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ORIGINAL RESEARCH ARTICLE

SHORTEST ROUTE: A MOBILE APPLICATION FOR ROUTE OPTIMIZATION USING DIGITAL MAP

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ABSTRACT

Businesses that have embarked on using digital maps have been able to increase employee productivity, communicate visually; reduce cost of logistics, planning, resources by more than half of its initial cost. Many industries that have benefitted from this technology include Online Markets, Delivery companies, Agriculture, Real Estate, Engineering, Media, Energy and Utilities, Insurance, Architecture. Seeing this need especially in Nigeria where cost of logistics is high, resources are wasted in the process and productive time is also wasted leading to fatigue and low outcome; there is therefore the need for route optimization for businesses in Nigeria. TSP (Travelling Salesman Problem) - Nearest Neighbour Algorithm is used to solve the problem of route optimization on Google MAP. This study developed a mobile application in Java, HTML and Google SDKs, to find shortest route between various numbers of locations enumerated on digital maps on a smart device. The application was implemented successfully on the Android Operating System for mobile devices. Anyone can download it from the Google play store, install and freely use.

1.0 Introduction

Optimization involves finding an alternative with the most cost-effective or highest achievable performance under given constraints, by maximizing desired factors and minimizing undesired ones (Ibidapo-Obe and Asaolu, 2006). Thus "Route Optimization" is planning destination(s) along a start-end combination with cost-effective or utmost achievable performance within known constraints. It involves maximizing manpower and customer satisfaction whilst minimizing inconveniences, time, resources and fatigue (Korel et al., 2018). One of the most important factors in the success of a central business region in recent times is cost reduction (manpower, logistics, time, resources.). This study provides a solution to an aspect of route optimization in a metropolis via a mobile application. This approach was considered because in recent times, people usually access information on the internet via mobile devices. The ShortestRoute mobile application is created using mapping technology to solve the travelling salesman problem (TSP) of finding the shortest route between multiple destinations while visiting each destination only once and returning to the initial destination, by using the Nearest

Neighbour Algorithm. In using this mobile application, users can easily find the shortest route with unlimited number of destinations, re-order the desired destinations, select any starting point (address) and save the list of re-ordered addresses for future use. In order to plan an effective route, important factors to be considered are convenience, time and an optimized route; ultimately saving money, resources and energy. For instance, a route of 9 addresses can be sequenced in 362,880 ways using permutations which can become stressful to enumerate and consider. It is time consuming to identify the optimal result by brute-force search. These problems emerge in real-life problems like a postman that needs to reach 50 different destinations to deliver letters or an online market dispatch rider who needs to deliver goods to about 20 different customers within a region. Imagine trying to plan a route for this number of destinations. Tedious! This mobile app solves such problem in seconds with options useful to the user. With the trend in technology, it is observed that businesses need to stay competitive (Brown et al., 2012) by reducing cost (in terms of time and deployed resources). Those that have embarked on using digital maps have been able to increase employee productivity, communicate visually; reduce cost of logistics, planning and resources by more than half of its initial cost. Industries that have benefitted from this technology include Online Markets, Delivery companies, Agriculture, Real Estate, Engineering, Media, Energy and Utilities, Insurance and Architecture amongst others.

