VISVESVARAYA TECHNOLOGICAL UNIVERSITY,
BELGAUM – 590014

A Major Project Report on

Autonomous Ground Vehicle

Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Engineering in

AUTOMATION AND ROBOTICS ENGINEERING

Submitted by

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ABSTRACT

An Autonomous Ground Vehicle must achieve bold performance and solid reliability to mature from laboratory curiosities to fielded systems. An Autonomous car (driverless car, self-driving car, robotic car) is a vehicle capable of sensing it's environment and navigating without human input. Autonomous cars can detect surroundings using a variety of sensing techniques. Advanced control systems interpret sensory information to identify appropriate navigation paths, as well as obstacles and relevant signage. The objective is to produce an autonomous vehicle which, upon its completion, will succeed through theory-based simulation, team implementation, system integration, periodical product assessment, and product realization through a design process. In competition, the vehicle is to autonomously negotiate a predetermined obstacle course. The vehicle must demonstrate the capability to detect and follow lanes, avoid obstacles, and navigate to waypoints via GPS. It is observed that the rash, careless and lane-changing habits of Indian drivers are leading to heavy traffics and cumbersome situations. A process or a machine or intelligence is to be developed to reduce the victims of the accidents and reduce the traffic in the metro-politic cities. The system should be helpful and affordable to the public and should not fail in any of its worst conditions.

ACKNOWLEDGEMENTS

We would like to thank our Principal **Dr.P.G Tewri**, Principal, BVBCET for giving me the opportunity and extending full-fledged support to work on this project. I also would like to thank my project guide **Prof Arun Giriyapur**, Head of the Department Automation and Robotics for sharing all the resources and guiding thorough out the course of time, the technical expertise helped to achieve the final goal of the project. **Prof. Aditya Deshpande** guiding us throughout the fabrication process and in new automotive technologies.

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Phase 1

Chapter 1

1.1 Mission Statement:

The motto of self-driving car is to organise ground traffic and reduces road accidents. The mission is to ensure safety of passenger using the autonomous car also taking care of the pedestrians within the vicinity of the vehicle. No asset, living or non-living, shall face any threat from this endeavour.

1.2 Articulation of Market Opportunity

Market opportunity can be efficiently put forth to following sections:

1.2.1 Customer:

1. The vehicles of this class are often known to face legal hurdles pertaining to the Road laws, the vehicle wouldn't be facing this as it would be operational in private properties.
2. Vehicle would be making note of respective landmarks in its path.
3. Vehicle would willingly embrace any alternate or subordinate paths.
4. It is often observed that customers give it a thought while they opt for any autonomous vehicle, this is addressed by the vehicle by providing a reasonable pricing.
5. Keep track of other vitals of the vehicle like battery level, distance travelled, current location etc.
6. Any customer with a quantified private property, where shuttles can be incorporated, can adopt the product.
7. Medical organisations, where they have long time patients who need regular examinations can take help of these vehicles and save the doctor's valued time.

1.2.2 Competition

1. Most advanced research is going in this field.
2. Second most growing sector of Indian market.
3. Most of the global Multinational Companies have been investing in this sector of the market like, Google, Apple, Audi, Ford, Volkswagen etc.
4. Self-driving cars have already assumed their paths in August 2016.
5. This would be one of the first affordable autonomous vehicles designed in the country.
6. Robotics sectors' growth can be easily articulated by successful completion of our project.

1.2.3 Company

List of Competitive products:

1. Googles' self-driving car.
2. Volvos' XC90 autonomous car in co-operation with UBER
3. Mercedes Benz's effort with Point Greycameras.
4. A start up from the students of IIT Kharagpur, a self-driving golf shuttle.

1.2.4 Technology

1. Exposure to new software technologies
2. Unrestricted access to technical laboratories.
3. Ability to obtain resources from Robot maker's hub.
4. Access to Solar Array Electric Vehicle (SAEV) from the Department of Automobile Engineering.

1.3 Market Segmentation

Broadly classified into the following sub-segment types:

1.3.1 Geographic

1. Replacement for shuttle services within private properties.
2. Replacement for e-karts in colleges, hospitals and other institutes.
3. Operational within the limits of the organizations property.

1.3.2 Demographic

1. Product would be generally bought by the organizations.
2. There would not be any discretion with respect to age, sex or any other criteria.

1.3.3 Behavioural

1. Customers would be eager to purchase an autonomous vehicle at much lower costs.
2. The customers would be looking at quicker shuttles even if it means self-driving ones.
3. As the company is new, a brand loyalty won't be looked at. The only branding in possession would be the name of BVB.

1.3.4 Psychographic

1. A huge risk will be looked upon when you consider the pricing of the products, hence clients would put in some though over it.
2. Accidents are never planned. When a driver is riding, he can respond in a better with his ability of stimulus. However, a sensor based system can't be accepted to perform that well. That shall remain to have a psychographic impact on our customers.

1.3.5 Benefits

1. Most trending research.
2. Eager implementation in India.
3. Success will enhance our chances to enjoy better working opportunities.
4. Success rate will have an effect on Departments' reputation.

1.4 Product Platform

Common design, formula, or a versatile product, based on which a family (line) of products is built over time.A platform is a business model that creates value by facilitating exchanges between two or more interdependent groups, usually consumers and producers. Exchange is one of the most fundamental parts of being human.

1.4.1 Components

Sr. No	Component Name	Make	Model
1	Camera	LOGITECH	930E
2	Servo Motor	Rhino	RMCS22
3	GPS module	RoboKits	GPS02
4	Processor	Raspberry Pi	3 model b+
5	Ultrasound sensor	UltraSonic Range finders	-LV-MaxSonar-EZ1
6	Encoder	Custom made	
7	Spur Gears	Custom made	
8	Servo Motor driver		L293D
9	Storage Device	SanDisk	16 GB

1.4.2 Processes

1.4.2.1Body Design:

The body designed should be favourable to the purpose of the vehicle. The body should pose its robust abilities to meet various standards. The body design should be simple and easy to fabricate and should not involve complicated bends or complicated machining like die casting etc.

1.4.2.2Knowledge

Every member of the project should be sound with their knowledge pertaining to the following factors:

1. The project would be in need of some complex software to process the video captured by the HD video camera.
2. We will be in need of redesigning the already built chassis according to our needs which would need few vitals of Mechanical studies.
3. A thorough study regarding the video processing that will be used for perception while we build the autonomous vehicle
4. Engineers would require strategies to care of the dead reckoning which is inherent to odometry to every autonomous vehicle.
5. Processors need specific set of codes on different platforms so there might be a need of some hard coding.

1.4.2.3People and relationship

This is a product based design which will be concentrating on sales of the synthesized product which would be requiring lot a people and manpower too as an asset for an effective and efficient completion of the project. Hence, maintaining and management of human resources becomes a vital part of the process.

1. The team leader should be clear with his ideas pertaining to how the team would be proceeding with their vision and objectives.
2. Human Resources manager should have the knack to manage his team mates and take care of their requirement and keep them satisfied at all times.
3. Spokesperson of the team should handle the responsibility of conveying the team’s ideas to the world and to any other subjects that would be needed, be it for procurement of the components required for the project or to market the designed product.
4. Chief Engineer should and must have an upper hand in terms of understanding the core concepts and principles of operation and should be taken care of, while he designs the system as a whole also remembering that the modularity of the product isn’t disturbed.

1.5 Architecture

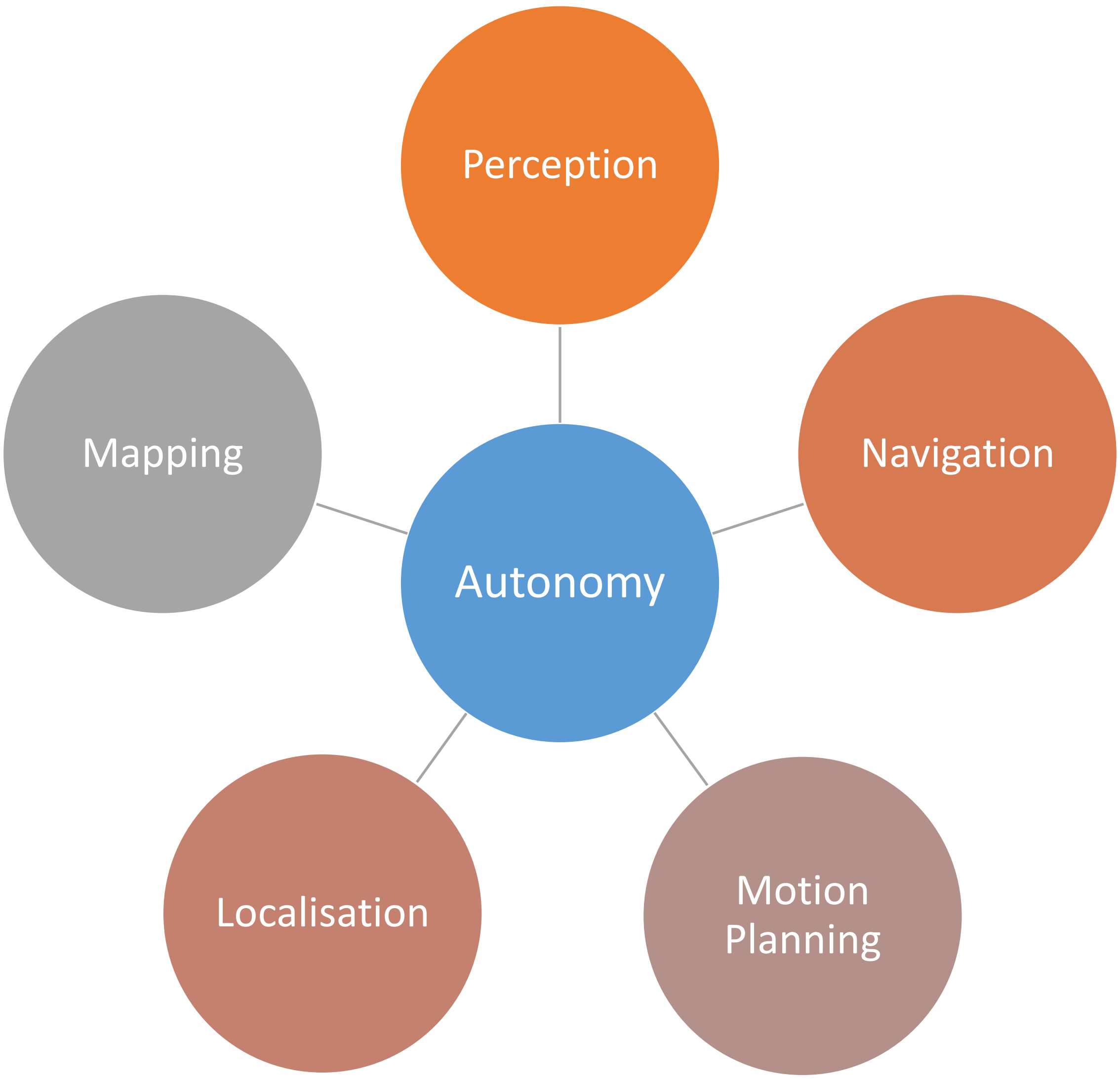


Fig. 1.5.1.1 Architecture

1.6 Assessment of new technologies

1.6.1 Perception

1.6.1.1LiDAR:

Light Detection and Ranging system is one of the widely used, sensor in the field of autonomous vehicles over the world.

D' = 2D = $^{\theta}\times\lambda$ / 2×∏ -- (1.6.1.1)

D'	Distance covered by emitted light.
D	Distance
θ	Phase difference
λ	Wavelength
∏	Constant

Fig. 1.6.1 Velodyne LiDAR

1.6.1.2 Frequency Modulated Continuous Wave RADAR:

In this system, the transmitted signal of a known stable frequency continuous wave varies up and down in frequency over a fixed period of time by a modulating signal. Frequency difference between the receive signal and the transmit signal increases with delay, and hence with distance. This smears out, or blurs, the Doppler signal. Echoes from a target are then mixed with the transmitted signal to produce a beat signal which will give the distance of the target after demodulation.

Instrumental Range = $F_r - F_t$ = *Speed of Light* / (4×*Modulation Frequency*)--(1.6.2)

F_r Frequency of the Receiver

F_t Frequency of the Transmitter

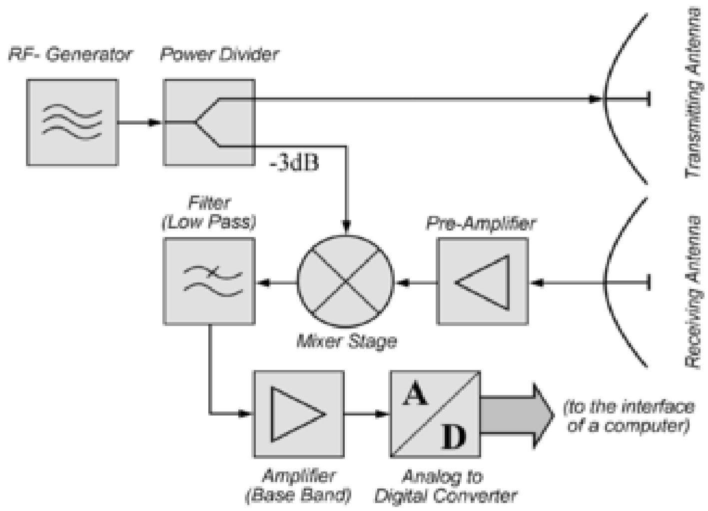


Fig.1.6.2 Block Diagram of FMCWR

1.6.1.4 Camera

Camera is widely used in autonomous cars in two different cases. Camera is used along with RADAR and LiDAR to detect sign boards and traffic signal with Image Processing. In the other case camera is used as primary sensor and the autonomy is achieved using Image/video processing. Camera is selected on focal length, shutter speed, communication interface, resolution, CMOS/CCD, frames per secondetc. Camera technology is economic and easy to process with only disadvantage is the amount of data to be processed.

1.6.1.3 Ultra-sound Range sensors

It is amongst the most common type of sensor used in many applications. Ultra sound sensors are economic and used to detect obstacles. Ultra sound sensors efficiency is reduced when objects are at considerably greater distances and when it comes to objects are travelling with greater velocities. However, its quick response with accurate data can’t be ignored to help the vehicle avoid immediate, unseen or the obstacles in the blind spot considering the camera.

1.6.1.4 Laser Kinects

The device features an "RGB camera, depth sensor and multi-array microphone running proprietary software", which provide full-body 3D motion capture, facial recognition and voice recognition capabilities.

Kinects are used when higher static efficiencies are expected whereas, laser Kinects are used where dynamic parameters come into picture.

1.6.2 Cognition

1.6.2.1Real Time Video Processing:

The real-time aspect is critical in many real-world devices or products such as mobile phones, digital still/video/cell-phone cameras, portable media players, personal digital assistants, high-definition television, video surveillance systems, industrial visual inspection systems, medical imaging devices, vision-assisted intelligent robots, spectral imaging systems, and many other embedded image or video processing systems**.**

This principle or say technology can be used to have an idea about the vehicles surrounding and ambience. This can be further used for mapping and localisation of the vehicle in any given terrain at disposal.

Fig 1.6.3 HD camera module

1.6.2.2Raspberry Pi 3

The Raspberry Pi is a series of credit card-sized single-board computers developed in the United Kingdom by the Raspberry Pi Foundation to promote the teaching of basic computer science in schools and developing countries.

The sensory feedback and the video processed would need an efficient and capable processor. This can be achieved by using the said device which has earned its fame in the field. We also have the option of using multiple processors in co-ordination if the product demands it.

Fig. 1.6.4 Raspberry 3 b+

1.6.2.3Machine Learning

Machine learning is a type of artificial intelligence (AI) that provides computers with the ability to learn without being explicitly programmed. Machine learning focuses on the development of computer programs that can teach themselves to grow and change when exposed to new data.

The process of machine learning is similar to that of data mining. Both systems search through data to look for patterns. However, instead of extracting data for human comprehension -- as is the case in data mining applications -- machine learning uses that data to detect patterns in data and adjust program actions accordingly. Machine learning algorithms are often categorized as being supervised or unsupervised. Supervised algorithms can apply what has been learned in the past to new data. Unsupervised algorithms can draw inferences from datasets.

With respect to autonomous vehicles, machine learning is not yet known to be used. However, there is some scope for machine learning to be used in the endeavour as it may prove to be useful in handling the manoeuvre of vehicle, velocity control in particular areas of the field of operation.

