An Automated Personal Carbon Footprint Calculator for Estimating Carbon Emissions from Transportation Use

Chiamaka Ann Marie Ajufo
Middlesex University Mauritius,
Flic-en-Flac, Mauritius
ajufoamaka@gmail.com

Girish Bekaroo
Middlesex University Mauritius,
Flic-en-Flac, Mauritius
g.bekaroo@mdx.ac.mu

ABSTRACT
Transportation is one of the biggest menaces to the planet, releasing several million tons of gases into the atmosphere on an annual basis. The growing use of transportation has expanded the concentration and release of these gases, which affect the environment in a number of ways such as depletion of the ozone layer, air pollution and more seriously, global warming and climate change. Among the different modes, road transportation is a significant contributor of greenhouse gas as it ejects dangerous gases directly into the atmosphere, and these emissions are predicted to increase drastically over the years. As such, it is essential to track and monitor emissions from transportation activities in an attempt to reduce the global emissions of greenhouse gases, through carbon footprint calculators. However, most of these calculators do not solely focus on transportation and the ones that do, require a substantial amount of effort and manual input. this paper investigates acceptance of an automated personal transportation-based carbon footprint calculator and its accuracy in monitoring and reducing carbon emissions. As part of this study, a mobile application called TCTracker was implemented using Global Positioning System (GPS) functionality and built-in artificial intelligence (AI) features. The acceptance of the tool was evaluated using the Technology Acceptance Model whereby involving forty users to evaluate four constructs notably, perceived ease of use, perceived usefulness, perceived enjoyment, and intention to use. Among these constructs, perceived ease of use and perceived usefulness had the highest scores, to also depict the acceptance of the tool, while also sustaining interest in carbon footprint tracking.

Author Keywords
Carbon footprint calculator; road transportation; automated; Technology Acceptance Model; mobile application.

ACM Classification Keywords
CCS→ Information systems → Information systems applications → Mobile information processing systems

INTRODUCTION

Road transportation has not only been a major source of air pollution but is also a key contributor of greenhouse gases (GHGs), where millions of tons of such gases including carbon dioxide (CO_2) are globally emitted into the atmosphere every year [1]. More specifically, while the entire transportation industry accounts for 24% of global CO_2 emissions, road transportation alone is responsible for 72% of all transportation-related emissions [2]. The release and concentration of CO_2 in the atmosphere have expanded because of the growth of transportation usage and is perturbing the earth, causing heinous climate change, global warming, and various associated repercussions [3]. Consequently, climate change prompted notably by carbon dioxide has associated direct negative impacts, such as deaths caused by heat waves, floods and droughts as well as other adverse effects including changes in the amount and patterns of infectious diseases [4, 5].

Due to these adverse effects of road transportation, it has become essential to manage and reduce carbon emissions. A common approach to determine CO_2 emissions from an activity is through carbon footprint calculation, which is recognised to assist in emission tracking and evaluation of mitigation measures applied by an entity [6]. In technical terms, carbon footprint is a measure of the total amount of carbon dioxide emitted into the atmosphere as a result of activities accumulated over a period of time, carried out by an entity [7]. Recently, numerous organizations have developed projects and tools to track and reduce carbon footprint in order to eventually diminish the impacts of climate change [8]. Among the tools, carbon footprint calculators are intended to monitor and facilitate the reduction of carbon dioxide emission, and despite methodologies for its calculations still being developed, it is emerging as a critical tool for greenhouse gas management making its utilization at even an individual level necessary [9].

Although various personal carbon footprint calculators have emerged online and on application sharing platforms such as Google Play, most carbon calculators focus on various activities of an individual including household energy use, diet and lifestyle and among others [10], instead of directly emphasizing on transportation related emissions. Consequently, such calculators are tedious for the users who only wish to determine their travel-based carbon emissions, as these tools also require various other details that are inconsequential to transport. In addition to requiring extensive manual input from users, some of these calculators also request specific technical details, such as one's vehicle engine model and year, which may be discouraging to users and hinder them from utilizing such tools [11]. Due to these restrictions, there is a necessity for the creation of a newer calculator that is solely transport based and automates most of the input, ultimately facilitating carbon footprint calculation by incorporating technologies such as GPS. Taking cognizance of these limitations, this paper investigates acceptance of an automated personal transportation-based carbon footprint calculator and its accuracy in monitoring and reducing carbon emissions.