1.1 Route Optimization

Routing optimization problems on networks consist of finding paths (simple paths, closed paths, tours, or walks) between nodes of the networks in an efficient way. These problems and their solutions have proved to be essential ingredients for addressing many real-world decisions in applications as diverse as logistics, transportation, computer networking, internet routing, to name a few. In many of these routing applications, especially those imposing deadlines on when to visit nodes, the presence of uncertainty in the networks (such as presence or not of some of the nodes) is a critical issue to consider explicitly if one hopes to provide solutions of practical values to the end users. The deterministic version of many routing optimization problems (such as shortest path problems, traveling salesman problems, vehicle routing problems) have been studied extensively over many decades. Due to the recognized practical importance of incorporating uncertainty, the uncertain versions of routing problems have also attracted increasing attention. Researchers have established distinct selection criteria. One intuitive and well-discussed way is to select a route with the largest probability of arriving on time (Bertsimas, 1992; Bertsimas and Sim, 2003; Bertsimas and Sim, 2004; Agra et al., 2012). For logistics and distribution companies, the rising cost of fuel means that they need to become efficient in the way they plan their transportation routes and schedules. The traditional methods of route planning do not address real time events that affect businesses every day. To accommodate customers short-notice requirements, route availability, and vehicle issues, route planning has to be able to respond quickly to any event to ensure the lowest cost of transportation. The basis for route optimization is the use of models to describe the transport network that needs to be planned. When building a model, the scope of the overall network should be well defined; ensuring that cogent information is considered, such as regulations and typical highway problems. The model has a number of components such as products, vehicles, and personnel.

Mobile GIS- Global Information System

The mobile GIS is emerging at the intersection of the evolution of mobility with the development of geo-informatics, it represents the user demand and ambition to exploit the geographic knowledge in decision support everywhere and anytime (Vu et al., 2019). Ubiquitous network analysis is a major requirement for many people moving with mobile devices, they need to comprehend their nearby location and manage their trips and movement. This aspiration is facing many challenges in online navigation from the accurate position to the geo data and up to algorithms and solutions for route problems. The visualization of the geospatial data is the main concern of the mobile user. Through it, the user can build his/her mental image about the space around. The mobile cartography is related to the display of geographic information on the screen of mobile device. It has distinct differences from digital cartography, first the screen size and resolution are much smaller, second, it targets only single user in mobility, third, it is not connected to a plotter or printer for hardcopy output, fourth, the user current location is the fundamental feature at the centre of the display, and finally it displays minimal amount of features. The main objective of mobile cartography is to make the user aware of his/her location, direction, and important features around, and this is for the real-time display of geographic information. The other applications of mobile cartography are the enquiry of existing geographic data and performing proximity and network analysis for the required destinations, such as the optimal path from origin to destination. The mobile cartography presents to the user the required geospatial information in the required time and adopts the geospatial data to fit the mobile device requirements at information level. The mobile device has limited hardware resources and most notably small screen with low resolution, which has effect on cartographic representation (Reichenbacher, 2001). The statistical maps are hard to be displayed on a mobile device, same as for cartograms maps related to dense analysis of geospatial data. The dot thematic maps are essential in mobile cartography in order to represent the locations important to a mobile user. The mobile user expects from the mobile GIS to display on its screen the position and direction of the user, the location of specific features and how to navigate from one place to another (Rajagopal et al., 2014).

TSP- Travel Salesman Problem

The Traveling Salesman Problem (TSP) is one of the most intensively studied problems in optimization (Claus, 1984; Kara and Derya, 2015). Loosely speaking, given a set of locations on a map, the problem consists of finding a tour that goes through each city exactly once and ends in the same point it started with. There has been much research done on finding efficient heuristics to get provably optimal and close to optimal solutions to TSP problems (Ha et al., 2018). In this study, the nearest neighbour algorithm is used to implement the Mobile Application. The nearest neighbour algorithm is easy to implement and executes quickly, but it can sometimes miss shorter routes which are easily noticed with human insight, due to its "greedy" nature. As a general guide, if the last few stages of the tour are comparable in length to the first stages, then the tour is reasonable; if they are much greater, then it is likely that there are much better tours. Another check is to use an algorithm such as the lower bound algorithm to estimate if this tour is good enough.

Minimum Travel Cost Approach For Travelling Salesman Problem

TSP is a prototype of hard combinatorial optimization problem where the possible solutions are (N-1)! and is considered NP-hard and NP-complete. The prevalent algorithms to solve TSP are heuristic algorithms which do not necessarily guarantee the minimum cost (Eleiche, 2015). The standard technique for obtaining lower bounds on the TSP problem is to use a relaxation that is easier to solve than the original problem such as the cutting-plane algorithm through linear programming initiated by Dantzig, Fulkerson and Johnson in 1954, but still unable to solve large instances (Averbakh and Lebedev, 2004).