1.6.2.4 CUDA

CUDA is a parallel computing platform and application programming interface (API) model created by Nvidia. It allows software developers and software engineers to use a CUDA-enabled graphics processing unit (GPU) for general purpose processing – an approach termed GPGPU (General-Purpose computing on Graphics Processing Units). The CUDA platform is a software layer that gives direct access to the GPU's virtual instruction set and parallel computational elements, for the execution of compute kernels.

CUDA can be used in autonomous applications when cameras are used as primary sensors and there is tremendous load on the system of computation because the amount of data that gets dump on it. CUDA can prove to be handy at such times by handling the computations efficiently at processor levels.

1.6.2.5 Distributed control systems

A Distributed Control System (DCS) is a computerised control system for a process or plant, in which autonomous controllers are distributed throughout the system, but there is central operator supervisory control. This is in contrast to non-distributed control systems that use centralised controllers; either discrete controllers located at a central control room or within a central computer. The DCS concept increases reliability and reduces installation costs by localising control functions near the process plant, but enables monitoring and supervisory control of the process remotely.

As there are multiple systems handling the vehicle, using DCS can be quite handy and effective to operate and mobilise the vehicle. For instance, three different systems viz. braking, accelerating and steering can be implemented using this concept.

1.6.2.6 Parallel Computing

Parallel computing is a type of computation in which many calculations or the execution of processes are carried out simultaneously. Large problems can often be divided into smaller ones, which can then be solved at the same time. There are several different forms of parallel computing: bit-level, instruction-level, data, and task parallelism. Parallelism has been employed for many years, mainly in high-performance computing, but interest in it has grown lately due to the physical constraints preventing frequency scaling. As power consumption (and consequently heat generation) by computers has become a concern in recent years, parallel computing has become the dominant paradigm in computer architecture, mainly in the form of multi-core processors.

Parallel computing is closely related to concurrent computing—they are frequently used together, and often conflated, though the two are distinct: it is possible to have parallelism without concurrency (such as bit-level parallelism), and concurrency without parallelism (such as multitasking by time-sharing on a single-core CPU). In parallel computing, a computational task is typically broken down in several, often many, very similar subtasks that can be processed independently and whose results are combined afterwards, upon completion. In contrast, in concurrent computing, the various processes often do not address related tasks; when they do, as is typical in distributed computing, the separate tasks may have a varied nature and often require some inter-process communication during execution.

As mentioned above there are many operations and computations to be handled or taken care of, which would need parallel computations and have been used in the due process.

1.7 Production Constraints

1.7.1 Functional

1. Possibilities in failure of electronic components should not occur.
2. No lag in processing.
3. Precision in steer ability.
4. Effective Battery Management System.
5. Precise control system with necessary feedback monitoring.
6. Dead reckoning should be taken care in odometry.

1.7.2. Safety

1. No person should be harmed.
2. Three Rules of Robotics must be followed.
3. Private property should not be harmed.
4. Safe transportation of passengers.

5. Shock proof.

1.7.3. Quality

1. Durable
2. Robust
3. Reliable
4. Shock proof
5. Design should be Easy to maintain

1.7.4. Manufacturing

1. Components should be easily available in local market.
2. Standard size and standard procedures to be used.

1.7.5. Timing

1. Process shouldn’t lag as major accidents may occur.
2. Prototype should be ready in deadline given.

1.7.6. Economic

1. Product should be affordable.
2. Spares should be economical.
3. Maintenance should be easy.

1.7.7. Logical

1. Code should be efficient with smaller source and byte code.
2. Control System should be efficient enough to tackle malfunctions.

1.7.8. Life Cycle

1. Easy to Recycle.
2. Eco-friendly.
3. Lower Carbon footprint emission.

1.8 Setting Supply Chain Constraints

1.8.1 Upstream:

1. Sensors and minor components required are procured from Local dealers, so that it can be easily replaced.

2. Advanced sensors like camera and controller are not compromised for quality, their failure can kill the whole concept.
3. Components are assembled in the campus and tested in the fixedpath.
4. Power sources like battery and other things are locally purchased.

1.8.2 Downstream:

1. The marketing of vehicle is done by publishing a technical paper.
2. The project is exhibited in various project fairs.
3. Some competitive platforms like 'SRISHTI' etc. are used to showcase our abilities and products.
4. Technical posters are made to advertise our project achievements.

1.8.3 Information:

1. Autonomous car has an electric motor of 2.5 kW.
2. Various techniques are used to achieve mapping, localisation, odometry, Navigation, Motion control, Obstacle detection etc. which are discussed in future part of the document.
3. A special gearing system is designed to facilitate autonomous steerability for the vehicle.

1.8.4 Selection of material:

1. AISI 1020 is used for chassis frame.
2. Sensors and minor components required are procured from Local dealers, so that it can be easily replaced.
3. Advanced sensors like camera and controller are not compromised of quality, their failure can kill the whole concept.
4. Power sources like battery and other things are locally purchased.

1.8.5 Finance:

1. Each team member contributes a fraction; fraction is the total budget divided by total number of students.
2. Some components and materials are funded by the Department.
3. The chassis is adopted from **BVB Motorsports Club**.
4. The resources available in the department are made use of.

Chapter 2

Requirements

2.1 Lead Requirements

1. The vehicle should be easy to operate.
2. There should be jerk less motion.
3. It should be stable.
4. It should consume least possible energy.
5. It should operate spontaneously to the stimulus.
6. Communication handshake should be achieved.
7. The communication should be as fast as possible.
8. It should have greater endurance time.
9. Panic free environment for the user.
10. Human reactions to certain unavoidable situations should be considered.
11. It should be durable.
12. The vehicle should be ergonomically designed.
13. Cost should be least as possible.
14. The vehicle should use organised wiring.
15. Should be compatible with software.
16. Should be safe for operation.
17. The speed of vehicle should not exceed 20kmph.
18. Error should be detected easily.
19. It should be easy to operate.
20. Should be able to provide information about the environment.
21. Prototype should not cause any harm to environment.
22. The vehicle should be efficient in all terms.
23. A emergency switch should be provided.
24. Possibilities in failure of electronic components should not occur.
25. No lag in overall processing.
26. Precision in steer ability.
27. It should have an effective Battery Management System.
28. Precise control system with necessary feedback monitoring.
29. Dead reckoning should be taken care in odometry.
30. Design should be easy to maintain.

31. Design should be robust.
32. Design should be reliable.
33. Parts should be easily available in market.
34. It should be environment friendly.
35. It should have low carbon foot print.
36. Safe transport of passenger should be assured.
37. It should be able to detect the obstacles.
38. Vehicle should be able to locate its own position.
39. The vehicle should be pedestrian friendly.
40. The path of operation should be fixed.
41. Three rules of Robotics must be followed.
42. Private property should not be harmed.
43. It should be aesthetically appealing.
44. Take proper input from the user.
45. Users input should be well interpreted.
46. Input would be in terms of location.
47. Line of sight should be around 100m.
48. Should utilise the input (teaching) given initially by the user to gain maximum data.
49. The path should be well defined.
50. Maintain a reasonable speed.
51. Appropriate sensors would be used.
52. Video cameras should have good quality of streaming.
53. Camera should have utilise its sight to map and localise close to at least 200 degree of its environment.
54. Data obtained from the camera should be efficiently managed.
55. Parallel computing should be implemented as far as possible.
56. The processor used should support parallel architecture.
57. GPS system shouldn’t fail.
58. Our own map should be generated.
59. The tyres used should have least slippage.
60. The odometry shouldn’t be affected by irregular surfaces.
61. Proper rotary encoder installation should be made.
62. Should be immune to external noises.

63. Obstacle detection system should differentiate obstacles from some inherent fixtures like lampposts.
64. Steering system should be efficient considering the specifications of the motors or any other sort of driver being used.
65. Quickener should be designed for appropriate steering system.
66. Lightest mechanism of rack and pinion should be used.
67. Odometry is often affected by the steering that takes place, it should be accounted using possible changes dynamically.
68. Appropriate indicators should be used while turning.
69. Proper prediction of steering angle according to the curve required.
70. Braking system of vehicle should be efficient.
71. Braking system should not fail.
72. Braking should be jerk free.
73. If possible, use of Electronic Braking System.
74. Prediction of obstacles should be well reciprocated by the braking system.
75. Motors shouldn't be affected by sudden changes in speed.
76. Drive system should be lag free considering least possible back lash error.

2.2 Indented Requirement List

2.2.1 Kinematics

1. There should be jerk less motion.
2. It should be stable.
3. Line of sight should be around 100m.
4. Lightest mechanism of rack and pinion should be used.
5. Proper prediction of steering angle according to the curve required.

2.2.2 Energy

1. It should consume least possible energy.

2.2.3 Signal

1. It should operate spontaneously to the stimulus.
2. Drive system should be lag free considering least possible back lash error.
3. Prediction of obstacles should be well reciprocated by the braking system.

4. Communication handshake should be achieved.
5. The communication should be as fast as possible.
6. Take proper input from the user.
7. Users input should be well interpreted.
8. Input would be in terms of location.
9. Should utilise the input (teaching) given initially by the user to gain maximum data.
10. Parallel computing should be implemented as far as possible.
11. The processor used should support parallel architecture.
12. Should be immune to external noises.

2.2.4 Cost

1. Cost should be as minimum as possible.

2.2.5 Ergonomics

1. The vehicle should be easy to operate.
2. The vehicle should be ergonomically designed.
3. Error should be detected easily.
4. Design should be easy to maintain.
5. Prototype should not cause any harm to environment.
6. It should have low carbon foot print.

2.2.6 Safety

1. Motors shouldn't be affected by sudden changes in speed.
2. Braking system should not fail.
3. Maintain a reasonable speed.
4. Private property should not be harmed.
5. The vehicle should be pedestrian friendly.
6. An emergency switch should be provided.
7. Safe transport of passenger should be assured.
8. Panic free environment for the user.
9. Should be safe for operation.
10. Human reactions to certain unavoidable situations should be considered.
11. Three rules of Robotics must be followed.

2.2.7 Quality

1. It should have greater endurance time.
2. Proper rotary encoder installation should be made.
3. Data obtained from the camera should be efficiently managed.
4. It should be aesthetically appealing.
5. Design should be reliable.
6. Design should be robust.
7. Precise control system with necessary feedback monitoring.
8. The vehicle should be efficient in all terms.
9. Possibilities in failure of electronic components should not occur.
10. It should be durable.
11. It should have an effective Battery Management System.

2.2.8 Assembly

1. Appropriate indicators should be used while turning.
2. Quickener should be designed for appropriate steering system.

2.2.9 Operation

1. Parts should be easily available in market.
2. Braking system of vehicle should be efficient.
3. Odometry is often affected by the steering that takes place, it should be accounted using possible changes dynamically.
4. Steering system should be efficient considering the specifications of the motors or any other sort of driver being used.
5. Obstacle detection system should differentiate obstacles from some inherent fixtures like lampposts.
6. The odometry shouldn't be affected by irregular surfaces.
7. There should be provision of mapping system.
8. Camera should have utilise its sight to map and localise close to at least 200 degree.
9. The tyres used should have least slippage.
10. Our own map should be generated.

2.3 Demand/Wish and Prioritizing the Requirements

Sno	Requirements	D/W	Ratings
1	There should be jerk less motion	D	7
2	It should be stable	D	8
3	Line of sight should be around 100m	D	10
4	Lightest mechanism of rack and pinion should be used	W	6
5	Proper prediction of steering angle according to the curve required	D	8
6	It should consume least possible energy	W	5
7	It should operate spontaneously to the stimulus	D	9
8	Drive system should be lag free considering least possible back lash error	D	9
9	Prediction of obstacles should be well reciprocated by the braking system	D	7
10	Communication handshake should be achieved	W	6
11	The communication should be as fast as possible	D	8
12	Take proper input from the user	D	7
13	Users input should be well interpreted	D	8
14	Input would be in terms of location	D	10
15	Should utilise the input (teaching) given initially by the user to gain maximum data	W	6
16	Parallel computing should be implemented as far as possible	D	10
17	The processor used should support parallel architecture	D	9
18	Should be immune to external noises	W	8
19	Cost should be as minimum as possible	D	10
20	The vehicle should be easy to operate	D	8
21	The vehicle should be ergonomically designed	W	7
22	Error should be detected easily	W	7
23	Design should be easy to maintain	W	8
24	Prototype should not cause any harm to environment.	W	5
25	It should have low carbon foot print	W	5
27	Motors shouldn't be affected by sudden changes in speed	D	10
28	Braking system should not fail	D	10
29	Maintain a reasonable speed	W	8
30	Private property should not be harmed	W	6
31	The vehicle should be pedestrian friendly	W	7
32	A emergency switch should be provided	D	10
33	Safe transport of passenger should be assured	D	10
34	Panic free environment for the user	D	9

35	Should be safe for operation	W	7
36	Human reactions to certain unavoidable situations should be considered	D	9
37	Three rules of Robotics must be followed.	D	10
39	It should have greater endurance time	D	10
40	Proper rotary encoder installation should be made	D	5
41	Data obtained from the camera should be efficiently managed	D	6
42	It should be aesthetically appealing	W	4
43	Design should be reliable	W	6
44	Design should be robust	W	6
45	Precise control system with necessary feedback monitoring.	D	9
45	The vehicle should be efficient in all terms	W	4
46	Possibilities in failure of electronic components should not occur.	D	10
47	It should be durable	D	9
48	It should have an effective Battery Management System.	W	5
49	Appropriate indicators should be used while turning	D	8
50	Quickener should be designed for appropriate steering system.	D	9
51	Parts should be easily available in market	W	8
52	Braking system of vehicle should be efficient	D	9
53	Odometry is often affected by the steering that takes place, it should be accounted using possible changes dynamically	D	8
54	Steering system should be efficient considering the specifications of the motors or any other sort of driver being used	D	8
55	Obstacle detection system should differentiate obstacles from some inherent fixtures like lampposts	D	9
56	The odometry shouldn’t be affected by irregular surfaces	W	7
57	There should be provision of mapping system	D	10
58	The tyres used should have least slippage	D	8
59	Our own map should be generated	D	10
60	The path to be followed should be well defined	D	9
61	Camera should have utilise its sight to map and localise close to at least 200 degree of its environment	D	10
62	Video cameras should have good quality of streaming	W	8
63	Vehicle should be able to locate its own position	D	9
64	The path of operation should be fixed	D	10

65	Vehicle should be able to locate its own position	D	10
66	It should be able to detect the obstacles	D	10
67	Dead reckoning should be taken care in odometry.	D	8
68	Precision in steer ability	W	10
69	No lag in overall processing.	D	10
70	Should be able to provide information about the environment.	D	8
71	The speed of vehicle should not exceed 20kmph	D	10
72	Should be compatible with software	D	7
73	Appropriate indicators should be used while turning	D	9

2.4 Identification of Lead Users

Lead users are users of a product or service that currently experience needs still unknown to the public and who also benefit greatly if they obtain a solution to these needs. Because lead users innovate, they are considered to be one example or type of the creative consumer phenomenon, that is, those "customers who adapt, modify, or transform a proprietary offering.

The concept of autonomous vehicle is widely researched and hence, we will have a wide array users coming from different backgrounds and various walks of life to assist us. A vehicle traversing on fixed paths is being designed and hence people in various educational institutes are bound to be our lead users.

Some of our Lead users can be:

1. The college (BVBCET)
2. Any other technical institute where the vehicle would be used
3. Organisations having their research on Autonomous vehicles
4. Students doing their PhD in the sensors that would be used in the vehicle
5. Automobile fraternity

Phase 2

Chapter 3

3.1 Identification of Competitive Products

Goods or service that can be sold in higher profitable quantities because customers prefer the competitive product compared to other products of competitors that satisfy a similar need in the market.

If we consider just autonomous vehicles as a whole we will be expecting too much of competition. However, we won't be doing that, rather we would just be focusing on the vehicles in competition which are being used in private or say fixed environment, as shuttles for transit within the property.

Following are the Competitive Products:

Auro Robotics

Found Robotics Research Group at IIT Kharagpur, India. This company is a start-up from the students there. They have successfully built a vehicle resembling a golf cart that can be used for traversal within the campus.

Auro uses latest technology to ensure safe navigation even on busy roads. The vehicle is equipped with Lasers, camera, GPS and multiple blind spot detection sensors providing it complete 360-degree vision upto 100 meters in all lighting conditions. The shuttle sensor stack is even capable of detecting people / pets lying flat on the ground.

Navya

NAVYA has been developing complex technological solutions towards sustainable mobility. NAVYA is mobilizing its expertise of intelligent transportation as to answer the societal, economical and sustainable challenges of the 21st century.

