Validating Trip Travel Time Provided by Smartphone Navigation Applications in Jordan

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ABSTRACT

This research aimed to validate the trip travel time provided by three selected navigation applications, through examining the error in the Estimated Time of Arrival (ETA) provided. The ETA was compared with the actual travel time measured from 204 selected urban and rural road segments in Jordan. The overall trip travel time accuracy was 70%, 57% and 52% for the Google Maps, Here-WeGo and Waze applications, respectively. Analysis results showed that the three applications' ETA measures vary from the actual trip time with different error levels ranging from minor errors of less than 10% to significant errors of more than 40%. It was found that Google Maps has the most distinguished accuracy, yet the provided information by Google Maps contains a certain amount of error in the ETA. Also, ANOVA test showed that there was no statistically significant differences between Google Maps and Waze-ETA mean errors, while Here-ETA mean error significantly differs from those of both applications. The significant contribution of this research is the detailed evaluation process of the estimated journey times using field data collected by trained drivers instead of crowdsourcing data. The usage of such applications will attract the attention of individuals, organizations and agencies in different related sectors.

KEYWORDS: Navigation applications, Estimated time of arrival, Google maps, Here-WeGo, Waze.

INTRODUCTION

Artificial intelligence is employed in Navigation Applications (NAs) and Intelligent Transportation Systems (ITSs) to estimate traffic conditions, such as speed, travel time and delay at specified road segments that can be utilized for designing optimal driving routes (Liebig et al., 2017). The user can view traffic conditions as color-coded segments, where the application predefines the color code, so that the user may plan the trip based on this information and the obtained traffic data can be utilized by the application itself to give a "route advice" to the user.

The reliability of information provided by these applications is the critical factor of the success and spread of them, because road users are looking to get correct information. Navigation reliability using smartphones can be evaluated by several techniques, such as questionnaires with application users, interviews, traffic sensors installed by government and private companies, field data collection and even using simulation to compare and validate the obtained results.

One of the essential features in NAs is traffic condition information, which can be either real-time or historical data collected from application users while they are moving. Real-time data is used when there are active users at a road segment at a time, whereas historical data is used when there are no active users at that time, which represents the best past prediction of traffic conditions. Smart routing algorithms were developed to improve the calculations and their predictions using both real-time and historical traffic experience.

Currently, NAs are developed in many countries

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around the world; some of them are operated to serve a specified geographical area, while others are limited to use by specific users. Additionally, many of these applications are available to use for free. By now, there is a variety of NAs which were developed by different companies and developers all over the world. For this research, a set of three popular NAs were investigated: Google Maps, Here-WeGo and Waze.

Traffic Studies Based on Data Provided by NAs

Many researchers have investigated different data types that are extracted from various NA features. The data provided by those features is considered to have high value in the fields of traffic monitoring, traffic management and safety studies. It is also a valuable resource for building reliable Advanced Traveler Information Systems (ATISs) that can serve in many roles to improve the performance of the transport process.

NAs are the product of merging mapping, global positioning system (GPS) and smartphone technologies. One of the most used applications is Google Maps; it was downloaded more than 5000 million times on Android devices only (Google Maps, 2020). It supports many different navigating features (Google Developers, 2020) and is available to use in more than 220 countries (Google Play Store, 2020A). Many studies were conducted using Google Maps traffic data, maps and routing features. Petrovska and Stevanovic (2015; 2016) have employed Google Maps traffic data in developing a visualization tool that can be used for live traffic and congestion analysis. Another system for displaying traffic conditions was presented by Zhou et al. (2015), who have evaluated the output of their urban traffic monitoring system by making a comparison between official field traffic data and Google Maps traffic data. In general, the estimated traffic speed by the system was closer to the official traffic data than Google Maps. Similarly, Pant et al. (2015) have used several public data sources to obtain traffic data to estimate traffic conditions. They have used Google Maps traffic data to evaluate the output of their system (TrafficKarma), which can be used for monitoring and visualizing traffic conditions. Nair et al. (2019) have collected traffic data for 29 cities for 40 days using Google Maps to study the traffic conditions over different cities. Moving from occupied field traffic studies to environmental studies, Google Maps were used to obtain traffic data in addition to manual traffic counts to study the contribution of traffic exposure to air pollution (Banica et al., 2017).