RELATED WORKS

Published literature focuses on presenting developed tools and disseminating findings related to application of carbon footprint calculators in various sectors, rather than addressing how to embed intelligence in such tools. A recent study conducted a top-down analysis of personal travelling-based carbon calculators to examine limitations of such tools and recommend features to improve such tools [11]. Among the existing travel-based carbon calculators, CarbonoCero calculates the tons of CO_2 emitted by the flights of its users [12] where end-users are required to enter the airport of embarkation and final destination, number of passengers/seats, and the class they would be flying in, i.e. economy, business or first class, and the application calculates the CO_2 emitted based on the details entered. Similarly, Carbon Carma allows users keep track of their carbon emissions and how much they drive using a small gadget that the user must purchase and place in their vehicle, referred to as a beacon [13]. The beacon works by triggering the application to start tracking carbon emissions of the car it is placed in when the user is in the car and the car is in motion. Likewise, Car CO_2 Tracker tracks how much CO_2 is emitted during the car trips of its users and uses GPS functionality to track distance travelled [14]. The user is required to select the fuel consumption of the car they wish to track (from low to very high), with this information and the recorded distance, the application is able to calculate CO_2 emissions, and display the value on the home page. In addition, Carbon Footprint in Vehicles [15] mobile application comprises of a singular page which displays a predefined list of vehicles and their respective grams of carbon dioxide the vehicle emits per kilometre driven (g/km). With this application, there is no tracking of CO_2 emissions in any sense. For this application to be useful, the user would have to search the application for their specific type of vehicle to get its g/km of CO_2 emitted, then monitor the kilometres travelled by the vehicle while driving and multiply that by the value shown in the application. Only then will the user be able to enumerate the CO_2 of their vehicle. This is a rather tedious procedure and can be demotivating to users.

As such, even though there exist a few personal carbon footprint tools that focus on transportation related carbon footprint of individuals, a manual approach is widely used to feed information to the tool in order to obtain carbon related information. The need for manual input also implies that end users need to remember details of trips (including vehicle used and distance, among others), which lead to inaccuracies if carbon footprint is being calculated every month or even every year. Because of these restrictions there is a necessity for the creation of a newer calculator that is solely transport based and automates most of the input in order to ultimately facilitate carbon footprint calculation and reduce inaccuracies.

PROTOTYPE DESIGN AND DEVELOPMENT

In order to fulfil the purpose of this paper, a mobile application called TCTracker was developed. The proposed tool focuses only on carbon emissions from road transportation activities as they account for 81% of the total energy use in the transport sector [16]. TCTracker aims to automate the process of calculating transport-based carbon emissions of individuals. The key features of the mobile app include:

- Location tagging which uses GPS technology to calculate carbon footprint.
- Automatically recording key parameters such as distance travelled, and method of transport used.
- Built-in algorithm to estimate transport carbon footprint of individuals in real-time.
- Enumerating users' monthly individual transport carbon footprint and providing the user with a summary.
- Providing some statistical information such as carbon emission breakdown by method of transport utilized used daily, weekly, monthly etc.
- Providing users with advice on the most proficient method to reduce transport carbon emanations.

TCTracker was developed using Android Studio due to its popularity and was appropriate for fulfilling all the functional and non-functional requirements of the system. For this application, Java was chosen, and the Support Library was used for the key features of the design. Classes used from this library include the Fragment, Drawer Layout (used to implement the navigation drawer) and CardView classes amongst others. The drawable package was used to a great extent for adding images, and gradients, and vector images. The Location and Geocoder classes were also implemented as well as the Google Maps API. The Location class was used for a number of things, notably for retrieving the latitude and longitudes of users' position, calculating the distance between two positions, and some methods form this class such as the getSpeed method was used to get the moving speed of the user. Geocoder was used to convert the latitude and longitude of a position into a street name, or country, or town, where users can see their start and end points. In addition, SQLite was used as database to store details pertaining to the carbon footprint of a user such as the date, distance, mode of transport and carbon footprint value of each journey, as well as the user's details such as a unique auto generated ID and profile details.

