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Exploring Factors that Influence Connected Drivers to Not Follow Recommended Optimal Routes

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Abstract: Navigation applications have gained popularity in recent years because they allow drivers to circumnavigate congested roads. Utilizing crowd-sourced information from users, these context-aware applications aim to always give drivers the fastest route to their destinations. With this basic assumption about drivers, how are these optimal routes followed and what factors affect their adoption? In this study, we conducted a semi-structured qualitative study with drivers that use navigation applications, and recorded at least one instance of their daily commutes and occasional trips to new locations. Our findings reveal that while drivers often choose the fastest route in urgent situations, there are still chances of deviation due to unfamiliarity of roads, lack of local context, and gaps and inconsistencies between the expected and realized navigation experiences. We present a set of recommendations to address the observed limitations of existing navigation applications and incorporating the observed nuances of the drivers.

1. Introduction

Advanced driver-assistance systems (ADAS) have become ubiquitous in modern vehicles because of the recent developments in communication and sensor technologies. They are primarily developed to improve driving performance, and car and road safety by providing automation and adaptive capabilities to vehicle systems. One of the most widely used tool for driver assistance are automotive navigation systems, which were initially designed to provide digital maps, route guidance for the shortest path to a destination, and traffic incident information [16]. As more private vehicles occupied our roads and more cities are being designed to accommodate and regulate their widespread use, modern automotive navigation systems now also provide information on the cheapest and fastest routes, and traffic condition.

1.1 Traffic Management and Navigation Systems

Today, more than half of the worlds population call cities their home due to urbanization and a rising middle class [28]. As we see a consequential increase in car ownership, our efforts in promoting and ensuring sustainable cities are at stake. With dense urban districts and complex road infrastructures, persistent traffic congestion poses a negative effect on our productivity, health, environment, and social equity [15]. The worsening traffic conditions have compelled drivers to circumnavigate congested roads. Several solutions have been introduced to address this growing problem. Intuitively, cities would resort to invest heavily on improving and increasing road network capacity; but adding more links between origin-destination pairs was proven to be counterintuitive and may cause longer travel times [2], [7].

Another approach was to efficiently manage traffic flow on existing road infrastructures by connecting current fleets to Intelligent Transportation Systems (ITS). Cities have already invested heavily on ITS infrastructure such as toll gantries, adaptive traffic signals, variable-message signs, and traffic detection systems, among others all aimed to regulate road use, to capture and provide situational information to drivers, and to redirect them from congested routes. At the same time, in-car navigation and other advanced driver-assistance systems are continually becoming more context-aware communicating with other vehicles, the ITS infrastructure, and other smart devices, as well as detecting its immediate environment [3], [4], [17]. However in some cases, in-car navigation systems are barely used and noticed [12], are becoming too complex to operate [13], are not always updated with the latest maps, and sometimes without access to real-time traffic information, which directly impacts their adoption and forcing drivers to find other options.

1.2 Navigation Applications

In the absence and or shortcomings of in-car navigation systems on some vehicle models, smartphone navigation applications such as Waze and Google Maps, have become a preferred alternative for drivers who experience traffic congestion on a daily basis. In the App Annie Rankings [1], Google Maps has consistently been the top choice since its introduction of GPS turn-by-turn navigation in 2008. Meanwhile, Waze reported in 2016 that they are already being used in 185 countries by more than 65 million monthly active users [31]. Other popular navigation applications include HERE WeGo, MapQuest and Bing Maps, but in other countries like Japan, Navitime has been a long time favorite. These navigation applications are free to use and has the

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	Driving Years	Nationality	Domicile	Driving Location
P1	1-5	Filipino	Mandaluyong, PHI	Philippines
P2	1-5	Filipino	Makati, PHI	Philippines
P3	1-5	Filipino	Taguig, PHI	Philippines
P4	1-5	Filipino	Makati, PHI	Philippines
P5	1-5	Filipino	Winnipeg, CAN	Winnipeg, CAN; Hawaii, USA
P6	>10	Filipino	Makati, PHI	Philippines
P7	>10	Japanese	Hakodate, JPN	Japan
P8	1-5	Filipino	Makati, PHI	Philippines
P9	1-5	Filipino	Makati, PHI	Philippines
P10	1-5	Filipino	Manila, PHI	Philippines
P11	5-10	Filipino	Quezon City, PHI	Philippines
P12	1-5	Japanese	Hakodate, JPN	Japan
P13	1-5	Japanese	Hakodate, JPN	Japan
P14	>10	Filipino	Hakodate, JPN	Japan

