A Driverless Future in India: Engineering Challenges in Design and Automation

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Abstract: ***A myriad of technological advancements in the automotive industry have made the idea of "self - driving" cars increasingly desirable over the past few years. However, automation technology has not yet made it to the consumer vehicle market in India, despite being commercially available in most major countries. This study found that this adoption gap is rooted in systemic issues in driving conditions that have made it difficult to implement a safe "driverless" experience for the end - user. The lack of sufficient standardisation across road networks and sub - regions of India impedes the accuracy and universality of perception systems in AVs, while sparse infrastructure and data availability issues obstruct online neural networks from being implemented reliably. Additionally, behavioural volatility on the road makes India a unique challenge for modelling the decisions of external agents from the vehicle's perspective. The paper also simultaneously explores alternative technologies that should be considered by manufacturers and regulatory bodies, but cost and pragmatic viability must be integrated into future research before full - scale implementations are initiated, especially in the context of developing countries.***

Keywords: Technology, Automation, Self-Driving, Cars, Automobiles, India, Algorithm, Driverless, Road Networks, Autonomous Vehicles, Neural Networks, Manufacturers, volatility, behavioural, sensors, end-user

1. Introduction

The past decade has seen the autonomous vehicle (AV) industry expand from a distant dream to a dominant force in automobile discourse with a valuation of nearly "$54.21 billion" in 2019 (MarketWatch). As the world becomes increasingly enamoured with the concept of "self - driving" cars, semi - autonomous driving features have made their way into many consumer - oriented vehicles and public transport systems (Ovide). However, these progressions have hardly extended to developing countries such as India, where the legality and adoption of self - driving cars has remained controversial despite positive public sentiment (Schoettle and Sivak). There are many tangible benefits to encouraging the availability of such vehicles anywhere in the world – including reductions in accidents caused by human errors, increased traffic efficiency, and overall improvements in convenience. Nonetheless, manufacturers have been unable to implement automation systems that are appropriate for the chaotic and often unregulated traffic dynamics found in India (Edelstein, "Self - Driving Cars Are Flummoxed by India's Chaotic Roads"). This paper will provide an overview of the general engineering challenges that have prevented key players from breaking into the Indian market, from both the physical design and software automation perspectives. Our goal is to establish the specific obstacles that make automated vehicles unfeasible for India at the moment, while providing prospective generalised solutions that should be explored in future designs.

Vehicular Environment and Sensor Design

This section will cover the systemic issues that have caused vehicular environments in India to be physically unconducive to self - driving cars. They have been broadly grouped into:

1) A lack of nation - wide standardisation, and
2) Insufficient presence of necessary infrastructure.

The absence of traffic standardisation manifests in several proverbial roadblocks for the engineering of autonomous vehicles. Firstly, the optical recognition algorithms used in most self - driving cars identify road signs through cameras and visual sensors for both navigation and path optimisation purposes (Thomas and Trost). This perception system essentially emulates the instinctive awareness and learned obedience of human drivers to make sure that the expected traffic rules are followed while collecting directional and obstruction - related information from the environment. Not only is "proper signage" sparingly available in India, but it is also inconsistent and often incorrect when present (Edelstein). While an experienced driver can discern between such information, or even follow the rules without visual cues, automated systems may struggle to do the same in a country where 'intuition' supersedes exhaustive signage in informing driving decisions. The usage of various private contractors in constructing and maintaining national highways such as the Yamuna Expressway (Ray) also means that the signage and operational functioning of different road systems can vary greatly, which must be accounted for in any successful optical recognition system.

Furthermore, the successful implementation of intelligent software for transportation is contingent on robust infrastructure, which is a far cry from the status quo in India (World Bank). While markets such as Germany have already witnessed the introduction of highly automated vehicles (up to Level 3 Vehicular Autonomy), network integration and stable navigation systems are required to achieve a fully realised "self - driving" experience in other regions (Wang et al.). Such vehicles are expected to heavily utilise V2X communication (vehicle - to - everything), which is an extension of V2V (vehicle - to - vehicle) networking that enables cars to communicate amongst themselves (TE Connectivity). This not only involves sufficient network and mapping coverage – which is still significantly low in rural India – but also road infrastructure that is consistent and sufficiently reliable to delegate safety and steering features to AI with low human intervention. The map below shows the LTE coverage of major network operators in India as of 2018:

Map of 4G Availability in India (McKetta)

Clearly, there are certain pockets of the country where even last - generation cellular availability is still in progress. The *instantaneous* data transfers that are necessitated by highly automated vehicles cannot be achieved under these circumstances. LTE transmission "has a latency of around 30 - 40 milliseconds", which is deficient to power systems that must make safety decisions within a fraction of a second (TE Connectivity).5G networks have still not been activated in India, and it is safely presumable that they will not be widely prevalent for several years (Guha). Additionally, most Indian roads have a distinct "lack of lanes and road barriers, lack of on - ramps and exit systems" (Thomas and Trost), presenting further issues in the vehicular environment that may impede on the safety of AVs in the absence of systematic and predictable paths.

