# AUTONOMOUS DRIVING ROBOT

## Draft Business Proposal

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A Business Proposal to TVSM for

# Autonomous Driving Robot

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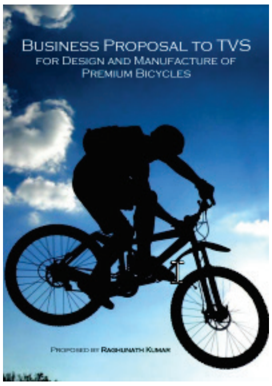
# THE AUTHOR



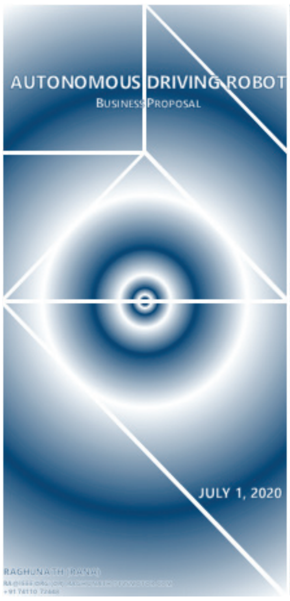

RaghuNath (RaNa) is an IIT Madras graduate with a Dual Degree (B.Tech+M.Tech) in Electrical Engineering.

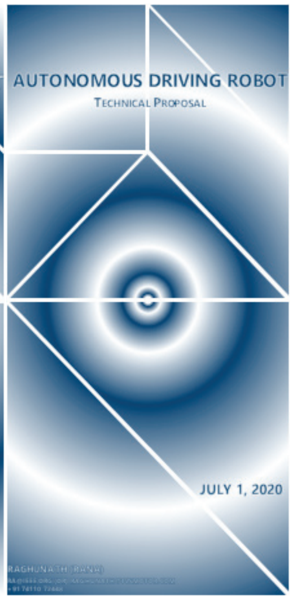
- 14 years of industry experience in R & D roles
- Received the service award (10-year) from TVSM
- Worked on PoC for Anti-lock Braking Systems (ABS), Battery Management System (BMS), and Electric Motors
- Holds the *highest* number of *granted patents* in AEG/TVSM as the first inventor, also has 15+ patent applications pending decision
- Proposed Premium Bicycles Business to TVSM in 2011, and the market growth predictions are close to reality
- Instrumental in the planning & support for the proposal of LED Lighting Business to TVSM in 2012


- Research paper in Computational Economics got accepted for a presentation at WEAI-2013 (Western Economic Association International) in Seattle, USA
- Delivered technical presentations at several international conferences in the fields such as ABS, BMS, Embedded Systems, Electric Motors, and Optimization
- Worked on machine learning & deep learning projects aimed at autonomous driving
- Has hands-on experience of full product design cycle including system modeling, hardware design, software programming, testing, and project planning

He is technically strong with a superior research appetite and a practical business aptitude - an exceptional combination.

These are the set of documents prepared for the proposal of *Autonomous Driving Robot*.



# 1 Executive Summary

We will address the transition between people-driven (standard) vehicles and autonomous vehicles. We mount a driving robot in the driver seat that adapts to any vehicle and provides the same driving experience as any other autonomous vehicle. The driving robot (our USP) is contrary to the traditional approach of building autonomous vehicles from the ground up.

The Indian passenger vehicle market grew at a CAGR of 6.2% during 2013-19, with an approximate addition of 3.3 million vehicles a year [1], while the world passenger vehicle market adds 77 million vehicles a year [2] to the roads.

With an average vehicle usage of 11 years [3], about 850 million standard vehicles (36 million from India) will coexist with the autonomous vehicles when they become a reality.

A 2% market capture, with US$ 11,000 per kit that adds autonomy to standard vehicles, results in a worldwide market of US$ 185 billion (US$ 8 billion in India). The subscription model gives scope for a higher (realistic) price and ensures profitability for all.

The relevance of this project comes from the ongoing social distancing practices getting interwoven in everyday activities. Commercial fleet operators face increasing indirect costs with human drivers. Driving robot is a useful product to address these challenges, in addition to improving vehicle utilization and reducing the accident rate.

Level 4 & 5 autonomy is in the research stage, and most companies are trying to build autonomous vehicles on a new platform from scratch by integrating the sensors & controls. This approach involves high development costs and results in expensive end-product.

Our product fits in standard vehicles, even without electric transmission. It can be shifted to other vehicles when the first vehicle encounters a problem, ensuring that the investment is available for utilization at all times. We shift the expensive computing setup to the server, and retain the essentials in the vehicle, effectively creating a shared central computing setup and a cost-effective solution.

Realistically, we can expect to deliver the 1st generation product (Gen-1) in three years with an estimated 10-year running life. Next-generation product focuses on improving the performance & features while reducing cost, size, and weight.

When the opportunity exists, we can configure our products to work for industries with hazardous environments or those looking for reduced human involvement.

We plan to work on this project with the least possible investment requirements by:

- Sharing the resources with the existing R & D setup
- Using the open-source tools and datasets
- Outsourcing modularized work
- Lower permanent employee count
- Validating extensively through simulations
- Eliminating LiDARs

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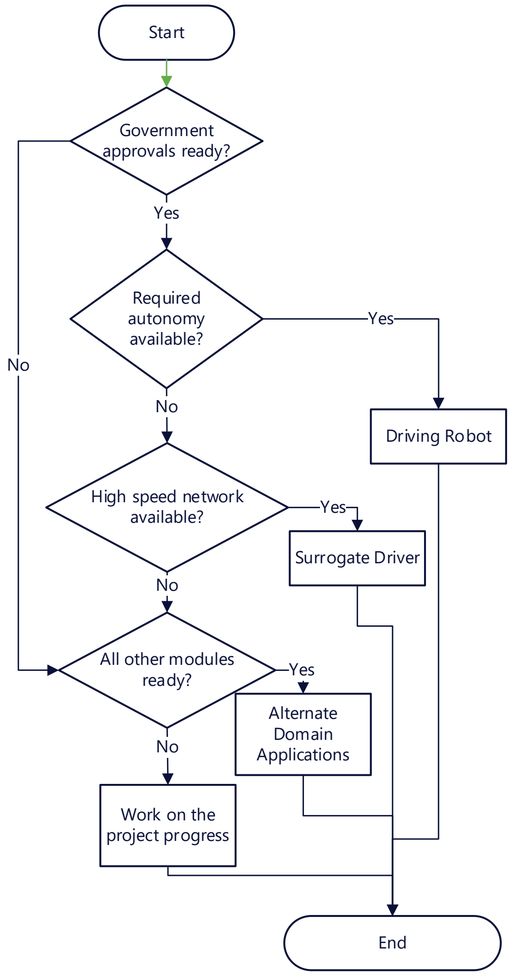
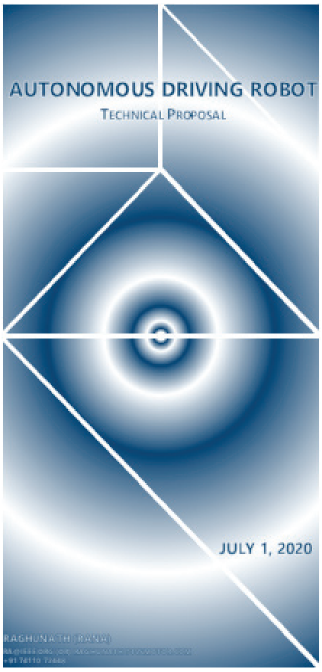
A series of risk mitigation methods are discussed, including the most important one – derivative business units. The project execution results in several independent derivative business units that help with the cash flow, even before the full product is ready. IPRs created during the development will generate revenue and help increase the valuation.




The project applies to the following areas (only indicative, not limiting)

- Optimistic technology-scenario (If the industry develops L4 or L5 autonomy solutions)
    - *Autonomous Driving Robot*
- Realistic technology-scenario (If 4G network delay is not limiting, or 5G is available)
    - *Surrogate Driver*
- Pessimistic technology-scenario (Possible, no definite limitations exist)
    - *Vehicle Testing Robot*
    - *Construction/Farm Equipment Operator*
    - *Last-mile Delivery Vehicle Operator*
    - *Hospitality Industry*
    - *Medical Assistance for Noncritical Services*
    - *Assembly Plant Operator*
    - *Hazardous Zone Vehicle Operator*
        - *Radioactive, Mine-Field, underwater, Extreme weather, Poisonous Gasses, Deep Excavation, Excessive Load Handling*

A strong IPR portfolio created as a part of the project execution, focusing on the central AI server, connected autonomy solutions, robotic applications for the vehicle, and other USPs, creates high value. The data collected from the sensors mounted on the sensors amounts to a vast database specific to Indian conditions with much commercial value.

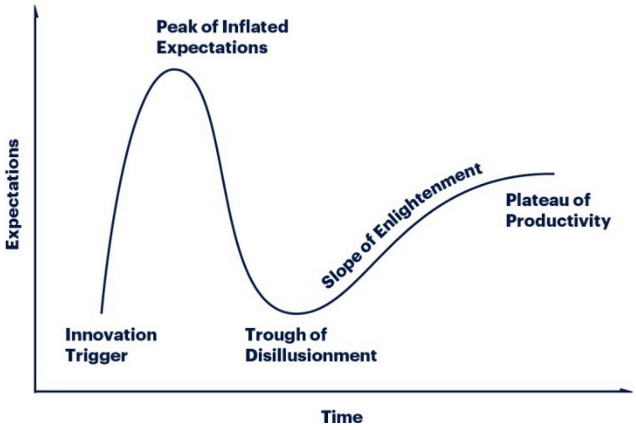



Given the market potential, the scope for profitability, individual's social distancing needs, increased availability of skilled resources in the pandemic time, reduced risk through derivative businesses, availability of computing power, and faster interface with the servers, now is most likely the right time to start this project to get ahead of the competition.

# 2 TECHNICAL INTRODUCTION

The document titled *Autonomous Driving Robot Technical Proposal* for discussing the technical overview of this project is prepared and included together with this. The summary of the technical proposal is here.

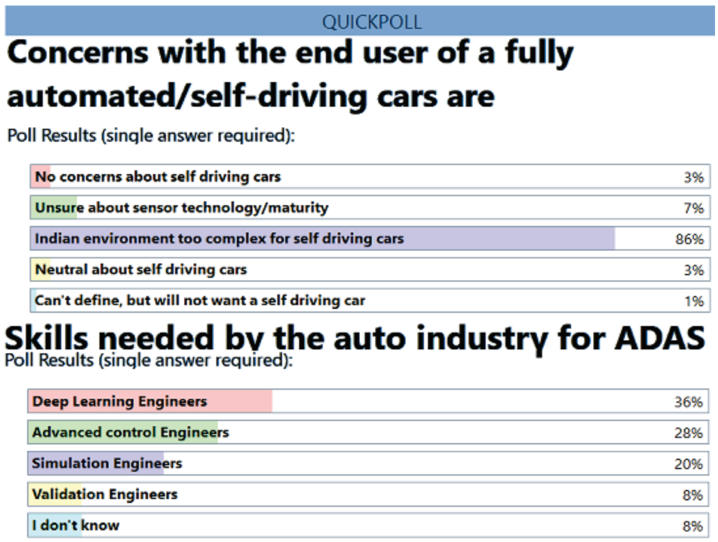
Mismanaged expectations (through highly controlled demonstrations, inflated promises, and impossible launch estimates) by few companies & several startups and aggressive funding by VCs in the past few years set the autonomous vehicle technology on a path to the *peak of inflated expectations* (on the Gartner hype cycle). Several of these expectations are also based on the millions of kilometers gathered in the simulations.




Very few companies have gathered the expertise required to take the autonomy levels to L4 or beyond. The L4 or L5 mode is active on the test vehicles only in limited geographies.

The set of accidents in recent years called for a reality check. The current state of autonomous vehicle technology and the progress is visible to the general public now. Future expectations are set on the autonomous vehicle technology with awareness about the limitations and possible failure modes.

We cannot expect that the next 20 years are the same as the past 20 years. The current technology is maturing and will have a breakthrough. The expectation of current technology is most probably near the *trough of disillusionment* and reaching the *slope of enlightenment*. The present trend of autonomous vehicle technology problems is to have (generally) limited scope with realistic expectations, such as a clearly defined geographical area (movement inside a campus or warehouse goods movement or last-mile delivery) or limited functionality (low-speed operation or heavy dependence on the in-vehicle driver).



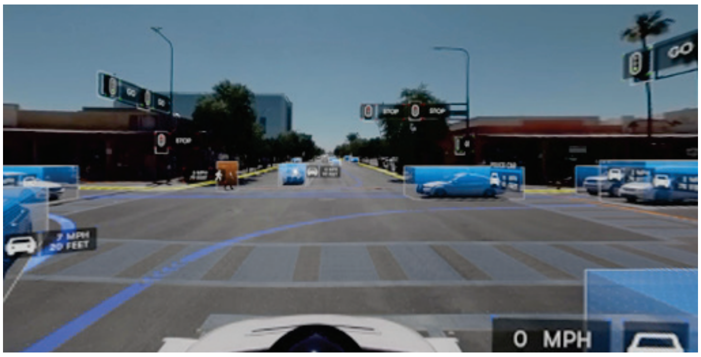

Our approach to the problem will focus on creating a portable autonomous vehicle driving system customized for Indian driving conditions, which can increase asset utilization.

A recent webinar on autonomous vehicle technology has over one thousand participants from all over India. The organizers surveyed the concerns, and almost everyone is worried that the Indian driving conditions are complicated for the existing solutions from the international companies and startups to work out of the box.

The other relevant question asked for the required skills. Deep learning is chosen as the first choice by over one-third of the participants, followed by advanced control systems, and simulations. The importance is rightly placed for very critical systems. Few more technical skills are equally essential but didn't appear in the survey question.

Deep learning has been the prima facie approach for many development projects in this technology area. End-to-end deep learning models heavily depend on training data to operate in a controlled environment. In real road conditions with unexpected situations, they are prone to fail. We will use deep learning methods along with the supervised learning concepts, to build the 3D environment model around the vehicle. The images on the right present the screenshots of the Waymo's vehicle controller's view, overlapped with the ground truth. The deep learning models detect the size, orientation, and speed of all the road objects and populate bounding boxes around the obstacles. This model of the environment and the actual environment are homeomorphic (from topology theory).

The critical question is, are the autonomous vehicles expected to drive like a human or much better? Human drivers depend on intuition during emergencies, but the same intuition cannot be attributed to computer programs. Classical control systems, combined with special algorithms for path planning in the homeomorphic spaces, provide the necessary navigation skills to the vehicle. Additional modules such as mapping and localization help the vehicle reach the destination safely. We will be able to implement hardcoded rules for road safety on top of the control modules and deep learning modules.




The development of full autonomy will take considerable time. We need to move the driver from the vehicle to a remote location to make the vehicle driverless. With the current state of technology, a most likely solution for the autonomous vehicle platform includes a complex mix of partial autonomy and remote override. The vehicle with partial autonomy acts much like a horse buggy – able to handle safety and basic maneuvers. Additional instructions can be given from the users from the vehicle or remotely.

Investments in 5G infrastructure from technology giants such as Reliance (Jio network) and satellite-based internet connectivity by SpaceX's Starlink project give hope for higher-speed connectivity to services such as the surrogate driver of our project.

This document proposes to develop a driving robot for autonomous vehicle driving solutions, which can be shifted from vehicle to vehicle. We shift the computational load to the central server where the decisions are taken and retain the essentials inside the vehicle. We take influences from robotic engineering and present developments in the autonomous vehicle technology to complete this product. The driving robot offers the best of both worlds: delivers the most value for money to the customers and provides vehicle autonomy.

# 3 Problem and Proposed Solution

## 3.1 People Linked Problems & Solution

With the ongoing COVID-19 pandemic situation, social distancing is an accepted way to contain the spread. For many years to come, the virus affects the way people think and respond to strangers being around them, even during their commute. They will want a guarantee about the excellent health of the drivers if they are going to take a cab.

In a touring vehicle, drivers practically stay all day long. The vehicle carries their items such as clothes and bags in the boot, reducing the baggage space for the customers.

An absent driver causes loss of revenue to the operator/owner when it is unplanned. Even in a planned leave condition, a backup driver needs to be employed to maintain the flow.

A distracted or an exhausted driver is most likely to make mistakes in the traffic resulting in repair & part replacement costs, legal expenses, and the increased insurance payments, including loss of revenue for the repair duration.

The driver's state of mind, the driving style, personal habits, and behavior have an impact on creating returning customers and affects long term profitability for a passenger vehicle. A sick or an ill-behaving or an aggressive driver upsets the customers who reduce the ratings.

The material transport requires skilled drivers to handle the routes with tricky road stretches. A fleet of vehicles following the same path requires multiple qualified drivers.

A lockdown situation (like now) forces the drivers to park the transport vehicles wherever they are and reach the nearest safe zone or their hometown. At the end of the lockdown period, all the drivers have to go back to the vehicles to start the transport operation.

Shift to autonomous vehicles will address the problem of social distancing to a certain extent. An autonomous fleet can handle any long-distance transport services well, and driver fatigue is not an issue. The autonomous fleet also avoids the problem of driver unavailability at remote locations in the mid of the journey.

Platooning of the autonomous fleet makes the solution economically sustainable by reducing the computational load on the follower-vehicles. At the same time, the lead vehicle shares all the road data and the results of its computations.

Planned or unplanned sick leaves do not exist for autonomous vehicles. The system is always equally attentive and operational all day long, including the weekends and holidays.

## 3.2 Technology Linked Problems & Solution

The switchover from standard (people-driven) vehicles to autonomous vehicles takes considerable time, given the problems with the current research [4]. The number of traffic violations is high in some places requiring a different approach for AI from the rest of the world. Transport infrastructure and support systems in many areas are not sufficient to integrate autonomous vehicles on the roads.

The traditional approach to autonomous vehicle development is expensive - prefers electric transmission, rigidly integrates all the sensors & actuators into the vehicle body.

The expensive autonomous vehicle in the traditional approach is a result of the following

- Focus on very high-speed vehicles, with expensive sensors, actuators, and computing
- Over-dependence on LiDAR whose cost is too high for inclusion in the production
- New vehicle platform with integrated sensors/actuators - expensive BoM & processes
- Data-intensive sensors need powerful GPU, high network bandwidth for algorithms
- Preference for electric drivetrain

The autonomous vehicles' cost becomes high for owners and fleet operators. They lose their revenue from the asset (vehicle) when it becomes inoperable for trivial problems related to regular vehicle parts. The autonomous vehicle needs to go to the service station for repair, rendering the asset unavailable for a few days if the spare parts are inaccessible.

There will be standard vehicles on the roads along with autonomous vehicles, until the end of the service life for the last standard vehicle. It is possible to convert these standard vehicles to include autonomous driving mode without a significant overhaul.

We place a modular robot-like-setup (may not look like a humanoid) in the driver's position to operate the accessible human controls such as brake, accelerator, and steering (and road safety compliant controls). An array of sensors for identifying the environment around the vehicle will provide a stream of inputs to the controller to operate the actuators for safe operation. For the convenience of reference, we will call this setup an Autonomous Driving Robot or just **Driving Robot**.

