Exploring Smart-Car Space in Urban India

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Abstract. Driving is a quotidian activity that people across cultures have long engaged in. Given the pervasive need for information on the go, the smart-car era is well nigh. To develop solutions in this direction, an understanding of users' needs with respect to their cars is necessary. In this paper, we present our exploratory study of user's driving behavior in urban India. We found that the basic need for a smart-car begins even before entering a car and is not confined to driving alone. Activities before and during driving cyclically impact each other. Moreover, we found that driving is not limited to users alone, but also involves critical participation from users' social circles. From these findings, we discuss design implications that can impact pre-driving and while-driving modes and can thereby inform future research in smart-cars for urban India.

Keywords: Ubiquitous computing · Smart-cars · Qualitative research

1 Introduction

Automobiles since their invention have catered to our basic need for transport. However, driving also entails a constant need for information, communication and entertainment. Researchers have therefore been utilizing ubiquitous computing that can serve these needs anywhere we go and build smarter cars for the future. In-car infotainment systems for instance, have comfortably weaved into our automobiles to support us with a variety of functionalities. Since communication while driving is addressed by mobile phones, researchers have also designed tools to ensure less distraction for in-car mobile phone usage while driving. MirrorLink (previously Terminal Node) for instance optimizes Smartphone content for in-car usage with minimal user distraction [19]. It mirrors Smartphone applications such as calls, maps & music for easy operability with in-car controls [5]. Furthermore, advanced cameras on smartphones have been used to alert drowsy drivers [27] and predict waiting time-windows during traffic signals [16]. These innovations show that cars can be potential avenues for next generation ubiquitous computers. Hence, in this paper we have presented our qualitative study on user's needs and challenges related to driving and the means of coping with them in urban India. Through this study, we intend to put forth certain design implications for future smart-cars.

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2 Related Work

Researchers from varied domains have explored driving habits of users in different locations across the world. These studies highlight that cars are not mere transportation means. They are extensions of our identities, preferences and personal spaces, as is evident in Bell's study [4]. Users' identity is manifested through personal belongings held in a car and personalization made to it.

Heikkinen et al. in their contextual study have conducted pre and post-trip interviews corroborated by on trip observations [9]. Their study reveals the role of mobile phones while driving primarily for entertainment, driving support and even work-related tasks. Their study also explored the supportive role of co-passengers serving the needs for information and entertainment. Likewise, Haddington and Rauniomaa focus on driver's actions to attend a call inside the car [8]. A 100 car study at Virginia tech revealed that the use of mobile phones and hand held devices were distractions leading to accidents [25]. This study indicates that in-car ubiquitous technology should also account for possible distractions to the driver.

Researchers also compare driving behaviors and car usage patterns across different countries. One such study by Ozkan examines driving behavior differences across Britain, Netherlands, Greece, Turkey, and Iran using Manchester Driving Behavior Questionnaire (DBQ) [20]. Even though DBQ measures behavior only in terms of driving errors and violations, it does reveal differences in driving behaviors due to environmental situations and traffic regulations. Similarly, a large-scale survey [15] assessed preferential differences among Austrian, American and South Korean car owners. It revealed varied cultural perceptions towards personal vehicles as luxuries as against necessities. Yet, as quantitative surveys, they do not reveal much about users' environment and accompanying needs. A contextual study in this space is thus required to corroborate such surveys and highlight intrinsic user needs.

Through an in-depth ethnographic study, Zafirgolu et al. examined car usage in Brazil, China and Germany [28]. They reveal that infrastructural issues determine driving in Germany and that security threats were critical in Brazil. However, the need for socializing on the move was high in Brazil and China. Their study shows how socio-cultural differences determine driving behaviors. Their study also implies that a qualitative data of driving habits is required in addition to dynamic driving data in order to have more robust findings.

It is suggestive from the cross-cultural studies that a dedicated field immersion for specific countries is worthwhile. Nonetheless, there is a dearth of studies to explore this space in the India. According to a global study [6], 48 % of Indian car owners want to upgrade to 'connected' vehicles, as against 27 % in USA, 22 % in UK and 20 % in Germany. Likewise, It is anticipated that the Indian auto- market will be larger than most European Markets by 2020 [11]. On the other hand, India being highest in reported road accident deaths from traffic causalities also warrants a dedicated understanding of driving behavior in this region [12]. At the same time, with nearly 74 million users on internet, India is set to become the third largest web-consuming country [13]. Thus, a study in this region is worthwhile given the challenges related to traffic, urban planning, and infrastructure [14]. In this paper, we share our qualitative

study to better understand driving behavior in India and identify design opportunities to contribute to the smart car space of the morrow.