Autonomous and flexible, the NAVYA ARMA does not require any driver or specific infrastructure. Intelligent and reliable, it can adapt to any situation by avoiding the static and dynamic obstacles. Environmentally friendly as it uses electrical energy, its batteries can be recharged by induction and can last from 5 to 13 hours according to the configuration and the traffic conditions.

Easy Mile

Founded in 2014, EasyMile is a high-tech startup specialised in providing both software powering autonomous vehicles and the last mile smart mobility solutions.

EZ10 is an electric people mover. It can transport up to 12 people (6 seating positions and 6 standing positions) and can cater to reduced mobility passengers. The shuttle has no steering wheel and neither dedicated front nor back. At any point on its route EZ10 can easily change its direction without needing a short turn.

3.2 Functional Analysis

3.2.1 Black Box

Fig. 3.2.1.1 Black Box

3.3 Target Specifications

3.3.1 Battery and supporting system for driving the motor

1. Voltage rating	48 V
2. Current	10 A (Peak)
3. Power Rating	4.8 KW
4. Charge time	About 4 Hour
5. Discharge time	About 10 Hours
6. Motor Speed	3000-6000 rpm
7. Number of Cycles	> 3000 cycles
8. Peak Torque	18 N-m

3.3.2 Sensor Specifications

1. HD Camera with HDMI port	10-12 MP
2. Ultra-sound sensor	10-20 m
3. Wi-Fi speed	4-6 mbps
4. Wi-Fi range	60-80 m
5. Encoder Resolution	32 bit
6. Storage Device	16 Gb

3.3.3Mechanical Targets

1. Maximum Speed	20 Km/hr
2. Braking Distance	2-4 m
3. Turning Radius	4 m
4. Vehicle Weight	<250 kg

3.4 Investigation of feasibility of product concepts

The term "feasibility study" is often used in context of product development processes. Feasibility studies focus on five subjects: technical, economic, legal, operational and scheduling feasibility studies. The best-known field is the economic one. While in economy science there is a standard-proceeding of a "feasibility study", in a technical context the term is used in different ways as shown by various research work.

3.4.1 Concept 1

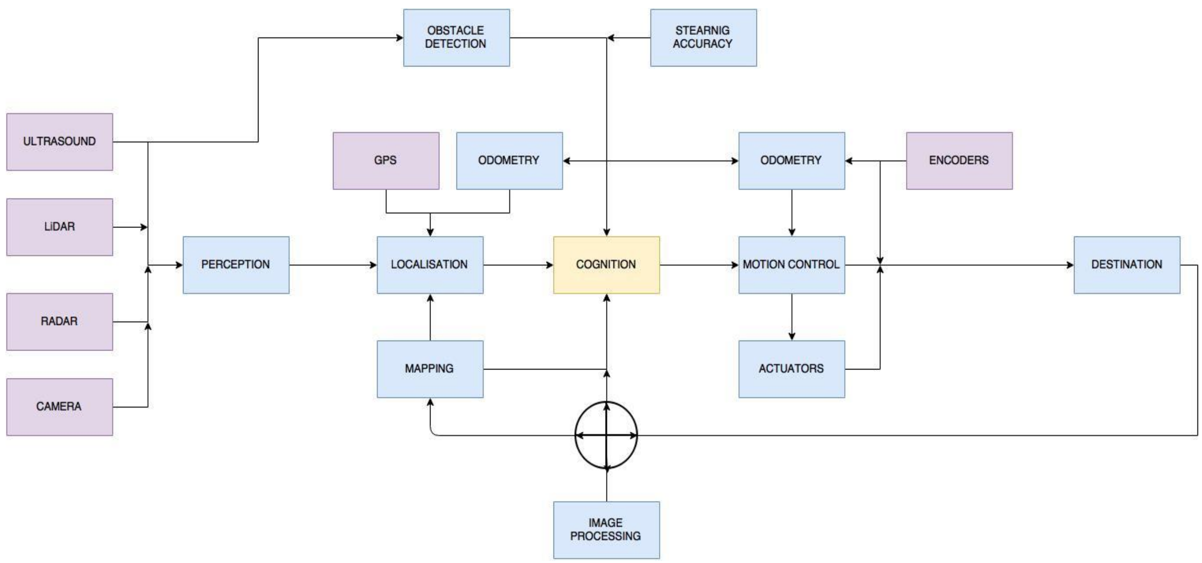


Fig 3.4.1.1 Concept 1

1. Technical
   1.1.1 The response time of sensors is in pico-seconds for which becomes tedious to be processed.
   1.1.2 The sensors used in the concept are of greater precision.
   1.1.3 The Radar and LiDAR make impeccable combination, which is efficient for Mapping.
   1.1.4 Adaptive Cruise Control can also be implemented in Concept 1.
   1.1.5 Radar can also be used to get obstacle velocity.
   1.1.6 LiDAR can be used to get 3D map of the area.
2. Economy
   1.2.1 The cost of sensors used is very high.
   1.2.2 The cost of controller is also very high.

1.2.3 Sensors should be imported, which makes it time consuming, high cost and cumbersome.

3. Legal
   1.3.1 Self- Driving cars may not be legal on road.
   1.3.2 Legal procedures should be followed like excise duty to import components.
4. Operational
   1.4.1 The sensory feedback should be organised in a manner to get the whole process in operating state.
5. Scheduling
   1.5.1 Time deadlines should be met as we import components.

3.4.2 Concept 2

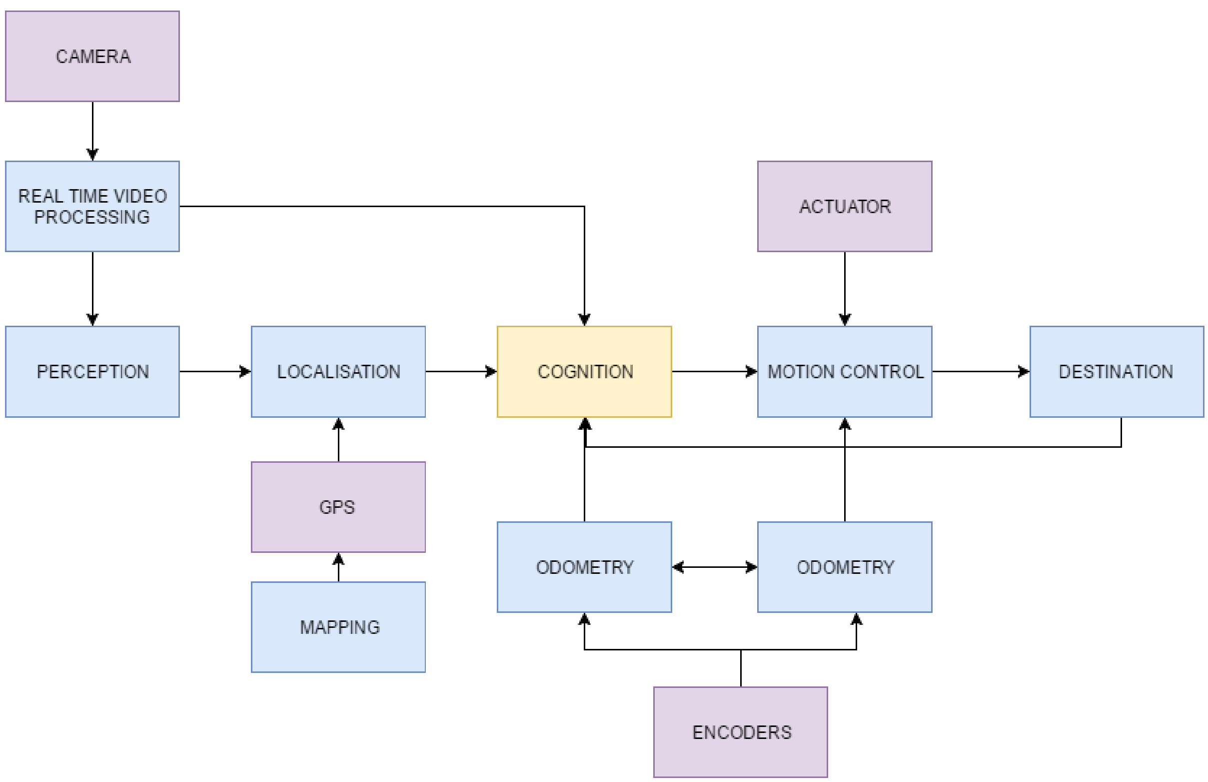


Fig 3.4.2.1 Concept 2

1.1 Technical

1.1.1 The response time of sensors is comparatively slow than that of sensors used in Concept 1.

1.1.2 The sensors used in the concept are of greater precision.

1.1.3 Hard-coding becomes unavoidable when it comes to image/video processing.

1.1.4 It becomes quite necessary to use extra sensors for obstacle detection.

1.1.5 This would be an unconventional but a novel way to approach in the field of mapping.

1.2 Economy

1.2.1 The cost of sensors used is considerably low.

1.2.2 The cost of controller is affordable.

1.2.3 The sensors used in this concept would be locally available.

1.3 Legal

1.3.1 Self- Driving cars may not be legal on road.

1.4 Operational

1.4.1 The sensory feedback should be organised in a manner to get the whole process in operating state.

1.4.2 It is too difficult to predict and analyse using cameras to follow a fixed path.

1.5 Scheduling

1.5.1 Time deadlines should be met as we import components.

Sr. No.	Criteria	Weight	Concept1	Concept2
1	Cost	0.15	5 / 0.75	9 / 1.35
2	Efficiency	0.20	8 / 1.6	7 / 1.4
3	Maintenance	0.10	5 / 0.50	5 / 0.50
4	Ergonomics	0.25	7 / 1.75	6 / 1.5
5	Safety	0.30	6 / 0.18	6 / 0.18
Total		1	4.78	4.93

3.5 Estimation of manufacturing costs

Sl. No.	**Systems and sub-systems**	**Cost (INR)**
1	SAEV (Not included)	1,10,000
2	Camera	20,000
3	Camera Module	1200
4	Controller/Process	5000
5	Ultrasound Sensor	2000
6	Stepper Motor	4000
7	12 V Battery	1000
8	Encoder Set	700
9	Miscellaneous	1000
10	Others	5000
	TOTAL	**50,000**

3.6 Performance Specifications:

3.6.1 Steering:

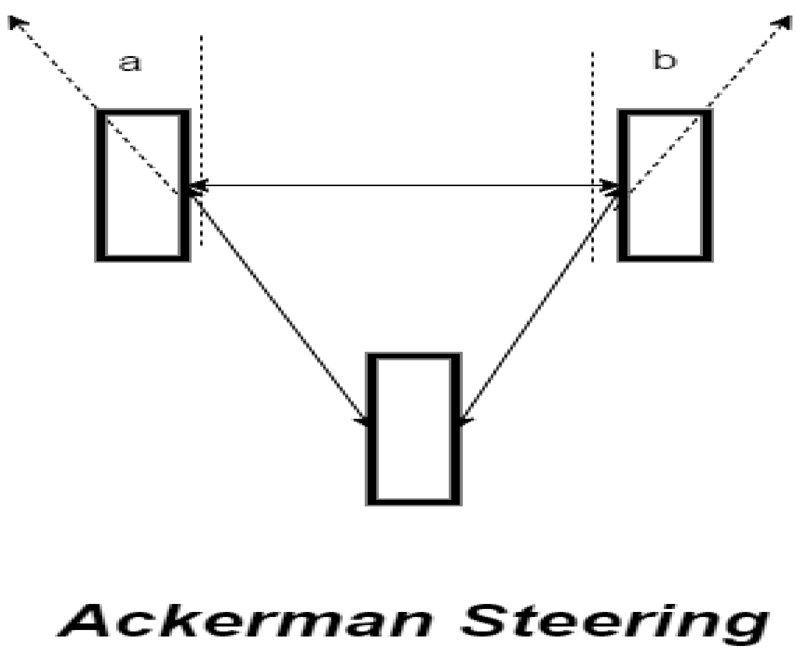


Fig. 3.6.1 Ackerman Steering

Inference:

a=b Ackerman Angle

Assume a steering wheel diameter of **0.3m** and an ergonomic steering effort of **30N**.

Steering torque (T) = F × r

= 30 × 0.15

= 4.5 Nm

Let us a consider a Factor of Safety of **1.5** to calculate the value of motor torque

Motor Torque = T × Factor of Safety

= 4.5 × 1.5

= 6.75 Nm

Further steering Calculations:

Wheel Base (L) = 1.98 m

Track Width (W) = 1.21 m

Assume,

Inner wheel (b) = 45 degree

Cot b = W/L + cot a

= 1.21/1.98 + cot 45

b = 31.7^0

Turning radius(r) = W/cot b + L/sin a

= 1.21/cot 31.7 + 1.98/sin 45

= 2.13 m

Outer wheel turning radius:

R_0 $= [L/\sin b – (w\text{-}w^1)/2]$

$= [1.98/\sin 31.7 – 0.605/2]$

$= 3.9$ m

R_i $= [L/\sin a – (w\text{-}w^1)/2]$

$= [1.98/\sin 45 – 0.605/2]$

$= 2.5$ m

Outer wheel steering angle:

θ_0 $= \tan^{-1} (L/r)$

$= \tan^{-1} (1.98/2.33)$

$= 40.31^0$

Inner wheel turning angle:

θ_i $= \tan^{-1} (L/(r-w))$

$= \tan^{-1} (1.98/ (2.33 – 1.21))$

$= 60.39^0$

Ackerman angle:

C $= (\theta_0 + \theta_i) / 2$

$= (60.39 + 40.36)/2$

Ackerman percent:

C % $= (C/\theta_i) \times 10$

$= (50.37/60.39) \times 100$

$= 83.4$ %

3.6.2 Braking Calculation

Let's assume pedal force of **100N**

Brake leverage = 1:1

Force on master cylinder (F_p) = 100N

Master cylinder diameter (d_p) = 0.02 m

Area (A_p) = $(\prod/4) \times (d_p)^2$

= $(\prod/4) \times (0.02)^2$

= 3.142×10^{-4} m^2

Pressure in master cylinder (P_p) = F_p / A_p

= $100 / (3.142 \times 10^{-4})$

= 318.18 kPa

Brake calliper diameter (d_c) = 0.015 m

Area (A_c) = = $(\prod/4) \times (d_c)^2$

= $(\prod/4) \times (0.015)^2$

= 1.7678×10^{-4} m^2

Pressure in master cylinder (P_p) = Pressure in brake callipers (P_c) = 318.18 kPa

Calliper Force (F_c) = $P_c \times A_c$

= $318.18 \times 1.7678 \times 10^{-4}$

= 56.254 N

Since the callipers have **two** pistons,

Calliper Force (F_c) = $F_c \times 2$

= 112.508 N

Co-efficient of friction(μ_r) on paver bricks is 0.35.

Frictional Force (F_r) $= F_c \times \mu_r$

$= 112.508 \times 0.35$

$= 39.3778$ N

Radius of rotor (r_r) $= 0.2$ m

Torque on rotor (T_r) $= F_r \times r_r$

$= 39.3778 \times 0.2$

$= 7.8756$ Nm

Tyre radius (r_T) $= 0.4318$ m

Force acting on Tyres (F_T) $= 7.8756 / 0.4318$

$= 18.238$ N

Linear deceleration (a_d) $= 8.17$ m/s^2

Vehicles max velocity (V_{max}) $= 4.1667$ m/s

Stopping Distance (d_{st}) $= (V_{max})^2 / (2\times a_d)$

$= (4.1667)^2 / (2\times 8.17)$

$= 1.062$ m

Braking efficiency $= a_d / \mu_r$

$= 8.17 / 0.35$

$= 23.342$ %

3.6.3 Solenoid Force Estimation

Force induced by solenoid (F_s) $= [\ (N \times I)^2\ \mu_0\ A] / (2 \times g^2)$

Where,

N = Number of turns

I = Current passed in the solenoid in Ampere

μ_0 = Permeability of free space = 1.256×10^{-6} T-m/A

A = Area of cross-section of the core

g = gap between the solenoid and plunger

First Consideration:

N = 1000

I = 10A

g = 0.0508 m

Core diameter (d) = 0.0254 m

A = 5.0604×10^{-4} m^2

F_s = 12.32 N

Second Consideration:

N = 1000

I = 10 A

g = 0.0508 m

Core diameter (d) = 0.0508 m

A = 20.25×10^{-4} m^2

F_s = 49.3 N

Third Consideration:

N = 2000

I = 6 A

g = 0.0508 m

A = 20.25×10^{-4} m^2

F_s = 70.98 N

Fourth Consideration:

N = 2000

I = 6 A

g = 0.0381 m

A = 20.25×10^{-4} m^2

F_s = 126.2 N

The fourth consideration meets with our braking pedal force of 100N with sufficient factor of safety.