The driving robot can be shifted from one standard vehicle to the other when the first vehicle faces a problem that requires more time than the swapping time. We can quickly put the asset back to operation for best utilization and revenue generation. We shift the AI (and the GPUs) to the central server to make decisions, and retain the essentials (sensors, actuators, and communication interfaces) inside the vehicle. This shift helps us avoid underutilizing the expensive dedicated computing time when the vehicle is idle.

Even in the case of an accident (totaling the vehicle), the rugged case of the controller safeguards the critical components of the driving robot, exposing only the relatively inexpensive actuators. This feature substantially reduces maintenance costs.

The driving robot reduces the driver footprint. The passenger vehicle users get an ample space since the driver seat is pushed forward to the maximum. Elimination of the driver's belongings increases the available baggage space. The driving robot interacts with the passengers in the most friendly manner.

The project can result in the following. More details about these projects are in section 6.

- *Autonomous Driving Robot* (with L4 or L5 autonomy) - Optimistic scenario
- *Surrogate Driver* (with reduced network latencies) - Realistic scenario
- *Multiple application areas* (requiring non-realtime reaction) - Pessimistic scenario

## 3.3 Analysis of the Solution

The autonomous vehicle introduction is subject to technology development in the industry and academia. Many experts' estimations point to over 15 years into the future before the full autonomy is ready.

In an optimistic case, we assume that the fully autonomous systems (software, algorithms, computing power) are available by the time we are ready with the rest of the systems. The majority of this research is from the universities and open-source groups with no restrictions on usage. Our internal research will improve the available material or add new features for better performance. Then we can horizontally deploy the possible solutions to our driving robot with minimal end-layer changes to match with our actuators.

Platooning of the vehicles is possible with the driving robot too. Platooning reduces the computational requirement for the follower-vehicles as opposed to independent driving. Platooning has an economic advantage with the pricing scheme that charges more for navigating dense and risky traffic. The vehicles communicate among themselves over the V2V network and form clusters of platoons for optimum pricing and drive efficiency.

Realistically speaking, we will still have level-3 autonomy by the time we create systems (actuators, sensors, communication networks, electronics) other than AI. We will have the physical unit without the required intelligence. In such a case, we can fall back to the human-in-loop system with the surrogate driver model.

Most trivial driving conditions are handled by the AI, and some by the remote surrogate operators. We shift the driver away from the vehicle. This shift gives us the flexibility to change the drivers as needed, avoid fatigue, and reduce the risk to life during accidents.

Platooning under this scenario includes the lead vehicle driven by the surrogate driver while the follower-vehicles run in semi-autonomous mode. Engagement and disengagement from the platoon require coordination by the driving robot software and pre-booking the surrogate drivers from the command center.

We train our AI models from the continuous data from the surrogate driver mode, to create a faster path to achieve better autonomy for our future generations of the robot.

The realistic scenario assumes that the network delays are sufficient for the operator (surrogate driver) to view the data, make decisions, and send the commands to the robot. This assumption places high trust in the network. Although we propose to have multiple 4G network channels for data paralleling and redundancy, we expect a choked system when multiple surrogate drivers are operating. The introduction of 5G removes these hurdles.

If the network delays do not provide reliable control of the vehicle by the surrogate driver, we can fall back on to other applications without the real-time requirement. These other applications are reducing the human physical presence in the vehicles where it is either dangerous to be there, or not required to be there.

Some of the application areas, such as restaurant services, hospitality industries, non-critical care medical facilities requiring physical isolation, can continue with the non-real-time response with the operator in a remote location. Farm equipment & construction equipment operation, extreme weather operations, crewless vehicles in defense applications monitoring landmines, last-mile delivery vehicles moving in spaces with less traffic at slow speed, need to monitor the surroundings. However, real-time response to the environmental changes will not be necessary in most cases.

When the vehicle with the driving robot is on the road, it can keep track of traffic rule violators and share the details with the traffic police. It can include a configuration where the traffic police can send a lookout notice for a given number plate. This feature builds goodwill with law enforcement agencies.

### 3.4 Vehicle Types

The vehicle types in focus are cars (for people) and small commercial vehicles (for material). The transmission range includes manual transmission, automatic transmission, and electric transmission (including hybrids). The manual 4-wheel drive vehicles are not part of the scope because of the complexity and lower vehicle presence in the market.

## 4 Market Size and Commercial Viability

### 4.1 Market Size & Scope

Over 36 million vehicles in India (about 850 million globally) will be available for exploration. The passenger vehicle sale number may grow in an optimistic case at about 6% (same as CAGR for the past few years). However, in an economic crisis (pessimistic case), the passenger vehicle market may shrink. Since the proposed business only accounts for the total accumulated vehicles in the pool, the number of vehicles going out of service can affect the target market size.

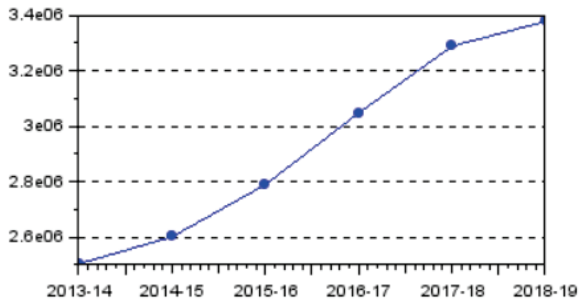



*Figure 1: Passenger vehicle sales in India.*

There are very few active projects in this field [5] [6] [7] [8]. This technology space is very narrow. Entry hurdles include the cumulative knowledge of robotic control engineering, algorithm design, testing infrastructure, and manufacturing capabilities, besides the standard technology available in the autonomous vehicle segment.

As per some optimistic predictions, the autonomous vehicle technology will be reliable by 2025 and will be commercially available by 2030 [20]. The purchasing customers include big businesses (with a lot of road usage) and wealthy individuals. Subscribing customers include taxi services, smaller businesses, and mid-income individuals.

The autonomous vehicles' cost per km travel will be higher than that of public transport but lower than that of people-driven taxies, further increasing the market penetration.

Realistic time estimates put the autonomous vehicles on the road on a commercial scale by 2045. Before such time, more human intervention (remotely) will happen, which is one of our derived businesses (surrogate driver platform) from this proposal.

As we progress with this project, our surrogate driver model will be ready much before the industry is prepared with full autonomy (L4 or L5). Our product (driving robot or surrogate driver platform) will still be profitable, independent of the vehicle type (ICE based or electric transmission) and irrespective of the state of autonomous technology development.

We collect the road data (objects, maps) and improve our AI models, a strategy very similar to that of Tesla Autopilot. This data is of substantial commercial value for market entrants.

This project comprises several modules, some of them individually or combining them give rise to a profitable commercial venture until the full project is ready. While the intellectual property (patents) brings-in money when monetized through the licensing route, combinations of the modules create viable business opportunities within and beyond automotive applications. Each of the possible businesses has a huge market opportunity, and we can explore their real potential as the project progresses.

## 4.2 Revenue Models & Business Strategy

The revenue channels are abundant in this business model. In the following subsections, this document mentioned some primary channels for better RoI. It is difficult to assess the effectiveness of each channel.

### 4.2.1 Subscription & Sale

The driving robot is likely to be purchased by wealthy individuals or big organizations. However, the sale number is going to be small. Even after the purchase, the premium subscription services such as updates, surrogate driving will bring the money.

Premium features are part of the attractive features that entice purchasing customers.

- a humanoid shell for the driving robot
- an artificial face that can show expressions
- a voice interface (including a connection to Alexa or Google Assistant or Siri)

The cost of the driving robot may be more than what a mid-income individual or a small business can afford for the first few product generations. It is better to offer the product on a long term subscription where the bulk investment is not required.

Possibilities of subscription offering:

- Pure Subscription: The robot will be with a single user for the subscription duration.
    - The ROI subsection details this model.

- Shared Subscription: Multiple users will share the same robot. Each of them has a fixed number of hours to use, and the allocation based on mini-auction. Those in need will bid the highest and take the robot. During the bid, they can also interact in a chat window to sort out if someone has a personal emergency.
    - This model is similar to Zoomcar's shared subscription model.
    - It helps that the driving robot is easy to fix and remove in less than 30 min.

The subscription fees may include insurance cover for damage to the robot, the vehicle, people, and any other goods in the vehicle. Since the robot's actuation system is operationally simple for vehicles with automatic transmission, fees may be marginally lower for some type of vehicles.

The subscription model primarily depends on the majority of the intelligence residing on the servers with minimal autonomy without the service subscription. This model also ensures that the customers get the most updated software for driving robots.

The subscription fees may include fixed charges and floating charges. The floating charges depend on the amount of data transfer required for the driving robot to operate, and the computational resources needed.

If the user has a straightforward road to travel, the charges may be lower. If a user chooses a bustling route, with heavy traffic, the alertness required for the driving robot is much higher, so the floating charges can be higher. For a given route, if part of the journey is with less traffic, and rest is with more traffic, the net expenses are cumulative of the corresponding independent dynamically calculated charges.

Cash flow will be from the general users & businesses who need mobility.

#### 4.2.2 User Analytics

We collect user data (with their consent) for user models that will be useful for advertising agencies in creating targeted promotions. We can share a part of the profit with the users as a discount or cashback or points, to motivate them to opt for sharing their data.

Cash flow will be from the advertising agencies and other user profilers.

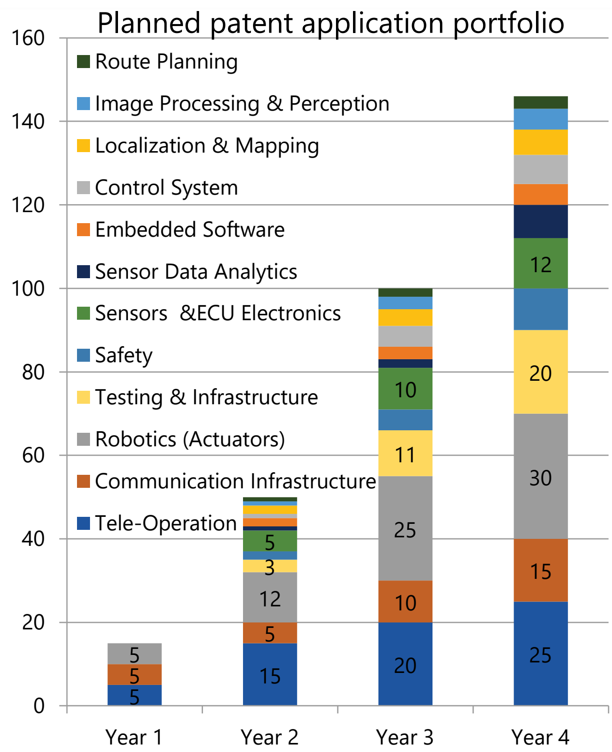
#### 4.2.3 In-vehicle Advertisement

This approach will engage the users through visual and audio means. Stickers on the driving robot and the actuators are part of visual means. An AI module with an audio chatbot interface, including an advertisement module, is useful. It can keep the users engaged with casual conversations, while it promotes the products simultaneously.

Cash flow will be from the local businesses on the route.

#### 4.2.4 API Access

Product customization (through custom modification) is possible. For example, someone who has motion sickness wants to go very slow. Some may want to go as fast as possible, as the law and safety modules allow. Customers may download such modules as plugins.




The companies that develop these modules get paid, and we get a share of their payment. They will pay a license fee for using the APIs for customizations. An additional benefit is the reduction of the need for developing features for a few users. The community develops its modules as plugins, similar to Google Home/Alexa user modules.

### 4.2.5 IPR Licensing

Patents are the most required asset of a strong technical organization for the long term survival. We will continuously work on creating patents that are valid in our regions of interest, most likely worldwide through the PCT route.

Our focus will primarily be on the areas with our USP, such as the connected autonomous vehicles, server-based AI, teleoperation, and robotics applications in the vehicle. The chart on the right presents a plan for the areas of focus for the patent generation. The initial set of patent applications may target broad coverage. As we progress with the project progress, we get into more focused areas for patent applications that strengthen our portfolio. We will choose the research topics strategically to make the portfolio attractive to any new entrant in the Indian scenario.

By the time the MNCs working on autonomous vehicle technology enter the Indian market, we will capture enough patent landscape (specific to Indian operating conditions, or alike). An easy way for them to get started is to get a license from us.

The primary motivation to apply for the patents is to use them for our project progress. We will grant licenses of our patents to the interested parties and generate revenues.

A strongly relevant (to the market needs at that time) patent attracts very high royalties, even for non-exclusive licensing. The additional benefit of licensing is multiple agencies testing and validating the concepts (from the patents) exhaustively, including the corner cases.

It is difficult to assess the real value that a patent has. Generally, a patent that is validated by making a successful product has the highest value.

### 4.2.6 Road Data

We have a large fleet of regular vehicles (under testing, CUFT, and customer vehicles). Some of these vehicles will be fitted with sensors to capture data from a variety of terrain conditions. Indian-like chaotic conditions are less recorded and less analyzed so far. Such data has been less used in training the deep learning models for autonomous vehicle implementation. Indian road conditions are unique in some aspects. The diversity of environmental, geographical conditions adds richness to the data.

We will focus on capturing the images from cameras to include different road types, various road vehicles (including two-wheelers), and pedestrians (with different types of hand luggage). The image data will primarily be useful for training the deep learning models for object detection and pedestrian/vehicle behavior predictions.

We will also capture the dense (HD) map data for all the regions to include road signs & special arrangements such as roadblocks, potholes, narrow lanes, and maximum height/width/weight restrictions. This data will be integrated with the commercial map provider's data (from Google/Here Maps/MapMyIndia) to make better decisions about route planning.

By the time the industry-leading companies want to start expanding to India-like traffic conditions, we would have amassed massive data. The value of the data we acquire over the next few years will be high, but it is difficult to quantify.

## 4.3 Customer Analysis & Use Cases

The target customer group for the patents and the road data are MNCs trying to enter Indian markets and the organizations (within India and elsewhere) that want to get started on autonomous vehicle technology for Indian-like conditions. Both the categories of companies may have less experience in handling a fleet of vehicles, and probably new to this technology. In some cases, these companies may have a product/solution related to autonomous vehicle technology. They may want to work on only developing their concept without struggling to create a complete ecosystem.

The target customer group for the final product includes many age groups with dependencies or those who want privacy & comfort during the commute/travel.

- School children
- Elders with mobility restrictions because of the health issues
- Working professionals that require mobility without sacrificing their time and comfort

### 4.3.1 SMBs & SMEs

Das (40, M) is a business owner with a distribution license. He has a limited and floating workforce availability, so he trains his recruits to get the materials delivered.

He subscribes to driving robots for his fleet of vehicles. He uses them to deliver his material to different parts of the city. Whenever the old vehicle develops performance issues because of extensive use, he moves the robot to a different vehicle.

He expands his business because of consistency in maintaining his material stock in the distribution network. His employees are happy with him because of the reduced workload.

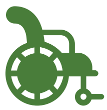
### 4.3.2 Small Industries

Manu (50, M) is a large-business owner offering purpose-made rugged cars. He asks drivers to take the vehicles to the torture track to identify failures. However, he faces high attrition and increasing employee costs.

He gets a subscription for multiple robots for his torture-track tests, with customized driving services with a programmable interface.

His staff runs multiple tests in parallel, putting his facilities to best use. His time to deliver products is the lowest. His profits increased, and employee retention is better than before.

#### 4.3.3 Limited Mobility

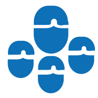


Rao (55, M) has a knee issue and limited mobility. His work demands him to move around. His car is a hatchback, and he cannot buy a self-driving car.

He subscribes for a driving robot and gets it tuned for his hatchback. It takes 30 minutes of assembly and a few minutes for vehicle configuration data download.

He is socially active, happy to be independent.

#### 4.3.4 Working Parents



Uma (32, F) is a working mother with three kids. She needs to drop them at daycare/school before reaching her office, and she finds it very difficult to attend the kids while driving.

She subscribes to the robot for three months and gets it tuned for her sedan. From her observation, the setup-time and effort are very little.

She is happy to feed her children on the way to their school. She manages to do some productive work while stuck in traffic on the way to her office.

#### 4.3.5 Connected People

Raj (35, M) is an IT professional with a difficult client. He has meetings in the evening hours when he has to go home. His family has three cars at home, and he picks his ride depending on his family convenience.

He subscribes to a driving robot with a limit of 3 cars and moves the robot among cars when needed. Reconfiguration takes only a few minutes on the unfamiliar car.

He attends the meetings from his vehicle during the commute. He is happy to have the same feature on all of his cars of different size and transmission type.

#### 4.3.6 Startup Entrepreneurs

Hema (29, F) is a tech-startup founder in self-driving vehicle space. She is struggling to find a platform where she can test her solution without developing the full solution.

She gets an API access license for controlling the vehicle with her algorithms. A background master control takes over in unsafe conditions.

She demonstrates her solutions to the VC, and they fund her project.

## 4.4 Investment Requirements & Timeline

The exact amount of investment required to execute this project and finish a product of this (unprecedented) complexity is unknown and is tough to forecast. The following subsections give an estimate of approximate investment.

Onetime requirements are the investments (both time and money) for setting up the teams and the necessary infrastructure. Recurring requirements are the investments for maintaining the technology projects active, costs for advancing through the phases, consultancy, and other engagement charges.

This document presents three levels of projections for each of the expenses (optimistic, realistic, and pessimistic) for the investment requirements.

- The optimistic case for the investment is the one with the lowest money requirements.
- The realistic case assumes what is possible for a business of this type if the existing market situations continue.
- The pessimistic case assumes worst-case expenses.

The section that discusses RoI considers the realistic scenario for the following expenses.

### 4.4.1 Salary Expenses

These are critical in retaining talent and getting expert help. These expenses include the following items.