Table 1 Participant demographics.

latest maps. With improved sensors in smartphones, these navigation applications also use floating car data from online users to estimate traffic conditions and uses that to suggest optimal driving routes. Maximizing connected drivers, Waze crowd-sources traffic and accident reports, and advisories of police presence, speed traps, and road closures to supplement its turn-by-turn navigation [14], [29], setting it apart from traditional navigation systems while supporting the notion of navigation as a social activity among drivers and navigators [10].

1.3 Potential for Behavioral Adaptation

Because of the ubiquity, cost-effectiveness, and positive utility of smartphone navigation applications, there is growing optimism of their potential in improving urban participatory sensing [24], [25], [32] and in shaping sustainable mobility patterns among driving citizens [5], [6]. There are three categories of travel information that can affect travel behavior, namely experiential, descriptive, and prescriptive [6]. Experiential information are provided as feedbacks or repeated information from previous experiences, while descriptive information depict current conditions based on historic or real-time data such as estimated times of arrival and traffic conditions. Utilizing experiential and descriptive information, prescriptive information can come as suggestions (e.g. shortest, fastest, and cheapest routes) and or guidance (e.g. turn-by-turn directions). Nowadays, most modern navigation applications provide descriptive and prescriptive information as their main features [23]. In Chorus's [9] and Ben-Elia's [6] literature reviews, they have highlighted the extensive focus of recent works on the positive effects of experiential and descriptive information to influence the travel behavior of car drivers. Experiential information has been proven helpful in adapting to uncertain conditions, while descriptive information is particularly valuable in coping with non-correlated and Black Swan events like road accidents and sudden bad weather. However, there is still relatively few studies about the implications of prescriptive information.

1.4 Route Choice and Drivers Compliance

Developers have so far focused on the assumption that drivers would always follow the fastest route to a destination. For most navigation applications, drivers are provided with a number of recommended routes based on a criteria and they can select which one to follow. By default, the fastest route criteria is set unless customizations are made. In the case of Waze, it immediately starts the turn-by-turn navigation and leaves it to the user to check alternative options [14]. However, this doesnt seem to be the case based on studies examining GPS track data. Zhu and Levinson [33] noticed from GPS tracks that drivers don't always choose the shortest path in their daily commutes. In the follow up work of Tang et. al. [27], some drivers even take a different route each day for their commutes. Fujino et. al. [11] conducted a more recent study to investigate the phenomena of drivers deviating from the suggested optimal routes of in-car navigation systems and where they usually happen. They analyzed GPS tracks that were collected over 4 years within a 20km^2 area in Kyoto, Japan. They found that drivers have made significant deviations on intersections with poor on-road signages and those near tourist areas. They also speculated on possible reasons for the deviations based on the physical characteristics of the intersections. While these studies already provide empirical evidence on the surprising route choice and non-compliant behaviors of drivers, none of them had prior knowledge whether the observed drivers used prescriptive information from in-car navigation systems or navigation applications. In the case of [11], they had no information on the intended route of the drivers nor do they know if the drivers were initially following the guidance of the in-car navigation system used to collect the GPS tracks. Thus, further investigation is warranted to understand why drivers deviated from the suggested optimal routes.

As more connected drivers use the descriptive and prescriptive information of navigation applications and more government stakeholders seek to use them in managing road networks, it is crucial that navigation applications become successful in shaping the travel behavior of connected drivers. Ali et. al. [4] argues that behavioral adaptation is directly affected by the degree of compliance a driver has with the information provided by navigation applications. Although they are referring to connected vehicle technologies, the same assertion can also be made for navigation applications because they provide the same kind of information.

