Intelligent Transportation Application for Smarter and Greener Commute

by

Geetansh Kakkar

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Abstract

It is well known that an information-rich environment needs to be developed where travelers and transit users have all the comprehensive and accurate information on travel options. The need is to capture, synthesize and deliver real time and up-to-date information, that is not only vehicle or infrastructure based but also environmentally relevant, that also supports building a transportation system that promotes environmental improvements.

This work, Intelligent Transportation Application for Smarter and Greener Commute, gives all the useful and relevant pieces of information that the commuters seek, before starting their commute [travel time, cost, route comfort, trip's green level (emissions caused), current traffic situation], displayed in a comparative manner for all travel modes. Observed incidents can be reported and also searched, by commuters. Additionally, the work provides green performance rating to the user and the best mode suggestion for the journey entered by user, based on the relative importance of various journey characteristics, to the user.

A sample of volunteer candidates were asked to use this in order to evaluate the work and a significant shift was seen in their travel mode choice from private to public transport. The idea to promote green transportation is also successfully executed through this work and the observations bolster this argument. With environmental concerns growing, the transportation system that a country needs should be one that improves the scene without affecting environment, something well implemented with this work. The impact of this work on future policy is that the information provided could also be used by the transportation agencies to see which areas are affected by incidents and restore normalcy at the earliest. Concisely speaking, smarter travel is guaranteed.

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Chapter 1: Introduction

Connectivity is rapidly changing our routine habits and the way we behave. Real-time information gives us a very unique power to make our own decisions, provides us with the details we need, to understand our world and various systems contained in it better. With advancements in technology, it has become all the more easy and convenient to reach out and connect to our family, friends and social circle. These technologies are now growing more and more widespread in a variety of areas, be it business, political or social. When talking about our transportation system, it means that there is now enormous awareness about what is going on in and with our transportation system. But then, it is also important to keep on using the newer technologies to come up with a better and even more connected system, to update the current.

What is required today is to develop a transportation system where accidents and collisions are less frequently observed than today. This is why Vehicle-to-Vehicle Communication is becoming important these days, because it allows the vehicles to communicate with each other and tell any special circumstances they are observing. Information rich environment needs to be developed where travelers, public or private vehicle commuters or freight managers are aware of how the transportation system is working at present. Travelers need to be provided with all the accurate and up-to-date information, like travel times, travel costs, emissions caused to the environment, transit schedules and any special or unwanted observation (accident or congestion) on a route they are about to take. Also, an effective traffic light system should be there where vehicles can communicate with traffic signals, especially in situations where unnecessary stoppage is caused by traffic light signals. Vehicle-to-Infrastructure Communication is gaining significance as well and so is Infrastructure-to-Vehicle Communication, to optimize the current transportation system.

This work mainly focuses on developing an information rich environment for the commuters who are about to make a journey, and want to have as much information as possible (relevant information) about the travel time, costs, emissions, present traffic situation etc. for all the travel modes. The extra significance given to environment is a key aspect of this work, along with importance given to all the travel modes. The comparison of how this work compares with other works in this area and its novelty aspects are given later on (Table 1).

The key research questions that this work intends to answer are:

1. Can delivering an information rich environment (all the key information, including the environmental effects) to the commuters, help in contributing towards increasing the awareness about green transportation along with improving today's transportation system?

2. The idea to promote green transportation has been around for quite some time now, especially with the growing concerns of global warming and with the spreading awareness of how the future will look like, if nothing is done today. There have been some practices to promote green transportation, but mostly, they have not been at the level of desperation that today's times demand and have not created the kind of impact today's times demand. How can we build further on those practices? Is there a significant way to promote green transportation?

3. Can we accumulate all the relevant traveling data for the commuters and show them together in a single platform, in order to assist them in making an informed decision? Can access to all the relevant information impact the commuter's transportation mode choice?

4. Can ensuring a greener environment be made the highest priority concern for the public when they are choosing their transport?

The context of this study is to come up with a mechanism to display all the relevant and accurate current information to the commuters. An application has been developed to deliver this information, Intelligent Transportation Application for Smarter and Greener Commute. This work also promotes green transportation and makes commuters aware of the emission count for their journey depending on travel mode. To evaluate this work, a survey was conducted towards the end, asking the volunteers to use this application and report their feedback by responding to the questionnaire, in order to evaluate this work (Appendix A). The trend observed on the sample was indeed motivating and coherent with the aim of this work (Chapter 4).

Literature Review

This work tries to give an information rich environment to the commuters or general public. It is an attempt to come up with a Traveler Information System, which forms an essential basis of the Intelligent Transportation System (ITS) Architecture. According to ITS Canada [16,17], ITS shall include a Pre-Trip Travel Information capability to assist travellers in making mode choices, travel time estimates, and route decisions prior to trip departure. This clearly explains how this work fits in the ITS world.

It is commonly believed that the use of travel information will allow travelers to make more efficient and precise travel decisions, which in turn will improve the efficiency of transportation network facilities [8]. Traveler information also forms a central part when dealing with transport challenges in congested towns and cities [9,10]. Researchers have found that providing advanced information has a great potential in influencing commuter's route choice, even when advising a route different from the normal one [11,12,13]. Abdel-Aty and Abdalla [11] showed that providing traffic information increases the probability of driver's diversion from their normal routes. Khattak et al. [14] found under incident conditions that delay information been given to the commuters, may

induce about 40% of the commuters to change their route to work, mostly the people with greater diversion opportunities, knowledge of more alternate routes, and lower congestion levels on their best alternate route. Further, Khattak et al. [15] found that drivers are more likely to divert to another route when they learn about a delay before the trip.

Ensuring transportation safety, smooth mobility while preserving the environment are some of the key aspects, on which our focus has shifted in recent times. This work also aims at ensuring a safe and sound transportation system. This is important because the amount of collisions being observed these days is increasing. It is expected that road collisions would move from 10th to 8th most common cause of death by the year 2030 [5]. World Health Organization concluded in 2004 that the number of road collisions has increased from around 0.9 million in 1990 to 1.3 million in 2004. Social and economic losses along with the personal damages are the outcome. All countries are unable to cope up with this. Low-income countries suffer from loss of lives, while the high income countries suffer from this, in addition to the losses due to the insurance claims and health care. Canada is no exception. In a large number of countries, road collision problem has damaged more than the traffic congestion problem (which in itself is harming the country, economically and financially). Again health concerns are of alarming proportions. According to IBM's 2011 Commuter Pain Report [6], with increased congestion rate and frequency these days, worldwide, forty two percent commuters declared their stress level had increased; 35% reported more anger; 16% percent each, respiratory problems and less sleep; and 13% claimed to have been involved in some sort of traffic related accident. Stress from driving is notably high in Mexico City, Milan, Bangalore, and Johannesburg (over 50% of respondents in these cities reported it). Respiratory difficulties arose most often in Bangalore, New Delhi, Beijing, and Shenzhen. Drivers in Moscow, India, China, and Singapore were the angriest about traffic congestion, while those in Milan, India, China, and Singapore suffered health affecting traffic accidents more than in other cities.

In addition to those, emissions from the vehicles are the single largest human-made source of carbon dioxide, methane and nitrous oxide, among others. Several diseases and deaths are caused, as a result. The most affected society members are the children. Poor air quality causes asthma, resulting in hospitalizations. Moreover, traffic congestions leading to slow speeds does not help the case either as it means more emissions at one single point. This work aims for sustainable and smooth mobility and that is how it goes about to reduce these harmful effects.

An effort has been made to report the Green Performance Rating to the user, just to give him/her some idea of where does the user stand in terms of green commuting and to get the user into some sense of comparison or competition with his/her peers, related to the issue. When the user sees this performance rating number of the peers, it does influence the decision making of the user, in terms of opting for greener travel modes [1].

Therefore, one can realize the importance and relevance of this work in today's times. Table 1 compares this work with other similar previous works in this area. It can be clearly seen how this work compares with them in terms of the amount and the variety of information displayed to the commuters. One can clearly see where this work scores, from its previous counterparts.

Looking online before starting a commute is something people across all countries are widely resorting to. There have been many literature evidences of the same that tell that a range of between 70% and 100% of people refer to these information just before beginning their trips [3,4,20,21,22]. Initiatives have been taken by many to come up with iPhone or Android applications that convey suitable information to the commuters about the traffic travel times and distances. Real-time information systems are very common in modern public transportation and a considerable amount of money is spent on such applications each year [2].

Google Maps and Google Traffic [Table 1], is an example of this, where people can look how the traffic is flowing at a particular place and also if they are unaware of how to reach the required destinations, then various options with their respective commute times are displayed. It allows the commuter to choose a travel mode and see suggestions for the route between a chosen source and destination, relative to that travel mode.

Other similar works also occur where people or agencies have looked to develop applications for the general public to assist them. Students from University of California Berkeley had created an application, Bay Tripper, to help users in San Francisco get around by finding their way through transit and bike routes [Table 1]. It was part of a research project in which they were trying to understand how to get more people to get out of their cars and onto bikes, public transportation, or just walk. In this work, travel times and travel costs are given along with the travel directions, however, only for the transit and bike modes. Additionally, the work gives transit schedules and some help to find a taxi/cab as well. This combination of information brought together by this application was a first of its kind and which is one of the reasons why this application gained good popularity in the San Francisco region.

There are others who have worked on building an application that lets people know about others who will take the same route and if they will allow car sharing (if yes, then at what price). The application was based on car-pooling, an initiative to reduce the traffic congestion on road, which can ultimately lead to a healthier and greener environment [25]. Other applications, which assist people to locate their cars in a parking area, have also been highly appreciated [26]. There are other applications that help find a parking spot in a parking area, to assist drivers in making a part of their journey more comfortable.

Road tripper application [Table 1] was developed which helps to map the trips. Turn-by-turn directions are displayed for car and walking modes. Travel time and travel distances

were displayed additionally. One of the main advantages of this work is that it is a global application, i.e. it can be used anywhere in the world to get directions for any journey (specific to car and walking modes, though).

NavFree is another application that allows free GPS (Global Positioning System) Navigation and gives travel directions from source to destination in map form [Table 1]. iWay is another similar application which gives travel directions (along with travel distance and travel time) as well as the current average speed observed on the route [Table 1]. One of its distinguishing features is that besides the journey source and destination, it also gives an option to choose a particular route the commuter might want to follow. This work, again, is global and we can use this for any source and destination pair (subject to the condition that either car, transit or bike route exists for that source-destination pair).

There are other set of works that were built to assist drivers in keeping a good check on their vehicles and the fuel count, so that they can be aware of the amount of fuel their journey burnt.

Vehicle mileage and fuel expense tracker, like the name suggests, keeps a track of the mileage of the driver's vehicle and the amount of fuel spent [Table 1]. It also reports the total travel cost that might be incurred based on the amount of fuel spent. Another work, Driver's Dailey Log [Table 1], helps in somewhat the same way, where a log of the driver is maintained and the travel distance and travel times of the driver on a particular journey are kept track of.

As can be seen, a wide variety of work has been done to assist the commuters in their travel. Some of them have met huge success, while some of them could not create a big impact. This work has a number of novel features that can help the commuters in a big way to make their journeys more comfortable (Chapter 5). Also, the work perfectly aligns

itself with the architecture of Intelligent Transportation Systems, especially when talking about the sub-category of Advanced Traveler Information Systems.