3.6.4 Smart Cheat Sheet Calculations for Servo Motor selection (Steering)

3.6.4.1 Establish Motion Objectives

1. Establish distance v/s Time Requirements

   Distance (d) = 0.63881 m

   Ergonomic Time = 10 s

   Radius (r) = 0.0508 m

   Max distance $= 2 \times 2\prod r$

   $= 2 \times 2 \times 3.14 \times 0.0508$

   = 0.63881 m

2. Required resolution

   A resolution of **24** degrees is considered with respect to steering axis

   Number of teeth = 15

   Gears engaged = 4 (assumed)

   $= 1/15 \times 4$

   = 0.2666 per revolution

3. Worst Case move

   This is considered for impulsive steering

   = 24 rpm in 2 s

4. Positioning accuracy

   Driven teeth (N_i) = 30

   Driver teeth (N_d) = 15

   Gear ratio $= N_i / N_d$

   = 30 / 15

   = 2

Since we are using reduction ratio which of 2:1. Positioning accuracy also gets multiplied by a factor of 2.

Max moving speed = 24 rpm = 0.753 m/s

Max acceleration = 0.3769 m/s

3.6.4.2 Gearing

Driven teeth (N_s) = 30

Driver teeth (N_m) = 15

Gear ratio (N_r) = N_s / N_m

= 30 / 15

= 2

Motor rotation (Θ_m) = 1

Steering rotation (Θ_s) = $N_r \times \Theta_m$

= 2 × 1

= 2

Motor velocity (ω_m) = 18 rpm

Steering velocity (ω_s) = $N_r \times \omega_m$

= 2 × 18

= 36 rpm

3.6.4.3 Inertial calculations and acceleration

Steering rod radius (r_d)	$= 0.0127$ m
Rod Area (A_d)	$= \prod \times (r_d)^2$
	$= 3.14 \times 0.0127^2$
	$= 5.069 \times 10^{-4}\ m^2$

Gear radius (r_s)	$= 0.0381$ m
Cast Iron density ($\dot{\rho}$)	$= 6800\ kg / m^3$
Mass (m_s)	$= 0.393$ kg
Steering inertia (J_s)	$= (m_s \times r_s^2) / 2$
	$= (0.393 \times 0.0381^2) / 2$
	$= 2.85 \times 10^{-4}$ kg- m^2

Gear radius (r_m)	$= 0.0254$ m
Cast Iron density ($\dot{\rho}$)	$= 6800\ kg / m^3$
Mass (m_m)	$= 0.175$ kg
Motor shaft length (L)	$= 0.0508$ m
Steering inertia (J_m)	$= [m_m \times (3r_m{}^2 + L^2)] / 2$
	$= [0.175 \times (4.516 \times 10^{-3})] / 2$
	$= 3.95 \times 10^{-4}$ kg-m^2

Gearing efficiency (e)	$= 0.98$
Reflected inertia (G_L)	$= (1/ N_r)^2 \times (J_m / e)$
	$= 0.25 \times 4.03 \times 10^{-4}$
	$= 1 \times 10^{-4}$ kg-m^2

Reflected inertia (G_M) $= (1/ N_r)^2 \times (J_s / e)$

$= 0.25 \times 2.908 \times 10^{-4}$

$= 0.727 \times 10^{-4}$ kg-m^2

Total inertia (J_{Tot}) $= G_M + J_m + G_L + J_s$

$= 8.527 \times 10^{-4}$ kg-m^2

Torque reflected (T_M) $= T_L / (N_r \times e)$

$= 4.5 / (2\times0.98)$

$= 2.3$ N-m

Inertial Torque (T_a) $= J_{Tot} \times \alpha$

where, α = acceleration torque

$= (\omega_{max} / t \times 2\prod)$

$= (2.51 / 2 \times 2\prod)$

$= 0.2$ Nm

$= 8.527 \times 10^{-4} \times 0.2$

$= 1.7$ Nm

Total torque (T_{total}) $= T_a + T_L$

$= 1.7 + 4.5$

$= 6.2$ Nm

Therefore, available torque is greater than the required torque.

3.7 Final Specifications

3.7.1 Battery and supporting system for driving the motor

Voltage rating	48 V
Current	10 A (Peak)
Power Rating	4.8 KW
Charge time	3 Hour
Discharge time	8 Hours
Motor Speed	3000 rpm
Number of Cycles	4000 cycles
Peak Torque	18 N-m

3.7.2 Sensor Specifications

HD Camera with HDMI port	5 MP
Ultra-sound sensor	6 m
Encoder Resolution	32 bit
Storage Device	16 Gb
Working Voltage	5V

3.7.3 Mechanical

Maximum Speed	15 Km/hr
Braking Distance	4 m
Turning Radius	4 m
Vehicle Weight	<250 kg

3.8 Assessment of production feasibility

Economic feasibility

1. To make the product affordable, a camera is being used instead of Radar and LIDAR
2. Individual elements of system are chosen in a way that they are both operational and cost efficient
3. As the sensors used are less number, are of lower cost and chosen in such a way that vehicle is build according to SAE standards which ensures safety and way that they are durable the maintenance cost is lowered

Technical feasibility

1. A Raspberry pi 3 is used as controller which fulfils following constrains: fast processing with low time lag, easy to program and also is low in cost in comparison to others
2. Precision in steerability is taken care with help of servo motor with high accuracy and precision value
3. Dead reckoning is taken care of with help of Kalmann filters
4. Effective battery management system is ensured by:
    i. Proper wiring and insulation
    ii. Efficient motor driver

Phase 3

Chapter 4

4.1 Extended Product Architecture

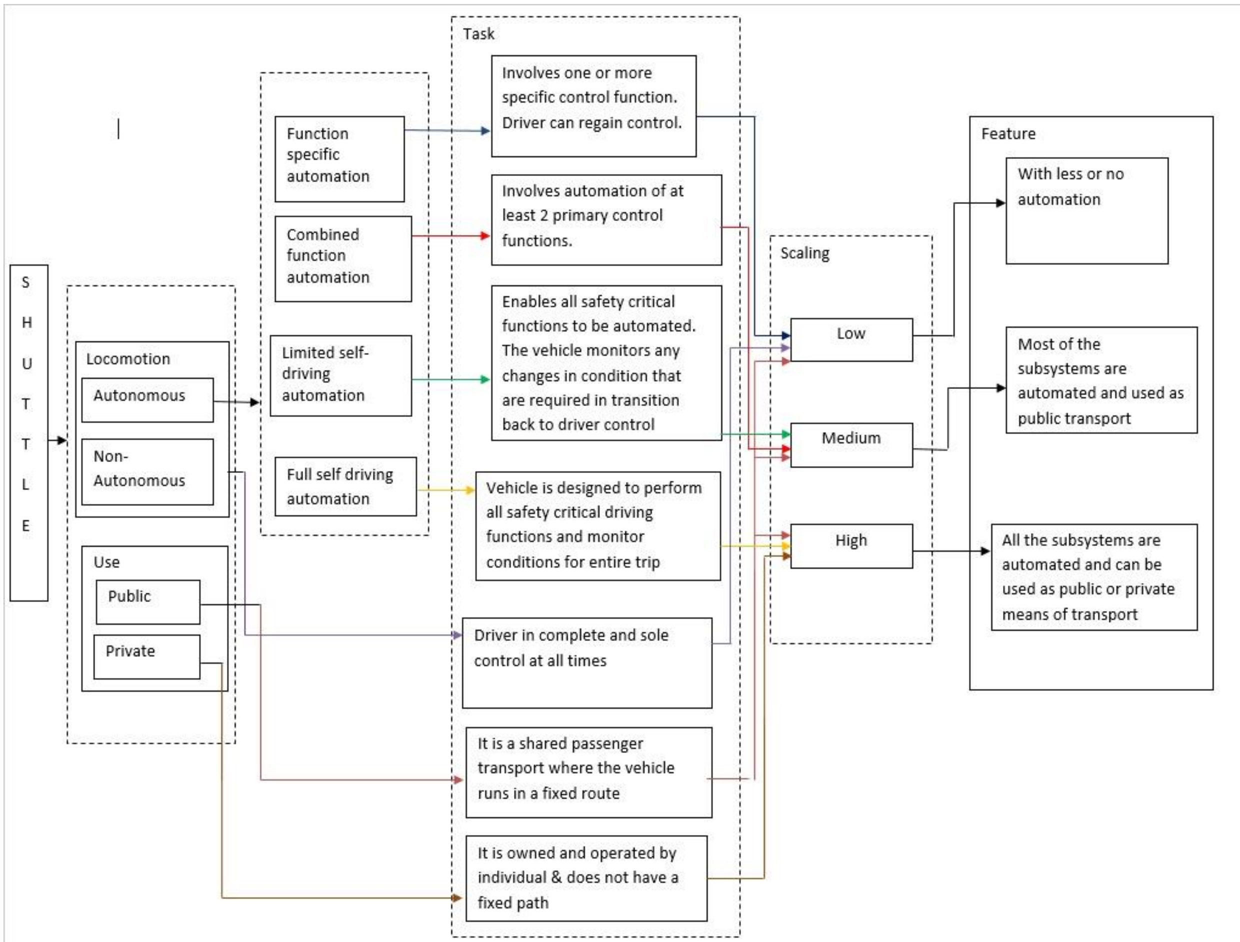


Fig 4.1.1 Extended Product Architecture

4.2 Alternate Architecture

4.2.1 Alternate Architecture 1:

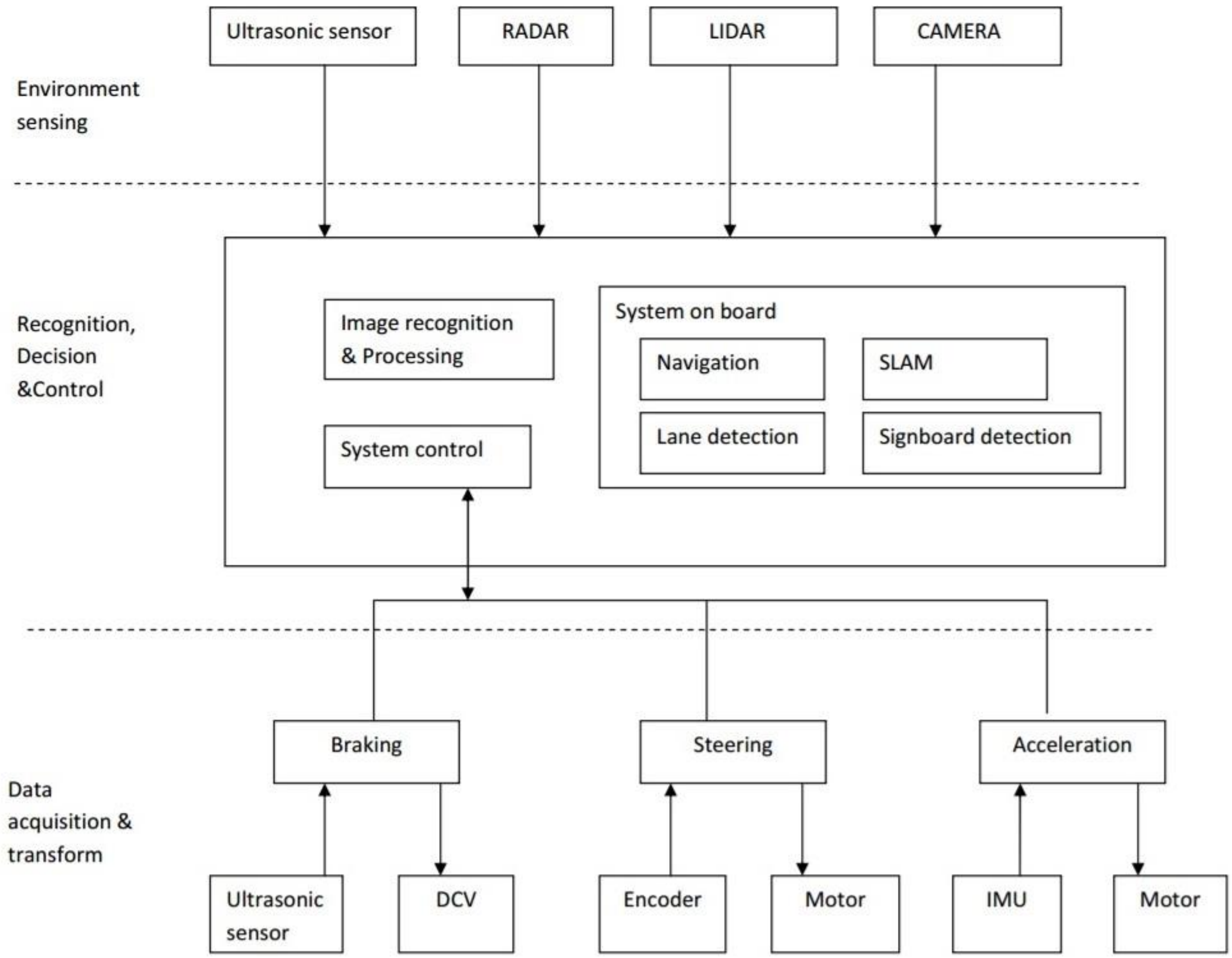


Fig. 4.2.1.1 Alternate Architecture 1

4.2.2 Alternate Architecture 2:

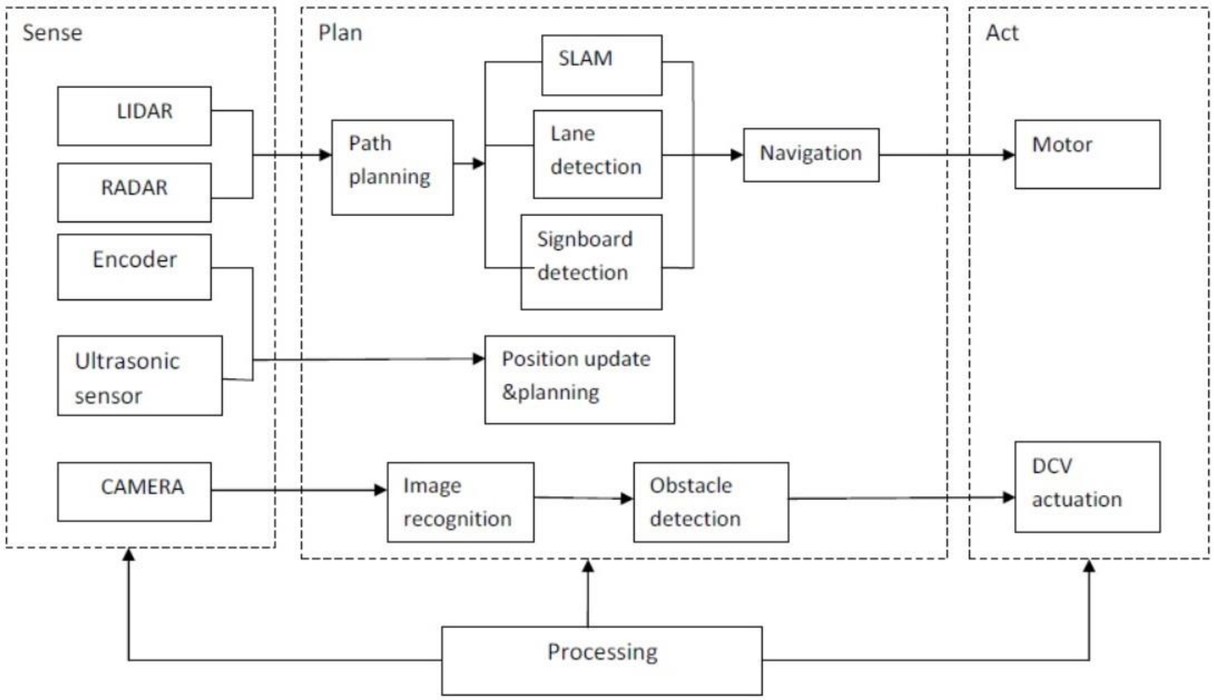


Fig 4.2.2.1 Alternate Architecture 2

4.3 Major subsystems

4.3.1 Path planning:

Path planning is considered as a significantly important part in creating the path network and thus to be a necessary task for any autonomous vehicle system. It is a method where in different paths to reach the final destinations are identified and the shortest is chosen and followed. With help of appropriate sensors, the vehicle should be able to follow the path decided.