Another widely used NA is Waze, which has been downloaded by more than 115 million users (Waze, 2020). It was adopted by Fire et al. (2012) with valuable information to make transportation more comfortable and more familiar. Waze application allows users to report accidents' locations, nearby police units, traffic jams and speed traps, which improves traffic delay prediction and assigns alternative routes to reduce congestion. Waze application was also employed to identify the intersections and areas which are expected to have a higher rate of accidents, in order to implement improvements to avoid these risks. Amin-Naseri et al. (2018) have studied crowdsourced data from Waze and compared it with data from common traffic management data sources. The findings of this research pointed out that Waze-crowdsourced data is an excellent source of broad coverage for traffic monitoring and has reasonable geographic accuracy. In the field of data validation, Goodall and Lee (2019) used traffic mounted cameras along an urban freeway section to extract the real accidents and incident number and locations and compare the results with Waze accident and incident real-time reports. They concluded that the cameras confirmed 13 out of 40 accidents and two reports were found to be false. Also, about 49% of incidents were confirmed by the cameras; hence there are many data sources which are involved in Waze. Sensors –if available-, GPS data and users' reports are the data sources for Waze. After validation and evaluation processes, this data may be used for traffic management and monitoring purposes when it reaches an acceptable level of reliability.

One more commonly used NA is Here-WeGO (HERE, 2020). It was downloaded more than 10 million times on Android devices only and about 100 million users are using Here maps (HERE, 2020; Google Play Store, 2020B). Saputra et al. (2018) have compared the three NAs; Google Maps, Here-WeGO and Wisepilot (Wisepilot, 2020), depending on Pingdom (SolarWinds, 2019) and GTMetrik (GTMetrik, 2019) to evaluate efficiency, where the three applications have shown a "good" performance on a scale of low, medium and good. Also, all of them scored 100 percent in the reliability test, while for testing functionality, usability and cartography, questionnaires were used and the results showed 100% success for Google Maps and Here-WeGo and 98% for Wisepilot. In terms of usability, Google has scored 70.62%, which is classified as good. Here-WeGo scored 55.97%, which is classified as acceptable and Wisepilot scored 43.40%, which is classified as low. Finally, in the evaluation of the applications' cartographical elements and representation, Wisepilot recorded the highest score with 70%, followed by Google Maps with 64% and then Here-WeGo with 42%. Also, Cheung and Sengupta (2016) have evaluated 20 NAs in terms of different aspects, such as high-level features, usability and popularity. Here-WeGo and Google Maps were among the top five in high-level features and popularity aspects, but in the usability evaluation, Google Maps occupied the 7th place and Here-WeGo occupied the 9th. On the other hand, Rettore et al. (2019) have used car traces with Here-WeGo traffic data accompanied by Traffic Data Enrichment Sensor (TraDES) in order to widen the coverage of traffic data in the case of absence of real-time traffic data from traveling cars at specified regions.

Many traffic studies use travel time estimation as a significant measure of effectiveness in the evaluation process. Such studies include, but are not limited to, the bus rapid transit (BRT) systems (Imam and Jamrah, 2012; Alomari et al., 2016; Al-Deek et al., 2017), transit signal priority (TSP) systems (Consoli et al., 2015), traffic control devices and intelligent transportation system infrastructure (ITS) upgrades (Consoli et al., 2013), traffic management in central business districts (CBDs) (Al-Omari et al., 2013) and traffic simulation software validations (Al-Omari and Ta'amneh, 2007).

