Optimization and Decision Making for Route Selection as an Alternative of Google Maps Considering Sustainability

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ABSTRACT

The concept of smart cities has been developed with advances in information and communication technologies (ICT). Aging infrastructure, declining budgets, changing population, sustainability, and investments are some of the current issues in urban environments. In many different types of the context of smart city solutions, transportation and logistics form the main part of that solution. Hence, there is a need for leveraging the digital footprint and using the data along with the decision tools to get the best performance of the infrastructure assets. The decisions between all options of transportation are currently based on current time and traffic conditions, and other factors such as sustainability, and costs are not considered. This paper aims to create decision support tools to make city planning and operations more efficient and improve the quality of life of citizens along multiple dimensions. The proposed method tries to investigate various factors of each transportation option including but not limited to the cost, times to be taken, and fuel consumption.

Keywords: Smart City, Transportation, Greenhouse Gas Emission, Sustainability.

INTRODUCTION

The idea of the smart city rises out of a reflection on how the advancement and unavoidable use of the Information and Communication Technology (ICT) can impact the urban advancement, the financial conditions, and the personal satisfaction. Over the last decades, cars have become the primary mode of transportation, and in turn, they have a large impact in the way our cities have and are being shaped (Amouhadi et al. 2019). Therefore, to understand the concept of smart cities it is important to understand why cities need to be considered as one of the important key elements in the future. Smart Cities depend on the instrumentation and interconnection of cell phones, sensors, actuators, and empowering the urban information collection. Hence, the examination of smart cities will generously enhance the ability for estimating and dealing with the urban streams expanding (Olufowobi and Bloom 2019).

Numerous real urban communities around the globe are seeing fast populace development, bringing about the expanded strain on the existing street and open transportation organize framework as the numbers on the everyday drive swell. Shrewd versatility – putting information, data, and alternatives in the hands of the voyaging open – has been valuable to a considerable lot of these urban communities, permitting better utilization of settled assets and more productive development around the urban space. Opening up live and static datasets for open utilization can be cheap and clear with respect to the cost of building a new physical foundation, especially where sensor data can be effectively gotten to through existing control frameworks and deliberately indicated new desirable foundation (O'Brien 2017).

For smart mobility in cities, there are some mobile and/or web applications such as Google Maps and Waze which help the user to move from one location to another on the basis of time and distance as the only factor to be considered for optimization. But, the main objective of this research is to come up with such an output which gives options to the user taking into consideration of time, distance, and fuel consumption after getting the input for the origin and destination by the user.

RELATED WORKS

To understand the concept of a smart city, it is important to recognize why cities are considered key elements for the future. Cities play a prime role in social and economic aspects worldwide and have a huge impact on the environment and economy (Albino et al. 2015).

Environmental change is affecting cities and their inhabitants more regularly. Therefore, city planners need to consider these challenges such as the need to improve air and water quality, and control noise pollution to create a healthy and enjoyable environment for city inhabitants. Within the last decade, climate change has become a greatly discussed topic. Globally, transportation accounts for 25 percent of all black carbon emissions, of which diesel engines account for approximately 70 percent. The U.S. produces approximately 6.1 percent of the world's fossil fuel and biofuel soot, and on-road vehicle emissions are expected to decrease by as much as 90 percent as federal fuel efficiency requirements increase (Council 2011). Therefore, policymakers are primarily pushing for more efficient vehicles, alternative fuels, and reducing Vehicle Miles Traveled (VMT) in order to reduce CO2 emissions. Those who develop vehicle have focused on building vehicles in order to improve powertrain efficiency and introducing alternative technologies such as hybrid and fuel cell vehicles (Barth and Boriboonsomsin 2009). Alternative fuel possibilities include many low-carbon options such as biofuels and synthetic fuels. But, less attention was always taken on reducing CO2 emissions by reducing traffic congestion. Fuel consumption and consequently CO2 emissions are increased as traffic congestion increases. Therefore, congestion mitigation programs should reduce CO2 emissions.