On launching the application, a home page is displayed, as shown in Figure 1. The date displayed is the date of the current day (which changes daily), below which every activity tracked on that day is displayed. Background processes are implemented that track the user's transportation activities and open a new page where users can view their speed and the duration of their journey in real time. Initially, a map pin is placed at the user's location once they begin tracking their journey, and another one is placed at the location where the journey ends (indicated by the user ending tracking). In the application, there is also a built-in algorithm to estimate transport carbon footprint of individuals in real-time. For this, distance is calculated though the use of the Google Maps API, to also store the latitude and longitude of the start and end points to eventually calculate the distance between them. The algorithm automatically selects a mode of transport based on various parameters, such as the average speed of a journey in relation to the distance covered. For example, if the average speed if 5km/h then the mode of transport considered will be "Foot", while also taking the distance travelled into account. The algorithm selects mode of transport based on previous research [17, 18]. As key challenges, for some modes such as car, bus and van/truck, the average speeds were virtually the same on the road and in the process, different considerations were made, e.g., detecting stationary times and patterns (e.g., bus), acceleration, etc. At the end of the trip, the users are able to change the mode of transport (if the one selected was incorrect), after the app provides details on distance covered and carbon footprint, which also enables the algorithm to reinforce its learning based on the users' modifications. For every personal travel activity, the application calculates the carbon footprint using the equation below:

$$Distance \times EF = Carbon\ emissions$$

Equation 1. Formula for calculating carbon emissions [19]

where:

- Distance is measured in kilometres per year (km/yr)
- EF (Emission Factor) is measured in kilograms of CO_2 per kilometre (kg CO_2e/km)
- Carbon emissions is measured in kilograms of CO_2 equivalent per year (kg CO_2e/yr)

CO_2 emissions are calculated through the use of emission factors which are representative values that relate the amount of air pollutants discharged into the atmosphere to a specific activity [20]. Emission factors are simply represented as the ratio of mass of a pollutant emitted per unit of activity generating the emissions [21].

Given that the transportation activities are calculated as background processes, end users can view the list of these activities and their corresponding carbon emissions each time the application is opened. Users can also edit and confirm activities and archive details for statistical purposes. Among the statistics, the user can view the carbon footprints for previous months or even customized periods by selecting dates from date pickers. In the process, the end user can also see all the modes of transport they have used categorized by carbon footprint, distance and most used, and details can be filtered and sorted. Key screenshots of the tool are depicted in Figure 1.