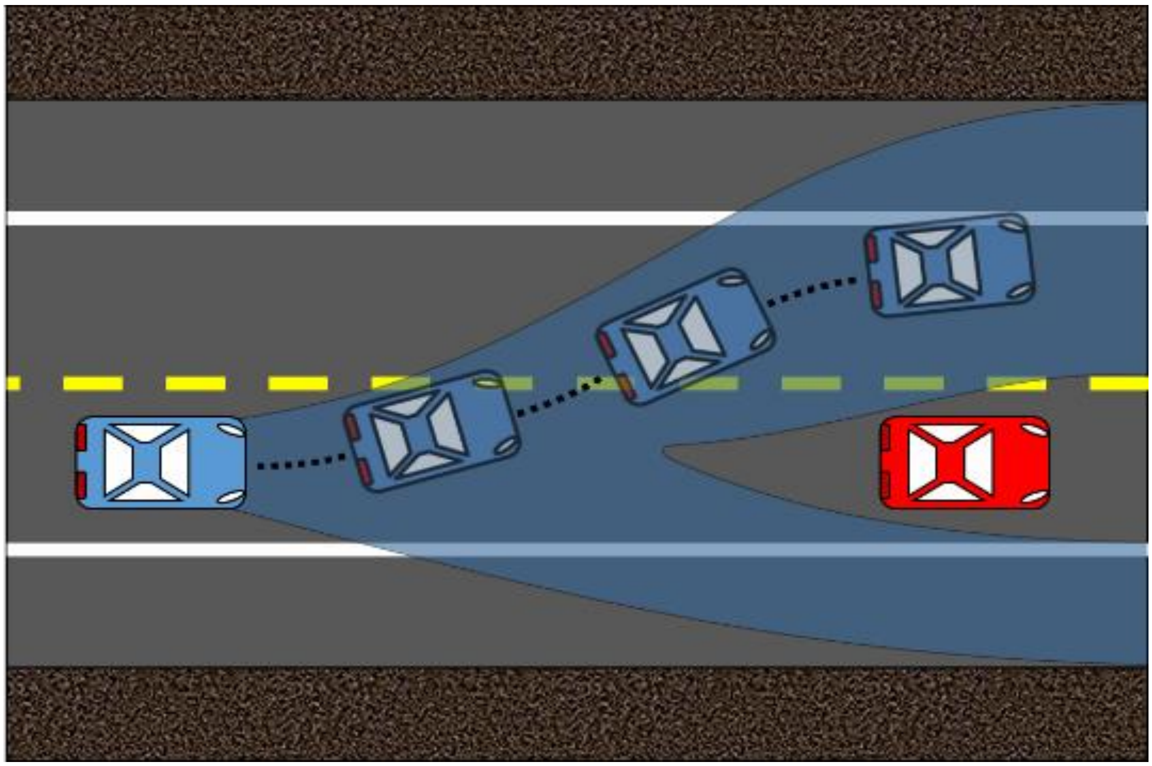


Fig 4.3.1.1 Path Planning

4.3.2 Sensing:

The autonomous vehicle consists of various sensors and the data from these sensors should be combined in order to know the surrounding environment and the system functioning. The sensor types include following:

GPS: This system helps the autonomous vehicle to localize itself by inertial updates and a global position estimate at high rates. GPS has slow update rate thus too slow for providing for real time system. The IMU and GPS combined together provide accurate and real-time updates for vehicle localization.

Camera: Cameras are generally used for object recognition, object detection task, such as lane detection, pedestrian detection. The camera should have free rotational movement so it can track objects in front and behind and both sides of vehicle.

Range sensor: These are vital when it comes to taking care of the worst-case scenario. Suppose, there are any undetected obstacles due to lag in the overall system computations, this subsystem shall come in handy. Here any minor/major obstacle that may obstruct smooth movement of the vehicle will be sensed by maintaining appropriate distance from the said obstacle.

4.3.3 Localization:

This is nothing but knowing the vehicles' position in its field of operation. This is achieved by means of setting milestones or say landmarks appropriately. This is done on first layer basis by taking inputs from basic sensors such as range sensor and from the camera with a more sophisticated approach.

4.3.4 Kinematic Modelling:

Sensor data is useless unless the kinematics of the vehicle or the system it is integrated with is considered. This ensures that all the data regarding the hardware or say actual working of the system is fed to the cognitive subsystem for efficient implementation of our objective.

4.3.5 Cognition:

Cognition is a process in which the person understands the information about the external object or phenomenon in response to the influence of acquired memory, knowledge and experience. To incorporate this feature in the vehicle first different situations that the vehicle can come across are listed according to which different reactions for the same are programmed in the system.

4.3.6 Vehicle Control:

For any vehicle to be controlled three vital subsystems need to be taken care of viz. accelerate, decelerate and steer, for movement of the vehicle. Hence, to make the vehicle autonomous, automation of these three systems is a must.

Steering is automated by designing a quickner-like arrangement powered by a servo motor whose feedback will be used to ensure desired movement of the rack in existing rack and pinion arrangement.

Braking is a hydraulic system. This is made autonomous by making changes to just the way how brake pedalling is carried out. A mechanical leverage is designed to make sure that braking is carried out using an electrical signal as input.

Accelerating is easy of the three subsystems as motor used to power the vehicle happens to be an electric driven motor which is controlled by means of a controller which accepts analog values. Hence, this is directly taken care by directly providing the motor controller with input from our main controller.

4.3.7 Battery Management System

We will be working with a high capacity battery of 48V, hence few precautions regarding pertaining to its usage is to be care of. We will be using 4 different voltage levels viz. 5V, 12V, 24V and 48V. This sub-system will ensure that no heating takes place and also seeing to it that individual component needs are met.

4.4 Interfaces

4.4.1 Hardware Interface:

Hardware of different type viz. active-passive, analogue-digital, and working is used to make the system work. We need to make them work in synchronous with one another to make sure that the whole system functions properly.

The microprocessor is connected to various input and output devices. The range sensor is connected to the processor in order to ensure that. The camera provides the processor with visual data from the surrounding in form of video.

4.4.2 Software Interface:

Image processing by means of video processing will be implemented by using OpenCV by using to Python as a language for programming. Other important task such as controlling the actuators and taking feedback from other peripheral sensors is done by the same software which will also be the cognitive system.

An algorithm will be designed and implemented such that all the parameters of the vehicles are monitored and kept in check and ensure that the vehicle reaches the destination. The flow of this algorithm should be as smooth as possible.

4.4.3 Data Interface:

Tremendous amounts of data will be collected simultaneously from the sensors set up on the vehicle, thus managing this data wisely to reap out its benefits becomes very much vital in the most efficient way possible.

The data will flow from the camera serially on the USB port of the microprocessor. The encoders will keep updating the positional code on the disc to the digital I/O ports of the system. Range sensors can't be ignored as well they will keep updating if there is any obstacle detected in the blind spot.

4.5Suppliers for key components

Component	Supplier
Microprocessor	Robokits
Encoders	Robokits
Motor (Steering)	Robokits
Camera	eBay
Lead-acid Battery	Local market
DCV	Local Market
GPS module	Robokits

4.6Make-buy analysis

Make

Component	Method	Material	Cost (INR)
Brake Extension	Welding/Metal cutting	AISI 1018	100
Gear	Metal cutting	AISI 1018	2500
Sensor supports	Welding	Steel/Fibre	500
Encoder fitting	Clamps	AISI 1018	200
Steel Core	Lathe Machining	AISI 1018	150

Buy

Components	Name	Cost
Steering Servo motor	Rhino RMCS22	2400
Camera	LOGITECH 930E	8450
DCV	Bosch 3 WE 6 AA 6XEG24K4	-
Battery	Exide	1500
Encoder Sensor	QRD1114	130
Controller	Raspberry pi model 3	3800
GPS	ROBOKITS GPS 02	1500
Gears	Custom made	2000 approx.
Ultrasound sensors	Ultrasonic Range Finder - LV-MaxSonar-EZ1	2100 per pc

Phase 4

Chapter 5

5.1 Marketing Plan

5.1.1 Target Customers

On a broader prospect, the autonomous car would be an end product to every individual who wishes to roam around in a particular environment without having to face the pains of driving around. However, considering the various standards and rules set by government, our customer would be brought down to just the people with private properties who wish to enjoy the perks of having an autonomous shuttle to loiter around.

Let's see our customers with respect to various prospects which are:

Demographic: This segmentation is based on the age, gender and various individual aspects of the individual using the product. Our customers would have no gender classifications however our product would need an individual of minimum 12-15 years considering the ergonomic characteristics of the car. Other than that, every other user can find his needs satisfied in the product.

Psychographic profile: This concerns with the interests and customer expectations, their precise wants and needs as they relate to the products and/or services we offer. All our customer will be looking in the shuttle would be the ergonomic comfort we have on offer along with the price we quote with NO compromise with safety whatsoever.

Cost needs are aptly addressed by placing the price reasonably low if we consider other competitors in the market.

5.1.2 Unique selling proposition:

A unique selling proposition or otherwise known as USP (unique selling point), is a factor that a business has that makes it different and or better than others out there. It makes a business stand out from the rest in a market. ***Your Safety, Our Responsibility.***

5.1.3 Pricing and Positioning strategy: This is quite a relative aspect considering every other parameter in the marketing plans and analysis. The pricing and products position in the market will be more dependent on fellow competitors. In our case, it's a widely researched topic through the world. Different techniques are used to achieve the same objective as that of our product, varying the costs that the respective companies incur. For example, it is well known that Lidars and Radars in conjunction with other capable range sensors have been employed in building autonomous cars. These sensors come with huge prices, however using them makes it easier to achieve the objective. We are using cameras and machine learning which reduces the cost of the product drastically. Considering that, our product would be adequately placed in the market as far as pricing is concerned. This part of marketing effort is already accomplished in the design and working of our unique product.

5.1.4 Marketing materials

We will be only printing brochures for marketing of our product when we launch our product.