- Employee salary
- Contractor fees
- Consultants' charges
- University collaborations including some Ivy League
- Partnerships with startups or consultancies
- Technology purchase or IP development

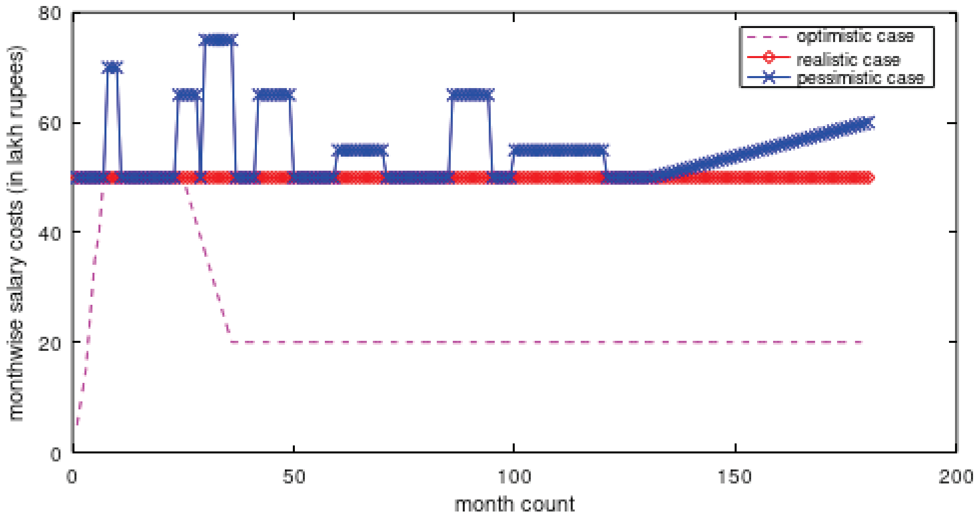



*Figure 2: Monthly salary costs for all three cases*

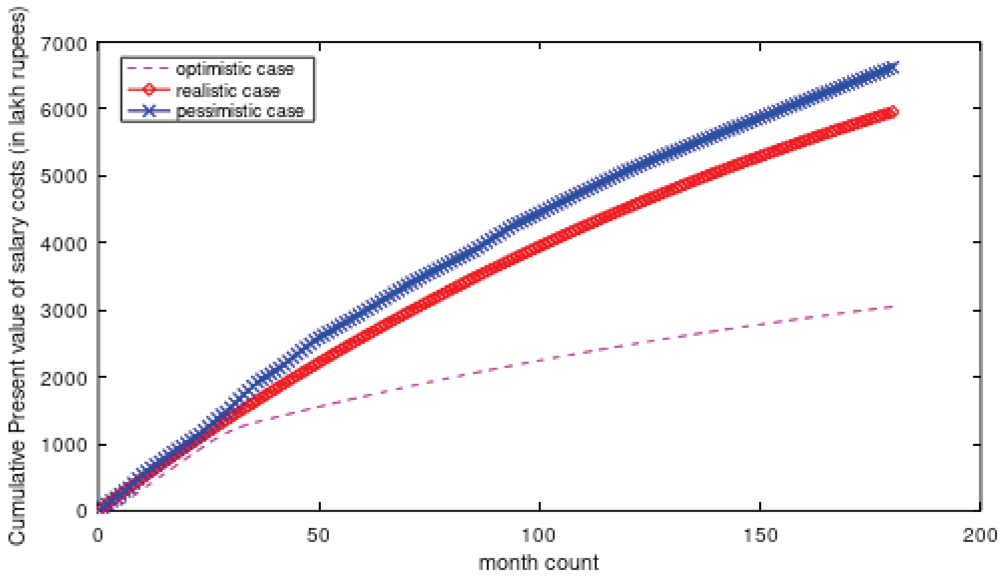



*Figure 3: Cumulative Present Value of salary costs for all three cases*

This document considered three possible scenarios of the market conditions, which result in the following cases of investment need in this category.

- In the optimistic case, the development will be done with minimum expenses, and will not require any more progress. We can expect the resource expenses ramping-up in six months, staying flat for the rest of the event or 1.5 years, ramping down to minimum required value during the next one year, and staying at the minimum during the service period. This pattern assumes that only the gen-1 product will be ready, and only improvements will happen. This pattern also assumes that the external consultancies will not be required.
- In the realistic case, the development will require the resources engaged from the start of the project. It will continue to work on further developments and next product generations. The salary costs will not come down, because of the continued investments in the resources and external engagements, for new developments. This case assumes that the resources keep joining the team, while some leave.
- In the pessimistic case, product development takes a long time and effort, requiring the intervention of the external skilled consultants. The development activity sees significant expenses intermittently. The salary costs also continue until the whole period of consideration, while these costs continue to increase with inflation.

### 4.4.2 Laboratory Setup & Prototyping Expenses

Prototyping expenses and this expense are used together in the RoI subsection for simplicity. These expenses are incurred every year during the development time. This document considered an extra year of investment for continued development. Some of the items included in this category are listed below.

- Simulation/modeling/design tools, GPUs, databases, storage, server access, evaluation kits, testbeds
- Building and IT infrastructure facilities
- Hardware PCBs, sensors & component purchase

- Software modules and control algorithms
- Mechanical actuator development
- Communication interfaces for data exchange and override
- Other capital/temporary assets relevant to the development

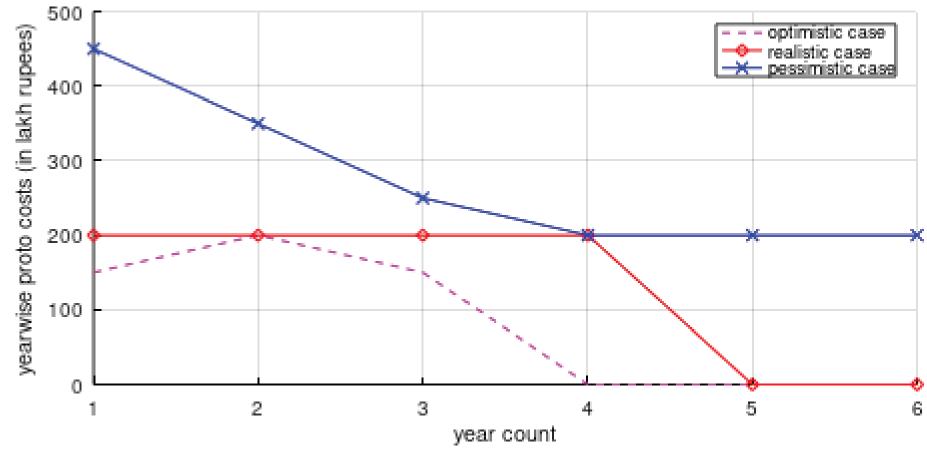



*Figure 4: Yearly proto costs for all three cases*

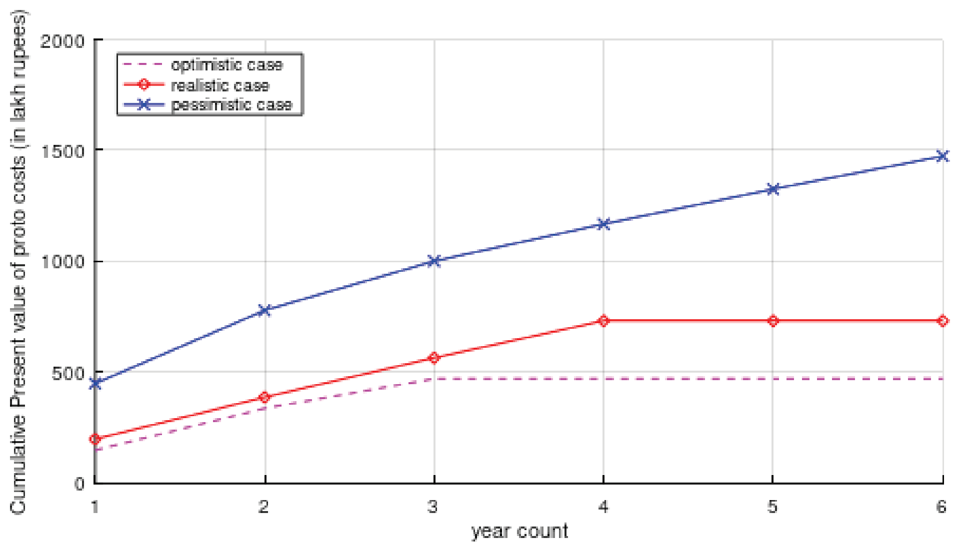



*Figure 5: Cumulative Present Value of proto costs for all three cases*

This document considered three possible scenarios of the market conditions, which result in the following instances of investment need in this category.

- The optimistic case considers that the existing facilities from TVSM infrastructure such as buildings, few testing facilities (and software) for hardware, and simulations are available for utilization during the execution of the project. The prototypes are generally first-time-done-right and do not require several iterations for successful implementation. The expenses begin from the start and end after the 3rd year after the two years of development activity. The costs are spread one year apart at INR 1.5 crore, INR 2 crore, and INR 1.5 crore.
- The realistic case considers that the existing facilities are already occupied and so available for only a partial time. The project execution requires a few critical facilities. The prototypes take a couple of iterations, but not too many. The expenses begin

from the start and end after the 4th year after the three years of development activity. The expenses are spread one year apart at INR 2 crore each.

- The pessimistic case considers that the infrastructure for the new team is created entirely independently, just like an independent startup system. The execution requires a large sum of money and effort to create them. The expenses begin from the start and end after the 6th year after the five years of development activity. The expenses are spread one year apart at INR 4.5 crore, INR 3.5 crore, INR 2.5 crore, INR 2 crore, INR 2 crore, and INR 2 crore.

### 4.4.3 Marketing Expenses

The marketing expenses are primarily for creating product awareness among the prospective customers and for generating a sale. This document assumes that the effort of the marketing campaign lasts for a few years, after which a new marketing drive needs to start. This document assumed a conservative 3-year gap between marketing campaigns.

This document considered three possible scenarios of the market conditions, which result in the following cases of investment need in this category.

- The optimistic case assumes that initial product awareness comes from the news articles and press releases. The expenses start from the 3rd year after the two years of development activity. The expenses are three years apart, amounting to INR 1.5 crore, INR 2 crore, INR 1.5 crore, and INR 0.5 crore.
- The realistic case considers that customers need marketing and test-runs for awareness. This case requires marketing for a focused customer segment, rather than for the general public. The expenses start from the 4th year after the three years of development. The expenses are three years apart, amounting to INR 2 crore each.
- The pessimistic case considers that the market is not ready for the driving robot, and we need to create awareness by having to run many free trials. The marketing expenses include these running costs. The expenses start from the 6th year after the five years of development activity. The expenses are three years apart, amounting to INR 4.5 crore, INR 3.5 crore, INR 2.5 crore, and INR 2 crore.

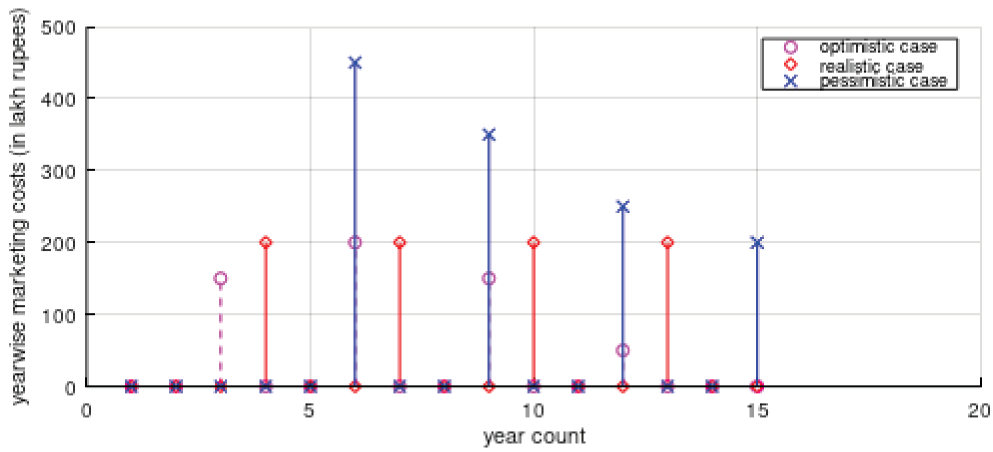



*Figure 6: Yearly marketing costs for all three cases*

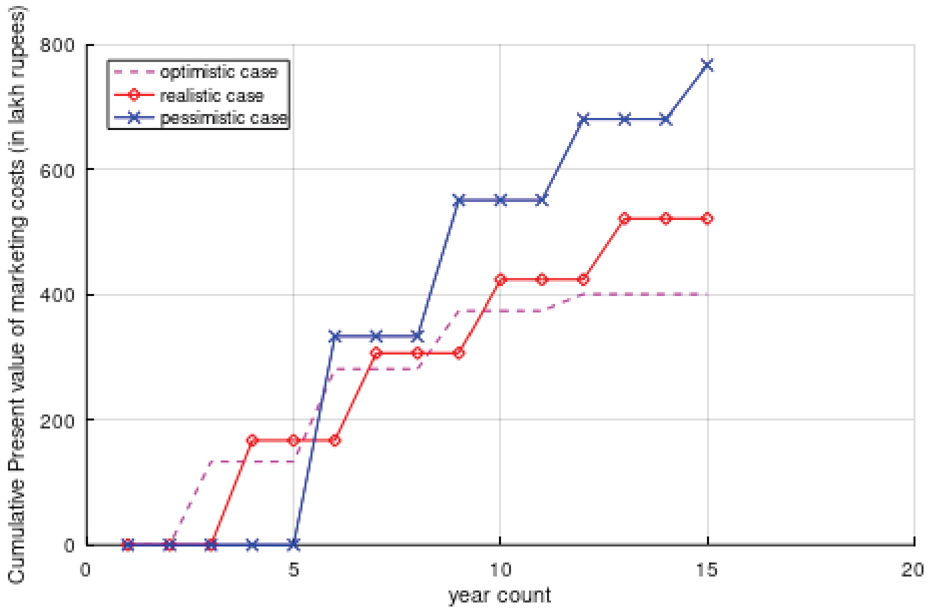



*Figure 7: Cumulative Present Value of marketing costs for all three cases*

### 4.4.4 Manufacturing Expenses

These expenses are the gross expenses for manufacturing the product in its final stages, not at the prototype level. This category includes the following items.

- Product Bill-of-Materials cost
- Process costs for each part
- Transportation costs for the sub-assemblies and final part
- Assembly/manufacturing line setup cost
- End-of-Line testing/debugging instruments' cost
- Manufacturing staff salary and wages
- Cost for power consumption and consumable items
- Assembly workers' training cost

This document considered three possible scenarios of the market conditions, which result in the following cases of investment need in this category.

- The optimistic case assumes that establishing an independent production line requires very minimal changes to TVSM, and costs less.
  - Most of the sub-assembling will be at supplier locations and final assembling & End-of-Assembling validations on our premises.
  - Costs of the critical components continue to fall and reduce overall costs. We bring more complexity into the software and use simpler hardware.
- The realistic case considers that suppliers manufacture some assemblies (parts with no IP). In contrast, we assemble a few critical parts (parts that have a possibility of reverse engineering) within our premises.
  - We manufacture some of the critical parts in-house to reduce the cost and maintain the intellectual property (IP).
  - Costs of critical components do not fall dramatically, but we try to work with them. Moderately complex software requires mid-range hardware.

  - For the RoI computation, this document assumed the product cost to be INR 20 lakhs. This value includes all the costs mentioned above and averaged to calculate the per-product cost for a projected volume of 20000 units per year.
  - With this, we will reach the threshold sale number of 34000 in about 1.5 years. The INR 20 lakh is only an indicative number for our reference, and not a target cost fixed based on cost calculations considering supply chain availability.
- The pessimistic case considers that the supply chain is very tough to get the required parts, and the essential components are expensive. We maintain a similar manufacturing setup, as stated in the realistic scenario. Increased complexity in the software still demands the use of complicated and costly hardware to meet the product requirements.

### 4.4.5 Test Facility Expenses

These expenses are clubbed with the lab setup and prototyping expenses during the RoI calculation for the sake of simplicity. This category includes the following items.

- Bench tests, vehicle tests, test tracks, chassis-dynamometers
- Software emulation tools, HiL environments, EMI/EMC facilities
- Sensor calibration and testing
- Part endurance, performance validation tests

This document considered three possible scenarios of the market conditions, which result in the following cases of investment need in this category.

- The optimistic case assumes that all the test facility requirements are already satisfied with the existing TVSM infrastructure. In this case, there is no need for an additional facility.
- The realistic case considers that most of the facilities (chassis dynos, part level test rigs, HiL setup, emulation tools, and test track) are available to TVSM. These facilities can either be shared or accessed without much effort. Few other facilities (real road emulation with dummy vehicles, EMI/EMC tests for the controllers, LiDAR/RADAR testing & calibration) require interfacing with external agencies.
- The pessimistic case considers that sharing the facilities with TVSM infrastructure is not possible because of over-booked slots. We might have to create independent facilities for the driving robot project. As stated in the realistic scenario, few services require a dependency on third party agencies.

### 4.4.6 Service & Warranty Expenses

These expenses are to account for establishing the service network and for part replacement. The RoI calculation had separate heads for service costs, operator costs, insurance costs, and server maintenance costs. Service & warranty include the following:

- Replacing the failed parts under warranty
  - Expenses under this head depend on the part failure rate and their respective costs. We will make design choices to bring this cost of failure to a low value.

- Maintaining the parts of driving robot, a standard failure avoidance method
- Vehicle fueling at predetermined fuel stations at predetermined intervals
    - Suitable for vehicles that travel within a known region.
    - For vehicles that require assistance in refueling, the nearest service station will be alerted, and they will approach the vehicle for fuel top-up.
- Vehicle service/cleaning at predetermined service stations/booths after a ride
    - Exterior cleaning at regular intervals
    - Interior cleaning requires human intervention to observe customer items left behind in the seats, or liquid spills, or damage to the property. This inspection requires an internal camera system where the operator observes the interior at the end of every ride to ascertain if the vehicle requires manual cleaning.
    - Interior hygiene maintained by spraying disinfectants after every ride
- Expenses for a central server for data upload/download, updates, and computations
- Expenses for customer interactions
    - To summon the vehicle for pick-up
    - For billing-related transactions
    - To know the destination, preferred route and driving style
- Data charges for the transactions and interactions
- Charges for computational evaluations on the server-side
- Operator costs
    - For surrogate driving or manual overriding in tricky situations
    - For assisting the passenger when required through audio
- Product insurance
    - We handle insurance company interactions

This document considered three possible scenarios of the market conditions, which result in the following cases of investment need in this category.

- The optimistic case assumes that the part failure under warranty is shallow, resulting in meager expenses for us. The customers also require very little assistance, and the vehicle goes in a familiar route with structured traffic. Passengers maintain good hygiene in the vehicle and do not cause damage.
- The realistic case considers that about a 1% failure rate is possible for the parts resulting in replacement costs.
    - These defects will be detected early through diagnostics, and the driving robot informs the nearest service station
    - Customers use moderate assistance from the command center
    - Surrogate driver requirement is moderate, but not always
    - The vehicle goes through familiar routes with dense traffic, requiring more data transfer and computations
    - Passengers sometimes forget items in the car and claim later. Service station operators handle these items
- The pessimistic case considers that the part failure rate is unknown and high
    - Passengers cause damage to the vehicle and create a requirement for cleaning the vehicles at the end of every ride, requiring manual intervention

- The vehicle goes through unknown roads with dense traffic, often triggering the requests for operator override to come out of tricky situations
  - Requires manual intervention for a fuel top-up

### 4.4.7 About the Expenses

Each phase of the project development requires a seed amount. The sensors and GPUs are expensive, owing to their limited production. A recent quote for mid-spec LiDAR from Velodyne is about US$17,000. The recent launch of a mid-spec LiDAR sensor element costs about US$100. Newly launched LiDAR from Luminar is US$1,000 at medium specification. RADAR [LRR] costs about US$700. This cost is only for the development, and the expenses for consultancy engagements and IP purchases are additional. It has to be a conscious and well-informed choice for every item, whether to create an in-house facility or to spend money to outsource the development. This choice is a tradeoff between long-term and short-term benefits.