EVALUATION METHOD

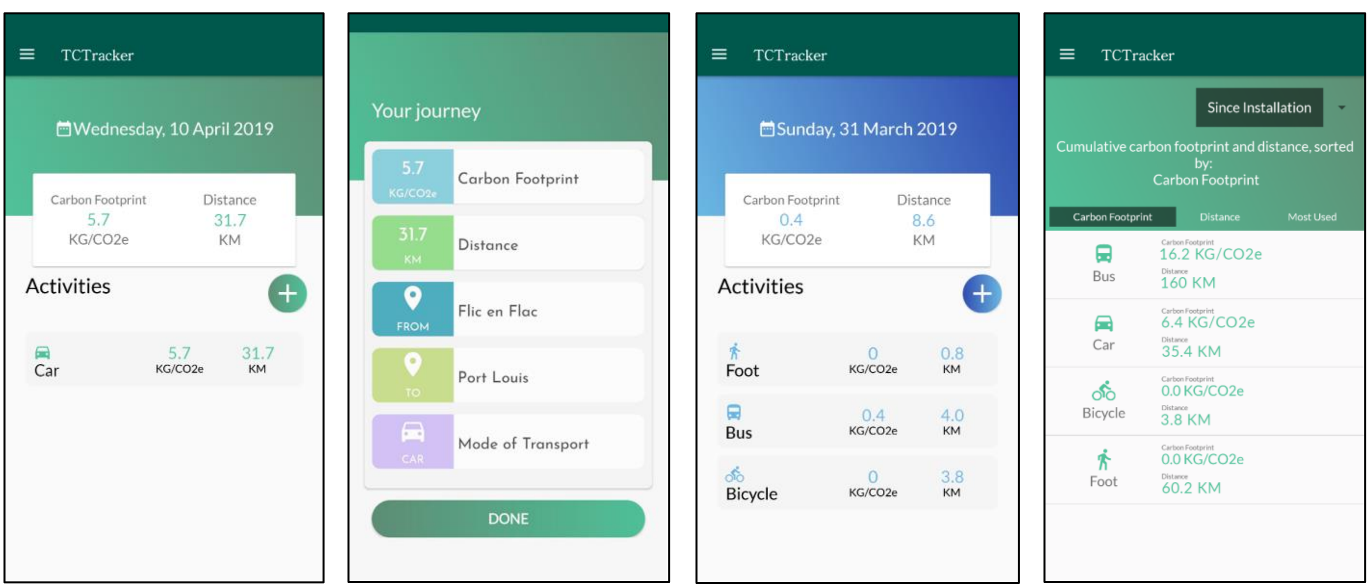

Figure 1. Screenshots of TCTracker

As per the research question, it was essential to determine the degree of acceptance and the capacity to which the application affected the users, while also representing the quantitative aspects of the evaluation. Technology acceptance is the determination of how people accept and perceive the use of technology [22]. This factor is essential to investigate since it provides sound predictions of usage by connecting behaviors to attitudes and beliefs (ease of use and usefulness) that are also consistent temporally and in context with behavior of interest [23]. In order to investigate acceptance of TCTracker, the Technology Acceptance Model (TAM) was applied. This model was created by Fred Davis and is a widely used methodology used for discovering the use and acceptance of technology and Information Systems (ISs) and it has been studied and proved to be accurate multiple times over the past years [24]. TAM uses two main constructs, perceived ease of use and perceived usefulness as the foundation for determining the user acceptance of any system [24]. These two constructs are influenced by "external variables", which are social, cultural, and political factors. Due to the prominence of the technology acceptance model, it has become the base of many studies and as a result some changes to the original model have been made. One of these changes include the creation of a new construct called perceived enjoyment. It was created during the study of a word processor and graphic package [25], and is used to measure how users enjoy using a system. That being said, these constructs, which are defined in Table 1, served as a basic unit upon which the evaluation questionnaire was designed. The questionnaire consists of 18 statements, which were evaluated against a 5-point Likert scale where 1 implied strongly disagree and 5 meant strongly agree. Prior to data collection, a pilot study was conducted in order to discover and remedy any complications that remained in the system. This involved 2 students who used the application for 4 days. Feedback obtained helped to finalise the evaluation process and application.

The target audience for this evaluation was Middlesex University Mauritius students irrespective of any demographic details. As such, there were only two criteria for selecting participants, which were: owning an android mobile device and staying in Mauritius for the duration of the evaluation process, as emission factors for Mauritius were used in TCTracker. The number of participants targeted was 40 in order to meet the minimum number required by TAM [26].

The collection of data was done in three parts. The first step was gathering participants and briefing them on the project, after which they were asked to read and sign an informed consent form for participating in the study. Secondly, TCTracker was installed on every user's mobile device, then they were provided with a short demo on how to navigate and use the application. In this step, users were instructed to use the application to track each of their journeys over the course of a week, after which they would receive an email prompting them to complete the online