Our work explores the human factors that affect the degree of drivers compliance with the recommended optimal routes given by navigation applications. We conduct a semi-structured quali-

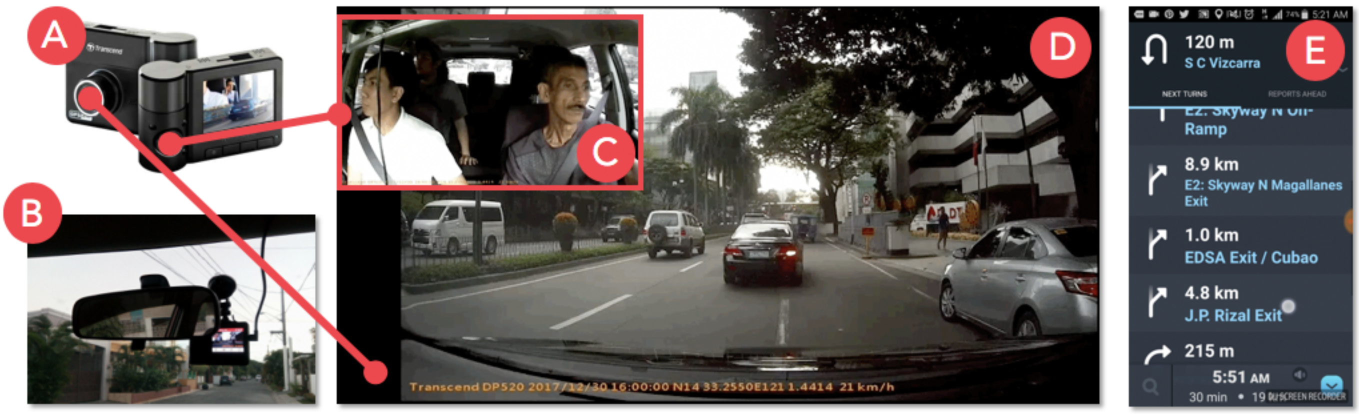

Fig. 1 The data collection setup. A) The commercial dash camera used; B) Position of the camera for optimal viewing angles; C) View of the driver and passengers; D) View of the road; E) Recording of the navigation application.

tative study to provide a detailed picture of how connected drivers use navigation applications in their daily commutes and occasional trips to new locations. We analyze how they incorporated navigation applications in their daily commutes and occasional trips, as well as how they select a recommendation to follow. We determine if, when and where deviations from the recommended routes happened, as well as the reasons why they made certain navigating decisions. Furthermore, we provide a thorough analysis of the results to help identify limitations of current navigation applications and user needs.

Our results show that drivers use more than one navigation application as well as other sources before and during the commutes and trips. It was also evident that eventual differences in expected and realized navigation experiences affect the drivers compliance with descriptive and prescriptive information. Our analysis of the deviations also shows repeated and clustered occurrences on certain trips which has direct implications on the assumptions made by the developers. Our combined analysis of the collected data allowed us to discuss design guidelines and future directions that can help ensure a high degree of compliance from drivers.

2. Method

In order to better understand how drivers incorporate connected navigation applications in their daily commutes and trips, and their compliance with the recommended optimal routes, we conducted a semi-structured qualitative study [26] and used grounded theory method [18], [19].

2.1 Participants

We recruited 14 participants with at least 1 year of driving experience and have used at least 1 connected navigation application were recruited through word-of-mouth and social network sharing (See Table 1). We only recruited drivers with at least a year of driving experience as they are likely to be adept in navigation and have acquired preferences (e.g. on safety, road condition, familiarity). We also made sure they have already used a connected navigation application as they are likely to have a considerable amount of experience with the features (e.g. turn-by-turn navigation, traffic condition, reporting). We purposely recruited drivers from the Philippines because of the large number of navigation application users.

Participants submitted their personal details and driving background using a Google Form survey at the beginning. This allows for an examination of possible motivations for their commutes and trips. Almost all participants are driving in Manila, Philippines and nearby areas. Despite having the same nationality as the majority, P5 only started driving in Canada.

2.2 Trip Recordings

Each participant were asked to record at least one instance of the following types of trips: Home-to-Work, Work-to-Home, and Home/Work-to-Unknown. The Home-to-Work and Work-to-Home trips represent their daily commutes. For the Home/Work-to-Unknown trips, the participants recorded their occasional trips to a location they don't usually go to or haven't been to before.