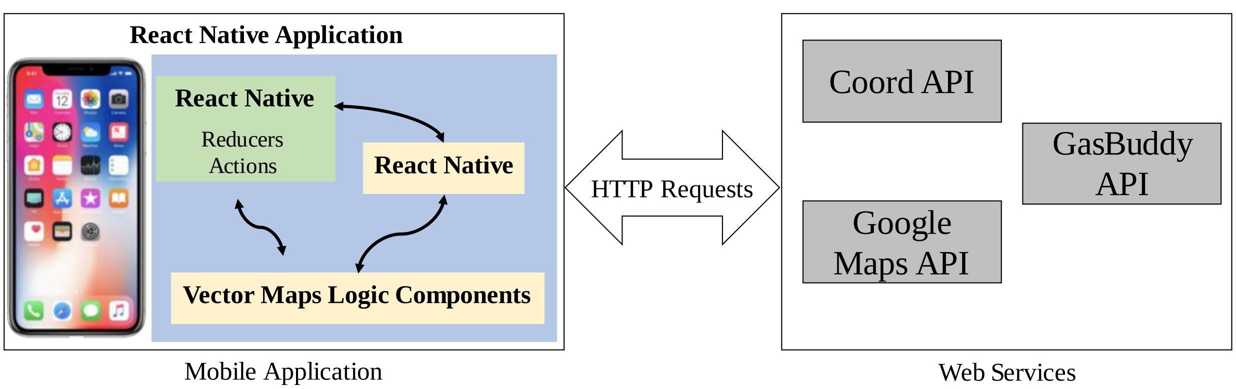

Figure 1. An overview of the proposed method.

In this research, a comprehensive methodology was developed to measure the vehicle CO_2 emission as well as showing the relationship between the traffic congestion and CO_2 emissions of the cars by optimization and decision making for route selection as an alternative of Google Maps. With this methodology, we can estimate how congestion mitigation programs will reduce CO2 emissions and consequently improve sustainability.

METHOD

This research paper develops and presents a system for creating a mobile phone application in order to retrieve distance, time, and CO_2 emissions for each road alternative that application suggests. Figure 1 shows an overview of the proposed method.

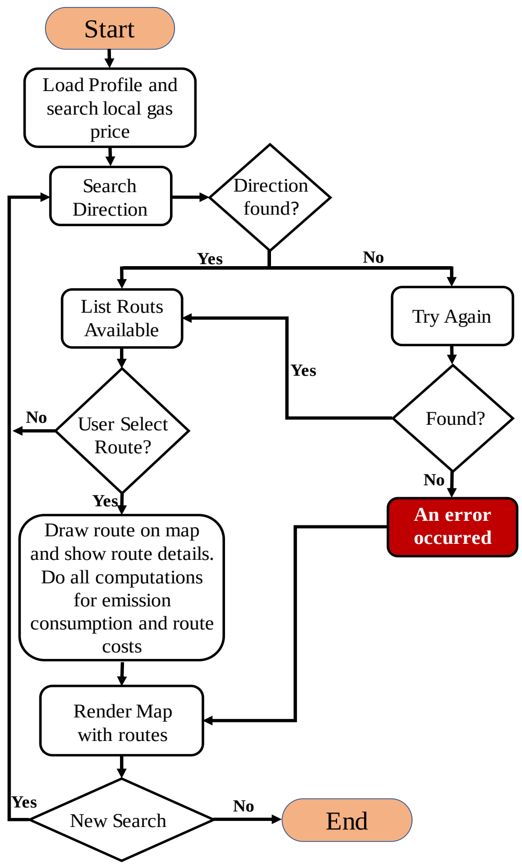

Figure 2. Basic flowchart of application load and directions lookup.