Construct	Definition	Measured item
Perceived Usefulness	The extent to which an individual thinks that the use of a system will benefit them by enhancing their performance of a task [28].	PU1 - I found TCTracker to be a useful application for tracking carbon footprint.
		PU2 - Using the application helped me reduce my transport-based carbon emissions.
		PU3 - The application selected my mode of transport accurately.
		PU4 - When detecting my mode of transport, the application had more hits than misses.
		PU5 - Using the application helped me observe the carbon footprint of my transport activities effectively.
		PU6 - Being able to view and sort my total carbon emissions into different categories (daily, monthly, yearly and since installation) helped me to enumerate my emissions.
Perceived Ease of Use	The extent to which an individual thinks the use of a system would be free from effort [28].	EU1 - It was easy for me to navigate through the application.
		EU2 - I did not have to manually input a large amount of information for carbon footprint to be calculated.
		EU3 - I found that I got familiar with the application easily.
		EU4 - The timely notifications made it easier for me to track my journeys.
		EU5 - Overall using TCTracker was easy.
Perceived Enjoyment	The degree to which the use of a system is perceived as enjoyable [25].	PE1 - Using the system was an enjoyable way to measure my carbon emissions.
		PE2 - I did not forget to use the application to track my journeys
		PE3 - It was not inconvenient having to reach for my mobile device before embarking on any journey.
		PE4 - Using the application did not feel like a burden.
		PE5 - Overall using TCTracker was a pleasant and enjoyable experience.
Intention to use	The degree to which an individual is willing to use a system in the future [29].	IU1 - I intend to use this application to track my future journeys.
		IU2 - I would use TCTracker if it was publicly available.

Table 1. Evaluation constructs used for TAM questionnaire

evaluation form. The final step was emailing the questionnaire to each of the participants for evaluation. The questionnaires were eventually collected while ensuring the required sections were correctly filled in. Once all the participants had filled the form and the responses were complete, data analysis took place.

RESULTS AND DISCUSSIONS

Results following application of TAM are provided in Table 2 and are discussed as follows.

Perceived Usefulness

A total of 92.5% of people found the application as a useful tool for tracking their transportation carbon footprint. Although, 60% agreed that TCTracker helped them reduce their carbon footprint and 40% either disagreed or were neutral to this. A majority of 85% agreed or strongly agreed that the application accurately selected their mode of transport, 15% were neutral and there were no negative responses. 80% of users agreed that the application had more hits than misses when detecting mode of transport, only 5% were opposed to this statement. This also highlights the effectiveness of the built-in algorithm to automatically select transportation mode and to estimate transport carbon footprint of individuals in real-time. The participants who disagreed with this statement highlighted that automatic selection of mode of transportation could be improved especially for cars, buses, vans and trucks, as some learning is also required by the tool. Because this method selects the transportation mode using the built-in algorithm, it could have selected bus when the vehicle was a van, especially when running the app for the first few days. Another thing which could have affected this is traffic, because the mode of transport is selected by the average speed of the vehicle, which is calculated through dividing the distance by the duration of the journey, if the user encountered traffic the duration will increase, thus decreasing the "average speed" which will lead the application to choose a mode of transport with a lesser average speed like bicycle or foot instead of car and some users may have experienced this issue. 75% of people agreed that the sorting functionality helped improve their enumeration of carbon footprint.

Perceived Ease of Use

The results for Perceived Ease of Use show that 87.5% of people agreed that navigating through the application was easy, 2.5% disagreed and 10% were neutral. 7.5% of people were neutral to not having to enter a large amount of information to calculate their carbon footprint while 92.5% agreed to the statement. In general, 92.5% of people said that the application was easy to use. Perceived Ease of Use had the highest average amongst the 4 constructs used. According to the results, the statement which most people agreed with was not having to input large amounts of information, none of the forty users disagreed and only three individuals were neutral, as the application had minimal points where the users' input was necessary.