3 Methodology

The following research questions were considered for the field immersion:

- What are users' quotidian driving practices?
- What are the challenging situations faced while driving?
- How do users respond to these challenges?

A team of two researchers gathered data in three-phases - open discussions, situational observations and guided interviews lasting 2 h. Discussions were undertaken to understand users' vehicle in general. Subsequently, for situational immersions, researchers were with users as they drove [3]. During the journey, researchers had open-ended conversations with users, where interview questions were conversationally weaved in. The focus was on actual events that users encountered as they drove, for e.g. traffic/road/driving condition.

Finally, one-on-one guided interviews were carried out with all participants, where participants clarified situational observations gathered by researchers. All interviews were undertaken in English, Hindi or Kannada, according to respondents' convenience. The extended interviews were carried out within a day of situational interviews to ensure easier recall of driving events [2]. Field study was undertaken in urban Bengaluru, which has seen burgeoning of population, poor planning and increasing traffic-related problems [21]. Users were selected according to following attributes: *vehicle owned, Smartphone used*; *expertise in driving*; *marital status*; and *gender*.

Twenty participants were interviewed as part of this qualitative study. They were recruited through snowball sampling and were between 20-40 years of age. All respondents owned a smart, media device. 12 participants were male and 8 were female. Of these, 8 male participants and 4 female participants were married and had at least one child. Out of 20 users, 14 owned both hatchbacks and SUVs, while 6 owned a sedan and a hatchback. Finally, 11 participants were local to Bangalore, while the rest had moved in with driving experiences from other places of India.

Data was gathered as field notes, audio and video captures. Data was analyzed through modified Grounded Theory method and affinity Analysis [7]. The latter exercise yielded 172-first level themes, which were abstracted into 66-second level and finally clustered into 5-third level themes. Findings from cluster analysis are described in subsequent sections.

4 Findings and Observations

4.1 The Car-A Personalized Shared Asset

Cars were more than means of transport for users. People affirmed that the vehicle lent them personal space and the means to socialize. They further enhanced their individual

space by personalizing it with accessories to meet personal needs. Yet, respondents shared the wheel with their family and car-pooled with their friends.

The sociality in driving practices meant that driving decisions were not personal and often influenced by members of one's personal network. Still there was a critical need to personalize and undertake personalization to maximize social experiences. To enable personalized experiences, users fitted accessories. Some adorned their cars with religious symbols. Others fixed stereos, wide-angled mirrors and reverse sensors. Minimal personalization was for those who avoided "*spoiling by overdoing.*"

Despite the private space it afforded, a vehicle was often shared between respondents and their personal social networks. Sharing occurred most when households with one vehicle had multiple family members. An interviewee mentioned sharing in his household as follows, "*My wife, brother and I share these two cars. My wife and I go out on weekends. Weekdays, my brother and I go to work in the same direction.*" Highlighting comfort as a factor in choosing between multiple vehicles, a user said, "*Depending on who commutes longer, we decide on X over Y, because X is comfy. If Dad or I go nearby, we take Y.*" Urgency and easy access to vehicle determined users' choice of vehicles. Wheel sharing revealed a lack of personalization. In this regard, a respondent said, "*I manually adjust seat level and incline. It's never the same from what it's left at. My wife, dad and brother adjust it for themselves.*"

Carpooling occurred when people were routinely bound for the same destination; were keen to avoid traffic challenges; and wanted to save fuel. Respondents mentioned car-pooling with friends and colleagues as well. Routine and leisure driving decisions were influenced by children and elderly parents. The father of a 3 year-old said, "*My son gets cranky on the way to school. But music soothes him. My H car has a music system, but not the V sedan. So, I prefer H.*" For the sake of his motion-sick toddler, a user avoided long, leisure drives.