To reduce the project expenses, we will stick to open-source software tools, open-source databases as much as possible for the algorithm development. Many universities keep their research work in the public domain to encourage the rapid development of the technology.

Further, we also depend on a freelancing model where we outsource the pockets of the development work. This model reduces the resource acquisition & maintenance costs. There are few shared spaces and university labs open for collaboration. We can access their labs for using their facilities at a much lower price than we investing in creating facilities.

### 4.4.8 Timeline

This document expects two years as an optimistic, three years as a realistic and five years as a pessimistic estimate for getting the initial proof-of-concept for Gen-1 ready. Further generations take about 3 to 5 years each. These estimations come from our earlier experience with working on a few advanced technology projects at AEG. A more detailed task plan is given in the additional document for the Gantt chart.

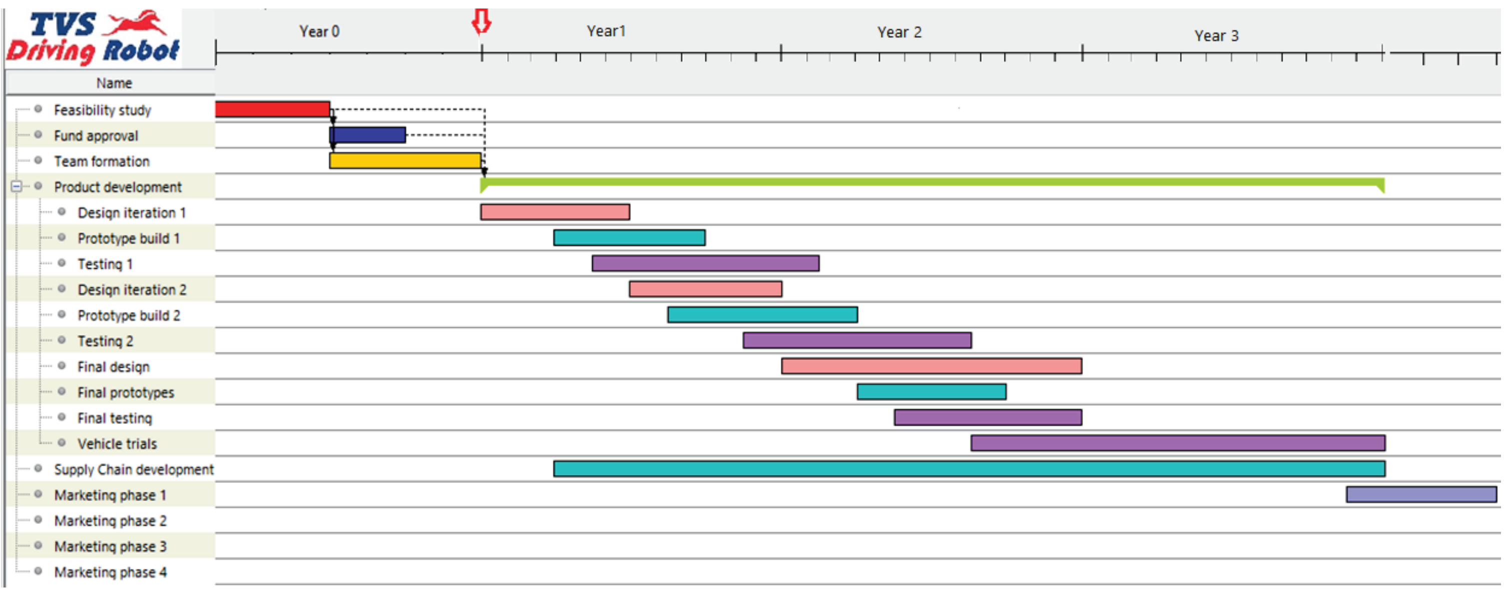



*Figure 8: Optimistic scenario: timeline view of the activities*

Some delays (failures of initial prototypes, component procurement, prototypes not meeting the specifications) are inevitable, and they push the project timeline further ahead. With the delay sources known, we make sure that we plan for alternatives for each of the parts/processes that encounter the cause of delay.

The following image gives a high-level view of the timeline of activities for product development for the optimistic scenario. It assumes a very smooth execution of events resulting in the successful completion of the project in two years.

## 4.5 Return on Investment (RoI)

### 4.5.1 For TVSM

#### 4.5.1.1 Sale-model

We assume a very low US$ 11,000 (INR 8.3 lakh rupees) price tag for the generation-1 product. This number is not a target price, but only a reference number for calculations.

We will get a 24 crore rupees profit if we capture 1% (7,300 vehicles) of the possible market (7.3 lakh vehicles). The potential market size is 60,000 crore rupees (8 billion USD for 2% of the 36 million vehicles) with a 4% profit margin. This profit will be possible well within two to three years from the proof-of-concept. This duration is the break-even time for the expenses made during the development.

For that to happen, if we wish to sell the driving robot, the cost of the product at the factory is 56% of the USD 11k, i.e., 4.9 lakh rupees. The remaining 40% of the product cost goes for the marketing, distribution, and service network.

All the subsystems will have to fit in this budget, including the recovery of the product development expenses. If meeting this cost target is difficult, we can offer the product on (monthly) subscription. Because of the difficulty in sticking to the cost targets, this may become a less preferred revenue channel.

#### 4.5.1.2 Subscription-model

The ROI may get delayed in this case if the customers do not commit to long term subscriptions. However, it is possible to aim for higher profit margins and continued customer base. We take a look at the present value of money for various services and the rental fees to assess profitability and the threshold sale volume.

The following items consider the realistic scenario, as quoted in the earlier section for the investment estimations. We consider the optimistic outcome of the project – Driving Robot.

In the realistic scenario, the product costs about 20 lakh rupees (expected) for TVSM. Its active life is ten years of subscription, and it takes three years for development.

The following cash flow is possible for a product that goes on subscription.

Other revenue channels (other than subscription, i.e., advertisement, data analytics, and API access) are difficult to establish for their contribution towards the cash flow. So, they are assumed to be negligible in the following analysis.

This document considered a total time of 13 (3+10) years in preparing the cash flow diagrams. The time unit is a month. The marketing expense of around INR 2 crore is assumed to be valid for a time slot of 3 years and is recurring. The IRR is 6% (slightly higher than TVSM's net profit margin values). If we invest the same amount of money in the continued business interests of TVSM, that investment would have returned around 4% as income.

This document assumes that the facilities (IT, buildings, labs) will be shared with this team to reduce the burden of expenses. Salary costs for the recruits is an additional expense.

- Production/Manufacturing cost (one-time) of INR 20,00,000: OUT, per product
    - This expense is a fixed cost without inflation. This cost comes down later due to the reducing component costs with higher production volume
    - This expense occurs at the end of the development period
    - For the sake of simplicity, we consider the manufacturing expenses per product for a projected production volume as this cost
- EMI (recurring every month, 120 times) of INR 20,500: IN, per product
    - This income is a constant sum of money coming to TVSM from the customer.
    - This income starts with the sale.
    - This income may include fixed and variable costs
        - Fixed costs are for the basic EMI
        - Variable costs include subscription costs for the premium services
            - Updates and software patches for better safety
            - Map updates and UI upgrades
            - Computation based costs – higher for busier routes
            - Dedicated surrogate drivers
- Marketing costs (recurring every three years, four times) of INR 2,00,00,000: OUT
    - This expense includes the print & AV media advertisements, awareness camps, demonstration rides, incentives for repeat customers, referrals,
    - This expense starts from the end of development time
- Server cost (one-time) of INR 20,00,000: OUT
    - This expense is the data server stationed at our premises
    - We establish the servers at the start of development trails
- Server maintenance, network data costs (recurring every month, 156 times) of INR 25,000: OUT
    - This expense includes networking charges, power, cabling, internet connectivity, data charges for higher bandwidth and download limits
    - This expense starts at the start of the project. Model training will also be done on the servers sometimes.
- Product insurance fee (recurring yearly, ten times) of INR 40,000: OUT, per product
    - This document assumed a 2% insurance premium rate for the product. The depreciation of the IDV helps in saving more money. However, the technology

being still in development, initial failures are possible, resulting in minor claims every year.
    - This expense does not include the reimbursements towards the sensors or other hardware failure. This expense covers the passengers, third party, and the vehicle itself.
    - This expense starts after the sale.
- Service costs, and part replacement costs (increasing annually, ten times) of INR 20,000: OUT, per product
    - The current dealer model can support the service of the vehicles. We can eliminate the setup expenses
    - Assuming that annually about 1% of the vehicles see a failure of the setup requiring a full replacement (or equivalent expenses), each vehicle gets about INR 20,000 share annually. The 1% of the vehicles requiring total replacement of the product is a rare case since we can cover most of the failures with a minor hardware upgrade or a sensor exchange. Solid-state LiDAR/RADAR is functional for over ten years. Only a few other items need to be changed.
    - This expense starts after the sale.
- Surrogate driver / Operator expenses (Recurring every month, 120 months) of INR 5,000: OUT, per product
    - This document assumed that a single driver could teleoperate about 4 to 5 vehicles at a time, since there may not be situations requiring full attention.
    - Even in peak hours that require most drivers to be available, off-peak hours can be managed with fewer operators in the control room, averaging the number to the one mentioned above
    - This expense starts after the sale
- Salary costs (recurring every month, 156 months) of INR 50,00,000: OUT
    - These costs are assumed to be from the start of the project.
    - Also includes some outsourcing roles, consultancy projects
    - Continued till the end of the project to represent further developments for future product generations
- Prototyping costs ( recurring every year, four times) of INR 2,00,00,000: OUT
    - This expense includes purchasing, product trials, vehicles
    - This expense includes necessary infrastructure arrangements such as lab setup, HiL, simulations, and equipment.
    - This expense includes minimal test facility arrangement costs. This document assumes that we partner with external agencies to conduct a few critical tests, such as EMI/EMC.

Table 1 represents the result of a per-product net cash flow analysis. The data in Annexure -1 substantiate table 1. The following says that when we calculate the discounted future cash flow to today’s date (before the development activity starts), we will have a net cash-inflow of INR 20,000. The total duration is three years of development and ten years of service life.

If the expenses and sale volume assumptions are correct, this value indicates the profit that we see today. If the expected sale volume is high, the project can be said to be already profitable at the time of development and funding.

This present value of profit multiplies with the number of products sold. The cash flow also includes capital investment towards the project execution. For profitability, the net profit from the break-even sale number offsets the investments to result in net positive cash flow.

| | | | |
|---|---|---|---|
| | future value | present value | 3 years of development, 10 years of service, per product cash flow, net profit |
| **Profit per robot** | INR 43,745 | **INR 20,085** | |
| | Final date | 31-Dec-33 | (3 dev + 10 service years) |
| | interest(%pa) | 6 | compounded monthly |
| | emi | INR 32,500 | IN, monthly |
| | Product Cost | INR 2,000,000 | OUT, once after 3 yrs of dev |
| | Insurance | INR 40,000 | OUT, yearly |
| | service costs | INR 20,000 | OUT, yearly |
| | operator costs | INR 5,000 | OUT, monthly |

*Table 1: Per-product cash flow items*

The interest rate (IRR of 6%) is an estimate to indicate that if we invest this equivalent money elsewhere, it would have returned this interest rate. Given the 4% net profit margin with the TVSM in the present market scenario, the present value of the per product cash flow will be close to INR 1.95 lakhs.

The product cost of INR 20 lakhs is assumed to show the calculations. Once we arrive at the actual/realistic estimate of the value, it can be substituted to get the net cash inflow number.

Operator costs are INR 5,000, assuming that a driver/operator can handle four vehicles. At the start of the project, a single driver/operator may have to handle a vehicle. As we provide more updates, this number increases. The operator only has to monitor and manage very critical maneuvers, handling up to ten vehicles. The number mentioned is the average.

Service costs are estimated based on the assumptions provided above. The actual service and parts cost will be calculated based on the standard hardware failure rate later.

The following are some scenarios that we can derive by changing a few parameters.

- Scenario 1: the interest rate is 4% instead of 6%
    - There is a substantial jump in the net cash inflow.

| | **modified** | **original** |
|---|---|---|
| Present Value | INR 195,551 | INR 20,085 |
| Interest(%pa) | 4 | 6 |
| EMI | INR 32,500 | INR 32,500 |
| product cost | INR 2,000,000 | INR 2,000,000 |

- Scenario 2: scenario1 + reduced EMI
  - the reduction in EMI is not very high to get a similar present value.

| | modified | original |
|---|---|---|
| Present Value | INR 19,745 | INR 20,085 |
| Interest(%pa) | 4 | 6 |
| EMI | INR 30,500 | INR 32,500 |
| product cost | INR 2,000,000 | INR 2,000,000 |

- Scenario 3: scenario 1+ increased product cost
  - Higher product cost with the same EMI brings about the equal present value.

| | modified | original |
|---|---|---|
| Present Value | INR 18,131 | INR 20,085 |
| Interest(%pa) | 4 | 6 |
| EMI | INR 32,500 | INR 32,500 |
| product cost | INR 2,200,000 | INR 2,000,000 |

- Scenario 4: Product value increases, EMI increases
  - Higher (25%) product cost increases the EMI by 17% only.

| | modified | original |
|---|---|---|
| Present Value | INR 18,259 | INR 20,085 |
| Interest(%pa) | 6 | 6 |
| EMI | INR 38,000 | INR 32,500 |
| product cost | INR 2,500,000 | INR 2,000,000 |

Table 2 represents the cash flow for the rest of the items from the above list. Data in Annexure 1 substantiate table 2. This table indicates that around INR 67 crores in today's value will be spent during the next 13 years.

| | future value | present value | 3 yrs of development, 10 years of service, net expenses for the product development and sale |
|---|---|---|---|
| **expenses** | -146,67,94,527 | **-67,34,80,345** | |
| | interest(%pa) | 6 | compounded monthly |
| | Marketing exp | 2,00,00,000 | OUT, once in 3 yrs, after development |
| | server cost | 20,00,000 | OUT, one time exp |
| | salaries | 50,00,000 | OUT, monthly, no hike assumed |
| | prototyping | 2,00,00,000 | OUT, once a year for 4 yrs |
| | server maintenance | 25,000 | OUT, monthly |
| | final date | 31-Dec-33 | (3dev + 10 service years) |

*Table 2: Cash flow items for the full project*

A few key points to note here are below.

- The marketing expenses are considered four times, each separated by three years, and this starts after the product development is finished.
- The salary costs are represented to include consultancy expenses, and also future project development efforts, including training the models using web-servers

- This document considers prototyping expenses for four years

The following are some scenarios that we can derive by changing a few parameters.

- Scenario 1: the interest rate is 4% instead of 6%
  - We see that the present value of the expenses is increasing.

| | modified | original |
|---|---|---|
| Present Value | -749,737,260 | -673,480,345 |
| interest(%pa) | 4 | 6 |
| Marketing exp. | 2,00,00,000 | 2,00,00,000 |
| salaries | 50,00,000 | 50,00,000 |
| prototyping | 2,00,00,000 | 2,00,00,000 |

Scenario 2: increased prototyping expenses

- 5% increase in the present value with the 50% increase in proto spending

| | modified | original |
|---|---|---|
| Present Value | -710,127,738 | -673,480,345 |
| interest(%pa) | 6 | 6 |
| Marketing exp. | 2,00,00,000 | 2,00,00,000 |
| salaries | 50,00,000 | 50,00,000 |
| prototyping | 3,00,00,000 | 2,00,00,000 |

The following image represents the cash flow (in rupees) for the items that are represented per-product, in monthly intervals. The development time is 36 months, while the 37$^{th}$ month sees the product getting produced. This table has annual charges and monthly maintenance costs.

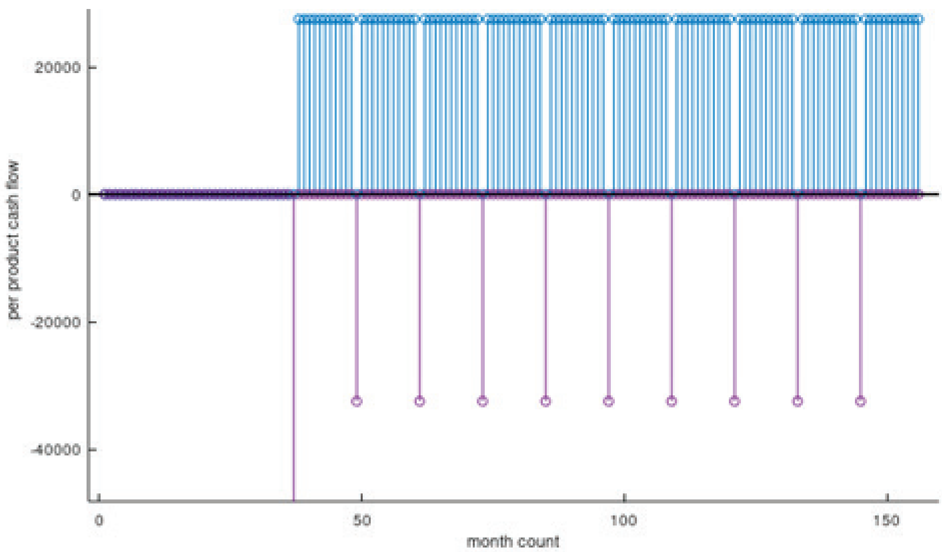



*Figure 9: cash flow of per-product items*

The following image shows the cash flow for the items that can be represented for the entire project only, not per product. The salary costs occur from the start of the project, and a few more large expenses arise infrequently.

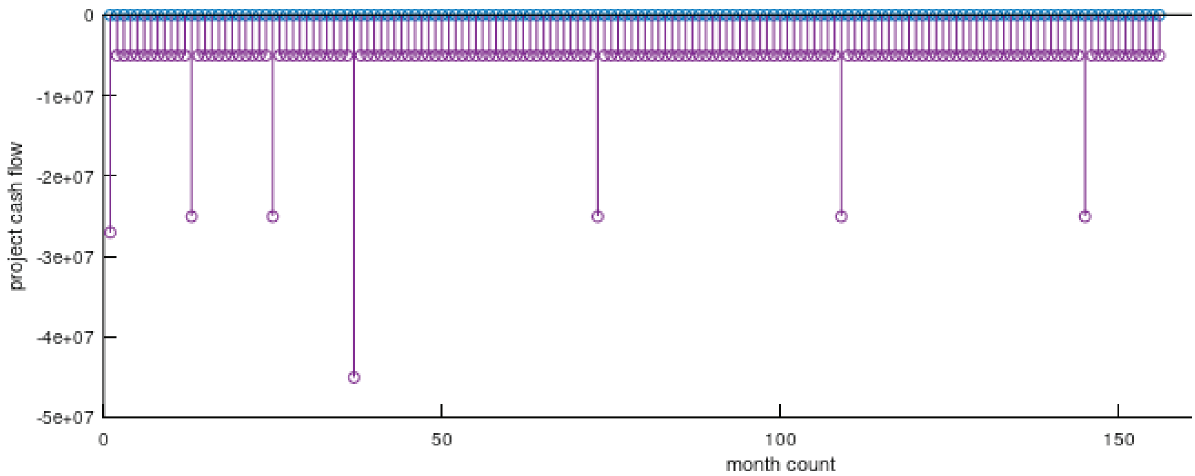



*Figure 10: cash flow of non-per-product (bulk) items*

#### 4.5.1.2.1 Break-even subscription number

We get a present value of INR 20,000 income per product from table 1. We get INR 67.34 crores as the present value of expenses from table 2. This data indicates that the threshold subscription is around 33,500. Beyond this sale number, the project becomes profitable.