As shown in Figure 1, all services that pertain in the mobile application and the web services are connected via simple HTTP (Hyper Text Transfer Protocol) requests. The proposed mobile application is developed in React Native. React Native is a cross-platform framework developed by (Occhino 2015) to create mobile applications targeting iOS and Android mobile phone operating systems while attempting to focus primarily in one programming language of JavaScript. But Java Script is not limited to only being used exclusively, native code such as Objective C and Java for iOS and Android can be used in order to leverage specific use cases such as accessing the mobile phone's hardware. The primary reason for selecting React Native is its flexibility and ease of use while helping to develop and evaluated this application. The React Native mobile application has three main components of:

1. *React Redux*: A React Native framework handles the state of the application. It comprises of reducers and actions in order to propagate the state to all screens of the application.

2. *Axios:* A React Native component that provides the ability to make HTTP requests to external web services.
3. *Maps Logic Components:* The core logic of the application which comprises of all models and screen components.

The basic flow chart of application load and direction look up is depicted in Figure 2.

Travel Time and Distance

The Google Maps API helps in getting the multiple routes based on the integrated depending factors including time and distance. Afterward, the same colored code as used in Google Map also used to show the traffic congestion. The red color shows the heavy traffic, orange color shows the light traffic, and blue color shows no traffic at all. The pseudo code for extracting time and distance information is shown in Figure 3.

Input: 1. Current user GPS position (latitude, longitude).
2. Destination position searched by place, calculated in coordinates (latitude, longitude).
Output: List of n routes $\{r_0\ldots r_n\}$ with route properties (e.g. arrival time, distance in miles).

get routes from Google API based on the initial user's position and destination position.
  for each route *r* in routes $\{r_0\ldots r_n\}$
    set r_{ad} the average duration of the route in minutes
    set r_{td} traffic_duration of the route in minutes
    set r_{gd} distance in miles
    for each encoded polyline of *r*
      decode encoded polyline
      set r_{dp} decoded polyline
return list of routes $\{r_0\ldots r_n\}$ with the set values.

Figure 3. Pseudo code for extracting time and distance information.

Travel Cost

In this research, the travel cost is calculated based on the current local gas price in the industry and travel distance. The current local gas price is calculated by GasBuddy service based on a user's address or Zip code (GasBuddy 2019). Hence, the application mainly searches local gas prices based on the user's location. Once a list of gas prices is obtained, the application displays the average gas price for each trip as shown in the pseudo code for extracting cost information in Figure 4.

Input: Distances r_d in miles of the route. Local gas price g in dollar amount.
Output: Total trip cost c in the dollar amount of route

get r_d distance from route and gas price g
  calculate and set gallons of gas per distance route r_{gd}
  r_c <- $r_{gd}\ x\ g$
return r_c

Figure 4. Pseudo code for extracting cost information.

Gas Emission

Next is the core logic for determining the gas emission calculations in the proposed mobile application. The CO_2 emissions are calculated using Equation (1) which is originally obtained from the Environmental Protection Agency ((EPA) 2018).

$$CO_2\ Emissions\ in\ grams = \frac{CO_2\ per\ gallon}{MPG} \times Travelled\ Distance \times Driving\ Style \quad (1)$$

Where *MPG* (Mile per Gallon) is determined by MPG of user's vehicle based on the user's selected profile vehicle. *Driving style* is normal driving versus aggressive/fast driving with values of 1 and 1.15 respectively. *Traveled distance* is the total travel distance in the mile. The *CO_2 emissions per gallon* of gasoline and diesel report annually from EPA. The developed application has the ability to update CO_2 emissions from a gallon of gasoline and diesel from the EPA website directly in order to calculate more accurate CO_2 emissions in grams. Once the emission value is calculated in terms of grams of CO_2, the next step is to calculate a sustainability index. The sustainability index in the context of this application is inspired based on (Barth and Boriboonsomsin 2009) as shown in Figure 5.