Statement	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Perceived Usefulness					
PU1 - I found TCTracker to be a useful application for tracking carbon footprint.	0.0%	5.0%	2.5%	42.5%	50.0%
PU2 - Using the application helped me reduce my transport-based carbon emissions.	2.5%	7.5%	30.0%	30.0%	30.0%
PU3 - The application selected my mode of transport accurately.	0.0%	0.0%	15.0%	62.5%	22.5%
PU4 - When detecting my mode of transport, the application had more hits than misses.	0.0%	5.0%	15.00	40.0%	40.0%
PU5 - Using the application helped me observe the carbon footprint of my transport activities effectively.	0.0%	2.5%	15.0%	47.5%	35.0%
PU6 - Being able to view and sort my total carbon emissions into different categories (daily, monthly, yearly and since installation) helped me to enumerate my emissions.	0.0%	5.0%	20.0%	37.5%	37.50
Perceived Ease of Use					
EU1 - It was easy for me to navigate through the application.	0.0%	2.5%	10.0%	42.5%	45.0%
EU2 - I did not have to manually input a large amount of information for carbon footprint to be calculated.	0.0%	0.0%	7.5%	37.5%	55.0%
EU3 - I found that I got familiar with the application easily.	0.0%	5.0%	12.5%	32.5%	50.0%
EU4 - The timely notifications made it easier for me to track my journeys.	0.0%	5.0%	27.5%	32.5%	35.0%
EU5 - Overall using TCTracker was easy.	0.0%	2.5%	5.0%	42.5%	50.0%
Perceived Enjoyment					
PE1 - Using the system was an enjoyable way to measure my carbon emissions.	0.0%	2.5%	15.0%	45.0%	37.5%
PE2 - I did not forget to use the application to track my journeys	7.5%	10.0%	20.0%	32.5%	30.0%
PE3 - It was not inconvenient having to reach for my mobile device before embarking on any journey.	2.5%	10.0%	22.5%	35.0%	30.0%
PE4 - Using the application did not feel like a burden.	10.0%	7.5%	27.5%	35.0%	20.0%
PE5 - Overall using TCTracker was a pleasant and enjoyable experience.	0.0 %	2.5%	7.5%	57.5%	32.5%
Intention to use					
IU1 - I intend to use this application to track my future journeys.	0.0%	12.5%	27.5%	40.0%	20.0%
IU2 - I would use TCTracker if it was publicly available.	0.0%	5.0%	22.5%	47.5%	25.0%

Table 2. Results

Perceived Enjoyment

Results showed that 82.5% of people either agreed or strongly agreed that using the system was an enjoyable way to measure their carbon emissions. 17.5% of people often forgot to use the application to track their journeys and even 12.5% claimed that having to reach for their mobile device was often an inconvenience. Looking further into this, it can be seen that among the 36 people who did not find it an inconvenience, 32 of them were within the age range of 18-24. This could be attributed to the dependence on mobile devices of the individuals that belong to this age group, as having to reach for their phones, or other mobile devices, would not have been so substantial an inconvenience. On the other hand, the relatively elder participants who have less desire for using mobile devices constantly, also seen here as the one individual who strongly said having to reach for my mobile device before embarking on any journey was an inconvenience was in fact the individual whose age range was 35-44. Overall, 90.0% of people said using the application was an enjoyable experience.

Intention to Use

For this construct, 80.0% of people agreed and strongly agreed that they intend to use the application in the future, 27.5% were neutral and 12.5% were opposed to this. Only 72.5% would use the application if it was publicly available, 5.0% disagreed with this and 22.5% of participants were neutral. Because the users found the application easy to use, useful and had an enjoyable experience, many of them agreed to continuing to use it to track future journeys, as some individuals mentioned in the additional comments that they are trying to be more aware of their carbon emissions.

General Discussions

One of the main issues with the existing carbon footprint calculators is that they require large amounts of manual input from users to be able to calculate their carbon footprint, which becomes a nuisance to users and may demotivate them from using such applications again. In order to address this issue, this study investigated acceptance of an automated personal transportation-based carbon footprint calculator and its accuracy in monitoring and reducing carbon emissions. According to the findings in this study, this issue has successfully been tackled, as 92.5% of respondents agreed and strongly agreed that manual input was seldom required. This objective has been attained considering almost all of the participants agreed that the application also helped them to reduce their carbon emissions and 60% had reduced their carbon footprint by using the application. This observation and reduction of carbon emissions is likely to continue as once again 60% agreed that they will use TCTracker to track all their transport activities in the future. The users also appreciated features such as the frequent notifications and the ease of navigating through the application as almost all users responded greatly to these. 82.50% agreed that they got familiar with the application easily and because familiarity breeds enjoyment [27], the users also enjoyed using the application. In regard to this, most users also said that using the application was an enjoyable way to track their carbon footprint, although 12.5% and 17.5% of people said that having to reach for their device before beginning a journey was an inconvenience and they often forgot to track their journeys respectively.

