AUTONOMOUS DRIVING ROBOT

BUSINESS PROPOSAL

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Make any vehicle autonomous

We will address the transition from (standard) people-driven vehicles[1] to AVs (autonomous vehicles). The AV technology development includes creating a portable robotic system with limbs and splitting the AI (Artificial Intelligence) to edge (for safety) and cloud (for mission control).

Instead of creating an autonomous vehicle from scratch, we will place the robotic system in the standard vehicle's driver seat. The driving robot will adapt to any vehicle to give the same mobility as a dedicated AV.

OPPORTUNITIES & SOLUTION

The social & commercial benefits[2] of AVs inspired many to start researching. Current attempts include building a dedicated AV or retrofitting the autonomy (on vehicles with x-by-wire features). These methods are tied to the vehicle. If the AV breaks-down due to a trivial part failure, the rigidly integrated autonomy stays idle, resulting in a lack of revenue from the asset (AV). Full AI inside the vehicle results in a costly AV, delaying bulk adoption.

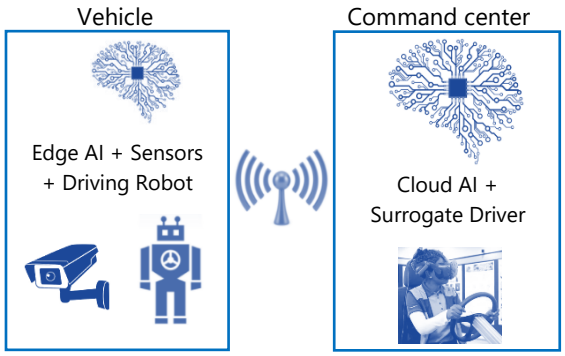
We will place a portable and removable robotic mechanism with the necessary edge AI to operate the driving controls. A command center connects to the vehicle via wireless networks[3]. Cloud AI and (remote) surrogate driving operators will be in the command center. This connected system is an *autonomous driving robot*.

Customer problem 1 to solve: the high upfront cost of the upcoming AV solutions

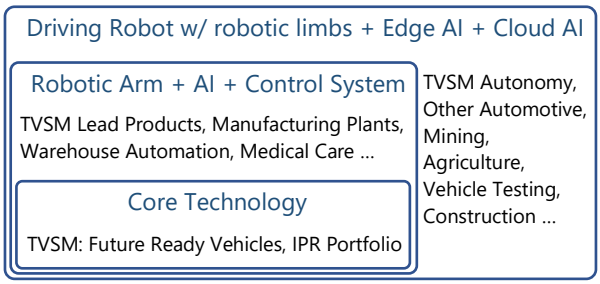
The AI is split between vehicle and cloud. The onboard (edge) AI avoids accidents, similar to today's active safety systems. Cloud AI handles vehicle operations. Multiple AVs share the cloud AI that gives mission-related instructions and routing. This split and shared AI reduces cost. The split ratio depends on the application and may be changed dynamically.

Customer problem 2 to solve: revenue loss during the AV downtime

If the AVs break down, customers themselves can port the autonomy to a different vehicle by shifting the driving robot and sensors (any number of times), maximizing the AV asset utilization.



AI learns from the surrogate driver's actions. Soon, the cloud AI operates the vehicle with minimal human intervention.



The autonomous driving robot and the components[4] are useful beyond[5] the automotive domain. Without having to design the actuators for the specific application, the driving robot lets us deploy tailored solutions.

[1] UNECE R.E.3 rev-6 u/s 2.1.5(L5), 2.1.6(L6), 2.1.7(L7), 2.2(M), 2.3(N), 2.4(O), 2.6(T), 2.7, and 2.8

[2] Improved safety, efficiency (fuel & time); Reduced emissions, insurance costs (premiums & claims)

[3] WLAN, 4G and upcoming 5G mobile networks

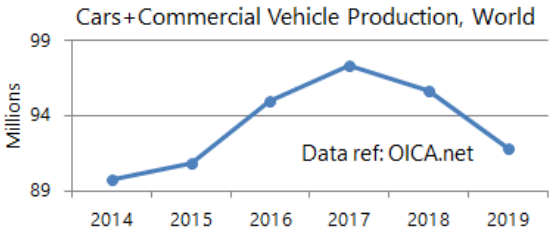
[4] robotic arm, teleoperation, perception, comm. infrastructure, road models …

[5] Ranging from construction, agriculture, and mining, to medical care, manufacturing, and warehouse robotics

Automotive

In the USA, a truck (or a taxi) revenue per week averages to US$ 4000 (or US$ 2000). During the downtime (two to three weeks for minor collisions) of an AV, the costly[6] traditional solution (vehicle + autonomy) cannot generate revenue. The driving robot can be shifted to other vehicles to maintain income from the asset.

