Available online www.unicrossjournals.com

UNICROSS JOURNAL OF SCIENCE AND TECHNOLOGY, UJOST

RESEARCH ARTICLE VOL. 4(3) SEPTEMBER, 2025 ISSN:2814-2233

Date Approved September 30, 2025 Pages 248 – 265

DESIGN AND IMPLEMENTATION OF A SYSTEM FOR OPTIMAL COLLECTION AND SUPPLY OF WATER PRODUCT

Ofem Ajah Ofem , Iwara Obono Ofem , Osahon Okoro

Computer Science Department, University of Calabar, Calabar.

Corresponding Author: ofemofemajah@gmail.com

Abstract

Investigation into the optimal way of supplying water product at Blue Rose Water Company has been conducted. The time taken for connecting between different company units has a direct relationship with productivity. The aim of this research is to design and Implement a system for optimal collection and supply of water product in Blue Rose Water Company that will lead to the maximum utilization of time in accessing the warehouse from the company. The objective is to reduce waiting time, fuel consumption, air pollution, and wear and tear of the vehicles. The methodology used in this research is the Object-Oriented Analysis and Design (OOAD) in simulating the land transportation network system in Marian Market. Java programming language will be used to simulate the algorithm. By developing a model to identify the shortest path for time efficiency in the transportation network system, the driver will know which path to follow to ensure the timely delivery of goods to its consumers, using the modified Dijkstra's algorithm. The program implementation shows that automated shortest path and use of modified Dijkstra's algorithm in land transportation network system improves efficiency and productivity, and reduces waiting time.

Keywords: Route, Water Products, Optimal, Source and Destination Nodes

1.0 Introduction.

Everyone desires to arrive at their destination on time. People who rely on public transit must obtain reliable bus information in order to decrease their waiting time at bus stops (Pradhan, 2013). Networks are required for the movement of people, the delivery of products, the communication of information, and the management of the flow of matter and energy.

The scope of network application is extremely broad. Roads, trains, cables, and pipelines are examples of phenomena that are represented and studied as networks. Mullai (2012), shows that the cost, time, and complexity of the network are important factors in network design and implementation. This can be achieved through the use of graphs: A graph is a mathematical abstraction that may be used to solve various networking issues. Locating the shortest routes plays a key part in the resolution of network-based systems. A variety of algorithms can be used in graph theory. In a graph-based network system, it is used to determine the shortest path. The complexity of the system is reduced as a result considering the network path, the cost, and the time required to create and maintain network-based systems (Mullai, 2012). The background of this project is based on a case study of design and implementation of an Optimal Water Distribution System in Marian Market using the Modified Dijkstra's Algorithm. The land transportation network system understudy consists of 7 nodes known as A, B, C, D, E, F and G. Each node here represents a bus stop.

Thorup (2014), indicates that land transportation has proven to be the most popular and reliable mode of transporting people, commodities, and services from one location to another, both locally and globally, throughout human history. Food, mail, and other critical products dealers arrange resorts in land transportation platforms to beat time as a matter of urgency in delivery. The usage of land routes in a land transportation system entails the use of approved links termed edges paths, which connect all nodes (bus stops) within a given geographical region of coverage. Lately, land transportation system has witnessed remarkable growth and improvement due to the emergence and rapid growth of information technology (IT) and the additional land safety measures put in place such as electronic devices to detect land turbulence. This way, enabling both drivers to avoid hazards and land users to patronize this means of transportation.

In real-life situations, the transportation network is usually stochastic and time-dependent (Thorup, 2014). In fact, a traveler traversing a link daily may experience different travel time on that link due, not only to the fluctuations in travel demand (source-destination matrix) but also due to such incidents as work zones, bad weather conditions, accidents and vehicle breakdowns. As a result, a stochastic time-dependent (STD) network is a more realistic representation of an actual road network compared with the deterministic one. In order to account for travel time reliability more accurately, two common alternative definitions for an optimal path under certainty have been suggested. Some have introduced the concept of the most reliable path, aiming at minimizing the probability of arriving on time or earlier than a given travel time budget. It is very necessary to note that computer scientist, engineers, network designers, programmers, road users, aviation industry should understand the rudiments and concepts used in land transportation network system as they constitute the stakeholders in this sector. Such concepts range from understanding the ever-growing variety of components and strategies put together and master the approach in land transport networks and behavior (Thorup, 2014).

This research aims seeks to achieve reduction in waiting time which is of interest to land transportation handlers. The application of modified Dijkstra's algorithm for optimal collection and supply of water product, in Blue Rose Water Company will lead to the maximal utilization of time in accessing the warehouse at Marian market. Taking the shortest route will not only save time, but also reduce the consumption of fuel, air pollution, and wear and tear associated with mechanical systems. A typical demonstration of a bird eye view of the land path of Blue Rose water to its warehouse is shown in the table below.

2.0 Related works

In reviewing this paper works carried out by outstanding researchers, we looked at the approaches to water product management taken by developing countries (e.g. Nigeria), factors and challenges of water products management and the current technologies used in developing and developed countries to address some of the challenges of water product management (Delling & Nannicini, 2008). In some studies on water factory produce trends in developing and developed countries, it was reported that for some cities in Nigeria, water factory management agencies are functional and also water product collection area available while in other cities, they still practice Local water factorying. Some of the major challenges faced were low participation of the water product management, prompt collection of products, Ineffective use of technology and little or no management systems of organized information (Barthélemy,2004; Bast et al., 2007). Efforts have been made to address some of these challenges. Recent technologies such as modernized water factory technology, compact water products collection buses, and good roads collection system have been put in place to address some of the above mentioned challenges of water product management (Adeyemo,2013; Li & Li,2007).

Using Object Oriented Analysis and Design methods to develop real-time systems has the potential to produce safer, more reliable and maintainable software. Instead of using functional decomposition of the system, the OOA approach focuses on identifying objects and their activities. Using the object -oriented approach, system analysts model information systems by identifying a set of objects, along with their attributes and operations that manipulate the object data. Researchers in the object-oriented community assert that the OOA approach has many advantages in meeting the requirements of OOP (Chen & Tan, 2004). Modified Dijkstra's algorithm has also been used extensively in optimizing water factory produce collection routes optimization in Malaysia.