NA Development and Validation

In the field of NA development and validation, Mena-Yedra et al. (2017) have proposed an "Adarules" system and compared the traffic prediction of this machine learning-based framework with simple and complex statistical models. The developed system, Adarules, had adapted with significant incoming data streams and different types of changes associated with several factors, such as season of the year, time and different road network changes. Also, this adaption takes place in a short time, where the accuracy of prediction increases as the amount of incoming data increases. Also, Barata et al. (2014) have developed My Traffic Manager (MTM), which uses data sent from drivers who are using MTM. Thus, the application shares the received data among all application users, which helps the drivers who are using MTM know the conditions of the specified road at a specific time. So, if there was a traffic congestion at a road segment, the driver may avoid it according to the route advice provided by MTM.

The use of NAs is not limited to single users; they are also widely used by traffic managers, traffic operators, utility companies, goods' distributors and many various agencies from both public and private sectors. Santos et al. (2011) have developed an application for vehicle routing, which was built based on Google Maps data (maps and traffic data). Different types of users used the developed application and it has provided accurate vehicle routes under different conditions. Tam and Lam (2013) have presented a methodology to validate the Speed Map Panel (SMP) system. It was conducted to validate the SMP system using floating car surveys to collect journey times and traffic speeds on specified paths after determining the sample size, then the SMP data was compared to actual measured data. All data points have been checked and it was found that all the data met the targeted accuracy level (±20% error) in both traffic speed and journey time estimation. Additionally, Herrera et al. (2010) have conducted a study to evaluate traffic data obtained *via* GPS-enabled mobile phones. They proved that using GPS-enabled mobile phones is feasible as a real-time traffic monitoring system by providing velocities of traffic on freeways, in addition to the high level of accuracy presented by this system.

In this research, traffic data collection was facilitated using the smartphone location feature, which was also used in different studies before, such as García-Albertos et al. (2019), who have used digital fingerprints of mobile phones to perform an accessibility study. This study has shown that this type of data has the advantage of addressing accessibility dynamically. Zhu and Gonder (2018) have studied the task of detecting driving cycles from wearable GPS data and focused on distinguishing driving cycles from other motorized trips. The numerical experiment showed that the accuracy rate of driving cycle detection reaches 89%. Tosi et al. (2014) have presented an approach for collecting, processing and predicting real-time vehicular traffic conditions using cellular network data and provided a regression model to describe the correlation between a cellular network and real vehicular traffic situation.

PROBLEM STATEMENT AND RESEARCH OBJECTIVES

Many studies on NA reliability and accuracy have been conducted over the last two decades. However, there is a lack of validation of traffic information obtained by NAs depending on field measured data. This study aimed at evaluating and validating the traffic information and Estimated Time of Arrival (ETA) provided by NAs through comparing a set of applications: Google Maps, Waze and Here-WeGo, based on collected field data from Jordan.

The significant contributions of this research are the detailed evaluation and validation of ETA provided by NAs using data collected by trained drivers instead of crowdsourcing data. Hence, the data used in validation will be more accurate and reliable, which gives a strong indication of the level of reliability of the NAs. So, the usage of such applications will attract the attention of individuals, organizations and agencies in different related sectors.

METHODOLOGY

A total of six NAs were installed, including Google Maps, Here-WeGo, Waze, Maps.Me (MAPS.ME, 2019), Sygic (Sygic, 2019) and Wisepilot. Many test trips were conducted to choose the most accurate applications to conduct a more detailed comparison, which has resulted in choosing Google Maps, Here-WeGo and Waze. Study locations included selected urban and rural roads in Irbid city, northern Jordan. The posted speed limits at all roads were collected from the field.