The sustainability indexes are derived based on Figure 5 and divided into three categories as it is shown in Table 1. In this research, the highway was considered in the program as a variable. Hence, the overall sustainability index can be determined by considering the fact that the trip contains more than 75 percent of the highway and the speed in MPH (mile per hour) was taken based on the severity traffic status. The overall sustainability factor then will be determined based on the traffic status as is shown in Table 1. It is important to notice that the traffic severity value is color-coded as red, green and orange for 0-39, 40-70, and +70 mph respectively which are the results of traffic status. Overall, an index of (0) enhances the chance to promote a lowering of CO_2 emissions.

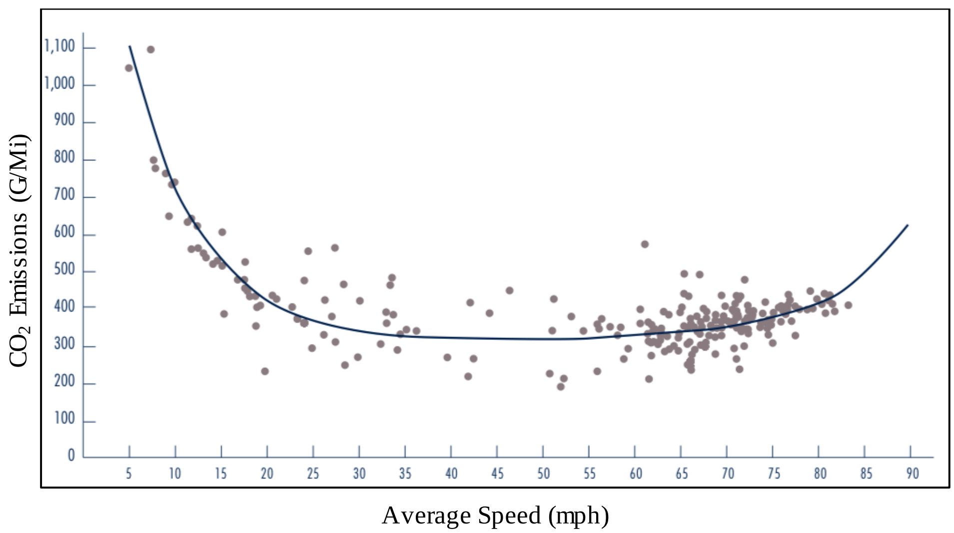

Figure 5. Emission vs. speed plot of individual trips (Inspired by (Barth and Boriboonsomsin 2009)).

Table 1. Sustainability index based on the speed and traffic status

Sustainability Index	Speed (mph)	Traffic Status
-1	0 – 39	City / Highway Traffic
0	40 – 70	No Highway Traffic
1	More than 70	No Highway Traffic

The sustainability color codes for this application are determined in order to compare the CO_2 emission of each route to the same destination. The green color shows that the route is sustainable, the red color shows that the emission of CO_2 is high.

Input: The route r to be used for calculations.
Output: The sustainability index of 0 and -1 for best and worst emission factor, respectively.

if r_{has_hwy} then:
  if $r_{distance\_hwy} / r_{total\_distance}$ >= 0.75 and if $r_{traffic\_severity}$ is green (good):
    return 0
  otherwise:
    return -1
otherwise (the route comprises of street thus):
  return -1

Figure 6. Pseudo code for extracting gas emissions information.

DATA COLLECTION AND SETUP

For evaluating the performance of the application, a trip to Laguna Niguel Family, California was taken as a testing platform. This test is collected on 29.6 miles in U.S. I-5 and CA-133 highways. When the mobile application is opened, the main screen labeled 'Home' will be shown. Because of the all recent smart cellphones, most of the users are familiar with the mobile version of the Maps applications such as Google and/or Apple map applications, thus the Home screen as shown in Figure 7(a) should bring the same experience. When the Home screen is launched, it performs two steps: (1) loads the local gas price based on your current location's Zip code; and (2) automatically renders the current's user map.