Generally, in developing countries, previous studies have shown that ineffective technologies and inadequate product facilities have been another source of challenge to the management of water products (Norhafezah, et al., 2017). A major drawback is the misuse of technology. Previous documentations have shown that sophisticated, expensive technological recycling, composting plants and other water products management systems in developing countries have failed. Reasons being that the systems might be too complex to implement or the public and stakeholders are not adequately and extensively consulted before adopting such systems. It was also observed that in developing countries, there is the failure of inappropriate technology hampered by imported mechanical and electrical parts which are often too expensive to replace or too difficult to manage. It is obvious that techniques that have often proven effective in developed countries prove to be ineffective in many situations in developing countries that do not have the needed infrastructure, or technical know-how to properly implement these technologies (Deiling,2008). With these limitations in existence, this research is an attempt to bridge the gap by developing a less complex system that would reduce produce congestion at storage points, provide spatial view of the location of water factory products and help transporters convey them to customers in the shortest possible time.

2.3.1 Brief description of the scope

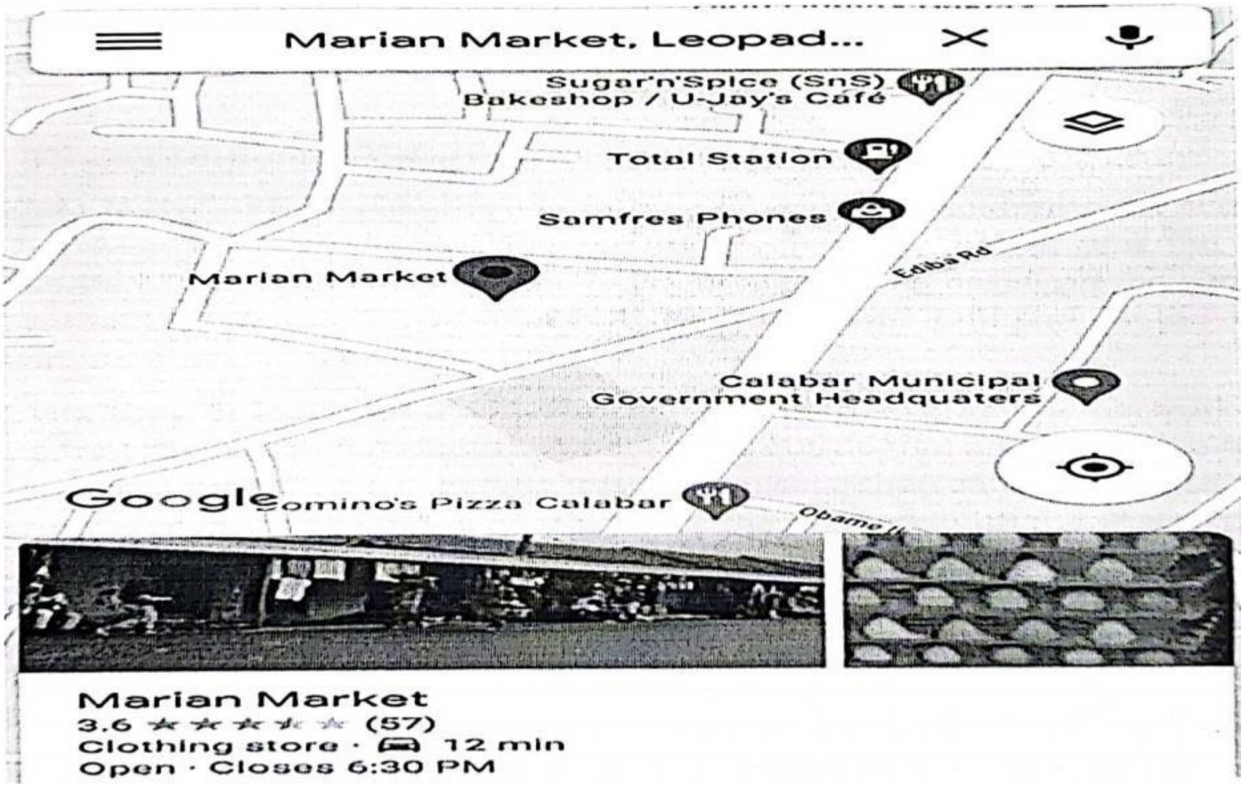

Figure 1: Map of the study area (Google map)

The location used for this project work was obtained from Blue Rose water company. The distance in kilometer (km) between locations in the graph was determined using Google maps location. Marian market in located in the heart of the old Town of Calabar in Cross River State.

The market's global positioning system coordinates are; 2.98093, 8.33794.

3.0 Research methodology

Irony and Rose (2005) asserted that, methodology is the systematic and theoretical analysis of the methods applied to a field of study. It consists of the theoretical analysis of the body of methods and principles related with a branch of knowledge. It also includes concepts such as paradigm, theoretical model, phases and quantitative or qualitative technique. Creswell (2003) defined methodology as the analysis of the principles of method, rules and hypothesis employed by a discipline. Creswell went further to state that, methodologies go beyond the approach of incorporating guidance for business analysis, project planning and management, project processes (examples: estimation, metrics, risk management), quality assurance, testing, role and responsibilities, reuse and architectural design. Methodology adopted for this study is outlined below:

- General research information
- Comprehensive site study
- Analyzing various requirements
- Collate all relevant data

- Modification and identification of variables
- Implementation of the algorithm
- Application

Table 1: Bus stops in Marian market and nodes

Marian market	Node Number
Building A	1
Building B	2
Building C	3
Building D	4
Building E	5
Building F	6
Building G	7

Table 2: Representation of destination nodes

S/N	Nodes	Node Number
1	A-B	2KM
2	A-F	4KM
3	A-G	5KM
4	B-G	1KM
5	B-C	4KM
6	G-F	2KM
7	G-C	2KM
8	G-E	3KM
9	G-D	4KM
10	F-E	1KM
11	E-D	3KM
12	C-D	1KM

3.2 THE PHYSICAL TOPOLOGY OF THE NETWORK

The network topology is the arrangement and connectivity of nodes and links or routes in a network. In this paper the network topology was derived as shown in fig 1.0 after the nodes and distances between the nodes were obtained.