This chapter gives an introduction to the thesis, statement of research questions and a comprehensive review of the previous literature that have focused on similar works. Chapter 2 presents how the application runs practically, page by page. Chapter 3 gives insights into the Numerical Physics, Computations, Statistical Physics and Analysis involved in various algorithms used or developed, in and for this work. Chapter 4 demonstrates the methodology adopted to evaluate this work and the results after evaluating it. Chapter 5 talks about the novel features this work offers and how they compare with other works in the similar area. Chapter 6 gives potential benefits of this work. Chapter 7 finally concludes the work with an appropriate summary and some useful suggestion for the future work.

Chapter 2: Application Running

This chapter describes the running of the application. The page-by-page screenshots of the work have been shown in Appendix B. The link to the work is given below.

http://geetansh.atwebpages.com/demo/

First Page

The application starts by asking the user to input a particular car type that the user owns or prefers (from a large database of cars that has been maintained for this work). This is important so that the application can provide the emission count of the journey that the user will be making if he/she takes that particular car for that journey. If the application user doesn't own a car, then he/she can input any dummy variable or can input "Do not own a car". After this, for the car owners, the car type has been stored.

Second Page

Now the application asks for the source and destination of the journey that the user intends to make. Once entered, the user can click on "Suggest Me" button to receive suggestions for the journey. The travel distance is displayed and following that, travel mode specific information is displayed for all the travel modes.

1. Car

Driving time, average speed observed on road currently, travel cost (fuel cost) per car's journey, emissions count, and green performance rating of the car.

2. Transit

Transit travel time, travel cost, emissions count (per person).

3. Bike

Travel Time (Cost and Emissions will be 0).

4. Walk

Travel Time (Cost and Emissions will be 0).

So, corresponding to the travel mode, all the relevant and crucial information for that travel mode are displayed. The application tells how green the commute will be, while giving all these information. Because the focus is on emission count, there is promotion of green transportation implied, something which was also observed when this application was evaluated by asking some of the volunteers to use it and give their feedback (Chapter 4). The user can see the emission count for all the travel modes together and compare. This feature of the work focuses on influencing the travel mode choice of the commuters.

The final choice to choose the travel mode is with the application user. But in this work, an algorithm has also been developed to tell the user of the best possible mode for that particular journey (Chapter 3). This is suggested in a user specific manner, by asking the user to rate (on a 0-5 scale, 0 being least important and 5 being the most important) the journey characteristics (travel time, cost, green level of the trip, etc.), in terms of their importance to the user before starting the commute. These inputs are taken into account in the algorithm that ultimately gives the user, best possible mode suggestion for that journey. Another feature is to give the user Green Performance Rating for all the journeys he/she has made till date. An algorithm was developed for that as well (Chapter 3). This again contributes towards promoting green transportation.

Third Page

After the user has chosen the travel mode, there is an option to get the driving directions to be followed for that. The driving directions are displayed textually as well as in map

form and can be seen for any mode. For e.g. for transit, the application tells what bus routes can be followed and what stopovers and transit changes need to be made, whereas for car, the application tells the driving route to be followed to reach the destination from source.

Fourth Page

If any commuter experiences any incidents during their commute (like accident on any route, congestion, construction or any unnecessary stoppage), then they can report their experience. "Report An Incident" option allows doing that.

Fifth Page

This above information is stored in the database (which contains other such information about incidents), and can also be viewed by other users as well. For the route that one is about to take, he/she can search for incident on that route, using "Search for Incidents" option. All the incidents that have been reported will be displayed accordingly.

Getting the Relevant Pieces of Information to Deliver to Commuters

The work started with getting to know what can be the most important pieces of information that general public seek before starting a commute. Based on the current knowledge in the subject of Intelligent Transportation Systems, it was thought that the following set of information, which if displayed together, would give all the valuable and relevant information, that commuters seek prior to start of their journeys. Also, in order to assist commuters in making an informed decision on mode choice, this works displays the required information in a comparative manner.

1. Travel Time: Time it takes to travel from source to destination, based on current road situation. The other details that are mentioned along side are: fastest driving time, and average speed for the whole journey, currently observed.

2. Travel Cost: Cost to go from source to destination. The cost includes fuel costs depending on the current fuel prices. Toll charges on the route, if any, are not counted in it, since governmental help might be needed to locate on which roads, toll charging counters have been set up. For public transports, the cost includes total ticket price to go from source to destination, even if it includes multiple public transport usage.

3. Green Level of the Trip: Depending on the travel mode used, the emissions count for the journey changes. For private vehicles, the emission count is known, depending on the vehicle model that is owned or preferred by the user (the database that has been maintained for cars, contains the information about on-road performance of cars, like their emissions count and mileage). The user is asked about this on the very first page of the application. For public transport, depending on the data available on the website of the regional transport agency, this information is displayed and accounted for while performing calculations. Since, this would vary from place to place, this feature is only for Vancouver, but can be altered to make application work in other regions. For bicycles and walking, there is no emission count, obviously.

4. Present Traffic Situation: The current traffic scenario that is observed on the roads. The information for any incident, like congestion, accident, construction or any unnecessary stoppage can be entered and be seen by any application user, specific to the route they are about to take or otherwise. The travel time and the average speed that the application displays (mentioned above) are already according to the current traffic scenario. If any commuter experiences or is aware of any incident that happened, then he/she can report it. The application has an option for reporting it, as mentioned above. Application users can see this information, through a button of searching for incidents.

The reported information is stored in the database for around 5 hours, since after that amount of time, it is expected that the incident must have cleared up. The time at which the incident is reported, is also shown, which also assists commuters.

5. Personal Health while Choosing a Mode: Sometimes, mostly for short trips, commuters who are more health conscious, can prefer to go for the trip via walk or bicycle than via car or transit.

This application brings that set information together, arranged according to the travel mode. The application users can clearly see all these details for all the travel modes, and then appropriately choose the travel mode, based on their preference or requirement for the journey, after weighing all the factors.

Promoting Green Transportation

Nothing can be enough when we talk about promoting greener transportation (transportation that focuses more towards environment). Things are being done, a variety of, and things need to be constantly done, or rather, efforts need to be increased exponentially. Efforts need to be made to make people realize and switch them to public transport. This is being done through other means like advertisements and notices at several places to constantly remind people. But this work reminds that an application like this can also do this and this is one of the novelty features in the application.

User Specific Best Possible Travel Mode Suggestion

Right now, this application is global and most of the time the thought process was that since it works globally, what could possibly be the benefits to make it local. The answer: One can try and come up with an algorithm to suggest the best possible travel mode choice for the selected journey details. This algorithm would vary from place to place

since the weight people of a certain area would give to the journey characteristics like time or cost, are different from what people in other areas might give. Also, the cost of one hour, when put in dollars, is different in different places (i.e. Value of Time is different for different places). That's why this feature can't be present in a global work. But, we can have something like this for a place like Vancouver only. And it can have a huge impact. Something like this has not been seen previously in any work in this field. So to make it work, an effort is made to ask the users themselves how they would rate the journey characteristics, on a scale of 0 to 5 (0 being the least important and 5 being the most important). So, suggestions would finally be given specific to the user's requirements. This part gives the best possible mode suggestion relative to the user, based on the preference ratings given by the user. Thus, this best possible travel mode suggestion would change with the user.

Which Car?

Enter source and destination of the journey.

Give preference ratings for travel time, cost, emissions, comfort during trip and present traffic situation. Enter previous green performance rating and the mode for this journey.

Click on “Suggest Me” to receive suggestions and information.

Information depending on the travel mode is displayed along with weather information for destination, Best Possible Travel Mode suggestion and User’s Green Performance Rating.

Click on “Get Directions” option for a travel mode to get directions on that travel mode.

Click on “Report An Incident” button to report any incident you faced. The incident gets stored in the database.

Click on “Search for Incidents” button to get information about incidents.

Figure 1: Figure showing how the application runs page by page.

CHAPTER 3: Numerical Physics, Computations, Statistical Physics and Analysis

Algorithms Used

Car's Green Performance Rating Algorithm (GPR)

A green vehicle or environmentally friendly vehicle is a road motor vehicle that produces less harmful impacts to the environment than comparable conventional internal combustion engine vehicles running on gasoline or diesel, or one that uses certain alternative fuels. For cars that are seen on roads, energy efficiency as well as the carbon emissions to the environment, both are the most important factors when we talk of greenness in the vehicles and hence, both are factored into the Car's Green Performance Rating algorithm.

For this work, a green car rating of 100 means that the car is the greenest, causing no harm (or almost no harm) to the environment. A green car rating of 0 implies the most polluting car.

If we take emissions in g/km and mileage in liters/100km, then more emissions would imply a lesser rating and more mileage would also imply the same (units are liters/100km, so more mileage means more liters of fuel consumed for every 100 km). A database of car types is maintained, which contains information about the emissions count as well as the mileage of the cars. From the database, the car with the greenest performance is given the highest green performance rating. Thus, cars with very low emissions of lets say 40 g/km and mileage of around 2 liters/100 km has a very high performance rating, say 95-96. Cars with very high emissions like 390-400 g/km and high mileage of around 18 liters/100km is given a very low Green Performance Rating, lets

say 10.

Hypothesis:

100-(a*emissions+b*mileage+c)=Green Performance Rating (GPR).

Since, we need to have one more case here to solve for all a, b, c, we can go for an average case that is sensible. Also since there is no fixed way to go about these things or a fixed answer for these things, it makes sense to go for a suitable and appropriate case. So we can assume that a car with emissions of roughly 200-240 g/km and mileage of around 7-8 liters/100km should give Green Performance Rating of 50. Again this is based on a hypothesis, because there cannot be any fixed result in this.

On solving,

100-(40a+2b+c)=96;

100-(390a+18b+c)=10;

100-(240a+8b+c)=50;

We obtain a=0.2 or 1/5, b=1 and c= -6

Therefore,

Green Performance Rating (GPR) =100-[emissions/5 +(mileage-6)],

[Emissions is in g/km and mileage is in liters/100 km]

GPR is used such that maximum value of GPR is 100 and minimum is 0.

These results are based on the constraints that have been mentioned before. Changing the constraints would change the coefficients and hence the generic equation above. From the

database, the car with the most green performance (in terms of emissions and mileage) was observed and given a very high green performance rating (96) and the car with the least green performance was observed and given very low green performance rating (around 10). Therefore, from the database used, Car's Green Performance Rating was always between 10 and 96 and a conscious effort has been made to include all the cars that exist on roads, thus ensuring an almost complete database (the lower case was not taken to be 0 to account for some cars that might exist but have not been accounted for in the database by mistake and the upper case was taken to be 96, for the same reason. There is a trade off between two factors, i.e. emissions count and the mileage, and from the database at least, all the cars fell in the range of 10-96. We might expect Green Performance Rating to go over 100 or below zero by seeing the equation, depending on the emissions and mileage, but since this is a tradeoff between 2 parameters, it is not practically observed. Also, in the future, if some cars are developed that might make this equation to practically go below 0 or over 100, we can still use this equation and call these exceptional cases as cases where Green Performance Rating is 100 or 0 respectively, or we can revisit the algorithm and change its constraints).