The autonomous truck/taxi that runs full-time may last up to three years before reaching 500,000 km. Our vehicle-mounted equipment outlasts the vehicle and can be easily shifted to other vehicles. The cloud AI gets improved continuously, making itself ageless at all times. Customers can continue using the vehicle of their choice with the driving robot.



The annual vehicle production in the world is over 90 million. With an average vehicle life of 11 years, over 900 million vehicles can coexist with autonomous vehicles. Current autonomy solutions do not address the standard vehicles. The existing retrofitting solutions are specific to the vehicle model. A 0.1% market capture results in 900,000 vehicles getting the driving robots. Just this sale is worth US$ 18 billion with a US$ 20,000 driving robot. The global AV market is expected to reach US$ 54.23 billion by 2026.

Regulatory barriers may delay RoI (Return-on-Investment), but vehicle autonomy has many commercial applications. Few countries gave approvals to run AVs on the roads, and many will follow suit.

[6] Level-3 AV solution from Waymo was expected to cost US$ 250,000 in 2017. This is expected to come down to US$ 5,000 by 2030.

Mining

Mining sites lose US$ 94,000 per hour (average) due to each equipment failure. Retrofitting an existing mining truck with one of the available solutions takes about two weeks. Our solution limits the revenue reduction and enables autonomy for older vehicles too. The driving robot works with the entire range of mining vehicles[7], enabling optimal asset utilization.

Mining industry giants such as Rio Tinto, BHP are investing in mining automation, supported by OEMs such as Caterpillar and Komatsu.

The mining automation market has a turnover of US$ 2.2 billion in 2017. The number of automated ultra-heavy mining trucks in the field is small but growing. The market is small but fetches good profits[8] without regulatory hurdles.

Agriculture & Others

Different farm equipment is required in each phase of the crop. A single driving robot and few mechanized vehicles replace multiple farm AVs, each for unique use. The top 1% of the farms[9] cover over 70% of the world's farmland - large farms benefit from AV applications. The global

[7] Excavators, Dozers, Rigid haul trucks, and ADTs

[8] CAT 793D mining dump truck costs US$ 4 million, autonomy enabled truck costs US$ 5 million

[9] 40,000 farms with over US$ 100,000 revenue in USA; 3.5Lakh farms with over 250-acre size in Europe; 85,000 businesses in broad-acre farming in Australia; 40,000 farms with over 250-acre size in UK;1.5Lakh farms with over 50-acre size in India

farm equipment automation market had a turnover of US$ 72.6 billion in 2019. Tractors and harvesters contribute to over 77% of mechanized farming tools, and they will be the first to turn into AVs.

The construction industry uses vehicles similar to those in the mining industry. The possible market size is big. The construction industry's top 100 companies posted a US$ 4 trillion revenue in 2018.

In-campus applications include staff mobility, material transport, and material handling in warehouses & manufacturing plants. The robotic arm finds the best use in warehouses and manufacturing plants but needs customization. Depending on the value perceived by the customer, profit margins can be high.

THE USP

In this extremely competitive technology space, our novelty comes from:

Portable autonomy: Movable to other vehicles, operates all human controls

Split AI: Edge AI for vehicle safety, sharable cloud AI for mission control

The split AI helps with a low up-front cost for the customers, but it requires fast network connectivity. We focus on well-connected areas with robust 4G/5G coverage or closed campuses & mining sites with a private wireless network.

The (difficult but possible) robotic arm dependant autonomous driving robot is applicable across multiple industries [10]. Several companies, including many startups, focus on a single application to design a snug fit solution, often missing the freedom to create a broader solution.

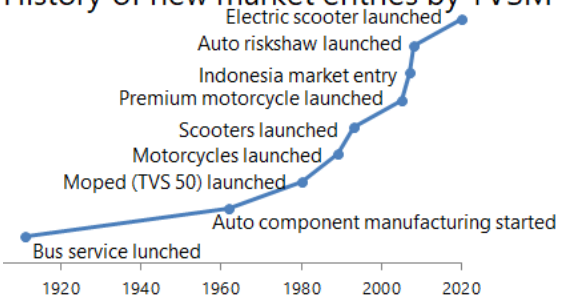
[10] On-road & off-highway vehicles, regardless of electronic complexity, fuel type, powertrain, or age

THE NEED

We must avoid mediocrity and position ourselves uniquely to move forward in the new autonomous vehicle era. We should focus on future technology trends, unlike those who failed to adapt [11].