3.2.1 Analysis of the physical topology of the network

From FIG 1.0, steps were carried out to analyze the network in other to obtain the shortest route from a chosen source to a chosen destination. The chosen source was Node A and Node F was chosen as the destination. The following keynotes were also used to represent the parameters used in the analysis of the network.

TL- Temporary label of a node/Upper bound which can be further updated to lower bound.

PL-Permanent label of a node/Permanent label which cannot be updated anymore further.

-Temporary label of a node *-Permanent label of a node n- A node in a network dij-Distance cost between node I and j.

N/B. The moment a node in the network is given a PL outside the source, its reachable neigbhbor is updated to get a new TL for its neighbor.

At level 1:

Assign a weight cost of 0 to the source node (A) and all reachable nodes from node A,which are node F, G and B is given dij as their temporary labels, while the non-reachable nodes from A are given co as their temporary labels. Thus, the node model at this level is:

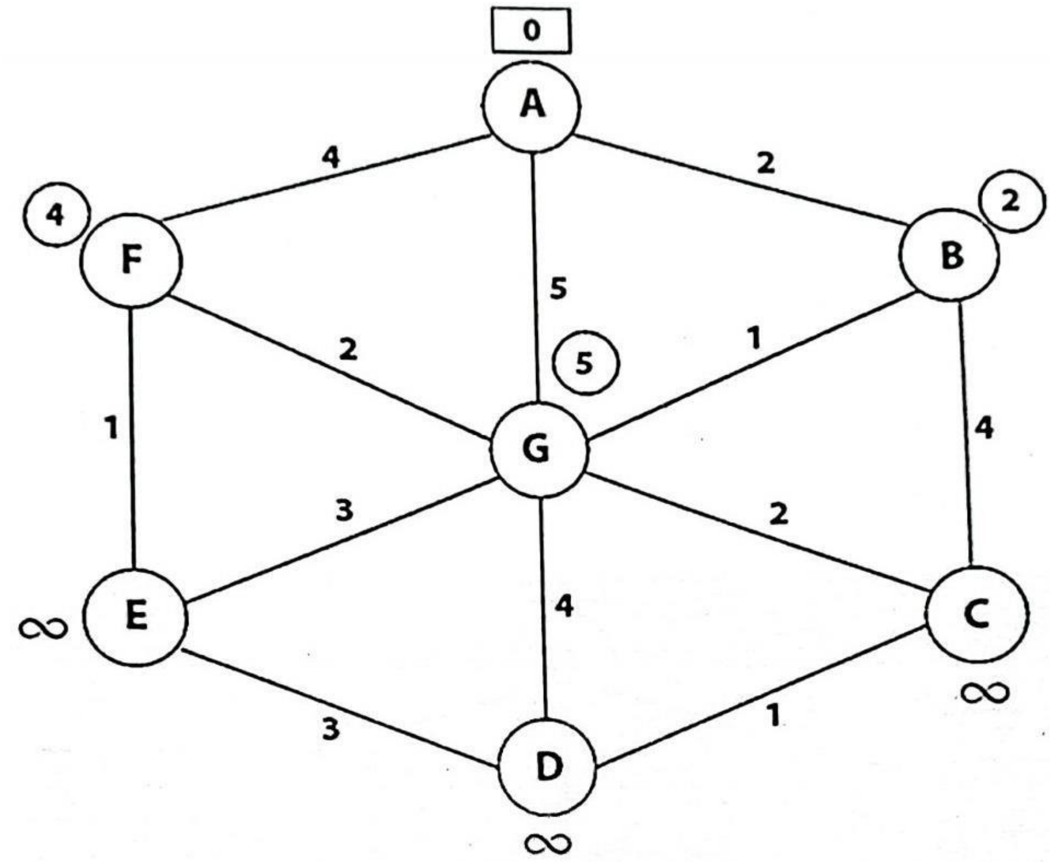

Figure 2: The network model at iteration 1

The sequence of the nodes are as follows:

A B C D E F G

0 2 8 8 8 4 5

At Level 2:

Compare the weight cost of all reachable neighbors of node A and make the smallest of them a permanent label (PL)

20

IF TL (B) <_ TL (F) AND TL (B) <_ TL (G)

THEN

ELSE

PL≠Node B

Subject to further comparison test

Hence, since the above logical condition is true, then PL =node B=2km See the network node and sequence of the nodes at level 2 below:

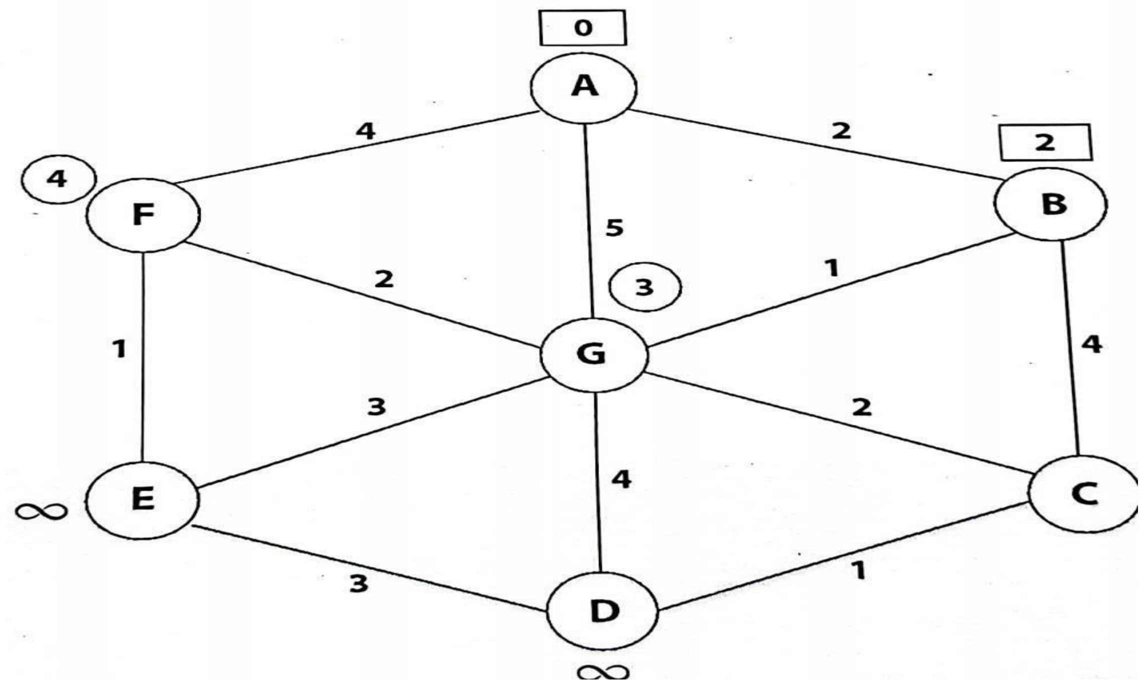

Figure 3: The network model at iteration 2

Now, node B is given a permanent label, we then update TLs for its reachable neighbors.

The sequence of the nodes at level 2 are as follows:

A B C D E F G

0 2 6 8 8 4 3

* *

At Level 3:

Compare TLS for nodes C, F and G, and make the smallest of them a PL.

IfTL(G)≤TL (F) AND TL(G)≤TL(C)

THEN

PL=Node G

ELSE

PL≠Node G

Subject to further comparison test.

Hence, since the above logical condition is true, then PL = node G=$3kk$

See the network model and sequence of the nodes at level 3

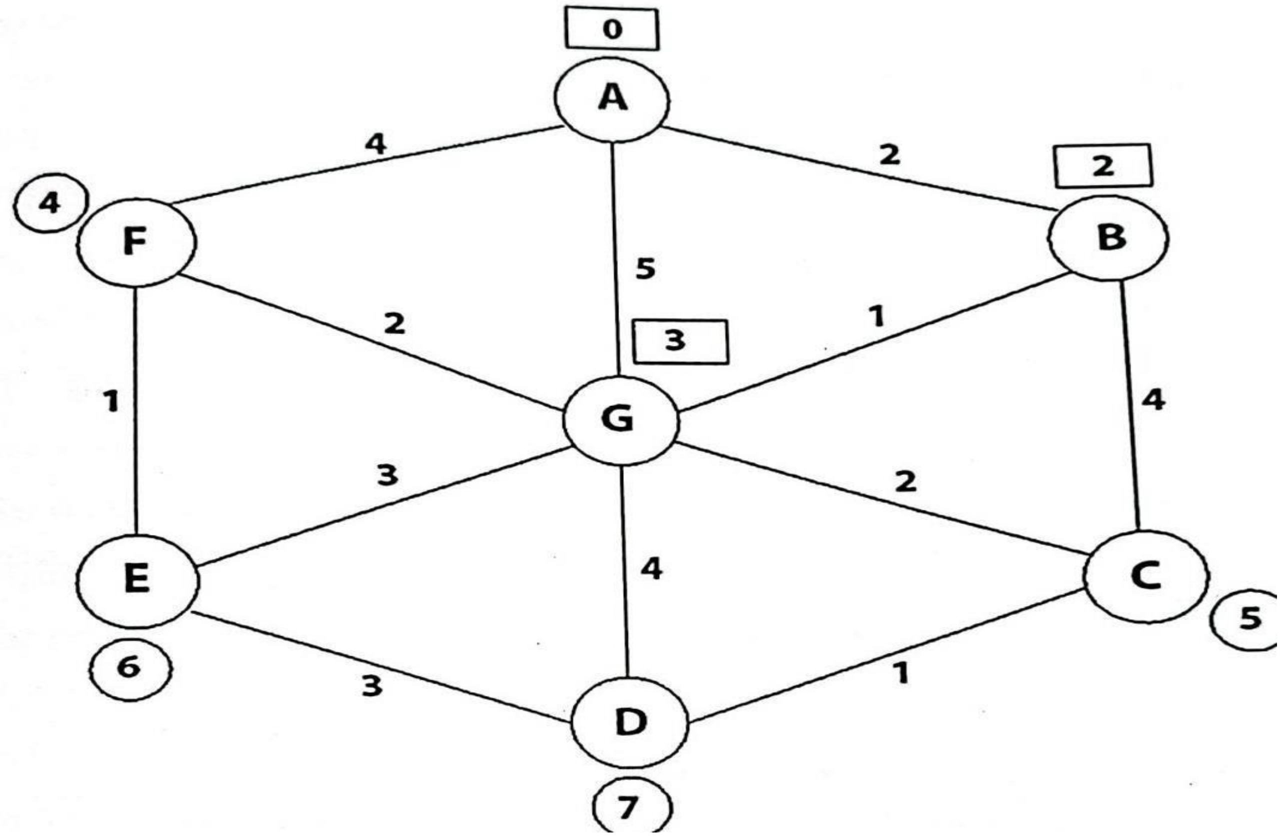

Figure 4: The network model at iteration 3

The sequence of the nodes at level 3 are as follows:

A	B	C	D	E	F	G
0	2	5	7	6	4	3

At level 4:

Compare TLs for nodes C, E and F and make the smallest of them (PL)

IfTL(F)≤TL(C)AND TL(F)≤TL(E)