Therefore, to sum up,

Green Performance Rating=100-[emissions/5 +(mileage-6)],

[Emissions is in g/km and mileage is in liters/100 km]

A sincere effort has been made to include all the cars in the database and the maximum and minimum Green Performance Rating used was 96 and 10 respectively. So, it can be safe to say that the Green Performance Rating always lies between 0 and 100.

Best Possible Travel Mode Suggestion Algorithm (Restricted to Vancouver)

The algorithm to calculate the best possible mode is explained below. It involves all the journey characteristics we discussed before. All these factors were taken to a common

scale ($, dollar) and then the final costs for all the modes were compared. For e.g. travel time, travel cost, green level of the trip, etc. all were converted to $, for each travel mode, using standard rules discussed below. Comparison was then made, by seeing the total cost for each travel mode. The factors such as how much does a commuter give importance to personal health while choosing a travel mode is something that is tough to calculate. Therefore, this factor will be removed for simplicity of this algorithmic process. While, present traffic situation will remain almost same for transit and car, it can be assumed to be perfectly smooth for bicycle users, because of special paths designed by Government for their use.

Operational costs of the vehicle are in the units of dollars only. The average hourly wage of people in British Columbia (BC) is 23.77 $/hr. This means on an average people earn 23.77 $ per hour and hence value of one hour in BC can be taken to be 23.77 $. Travel time costs can be calculated by visualizing how many hours does the mode take and computing it in $ then. It is the product of travel time and the cost of time per hour.

Green level of the trip or greenness of the commute will also have a cost, as lesser the emissions, better it is for the environment. If the vehicle does not use fuel or cause any emissions, then the cost here would be 0 $. Therefore, green rating of 100 for the car implies 0 $ worth of green cost. Now, average emissions in BC are observed to be 136.2 g/km of CO2. The average mileage seen on road for new and old vehicles combined is 10 km/l or around 6 miles/l. This brings average Green Performance Rating of 68 (from the Car's Green Performance Rating algorithm described above). This average Green Performance Rating can be taken to be equivalent to average hourly wage of BC if the travel mode takes 1 hr. We could have adopted another possible way to convert the green level of the trip to the scale of $ by seeing the amount of carbon emissions and using that to straight away calculate the cost, something that would have been more easy, but this algorithm also shows some relationships between green costs, time and green performance rating of car. More is the travel time, or lesser is the Green Performance

Rating, more is the green cost. We need to interpolate all the other points and calculate the green costs accordingly. For example, if the car, has Green Performance Rating of 36 and does 1 hour of driving, its green cost would be 23.77x2=47.54 $ (or 48 $) (when talking about 1 hour of driving, Green Performance Rating of 100 gives 0 cost, where as Green Performance Rating of 68 gives around $ 24 cost, so by linear extrapolation, we get that Green Performance Rating of 36 would give 48 $ of cost). Similarly a Green Performance Rating of 68 driven for 2 hours fetches same cost of 48 $. However, Green Performance Rating Car of 36 driven for 2 hours costs 96 $ worth of green cost. This is obtained since green cost is taken here to be proportional to time and negative of Green Performance Rating of car. The emissions caused are actually a function of the distance, but to account for real time scenarios, like when congestion or any incident delays the trip, we expect more emissions even though distance has not changed. This suggests that green costs are in a way, dependent on travel time, which has been exploited in this study.

The green cost for cars is calculated using the Car's Green Performance Rating, which in itself is calculated using the data for emissions caused as well as the fuel efficiency, i.e. the green cost itself contains information for the travel costs (operational costs) as well as the cost due to the emissions. Therefore, when green cost is being mentioned, it contains the information about the travel (operational) cost, and hence the operational cost would not be mentioned separately. Similarly, for transit, the ticket prices paid by the users are the travel costs. Cost due to emissions needs to be calculated and added to the travel cost to get the green cost. For transit, the emissions caused by the bus is effectively 1100 g/km. considering an average load carry of 45-50 passengers by the bus, we get 22 g/km of emissions by the person, when the person is travelling by bus. Now, we can calculate the Green Performance Rating of the Bus, limited to the emissions caused only (this is different from the Car's Green Performance Rating Algorithm which contained both the information, emissions caused as well as fuel efficiency). Therefore, Green Performance rating of Bus comes out to be 95 (ignoring the mileage part). The travel cost needs to be added to this. Green costs for other two modes are 0 $.

The total sum of all these costs tells us the total costs for each mode and the mode with least total cost is the BEST POSSIBLE MODE CHOICE for that journey.

A better approach than this was used here, where the total sum is replaced by the weighted sum, with the weights given by the user. The user will be asked to rate the journey characteristics, depending on their importance to him/her. Now after taking the inputs, we can multiply the individual costs with the weights assigned by the user and then make the calculations. Therefore, the algorithm is:

Ask the user what weights (0-5 scale, 0 being the least important and 5 being the most important) would they assign to the journey characteristics, namely
TT: weight for Travel Time.
TC: weight for Travel Cost.
EC: weight for Cost due to Emissions.
TrC: weight for Present Traffic Scenario.
C: weight for comfort during the trip.
The weight for comfort during the trip is used specifically to give suggestions to the application users on what directions to follow for the most comfortable journey, to reach from source to destination, i.e. to have a route where there are very few or no stopovers, in case the user is using transit. These weights are merely the relative importance of these variables to the user.

Best Possible mode choice= Mode with minimum Total Cost

Total Cost for a mode= (Travel Time Cost)*TT +(Travel Cost)*TC
+ (Emissions cost)*EC + (Traffic Cost)*TrC

Again, this algorithm is specific to the user and would change depending on the user and his/her preference ratings for the journey characteristics.

Example 1, from University of British Columbia to Downtown, Vancouver.
Let's assume no incident and the weights entered are 1 for each, so the weighted sum can be taken to be normal sum only.

Costs:

1. Car [AUDI, A3, Sportback, 2.0TDI, 140PS]

    Travel Time Cost: 7.5 $ (19 min)

    Green Cost: 4.9 $ (for GPR of 79 driven for 19 min).

    [Fuel cost information is contained in the green cost]

    Total Cost: 12.4 $

2. Transit

    Travel Time Cost: 14.3 $ (36 min)

    Travel Cost: 2.75 $ [ticket price]

    Emissions Cost: 2.2 $ [Green Performance rating of 95 driven for 36 min, gives 2.2 $].

    Total Cost: 19.25 $

3. Bicycle

    Travel Time Cost: 17.4 $ (44 min)

    Travel Cost or Operational Cost: 0 $

    Emissions Cost: 0 $

    Total Cost: 17.4 $

4. Walking

    Travel Time Cost: 52.3 $ (2 hrs 12 min)

    Travel Cost or Operational Cost: 0 $

Emissions Cost: 0 $

Total Cost: 52.3 $

BEST POSSIBLE MODE CHOICE: Car (Travel mode with least total cost)

If the weights entered were TT=2, TC=EC=TrC=1; then the Travel Time Cost for each of the modes would get multiplied by 2 before summing with other costs, for each mode. The final result would give the best possible mode choice for this user (Car, again).

Example 2, from University of British Columbia to Metrotown, Burnaby, BC.
Let's assume no incident and the weights entered are again 1 for each, so the weighted sum can be taken to be normal sum only.

Costs:

1. Car [Bentley Continental 4.0 GT V8 Auto]

Travel Time Cost: 13.9 $ (35 min)

Green Cost: 23.3 $ (for GPR of 46 driven for 35 min).

Total Cost: 37.2 $

2. Transit

Travel Time Cost: 26.9 $ (1hr and 8 min)

Travel Cost: 5.50 $ [ticket price]

Emissions Cost: 4.2 $ [Green Performance rating of 95 driven for 1hr and 8 min, gives 4.2 $]

Total Cost: 36.6 $

3. Bicycle

Travel Time Cost: 34.1 $ (1hr and 26 min)

Travel Cost or Operational Cost: 0 $

Emissions Cost: 0 $

Total Cost: 34.1 $

4. Walking

Travel Time Cost: 97.5 $ (4hr and 6 min)

Travel Cost or Operational Cost: 0 $

Emissions Cost: 0 $

Total Cost: 97.5 $

BEST POSSIBLE MODE CHOICE: Bike

If the weights entered were TT=2, TC=EC=TrC=1; then the Travel Time Cost for each of the modes would get multiplied by 2 before summing with other costs, for each mode. The final result would give the best possible mode choice for this user (Car). This is expected since, if the user gives a higher priority to time, then you expect the mode with least travel time to be the winner, especially when other modes take somewhere around double the amount of time for the same journey.

User's Green Performance Rating Algorithm

The first phase (page) in this work, deals with getting some valuable information about a user (car details). We can try and extract some patterns (habits) from this. We can think about suggesting a Green Rating for that user. This will basically imply the answer to this question, what is the percentage of emissions caused by this user with respect to the least green commuter (hypothetical commuter, one who uses Car with Green Performance Rating of 0). We can evaluate all his journeys depending on the mode preference he made for that journey. We can also evaluate all his journeys as if made with the least green car (Green Performance Rating of 0). The ratio of the two, would give us his Green Rating (or rather, 1-ratio, would give us that). This can be evaluated in percentages as well [(1-

ratio)*100]. This will be crucial, as its important to tell the commuter how much green commuting he/she is doing. The result can be constantly updated as more and more journeys are made by the user. For implementation of this, we can just keep on updating the User's Green Performance Rating, every time the user makes a journey, since we can calculate the green performance of that journey by knowing the travel mode used. The rest of the work is just updating the Green Performance Rating as the user makes more and more journeys.

Therefore,

User's Green Rating= [1-(total emissions by user to the surroundings/ total emissions by the hypothetical user with least green car to the surroundings)]

Thus, we are extracting general travel patterns of the user, and giving him the rating.

CHAPTER 4: Evaluation of the Work

To evaluate this work, a sample of volunteers was asked to use this application and give their feedback. In total, sample count of 90 used this and reported their feedback, by giving their response to the questionnaire (Appendix A). A diverse group of volunteers were asked to participate.

The questions they were asked, focused on what percentage of their journeys were done by each of the travel modes before using this application and after the first week of application use. These feedbacks were then taken after each consecutive week. Here the focus was to know what percentage of the journeys was made via each of the travel modes after the use of this application. This is likely to give a trend of whether this work is influencing the travel mode choice patterns of the commuters, which was one of the motives. Then, there are some questions asked to know whether the novel features of the application, like providing green performance rating to user and giving the best possible mode suggestion to the user is indeed being used by commuters and is indeed creating an impact or not.

The results that were obtained were coherent with the aim of the work, i.e. promotion of green transportation and make people think about the travel mode choice to a good enough extent, with key stress on environmental significance.

The diversity of the sample that was asked to evaluate this application can be seen from the following plots.