Not only was the application enjoyed by users, 37 of them also thought that it was a useful tool for calculating carbon emissions. When it came to selecting mode of transport, the application selected it more accurately than not and 80% of users agree with this, and a significant percentage of people also particularly liked the sorting features of the application. It is seen that users generally enjoyed using the application. The enjoyment and usefulness are further supported by multiple users mentioning using the application to track their future journeys, despite the completion of the study. All things considered, all four constructs of technology acceptance as well as the research question have been fulfilled. TCTracker, after having been evaluated under the constructs of the Technology Acceptance Model, has passed all the criteria hence user acceptance has been attained. Among the constructs, the one with the highest score was Perceived Ease of Use with an average of 4.28, followed by Perceived Usefulness at 4.09, then Perceived Enjoyment and Intention to Use at 3.87 and 3.80, respectively. Nevertheless, the study also had different limitations that provide avenues for future work by the research community. Firstly, evaluation did not consider some technical aspects including accuracy of calculated carbon emissions for every end user as they had limited knowledge to determine such quantitative values. In addition, the tool had various limitations pertaining to the development of a carbon footprint calculator for the context of Mauritius, including lack of standardized emission categories and factors [10].

CONCLUSIONS

This study investigated acceptance of an automated personal transportation-based carbon footprint calculator and its accuracy in monitoring and reducing carbon emissions. In order to achieve this key purpose, an android mobile application named TCTracker was designed, developed and tested. The application aims to automate the calculation of transport-based carbon footprint of individuals through the use of location tagging, GPS and built-in algorithms to calculate carbon footprint through autonomously detecting key parameters such as distance travelled, speed and mode of transport used, to consequently relieve the user of manual input. After the application prototype was implemented, evaluation was conducted with a total of forty individuals through the application of the Technology Acceptance Model. Results from the questionnaire show that overall, users accepted and enjoyed using the application, as all the constructs of the Technology Acceptance Model had above average means, mostly perceived enjoyment, and perceived usefulness. In conclusion, results discussed in this paper show users were able to track their carbon emissions in an automated manner and the proposed tool was accepted by participants of the study. As future works, TCTracker can be extended to include further algorithms to reinforce learning following collection of more data after utilization by end-users. Additionally, rather than focusing only on road-based transportation, various other modes could be considered including airplanes, and boats, among others. In addition, evaluation could be extended to more quantitively determine accuracy of calculated carbon emissions based on the implemented automated features of the tool.

REFERENCES

[1] J. Hu, R. Wood, A. Tukker, H. Boonman and B. de Boer, "Global transport emissions in the Swedish carbon footprint," *Journal of Cleaner Production,* vol. 226, pp. 210-220, 2019.

[2] S. Wang and G. Mengpin, "Everything You Need to Know About the Fastest-Growing Source of Global Emissions: Transport," 2019. [Online]. Available: https://www.wri.org/blog/2019/10/everything-you-need-know-about-fastest-growing-source-global-emissions-transport. [Accessed 10 Apr 2020].

[3] G. Santos, "Road transport and CO2 emissions: What are the challenges?," *Transport Policy,* vol. 59, pp. 71-74, 2017.

[4] N. Arnell and S. Gosling, "The impacts of climate change on river flood risk at the global scale," *Climatic Change,* vol. 134, no. 3, pp. 387-401., 2016.

[5] X. Wu, Y. Lu, S. Zhou, L. Chen and B. Xu, "Impact of climate change on human infectious diseases: Empirical evidence and human adaptation," *Environment international,* vol. 86, pp. 14-23, 2016.

[6] Carbon Trust, "Carbon footprinting. An introduction for organizations," 2007. [Online]. Available: http://www.carbontrust.co.uk/publications/publicationdetail.htm?productid=CTV033. [Accessed 4 Apr 2015].

[7] C. Pertsova, Ecological economics research trends, New York: Nova Science Publishers, 2007.

[8] S. H. Matthews, C. T. Hendrickson and C. L. Weber, "The Importance of Carbon Footprint Estimation Boundaries," *Environmental Science & Technology,* vol. 42, no. 16, pp. 5839-5842, 2008.

[9] D. Pandey, M. Agrawal and J. Pandey, "Carbon footprint: current methods of estimation," *Environmental Monitoring and Assessment,* vol. 178, no. 1-4, pp. 135-160., 2010.