The current success of TVSM is a result of bold steps taken using the technology and decisions to pivot into new businesses. Global companies' average lifespan is shrinking [12] because they lack innovation and stop taking risks with technology.

History of new market entries by TVSM



EV (Electric vehicle) is a step towards portfolio diversification to keep up with the market trend. But entry barriers to the EV market are low. Many businesses will soon assemble imported kits and flood the market with EVs, causing a price war.

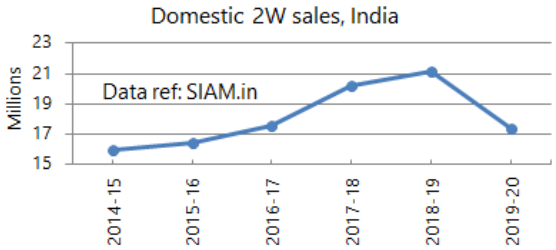
A few years ago, we started working on EV technology. As a result, now we have a low third-party dependency for EVs. If we do not work on this proposal, we cannot expand into new businesses or master the essential skills for future products. Some of these skills are already required [13].

The last-minute cost of technology acquisition for our future products will be very high. We cannot automate our future production plants economically without robotic arms (a part of this proposal).

[11] Kodak, Nokia, Xerox, Blockbuster, Blackberry, and Polaroid failed to foresee the technology trends

[12] Average lifespan of companies listed in S&P 500: 61 in 1958, 18 in 2017, lower in the coming years

[13] Security, Data analytics, Model based automatic OTA file creation, Communication infrastructure …



India's domestic two-wheeler sales (and overall automotive sales) declined in FY 2019-20. The decline is due to lower GDP growth and price hike while complying with regulatory norms. Hopes are high for normalcy but may take time[14].

The automotive business landscape is ever-changing. Shared mobility is gaining traction, and personal vehicle ownership may come down. Established OEMs face turbulent times, and their role may be limited in the future of mobility.

The autonomous driving robot is a select mix of diverse engineering technologies that opens up doors to exciting prospective businesses with a competitive edge for robust bottom-line growth.

Commercial Viability

Commercial viability depends on the asset cost and time to get RoI. Profitability to all the parties (TVSM & customers) ensures the driving robot's success.

The AV is expected to have a lower accident rate[15], lower insurance liability[16], lower part failure[17], and better mileage[18].

Autonomous trucks and taxis travel up to 200,000 km/year. In a few years, the dedicated AV becomes non-operational. The driving robot gets renewed each time the cloud AI gets updated. The shiftable vehicle-mounted setup is long-lasting and adapts to use on a suitable vehicle (better mileage, fit for the load) any number of times, enabling optimal asset utilization for mining and agriculture.

Due to the split AI pattern, the driving robot's initial cost is lower than other retrofitting counterparts. The autonomy asset downtime (vehicle breakdown) is lower than other retrofitting solutions due to quick portability.

All the scenarios where the AVs are viable are strongly applicable to the autonomous driving robots. The need for lower upfront costs and lower AV downtime justifies the use of autonomous driving robots.

The exorbitant cost of taxi medallions[19] still makes the taxis profitable in the USA. The driving robot may cost less than the medallion's price-drop in recent times.

TVSM's revenue channels include the sale (or lease) of driving robots, subscription to cloud AI or surrogate driving, IP rights licensing, and road-data sale.

Strategic Plan

We begin with the core technology modules (robotics, controls, sensors, ECU, wireless comm). Later we work on robotic limbs that can be teleoperated and vehicle control through remote surrogate drivers. The AI for driving will be developed as the project progresses.

We start working on our home ground - automobiles in the complex Indian traffic conditions - and create a solution. The autonomous driving robot is independent of the application or vehicle, or country. The driving robot is not a universal design. However, it is a base module with different functionality for different industries, countries, traffic rules, and user behavior.

[14] India's GDP contracted by 23.9% in the Apr-Jun quarter of 2020. Goldman Sachs predicted that India's GDP would contract by 14.8% in FY 2020-21
[15] Human error caused accidents are 92% - NHTSA
[16] Up to 15% lower insurance premiums
[17] Up to 35% lower service costs from low part wear
[18] Up to 30% lower fuel consumption

[19] City taxi permit in the USA; NYC badge sold at US$ 1 mil in 2013, US$ 200k in 2019, US$ 130k now

We may pivot to profitable areas (automotive/mining/farming) with a little effort to deploy the re-tuned design. Our solution brings the focus to vehicle autonomy for everyone, not just the rich.