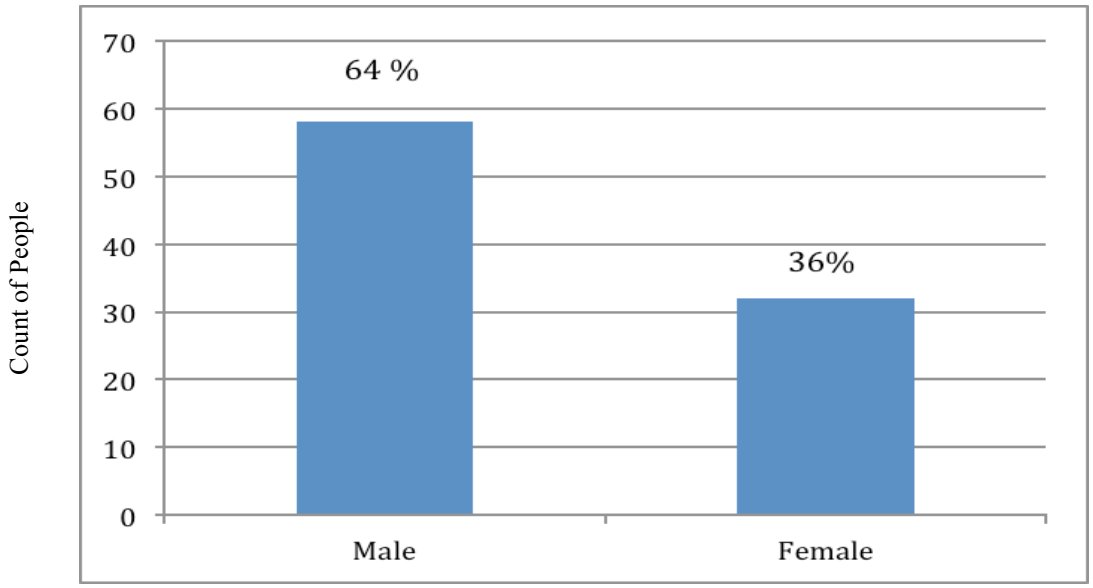

Figure 2: Figure showing the count of male and female, who participated in the survey to evaluate the work.

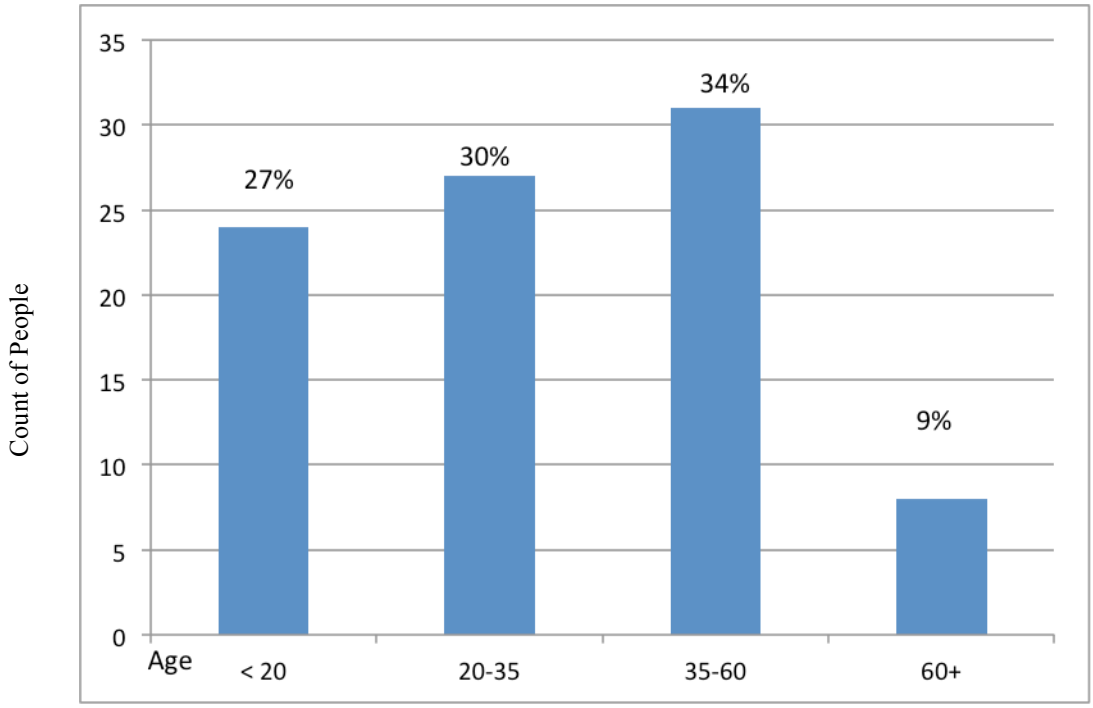

Figure 3: Figure showing the percentage of different age group people, who participated in the survey to evaluate the work.

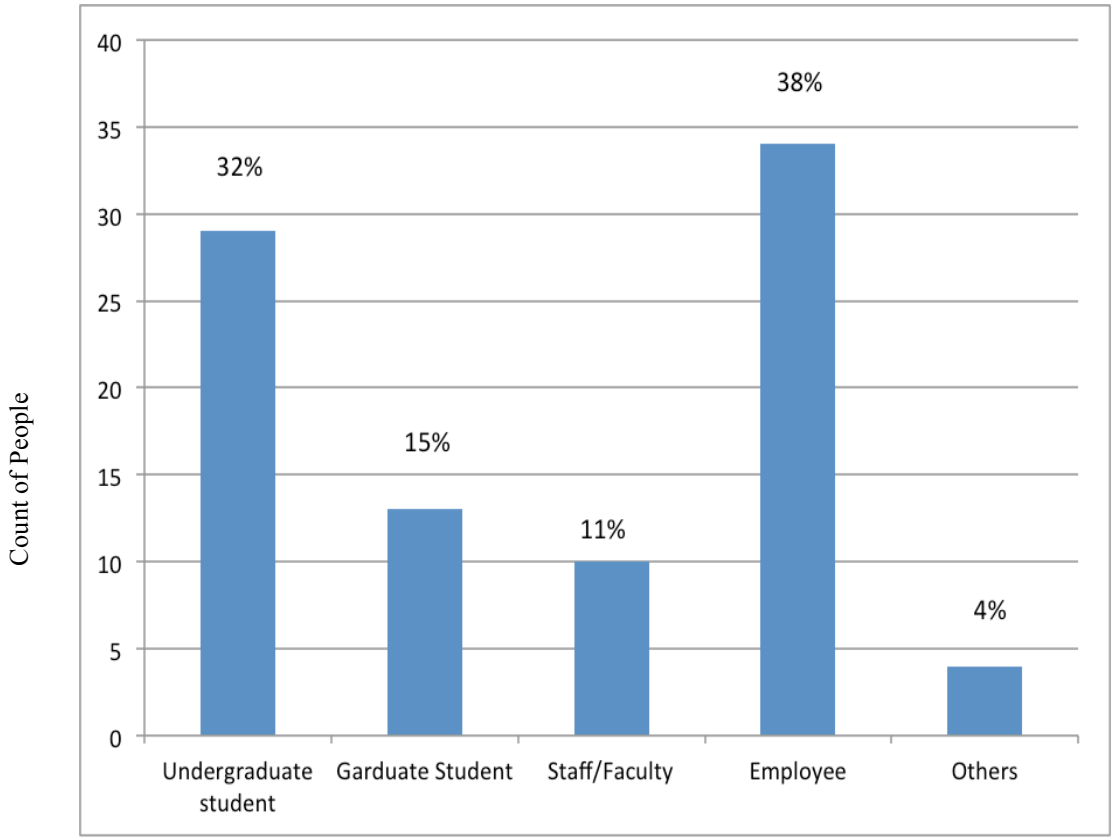

Figure 4: Figure showing the occupation of the people, who participated in the survey to evaluate the work.

Some useful results were obtained from the response to the questions that targeted at knowing how the people evaluate this work. People reporting less dependence on car (0-20% dependence) increased week after week, from the time when they started using this application. Again people reporting high dependence on car (80-100% dependence), decreased week-by-week, as can be seen clearly from Figure 5.

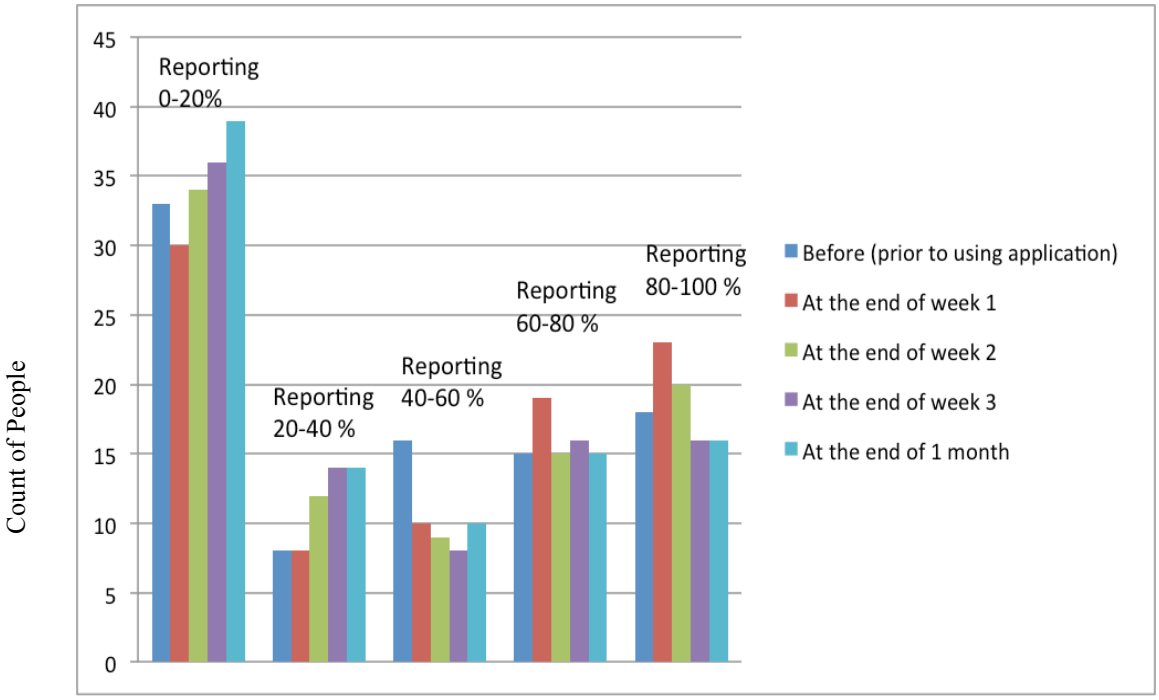

Figure 5: Figure showing count of people and their dependence on car, after each week, from the time they started using this application.

Trend for dependence on transit showed reverse effect to the trend for dependence on car. Count of people reporting 80-100% dependence on transit, week after week from the time they started using this application, increased, as can be seen from Figure 6.