THEN

PL = Node F

ELSE

PL≠node F

Subject to further comparison test

Hence, the above logical condition is true,

THEN PL = node F = 4km

See network model and sequence of the nodes at level 4

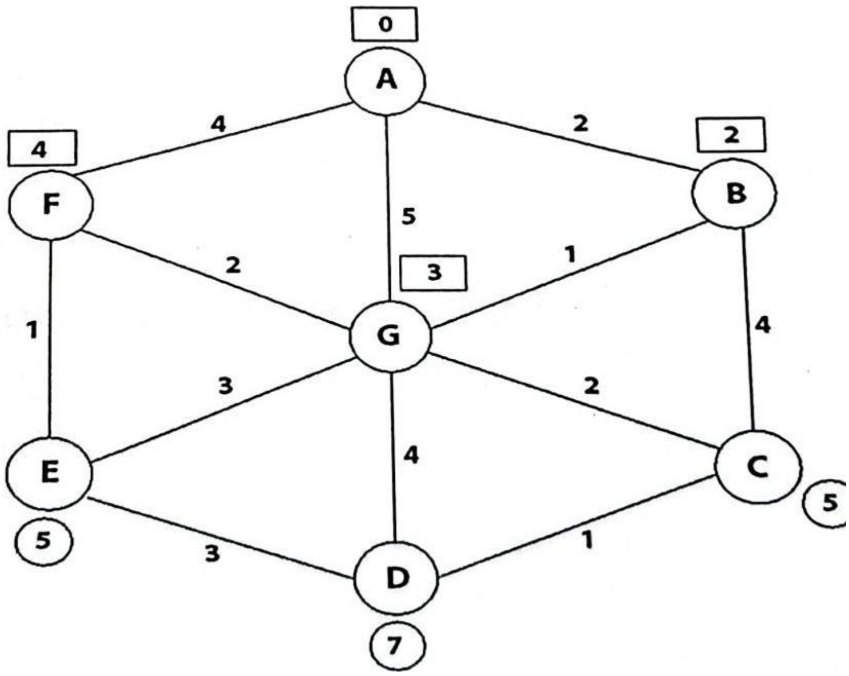

Figure 5: The network model at iteration 4

The sequence of the nodes at level 4 are as follows:

A	B	C	D	E	F	G
0	2	5	7	5	4	3
*	*				*	*

At Level 5:

Compare TLs for node C, D and E and make the smallest of them a PL
Note:
If there is a tie, choose any path
IfTL(E)≤TL(C)AND TL (E)≤TL(D)
THEN
PL =node E
ELSE
PL≠node E
Subject to further comparison test
But since the above logical condition is true then
PL = node E = 5km

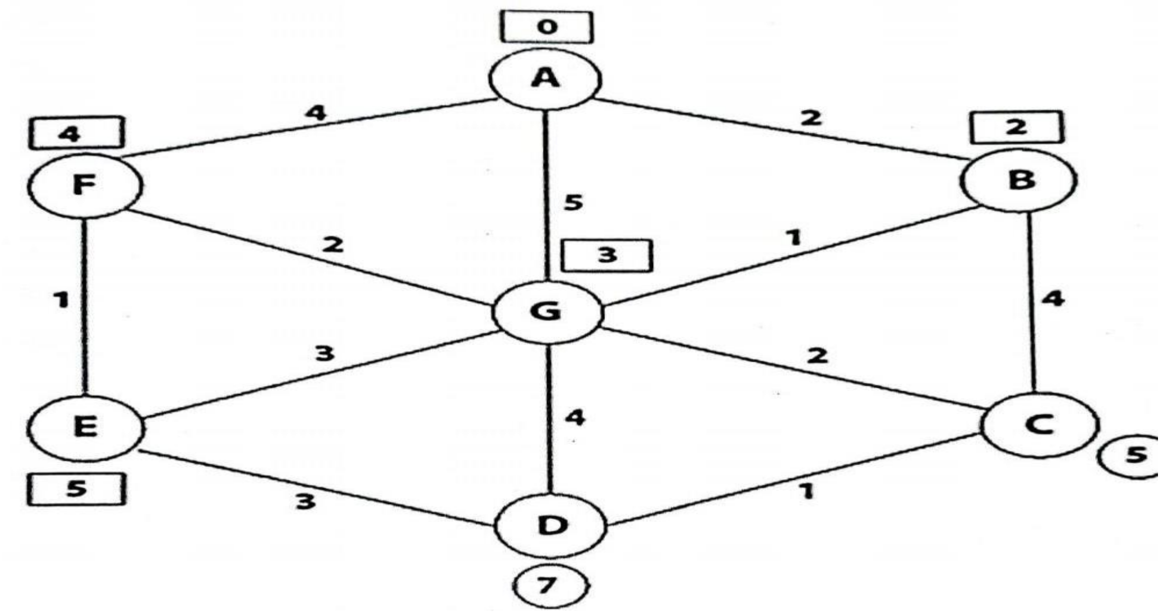

Figure 6: The network model at iteration 5

See the network model and sequence of the nodes at level 5

A	B	C	D	E	F	G
0	2	5	7	5	4	3
*	*			*	*	*

At Level 6:

Compare TLs for nodes C and D, and make the smallest of them a PL. IF TL (C) <_ TL (D)
THEN