5.2 Define Part Geometry

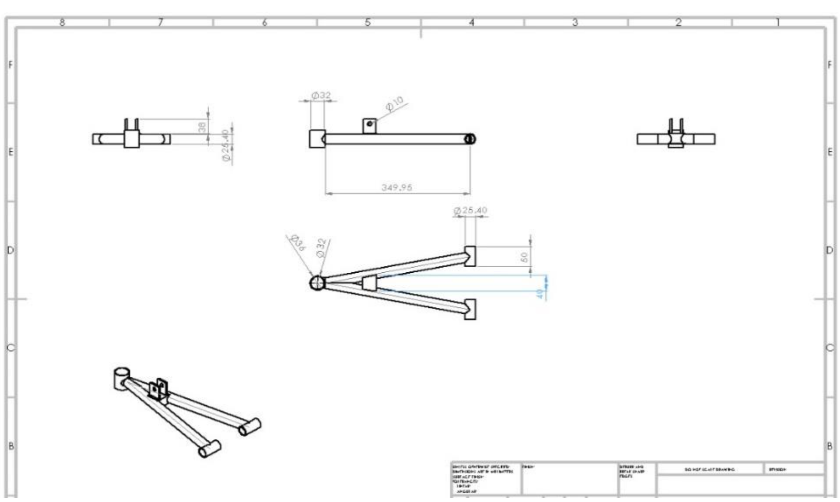


Fig 5.2.1 A ARM 2D Drawing

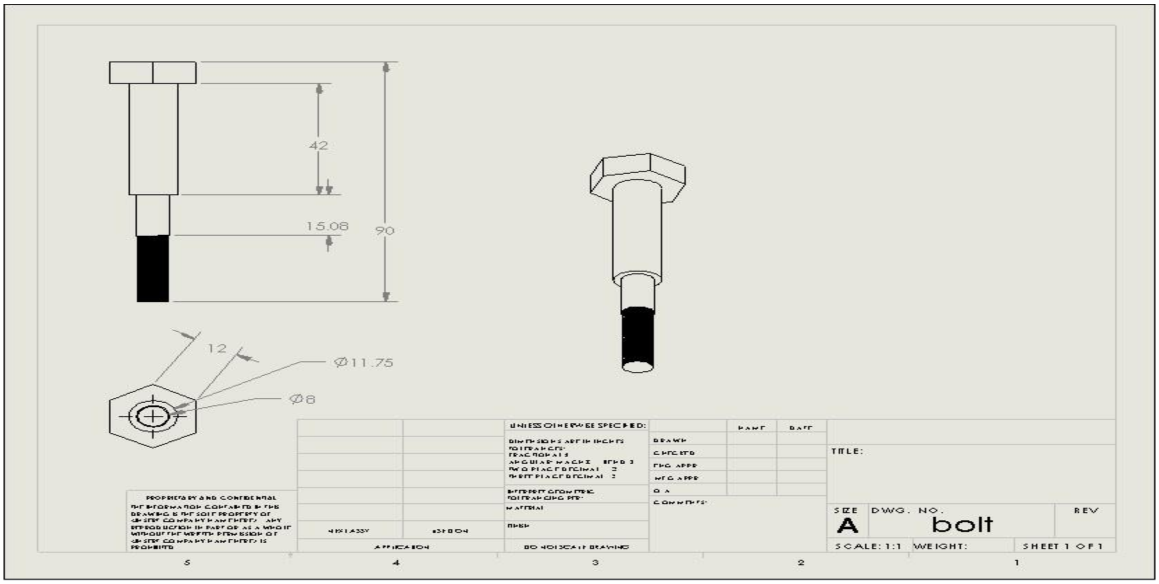


Fig 5.2.2 Hexagonal Bolt 2D Drawing

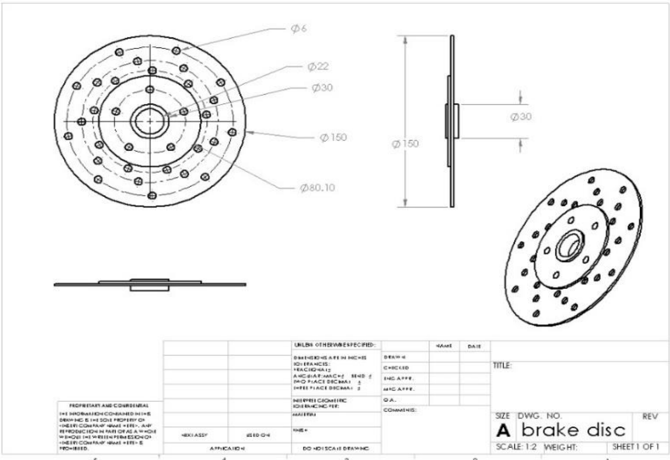


Fig 5.2.3 Brake Rotor 2D Drawing

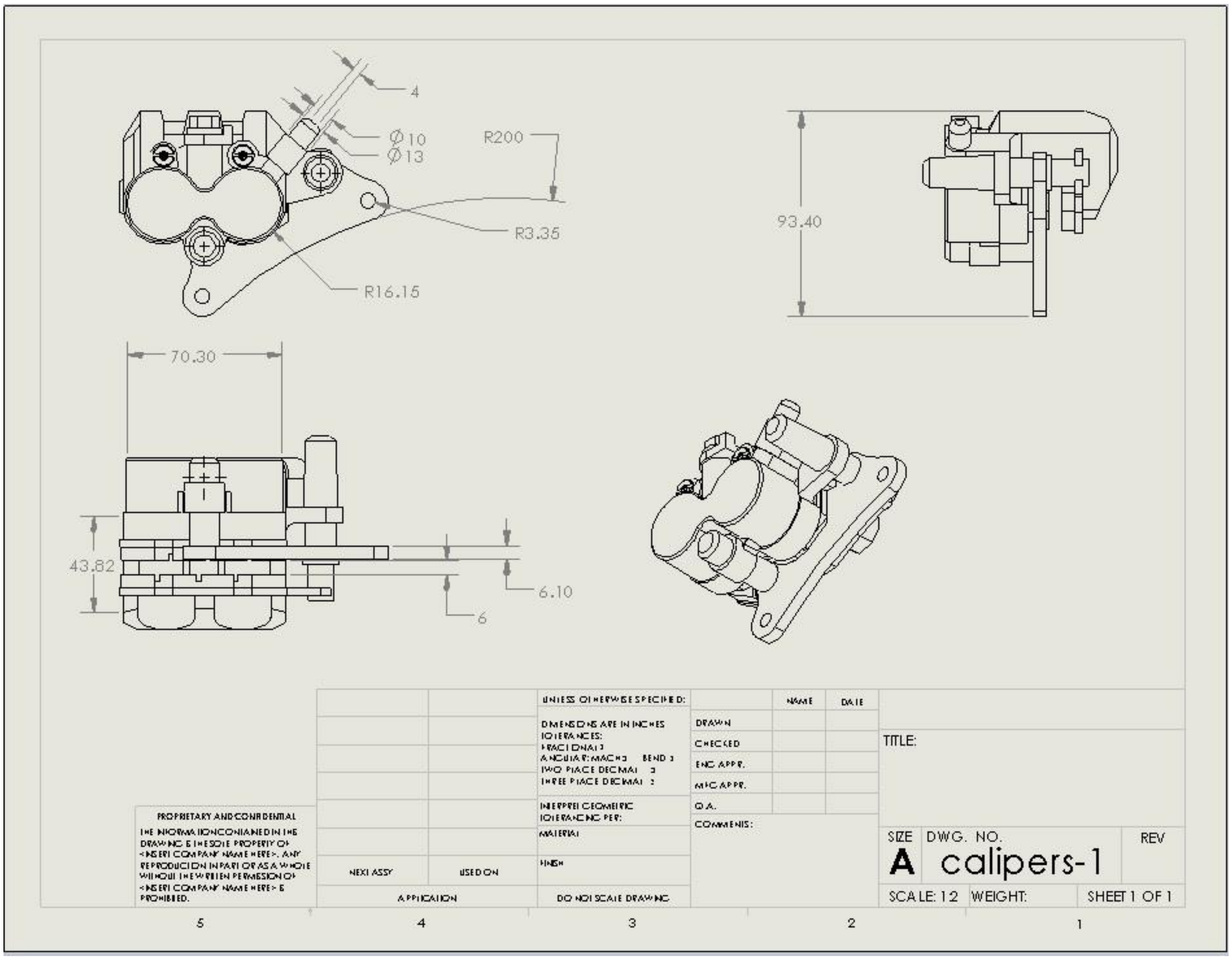


Fig 5.2.4 Brake Caliper 2D drawing

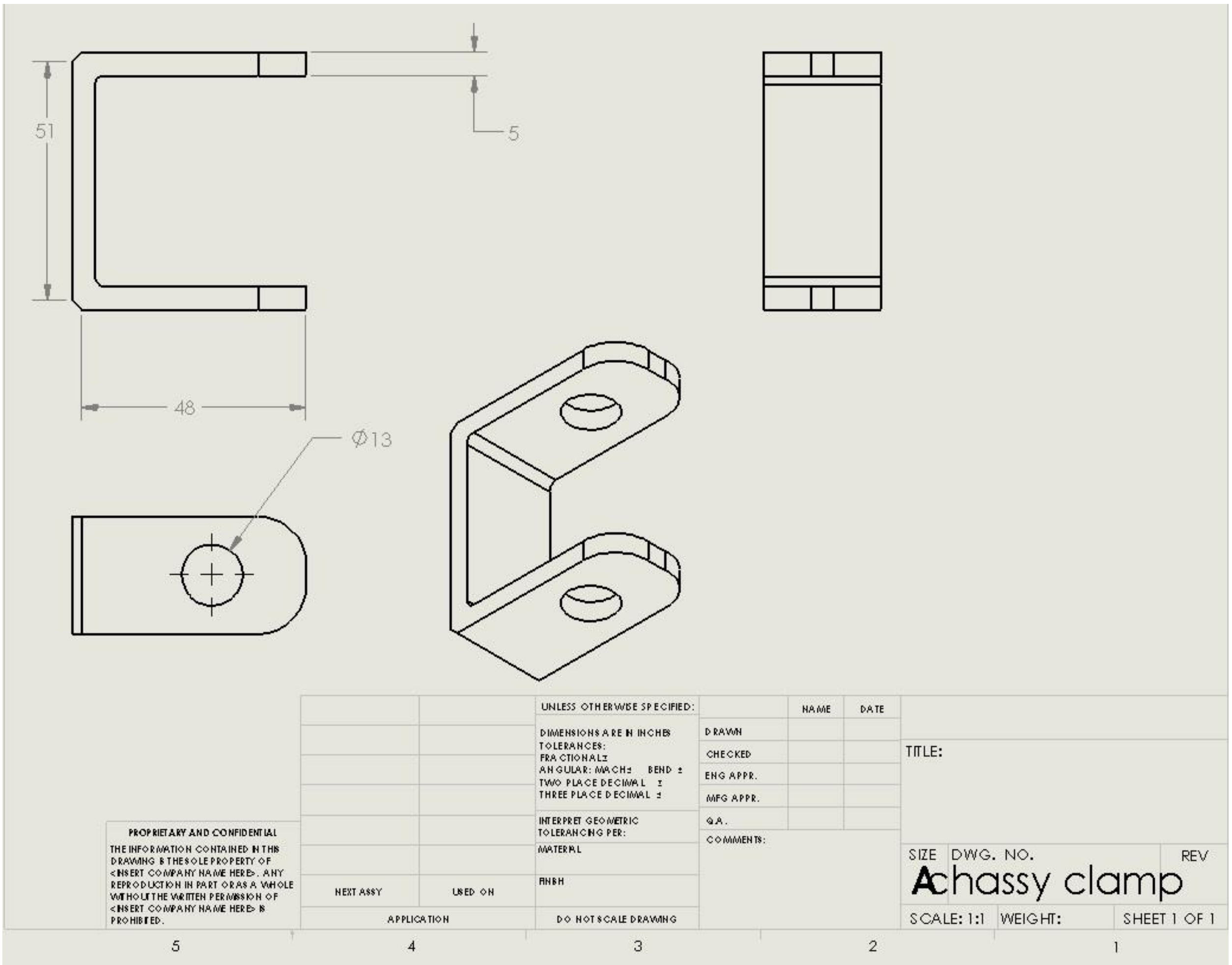


Fig 5.2.5 Chassis Clamp 2D Drawing

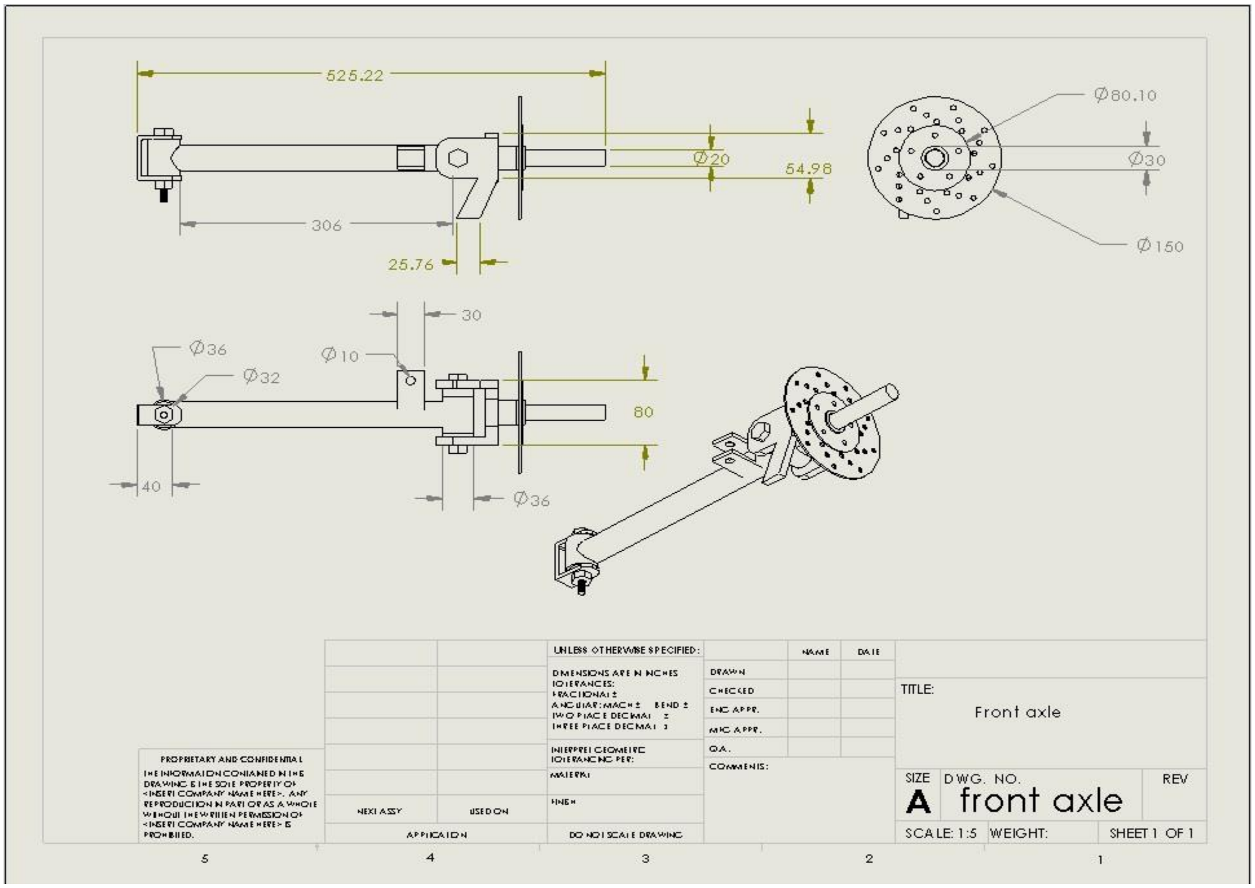


Fig 5.2.6 Front Axle 2D Drawing

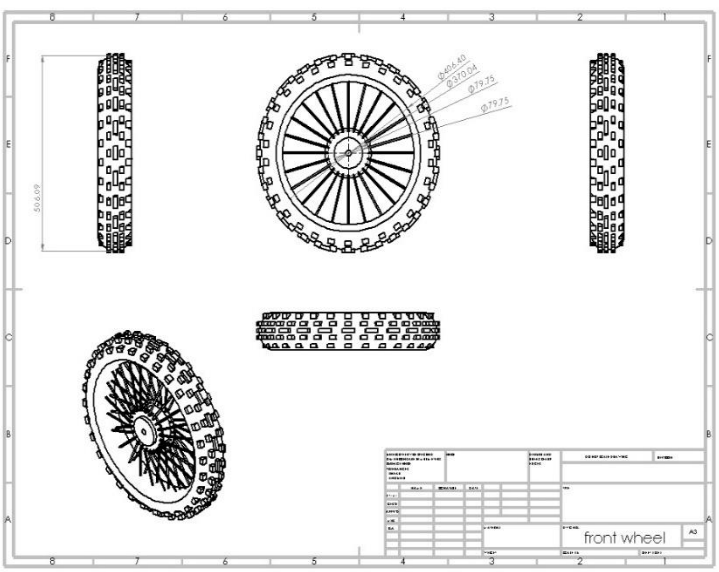


Fig 5.2.7 Front Wheel 2D drawing

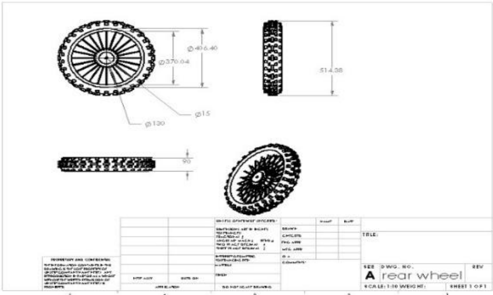


Fig 5.2.8 Rear Wheel 2D Drawing