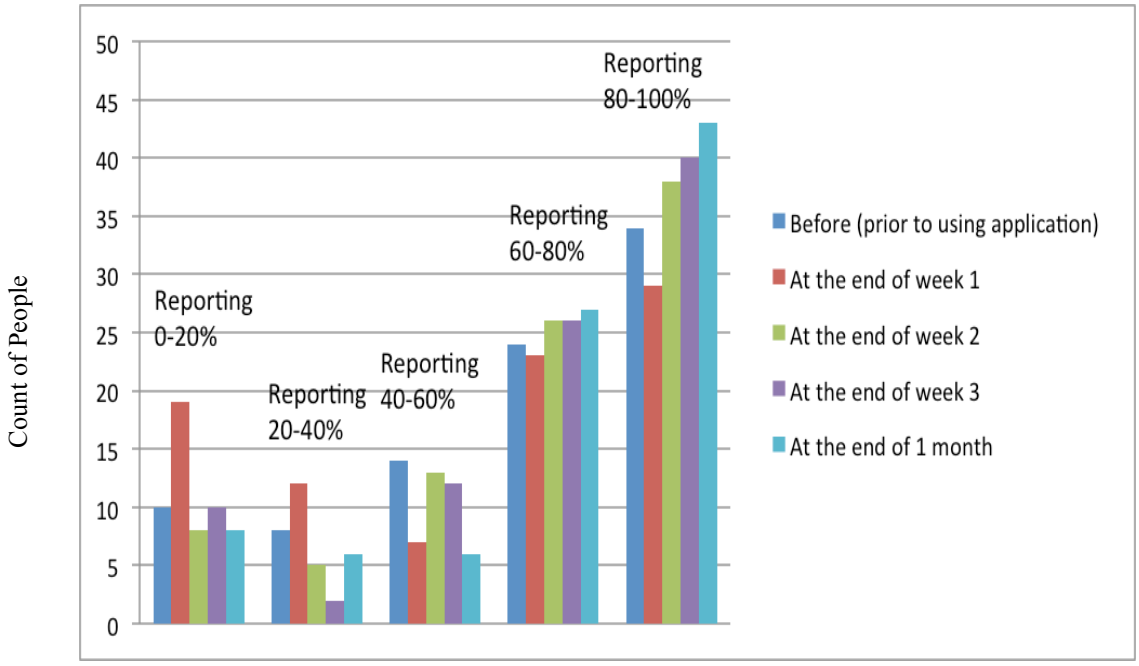

Figure 6: Figure showing count of people reporting dependence on transit, after each week, from the time they started using this work.

Similarly, trend for dependence on bi-cycle is shown, which showed similar nature to the trend for dependence on transit. Count of people who were very less dependent on bicycles for their journeys during the week, went down after each week, from the time they started using the application (Figure 7).

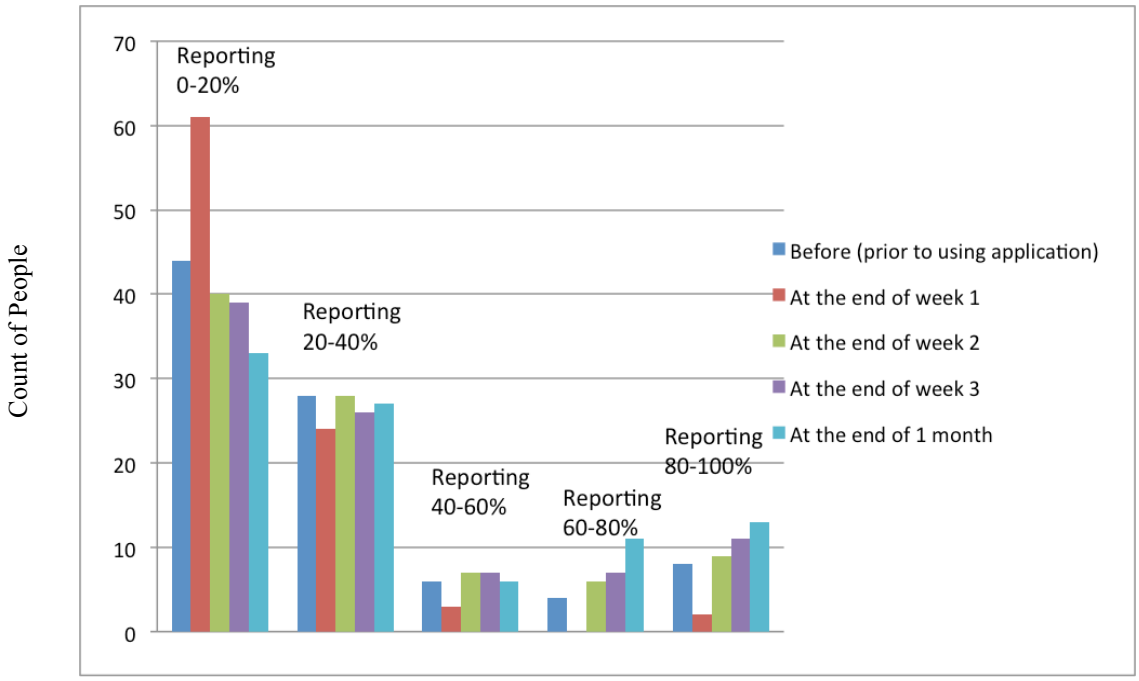

Figure 7: Figure showing count of people reporting dependence on bicycles, after each week, from the time they started using this work.

Additionally, some other meaningful trends were also obtained from the responses. The count of people who used the best mode suggestion given by this work, prior to making their journeys, increased after each week. This shows some level of public acceptance, which also makes sense, since this was a novel feature in this work and something that was expected to attract public. It was also noted that the count of people who reported that they found this suggestion useful, in terms of their priorities (be it time or travel cost or something else), increased with each week. This justifies having this feature in the work. It may be too early to say the kind of impact this work will have in the society by just asking a certain section of people evaluate it, but there is no reason to deny the fact that this work would be able to come up with similar trends over the whole society. The fact that this feature was used by good percentage of the sample and was found to be useful for a good percentage of the sample can be seen from Figure 8 and Figure 9.

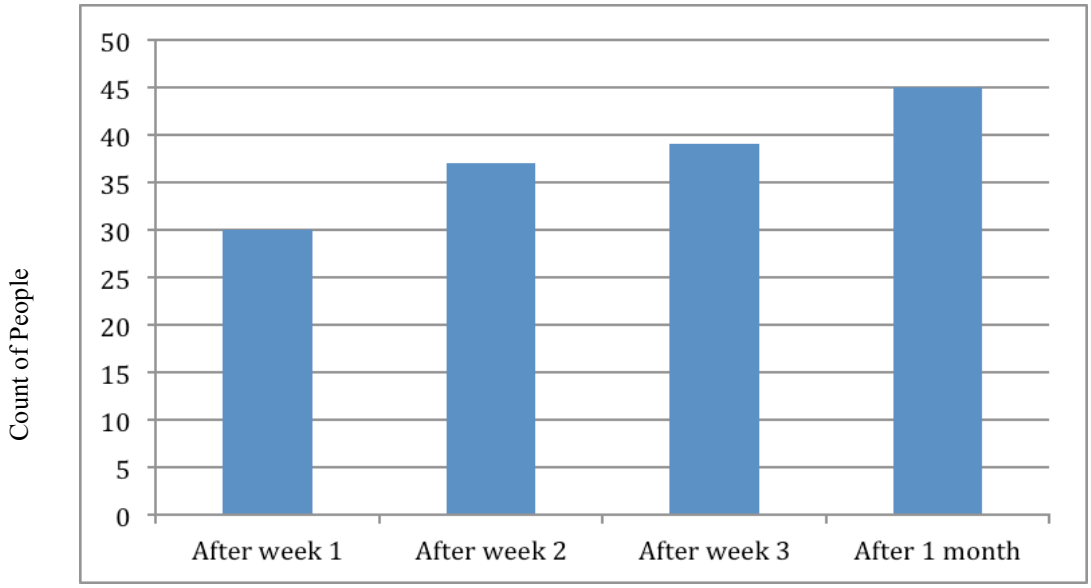

Figure 8: Figure showing count of people who used the best mode suggestion feature of the application.

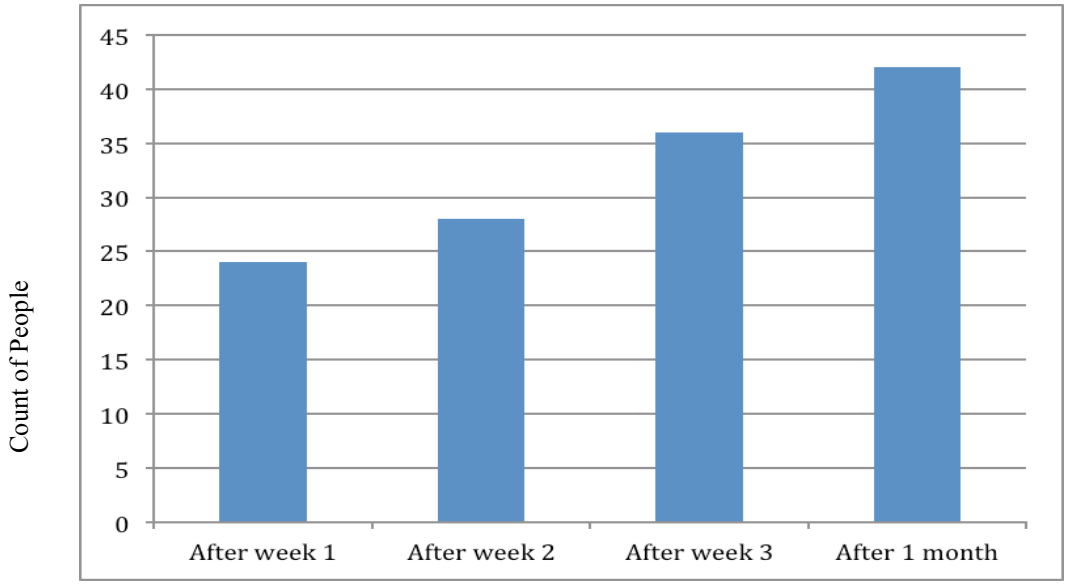

Figure 9: Figure showing count of people who found the best mode suggestion feature in the work, useful to them (in terms of their priorities).

Similarly, it was worth noting if the sample was indeed getting influenced by the other main features in the work, namely User's Green Performance Rating given to the user and making commuters aware of the emissions count that their journey would cause, depending on the travel modes. The fact that these features influenced a good percentage

of the sample, clearly suggests accomplishments of the motives of the work, and this also justifies the importance of having these features in this work. Figure 10 and Figure 11 give some trends which bolster the argument.

Figure 10 also justifies how seriously sample took the "User's Green Performance rating" feature of the application and this surely helps promote green transportation. This figure gives the count of people who found the "User's Green Performance Rating" feature being reported to them useful, in terms of motivating them to adapt a more environment friendly mode for the journey. Similarly, Figure 11 shows the count of people who found the emissions count being displayed to them before starting their journey, useful or influential in opting for a more environment friendly mode for that journey.

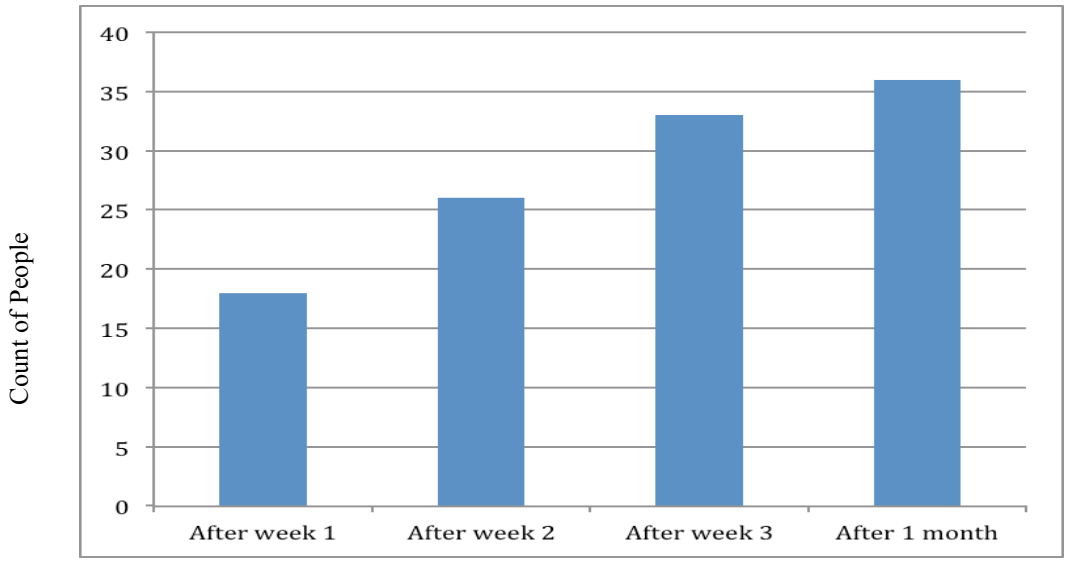

Figure 10: Figure showing the count of people who found the user's green performance rating feature in the application, influential in deciding travel mode.