The above analysis does not consider a few factors such as

- the percentage of customers dropping out of the subscription scheme before the agreed tenure (challenging to get statistics for such a unique business model)
- inflation of the development costs (unpredictable)
- the interest rate on the capital borrowed from banks (since the investment is gradual, TVSM can fund this money)
- depreciation benefits of the assets, government incentives for the R & D investments.

Important to note is that some factors reduce profitability, while some factors increase profitability. Including these items in the cash flow analysis will not dramatically change the profitability, but will have a small impact.

### 4.5.2 For the Subscribing Customer

Ideally, the customer incurs similar material expenses with our product as one does on a standard vehicle with a driver. The EMI replaces the driver's salary and his maintenance expenses, such as allowances for overtime, and food expenses.

In reality, there are a lot of indirect costs that the owner experiences due to human involvement. Every driver comes bundled with a unique combination of habits, body language, health status, communication skills, and emotions.

A ride by an angry or distracted rider is most likely to attract a bad rating from the customer. This ride eventually leads to a reduction of average customer rating for the rider and also for the taxi service. The loss of rating has a ripple effect on future profitability. The loss of future revenue is difficult to quantify.

A distracted driver is likely to cause an accident. That can put the vehicle out of service for a couple of days. In addition to repair & part replacement expenses, legal problems take a long time or much money to settle. This document expects the worst-case part replacement cost to be about 50% higher than the careful driving's part replacement costs.

If a sick driver does not turn up for work, the fleet operator has to

- Allot one from the pool of the buffer drivers (on contract)
- Pay any open driver higher amount to run the vehicle
- Lose the day's revenue

If the driver turns up sick for work and infects the customers, the consequences are worse. This document expects the average loss of revenue due to the ill driver is up to 5-day pay.

The average urban driver salary (for individual vehicle owners) in India is upwards of INR 20,000. Using the driving robot will increase safety for lone travelers, improve vehicle utilization, and dependable service without random-sick-leaves and fatigue issues.

Many owners will feel that the driving robot will satisfy their requirements for social distancing. The vehicle owners will be proud to be plying in an autonomous vehicle. These emotions will encourage customers to increase their budget to reach our sales price number.

The majority of our near-future customers are not individual owners whose vehicle utilization is less than 10% of the time. Commercial fleet operators will be our major customers.

Consider a customer with a fleet of around 100 vehicles attached to a cab aggregator or car rental agency (Uber, Enterprise, Hertz, Lyft, Ola). He operates his vehicles within city limits in one shift with a driver for every vehicle. The income and expenses for each vehicle are below.

Cars costing below INR 5 lakh can charge between INR 11 to INR 22 [24]. Assume that the average income per km, including peak and non-peak hours, is INR 13.

| | | |
|---|---|---|
| Driver salary | INR -15,000 | |
| Fuel charges (7500km) | INR -25,000 | |
| Service costs | INR -5,000 | |
| Part replacement costs | INR -4,000 | |
| Car EMI (4 lakhs, seven years) | INR -7,000 | |
| **Total expenses/car/month** | | **INR -56,000** |
| Total income ( INR 13/km) | INR 97,500 | |
| Less cab aggregator 20% tax | INR -19,500 | |
| **Effective income/car/month** | | **INR 78,000** |
| **Net profit/car/month** | | **INR 22,000** |

When we consider the intangible expenses because of the drivers, the additional expenses are up to INR 7,500 (4,500+ 3,000). This inclusion of intangible costs brings the net profit from each car to **INR 14,500**.

If the owner uses the driving robot, the same vehicle operates full day long. This vehicle, with a human driver, runs for a single shift of 12 hours. With the driving robot, this vehicle runs for a full day. The driving robot does not have any factors for the loss of income as the human drivers do in the earlier paragraphs.

The income and expenses (monthly) for each vehicle looks like below.

| | | |
|---|---|---|
| Driving Robot EMI | INR -37,000 | |
| Fuel charges (15000km) | INR -50,000 | |
| Service costs | INR -10,000 | |
| Part replacement costs | INR -8,000 | |
| Car EMI (4 lakhs, seven years) | INR -7,000 | |
| **Total expenses/car/month** | | **INR -1,12,000** |
| Total income( INR 13/km) | INR 1,95,000 | |
| Less cab aggregator 20% tax | INR -39,000 | |
| **Effective income/car/month** | | **INR 1,56,000** |
| **Net profit/car/month** | | **INR 44,000** |

There is **INR 22,000 (100%)** increase in net profit per car, with an EMI on driving robot being much higher than our calculations from the earlier section. He does not need to have backup drivers to cover for any driver going on leave. If we include the intangible losses due to the human element, the fleet operator's profit will increase by **INR 29,500 (204%)** per car.

With his fleet size of 100 vehicles, the owner sees an additional INR 22 lakh profit per month from these vehicles, which is a surprising INR 2.64 crore per year. Even after a tax of 30% on this amount, INR 1.85 crore is available for re-investment in the vehicle business for expansion into multiple cities or with more vehicles of higher price bracket. The per-km charges are between INR 12 to 24 (5 lakh to 10 lakh car) and INR 16 to 32 (10+ lakh car). The increased income will compensate for the increase in (expensive) car's EMI.

The lucrative option of expansion of the business possibility will undoubtedly attract the prospective customers into investing their efforts in the driving robots and subscription.

# 5 THE USP

There are already some companies working on developing autonomous vehicles. They are primarily focusing on developing a new platform that can include all the features. The main USP for the proposed project is being able to address the users of existing vehicles that want the features of the autonomous vehicles.

We aim primarily at cost-conscious customers. Our solution is the best fit for the Internal Combustion Engine (ICE) based vehicles. There is no autonomous mobility solution available for these segments of vehicles in the market. We shift the expensive AI implementation to the server with the essential sensors/actuators/communication setup in the vehicle.

We enable the low-acquisition cost of the vehicles. We do not require a specific type of vehicle for implementation - customers can implement our solution on any used vehicle of any make. There is no down-time for the vehicle due to the human driver issues, and the profitability is high when used in a commercial scenario. Our solution is ideal for the non-EV fleet of commercial vehicles.

Our USPs are:

- Driver-less mobility among human-driven vehicles at lower cost
- Convert any vehicle into an autonomous vehicle
- Portable & Modular setup
  - movable from one vehicle to the other in under 30 minutes
  - no loss of revenue during the vehicle down-time
- Server-based AI implementation with a possibility of surrogate driver override
- No downtime compared to human-driven service
- Best suited for price-conscious non-EV fleet too

# 6 Derivative Businesses

The project involves working on the following modules. Each of these modules progresses in parallel with independent teams working collaboratively, and combining the modules can give rise to derivative businesses.

- Control and AI Algorithms
- Sensors and Electronics
- Mechanical Hardware

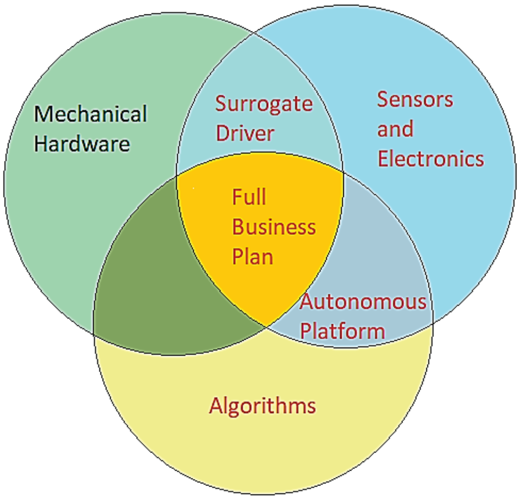



*Figure 11: The individual modules and combinations.*

## 6.1 Control and AI Algorithms

This module gives intelligence to the driving robot. We can use the advancements in the autonomous vehicle space here, and all the innovations of the implementations from this module apply to the entire industry.

### 6.1.1 Commercial Viability

The team working on this module can establish an individual business unit after a certain level of validation in the developed algorithms. The intellectual property (IP) rights for the tested and certified algorithms are precious, because of the lack of development teams in some organizations or the lack of time for the development as a part of their go-to-market-fast plans.

The development of the algorithms requires extensive modeling and testing. Although the majority of research in the autonomous vehicle domain by the research organizations is open for use, the number of patents in the autonomous vehicle technology is increasing (as per the WIPO report). We can finetune key algorithms (communication strategy, route planning, object classification, image segmentation, natural language processing, sensor fusion, data handling, feature extraction, image processing) for lower execution time or reduced computational load.

## 6.2 Sensors and Electronics

This module has the sensor network and the support structure, including the OS, computational HW. AEG engineers work on various projects in the same direction.

### 6.2.1 Commercial Viability

The sensor modules available from the vendors are costly but offer limited options without much scope for customization. The in-house team reduces the cost of the final product, much like any other R & D setup. Another advantage of having this team is knowledge accumulated with different points-of-view from multiple domains of expertise.

Since developing the sensor elements take time, we start with the commercially available sensors along with the custom-designed hardware. We then explore ways to build sensor modules and sensors in-house. It is the goal of the team to have a custom platform, much better than what is available in the market, that suited to a wide range of applications within this domain and elsewhere.

Well-rounded hardware that can support the required AI include GPUs, communication modules is a rare commodity and have good demand. Many businesses do not explore this area, primarily due to the complexities involved and lack of accumulated knowledge over broad domain areas. It will be an excellent opportunity for TVS to offer hardware solutions. This hardware gets validated by the customers in higher numbers than what we could test with our facility alone.

## 6.3 Mechanical Hardware

This module is the muscle of the driving robot and has actuators for controlling the vehicle. This module also includes mechanical packaging and developing robotic mechanical systems.

### 6.3.1 Commercial Viability

The required modules for actuating the vehicle controls are unique to our business. We can borrow design elements from other industries such as robotics, mechatronics, industrial automation. They develop some of these modules for low production volume and non-automotive applications and may cost high. We need to create a low cost and robust solution that suits our needs. Honestly, the business opportunity is slim for this.

## 6.4 Driving Robot

This product is the sweet spot, the complete project. This robot requires all the modules to be ready. With this being complete, we create a USP for ourselves that differentiates us from the rest of the market who are shaping the autonomous systems on a new platform. The focus of this entire document is on appraising this case. The implementation is limited by

- Availability of L4 or L5 autonomy solutions
- Legal approvals from the government

## 6.5 Surrogate Driver

This implementation requires all the modules except the AI. We will have everything but the brains that can drive the vehicle. We bring the human-in-loop with a surrogate driver. This system transmits all the data to the person in the command center or elsewhere operating the vehicle's controls. The surrogate driver can see all the sensors data, streaming videos, sometimes more than what a human driver sitting in the same car can see. The surrogate driver then remotely drives the vehicle.

A drawback of this method is the response time in a few critical situations. The driving robot needs necessary autonomy that can take a few decisions on its own. The driving robot can brake under risky conditions or slow down to provide cushion time for the commands to arrive.

The current 4G network has an estimated 30 to 40ms round trip network delay, which is challenging to manage when the vehicle is going at high speeds. The introduction of the 5G network reduces the delays to below 1ms. The low-latency network limits this implementation for command and data transfer.

### 6.5.1 Feasibility

The surrogate driver is essential in many situations, where a human operator requirement exists but challenging to position the operator.

- In a mining site, or a radioactive site where material transportation is required
- Users who like to use this instead of their drivers
- Users who alternate between them driving and using the chauffeur services
- Commercial applications where the drivers are required to operate a vehicle fleet
- Transport services, to reduce the need to send multiple drivers in the same vehicle

The commercial benefits of using surrogate drivers include the following, and they promote a strong business possibility for this solution.

- Reduced expenses in retaining buffer drivers for fleet owners
- Improved vehicle utilization and better revenues
- Pay-per-use (subscription service components) for individual owners
- Skilled and trained drivers suitable for the route type on demand
- Technology integration for better safety – lower insurance premiums
- Reduced life risk – lower insurance premiums
- Smaller driving robot footprint – more userspace
- Seamless technology integration for payments and other interactions
- Reduced indirect loss of future income (resulting because of bad drivers)

This implementation requires the command center with a vast network support infrastructure that can handle all the server connections at a time. The infrastructure also has to support the command center to many vehicle interactions and even a surrogate driver from a location different from the command center. The interface is through the network providers. We need to establish a cloud server to handle all such interactions between independent surrogate drivers and the driving robots.

## 6.6 Autonomous Driving Platform

This solution is the combination on which every other OEM and autonomous vehicle research companies are working. This solution requires the AI & control algorithms and electronics & sensors to be ready. With this, we will be at par with the industry.

### 6.6.1 Feasibility

The profits from this module depend on the technology differentiation and competitor density in the market. Strong USP needs to be established in the algorithms and hardware to survive with this as the sole product. Those companies interested in developing the autonomous vehicle platform will be the target customers.

## 6.7 Robotic Arm

This solution is the combination several startups are trying to explore. This solution requires partial development in mechanical actuators resulting in a robotic arm. The electronics, control algorithms and software will be fully functional. We borrow the design elements of the arm from the robotics industry.

### 6.7.1 Feasibility

The world robotic arm market is valued at US$ 18 billion in 2018 and is growing at a CAGR of over 13.8%. Medium & large scale industries that are trying to minimize their workforce and achieve consistency in delivery prefer the robotic arms. They are looking for complex tasks such as picking the heavy or lightweight items at any orientation, reading the labels, or symbols to understand their type. Assembly and production factories increasingly incline towards automation with the robotic arms, in a bid to reduce the person dependency based on the experiences during the COVID-19 time.

The addition of the camera systems, along with the smart deep learning algorithms, makes an excellent pick-and-sort machine for the assembly lines or the large warehouses. Some tasks are tough to automate. With the basic AI for the robotic arm, this becomes an independent system that can organize and assemble the components. Including a surrogate operator expands the reach to a wide variety of applications.

## 6.8 Vehicle Testing Robot

This solution is the combination a few successful companies have implemented. This system requires electronics, sensors, actuators, control algorithms, and AI with limited intelligence. The testing robot executes preprogrammed instructions through the mechanical setup, actuated through the electronics and an ECU. 4G network latency does not limit this solution.

### 6.8.1 Feasibility

Medium & large scale industries that have test vehicles to go through torture track tests, or endurance tests, or performance tests will find this interesting. This solution is useful for vehicle certifying agencies. There are a few solutions available in the market today, by they are costly.

## 6.9 Farm Equipment Operator Robot

The application is very similar to the vehicle driving the robot, without requiring real-time control. The driving robot has all the sensors, electronics, software, and control algorithms but basic AI. The risk of accidents is less compared to the road situation. We can operate this as an independent system or surrogate system.

### 6.9.1 Feasibility

The Indian farm mechanization industry was around US$ 5.3 billion in 2019. Tractors have widespread use in India, while the harvesters are less popular. Tractor adoption is less in hilly regions. However, with the increasing trend of large organizations backing small farmers or doing it themselves through mechanization helps growth in the sector. Large scale farming gets benefited through the driving robot operating the tractors, and it provides an attractive alternative to the fragile supply chain of workers.

## 6.10 Construction Equipment Operator Robot

The application is very similar to the farm equipment sector in terms of technical requirements and safety. This solution is possible as a fully automated model or a surrogate model.

### 6.10.1 Feasibility

The operator salaries in this segment are very high compared to the road vehicle drivers. This segment caters not only to the real estate for the general public but also for the massive infrastructural projects and large scale industries. Demand for industrial development is always high, and replacing the human operator with the automated system increases the system efficiency and reduces the losses due to errors.

## 6.11 Last-mile Delivery Vehicle Operator Robot

This solution is similar to driving robot on the roads, but with a restricted speed range. These vehicles originate from the delivery van to reach the destination nearby in the areas not accessible for the large trucks.

### 6.11.1 Feasibility

With several shoppers preferring not to visit or pick up their items from the stores, the demand for direct home delivery is increasing. Employing the required delivery staff for meeting this demand is expensive, and it calls for colossal workforce management. Automating the last-mile delivery reduces the expenses and increases productivity.

## 6.12 Hospitality Industry Associate Robot

The driving robot has access to all the environmental aspects to address customer interaction with social distancing. This implementation requires limited mechanical actuators, limited AI implementation, but full implementation of sensors and electronics. The robot transmits the video and audio feed to the operator in a remote location and performs limited actions through the actuators.

#### 6.12.1 Feasibility

The hospitality industry has a high interaction with customers. Surrogate operators (controlling the robot) reduce the risk of decease transmission and safeguard themselves from sickness. Some of the application areas that get benefited are

- Restaurant food servers
- Front desk operators
- Supermarket billing counter operators
- Eatery joint cash counter operators

### 6.13 Non-critical Medical Care Robot

The driving robot has access to all the environmental parameters similar to the hospitality industry robot, and the implementation is identical too. However, the skill required for the operators is entirely different. This solution is best suited for medical professionals. The need for these care robots is high in the medical care industry, as seen by the events during the COVID-19 pandemic.

#### 6.13.1 Feasibility

The Indian medical industry was valued at US$ 62 billion in 2017 and is growing at a CAGR of over 16%. The profit margins are very high, and the demand for staff safety is ever increasing. The patient care robots and first-level screening robots are easy to disinfect. The robot mitigates the risk of staff getting affected by a virus.

### 6.14 Hazardous Zone Vehicle Operator Robot

The preference for human lives is the highest when it comes to operating in hazardous environments. Most of these operations do not require real-time response. However, they facilitate the isolation of the operator from the vehicle ambiance. Some of these are special-purpose operations in the narrow scope of industries. This implementation requires sensors, actuators, control algorithms, electronic hardware, and embedded systems. This solution also involves the application of a secure & fast communication network, and the operator is placed in a secure remote location away from the hazards.

#### 6.14.1 Feasibility

Several industries have the requirement for remote operators. Defense applications require demining vehicles that can be controlled by a remote operator. Border control applications to monitor and detect intrusion need stealth mode, which is possible with the driving robot. Factories and facilities with radioactive leaks or poisonous gas leaks will be interested in safeguarding the staff.

The driving robot with a robotic arm is the best solution for applications that require operation in extreme conditions. There are few bespoke industry solutions for these applications, but the market penetration is not high. There are several opportunities open for exploration with this solution.

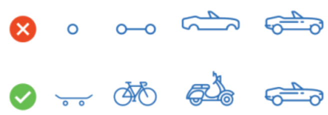
# 7 Driving Robot Generations

Section 3 identifies the vehicle types in focus and product generations. The requirements for all the modules are very similar among the range of vehicles under consideration. This section gives a glimpse of the technical features of the product generations.