The study drivers were trained for data collection by driving their cars following specific rules, such as driving at the maximum possible and safe speed without exceeding the road speed limit. Also, the drivers were instructed to comply with all applied traffic rules in Jordan. The reduction of the speed is only due to traffic delays, traffic signals, roundabouts, crossing pedestrians, on-street parking or any (road, traffic or control) conditions which may force the driver to slow down. Free flow speeds were collected by cars running on every road segment involved in this study with an ultra GPS logger turned on to collect speed and location data at every second.

By hitting a request for the same trip using the three applications, as shown in Figure 1, the ETA was shown for every application. Then, the driver should check whether the three applications suggested the same route or not; if yes, the driver begins the trip following the suggested route and starting a stopwatch to measure the actual trip time. All recorded ETAs from the applications and the actual time with the origin and destination of each trip were filled into spreadsheets.

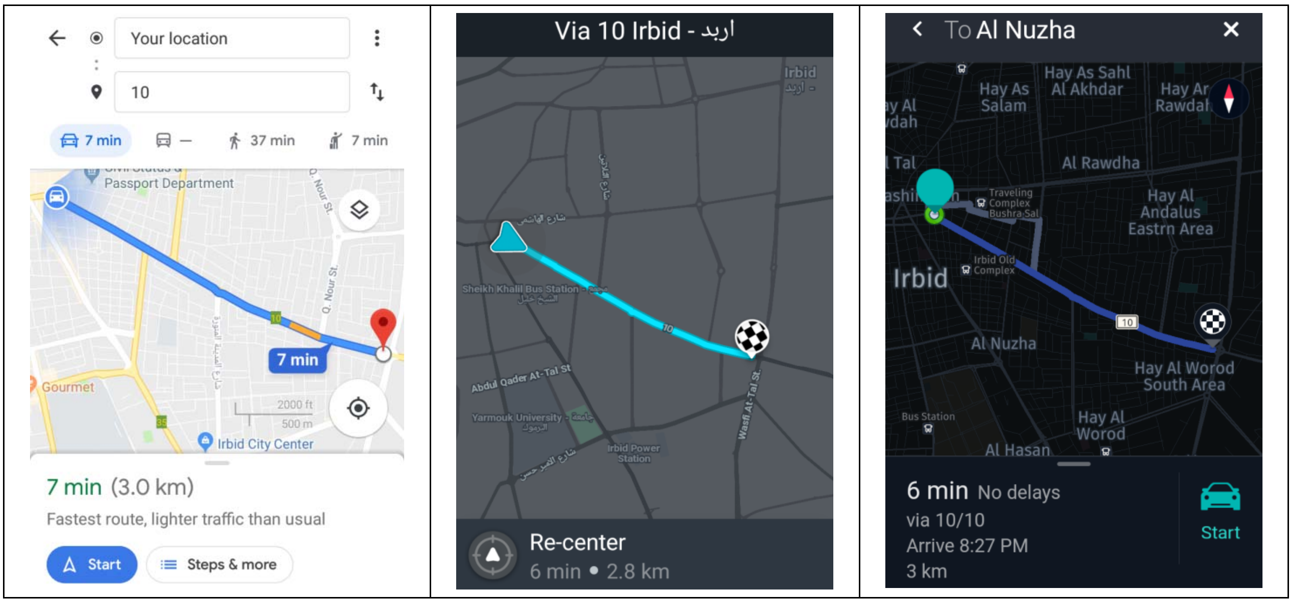

Figure (1): Google Maps ETA (left), Waze ETA (middle) and Here-WeGo ETA (right)

The route between origin and destination has been drawn on ArcMap (Esri, 2019); then, the spreadsheet was joined to the spatial data.

ArcMap facilitates dealing with attribute data (numerical and categorical) and spatial data (trip lengths and trip paths). Also, it can conduct overlay analysis, which is necessary to determine main variables, such as the number of roundabouts, signalized intersections and on-street parking that were traversed during each trip. Later, the data was exported to an excel file to make the importing process to SPSS (IBM, 2020) analysis software possible.