Inside the participant's vehicles, we attached a commercial dual lens dash camera behind the rear-view mirror (Figure 1B) to record the changing conditions on the road (Figure 1D), and the driver and passenger/s attention (Figure 1C). We wanted to capture how a driver and/or a navigator (because it can be someone besides the driver) behaves and what is seen on the road when a deviation happens.

The dash camera also recorded the GPS tracks, speed, and in-car conversations. For P1, P2 and P6, a data collector was riding with them to perform shadowing and asked questions as needed. The rest collected remotely and were asked to think aloud. Before each trip, participants noted down their origin, destination, reason for the trip, and the first activity to be done upon arrival (e.g. attend a meeting, attend family gathering, etc.).

To keep track of the application behavior and recommended routes, participants recorded the screen of their smartphones with the application open (Figure 1E). This allowed us to observe how the driver and/or navigator used the application while navigating. After data collection, we mapped each trip's actual route taken, original recommended route, the deviations (if any) made, and the rerouting recommended after each deviation (Figure 2). Lastly, we processed the in-car videos using OpenPose [8] to track their gaze.

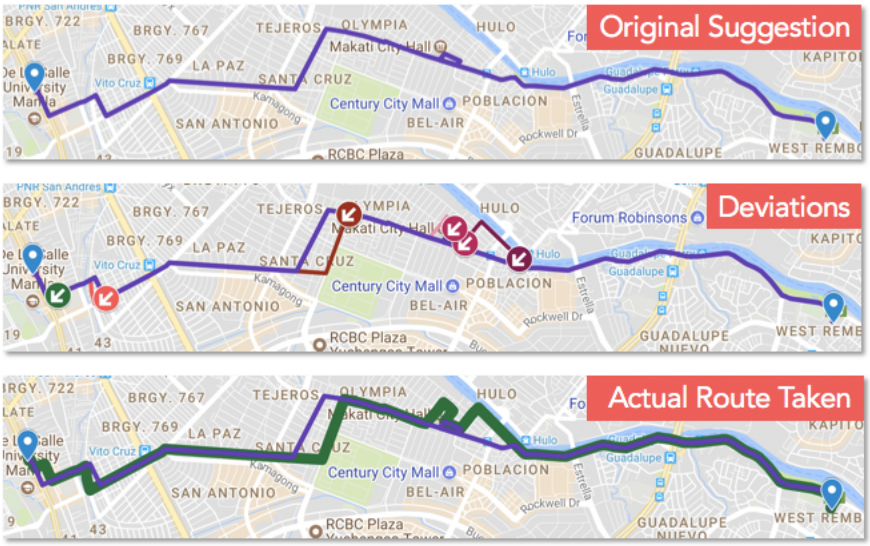

Fig. 2 Traces of the [Top] navigation application's recommendation in violet, [Middle] deviations made by the driver during the trip (arrows symbols), and [Bottom] the actual route taken by the driver in green.

2.3 Post-Collection Interview

In a separate interview after the data collection, we asked the participants their motivations and experiences in using connected navigation applications, and their perceptions about the recommended routes. The interviews lasted between 60 to 90 minutes on average, and were focused on examining the motivations behind choosing a route, the deviations made(if any), as well as other observations and insights from the videos.

3. Findings

3.1 Application Usage

First, we want to investigate the applications used by the drivers, the information they sought, and the order by which the information were used. For this, we looked into the answers from the pre-collection questionnaire and compared it with the smartphone recordings and answers to the post-collection interview.

3.1.1 Applications and systems used

Waze and Google Maps were the mostly used navigation applications by the drivers for most of the trips. In daily commute trips, Waze is primarily used when drivers have previous experiences of traffic congestion along their regular and familiar routes. They see Waze as an authoritative application specially when they have a clear intention to avoid being late or the heavy traffic. Even though Google Maps also provide turn-by-turn navigation and live/historical traffic information, drivers still put a lot of weight on the social aspect of Waze wherein other drivers can manually report traffic conditions, accidents, and road closures. Drivers gain a sense of confirmation as Waze shows manually reported traffic conditions to the ones they derive from the GPS tracks of connected drivers (P3, P4, P8). Since the road incident reports can be quite vague, drivers also acknowledge the usefulness of the public comment feature that allows other drivers who have passed by that area to share details about the incident. P6 shares that once when he was stuck near the tail of a standstill traffic, his passenger checked the public comments feature helped to get real-time updates from the drivers near an accident. It helped him decide whether he should wait longer or start finding other options.