Driving ensured family time through socializing and extended conversations. To enable sociality, people undertook measures like renting vehicles and turning down media devices. To optimize on family time, people reduced speeds and adopting greater safety practices. With preferences of family members tied into their driving, it was natural for users to perceive the car as an extension of their home. It afforded space during commutes for storing children's toys, toiletries, food and pillows. Recreating a 'multi-utility space' was critical in long journeys. The intimacy of enclosed spaces was negotiated constantly by users. Most significantly, they carried the comfort bubble of their home. As technology providers, we must consider personalization of settings in this shared space through ubiquitous devices.

4.2 Activities Before Driving

People undertook planned and pre-emptive activities prior to turning the engine on. These would influence their drive and journey. In turn, activities undertaken prior to driving were determined by past experiences and learning of users. Measures for safety and route planning/navigation aid were the most common pre driving activities. There were some activities undertaken as soon as users entered the car, irrespective of whether they were drivers or passengers. Wearing the safety belt and ensuring the

safety of their personal belongings were some of them. Many respondents preferred comfort and ensured that the rest of the journey required least effort for certain activities, including music listening, accessing the mobile from easy-to-reach locations in the car and basic controls [air conditioner, rearview mirrors and sun visor].

Pre-driving activities were also about pre-empting critical eventualities like lack of fuel. If it were near low, users would get a fuel recharge at the earliest opportunity. Some respondents ensured safety by relocking their doors and checking their belongings before restarting their vehicle after a traffic signal. Some of the factors that influenced people's choice of vehicles before heading out were infrastructural conditions of the city and destination planned. A participant, who owned a big and small vehicle, explained that his preferences to take a big sedan or a smaller hatchback for the day were driven by availability of parking space. Most tasks were undertaken to ensure smooth driving experience and seamless connectivity. Thus, the need for a smart car experience began even before users entered their car and continued after they stepped out.

4.3 Activities While Driving

Of all activities undertaken while driving, music, navigation support and communication on mobile were predominant. Music was considered ubiquitous to driving in most conditions, including while driving alone and with others. Activities related to safety and social conversations with co-passengers were common too. In fact, multitasking occurred when a parallel activity required less effort and did not interrupt the primary, or attention demanding activity of driving. Hence, even phone calls were deferred. However, priorities and activities changed when people became passive drivers. Switching on music or connecting the mobile device frequently occurred, whilst changing music playlists was less. The latter was time-consuming when on the move and was done before a journey. Other user activities were related to safety and comfort, for e.g. being alert for traffic-related visual cues, or adjusting the air conditioner.

Ensuring safe conditions in driving was critical. The dashboard was constantly monitored for 'warning' signs; i.e. fuel, odometer, oil/brake lights. Users multitasked between attending to car's functionalities and road requirements. People also undertook other activities as passive drivers or passengers, including socializing with friends/family, or playing '*antaakshari*' [a musical game played between two or more people]. Some used the time to plan their work. Many undertook coordination for pre-planned journeys. A respondent, who often did long journeys with others said, "*Not all are familiar with the destination. Each of us drives on our own. So, I reset our Odometer and start. We call each other, as we drive to check how many kilometres we've done and guess our distance from each other.*"

Music listening while driving was a norm. Users felt that it provided relief from the task of handling road conditions/driving. It was also a continuous activity to accompany the primary job of driving. There were different choices to music. Few preferred radio. Others wanted their own content. Listening to the radio was a substitute for some, when the primary source of music [e.g. an iPod] was unavailable. For others, the choice was driven by easy accessibility of storage devices. Context, such as user's mood, preferences, driving challenges and need for comfort levels also determined

music preferences. Explaining his preferences, a user said, "*When alone I listen to English. With family it's Hindi. With mom and dad it's safe, old Hindi. When I'm sleepy, or when I drive long, I like a mix of Old Bollywood and English.*" It was interesting how spouses managed music preferences on shared devices. A respondent, who shared the wheel with his wife said, "*Our music is dumped in one iPod. Whoever drives gets to hear their choice. It's the driver's prerogative.*"

Another primary activity was managing communication on the move. Users restricted it to situations, where communication could not be deferred. An entrepreneur who had to be in touch with clients, said he will pull up and answer only client calls. For another respondent, calls from his wife (who recently had a baby) were urgent, since "*She doesn't call when I'm driving. But when she does, I know it's important.*" Familiarity with each other's context prompted users to decide on answering calls/messages. Most users preferred calls, messages and checking e-mails at particular time-windows, i.e. traffic signals or when the car was stationary. People wanted to weave in communication with driving by having easy access to a mobile phone [switching on speakerphone, Bluetooth and placing it in easily reachable locations].