Minimum Travel Cost

A full graph of N nodes (with number of edges N*(N -1) having edges of equal cost C, the tour cost is N*C and there are (N-1)! tours satisfying this cost. For asymmetric graphs, where Cij ≠ Cji, the TSP states that there are (N-1)! tours visiting all nodes (each node once) and returning to the origin, but the required is the tour of least cost. This can be achieved by visiting each node through its least travel cost. The least travel cost for each node is the sum of the cost of incident edge with minimum cost and cost of outgoing edge with minimum cost.

$$C_i = \min C_{incident} + \min C_{outgoing} \tag{1}$$

where: C_i is the least travel cost of node i,

$C_{incident}$ is the edge cost from node k to node i, and

$C_{outgoing}$ is the edge cost from node i to node j.

In ideal situations, (though rare), the aggregation of the sequence of minimum travel cost (nodes: k, i, j) for each node will be the tour with least cost. The minimum travel cost unifies the directions of paths for the minimum travel cost of each node thus minimizing the TSP total cost.

Android Based Mobile Application Development

In the advancing world of technology mobile applications are evolving at a fast pace to give users a unique personal experience. Google released Android which is an open-source mobile phone operating system with Linux-based platform. It consists of the operating system, middleware, and user interface and application software. Android is a new, next-gen mobile operating system that runs on the Linux Kernel. Android Mobile Application Development is based on Java language codes, as it allows developers to write codes in the Java language. These codes can control mobile devices via Google-enabled Java libraries provided in the Google Android SDK. Aside the standard Java Virtual Machine (JVM), Google has created a custom VM called Dalvik which is responsible for converting and executing Java byte code on Androids. As developers, we only need call the relevant Application Programming Interface (APIs) to develop applications on the Android platform as we build product the interface via layered approach. As at early 2015, 48.61% of mobile devices are operating on Android OS, 11.04% on iOS, 14% on Windows and 26.34% use other operating systems (Android, 2015). This gave a clear distinction on the platform to create the mobile application apart from the reality that android application courses are easier to access, create cheaper platforms for learning, an open marketplace and simple to inculcate for a mobile application beginner (Brahler , 2010).

2. Methodology

Programming, testing and deployment tasks were accomplished to build the mobile app by:

App development using OS with Eclipse IDE, JDK (Java SE Development kit) IDE and XML (Extensible Mark-up Language)

Called Google Map API for the access to Digital Maps using Java programming language

Invoked GPS (Global Positioning System) on mobiles for Navigation to find the current location of user

Created a test website using HTML (Hypertext Mark-up-Language), JQuery (JavaScript Query) and JavaScript that gives full instruction on how to use, navigate and download the Shortest Route mobile application (www.shortestroute-app.com)

Created required certificate and version for publishing on the Google Play Developer Console
Uploaded product on the Google Play Developer Console for Beta and Alpha Testing
Final live upload to the Google Play Store for user download and installation.
Uploaded product on the Google Play Developer Console for Beta and Alpha Testing
Final live upload to the Google Play Store for user download and installation.

Figure 1 shows some stages of the ShortestRoute Mobile Application Development as described in steps i to iv above.