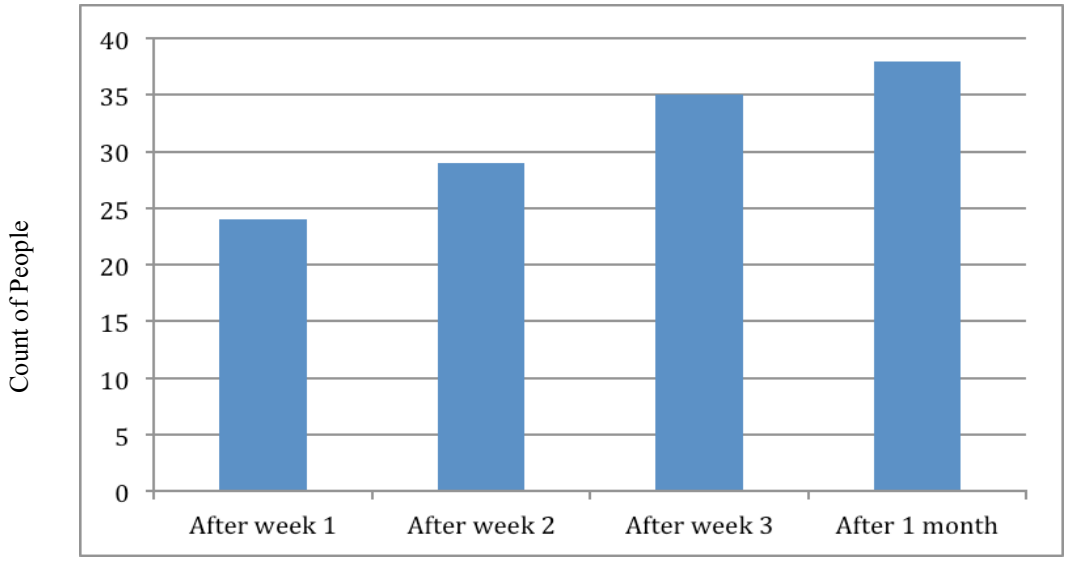

Figure 11: Figure showing count of people who found emissions count for each travel mode being reported to them, prior to starting their journeys, influential in deciding travel mode.

It was also seen that the travel mode preferences of the sample shifted to more environment friendly travel modes, after the subsequent use of this work, something that can be seen from Figure 12.

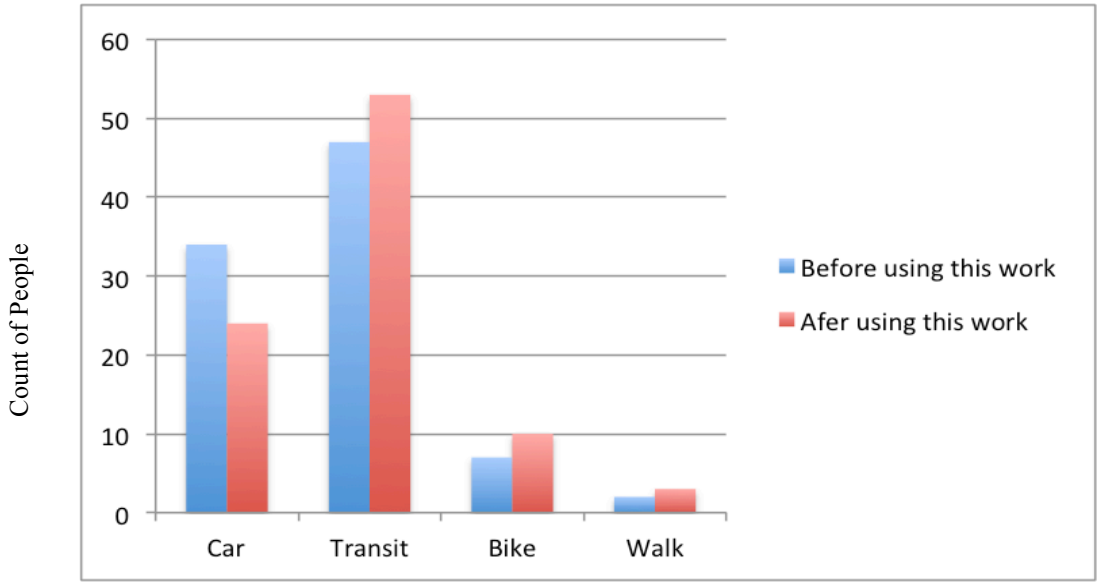

Figure 12: Figure showing how the travel mode preference of the sample shifted to more environment friendly modes, after using this work.

CHAPTER 5: Novelty in the Work

In this work, an initiative is being taken to promote green transportation and influence the thinking of the people to a good enough extent, with key motive to promote eco-friendly driving. In order to improve the transportation system without damaging the system and to promote green transportation, the work is one of the techniques (developing applications) that can be done. The need is to focus on other things as well, but this work alone has potentials of a huge impact, something that can be seen from the evaluation of this work (Chapter 4).

There has been an urgent need to focus on influencing the mindset of the people. This work also focuses on influencing the mode choice thinking of the people, by showing them various characteristics of their journey (travel time, travel cost, green level of the trip, comfort during the trip, present traffic scenario, and personal health while choosing a mode) clearly highlighting the key aspect of environment consciousness, to showcase its importance. Something like this is the need of the hour and is absent in today's world. This makes this work a first of its kind. There have been a lot of concerns growing in recent times about this, but the execution is not at the level of desperation and has not created the impact that these times demand. This work, has huge potentials, as studied earlier and also described in Table 1, and scores over most of the previous works in similar area.

An effort to make people realize and switch them to public transport is being done through other means like advertisements and notices at several places to constantly remind people. But an application like this can also do this was not realized before and this is the one of the earliest works to be able to create that impact. Topic of green transportation is very much in demand these days. The previous works in this area have been mentioned and also included are the details of the information that those works provided (Table 1). This application has a lot of novel points, as can be seen from table.

The diversity of this work and the number of areas (providing information) it focuses on is huge.

Providing all the relevant and the most important information that a commuter needs before starting their trip, is one such aspect that this work boasts of. Efforts have been made, but this work is the most concise and the latest in that respect. It is also important to give commuters all this information, so that they can not only make an informed decision about their journey, but also think about environment consequences of their journey.

Other algorithms are also used in this work, which contribute towards the completeness of the work. Energy efficiency as well as the carbon emissions to the environment, both are the most important factors when we talk of green vehicles and hence, both have been factored into the Car's Green Performance Rating algorithm.

Certain algorithms used in this work are completely novel. No attempt has been made to work on them prior to this work [refer to Table 1 for comparisons]. However, certain features in this work, like giving a green performance rating to the user's car, is something that has been referred to before, like in Britain a website was developed that gives a green performance rating of the vehicles depending on their performance on road. It was mainly developed to assist mew car buyers in making a perfect choice regarding what car to buy and gives a comparative analysis of various features of that car, including the green performance feature. But, something like this can be used to promote green transportation as well to remind users about the on road performance of their and its effects on environment, is quite novel.

Works	Travel Distance	Travel Time	Travel Cost	Average Speed	Travel modes	Transit Schedule	User's Car's Performance	Emissions Caused	Directions Guidance	Weather Condition on route	Best Mode Suggestion	Present Traffic Scenario	Global or Region Specific
Road Trip Mapper	✓	✓	x	x	Car and Walk	x	x	x	✓	x	x	✓ (map)	Global
Bay Tripper	x	✓	✓	x	Transit and Bike	✓	x	x	✓	x	x	x	Region Specific
Nav Free	x	x	x	x	Car	x	x	x	✓	x	x	x	Region Specific
iWay	✓	✓	x	x	All	x	x	x	✓	x	x	x	Global
Vehicle mileage and fuel expense tracker	x	x	✓	x	x	x	x	x	x	x	x	x	Global
Driver's daily log	✓	✓	x	x	x	x	x	x	x	x	x	x	Global
Google Maps	✓	✓	x	✓	All	Implicit	x	x	✓	x	x	x	Global
Smarter and Greener Commute	✓	✓	✓	✓	**All**	**Implicit**	✓	✓	✓	✓	✓ **(local to Vancouver)**	✓	**Semi-Global**

Table 1: Table showing comparison of this work with other works in similar area, in terms of the quantity and quality of information provided.

It is worth mentioning here that this work has been termed as semi-global purely because of a certain aspect of this work being applicable to a local region (Vancouver). Only the "Best Mode Suggestion" and the travel cost for transit, that the work provides is something that is for local reference, since, in the algorithm to come up with the best mode suggestion (Chapter 3), the Value of Time is used for the Vancouver region. The user's car performance is specific to the region as well, as in, the mileage (used in algorithms) for any car type is same as what is observed on Vancouver roads. It is worth mentioning that if these variables are used specific to any other city, then this application can be used in full capacity in that region, since all other features (like travel time, cost, directions, average speed) that this application reports, are global.

Other than the novelty in terms of information given to the users, this work also boasts of novelty in terms of the algorithms used in various parts of the work. The use of Best Possible Mode Suggestion has never been seen in any of the previous works. Giving the user his/her Green Performance Rating is another such aspect, which has never been seen before. These two algorithms are completely novel and these ideas have been used for the first time in a work related to ITS. Providing Car's Green Performance Rating is something, which has been observed earlier in websites like nextgreencar.com. The approach is also similar, the rating is given depending on the energy efficiency of the vehicle (mileage) and the emissions caused. But the previous work was local to the Britain region. Here, an algorithm for the Vancouver area, using the mileage and the emissions of the car observed on the roads of British Columbia, is developed. Other novel aspects obviously include the pieces of information made available to the commuters through this work, a comparison of which is made in the table, clearly showing where this work scores over others and where it lacks (purely because of different motive in mind right from the start of the work).

Other Features

Making applications is all a game of algorithms. If something has been developed, we can try and go one step ahead by making it better through better design or better algorithmic procedure, Here, the work is being done to make the final product more relevant to the urbanizing and modernizing society, and hence using better algorithms than before, adds to the novelty aspects.

For a long time, specifically assigned teams have been sending traffic information and other important data to agencies. The next step towards this is indeed, to not necessarily form specific teams for this task, but ask general people to deliver the information, something that would cost less and would cover more territories at virtually no cost. The only aspect we might be losing through this is the accuracy and the reliability of the data. This can be resolved by maintaining a trust counter of the people that are sending out the data, so that people can think about how reliable it might be (but since, we are trying consciously not to have the users set up a profile for them, because that is something that puts the application users off, there this methodology was not adapted). Or simply by maintaining the count of a particular data or information stored in the database. More count means more reliability.