For this research, data was collected from Irbid, which is the second-largest governorate in Jordan, with a population of 1,957,000 residents (DOS Jordan, 2019). Data was collected from selected urban and rural roads at various times of weekdays and weekends during the period from February to September 2019.

RESULTS AND DISCUSSION

A total of 612 data points (204 data points for each application) were collected to validate the trip time provided by the three chosen applications. Each data point included the ETA for a trip, such that each trip ETA was claimed from the three applications to facilitate the comparison process and to ensure that the trip conditions are always the same.

The error in each ETA and the percentage error were calculated using Equations 1 and 2, respectively. Table 1 provides a general overview of the collected data to compare the error in ETA provided by each application.

Error = Actual Trip Time – ETA Provided by the Application ....(1)

Error (%) = [|Actual Trip Time – ETA|/ (Actual Trip Time)] * 100% .... (2)

Table 1. General overview about errors in ETA for each application

Application	Here-WeGo	Waze	Google Maps	Overall
Maximum Error (Min)	12.330	9.920	6.083	12.330
Minimum Error (Min)	0.020	0.020	0.020	0.020
Mean (Min)	1.790	1.735	1.240	1.588
Standard Deviation (Min)	1.935	1.433	0.967	1.518
Number of Trips	204	204	204	612

To have a more in-depth insight into the data, more details were taken into consideration and a set of error ranges were constructed. The percentage of errors for each application was categorized based on these ranges. Also, the cases of overestimated ETA were separated from those of underestimated ETA cases.

Figure 2 demonstrates the error distribution among five defined categories for the three applications. It shows that almost one-third of the trips have an ETA error of less than 10% for all applications which could be ignored, because the majority of data points that fall in this region have an error of less than one minute, considering that applications provide rounded ETA to the nearest whole minute. Google Maps application has approximately the same proportion of trips in the (10-20 % error) category as in the first category, meaning that about two-thirds of trip ETA have errors of not more than 20%.

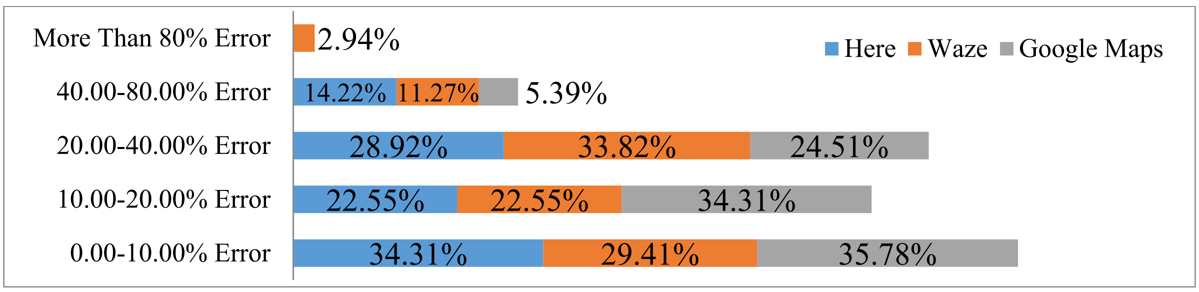

Figure (2): Percentage of trips for each error category for each application

It also has about 5% of trip ETA values in the (40-80 % error) range with no trip ETA values of more than 80% error. Also, Here-WeGo application did not have trip ETA values of more than 80% error, while Waze application had about 3% of trip ETA values with more than 80% error.

A large proportion of trips for the Waze application were in the highest three error categories. On the contrary, Google Maps had 95% of trips with an error of less than 40% and Here-WeGo error did not exceed 80%. By assuming that ±20% is the maximum acceptable error in travel time estimation provided by the NAs, Google Maps scores 70.09% overall accuracy, while Here-WeGo scores 56.86% overall accuracy and Waze scores 51.96% overall accuracy. For the three applications, the data highlighted that there is a considerable amount of errors that are more than 20%, so it is recommended to find the causes behind these errors and fix them by NA developers to increase the accuracy and reliability of the applications. Hence, it is imperative to employ the presented methodology in this study by NA developers in order to check for errors (amount and frequency of errors) and validate the output of their applications in different regions. Figure 3 illustrates the general tendency of each application in travel time estimation, which is produced from the collected data.