PL = node C

ELSE

PL = node D

Hence, since the above logical condition is true, then PL =node C=5km

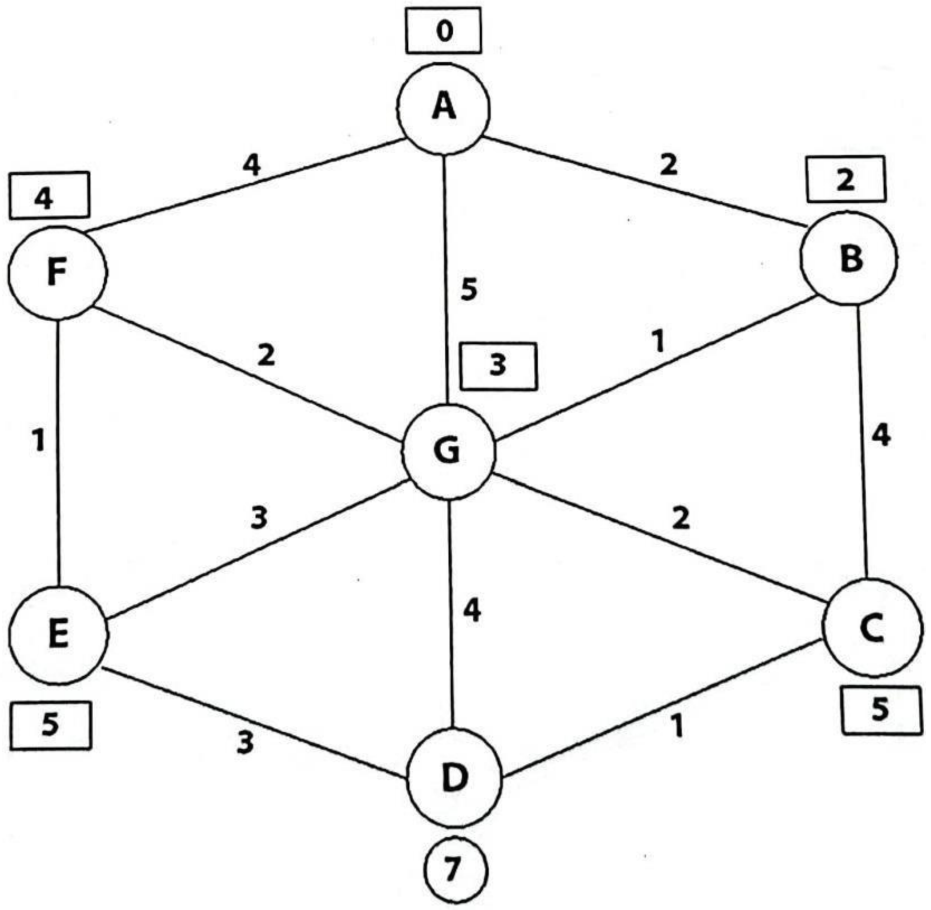

Figure 7: The network model **at** iteration 6

See the network model and sequence of the nodes at level 6

A	B	C	D	E	F	G
0	2	5	7	5	4	3
*	*	*			*	*

At Level 7: Update PL for node D and make it a permanent label automatically. Hence, the algorithm automatically comes to a halt. See its network model and its sequence of nodes below:

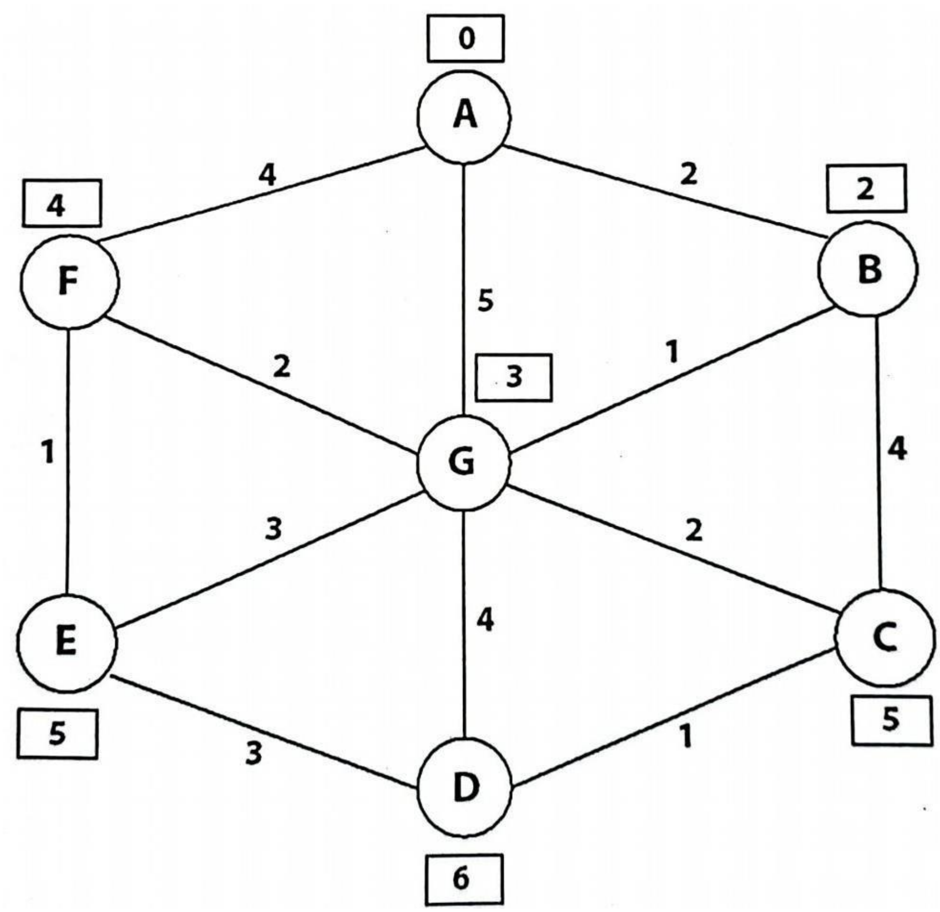

Figure 8: The network model at iteration 7.

See sequences of nodes

A	B	C	D	E	F	G
0	2	5	6	5	4	3
*	*	*	*	*	*	*

Number of nodes

Node A which is the source node, represents the Blue Rose water company at Marian market where water is produced at commercial quantities to be distributed to their customers at the warehouse, passing through B, C, D, E, F and G situated within Marian market. The nodes represent the buildings while the edges represent the direct distance in kilometer from Blue Rose company i to the warehouse j in the network.

The source node is A and destination is node D. The aim is to determine the shortest path that will lead to the minimal utilization of time in accessing the warehouse from the company, at a constant speed of 30km per hour, via the interconnected nodes in the network. Hence, five (5) alternative routes were chosen for the test.