The coding is intermediate-high level and the structure is organized. Attempts are being made to make applications related to Intelligent Transportation Systems, described in Table 1, but some of them have lacked substantial design, some have lacked definite algorithmic procedure, while some have been mainly region-specific. The work is built using HTML5, that gives the flexibility to develop this application across all platforms, Android, Blackberry, Symbian, Windows and iOS, thus ensuring a wider applicability through a wider audience.

As mentioned before, making an application is all about algorithms. A better algorithm on some old work essentially increases its value. Working on application is in some ways similar. There are 2 important things regarding novelty, a) a new and unique work and b) use of better algorithms on something already being done, very much like use of a particular method or procedure in a field in which it was not used before. This application boasts of novelty in both these aspects. The work is a first if its kind in a lot of ways and in certain aspects, like crowd sourcing, which are very much in use today, a better and more advanced approach is being used.

CHAPTER 6: Uses of the Work

Main benefits of this work will go to the travellers. As stated before, once they have real time and accurate information available to them, they can make an informed choice about their commute. If they see that a region, through which they need to pass, is affected by an incident (be it accident, congestion, construction or any unnecessary stoppage), then they can alter their path or if possible, cancel or postpone their trip. The transport system would become more sustainable and operate more efficiently, the benefits of which would again go to the travellers. Greener environment again speaks of profit in the health. Other benefits include savings in time, money, and more comfortable journeys.

The information provided can also be used by the transportation agencies to see which areas are affected by any incidents, get the information and restore normalcy in the region as soon as possible. Travel alerts that the agencies send to people entering the area of incidence can be done in a better manner. Industry gains the benefits as well, since sustainable transport provides economical benefits, increased profits and costs. In nutshell, smarter travel is guaranteed.

The benefits of a sustainable transportation system are huge. Due to agglomeration effect, the benefits of an improved transportation system would go to all the sectors of the economy. Due to less congestion on roads, the issues like respiratory problems among travelers and stress related issues among drivers, would be toned down. Fewer accidents on roads mean less claims and the benefits of that go to government as well.

Main benefits to the travellers are:

1. Accurate, relevant and up-to-date information available to the commuters.
2. Greener transportation ensures improvement in health of the commuters.
3. Monetary and time savings for the commuters.

4. Large variety of information available to the commuters, means more comfortable journeys for the commuters.
5. Suggestions provided in this application are given specific to the user. Like, the Best Mode Suggestion is given after the individual enters his/her preference rating for travel time, travel cost, emissions caused by the individual's journey, etc.

Main benefits to the transportation agencies and environment are:

1. Sustainable and smooth mobility observed.
2. Promotion of green transportation, thus protecting environment.
3. Commuter's preference to switch from private to public transportation.
4. Travel alerts that the agencies send to the individuals, who are about to enter an area affected by incident, can be done in an optimized manner.
5. Industry gains the benefits as well, since sustainable transport provides economical benefits, increased profits and costs.

As mentioned before, this work comes under the category of Traveler Information Systems, which form an essential part of the Intelligent Transportation System (ITS) Architecture and since this work is quite novel and unique, it can help carry the ITS work forward. According to Transport Canada, ITS shall include a Pre-Trip Travel Information capability to assist travellers in making mode choices, travel time estimates, and route decisions prior to trip departure. It consists of four major functions, which are, Available Services Information, Current Situation Information, Trip Planning Service, and User Access. Information is integrated from various transportation modes and presented to the user for decision-making. It can be clearly seen how this works perfectly aligns itself with the fundamentals of the ITS world.

CHAPTER 7: Conclusions and Future Recommendations

Conclusions and Summary

To sum up, this work is one of the ways to improve the transportation system and smoothen the mobility while giving significance to the environment. This is also one of the unique ways to promote green transportation. There are a number of other ways through which this needs to be done and is being done, but this work is a good take on trying to better the transportation within a country and promoting green transportation.

Before starting this work, one of the research questions was focused on finding out whether delivering information rich environment to the commuters can help in contributing towards increasing the awareness about green transportation along with improving today's transportation system. The evaluation of the work showed that delivering this information rich environment to the commuters does contribute towards making people switch to more and more environment friendly travel modes. The benefits of this work highlight how this work can contribute towards improving the present day transportation system, since the benefits of this work go to both travelers and the transportation authority and the impact of this work can surely contribute towards strengthening the transportation sustainability and smoothening the mobility.

Another research questions was focused on finding whether accumulating and delivering all the information to the commuters would assist them in making an informed decision and contribute towards their travel mode choice decisions. Bringing together all these information surely makes these information more accessible, since now commuters would get everything on a single platform. Information about whether/which incidents were reported and where, gives them the option and flexibility for the route choice. The evaluation of this work also describes some patterns and trends that showed how this work successfully helped in making more people switch to environment friendly modes.

Displaying the information in a comparative manner, for all the travel modes, highlighting the environmental aspects clearly, helps promote green transportation, which was the main focus of other research questions. Also, it does trigger the travel mode choice thinking of the people. Because of this we were able to see some of the meaningful results while evaluating this work. The key aspect of environment consciousness is highlighted throughout the work.

The evaluation of this work also gave some useful results, which showed how the novel features in this work were indeed being used by the sample and were showing the impact we expected. The novel features in this work were always expected to attract public and now knowing, that there was a sense of acceptability from the sample, our claim that this work can indeed serve the society and show significant improvements in the society, is also bolstered.

Chapter 1 gave an introduction to the work and some insight into the previous related works. Chapter 2 informed about the running of the application, step by step. Chapter 3 dealt specifically with the algorithms used in the work. Chapter 4 showed some of the results, when this work was used by the sample to evaluate it. The results are certainly motivating and show that the impacts this work can create are enormous, in terms of improving the transportation system. Chapter 5 talked about the novelty features in the work and how this work compares with the other previous works in similar areas. Chapter 6 listed potential benefits of the work to travelers, transportation agencies and the environment. This Chapter (Chapter 7) gives some thorough conclusions and summary of the work, along with some recommendations for future work on this.

Future Work Recommendations

Some future recommendations to make this work better, are listed below.

Giving suggestions to the commuters when there are more then one travel modes involved, like when a commuter is trying to make a part of the journey through car and the other part through transit (or, through a combination of other modes). This would clearly require some extra information, like information regarding the parking guidance for the commuters, so that we can display what are the suitable places, where the commuters can park their cars (for example) and make the rest of their journey through some other travel mode. Providing parking guidance is another complete area and this kind of work would require a good enough amount of time and effort.

Right now, we have relied on Google open layers to predict travel distances and times. We can surely club this application with some other mechanism that the local transportation authority of Vancouver is trying to develop to accurately predict travel distances and time in Vancouver. Improving the accuracy and reliability of the data would also go a long way in getting public acceptance.

Seeking some governmental help, to try and get some idea about where the toll charging counters are, will help in getting some information about the roads where toll price is being charged and this would, in turn, help in suggesting the car users, total travel costs which would also include toll costs.

Also, in the algorithm for the Best Possible Travel Mode Suggestion specific to the user, the cost due to emissions was assumed to be linearly proportional to travel time and negative of Car's Green Performance Rating. Efforts can be made to come up with the exact relation between these parameters, for improvements in accuracy and reliability and for future considerations.

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Appendices

Appendix A: Evaluation of the Work- Questionnaire

Part A:

Gender: □ Male □ Female

Age: □ (<20) □ (20 – 35) □ (35-60) □ (60+)

Are you:

□ Undergraduate student □ Graduate Student □ Staff/Faculty

□ Employee □ Others (Specify)_____

Part B:

What is your primary mode of transportation?

□ Car □ Transit □ Bicycle □ Walk

□ Others (Specify)_____

What percentage (%) of your journeys were made by these following modes, before this week?

a. Car _____

b. Transit _____

c. Bicycle _____

d. Walk _____

Answer the following questions for this week only.

What percentage (%) of your journeys was made by Car? _____

What percentage (%) of your journeys was made by Transit? _____

What percentage (%) of your journeys was made by Bicycle? _____

What percentage (%) of your journeys was made by Walk? _____

After using this application, what your mode of travel primarily for the following distances?

a. <5 km _____

b. 5-15 km _____

c. 15-30 km _____

d. >30 km _____

Did you make your journey according to the best mode suggestion made by the application?

□ Yes □ No □ Did not refer to it

Did you find the best mode suggestion useful of appropriate (like, did it help you in making the journey in lesser time or with more comfort, based on your priority)?

□ Yes □ No □ Somewhat

Did you find the green performance rating of user, provided by the application, influential in your mode choice decision?

□ Yes □ No □ Somewhat

Did you find the green performance rating of car or the emissions count, provided by the application, influential in your mode choice decision?

□ Yes □ No □ Somewhat

Additional Comments about any feature of the application.

_____

_____

Appendix B: Screenshots of the Work

The application starts by asking for the car type that the user owns or prefers, to be chosen from a long database of car types maintained, with information about their on-road emission count and mileage contained within.

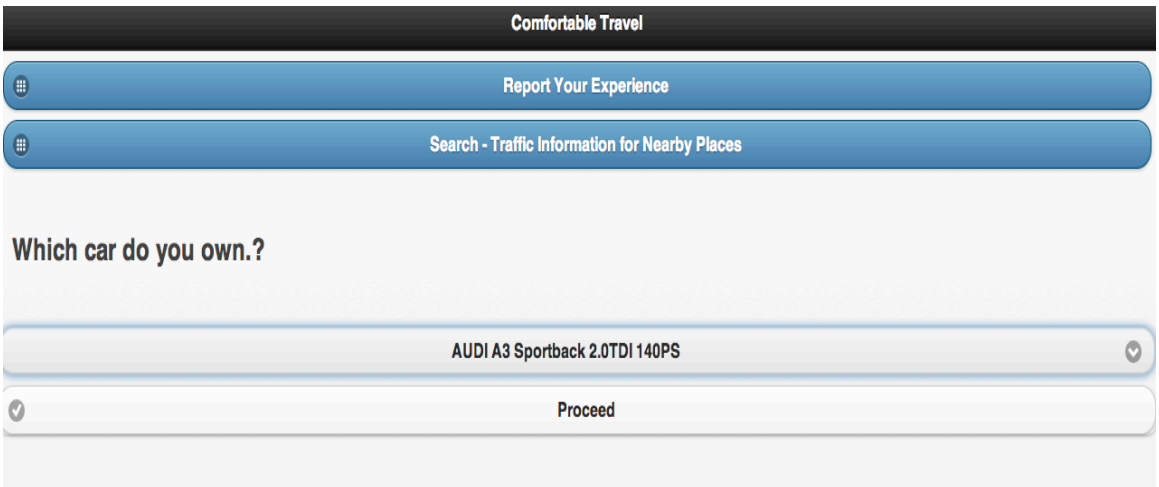

Figure 13: Figure showing page 1 of the application.

After clicking on 'Proceed', user is asked to enter the source and destination for the journey that he/she intends to make. Also, to suggest the Best Mode for this journey, specific to that user, user is asked to rate the various journey characteristics (travel time, travel cost, emissions that the journey will cause to the environment, comfort during the commute and present traffic situation) on a 0-5 scale. This will help evaluate the Best Mode Suggestion specifically for this individual for this journey. Also, an effort is made to give the user a green performance rating for all the journeys made by him/her till date.