Thus, participants deferred and did not stop communication events. Unlike navigation support, which was seen as a break from driving, music/mobile media consumption was not. Despite the cognitive load, it allowed weave-ins during driving and media devices were hence kept accessible. Yet, safety and coordination activities when not done through mobile were seen as breaks. Our findings reaffirm opportunities for providing lightweight entertainment and information to users.

4.4 Context Determined the Use of Driving Support Systems

The use of features or facilities made available for driving was dependent on how well they fitted to people's present situation. It varied from conditions as dynamic as users' driving context, to something all-encompassing as their social roles and technology comfort. Usually, tried and tested workarounds were preferred to features bundled in vehicles, which users then considered as redundant. Preferences and expectations were greatly determined by users' social roles and technology exposure.

Participants mentioned not having used certain facilities in their vehicle, since there was nothing that necessitated it. There were other functions, which were not used unless prompted by an event. For instance, wipers and hazard lights were used only in rains, while the odometer was for out-of-town jaunts. The use of functions depended on how important it was for people's daily driving. Besides, as a user pointed out, they were workarounds, which made certain features redundant.

Needs and actions of users were always context driven. Present context determined the urgency of weaving communication into driving. In this regard, a respondent revealed, "*It depends on which call or message is important. If my boss calls, I answer. But tomorrow I will not.*" Context also determined the speed at which people drove. Respondents explained that they drove fast to work, but drove slowly with family to savor the moments spent with them.

Context also influenced the means adopted for navigation support. Navigation aid was minimal for straight stretches, or familiar routes, or in the presence of adequate

road signage. Users mentioned not wanting GPS aid or planning for familiar destinations. However, on unfamiliar roads, people would call their social circle for navigation aid. Often they would even ask for landmark-based directions from strangers. An interviewee said, "*After I drive into a town from the highway, I must know where to turn. I promptly roll down my windows to ask the auto or truck drivers, tea-stall owners and corner shop guys. They point out landmarks and I follow that.*"

People were particular about what they considered non-negotiable. If features did not address basic concerns, such as privacy, it was less likely they would use them. Connecting to in-car gadgets was avoided, if it intruded on privacy. A respondent recounted, "*Once, my boss dropped me back and his wife called. He answered* via *the car speaker and said he was with someone. She hung up. It was so embarrassing. Now, I will never connect my car-phone.*" Similarly, users expressed displeasure over a recent law to remove window tints, since it compromised their privacy and safety. One of the contexts, particularly for women, was in the social roles they played. Driving signified self-reliance for some female respondents. For others, it was a sign of sharing equal responsibilities with male family members. Yet, there were many instances where women played a passive role. One of these was for car servicing. "*When the car is being serviced, I wait in the other car. I don't talk to the mechanic. My husband does,*" a respondent stated. There were also instances of gender interdependencies. For instance, an interviewee said, "*I drove all the way to Shimoga and my husband checked for directions on his GPS to guide me.*"

4.5 Learned Responses from Driving Experiences

Driving was a series of learned responses in a loop. People had to constantly relearn their responses to effectively address the ever-changing road and traffic conditions in the city. Initial learning was by drawing upon learned responses and knowledge of members in one's social network and even from online, special interest groups. Over time, people drew on their own repository of experiences to respond to situations and even devise workarounds to them.

Learning was a continuous activity. It ranged from responding to cues about car diagnostics and mechanism, to information about routes and navigation support. In addition, users learned driving in a smaller vehicle and shifted later to larger ones. Initially, people sought support from friends and family while parking, entering a busy road from a by-lane, highway and night driving. Support was also sought for car diagnostics, because many feared appearing ignorant. With learning though, people believed that they were better equipped. Previously perceived challenges were not daunting anymore, for e.g. operating stick shift vehicles and dashboard controls.