Gaining customer trust is difficult for new technology with safety effects. We may partner with prospective customers during the development. It gives the participant an insight into the technology to identify the optimum ways to benefit. This link gets us the field data and access to their fleet for testing.

Large fleets of taxis & trucks [20] from developed countries and large fleets of trucks from developing countries are our target customers. They have sufficient revenues to buy or lease the driving robots and make the best use of portability to shift to other vehicles.

Top-tier mining companies started AVs in the field and are working on retrofitting their trucks. We may look for mid-tier companies, such as Coal India or Vedanta, with funds to invest in a few AVs. We may lease abandoned mining sites for the development activities. We may partner with the mine owners for further steps.

Developed countries with very high farm equipment mechanization are our target customer group. We will partner with them and offer trials to earn their trust.

We should work with insurance providers for reduced premiums as incentives to the customers. We should work with regulatory bodies to develop mutually agreeable conditions for AV testing in the field. We should work with infrastructure providers for v2x or wireless networks.

[20] Value/truck/year: VRL logistics INR 50L revenue, INR 2.3L profit; Agarwal P & M has INR 50L revenue; Greyhound Lines US$ 600k revenue, US$ 21k profit; FedEx Freight US$ 4.8 mil revenue, US$ 37k profit; Value/taxi/year: Uber/Lyft driver US$ 24k; NYC TaxiGroup driver US$ 30k; Ola/Uber driver INR 3L

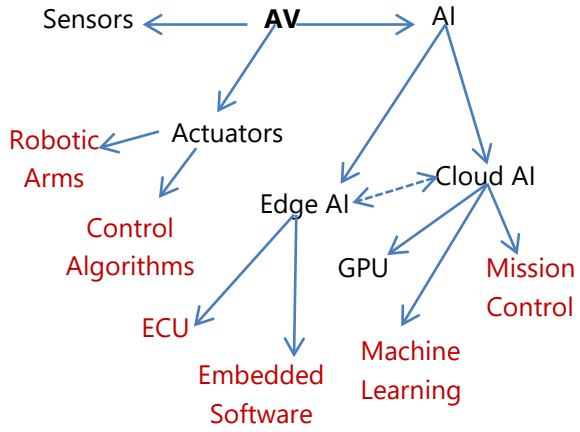
Most of our continuous revenue can come from the subscription to cloud AI and value-added services. We need to set up the command center to showcase to large customers as a benchmark and extend its services[21] to smaller customers.

We should collaborate with research organizations for their open-source work. We should partner with a few startups, without IP conflicts, for fast track progress.

We should avoid reinventing the wheel and reuse the existing work on autonomy to skip years of repeated research.

Implementation Plan

We will evaluate feasibility from the patent perspective and approach the least blocked path in our target direction.



We will Research, Engineer & Develop the AI and Robotics for Mobility (REDARM) either independently or through research collaborations.

A high-speed wireless network connection is the backbone of our execution. We will work on identifying the bottlenecks of existing wireless networks and delays.

We will establish a pilot concept for the connected vehicle and command center over a wireless network. We will work on custom data slicing and link aggregation.

[21] Surrogate driving, fleet management, service station coordination, fuel station coordination …

We will include the connectivity to the upcoming 5G network in the ECU.

We will build an internal communication network to get data from the sensors and send commands to the actuators, with multiple security and redundancy layers.

We will build AI infrastructure for the command center, such as GPU clusters, machine learning models, perception algorithms, and teleoperation gear. We will create the ECU to suit different sensors required for various industries.

We begin by buying industrial robotic arms and create custom designs later. We will design the robotic arms with enough degrees-of-freedom to be suitable for all intended applications.

Cloud AI may override the surrogate driver's inputs, and passengers may override the command center's inputs for operational safety.

We will work on teleoperation, supported by third parties. We will use the link-aggregation feature with 4G networks and use 5G-compatible hardware.

We will collect field data for the related application and start building road safety policies and perception algorithms.

The PoC-1 executes the teleoperation of a robotic arm.

The PoC-2 enables vehicle control through the teleoperation of robotic arms.