What does this mean from an engineering standpoint? In order to implement AVs in developing countries with low infrastructure and standardisation, we will have to make automation systems less reliant on the external environment. Currently, electromagnetic sensor technologies such as LiDAR, RADAR, and ultrasonic reflectors are used in tandem with visible - light cameras to detect objects in the car's short - range surroundings, but due to their limited detection capabilities, they serve only as confirmatory data collectors for the software rather than primary decision - making tools (Vargas, Jorge, et al.). Advances in offline mapping algorithms, such as the 3D LiDAR reconstruction outlined in Wang, Zhen et al. may inspire future automation design within the industry to become less inherently tied to external infrastructure. Furthermore, emphasising satellite navigation could enable AVs to function reliably in underserved rural areas. The implementation of truly distributed networking hardware, based on decentralised protocols focused on local connectivity (V2V) rather than external networks would significantly improve the viability of autonomous vehicles. Such hardware could take the form of a DSRC (dedicated short - range communication) module that would enable physically proximate autonomous vehicles to exchange safety and environmental data, such as "road conditions, congestion, crashes, and possible rerouting" (Vargas, Jorge, et al.). Unfortunately, a dependence on local connectivity would necessitate the simultaneous introduction of a huge AV fleet on Indian roads, which presents a Catch - 22 in terms of policy. Installing the necessary hardware for higher - level autonomy but disabling these features until the driverless network expands – similar to Audi's 2019 plan for their A8 cars – could give engineers greater flexibility in terms of implementation (Edelstein, "Audi Gives up on Level 3 Autonomous Driver - Assist System in A8").

Behavioural Modelling and Traffic Conditions

Although traffic volatility and behavioural factors have been tackled briefly in the previous section, we will now elaborate on the direct implications of these concerns on algorithmic modelling for AVs in India. The use of machine learning in navigation and safety algorithms makes the success of autonomous decision - making dependent on the *quality* of training data available to the manufacturer. If existing data is highly reflective of real - world conditions, environmental perception information from the car's sensors can be used to assess optimal manoeuvres through micro - predictions about other vehicles, pedestrians, and aggregate traffic movement. However, this is only possible when those real - world conditions can be reasonably generalised for the population at large.

The widespread divergence between established road laws and practical traffic behaviour in India are extensively documented. Travis Kalanick, the former CEO of Uber, described the country as "the last place one would want to develop self - driving cars" (Gent). Severe congestion is a tangible result of urban overcrowding, but India's chaotic driving conditions extend further than still traffic. Weak rule enforcement on roads results in "anarchic" vehicle interaction, including unrestricted lane - switching and takeovers (Waddell). In the view of computer - vision expert Daniel Asmar, "humans can deal quite well with that, " while autonomous vehicles designed to always err on the side of caution can malfunction entirely when faced with challenging dilemmas. While existing programs such as Tesla's AutoPilot perform well on open roads, they are substantially less proficient at handling unexpected obstacles and erratic drivers (Barry). If driving environments were entirely populated by driverless vehicles, it could be more feasible to implement Level 3+ automation in consumer cars (as traffic rules could be strictly enforced through software) but programming interaction between AVs and human drivers will remain a serious engineering challenge if they are to co - exist.

As deep neural networks continue to improve in their predictive ability, these issues are expected to merely boil down to the availability of data. If we have sufficient real - world data to model driving algorithms and on - board processing power, the complex decision - making structures of neural networks can theoretically emulate empirical driver behaviour with high accuracy (Grigorescu et al.). Still, the aggregate data collection operations required to achieve such accuracy may require sensors to be installed in cars before driverless features are ever brought to market. Efficient engineering solutions to the data availability issue may also manifest as investments in long - term aggregation of data from traffic cameras (where available) and installation of traffic - lights with networking features. Another possible short - term solution may be to focus on automating public transit and creating separate lanes for autonomous vehicles in populous cities.

2. Conclusion

Ultimately, the key engineering problems associated with the introduction of autonomous vehicles in India can be boiled down to the following:

a) Absence of standardisation in the vehicular environment and its impact on accuracy of perception systems
b) Varying and insufficient infrastructure to reliably support autonomous decision - making
c) Divergences in driving behaviour and law enforcement that impede predictability
d) Gaps in data availability for the region

However, there are several other socio - cultural factors that may also make this an unfeasible venture:

a) The government investment required to accommodate autonomous vehicles and install the required infrastructure may present a significant opportunity cost, which may not be worthwhile for a developing economy.
b) Driverless cars are inherently likely to displace human drivers, which may result in occupational displacement and unemployment.
c) In the early stages, the high cost of these vehicles will make them inaccessible to most of the population, which may disincentivise further investments into the industry.
d) Expensive duties levied on imported vehicles will prevent foreign manufacturers from investing in Indian AV infrastructure.

Future research should quantitatively investigate the viability of decentralised networking and locally - oriented perception systems as prospective solutions to infrastructural issues. Moreover, the behavioural volatility that distinguishes India from other AV markets can be employed to investigate the path - finding and obstacle navigation accuracy of deep neural networks as new algorithms are trained to better fit domestic road conditions. Manufacturers and engineers must also account for the emphasis on cost - reduction in the Indian market, which may present a different set of challenges entirely. In the short term, it may be worth exploring the introduction of lower - level automation to the Indian vehicle market before 'truly' self - driving features such as Level 4+ automation can be made widely available. Including locally - functioning adaptive cruise control and steering assistance (Levels 0 - 3) to a broad range of cars would allow drivers in India to experience the convenience and safety improvements offered by automation without any ambitious changes to national infrastructure.

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