Accurate estimation term refers to ETA with an error of less than 5%; one-fifth of the ETA values by Here-WeGo and Google Maps seem to be very accurate, while about 16% of Waze ETAs were accurate. However, Google Maps and Waze tended to overestimate the ETA in more than 50% of the trips. On the other hand, Here-WeGo went in the opposite direction and provided underestimated ETAs in 68% of the trips, because Here-WeGo presents the case of the absence of traffic data. In both cases, overestimation and underestimation are undesired outputs because of the reliability issue, since this estimation will be used to make an important decision. So, it is required to meet a certain level of accuracy.

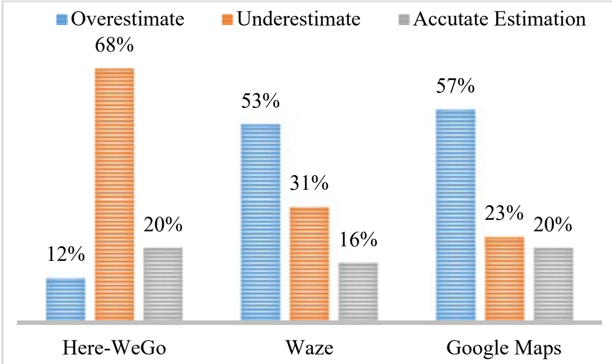

Figure (3): Percentages of overestimation, underestimation and accurate estimation for the three applications

Table 2 shows the number of trips for each application based on the error band of ETA in two cases; overestimation and underestimation. It is clear that Here-WeGo tends to underestimate the ETA in most of the cases with a significant proportion of trips in the third error band (20-40% error), while Waze and Google Maps tend to overestimate the ETA with about 65% maximum overestimation error for Google Maps with the majority of trip ETA below 40%. Also, Waze tends to overestimate, but with higher error in ETA and most trip errors were above 10% with a maximum error of about 137%.

Table 2. Number of trips with overestimated and underestimated ETA for the three applications

Application		Max. Error	Min. Error	Error					No. of Trips
				5% - 10%	10% - 20%	20% - 40%	40% - 80%	More than 80%	
Here	Overestimated	57.89%	5.26%	10	8	5	1	0	24
	Underestimated	73.33%	5.13%	19	38	54	28	0	139
Waze	Overestimated	136.84%	5.26%	15	28	43	17	6	109
	Underestimated	55.35%	5.13%	13	18	26	6	0	63
Google Maps	Overestimated	65.35%	5.26%	22	46	39	9	0	116
	Underestimated	52.38%	5.01%	11	24	11	2	0	48

In order to compare the mean errors of the three applications, ANOVA test was conducted. Table 3 shows a summary of ANOVA test results, which has been conducted on five different levels. The urban routes were divided into four different levels based on trip length. ANOVA tests the null hypothesis that the mean errors in ETA for the three applications are the same against the alternative hypothesis, in which at least one mean of the errors in ETA is different from the others.

ANOVA test was run once for every level; homogeneity of variances was tested using Leven's test, while normality was tested using Shapiro-Wilk test. For all levels, ANOVA test p-value was less than the significance level of 5% based on 95% confidence interval; hence, the null hypothesis is rejected and the data provided sufficient evidence at 5% level of significance to conclude that at least one application has a mean error in ETA that is different compared to the other applications. This conclusion is applicable at all levels. All ANOVA test assumptions were met at the first two levels and rural route level, but the normality assumption was violated at the third and fourth levels. Also, the homogeneity of variances was violated at the third level only.