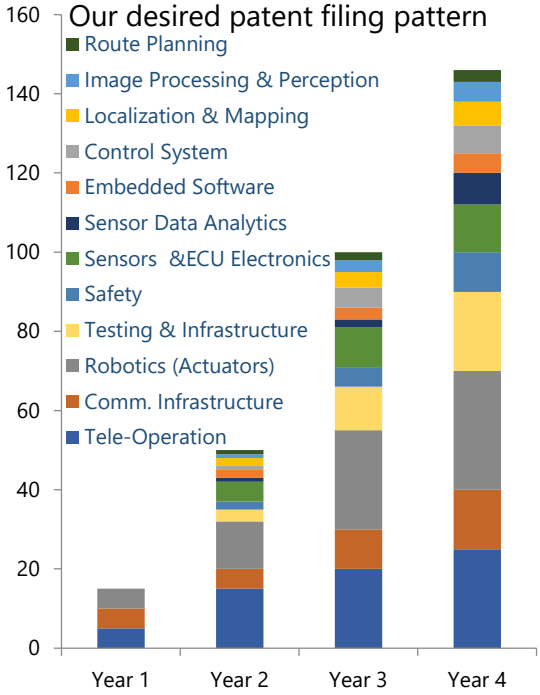
The PoC-3 controls different functionality in multiple distinct vehicles.

The PoC-4 enables collision avoidance and limp-home mode in the vehicle.

The target deliverable is a driving robot (with L3 autonomy) demonstrating driving multiple vehicles on the road with light traffic, using a combination of edge AI, cloud AI, and a surrogate driver.

Risks & Mitigation Plans

If we step into someone else's IP space, we may face IP infringement suits. We will conduct whitespace analyses and freedom-to-operate analyses to identify the right technical direction.



The vast economic opportunity attracts many market players[22], including OEMs. We will file patent applications focusing on our USPs to create a firm position in the ecosystem.

The local governments regulate road vehicles. If we do not get permission to run the AVs on the roads, we will continue with closed campus tests & simulations. We may decide to pivot to an appropriate application field.

Accident liability can be an issue. We will have agreements with the customers and follow the evolving regulations.

[22] Automotive: Waymo, Uber, ArgoAI, CommaAI, Torc robotics, Phantom Auto, Polysync, X-matik, Kopernikus Automotive, Ghost locomotion …
Agriculture: Bearflag robotics, Rabbit tractors, Agrobot, Abundant robotics, Harvest Croo, Iron Ox, Blueriver Technologies, Rowbot solutions …
Mining: ASI robotics, Zyfra industries, SafeAI …

The driving robot requires high data transfer rates. If the 4G/5G is not available (or slow), we will shift more functionality to the edge AI. We will limit the driving robot to geographies with a fast private or public network. The edge AI will have policies to handle sluggish wireless networks so that safety is maintained and the mission is not severely affected.

The rooftop-mounted sensors accumulate dirt. We will explore sensor cleaning methods. In the later generations of the driving robot, we may place sensors inside the vehicle, emulating a human driver.

Refueling may require human intervention. Edge AI may track the fuel to inform the command center when the vehicle needs to refuel. Later, we will work on automated fuel filling devices using the robotic arms.

The skillset required for AV development is in high demand. We may face difficulties in finding and retaining the right talent. We will work with a few permanent employees and several (long term & short term) contract employees and encourage remote working practices.

Timelines for the project milestones are difficult to meet due to the project's exploratory research nature. We will plan for parallel tracks for critical technologies.

The cost is high for dedicated facilities. We will time-share TVSM's facilities and skilled workforce. We may reach out to OEM partners or VCs for extensive funding.

Exit plan: If the project does not become viable because of factors beyond our control, we may exit through a sale. The team, IP assets[23], testing facilities, and supply-chain information are valuable for a technology project. After a valuation, we can approach other OEMs and potential partners with an offer for sale.

[23] Design documents, Patents, Road data for Indian conditions, Design know-how, Prototypes …

CONCLUSION

Vision: improve work efficacy and everyone's safety by making any vehicle autonomous.

Mission: make the vehicle autonomy financially viable to many at work, not just the rich.

Strategy: retrofit even the oldest (on-road or off-highway) vehicles to enable them with autonomous mobility through human-like controls, AI, and remote override.

Goal: solve two problems: the high upfront cost for the upcoming AV solutions and revenue loss during (off-highway) vehicle downtime.

We need to adapt to the technology trend and create centers-of-excellence to make our future products safer and wanted.

The approach to vehicle autonomy with the driving robot is difficult but possible.

TVSM taking up this project will accelerate the pace of execution and, in turn, help TVSM endeavor into profitable future businesses in addition to improving the existing products with this knowledge.

References

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