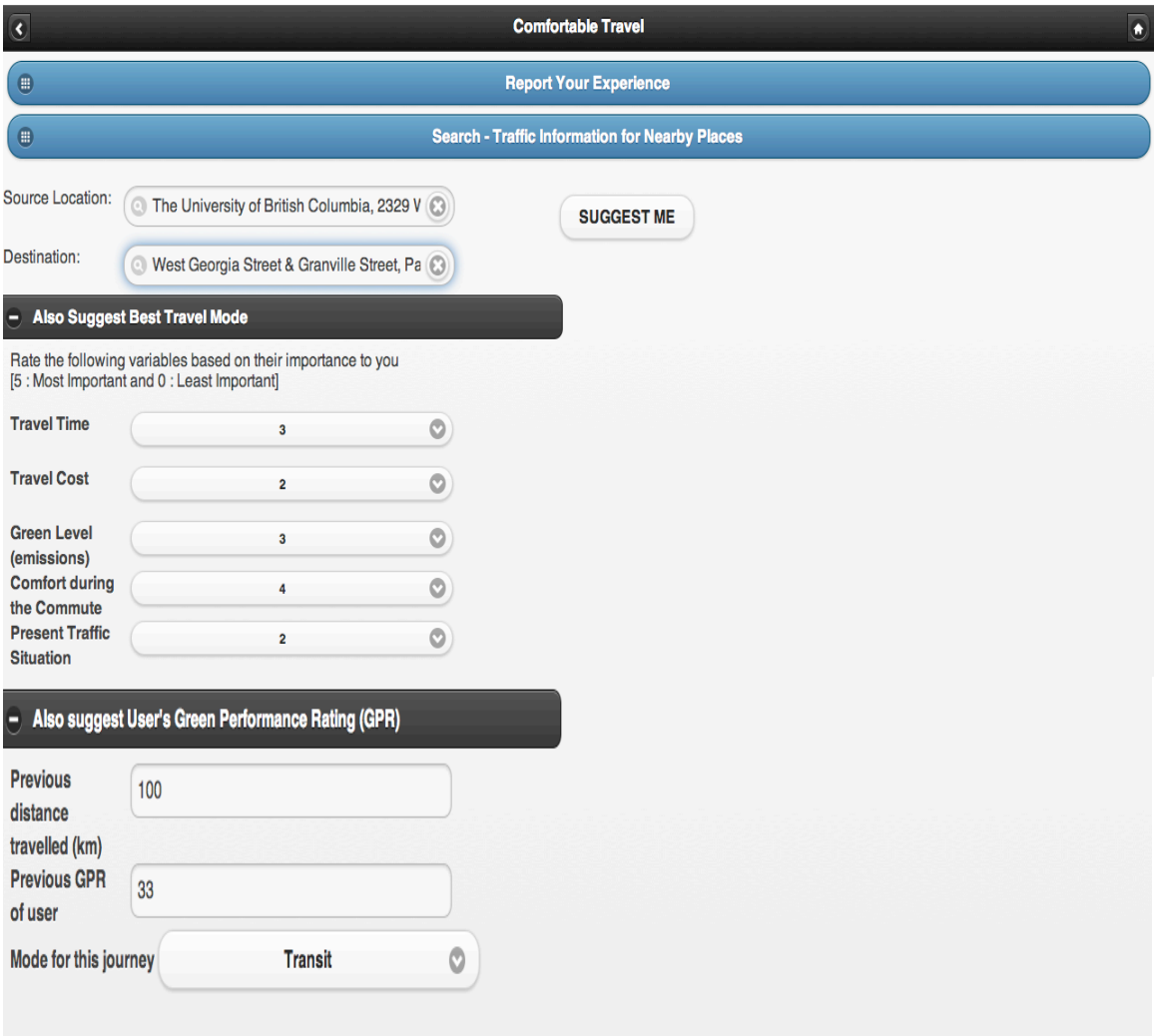

Figure 14: Figure showing page 2 of the application (data entry part).

After clicking on "Suggest Me" button, suggestions can be viewed, as shown in Figure 15.

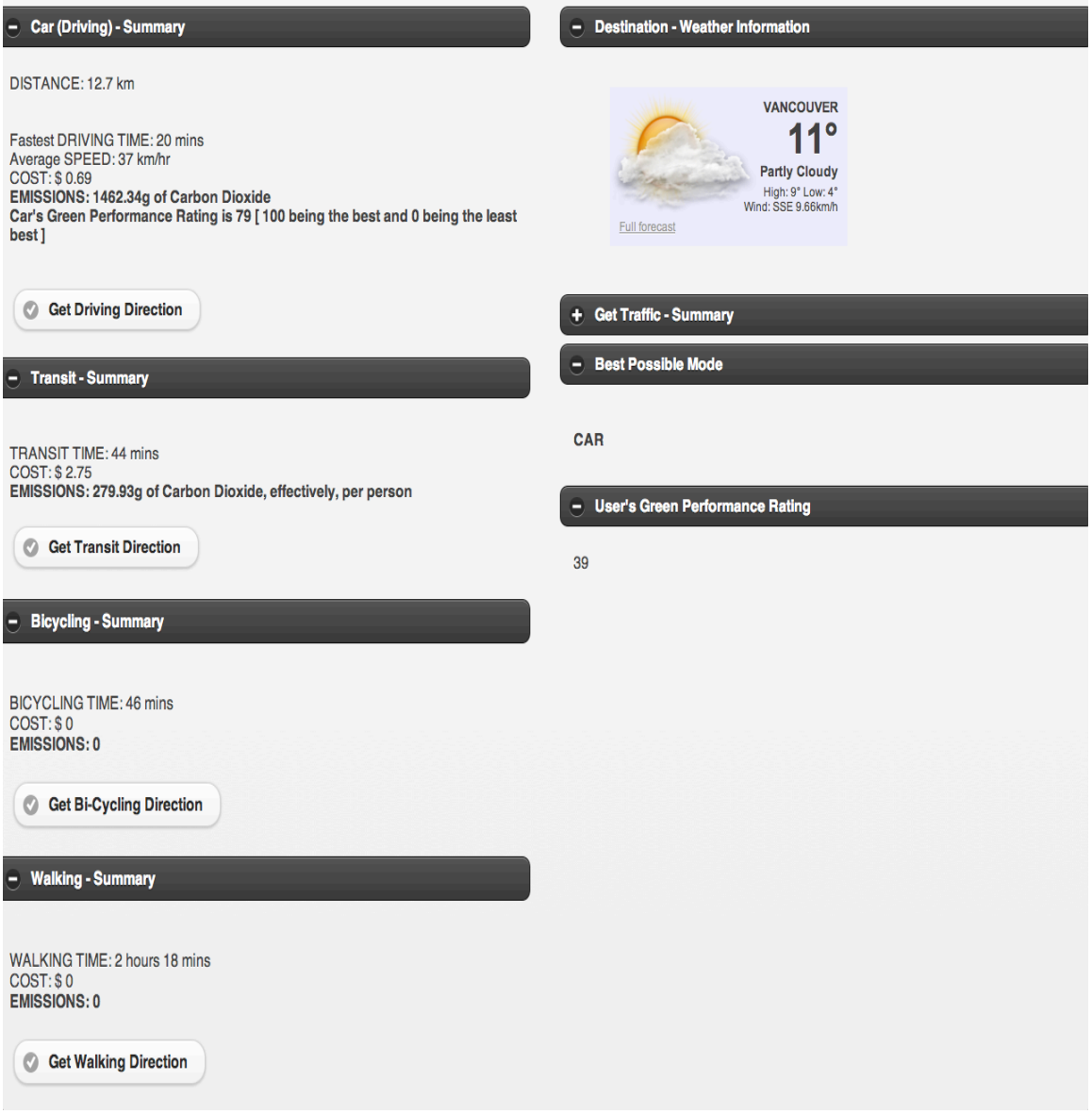

Figure 15: Figure showing page 2 of the application (suggestions part).

Travel directions can be seen in map or textual for all the travel modes, by clicking on suitable buttons.

To report any incident, user can click on “Report An Incident” button and similarly, if the user intends to search for any incident, the user can click on “Search for Incidents” button.

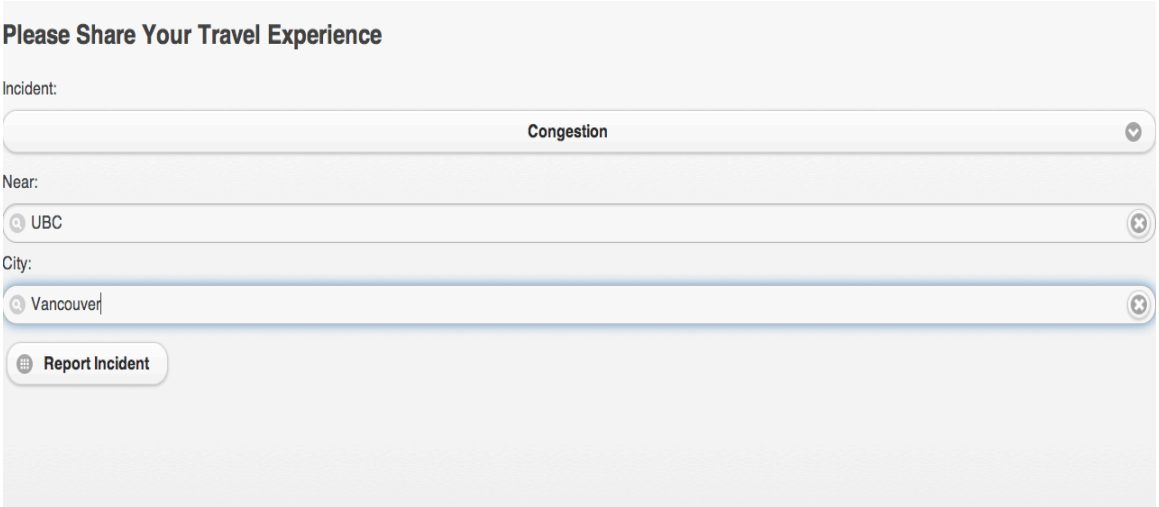

Figure 16: Figure showing reporting an incident feature.

After clicking on "Report Incident", the following confirmation appears.

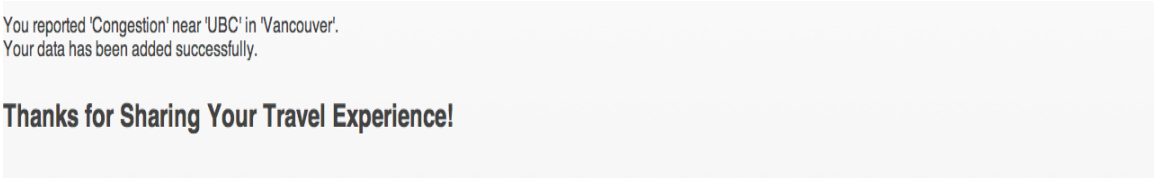

Figure 17: Figure showing confirmation of the incident (data) reported.

On searching for incidents, the information entered into the database is displayed.

Figure 18: Figure showing searching for incidents feature of the application.