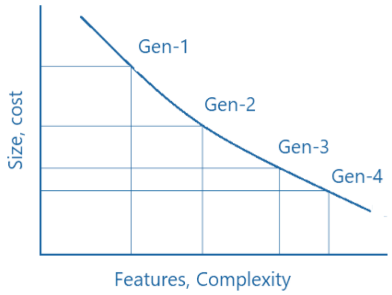
Because of the differences in the vehicles' mechanical construction, the control algorithm tuning is different (force & movement for steering, brake, accelerator, and gear stick). We tune the parameters and flash them in the controller after fitting the robot in the vehicle.

Out of these vehicles, the vehicles with manual transmission require a slightly more complex mechanical actuator setup. These vehicles under consideration have several mechanical switches/buttons/knobs in very different locations. A general-purpose robotic arm handles these but also increases the control-complexity because of the more DoFs.

The project generations are the deliverables of each phase with increasing complexities. Each stage results in an MVP (Minimum Viable Product). The image on the right indicates only the increasing set of features, not the size.



In all the product generations, the driving robot comes with a good communication setup. The driving robot sends data to the command center and requests for (and sometimes gets voluntary) overriding commands for vehicle control under few conditions.




As the generations progress, the number of vehicles each command center staff handles increases because of reduced dependency on human involvement with later generations of the project.

Some controls for functions such as wipers or headlamps exist in the vehicle for human operators to use. The sensors we use may not need to operate these controls. We mount all the sensors on a fixture over the vehicle roof.

We place the driving robot in the driver's seat. The three-point seat belt is useful for humans to maintain their position in the seat during turns to compensate for the centrifugal forces.

The human neck & the eyeball movements maintain a stable image to see. We adjust our hand and leg positions to compensate for the minor changes in the relative distances. The driving robot will be rigidly fitted to the seat to avoid relative movement during the bumpy ride (potholes, speed breakers, sharp turns, accelerations, or braking). The robot may not adjust to the dynamic distances of the controls, such as accelerator, brake, and clutch pedals.

- Use multiple fasteners to avoid moving the driving robot in the seat
- Create a custom seat that replaces the OEM seat, which has rigid mounting of the driving robot and all its actuators.
    - The standard 4 point mounting for the robot's driving seat is easy to install

We can proceed with the project in the following order of increasing complexity/difficulty.

- Generation 1:
  - Works under controlled road environment conditions
  - Works with pre-defined operations for known vehicle types
  - Sufficient processing power for full autonomy or surrogate driving mode
  - Sensor inputs are adequate to take decisions in familiar situations
  - Mechanical actuators are adequate to operate the vehicle

- Generation 2:
  - Higher speeds in the traffic are supported
  - Works under road situations with sufficient lighting
  - Identifies road symbols, and objects
  - Responds to traffic signals
  - Sensor inputs are sufficient (and redundant) to enable operation

- Generation 3:
  - Highway speeds supported
  - Works in unknown roads & lighting conditions
  - Responds to other vehicles' movement around itself
  - Processing power is high
  - Sensor inputs are redundant sometimes to enable fail-safe operation
  - Majority of the control hardware is an in-house design
  - Mechanical actuators are robotic limbs for higher usage flexibility

- Generation 4:
  - Supports much higher speeds than highway limits
  - Works with all road conditions including chaotic city roads
  - Identifies and predicts the probabilistic positions of all the objects around
  - Learns and improves its deep learning models on the go
  - Includes V2X interfaces, payment gateways
  - Supports platooning to reduce the computational burden for all vehicles

- Phase 5:
  - No speed limits from the driving robot
  - Works with all driving conditions, including all situations
  - Creates a 3D model of the environment around itself for better control
  - Most of the control hardware and few sensors are in-house designs
  - Operates with fully robotic hands that work the steering wheel and other control buttons just like a human hand operates
  - Processing power is very high, also support edge/fog computing
  - Chooses the most appropriate deep learning model based on the conditions
  - Includes customer interface channels through voice too (Siri, Alexa)

Go to ToC ↑

# 8 TEAM STRUCTURE & RESPONSIBILITIES

## 8.1 TEAM

This document proposes the following formation of the team to take advantage of the strength in rigid team structures and also the flexibility in contract employee engagements. Team activities and dependencies will be monitored & tracked using modern task management tools.

One of the significant focus items during the execution of the project will be to reduce the person dependency. It is achieved by creating thorough documentation, maintaining FMEA, generating process charts, and supplier contact lists.

The teams will be encouraged to research on relevant technical areas. We will incentivize the team to file patents, and they may publish their research only after a patent filing is complete. Patents that are getting processed for filing will go through a panel for filtering – for commercial viability. We propose to clear the pending patent application requests within a maximum time limit – say five working days. We will also file provisional specifications at Indian Patent Office within five working days.

Claim drafting will be completed within 30 working days along with the full specification document and kept ready for future modifications of the scope. We will file this document with the IPO before the 12-month deadline.

A demonstration module will be kept ready with the patent team while the inventor is still working on the concept. We will use this module for presenting it to the controller at the time of the hearing. Some patents will be set aside as trade secrets. A granted patent or a trade secret earns the inventors a cash bonus.

There will be few critical resources in the team on permanent roles that handle primary technical functions, integration, and coordination. Few members will be on long term contract roles, typically for two years or so, and handle support functions. This layer of contract roles is floating, and we can replace the bottom 20% every year based on their performance and contribution.

Few members will be on short term contract roles and will be engaged only for the duration for the task. We plan and give them intermittent projet tasks purposefully to avoid them get the bigger picture of the project. We scope the project for them to make sure there are minimal dependencies with other contractors. This three-layer system helps us manage employee costs while engaging the best resources at all times.

This document proposes to have an independent management stream to take the administrative load off of the technical staff. In contrast, a few critical decisions are made by them. The management team is the face of the project that facilitates the team for the smooth running of the project. Some of the long-term contract employees will be selected through competitions to solve ongoing problems, very similar to Kaggle.

Go to ToC ↑

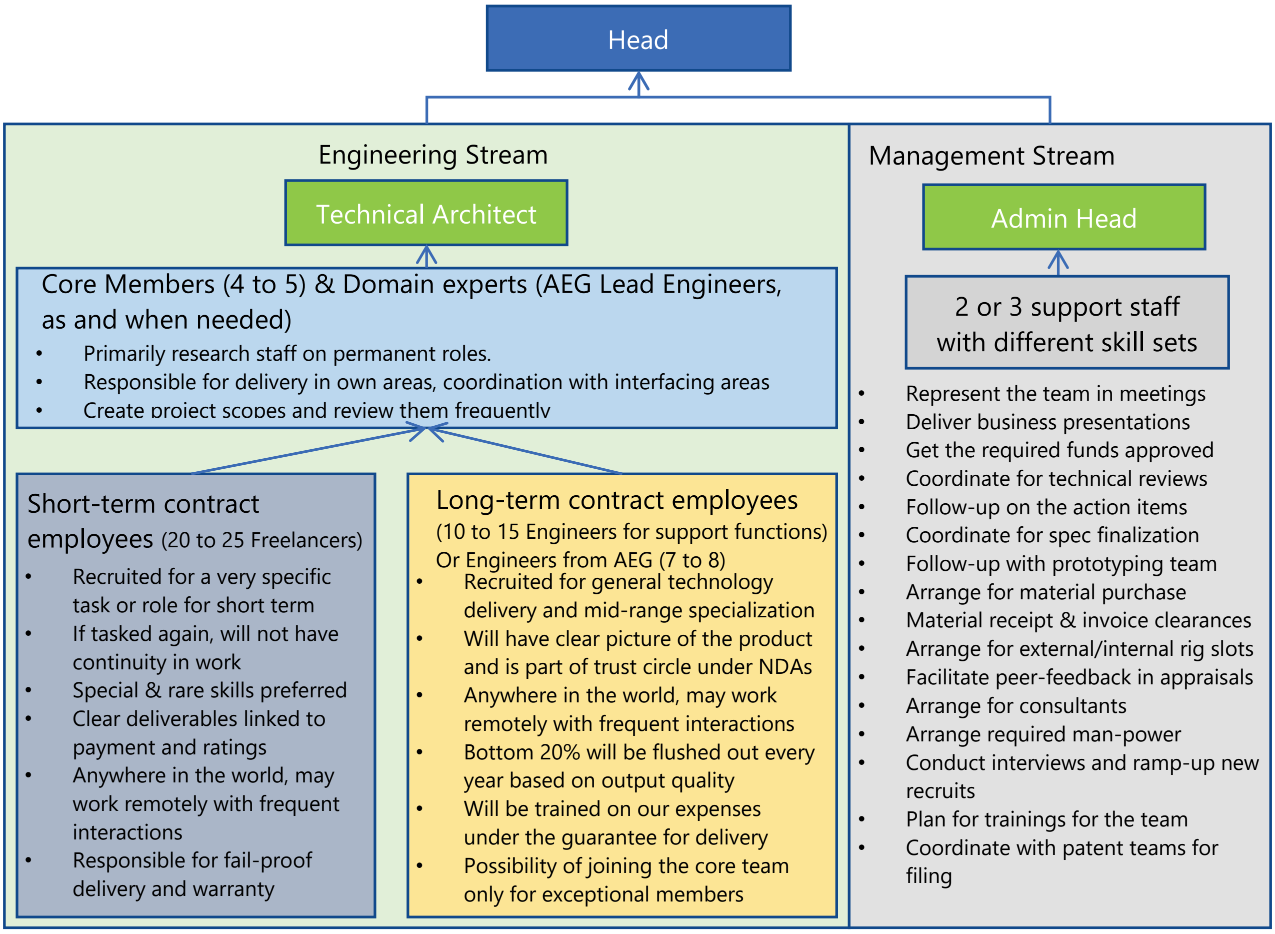



*Figure 12: Proposed team structure*

The following section summarizes the responsibilities for each of the modules that are handled by the core members. A set of engineers from the core team and the contract teams share these responsibilities and work on solutions to create multiple centers-of-excellence.

The following sections indicate the responsibilities that team members of the corresponding teams assume. It is difficult to predict the number of engineers required for each team. Core members and they decide the number of working engineers and contract positions for executing the tasks.

For the Controls team and Sensors team, this document proposes 1 or 2 core members each, while for the mechanical team, this document suggests one core member. Each of the core members begins by sharing the listed responsibilities. They eventually delegate these responsibilities to their recruits.

## 8.2 Control and AI algorithms

The team comprises control system engineers, data engineers, data scientists working on:

- The processing method of the images from the Cameras
- Data processing algorithms from other sensors such as Radar
- Localization of the present position using mapping tools
- Data processing from vehicle feedback sensors such as steering, brake, accelerator

- Identifying the instructions from the road symbols, people's gestures
- Identifying impending collision/accident and avoidance
- Predicting the future paths of the vehicles/objects and planning the path to travel
- Implementing various control loops for speed control, position control
- Interfacing with the cloud/fog/edge server to exchange data when required
- Improving the Deep learning models (through RL methods)
- Algorithm design – obstacle avoidance, path optimization for least effort

## 8.3 Sensors and Electronics

This team comprises electronics engineers and data-processing engineers working on:

- Electronic circuits to integrate the sensors with the system
- Communication protocols to send commands and receive data from the sensors
- Handling the data from the sensors to arrive at meaningful information
- Integrating sensor information (sensor fusion)
- Integrating position sensors such as GPS, GLONASS
- Developing protocols for server integration/updates and communication interfaces
- Working on the modular sensor array mounted on the vehicle

## 8.4 Mechanical Actuators

The team comprises robotic mechanical engineers working on:

- Degree-of-Freedom (DoF) analysis for the required operations
- ROS environment simulation for various scenarios in the vehicle
- Packaging the elements for least interference and optimal use
- Design of mechanical components for mass production
- Sensor packaging and thermal management


# 9 SWOT Analysis

## 9.1 Strengths

- Head-start in the business, possible with the current TVS engineering strength
- Seasoned engineering staff to handle technical challenges
- Excellent manufacturing teams and supply-chain possibility
- Contacts with best-in-class vendors and prototyping facilities for components and circuits through previous engagements (proof-of-concept stage will be natural)
- Established brand value for reliable products

## 9.2 Weaknesses

- An unfamiliar product for the teams
- We do not have home-grown hardware or algorithms available – need to work on
- We have to design mechanical actuators; no off-the-shelf products available

- Talent acquisition is an expensive affair
    - We will reduce person dependency and establish design procedures
- Brand recognition beyond our mainstream vehicles is difficult to establish
    - We may start as a spin-off business after specific progress in the project
- The robot has to adapt to human-like controls – tricky to develop
    - We will borrow technology from the robotics industry
- Continuous monitoring/override may not be possible with missing network coverage
    - We will include backup communication channels with multiple networks

## 9.3 Opportunities

- Availability of technology and ecosystem for the development
    - Computing, servers, and communication network
- An early start in the applied field of autonomous vehicles
- Option to work with non-EV platforms and non-automatic transmission setup
- Unique application that has the potential for getting a stronghold in the market
- Availability of open-source community support for most of the control algorithms
- Cloud computing subscriptions reduce the training costs – several options available
- Contacts from prior engagements with Universities (MIT, Stanford, UCLA)
- The uniqueness and difficulty of the design challenges ensure that we create enough entry barriers for new entrants into the same business
- The increased unwillingness of the people to share space with random driver/passenger in shared mobility (fear of infections and cleanness issues) [12]
- Modular and vehicle-independent platform development attracts users
- Better availability of technically competent people in the current economic conditions
- Reduced competition from the startups due to their low funds in the current economic downtrend situations
- Scope for the international market entry

## 9.4 Threats

- The talent pool of this domain change jobs fast
    - We will have few stable resources to steer the projects within TVSM
- Clarity on the legal issues in case of accidents is missing (ethical decision making)
    - We will work with government bodies for forming the rules
- Possibility of hacking (loss of vehicle control and user data leak)
    - We will work on a robust encrypted communication interface.
- MaaS gaining popularity among the new users reduces market growth [11]
- Technology reduces the need for people's movement
- Government policies are not available on this technology field
    - We will be ready with alternate businesses in related industries

# 10 Competition Analysis

## 10.1 Present Players

At the moment, there is only limited competition in the narrow field of driving robots [5] [6] [7] [8]. The available products are difficult to mount on all vehicles and are not portable.

AB Dynamics and SEA limited work on robots for testing setup. Ivobility is a proof-of-concept. However, Tecpond from Austria is close to what this document proposes here. There are several directions possible for improvement. They also focus on testing. Ati and Flux Auto began working in this direction, but they focus on customized bodies and trucks, respectively. Swaayatt robotics is working on a single platform and is not modular.

Apple acquired Drive.ai. Starsky was focusing on truck autonomy. Magna and Lyft entered into a joint venture to develop a modular autonomous driving platform. Kopernikus Automotive limits the application to advanced vehicles with drive by wire, and they target valet parking.

AB Dynamics' vehicle testing robot costs close to 1 crore rupees, including taxes. One expects that others' products for vehicle testing cost in the same range.

## 10.2 Future Mobility & Research Trends

Future mobility is a massive theme in research funding, which speeds up product development. The funding scenario for startups can show the industry direction. Since 2009, VCs pumped $197.3 billion into the research, and this number is $33.5 billion in 2019 [9] [10].

VCs direct most of their funding towards the companies that work on image processing from the perception sensors (Cameras, LiDARs, RADARs). Those working on full-stack SW tool development, and those companies that build the sensor modules also get funded. Most of these fields overlap with the requirements for the pure autonomous vehicle technology development.

Large corporations invested their time, money and efforts in developing autonomous technology collaboratively [13], Amazon, Apple, Aptiv, Audi, Baidu, BMW-Intel-Mobileye, Bosch-Daimler, Cisco, Continental, DAF-Daimler-Iveco-Scania-Volvo, Didi, Ford, GM-Lyft, Honda, Huawei, Hyundai, JLR, Magna, Nissan/Renault, Nvidia-Paccar, Samsung, Tesla, Toyota, Valeo, VW-Ford-Argo.ai, Google, Yutong, ZF-Nvidia-Baidu. Similar to startups, these companies also focus on different aspects of autonomous vehicle technology.

The proposed project is different from standard autonomous vehicle development. It introduces the physical driving robot unit instead of the x-by-wire control included in the car.

Other than the mobility, the applications in various areas such as surveillance, factory automation, autonomous shuttles, defense, hospitality industry, medical care, industrial robotics, farm equipment mechanization, construction equipment automation have parallel technology development related to the existing project.

### 10.3 Risk Mitigation Methods

Risk mitigation is possible at multiple levels:

- Derived Businesses within and beyond automotive technologies
  - Incorporate multi-channel cash flow
  - Can spin-off from the principal business later
  - Create modularity and brings clarity on sourcing the technology
- Reduced investment
  - Use open-source tools/resources
  - Employ contract/freelance employees for non-essential & high-value items
  - Use de-centralized offices – work remotely; helps access global talent
- Server dependent product
  - Include basic functionality (MBQ) in the product, by creating dependence on the server connectivity for customer-pleasing features (AQ)
  - Maintain customer loyalty by offering features at a high value per money
- Collaborations
  - Reduce the need to establish independent lab facilities by using shared lab facilities from institutes/organizations
  - Reduce the need to hire full-time resources by sharing resources under the agreements within the partners
  - Reduce the need to validate the datasets and algorithms by using shared common knowledge and already established methods
- Focusing the efforts
  - Single-target for the team to bring startup-like speed
  - Reduced variants in the products reduce sourcing difficulties
- Decentralize the knowledge (yet maintain ownership)
  - Reduces person dependency and increases team knowledge
  - Establishes incredible documentary evidence for certifications later

# 11 Legal and Other Aspects

A total of 4,67,044 road accidents have been reported in India in the calendar year 2018 as per the report of the Ministry of Road Transport and Highways (MoRTH), claiming 1,51,417 lives and injuring 4,69,418 individuals. A 90% drop in the number of accidents is estimated to be possible with autonomous vehicles.

The 1968 Vienna Convention on Road Traffic is an accord. One fundamental principle of the Convention is that driver controls and is responsible for the behavior of the vehicle in traffic.

In March 2016, the United Nations Economic Commission for Europe (UNECE) amended the Vienna Convention on Road Traffic to allow automated vehicles, provided that the technologies conform to U.N. vehicle regulations. The driver can override or switch off the technology.

Germany is the first country to regulate automated driving within a legal framework. Indian Motor Vehicle Act does not allow fully automated systems; it needs a person to be in control.

However, M & M and Escorts demonstrated autonomous farm tractors. Indian self-driving vehicle startup Ati is working on moving cargo for factories within their premises.

Fatal accidents involving autonomous vehicles in the recent past made everyone realize that legal matters and technology development are interlinked.

The most important topic for discussion is the liability of autonomous vehicles for accidents or traffic violations. Currently, several independent types of research within this topic are ongoing across the world.