To find where the differences between the groups were, Tukey HSD multiple comparisons were checked and it was found that at all levels, Here-WeGo was different from Waze and Google Maps, while Waze and Google Maps means of ETA error difference was always not significant. By checking the means at all levels, Google Maps mean error in ETA was the closest to zero at all urban route levels, which usually has overestimated the ETA. Then, Google Maps was followed by Waze, which was closer than Here-WeGo to zero error, while on the rural route level, Here-WeGo was the closest to zero error, yet it underestimated the ETA when Waze and Google Maps overestimated it.

Table 3. ANOVA test results for comparing the mean errors of the three applications

Trip Length	App.	Mean (MIN)	Std. Dev.	N	Homogeneity of Variances		Normality Test Shapiro-Wilk		One-way ANOVA		Multiple Comparisons	
					Levene's Statistic	Sig.	Statistic	Sig.	F	Sig.	(I) App-(J) App	Sig.
Less Than 2 km	Google Maps	-0.27	1.178	41	1.481	0.232	0.985	0.213	18.3	0.000	G-H	0.000
	Here	1.27	1.422	41							G-W	0.847
	Waze	-0.44	1.589	41							H-W	0.000
2-2.5 km	Google Maps	-0.13	1.489	33	0.839	0.435	0.978	0.095	11.4	0.000	G-H	0.001
	Here	1.60	2.007	33							G-W	0.820
	Waze	-0.40	1.984	33							H-W	0.000
2.5-3.5 km	Google Maps	-0.25	1.596	42	7.126	0.001	0.901	0.000	11.0	0.000	G-H	0.000
	Here	2.25	2.731	42							G-W	0.348
	Waze	0.51	2.973	42							H-W	0.005
More Than 3.5km	Google Maps	-0.27	1.594	31	2.609	0.079	0.922	0.000	10.7	0.000	G-H	0.000
	Here	2.34	2.776	31							G-W	0.483
	Waze	0.41	2.393	31							H-W	0.004
Rural Roads	Google Maps	-1.09	1.472	57	1.683	0.189	0.993	0.599	25.8	0.000	G-H	0.000
	Here	0.68	1.407	57							G-W	0.982
	Waze	-1.14	1.734	57							H-W	0.000

One-sample T-test was conducted on the same data at the same levels, which restated most of the ANOVA test results. Table 4 contains the results of the test, with the null hypothesis that the mean ETA error of the application equals zero and the alternative hypothesis that the mean ETA error of the application does not equal zero at a 5% significance level. Basically, at all levels, the data did not provide enough evidence to reject the null hypothesis for Google Maps and Waze, except in the rural routes, while it was the opposite for Here-

WeGo at all levels. Even at the rural routes, the data provided enough evidence to reject the null hypothesis and to conclude that the ETA error for Here-WeGo does not equal zero at a 5% level significance.

The results of this research showed that the route length did not raise the error amount to a level that proves significantly that the mean error does not equal zero for Google Maps and Waze. However, the route type, urban or rural, affected the error level for the two applications. On the other hand, Here-WeGo ETA mean error was not affected by both factors; route length and route type and the mean error was always significantly different from zero.

Table 4. One-sample t-test comparing the ETA error means with zero error for the three applications