For short commute trips that doesnt have many alternative routes and doesn't normally experience significant traffic congestion, P5 opt to use Google Maps instead. She expects to see her regular route as the recommended route by the application and just checks the estimated time of arrival. Additionally, she shares that because Google Auto is installed in her vehicle, she prefers to use Google Maps because she can view the route guidance in a wider screen compared to her smartphone.

For drivers in Japan, in-car navigation systems are used primarily because most vehicles are already equipped with them. The in-car navigation systems already provide basic navigation features and are connected to the local intelligent transportation systems. P13 shared that in one of his previous trips, the in-car navigation system provided a traffic advisory because of an accident in the national highway. It guided him leave the national highway using the nearest exit.

In places that the drivers in Japan (P7, P12, P13, P14) drove in, they did not experience any heavy traffic thus, they were not so compelled to download and use another navigation application. However in on of P14s trips, she used and followed Waze when her in-car navigation system started giving incorrect directions. She was noticeably surprised when the in-car navigation system guided her to a direction that opposite from the destination. She still made the turn as guided by the system but she had already asked one of the passengers to look for the next turn. The passenger used Waze. P12 particularly used Waze in one of his occasional trips because it shows the location of speed cameras. He found it very useful especially when driving in an unfamiliar location. He shares that this is not provided by his in-car navigation system.

Other than those mentioned above, drivers also sought information from Twitter and Facebook to check updates from the pages of the transportation agencies (P3, P4).

3.1.2 Information Sought

Drivers were mostly checking the estimated time of arrival of the recommended routes, the roads they needed to take, and the traffic condition as their main criteria for choosing a recommended route to follow. Some of the drivers also checked incident reports and updates (P4, P6) to know how much longer they needed to wait in congested roads.

Drivers were also seeking localized and contextual information such as transport policies (e.g. travel demand management policies, truck ban hours) and flooding (P3, P4, P8). Travel demand management policies disallow certain vehicles to use public roads on specific time periods. P4 sought this information because he wants to know if he needs to leave earlier than usual to avoid getting apprehended. P7 also shared that during winter, he is seeking local information about roads that are not too slippery and safe to drive on.

For longer and or occasional trips, drivers were also seeking information about familiar landmarks (P3, P4), good parking spaces and local directions. While in-car navigation systems and navigation applications can provide these information, drivers still seek the knowledge of a local that knows the ins and outs of an unfamiliar place.

3.1.3 Usage behavior

Drivers have been observed to have different behaviors in accessing information and using these to decide which route to take.

Daily commute trips. Before starting their daily commute trips, drivers first check the estimated time of arrival (ETA) of the recommended route. They want to have a quick overview of how long it will take them to get to their destinations. Then, they check their familiarity with the roads that were recommended. They usually check how close it is to their regular routes. If it is completely new to the drivers, they check the alternative recommendations and see if their regular route is included. They check the differences between the estimated times of arrival. If they are leaving very late and or in a rush, they only check the ETA (P4, P10).

During the trip, drivers start the turn-by-turn navigation but only some of them chose to follow it. For example, P10 still follows her regular route to work but still keeps Waze on to get traffic updates. However in the case of P8, she shares that she always follows the suggested route.

When they suddenly experience slowing down due to unexpected traffic build up, they first check what caused it using the navigation application. If there are no reports on the application, they check Twitter and or Facebook (P3, P4). For alone drivers, they only get to check this information once they are slowing down or in a complete stop. But when with passengers, drivers ask them to check why theres a sudden slow down in traffic and to look for possible alternative routes (P6).