Table 3: Alternative Routes from the network

R1: A → F → E → D: 0 + 4 + 1 + 3 = 8KM
R2: A → G → D: 0 + 5 + 4 = 9KM
R3: A → B → G → C → D: 0 +2 + 1 + 2 + 1 = 6KM
R4: A → B → C → D: 0 +2 + 4 + 1 = 7KM
R5: A → F → G → E → D: 0 +4 + 2 + 3 + 3 = 12KM

From the above computed routes, it is can be seen that the shortest route is route 3 in the network and its shortest weight cost is 6km.

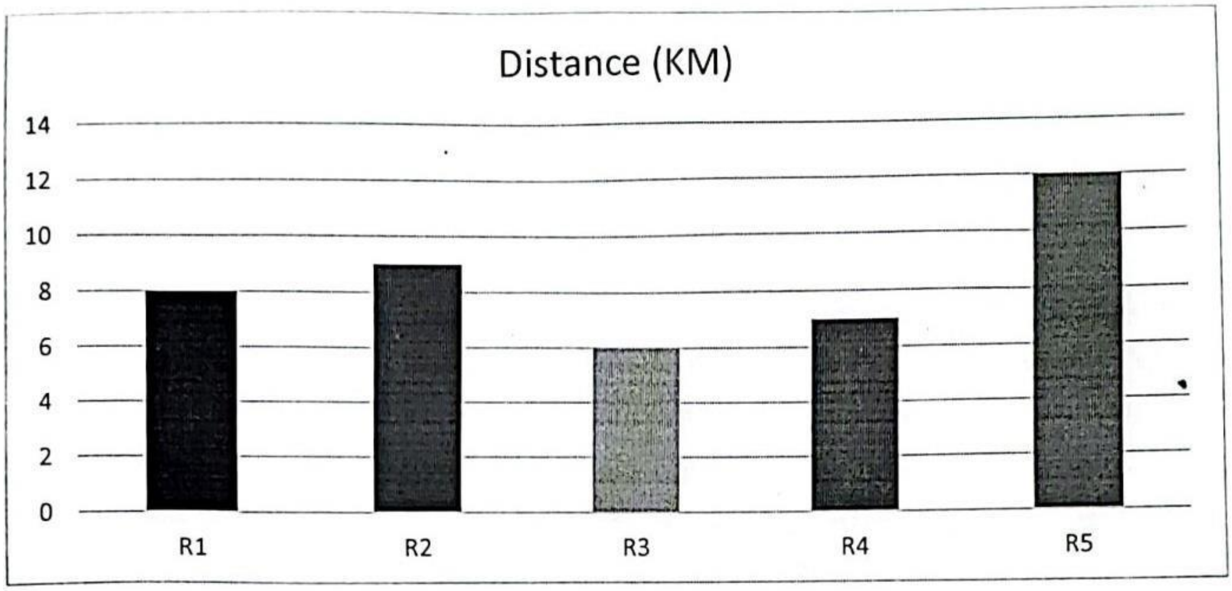

Figure 9: Graph of distance in kilometer against Routes

Advantages of the use of the modified Dijkstra's Algorithm:

Since time is a very important resource to both the distributor (the bus driver), the Management of Blue Rose water factory, and the customer, efficient utilization of this modified algorithm will be of great importance both to the customer, the bus driver and the management of the water factory in the following ways:

i. If the bus driver traversed through the shortest route in the network from the source node to access the destination node he will use less fuel, reduce the wear and tear effect of the his bus (E.g. tyre, brake, lining, etc.) and will access his destination at the shortest possible time.

ii. For the management of the water factory, there will be an increase in the profit based of the business transaction via the supply of its products through the shortest route in the network.

iii. Finally, on the side of the customer, time is money for their businesses, hence adequate utilization of this algorithm will increase their optimal time for receiving the water factory products

5.3 Conclusion

Analysis of the shortest path of a proposed system for optimal collection and supply of water product was carried out in this paper using the Modified Dijkstra's algorithm. Blue Rose water company, which is the case study, is used as the starting point, which represents the initial node A on the weighted graph in figure 3. The end point is taken to be the warehouse, which represents our target node D. From the results obtained, it can be concluded that the shortest distance between Blue Rose water company and the warehouse is 6km. This has to be put into consideration by Blue Rose water company so as to cut down cost and save time of the customers, as a result of the shortest route identified in this study.

References

Agarana, M. C., Omoregbe, N.C., & Ogunpeju, M. O. (2016). Application of Dijkstra Algorithm to Proposed Tramway of a Potential World Class University. Applied Mathematics, 07(06), 496-503. https://doi.org/10.4236/am.2016.76045

Alam, M.A., & Faruq, M.O. (2019). Finding Shortest Path for Road Network Using Dijkstra's Algorithm. Bangladesh Journal of Multidisciplinary Scientific Research, 1(2), 41-45. https://doi.org/10.46281/bjmsr.v1i2.366

Anupama, T. & Anuj, K. (2014).Routing Algorithm for Computer Networks. Research Scholar, Mewar University. Accurate Institute of Science and Technology. International Journal of Advanced Research in Computer Science & Technology, 1(3):1-14.

Bast, H. Funke, S. Sanders, P., & Schultes, D. (2007). Fast Routing in Road Networks with Transit Nodes. Science, 316(5824), 566.https://doi.org/10.1126/science.1137521

Binder, &, Nannicini D. (1999). Time-Dependent SHARC-Routing.In

Proceedings of the 16th Annual European Symposium on Algorithms (ESA'08), volume 5193 of Lecture Notes in Computer Science, pp.332-343 Creswell, J. (2003).Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. Thousand Oaks, California: Sage Publications

Delling, D. & Nannicini, G. (2008). Bidirectional Core-Based Routing in Dynamic Time-Dependent Road Networks. International Symposium on Algorithms and Computation. 812-823.