Trip Length	App.	Mean (Min)	Standard Deviation (Min)	N	t	df	Sig. 2-tailed	Mean Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Less Than 2 km	Google Maps	-0.268	1.178	41	-1.457	40	0.153	-0.268	-0.640	0.104
	Here	1.269	1.422	41	5.712	40	0.000	1.269	0.820	1.718
	Waze	-0.439	1.589	41	-1.767	40	0.085	-0.439	-0.940	0.063
2-2.5 km	Google Maps	-0.125	1.489	33	-0.483	32	0.632	-0.125	-0.653	0.403
	Here	1.602	2.007	33	4.585	32	0.000	1.602	0.890	2.314
	Waze	-0.398	1.984	33	-1.152	32	0.258	-0.398	-1.102	0.306
2.5-3.5km	Google Maps	-0.252	1.596	42	-1.021	41	0.313	-0.252	-0.749	0.246
	Here	2.248	2.731	42	5.336	41	0.000	2.248	1.397	3.099
	Waze	0.510	2.973	42	1.112	41	0.272	0.510	-0.416	1.437
More Than 3.5km	Google Maps	-0.270	1.594	31	-0.944	30	0.353	-0.270	-0.855	0.314
	Here	2.342	2.776	31	4.699	30	0.000	2.342	1.324	3.361
	Waze	0.407	2.393	31	0.947	30	0.351	0.407	-0.471	1.285
Rural Roads	Google Maps	-1.089	1.472	57	-5.585	56	0.000	-1.089	-1.479	-0.698
	Here	0.683	1.407	57	3.666	56	0.001	0.683	0.310	1.056
	Waze	-1.142	1.734	57	-4.970	56	0.000	-1.142	-1.602	-0.681

CONCLUSIONS

This study aimed at validating the ETA provided by the three navigation applications; Google Maps, Here-WeGo and Waze, based on field data. The investigation was based on the error in the ETA provided. There is a lack of research in this area, as was shown in the literature review. This is part of a new field of multidisciplinary research that depends on computer science, data science, navigation, mapping and geographic information system (GIS).

In this study, data collection methodology was presented to obtain field data in order to validate the selected NAs. Data was collected from Irbid city, Jordan, by trained drivers using the selected applications to obtain the ETA for the specified route between the origin and the destination, accompanied by an application that returns the location and the speed of the car every second. After completing field data collection, data preparation was done using ArcMap software to draw the routes obtained by the NAs to calculate the length of the trips for trip data. Consequently, the data analysis phase started by three different NAs; Here-WeGo, Waze and Google Maps. The data was validated by comparing the NA-provided data with the collected field data to test the results for accuracy.

The overall accuracy was 70%, 57% and 52% for Google Maps, Here-WeGo and Waze, respectively. Analysis results showed that the three applications' ETA measures vary from actual trip time with different error levels ranging from minor errors that are less than 10% to significant errors with more than 40%. This research draws the path for future studies to investigate the factors that contribute to these errors and to overcome or reduce errors in these applications, so that the reliability of these applications can be increased and their use may be extended. Google Maps recorded the best accuracy among the three applications, with about two-thirds of trips having less than 20% error. Generally, Google Maps and Waze tend to overestimate the ETA, while Here-WeGo tends to underestimate the ETA.

ANOVA test for comparing the ETA mean errors for the three applications proved that at all trip lengths, there was no statistically significant difference between Google Maps and Waze ETA mean errors, while Here-WeGo ETA mean error significantly differs from both. When testing whether the mean ETA error for each application is equal to zero or not, Google Maps and Waze ETA mean errors were significantly equal to zero (more accurate) at all trip lengths on urban roads, but they were not equal to zero at rural roads, while Here-WeGo ETA mean error was always not equal to zero (lower accuracy).

The determination of the error amount or level for the NAs at a specified region is very crucial for both users and NA developers. The users can decide to what extent they can rely on such applications based on the error level and error frequency. At the same time, NA developers can enhance the provided data once they are notified by the errors that exist in the traffic data they provide to assure the quality of the traffic data presented by the application to meet the requirements of various users and to fix any possible problems. The results obtained in this research are expected to attract the attention of individuals, organizations and agencies in the related sectors.

Finally, the methodology of this research can be used as a technical note, to describe the technique that can be applied broadly, in validating the selected navigation applications. The step-by-step analysis employed in this research can be utilized for future studies to investigate more factors that may affect the validity of navigation applications. Future research will be extended to cover more roadways and locations in Jordan and around the world to include all the possible characteristics and variability regarding roads, intersections, vehicles and drivers.

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