Occasional trips. For shorter trips to unknown locations, they only used one tool for route guidance. For longer trips, P3 & P4 said that they use Google Maps for planning the trip and Waze/in-car navigation system during the actual trip. First, they looked for landmarks that they can use during the trip. In some trips, they switched to another application because of unreliable or missing information. For example in P12s trip, they stopped following the in-car navigation because its map is not updated with the new roads. They then switched to Waze.

3.2 Route Choice

Before starting their daily commutes, all of them checked the estimated time of arrival (ETA) and their familiarity with the roads in choosing a route to follow. When they had an important agenda (e.g. meetings, parties) and they were already running late, they chose the fastest recommendation of the application without consideration of familiarity. But when they were leaving early, they always checked the ETA of their regular route and compared with the fastest recommendation. They would chose their regular routes over the fastest recommendation if the time difference is negligible (P4). Some participants shared that they choose a recommended route with less traffic congestion (P3), shorter distance (P3, P5) and straightforward paths (P2).

For occasional trips, participants chose routes with familiar landmarks (P3, P4), roads familiar to them (P5, P6, P7), and routes suggested by friends living near their destination (P8, P9).

Interestingly, some drivers shared other reasons for picking a route. For example, P6 once chose a route with a gas station along the way because they are taking a long trip while P14 chose a route with a specific restaurant along the way because they havent eaten lunch yet. Other reasons include the need to visit convenience stores (P6, P7) and toilets (P13), and to drop off passengers on the way to work (P6).

3.3 Deviations

We also want to investigate if and how the driver deviated from the recommended routes. For this, we analyze the traced recommended routes and actual routes taken by the drivers. Then, we ask the drivers about these deviations during the post-collection interviews.

During the 30 commutes and trips, participants deviated 89 times in total. Participants did it 15 times for home-to-work (M=1.88, SD=2.34), 18 times for work-to-home (M=3.60, SD=7.05), and 56 times for occasional trips (M=2.95, SD=3.50).

Because the participants were more likely to choose faster routes that are different from their usual, they deviated often especially when their usual routes now have better traffic conditions than what the application said. In cases of inconsistencies and sudden changes in the road that the application is not reflecting, they would only follow alternatives if familiar and there is an immediate benefit to it. Another common factor is the lack of consideration for local traffic schemes which prohibit certain cars to pass through certain roads. Some participants cited instances when they were apprehended after following the application (P6). It is also worth noting that the work-to-home trips have the most deviations on average. This could be due to the fact that drivers don't usually have agendas at home and would rather choose straightforward paths than short and complex ones. Other factors include traffic lights, impassable roads, late advisory updates (roads were unexpectedly blocked), security (poor street lighting), additional cost (toll fee), and restricted access (gated communities).

For occasional trips, participants chose to follow familiar routes or those recommended by peers living near their destinations. They often used Google Maps to familiarize and only use the navigation application in parts of the trip they totally have no knowledge of. For example, some of them knew the directions to a specific area or city but once they got there, they don't know how to get around anymore (P4, P5, P8).

Compared to the estimated time of arrival of the chosen recommended routes, these deviations shortened the total trip time of 14 trips by an average of 4.13 minutes (SD=2.80).

4. Design Implications

In this section, we present a series of design implications based on our analysis of trip recordings and interviews. These recommendations should be taken as a starting set of considerations in ensuring that the next iteration of navigation applications can incorporate the nuances of a connected driver to increase the chances of behavioral adaptation.

4.1 Make uncertainty visible

It is observed from the collected data that crowd-sourced navigation applications such as Waze and Google Maps have the tendency to show unreliable and outdated descriptive information like displayed traffic conditions and reports. This is due to the open problems on data sparsity and in ensuring the integrity of collected reports [5], [21], [30]. It also emerged from the recordings and interviews that the drivers were starting to ignore these descriptive information and rely on their previous experiences. Although the drivers are unlikely to totally disregard its utility, it is still important to be transparent with the nature of the data we present to our users. This can be implemented by embracing the uncertain and decaying quality of the crowd-sourced information and trying different visualization strategies. For example, Waze consistently display a heavily congested road in red and after a few minutes (decay), it either disappears or changes color based on new information. Applying our recommendation, application can slowly fade the colors as time passes until an updated information is ready. This allows drivers to act properly on information that they know was posted minutes ago.