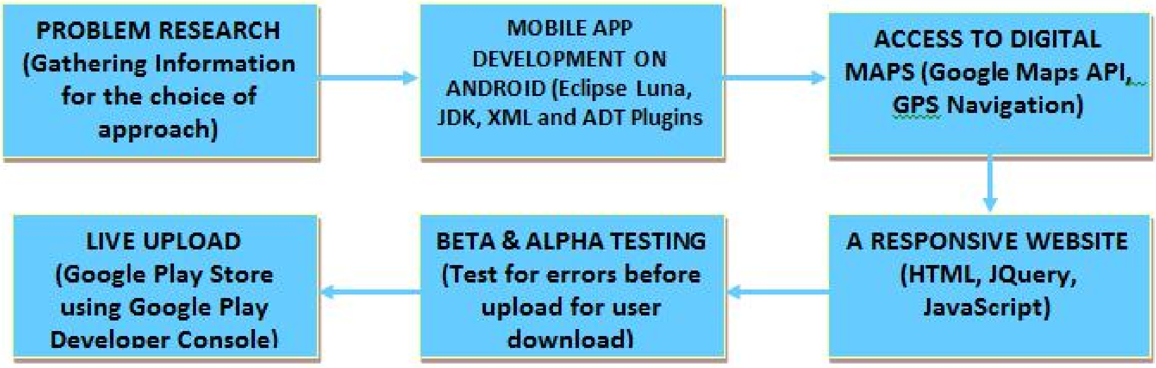

Figure 1: ShortestRoute Development Chart

For the nearest neighbour implementation so solve the TSP, the algorithm is depicted in the flowchart of Figure 2. The sequence of the visited vertices is the output of the algorithm.

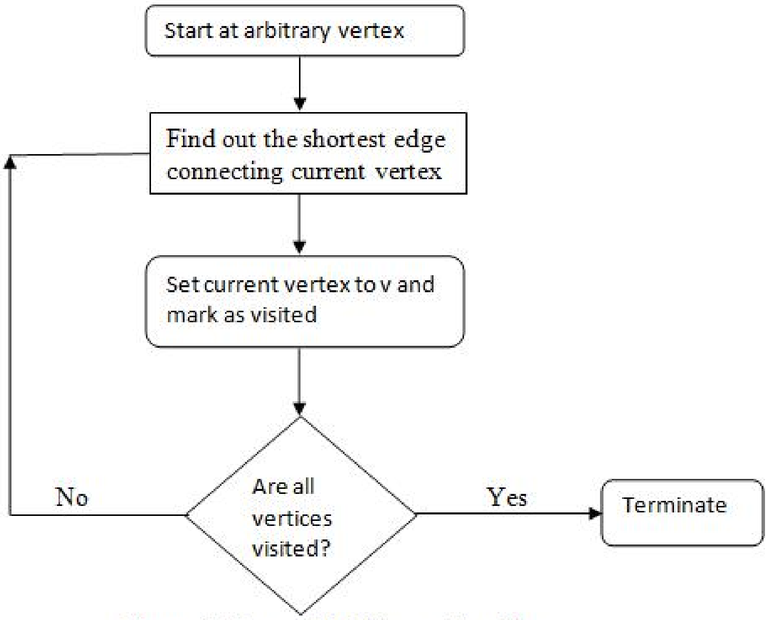

Figure 2: Nearest Neighbour Algorithm

Google Maps provides directions, interactive maps, and satellite/aerial imagery of many countries. Google Maps is the only site surveyed that readily allows users to search by keyword for points of interest, and its mapping service allows users to refine searches interactively. The

API uses images from the popular Google Earth application to provide optional satellite views of locations around the globe. This is also the best site for viewing international online maps because it does not require complete address information. 57% of all digital maps use the Google Maps API (Reichehenbacher T. 2003). Using the Google Map application programming interface is a skill any programmer could learn by consulting the accompanying Google documentation, numerous online support groups and tutorial sites. With the Google Map API, we were able to create a map layout. Since Smart mobile devices already come with a GPS Tracker, our Android Mobile Application provides users ability to view current location, unlimited numbers of location on the map, get the route pattern, order the route and save the route via their Android OS Mobile Devices. It is important to evaluate the features of the mobile application and the development of the application. There were a wide range of compatibility and design requirements from the Google Play Developer Console to publish the ShortestRoute mobile application. However, before publishing on play store, the mobile application was tested for functionality and compatibility for all android OS devices from version 3.0. Currently, most android mobile devices run on version 4.4 or later. The ShortestRoute mobile application was tested on 23 different mobile devices from different products that include HTC, Nokia, Tecno, Sony, Huawei, Infinix, Samsung and Gsmart. A rigorous test on different Android OS versions ranging from 3.0 (Honeycomb) to 5.1 (Lollipop) was carried out before embarking on Google Play Developer Console for publishing. We tested the built App to ensure successful implementation of basic features such GPS tracking, Map loading and zooming, time and distance indicators, ability to save or delete locations. Several functionality evaluations were carried out to develop a flexible mobile app for users with notifications guiding the user.