Europe established a project called AdaptIVe (Automated Driving Applications and Technologies for Intelligent Vehicles) to research on the liability of the autonomous vehicles.

## 11.1 Data Protection

The autonomous vehicle generates many data points regarding the road, traffic, passengers, their behavior & interactions, surroundings, route, destinations, time of travel. Any data that gives a clue about a person is personal data. We need to protect this data needs under the related laws in every country.

When we collect the data from the ride, we store some data on the vehicle's black box, while some in the cloud server. We use some of the camera-generated data for re-tuning the algorithms for improvements. We need to establish the ownership of this data needs through initial agreements with the customers.

The vehicle can keep track of users' profiles, likes/dislikes, buying habits, and even credit card information. Payment authentication for the services used in the autonomous vehicle requires users to share their information. Data encryption and authentication is needed.

We need to establish an encrypted communication interface, the method of storing the data on the servers, and a way to distinguish personal data from general data.

## 11.2 Cyber Safety

Autonomous vehicles have a significant threat from hacker groups. Due to the enormous complexity of the software, and the re-use of libraries, some known bugs remain unnoticed.

These loopholes are open for exploitation by the hackers who can override the vehicle controls and may even cause accidents resulting in the death of the passengers. Someone could tap user data and use them for identity theft or scams.

The autonomous vehicles get integrated into the home security systems, enabling user routines to be executed, such as setting the temperatures, preparing coffee, and turning on the oven. Weak security on the vehicle would allow unauthorized access to anyone.

One way to reduce the loopholes is to employ ethical hackers to keep locating bugs and fixing them. Another way is to announce bounty for bug finders.

## 11.3 Administrative Law

This topic covers road traffic law in general (such as licensing, certification, traffic rules). Some of the critical legal challenges under this topic are the following:

- What kind of driving-license is available to the autonomous vehicle controlling software? Domestic or international license?
- Does the autonomous vehicle user require a license?
- If there is an update to this software, will the older license be revoked?
- If the AI supports only the Level 3 autonomy, how to enforce the driver's attention?
- Will the autonomous vehicles be restricted to a few areas and restricted lanes?
- If an autonomous vehicle violates a traffic rule, does it self-report to the police?
- Should there be an indicator on the vehicle to show who is in control, human, or the software?

## 11.4 Criminal Law

Who is responsible if a crime happens inside an autonomous vehicle?

- person/businesses owning the vehicle
- passengers
- certifying body/testing agency
- licensing authority
- developer
- the serviceman who fitted the autonomous system
- any other entity linked in the design/development of the product

In case of damage caused by a vehicle, the driver will be booked under a suitable section using the general interpretation of the act.

If the passenger/driver in the autonomous vehicle has to be careful, is he expected to:

- Check the functionality
- Check the working of the algorithm
- Check the operation of sensors
- Take over the control when there is a situation

If the fully autonomous mode expects him to be attentive to the vehicle's behavior, the purpose (to ease the people movement) of the autonomous vehicle is lost.

If the user disproves his negligence during an accident, the criminally responsible entity is the manufacturer. It is vital to understand and interpret corporate criminal liability.

Motor vehicle act must be made tighter. If a traffic violator causes an accident, the other vehicle (driving robot, passengers, and the owner) needs to go, free from the hassle of facing legal charges.

An accident is a result of the driving robot taking a decision. However, the execution taking longer due to the vehicle dynamics is typically a result of the other party violating the rules. Under such situations, we can quickly produce evidence from the stored data.

The same data can be used to given feedback to the insurance companies while they are processing the claim. We can propose and try to convince appropriate authorities to deny insurance claims for the violator's vehicle that causes a traffic incident. Then road traffic users will be more careful with the autonomous vehicle around them.

### 11.5 Ethical Issues

A human driver takes split-second decisions when faced with an emergency. A driving robot's decision is the outcome of the software program running in it.

- If the AI has to choose between saving the people in the car and the pedestrians, what will it choose?

Trolley problem – the autonomous vehicle is bound to hit either a group of five or a single person – should it kill one to save five?

A recent survey conducted by MIT (Moral Machine) has multiple variations of the trolley problem under different circumstances. People from 233 countries took four crore surveys. The study highlighted the cultural/geographical bias in moral decision making.

### 11.6 Miscellaneous

The local governing bodies such as BDA, CMDA, MMRDA, and DDA (in addition to the central and state government bodies) play an equally important role in defining the road map for the technology adaption.

We should collaboratively work with them to plan our introductory markets.

## 12 Ecosystem

The future of manufacturing depends on the ability of organizations to delegate their workload to partners/contractors in the manufacturing ecosystem. They can free themselves to react to the needs of demanding customers quickly, and retain enough bandwidth to focus on high priority items to achieve higher profitability.

We need to actively contribute to creating a customer-focused ecosystem for a satisfying experience with the driving robot.

The first support system that we need is related to manufacturing.

- We need to establish a standard manufacturing support system (a lean supply chain and a reliable vendor system). The vendors include those who manufacture essential assemblies and supply as well. For the sake of simplicity, this document proposes to include the internal teams/departments working in the background for product improvements, such as research, production, quality purchase, and finance.

The next support system that we need is the sales network.

- One may question the need to have a showroom for a product of this complex nature. Customers always want to get a feel of the product before investing the money in the product. A set of showrooms in some key locations offering demonstration rides will supplement our marketing efforts, and set realistic expectations about the driving robot. Some of the dealerships in critical areas will support us for this.
- While the marketing efforts bring the customers to the showrooms, the showroom staff needs to give assurance to the customers about the performance of the driving robot and work with the customers to highlight the RoI possibility for the customer.

The next support system that we need is the after-sales network. There are many categories under this segment. We maintain some of them, and our partners maintain some of them while third parties maintain the rest of them.

- We need to ensure *spare part* availability through the dealers. Our existing dealer network can help with this.
- We need to have *analytics teams* working at the central server to analyze the data received from the driving robot about its performance metrics and failure probability of its components. This approach is similar to a digital twin system. Based on these metrics, we need to call the driving robot for the replacement of parts marked for most failure probability, depending on their safety footprint. Our partners or third parties can support this.
- We need partners for *fuel supply*. We can coordinate with the local fuel filling stations to achieve this. Once the fuel level goes below a threshold, the driving robot sends a message to the nearest fuel partner. The vehicle is assigned a token number, and it approaches the fuel filling station's designated fuel outlet. The next process can be
    - Manual – the trained operator fills the predetermined amount of fuel. The operator enters the payment details in the server, and the payment settled by the bank electronically.
    - Automated (wherever supported) – the wireless exchange of digital signature between the driving robot and the fuel dispenser, creates authorization. The fuel lid opens automatically, and any operator from the filling station can route the fuel nozzle into the tank's opening. The vehicle sends a secure digital wireless message to the filling station about the amount of fuel and makes the electronic payment wirelessly.
- We need partners for *sanitizing/cleaning* the vehicle. For a commercial vehicle, after the end of every ride, the vehicle is expected to be sanitized. As a part of this process, we also need to make sure if there is any item left behind by the earlier customer.
    - We can coordinate with the local garages to employ their manual workforce to inspect the vehicle when it arrives into their facility, subject to a maximum waiting time limit. The vehicle will be cleaned thoroughly with disinfectants at all the possible contact points and inspected for any articles left behind. Such

items will be packed in a sealed envelope, marked with time & vehicle identification, and securely placed in the vehicle storage area.
  - We can coordinate with few partners to arrange for automatic washing services. The exterior will gets cleaned by passing through the channels. In contrast, the interiors get inspected by a cleaning arm with a camera assist. An operator from the command center controls the arm to examine for the articles left behind or liquid spills. Such situations require manual intervention. The robotic arm sprays disinfectant liquid on all the contact points and circulates fresh air.
- We need partners for *roadside assistance* when the driving robot fails, or an accident happens, or a minor incident occurs immobilizing the vehicle. The possibilities are multi-fold. The driving robot may not be in a position to inform the command center about the event. The command center's server needs to identify the absence of contact with the driving robot (or an SOS message from the driving robot). Then a service center needs to be informed based on the last known location for a rescue operation. This method works very much like the aircraft tracking system from the ATC tower. The response team on the field should have sufficient training in rescue operations, as well as debugging the driving robot failures. The stranded passengers need to be provided with an alternate vehicle to complete their journey.
- For a commercial fleet with driving robots, we need the support of *user interface software* in the form of a web application or phone app. This interface enables the users to request a vehicle from their current location. The driving robot gets the information from the booking server seamlessly through secure channels and arrives at the customer pick-up location.
- For a commercial fleet with driving robots, *in-vehicle customer interaction* plays a vital role. It enables dialogue with the customer to identify his driving preferences. If there are special requests during the ride or if there is a minor change in the drop-off point, the driving robot addresses these requests. We need support from partners to develop these modules with different language support and dialect support to help customers feel comfortable and safe. This module will be mostly an AI-based (audio) chat-bot that can speak with the customers. Some possible modes are – city tour guide mode, emergency response mode, infant/child mode, and general interactive mode. The command center loads these modules into the driving robot dynamically based on the request. This support system of developers (independent and contract-based) helps build a plethora of modules for better interaction. Some of these modules can be made payable by the customers.
- Once the customer enters the vehicle and identifies the drop-off point, the vehicle needs to access the *maps to determine the route* it needs to take. The maps for the given cities prepared by our partners get stored in the driving robot and the servers. These maps are mostly detailed road maps, including the lanes, traffic signals, tunnels, narrow junctions. These maps include few dynamic updates (from standard map services such as Google Maps) about the traffic updates and route closures.
- After the customers get down at their destination, the banking partners *process the payment*. There will only be cashless transactions through the credit/debit card

registered with the user login in the booking interface (web or phone). The trip fare and the other service charges will be levied and informed to the user through an email and a message.

- If the driving robot detects any vandalism or violent behavior during or after the ride, the nearest *traffic police station* will be informed. The driving robot also shares proofs for necessary action. The same module will also be useful in identifying the traffic violators and offenders who may have created a near-miss accident for the vehicle.

The next support system will be infrastructural developments and law improvements from the government.

- We need *road infrastructure* to be better and safer for autonomous vehicles to use. Signal visibility needs to be higher. The autonomous vehicles should have dedicated driving lanes, dedicated entry zones at toll gates, and reserved parking zones in cities.
- We need the systems that enable *communication* among the vehicles and with the road infrastructure (*V2X*). This interface allows for the road infrastructure to supply the vehicles with suggested routes, traffic information, and signal information to the autonomous vehicles to allow better route planning. With this method, the local authority can regulate traffic in the city, avoiding congested zones.
- Relevant government bodies should amend the *Motor Vehicle Act* to allow autonomous vehicles to ply on the roads. We need to work with the corresponding ministries to allow these vehicles.

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# ANNEXURE - 1

# 1 CASH FLOW

The following cash flow tables support the values in section 4.5.1.2, and the profit values mentioned there.

As mentioned in the section, the following assumes that the first three years are for product development and the continued development for another year. The sale starts in 4th year, where the marketing starts and the product-related expenses also begin. However, this document chose to maintain the salary costs to represent the continued investments in the area to cater to future developments. The following assumes that the project starts in 2021.

## 1.1 CASH FLOW TABLE 1 (PER PRODUCT ITEMS ONLY)

This table details some of the cash flow items that we express as product value. Positive values are inflow to TVSM, and negative values are outflow from TVSM.

| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Jan-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Feb-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Mar-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Apr-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-May-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jun-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jul-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Aug-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Sep-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Oct-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Nov-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Dec-21 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jan-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Feb-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Mar-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Apr-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-May-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jun-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jul-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Aug-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Sep-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |

| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Oct-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Nov-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Dec-22 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jan-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Feb-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Mar-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Apr-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-May-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jun-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jul-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Aug-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Sep-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Oct-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Nov-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Dec-23 | 0 | 0 | 0 | 0 | 0 | INR 0 | INR 0 |
| 1-Jan-24 | -INR 2,000,000 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 2,032,500 | -INR 1,698,994 |
| 1-Feb-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,871 |
| 1-Mar-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,763 |
| 1-Apr-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,647 |
| 1-May-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,536 |
| 1-Jun-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,422 |
| 1-Jul-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,312 |
| 1-Aug-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,199 |
| 1-Sep-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 22,086 |
| 1-Oct-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,978 |
| 1-Nov-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,866 |
| 1-Dec-24 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,759 |
| 1-Jan-25 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 25,585 |
| 1-Feb-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,539 |
| 1-Mar-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,440 |

| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Apr-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,331 |
| 1-May-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,227 |
| 1-Jun-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,119 |
| 1-Jul-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 21,016 |
| 1-Aug-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,909 |
| 1-Sep-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,803 |
| 1-Oct-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,701 |
| 1-Nov-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,596 |
| 1-Dec-25 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,495 |
| 1-Jan-26 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 24,098 |
| 1-Feb-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,288 |
| 1-Mar-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,195 |
| 1-Apr-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 20,092 |
| 1-May-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,994 |
| 1-Jun-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,892 |
| 1-Jul-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,795 |
| 1-Aug-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,694 |
| 1-Sep-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,594 |
| 1-Oct-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,498 |
| 1-Nov-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,399 |
| 1-Dec-26 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,304 |
| 1-Jan-27 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 22,698 |
| 1-Feb-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,109 |
| 1-Mar-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 19,021 |

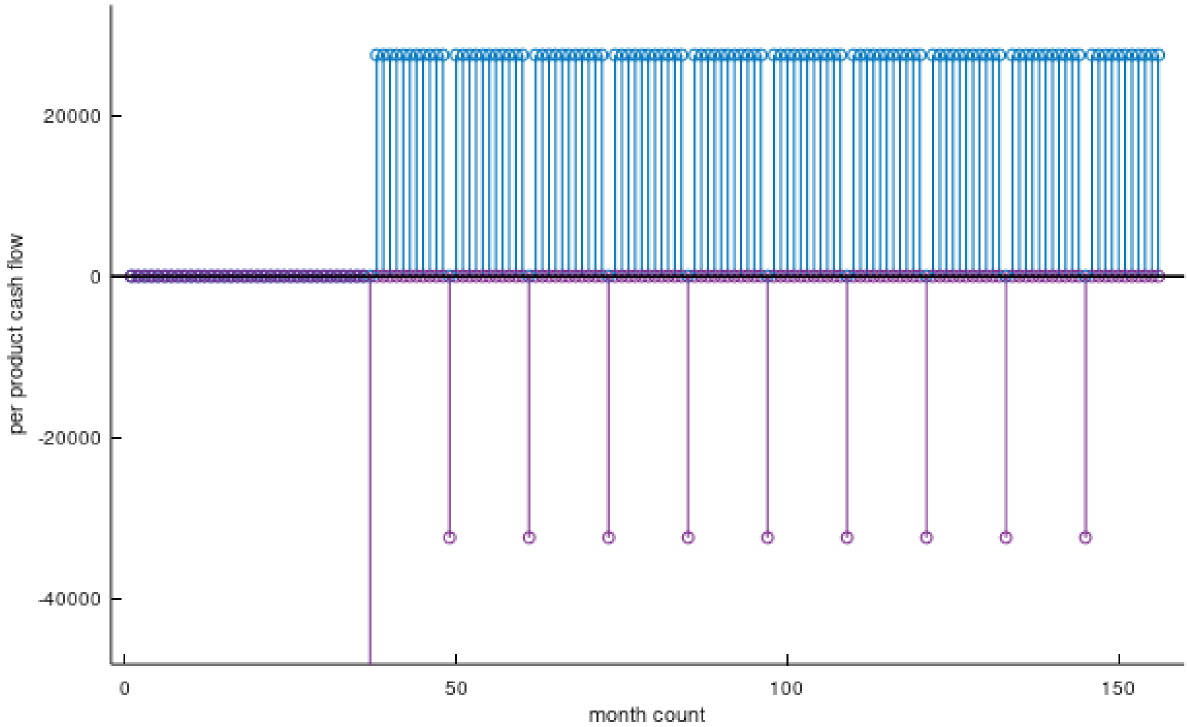
| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Apr-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,925 |
| 1-May-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,832 |
| 1-Jun-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,737 |
| 1-Jul-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,645 |
| 1-Aug-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,550 |
| 1-Sep-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,456 |
| 1-Oct-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,366 |
| 1-Nov-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,272 |
| 1-Dec-27 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 18,183 |
| 1-Jan-28 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 21,380 |
| 1-Feb-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,999 |
| 1-Mar-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,913 |
| 1-Apr-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,823 |
| 1-May-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,735 |
| 1-Jun-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,645 |
| 1-Jul-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,559 |
| 1-Aug-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,470 |
| 1-Sep-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,381 |
| 1-Oct-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,296 |
| 1-Nov-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,208 |
| 1-Dec-28 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 17,124 |
| 1-Jan-29 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 20,134 |
| 1-Feb-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,950 |
| 1-Mar-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,873 |

| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Apr-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,787 |
| 1-May-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,705 |
| 1-Jun-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,620 |
| 1-Jul-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,539 |
| 1-Aug-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,455 |
| 1-Sep-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,371 |
| 1-Oct-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,291 |
| 1-Nov-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,208 |
| 1-Dec-29 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 16,129 |
| 1-Jan-30 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 18,965 |
| 1-Feb-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,966 |
| 1-Mar-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,893 |
| 1-Apr-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,812 |
| 1-May-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,734 |
| 1-Jun-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,655 |
| 1-Jul-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,578 |
| 1-Aug-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,499 |
| 1-Sep-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,420 |
| 1-Oct-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,345 |
| 1-Nov-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,267 |
| 1-Dec-30 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,192 |
| 1-Jan-31 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 17,863 |
| 1-Feb-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 15,038 |
| 1-Mar-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,969 |

| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Apr-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,893 |
| 1-May-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,820 |
| 1-Jun-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,745 |
| 1-Jul-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,673 |
| 1-Aug-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,598 |
| 1-Sep-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,524 |
| 1-Oct-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,453 |
| 1-Nov-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,380 |
| 1-Dec-31 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,309 |
| 1-Jan-32 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 16,825 |
| 1-Feb-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,165 |
| 1-Mar-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,097 |
| 1-Apr-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 14,026 |
| 1-May-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,957 |
| 1-Jun-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,886 |
| 1-Jul-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,818 |
| 1-Aug-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,748 |
| 1-Sep-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,678 |
| 1-Oct-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,611 |
| 1-Nov-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,542 |
| 1-Dec-32 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,476 |
| 1-Jan-33 | 0 | INR 32,500 | -INR 40,000 | -INR 20,000 | -INR 5,000 | -INR 32,500 | -INR 15,845 |
| 1-Feb-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,340 |
| 1-Mar-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,278 |

| Date | Product cost | Customer EMI | Insurance costs | Service, part costs | Control center costs | Cash flow | Present Value |
|---|---|---|---|---|---|---|---|
| 1-Apr-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,211 |
| 1-May-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,146 |
| 1-Jun-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,080 |
| 1-Jul-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 13,015 |
| 1-Aug-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 12,949 |
| 1-Sep-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 12,884 |
| 1-Oct-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 12,821 |
| 1-Nov-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 12,756 |
| 1-Dec-33 | 0 | INR 32,500 | 0 | 0 | -INR 5,000 | INR 27,500 | INR 12,693 |

The following is a graphical representation of the cash flow in a time-series plot.