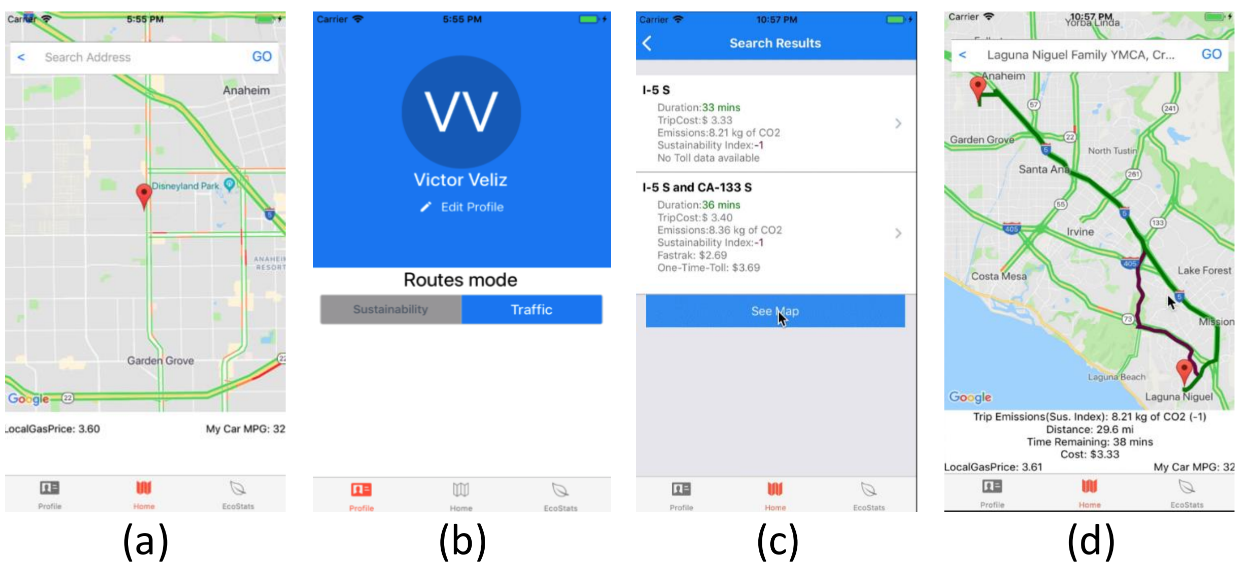

Figure 7. An overview of the mobile application performance.

By pressing the 'Profile' tab in the bottom-left corner of the application, the screen will navigate to the 'Profile' screen as shown in Figure 7(b). The profile screen shows details about the user's profile information wherein the user will enter their vehicle MPG. The search results screen as shown in Figure 7(c) displays the statistics of the general usage of the application by clicking the bottom-right tab. This includes the aggregation data of the daily emission consumed.

RESULTS AND DISCUSSION

As per the data obtained, the user of this application will have his/her own choice of route selection criteria from the available alternatives. For instance, if the user's criterion is only the time to reach the destination, then he/she can go with the alternative with the least time neglecting the other two factors. On the other hand, if the user is concerned about time and fuel cost in order to go as a sustainable alternative, then he/she will choose the one with the combination of less time and less cost. It is solely the call of the user what to and what not to consider as it always depends on the type of the trip being carried out. Since this analysis carried out is not the concept of decision making, the user is the prime decision maker

CONCLUSION

This paper has shown a portion of the advantages of discharging open information on versatility alternatives in real urban areas, to better advise clients of the portability administrations, scientists understanding the city and organizations making quality, experiences, and apparatuses from such uninhibitedly given profitable datasets. By seeing out the clear elucidation by the code created, it can be concluded that if the user gets a better and clear vision of the route choices and alternatives, then the user can easily decide which route to go for as per his/her preferences and the reason of the trip undertaken. The future direction of this study is to use the Google Maps API to determine the toll road of the trip and get a better list of alternative routes which is currently ongoing by the authors. By adding this option, the routes are optimized based on the combination factors and the user could make a decision based on personal preference.

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