When the app is about to launch, the following conditions are considered.

If Internet connectivity is on and GPS is on, it would automatically find the user's current location and automatically becomes the "starting point" of the journey.

If Internet connectivity is on and GPS is off, it would show a dialogue box asking if you need GPS on. If yes, immediately points to settings where GPS/location is activated. If no, the mobile app continues with the world map display. Once the first address is entered, it takes it as the "starting point".

If Internet connectivity is off and GPS is on, a dialogue box is opened to ask if user wants to turn it on internet connectivity. If yes, it immediately points to settings where internet connectivity is activated and shows a notification that mobile app should be reopened if it has been activated. If no, a notification explaining that the mobile app cannot work without internet access will come up.

If Internet connectivity is off and GPS is off, the process for turning on Internet connectivity and GPS above will initiate.

If Map connectivity is not showing, then the mobile device needs to install or update Google Play Services on the mobile device.

Figure 3 shows the app interface while Figure 4 illustrate the framework for the mobile app operations.

Figure 3. The interface of the ShortestRoute Mobile App

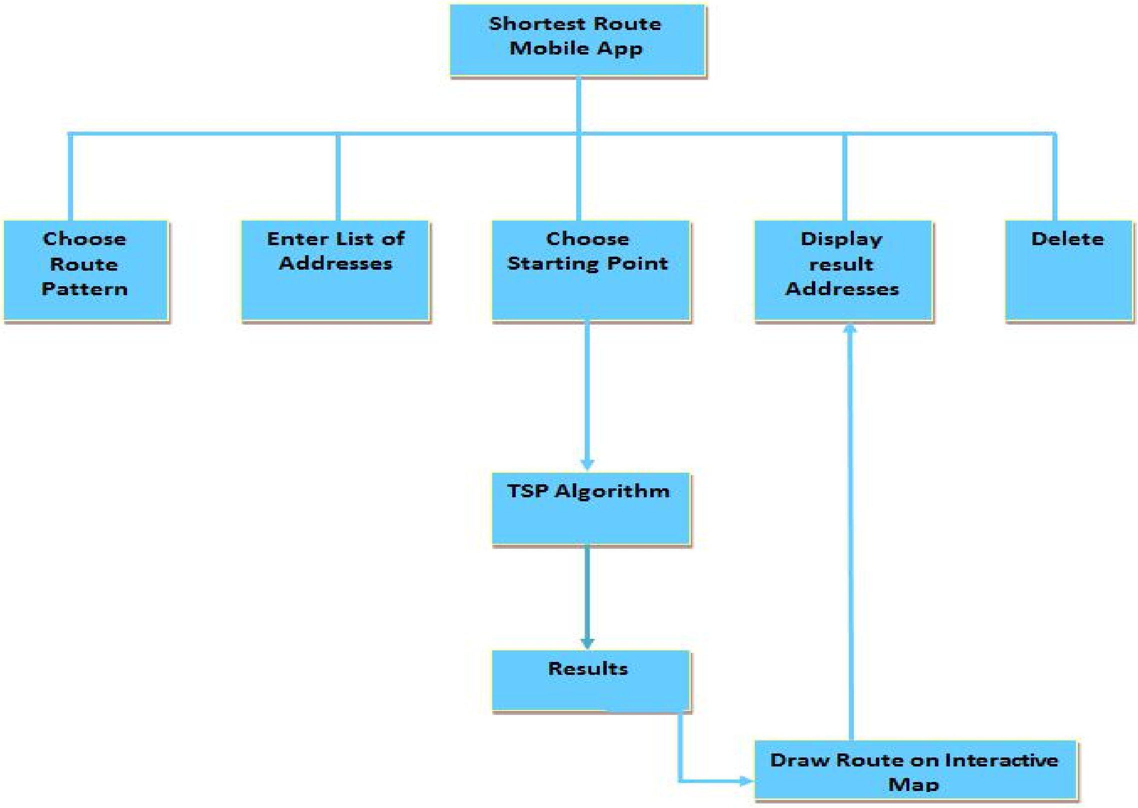

Figure 4. ShortestRoute Framework Architecture