4.2 Provide real personalization

Drivers are idiosyncratic and yet, existing applications still insist that all drivers are in a rush by default. It is also worth noting that in some of the trips, the deviations were mostly clustered on certain areas because the application assumes that the drivers just missed the turn and needs to be rerouted to the recommended route. However, drivers already pointed out that they were already deliberately ignoring those. While it is hard to define a concrete and definitive set of conditions that will satisfy their needs, we can start by learning their mostly used routes so that we dont end up annoying them with successive reroutes. Applying this recommendation, future navigation applications can show the estimated time of arrival of their mostly used routes so they can properly decide whether they should take a better and new alternative or stick with their regular.

4.3 Let drivers provide situational context

Currently, navigation applications know a lot of about the spatial context of the driver. However, it would also benefit if such applications would know what the drivers will do at the destination. As mentioned earlier, drivers are not always rushing. Some of them even want scenic routes or routes that will allow them to discover new places or stores along the way [22]. Waze and Google Maps already allow its users to connect their calendars so that they can get alerts of when they should leave. It can also allow quick searches if the location of the calendar event is already provided. However, further understanding is needed to properly identify which recommendation should be given. We recommend that future navigation applications allow drivers to define the intent behind the trip on top of knowing the name of the event. For example, if the driver will be going to some tourist destinations, it can infer from the locations that the driver is sightseeing. Then, the application can recommend routes that are scenic and less congested, to maximize the experience.

4.4 Let drivers access the local wisdom of its close network

In uncertain conditions, aside from defaulting to what they are familiar with, drivers are also seeking information from their close friends. Since some applications already provide functionalities to maintain a network of friends within the application, we recommend that that network be maximized to its full potential. Further, we recommend that the learned and mostly used routes by a drivers close network of friends be integrated in the recommendations. One benefit of this is that it provides a sense of community and a sense of familiarity. Additionally, leveraging this information allows the application to improve its recommendations to other drivers who are also going to the same destination.

4.5 Be more persuasive or be an empathetic other

Drivers seem to be exhibiting cases of the Einstellung effect [20] wherein people are biased towards what they already know. Even though a better option is already provided, they still choose what is already familiar to them. We observed this when some drivers made a number of deviations to follow their familiar path but ended up taking a longer path and later ETA compared to what was recommended at the beginning. Since navigation application provide prescriptive information in the form of route guidance and descriptive information in the form of traffic conditions and crowd-sourced reports, we recommend that such information be presented in a more persuasive or empathetic manner. This can be achieved through persuasive design strategies. One benefit of this is that it allows the drivers to properly consider its options once the rationale behind the recommendations are known.

5. Limitations & Future Work

In this study, participants mostly from the Philippines and Japan, and this bias in the sample may have affected our results. Many of the participants also did not give a complete set of trip recordings for us to analyze. Lastly, we acknowledge that the recorded trips have varying origin-destination pairs thus, controlling some variables like the unknown destination could give us clearer results.

In the future, we would like to perform simulation studies to control some variables and gain better insights in explaining the factors that emerged from this work. We also would like to design and test prototypes that try to address the application shortcomings identified in this work to see how they can improve the efficacy and adoption of recommended optimal routes. Future research may also investigate how we can model a driver's intent to deviate from intended routes.

6. Conclusion

With government stakeholders and developers attempting to use navigation applications in shaping the travel behavior of connected drivers, it is important to understand the nuances of the emerging navigation behavior of drivers as such systems and applications get integrated in their daily commutes and occasional trips. We studied the motivations of drivers in choosing a navigation tool, as well as their criteria for choosing a route to follow. We also recorded and analyzed when and how deviations happened from the recommended routes. We found that drivers don't always choose the fastest route, which augments the findings of [22], [33], and even if they will, there are chances that they will not comply especially when the previous information shown by the application does not match what they see on the road.

We presented a set of recommendations that can help ensure a high compliance from users, eventually leading to successful behavioral adaptation of drivers. These include improving the visualization of uncertain information, providing real personalization, letting drivers provide situational context, letting drivers access the wisdom of their friend networks, and following a persuasive design strategy.

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