[10] G. Bekaroo, D. Roopowa and C. Bokhoree, "Mobile-based Carbon footprint calculation: insights from a usability study," in *IEEE 2019 Conference on Next Generation Computing Applications (NextComp)* , 2019.

[11] G. Bekaroo, D. Roopowa, A. Zakari and D. Niemeier, "Calculating carbon emissions from personal travelling: insights from a top-down analysis of key calculators," *Environmental Science and Pollution Research,* vol. 28, no. 7, pp. 8853-8872, 2021.

[12] Carbonocero, "Carbonocero," 2018. [Online]. Available: http://www.carbonocero.org/nosotros.php. [Accessed 15 October 2018].

[13] Co2carma, "About Us - Carbon Carma," 2018. [Online]. Available: https://www.co2carma.com/about-us/. [Accessed 18 October 2018].

[14] 32BitsCo, "Car CO2 Tracker," 2017. [Online]. Available: https://play.google.com/store/apps/details?id=com.tracker.carco2tracker&hl=en_AU. [Accessed 18 Mar 2021].

[15] Green Engineering Tips, "Google Play," 2018. [Online]. Available: https://play.google.com/store/apps/details?id=com.co2.automobile&hl=en_US&gl=US. [Accessed 20 Mar 2021].

[16] L. Chapman, "Transport and climate change: a review," *Journal of Transport Geography,* vol. 15, no. 5, pp. 354-367, 2007.

[17] D. Berry and D. Belmont, "Distribution of vehicle speeds and travel times," in *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability,* 1951.

[18] Think Metric, "Speed," 2021. [Online]. Available: https://thinkmetric.uk/basics/speed/. [Accessed 10 Jun 2021].

[19] ShrinkThatFootprint, "Calculate your carbon footprint," 2017. [Online]. Available: http://shrinkthatfootprint.com/calculate-your-carbon-footprint. [Accessed 14 December 2018].

[20] EPA, "Basic Information of Air Emissions Factors and Quantificatio," 2016. [Online]. Available: https://www.epa.gov/air-emissions-factors-and-quantification/basic-information-air-emissions-factors-and-quantification#About%20Emissions%20Factors. [Accessed 11 November 2016].

[21] Eastern Research Group, "Recommended Procedures for Development of Emissions Factors and Use of the WebFIRE Database," Office of Air Quality Planning and Standards (OAQPS), U.S. Environmental Protection Agency, North Carolina, 2013.

[22] P. Legris, J. Ingham and P. Collerette, "Why do people use information technology? A critical review of the technology acceptance model," *Information & management,* vol. 40, no. 3, pp. 191-204, 2003.

[23] B. Wixom and P. Todd, "A theoretical integration of user satisfaction and technology acceptance," *Information systems research,* vol. 16, no. 1, pp. 85-102, 2005.

[24] P. Surendran, "Technology acceptance model: A survey of literature," *International Journal of Business and Social Research,* vol. 2, no. 4, pp. 175-178, 2012.

[25] F. D. Davis, R. P. Bagozzi and P. R. Warshaw, "Extrinsic and Intrinsic Motivation to Use Computers in the Workplace," *Journal of Applied Social Psychology,* vol. 22, no. 14, pp. 1111-1132, 1992.

[26] G. Bekaroo, R. Sungkur, P. Ramsamy, A. Okolo and W. Moedeen, "Enhancing awareness on green consumption of electronic devices: The application of Augmented Reality," *Sustainable Energy Technologies and Assessments,* vol. 30, pp. 279-291, 2018.

[27] R. Raghunathan, "Familiarity Breeds Enjoyment," 17 January 2012. [Online]. Available: https://www.psychologytoday.com/us/blog/sapient-nature/201201/familiarity-breeds-enjoyment. [Accessed 13 April 2019].

[28] F. D. Davis, "Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology," *MIS Quarterly,* vol. 13, no. 3, p. 320, 1989.

[29] M. J. Alsamydai, "Adaptation of the Technology Acceptance Model (TAM) to the Use of Mobile Banking Services," *International Review of Management and Business Research,* vol. 3, no. 4, pp. 2018-2021, 2014.