Fan, DongKai P (2010). Improvement of Dijkstra's algorithm and its application in route planning. https://doi.org/10.1109/FSKD.2010.5569452

Hetzel, P., & Jacobson, V. (1988). Congestion avoidance and control. Proceedings of ACM SIGCOMM 1998,314-329.

Huang, Y.Z., Yi,Q.M.,& Shi,M. (2013). An Improved Dijkstra's Algorithm Based on Search Strategy. Applied Mechanics and Materials, 380-384, 16251628. https://doi.org/10.4028/www.scientific.net/amm.380-384.1625

Irony, S.I. and Rose, A.A. (2005) “Designing a Strategic Information Systems Planning Methodology for Malaysian Institutes of Higher Learning (isp-ipta). Issues in Information System, 5, 1.

Liu, C.L. (2010). CDADE: Conflict detector in activity diagram evolution based on speech act and ontology. Knowledge-Based Systems,23(6),536546.https://doi.org/10.1016/j.knosys.2010.03.011

Mahfiy & Whiting, P., (2012). A method for finding the shortest Route through a road network”. Operational Research Quaterly. 11 (1/2):37-40. doi:10.1057/jors.1960.32.

MG, A. (2015). An Intracity Route Management System Sanchari Mitra. International Journal on Recent and Innovation Trends in Computing and Communication, 3(4), 2302-2306. https://doi.org/10.17762/ijritcc2321-8169.1504115

Mocková,D., & Rybičková, A. (2014). APPLICATION OF GENETIC ALGORITHMS TO VEHICLE ROUTING PROBLEM. Neural Network World 24(1), 57-78. https://doi.org/10.14311/nnw.2014.24.003

Mullai,M. (2012). Fuzzy L-Filters. IOSR Journal of Mathematics, 1(3), 21- 24. https://doi.org/10.9790/5728-0132124

Navone, E.C. (2020, November 19). Dijkstra's Shortest Path Algorithm-A Detailed and Visual Introduction. FreeCodeCamp.Org.https://www.freecodecamp.org/news/dijkstrasshortest-path-algorithm-visual-introduction/

Norhafezah, K., Nurfadzliana A. H and Megawati, O. (2017). Simulation of Municipal Solid Waste Route Optimization by Dijkstra's Algorithm. Journal of Fundamental and Applied Science. (9), 732-747.

Peyer, S., Rautenbach, D., & Vygen, J. (2009). A generalization of Dijkstra's shortest path algorithm with applications to VLSI routing. Journal of Discrete Algorithms, 7(4), 377-390. https://doi.org/10.1016/j.jda.2007.08.003

Pradhan, A., & Mahinthakumar, G. K. (2013). Finding All-Pairs Shortest Path for a Large-Scale Transportation Network Using Parallel Floyd-Warshall and Parallel Dijkstra Algorithms. Journal of Computing in Civil Engineering, 27(3), 263-273. https://doi.org/10.1061/(asce)cp.1943-5487.0000220

Pratap Singh, D., & Khare, N. (2016). Modified Dijkstra's Algorithm for Dense Graphs on GPU using CUDA. Indian Journal of Science and Technology, 9(33). https://doi.org/10.17485/ijst/2016/v9i33/87795

Pushpalatha & Anuradha, (2019). Extending Lifespan of the Network using Shortest Path Low Latency Routing Protocol (SPLLR) for Wireless Sensor Networks. (2019). International Journal of Innovative Technology and Exploring Engineering, 9(1S), 355359.https://doi.org/10.35940/ijitee.a1071.1191s19

Rachmawati, D., & Gustin, L. (2020). Analysis of Dijkstra's Algorithm and A* Algorithm in Shortest Path Problem. Journal of Physics: Conference Series, 1566, 012061. https://doi.org/10.1088/1742-6596/1566/1/012061

Rumpe, B. & Sandner, R. (2001). UML-Unified Modeling Language im Einsatz. Teil 3: UML-RT für echtzeitkritische und eingebettete Systeme (Unified Modeling Language in Practice. Part 3:UML-RT for Real-Time and Embedded Systems). Auto,49(11), A15. https://doi.org/10.1524/auto.2001.49.11.a15

Sabri, N.A. M., Basari, A. S.H., Husin, B., & Samah, K. A. F.A.(2015).The Utilisation of Dijkstraâ TMs Algorithm to Assist Evacuation Route in Higher and Close Building. Journal of Computer Science,11(2),330-336. https://doi.org/10.3844/jcssp.2015.330.336

Safarinejadian, B., & Mozaffari, M. (2015). Mobile Agent Based Distributed EM Algorithm for Data Clustering In Sensor Networks. Intelligent Automation & Soft Computing, 22(1), 45-60. https://doi.org/10.1080/10798587.2015.1039246 44

Shivani, & Bansal, D. (2017). Technique for Text Region Detection in Image Processing. International Journal of Advanced Research in Computer Science and Software Engineering, 7(7), 68. https://doi.org/10.23956/ijarcsse.v7i7.100

Shu-Xi,W.(2012).The Improved Dijkstra's Shortest Path Algorithm and Its Application. Procedia Engineering, 29, 1186-1190.

https://doi.org/10.1016/j.proeng.2012.01.110

Thorup M. (2014).“Undirected single-source shortest paths with positive integer weights in linear time”. Journal of the ACM (JACM). 46 (3):362-394. doi: 10.1145/316542.316548. Retrieved 24 July 2017.

Wai & David M. (2018). Mount “Design and Analysis of Computer Algorithms" Department of Computer Science volume 5369 of Lecture Notes in Computer Science, pp. 813-824.

Wei,S., Shimbel, D., & Whiting P (2010). “Structural parameters of communication networks". Bulletin of Mathematical Biophysics.15(4): 501-507. Woltmann, S. (2021b, January 27). Dijkstra's Algorithm (With Java Examples). HappyCoders.Eu. https://www.happycoders.eu/algorithms/dijkstras-algorithm-java/

Yurkiewicz, J. (1989). Operations research: Applications and algorithms, by Wayne L. Winston, duxbury Press, Boston, 1987, 1025 pages.