Google Maps is used for displaying locations/addresses, showing the user's current location and route directions of the user's listed addresses (Hu, 2012; Hu and Dai, 2013). The Google Earth Engine is used as the webserver to get information for location points' addresses. The mobile app runs on Google Play Services and internet connectivity. A temporary, responsive test

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website (www.shortestroute-app.com) was created with Dreamweaver IDE, HTML and JavaScript Query! to give users easy access to information on the navigation and step-by-step guide for ShortestRoute Mobile Application usage. The responsive website also gives access to easy download of the mobile application from Google Play Store. This was to provide an optimal viewing experience, easy reading and navigation with a minimum of resizing, panning, and scrolling across a wide range of devices (from desktop computer monitors to mobile phones).

Google Play, which was originally referred to by Google as "Android Market," is Google's official store and portal for Android apps, games and other content for Android-powered phone or tablet, just as Apple has its App Store. ShortestRoute Mobile App is successfully uploaded to the Google Play Store for downloads after going through the Beta and Alpha Test phases. Anyone could visit www.play.google.com and search for ShortestRoute. It automatically opens the download page shown in Figure 5 below.

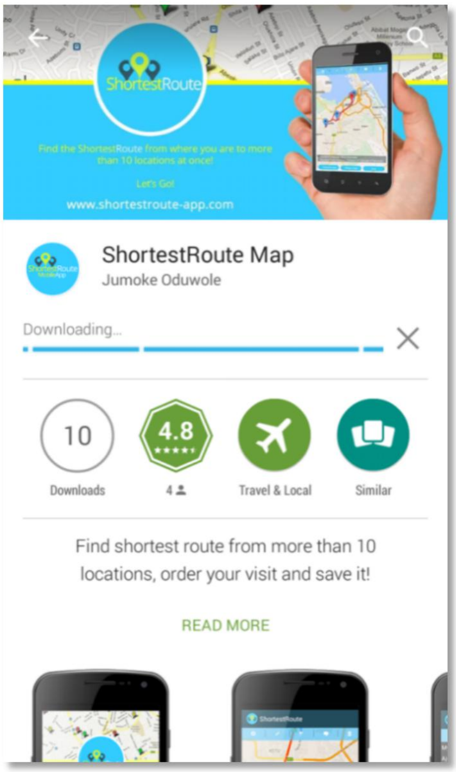

Figure 5. ShortestRoute view on Google Play Store via smartphone

3. Results and Discussion

Typical screnshots of the startup are provide in Fugures 6 and 7.