Learning from experience also made people discern a vehicle's likely response to certain driving actions. Many respondents explained how they changed their driving style based on engine feedback. Users could also guess when there was a problem with their vehicle and would take pre-emptive steps. Experience also taught people how to respond to traffic/road challenges. For instance, a respondent stated, "*If I stay long in these intersections, I can never get out. So, I wait for an auto rickshaw like this to turn and I turn with it, using it as a cover, since autos can worm their way.*"

Navigation though was not resolved, despite driving experience. Alignment of roads in familiar cities and unfamiliar towns was a challenge. Others mentioned challenges like incorrect directions from local people, improper road signs or signs written in local scripts. It was thus found that initial learning entailed understanding the user's immediate vicinity, i.e. the automobile; its controls and response mechanism. The next level of learning was to understand larger space, i.e. roads, traffic and navigation. Learning ensured that users became less risk averse.

5 Discussions and Research Implications

Our study reveals that the car was perceived as an extension of the self (identity) by users, than as mere transport as discussed in [4]. The need for easy communication was also felt across all the users, as highlighted by Heikkinen et al. [9]. Some of the widely discussed emerging economy problems such as infrastructural constraints, navigation problems and safety [28], were also strongly dominant in Indian driving context. It may imply that there are common problems faced across nations, which can be addressed to achieve ideal smart-cars with culture-specific adaptations.

However, there were some differences in our premise, which led us to certain findings. Zafiroglu et al. [28] and Jeon et al. [15] have discussed infrastructural problems that affect user's route planning and way-finding. However, our study revealed that route information in India was not just limited to directions but also to avoid mob-protests, potholes, road-blockages and similar other unpredictable events.

Several studies including Haddington and Raoniuomaa [8] have also pointed out the role user's social circles play in driving experience especially in terms navigation, safety and communication support. However, in our study, the social roles were not confined to user's closed social members. They also extended to members outside of the vehicle and local sources of information (such as Rikshaw pullers and passersby etc.). Most importantly, findings by Haddington & Raoniuomaa [8], Heikkenen et al. [9], Jeon et al. [15] and Lee et al. [17] focus mainly on in-car interactions on the go. Whereas, our open-ended approach towards understanding user's activities associated with driving led us to infer that pre-driving decisions critically affect driving. In other words, there is a strong need in users to stay connected with their driving experience, which starts even before they enter their cars. This clearly indicates that ubiquitous systems designed to build smart-cars, should also take into account pre-driving activities users undertake for a seamless driving experience. Figure 1 illustrates how activities before driving affect user's experience while driving.

Actions undertaken before and while driving support each other in a continuous loop. In fact, activities before driving enable users to devise workarounds to cope with challenges while driving. By virtue of learning from prior experience of driving, users devise better coping strategies and pre-emptive steps to deal with various challenges. Workarounds are determined by certain innate conditions, for e.g. users' social roles/identities and driving skills to name a few. The study findings have helped us realize a design space for smart-cars, which includes before and while-driving situations. In the following sections, we highlight some of these avenues for further design and research to build well-integrated smart-cars in the near future.

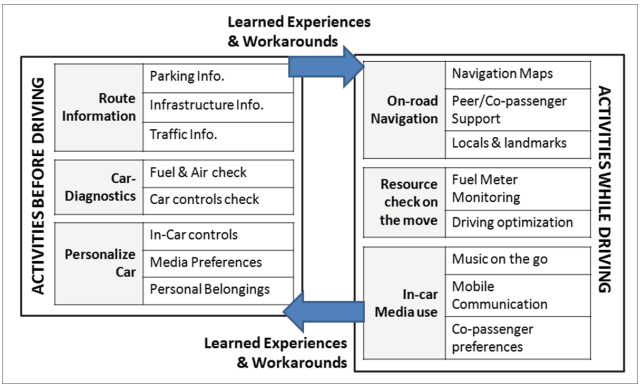

Fig. 1. Smart-Car design space: activities before and while driving

The study findings have helped us realize an overarching research and design space for smart-cars, which includes before and while-driving situations. The research opportunities also include harnessing users' social circles to offer seamless driving experiences. In this regard, we believe there is a strong need for an intelligent ubiquitous solution to keep us connected with our cars at all times. Such solutions can leverage on the advances in smart devices technology (e.g. smartphones, wearable devices etc.) and augment the experience via in-car controls and ambient technologies. In the following sections, we highlight some of these avenues for further design and research to build well-integrated smart-cars in the near future.

