	Different	0
9	Same	1
10	Same	1

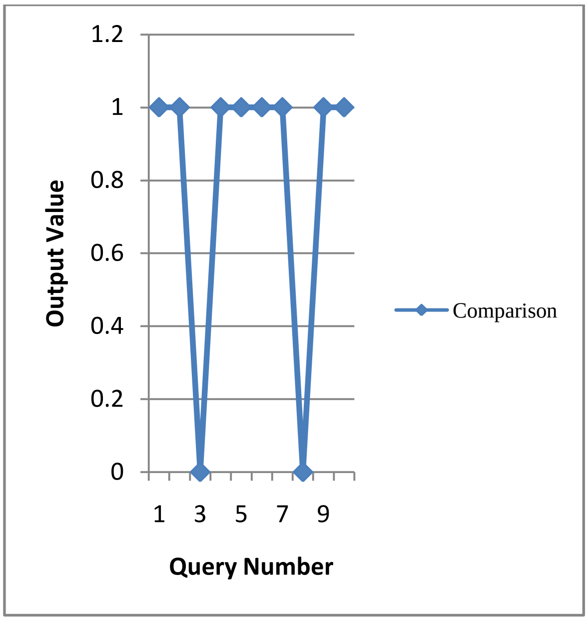

Figure 6: Chart showing computational results of comparison of static dijkstra's algorithm vs. the modified algorithm

V. Conclusion

The ever increasing number of vehicles on the road inevitably leads to an increase in traffic congestion thus there is consistently a need for better traffic management algorithms.

This paper presents results for a road transportation model which is capable of providing real time information for deciding the optimal alternate route a motorist can take when the condition of the road networks is capable of resulting in a traffic congestion. The results show that computation based on shortest distance alone does not guarantee fastest arrivals. Parameters such as state of the road and road congestion contribute immensely.

However, computations based on these parameters were obtained from an existing traffic historical data stored in the database. There is a need to develop a system that has sensors for capturing the data on a real-time basis because of the transient and unpredictable nature of traffic.

References

[1]. Abousaeidi, M., Fauzi, R., and Muhamad, R. (2016). Geographic Information System (GIS) modeling approach to determine the fastest delivery routes. Saudi Journal of Biological Sciences 23, 555–564.

[2]. Alazab, A., Venkatraman, S., Abawajy, J., and Alazab, M. (2011). An Optimal Transportation Routing Approach using GIS-based Dynamic Traffic Flows. 3rd InternationalConference on Information and Financial Engineering IPEDR vol. 12 IACSIT, Singapore. Pp 172 – 176.

[3]. Al-Enazi, M. (2016). Traffic Congestion Evaluation using GIS Case Study: Jeddah City (2016). International Journal of Computer Applications (0975 – 8887) Volume 138 – No.1

[4]. Khan, K., and Ather, D. (2018). A Note on Routing Methods to Determine the Shortest Path in Transport Networks. International Conference on Advanced Computing (ICAC). College of Computing Sciences and Information Technology (CCSIT) ,TeerthankerMahaveer University , Moradabad

[5]. Koshak, N.A. (2006), "Developing a Web-Based GIS for Hajj Traffic Plan". Journal of Urban Planning Research, Cairo University, Vol. 6, Issue 6. Pp 1 – 13

[6]. Ogunbodede, E. F. (2006), "Assessment of traffic congestions in Akure (Nigeria) using GIS approach: lessons and challenges for urban sustenance". Department of Geography & Planning Sciences, AdekunleAjasin University, Akungba-Akoko, Ondo State, Nigeria. http://download.sue-mot.org/Conference-2007/Papers/Ogunbodede.pdf [Retrieved 4th February 2012].

[7]. Ogunbodede, E.F. (2008). Urban Road Transportation in Nigeria From 1960 To 2006: Problems, Prospects And Challenges. Ethiopian Journal of Environmental Studies and Management Vol.1 No.1 . pp 7 – 18.

[8]. Oyedepo, J.O., Aladejuyigbe, J., Etu, J.E., Ekudehinmi, R., and Akande S.O. (2019). Routing and Scheduling of the Federal University of Technology Akure Campus Shuttle-A Geographical Information System Approach. ABUAD Journal of Engineering Research and Development (AJERD) ISSN: 2645-2685 Volume 2, Issue 1, 1-10.

[9]. Ranya, F.A.E., Abdelrahim, E., Salah, E.K.S., Aisha, E.M., Nagla, A.G., and Mohamed, S.A.A. (2016). Route Network Analysis in Khartoum City. SUST Journal of Engineering and Computer Science (JECS), Vol. 17, No. 1, 2016.

[10]. Singh, A.K. (2010). Web Based GIS Route Finder System. M.Tech Project Report. Department of Computer Science and Engineering, Indian Institute of Technology, Bombay.