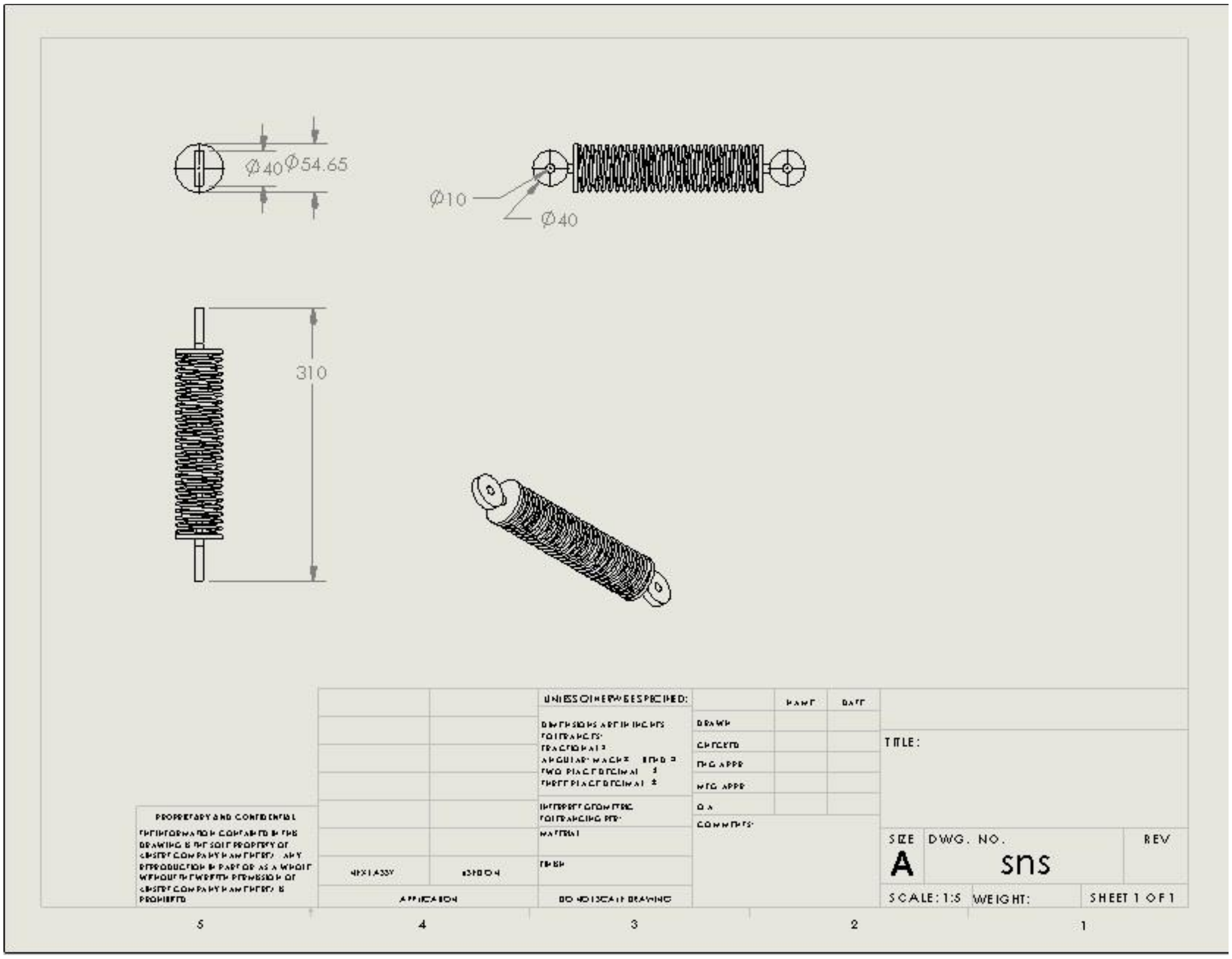


Fig 5.2.9 Springs 2D plot

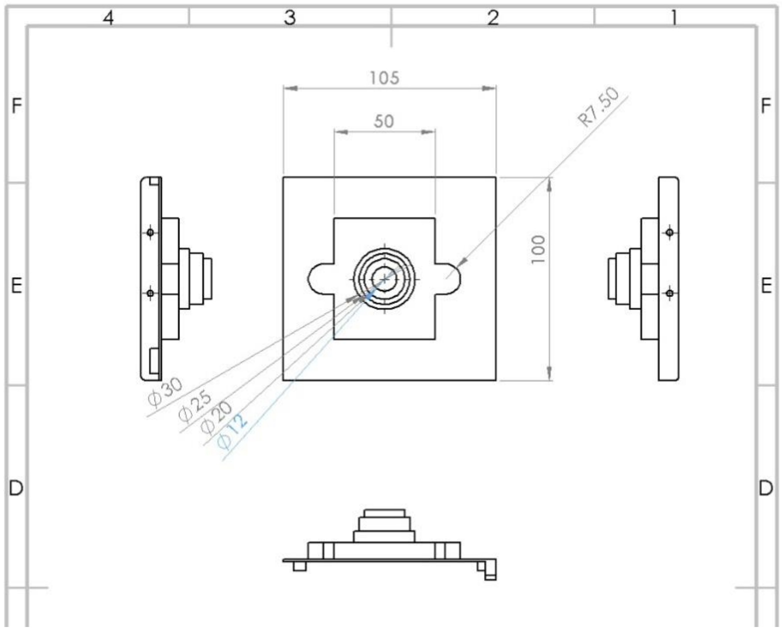


Fig 5.2.10 Camera

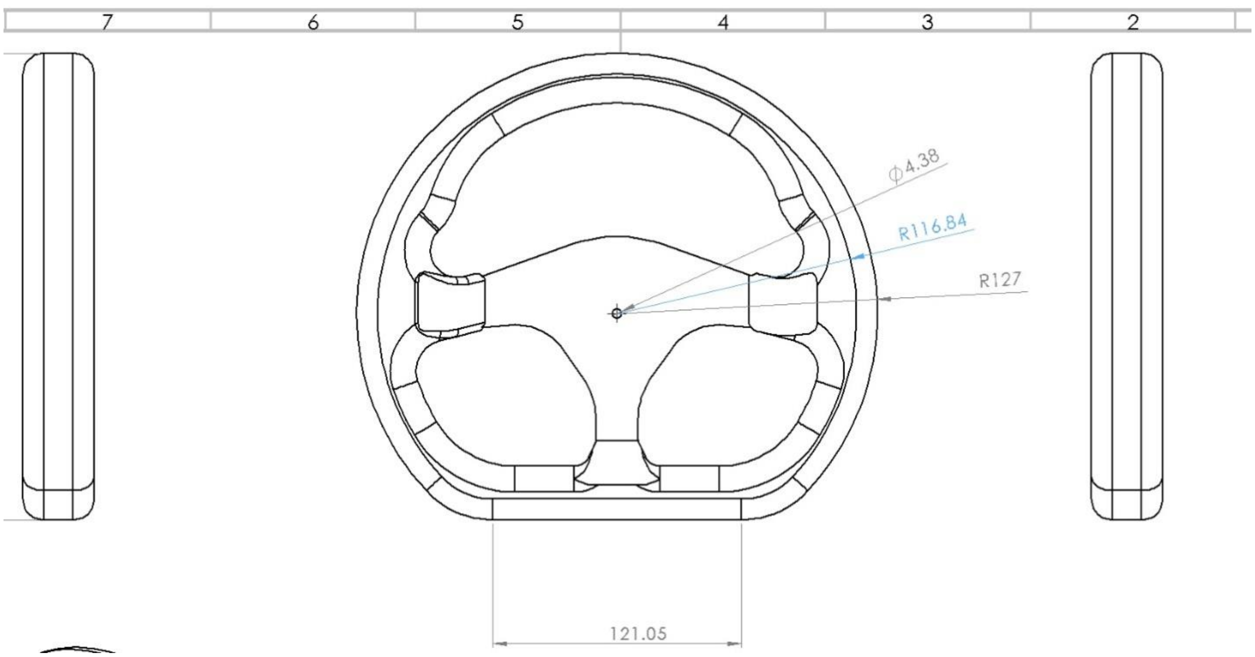


Fig 5.2.11 Steering Wheel 2D Drawing

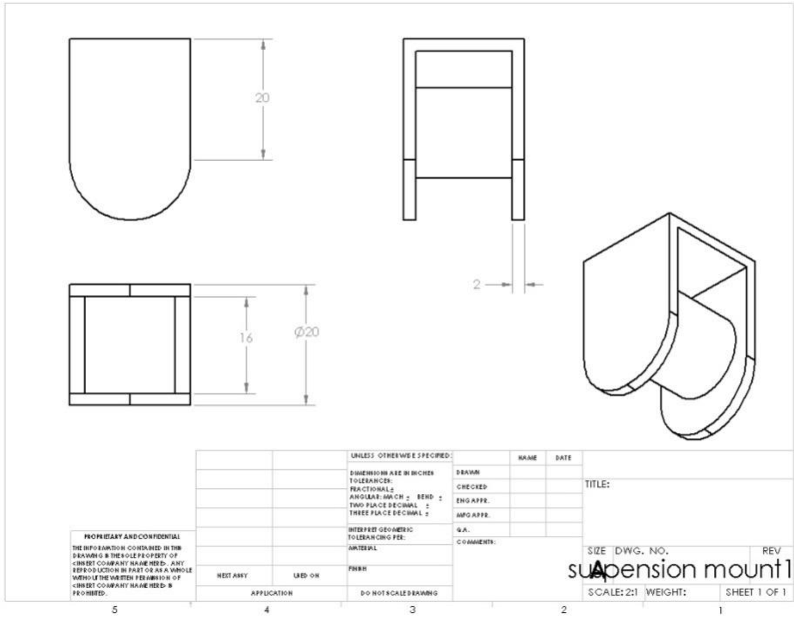


Fig 5.2.12 Suspension Mountings 2D Drawing

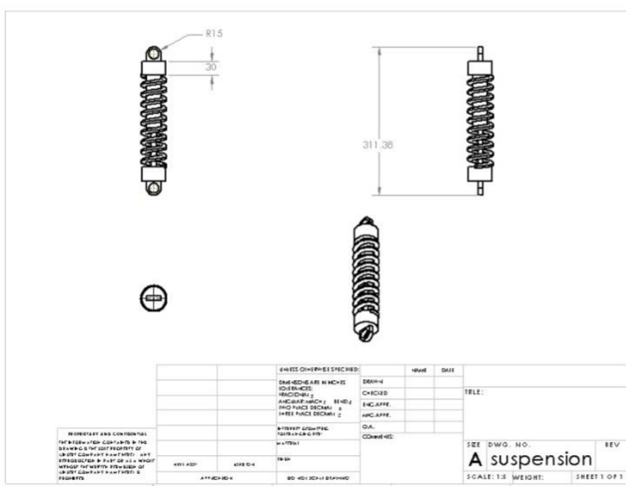


Fig 5.2.13 Struts 2D Drawing

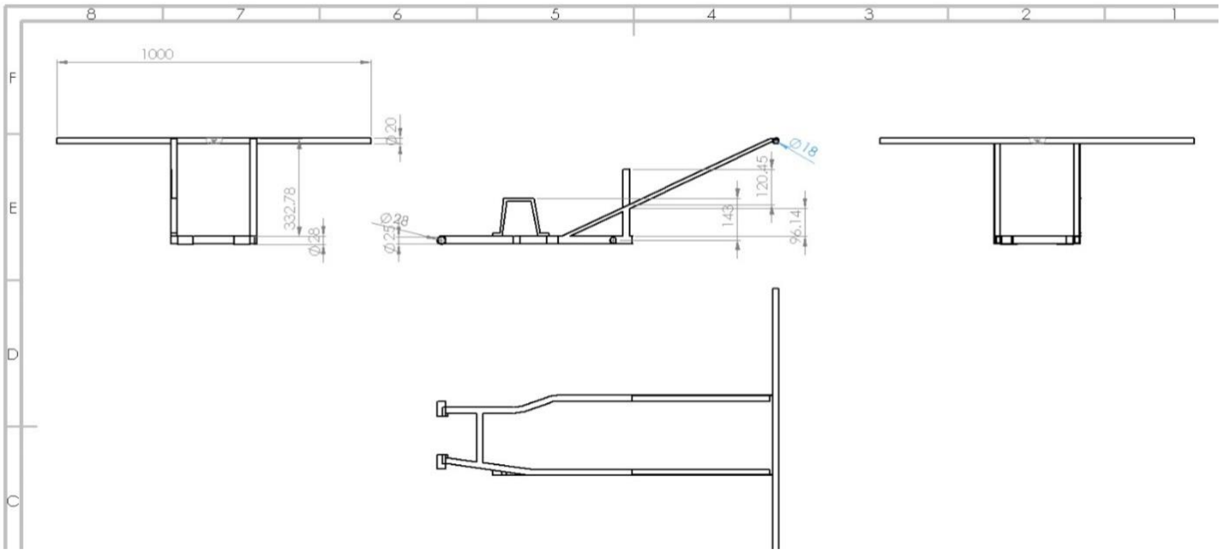


Fig 5.2.14 Swing Arm 2D Drawing

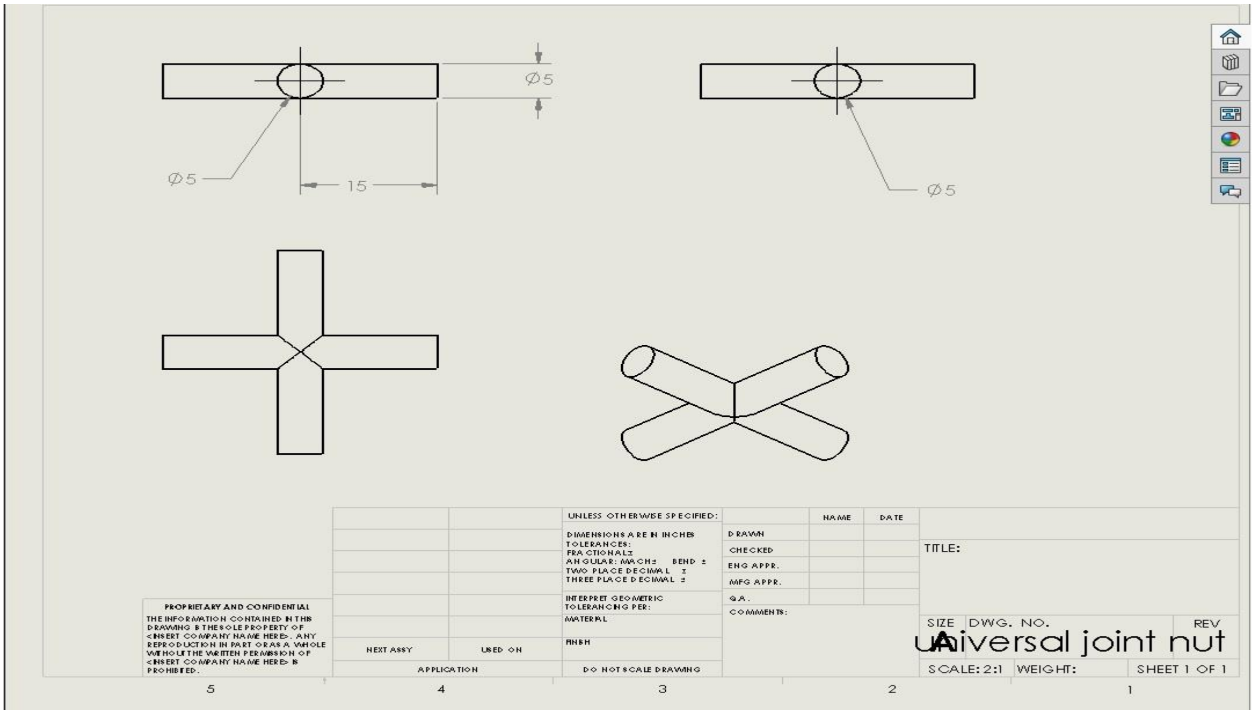


Fig 5.2.15 Universal Joint Nut 2D Drawing

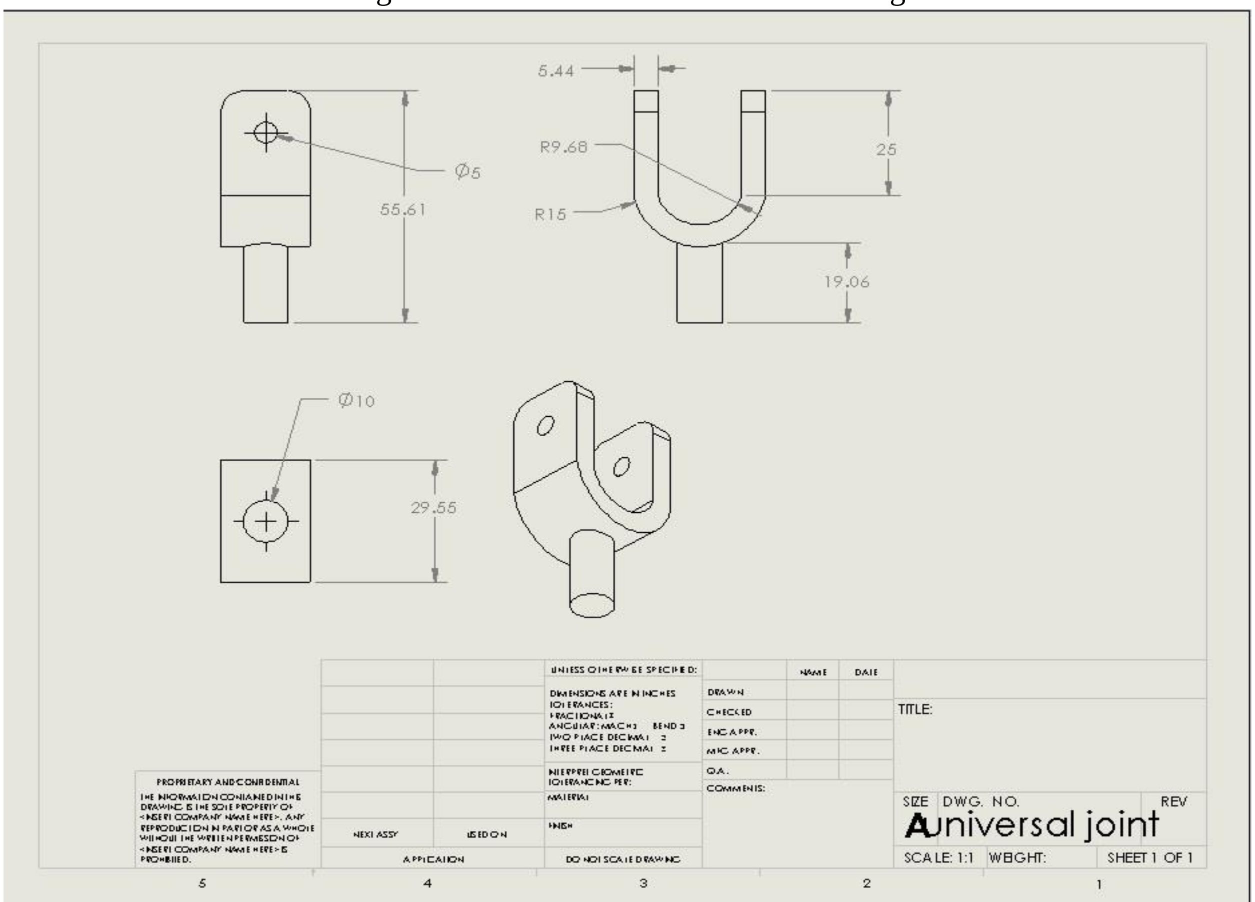


Fig 5.2.16 Universal Joint 2D Drawing

5.3 Design for X