5.1 Weaving the Personal and Social Car

Influences from social/personal network greatly affected users' actions in navigation, personalization, in-car activities and safety related strategies. It was perhaps a cultural manifestation of preference for interdependence, unlike the individuality of Europe and North America [24]. In fact, to cope with varied familial needs, users had a smaller hatchback and a larger sedan/SUV. This strategy ensured personal and social space in changing contexts. Several decisions before entering the car such as media preferences, wheel sharing and car-pooling heavily involved people's social circles. Thus, it is reasonable to infer that the car constantly keeps switching its role as a personal and a shared asset.

Despite sociality of driving, there was the issue of personalizing features for those, who shared a vehicle. Few workarounds to the absence of personalized music device was to take turns to consume content within pre-designated time windows, or create different folders in the same device before starting the journey. In-car seating and other controls also needed adjusting. This highlights the need for an intelligent-solution that understands users personally and personalizes the vehicle based on their requirements. For instance, a shared car can have multiple profiles (akin to desktop computers with two accounts) for different users, which can be activated via smart devices.

While there have been solutions designed to engage co-passengers in monotonous drives, such as [12, 23], there is still an opportunity to utilize ambient technologies in

cars to engage co-passengers in the driving experience. There is a similar opportunity for developing traditional games among people (e.g. *antakshari*), into an inter-device game, between multiple devices carried by occupants. These are certain research avenues to design solutions for people's social space in driving.

5.2 Enhanced Navigation – Beyond Maps and Routes

Route information was crucial to people before the journey. A factor that made navigating and route planning daunting was the presence of unpredictable road blocks in addition to infrastructural and traffic challenges. Solutions have already been tested to detect such challenges through Smartphone sensors [16, 18]. Thus, further examining the capabilities of sensors on smartphones for driving can be worthwhile. However, researchers should also consider how social roles can impact sharing of route related/navigation information with the community. There is an opportunity to integrate such technologies with social media (given its popularity in emerging markets) [26]. However, route planning is not always done real time given the practice of using printouts of online maps, or memorizing landmarks before getting inside the vehicle. In this regard, it would be worthwhile to further explore the capability of smart-cars, to learn from user's previous driving experiences and put forth the information for offline usage in upcoming drives.

Navigation has often been a challenge inside cities with dynamic road conditions, complex routes and lack of authentic information. People often seek directions to nearest landmarks from friends, passersby and online navigation tools. Leveraging this coping strategy, future smart-cars can have landmark-based incremental navigation for better visual judgments, apart from turn-by-turn contextual navigation [17]. It is also an opportunity to explore intelligent ways of integrating social, local and technological sources of navigation.

5.3 Intelligent and Ubiquitous Car Diagnostics

Checking for fuel and air before driving was essential for users to ensure smooth driving experience. Users were also concerned about any abnormal feedback from the car while driving and often depended on friends and family for support. Perhaps this can be an area for audio/voice based alerts or feedback while driving to ensure less distraction and allowing users to prepare for an action. Moreover, technologies such as 'automatic' [1] can be utilized to connect car to smart-devices for a ubiquitous car diagnostics. It is also an opportunity to investigate communication support systems during car breakdowns. A design direction can be to build intelligent systems that recommend driving optimizations, according to a vehicle's capabilities and user's skill levels.

5.4 Design for Safety and Social Support

Gender identities influenced how users coped with navigation challenges and safety, especially night-driving for female users. Our findings revealed that a close involvement

by family and friends to ensure safety at such times was common. Map-based applications such as Safetipin utilize this factor [22]. Contacting close family members before the journey highlights the social roles played to ensure safety even before driving. Communication devices and sensors can be leveraged further to detect safety threats around the car and connect to appropriate authorities, as well as users' personal network during such threats. A crowd-sourcing approach can be taken here as well to enable people to broadcast route safety to others.

6 Conclusions

A primary implication of our study is that a smart car experience is not confined to driving alone, but begins even before a journey is undertaken. Activities before driving and the experience during a drive impact each other in continuous cycles. Besides, the presence and influence of users' social circles for informational and emotional support is critical to the driving and pre-driving experience. In all this, the car has to continually shift between personal and social spaces. Consequently, the design space for a smart-car has wide implications for pre-driving and post-driving situations. It also suggests that design avenues for next generation smart-cars should not be confined to users (drivers in this case) alone, but should also focus on members of social circles and other social information sources too. Thus, the findings and implications from this study lay the foundation for future research on smart-cars in India.

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