(Same as figure 9)

## 1.2 Cash flow Table 2 (for the full project items only)

This table lists a few more items from the cash flow, which are required for the entire project and are challenging to assess per product basis. Positive values are inflow to TVSM, and negative values are outflow from TVSM.

| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Jan-21 | | -INR 2,000,000 | -INR 5,000,000 | -INR 20,000,000 | -INR 25,000 | -INR 27,025,000 | -INR 27,033,634 |
| 1-Feb-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 5,001,119 |
| 1-Mar-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,978,211 |
| 1-Apr-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,952,970 |
| 1-May-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,928,665 |
| 1-Jun-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,903,676 |
| 1-Jul-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,879,613 |
| 1-Aug-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,854,872 |
| 1-Sep-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,830,257 |
| 1-Oct-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,806,554 |
| 1-Nov-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,782,184 |
| 1-Dec-21 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,758,717 |
| 1-Jan-22 | | | -INR 5,000,000 | -INR 20,000,000 | -INR 25,000 | -INR 25,025,000 | -INR 23,578,727 |
| 1-Feb-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,710,584 |
| 1-Mar-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,689,006 |
| 1-Apr-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,665,232 |
| 1-May-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,642,339 |
| 1-Jun-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,618,801 |
| 1-Jul-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,596,137 |
| 1-Aug-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,572,833 |
| 1-Sep-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,549,648 |

| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Oct-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,527,322 |
| 1-Nov-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,504,368 |
| 1-Dec-22 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,482,264 |
| 1-Jan-23 | | | -INR 5,000,000 | -INR 20,000,000 | -INR 25,000 | -INR 25,025,000 | -INR 22,208,943 |
| 1-Feb-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,436,927 |
| 1-Mar-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,416,603 |
| 1-Apr-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,394,210 |
| 1-May-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,372,647 |
| 1-Jun-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,350,477 |
| 1-Jul-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,329,128 |
| 1-Aug-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,307,179 |
| 1-Sep-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,285,340 |
| 1-Oct-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,264,312 |
| 1-Nov-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,242,691 |
| 1-Dec-23 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,221,871 |
| 1-Jan-24 | -INR 20,000,000 | | -INR 5,000,000 | -INR 20,000,000 | -INR 25,000 | -INR 45,025,000 | -INR 37,637,007 |
| 1-Feb-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,179,168 |
| 1-Mar-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,159,343 |
| 1-Apr-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,138,254 |
| 1-May-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,117,947 |
| 1-Jun-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,097,068 |
| 1-Jul-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,076,963 |
| 1-Aug-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,056,292 |
| 1-Sep-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,035,726 |

| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Oct-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 4,015,922 |
| 1-Nov-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,995,560 |
| 1-Dec-24 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,975,954 |
| 1-Jan-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,955,795 |
| 1-Feb-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,935,738 |
| 1-Mar-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,917,710 |
| 1-Apr-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,897,846 |
| 1-May-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,878,719 |
| 1-Jun-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,859,053 |
| 1-Jul-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,840,116 |
| 1-Aug-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,820,646 |
| 1-Sep-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,801,274 |
| 1-Oct-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,782,621 |
| 1-Nov-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,763,442 |
| 1-Dec-25 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,744,975 |
| 1-Jan-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,725,987 |
| 1-Feb-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,707,095 |
| 1-Mar-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,690,114 |
| 1-Apr-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,671,404 |
| 1-May-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,653,388 |
| 1-Jun-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,634,865 |
| 1-Jul-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,617,028 |
| 1-Aug-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,598,689 |
| 1-Sep-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,580,443 |

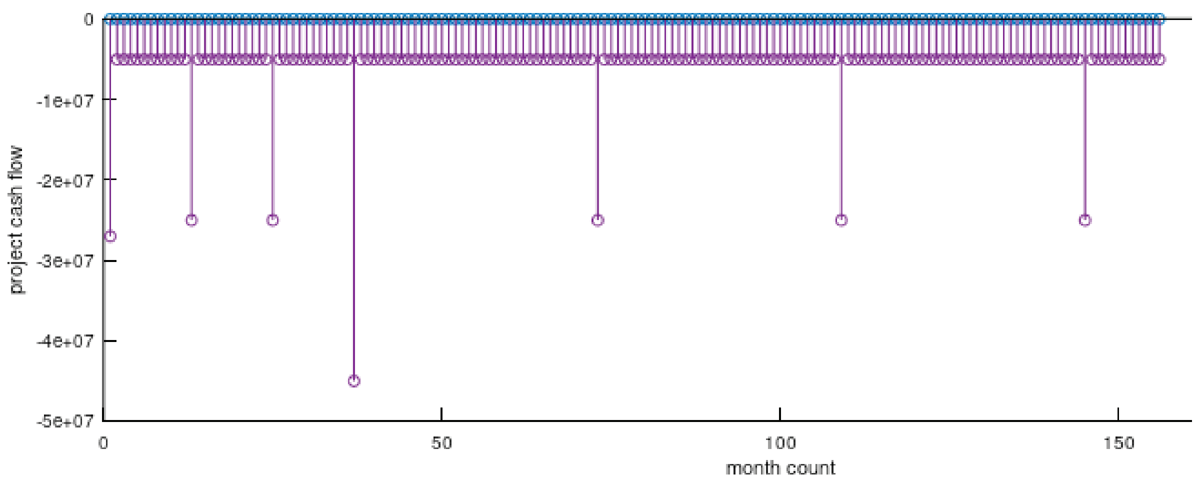
| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Oct-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,562,873 |
| 1-Nov-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,544,809 |
| 1-Dec-26 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,527,414 |
| 1-Jan-27 | -INR 20,000,000 | | -INR 5,000,000 | | -INR 25,000 | -INR 25,025,000 | -INR 17,477,804 |
| 1-Feb-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,491,735 |
| 1-Mar-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,475,740 |
| 1-Apr-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,458,117 |
| 1-May-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,441,148 |
| 1-Jun-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,423,701 |
| 1-Jul-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,406,900 |
| 1-Aug-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,389,627 |
| 1-Sep-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,372,440 |
| 1-Oct-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,355,891 |
| 1-Nov-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,338,876 |
| 1-Dec-27 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,322,492 |
| 1-Jan-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,305,646 |
| 1-Feb-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,288,886 |
| 1-Mar-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,273,284 |
| 1-Apr-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,256,687 |
| 1-May-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,240,707 |
| 1-Jun-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,224,275 |
| 1-Jul-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,208,454 |
| 1-Aug-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,192,186 |
| 1-Sep-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,176,001 |

| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Oct-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,160,416 |
| 1-Nov-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,144,392 |
| 1-Dec-28 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,128,962 |
| 1-Jan-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,113,097 |
| 1-Feb-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,097,313 |
| 1-Mar-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,083,125 |
| 1-Apr-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,067,493 |
| 1-May-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,052,441 |
| 1-Jun-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,036,964 |
| 1-Jul-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,022,062 |
| 1-Aug-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 3,006,739 |
| 1-Sep-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,991,494 |
| 1-Oct-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,976,815 |
| 1-Nov-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,961,721 |
| 1-Dec-29 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,947,188 |
| 1-Jan-30 | -INR 20,000,000 | | -INR 5,000,000 | | -INR 25,000 | -INR 25,025,000 | -INR 14,602,872 |
| 1-Feb-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,917,378 |
| 1-Mar-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,904,014 |
| 1-Apr-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,889,290 |
| 1-May-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,875,112 |
| 1-Jun-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,860,535 |
| 1-Jul-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,846,498 |
| 1-Aug-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,832,065 |
| 1-Sep-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,817,706 |

| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Oct-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,803,879 |
| 1-Nov-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,789,663 |
| 1-Dec-30 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,775,974 |
| 1-Jan-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,761,899 |
| 1-Feb-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,747,896 |
| 1-Mar-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,735,308 |
| 1-Apr-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,721,440 |
| 1-May-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,708,085 |
| 1-Jun-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,694,355 |
| 1-Jul-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,681,133 |
| 1-Aug-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,667,539 |
| 1-Sep-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,654,014 |
| 1-Oct-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,640,991 |
| 1-Nov-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,627,600 |
| 1-Dec-31 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,614,706 |
| 1-Jan-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,601,449 |
| 1-Feb-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,588,259 |
| 1-Mar-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,575,981 |
| 1-Apr-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,562,920 |
| 1-May-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,550,343 |
| 1-Jun-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,537,413 |
| 1-Jul-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,524,961 |
| 1-Aug-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,512,159 |
| 1-Sep-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,499,422 |

| Date | Marketing expenses | Server costs | Salaries | Proto costs | Server maint. | Cash flow | Present value |
|---|---|---|---|---|---|---|---|
| 1-Oct-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,487,157 |
| 1-Nov-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,474,547 |
| 1-Dec-32 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,462,404 |
| 1-Jan-33 | -INR 20,000,000 | | -INR 5,000,000 | | -INR 25,000 | -INR 25,025,000 | -INR 12,200,839 |
| 1-Feb-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,437,497 |
| 1-Mar-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,426,332 |
| 1-Apr-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,414,030 |
| 1-May-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,402,184 |
| 1-Jun-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,390,004 |
| 1-Jul-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,378,276 |
| 1-Aug-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,366,218 |
| 1-Sep-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,354,220 |
| 1-Oct-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,342,668 |
| 1-Nov-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,330,790 |
| 1-Dec-33 | | | -INR 5,000,000 | | -INR 25,000 | -INR 5,025,000 | -INR 2,319,353 |

The following is a graphical representation of the cash flow in a time-series plot.




(Same as figure 10)

# ANNEXURE - 2

## 1 DATA FOR THE PLOTS

### 1.1 SALARY EXPENSE PROJECTIONS

The following shows the data and the MATLAB code used for creating the plots for the salary expense projections for the section 4.4.1.

```
clear
r=ones(1,180);p=r;o=r;
o(25:180)=[linspace(1,0.4,12) [0.4*ones(1,108+24+12)]];o(1:6)=[0.1 0.2 0.3 0.5 0.7 0.8];
p(8:10)=1.4;p(24:28)=1.3;p(30:36)=1.5;p(42:49)=1.3;p(60:70)=1.1;p(86:94)=1.3;p(100:120)=1.1;
p(131:180)=linspace(1,1.2,26+24);
p=p*50;r=r*50;o=o*50;
figure
plot((o),'m--');hold on;plot((r),'r-d') ;plot((p),'b-x');
legend(['optimistic case';'realistic case';'pessimistic case'])
xlabel('month count')
ylabel('monthwise salary costs (in lakh rupees)')
pv.o=o;pv.r=r;pv.p=p;
irr=6;%annual interest compounded monthly.
myfrac=1+(irr/12/100);
months=1:180;
pv.o=pv.o ./ myfrac.^(months-1);
pv.r=pv.r ./ myfrac.^(months-1);
pv.p=pv.p ./ myfrac.^(months-1);
figure
plot(cumsum(pv.o),'m--');hold on;plot(cumsum(pv.r),'r-d') ;plot(cumsum(pv.p),'b-x');
legend(['optimistic case';'realistic case';'pessimistic case'],'location','northwest')
xlabel('month count')
ylabel('Cumulative Present value of salary costs (in lakh rupees)')
```

Go to ToC ↑

# ANNEXURE – 3

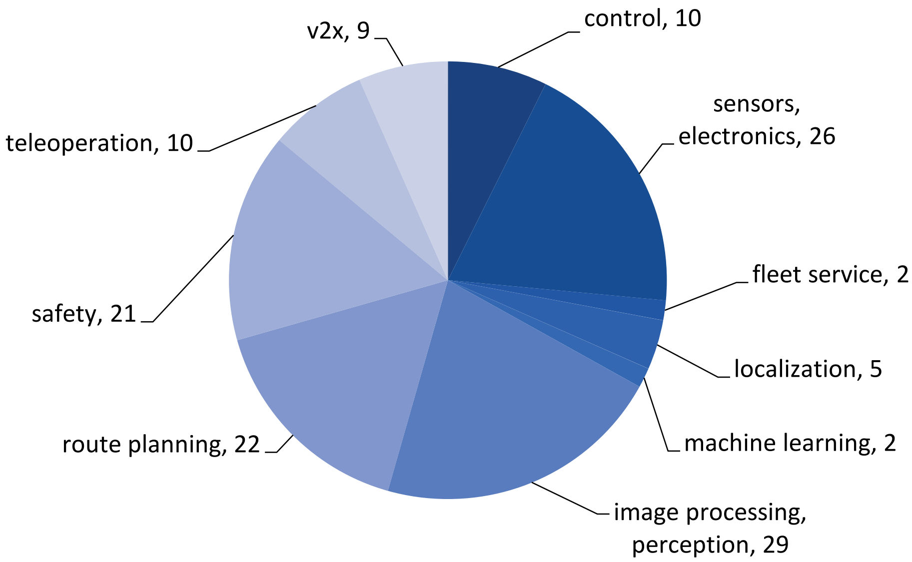
## 1 ACQUISITIONS FOR EXPANDING THE PATENT PORTFOLIO


### 1.1 GOOGLE ACQUIRED 510 SYSTEMS (2011)

- Anthony Levandowsk founded 510 systems & Anthony's Robotics
- Both were acquired for US$ 20 million in 2011 to create Waymo
- 510 Systems has the know-how of making the first self-driving vehicle for industry
- They had the LiDAR technology which was used in earlier Google projects

### 1.2 AMAZON ACQUIRED ZOOX FOR US$ 1.2 BILLION (2020)

- Klay founded zoox in 2014
- They have filed 136 patents in various areas connected to autonomous technology
- Zoox licensed Stanford University's patents for autonomous tech to get started
- Zoox licensed KTH University's patents for electric vehicle technology
- They had a US$ 2.7 billion valuation in 2018 mostly due to their patents

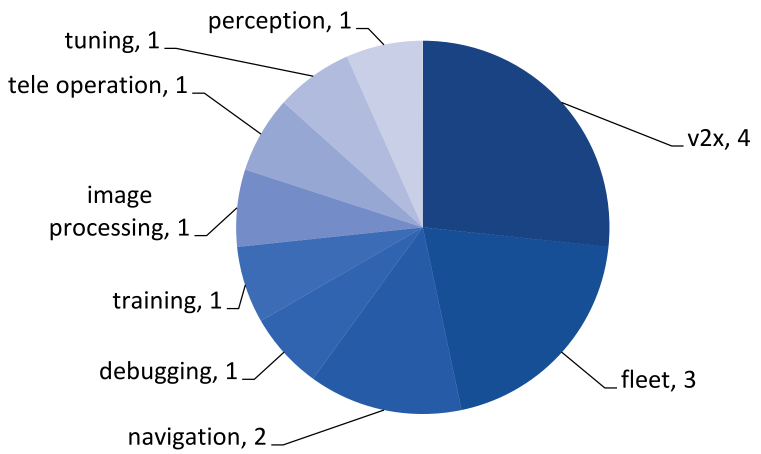



### 1.3 GOOGLE ACQUIRED LATENT LOGIC (2019)

- Shimon Whiteson founded latent Logic in 2017
- They had a valuation of US$ 8 million in June 2018, deal price unknown
- They had expertise in imitation learning
  - As opposed to well-practiced reinforcement learning
- They filed1 patent (applied in 2018), no more data available

## 1.4 Apple Acquired Drive.ai (2019)

- Seven Ph.D. students founded Drive.ai at Stanford Univ in 2015
- They raised US$ 77 million through multiple funding rounds
- It was valued at US$ 200 million in 2017, deal price unknown
- They had 15 patents filed – related to different aspects of tech




## 1.5 Uber Acquired Otto (August 2016)

- Anthony of 510 systems founded Otto in January 2016
- The deal price was 1% of Uber stock (about US$ 680 million)
- They had developed in-house 64 channel LiDAR tech
- Otto focused on self-driving trucks
- IPR details are unknown

## 1.6 Uber Acquired Mighty.ai (2019)

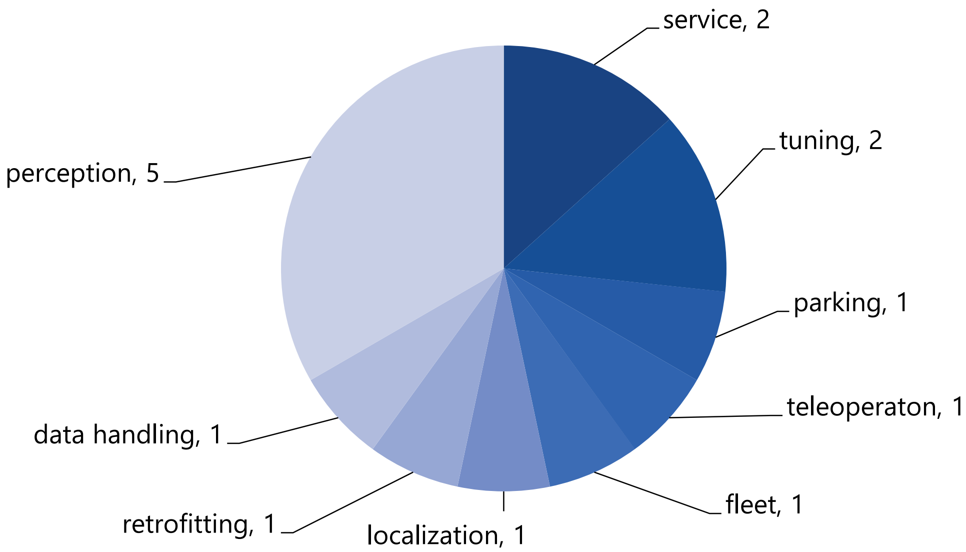
- Matt Bencke founded Mighty.ai in 2014
- Mighty.ai had the platform for labeling the data
- They are valued at US$ 85 million in 2017, deal price unknown
- They had one patent filed – related to the assessment of accuracy

## 1.7 Ford, VW Acquired Majority Ownership in Argo.ai

- Bryan Salesky and Pete Rander founded Argo.ai in 2016
- They had a US$ 7.25 billion valuation in June 2020
- Ford invested to US$ 1 billion in 2017, VW invested US$ 2.6 billion in June 2020
- They are working on creating self-driving systems including the sensors and HD maps
- They have 31 patents related to LiDAR technologies including silicon level designs

## 1.8 GM Acquired Cruise Automation (2016)

- Kyle Vogt and Dan Kan founded Cruise in 2013
- They were valued at US$ 19 billion in 2019; the deal price was US$ 1 billion (2016)
- They have 15 patents in different application areas




## 1.9 Some More Notable Acquisitions

There have been some more acquisitions. The following is by no means an exhaustive list.

- Toyota acquired JayBridge Robotics in 2016
- Daimler acquired Torc Robotics in 2019
- TomTom acquired Autonomos in 2017
- Delphi acquired nuTonomy in 2017
- Tesla acquired DeepScale in 2019
- Intel acquired Mobileye in 2017