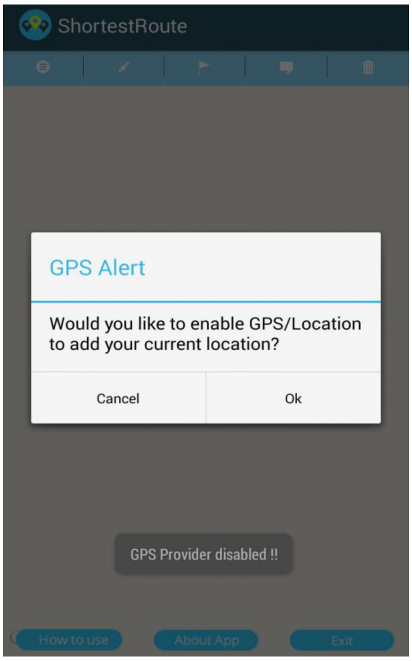

Figure 6. ShortestRoute mobile App showing the GPS Dialogue Box

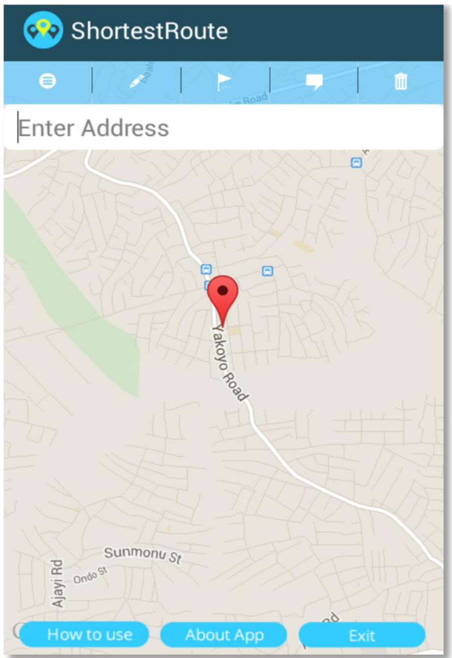

Figure 7. ShortestRoute mobile App when GPS is on, automatically points to user's current location

For the 20 sample runs performed with locations in Lagos metropolis, the product generated feasible paths which are optimal in all cases. ShortestRoute Mobile application was found easy to use; appropriate notifications were generated to notify user on every step to take while using the app. All the possible uncertainties in the use of the mobile application were covered. However, the application can also be easily updated to accommodate new features and developments that include real-time traffic update data. ShortestRoute integrated the combination of existing innovational technologies for its implementation. Some of these technologies include an android mobile app, Google Maps, GPS Tracker, a responsive website and the Google App Engine as webserver for feeding information to the mobile app. ShortestRoute Mobile App users includes street travelers, tour guides, delivery service providers, tourists, professional drivers and logistics planners. The app solves the problem of routing for individuals or firms and help improve productivity and efficiency. A ShortestRoute Mobile App user saves time, resources, energy and cost of transportation by easily entering address on the mobile app and getting the best route pattern for his journey. The mobile application with its user friendly interface will enable developed countries include traffic updates with Real time data to get best route with time.

The following improvements could be considered in future research:

Currently, the app gives best route with respect to total distance and not expected duration of travel because it does not incorporate traffic updates that could give the best time. Real-time data on traffic updates can be integrated into this application.

ShortestRoute mobile App is currently not capable of showing the walk routes and bus routes to users. This can be integrated from the Google App Engine webservers to allow walk routes and bus routes in the route Optimization method.

ShortestRoute Mobile App does not give information for different modes of Transportation. This feature can be integrated in future research.

Google Streetview can be integrated showing the street view of locations entered.

ShortestRoute Mobile App can be implemented on other Mobile OS platform to allow users on other Mobile OS platforms such as Apple iOS or Microsoft Windows get the benefits of the app.

Voice Mapping to give directions during navigation to multiple destinations and Message Texting to automatically receive SMS (Short Message Service) on routes planned and other features used.

4.0 Conclusion

ShortestRoute mobile app was successfully developed, tested and deployed to the Google Play Store for Android devices. Adopting it cuts logistics planning cost thereby increasing business performance, productivity, growing delivery volumes and customer satisfaction in businesses. Shortest ShortestRoute can be used by individuals, tourists, campaign managers, band tour managers, businesses that run transport systems as in schools, street travelers, professional drivers, delivery service providers, mail dispatch services in making informed decisions about different locations to visit. It is cost effective, for all it only requires is an android mobile device and Internet connectivity. This route optimization mobile app has proven to be useful to users who have currently installed the app and are using it to run and plan routes frequently, as evident in their online review comments. Business owners should adapt its use for better performance in their businesses. The ShortestRoute can be extended to manage schedules, and appointments for users. Reports could be generated on transport logistics performance using Key Performance indicators.

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