Design for Manufacturability (DFM) {SolidWorks}

Suspension Arm - Front

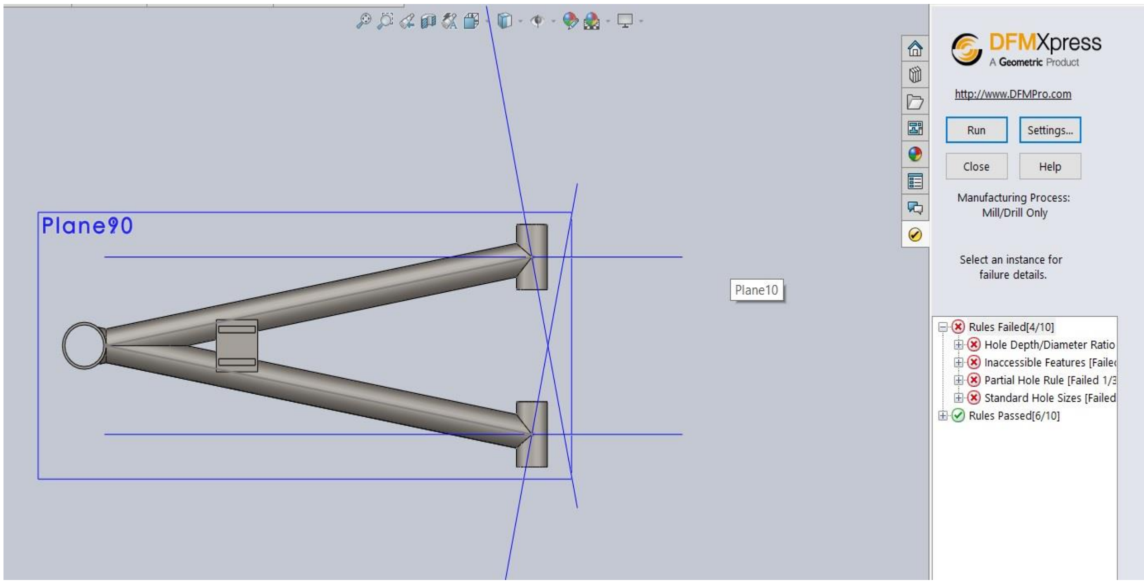


Fig 5.3.1 A Arms

Bolt

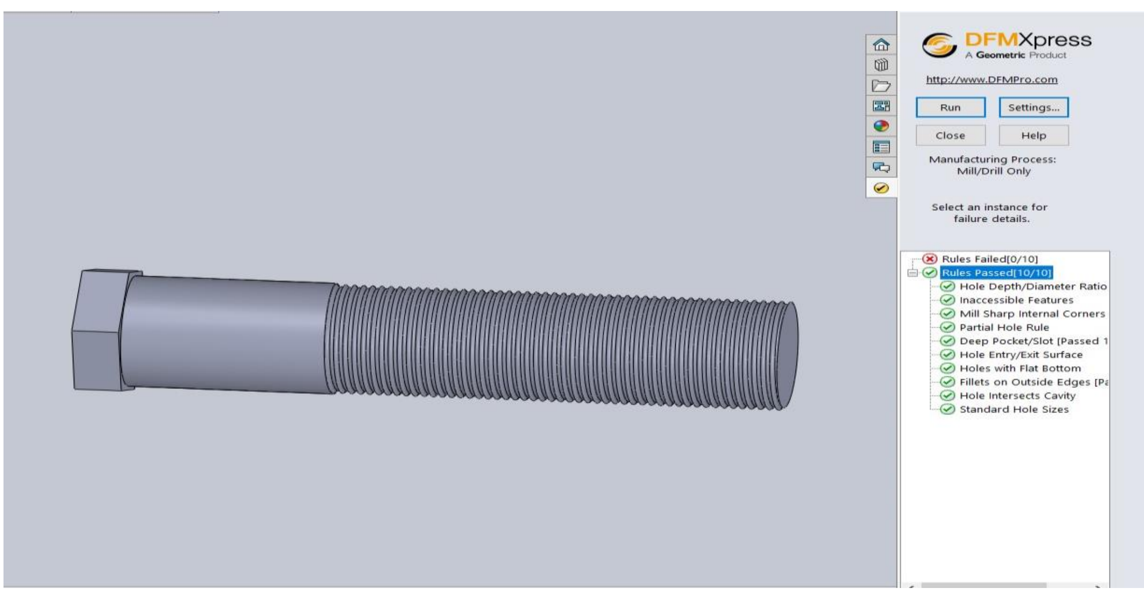


Fig 5.3.2 Hexagonal Bolt

Chassis

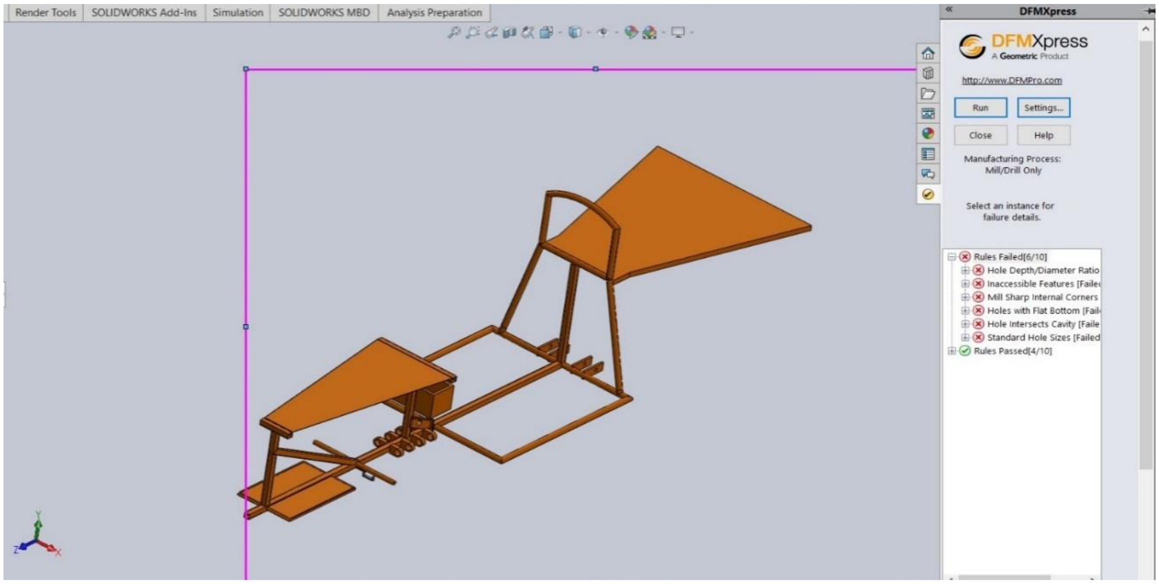


Fig 5.3.3 Chassis

Motor End Gear

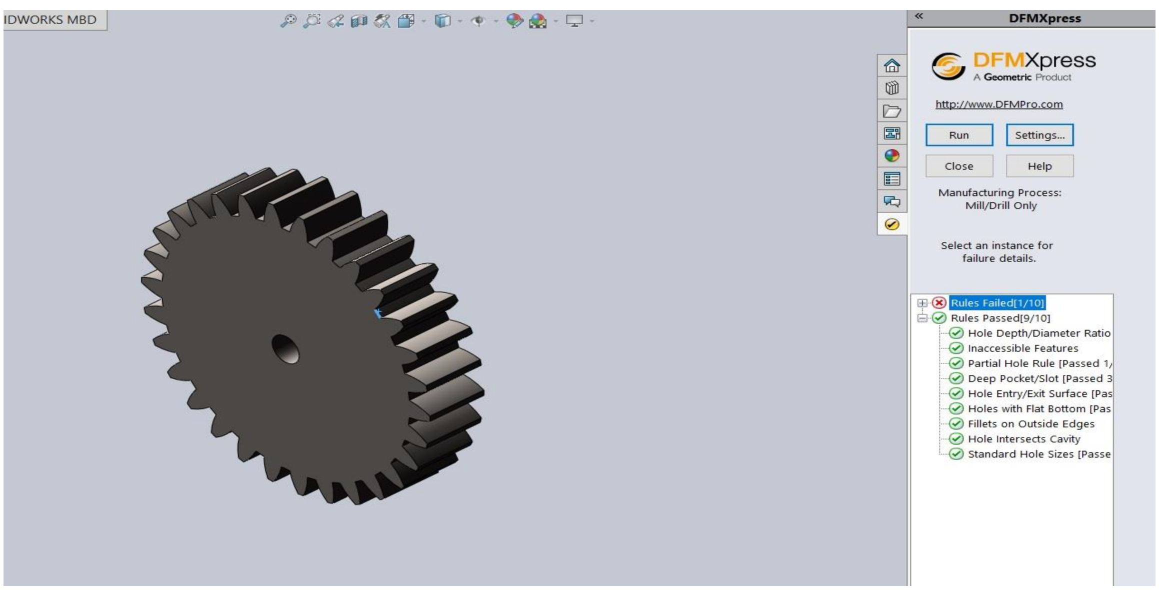
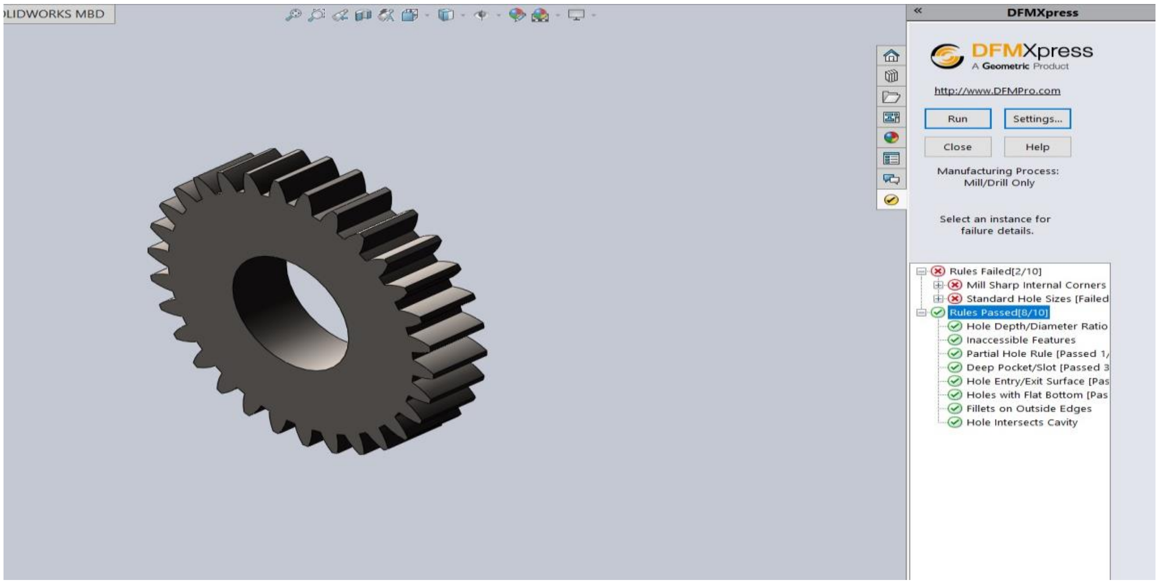


Fig 5.3.4 Driving Gear

Steering column end gear



5.3.5 Driven Gear

Nut

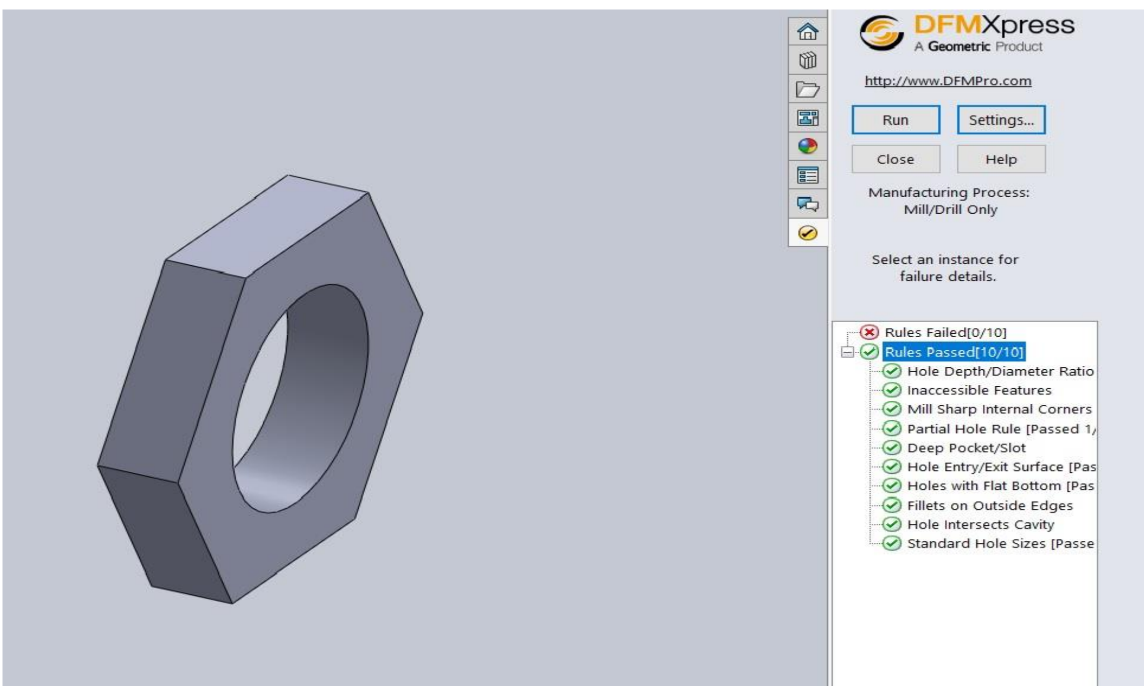


Fig. 5.3.6 Hexagonal Nut

Strut

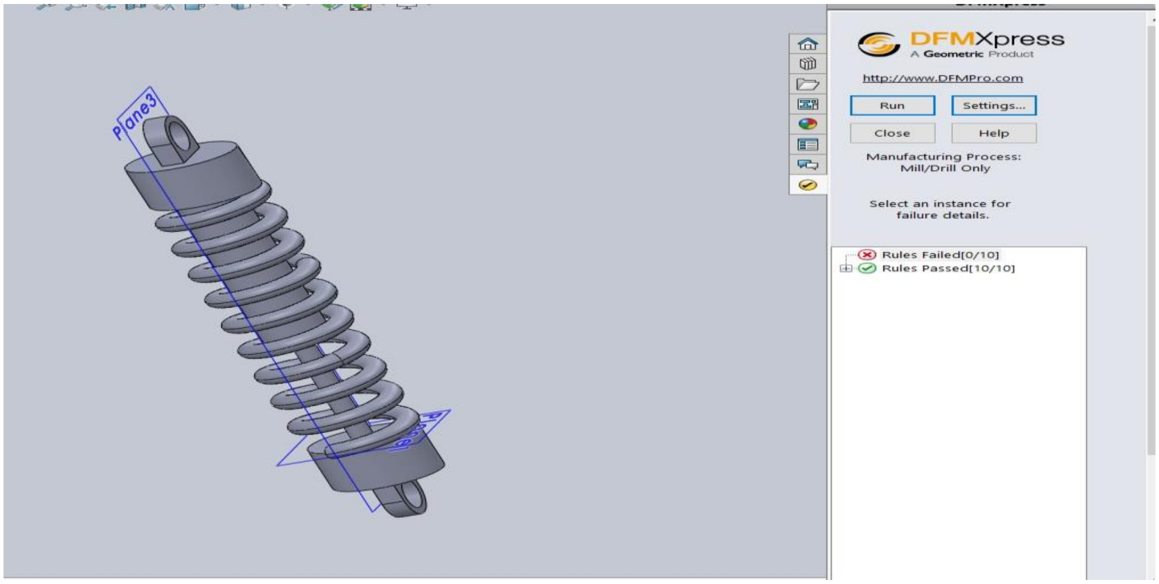


Fig. 5.3.7 Strut

Swing Arm

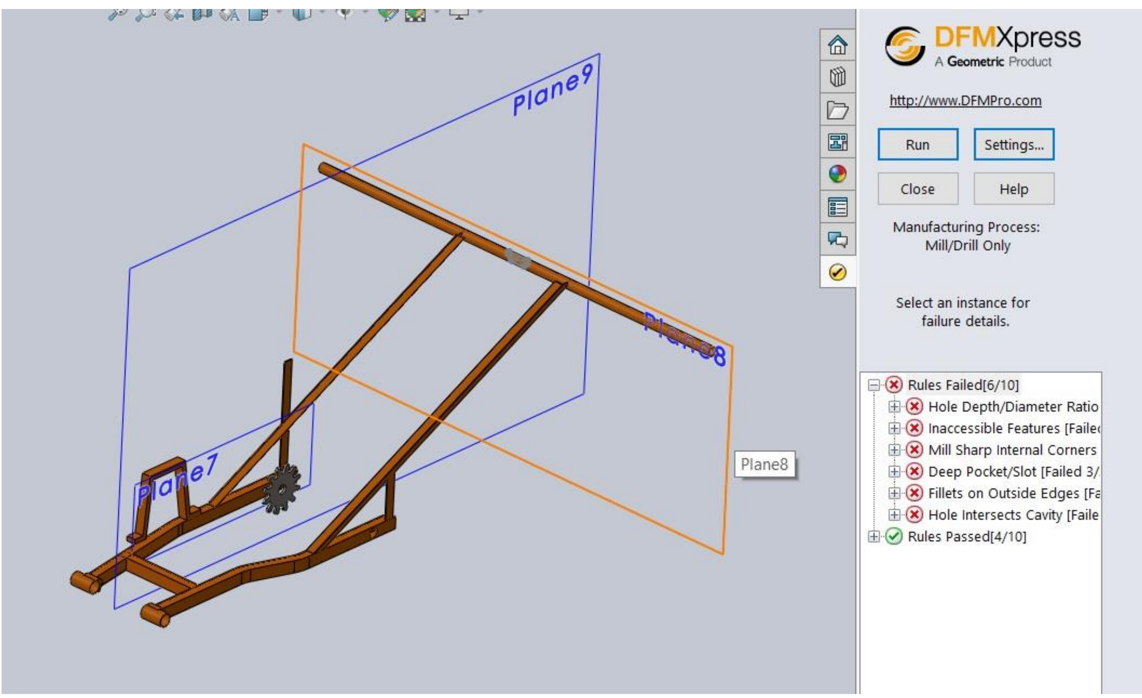
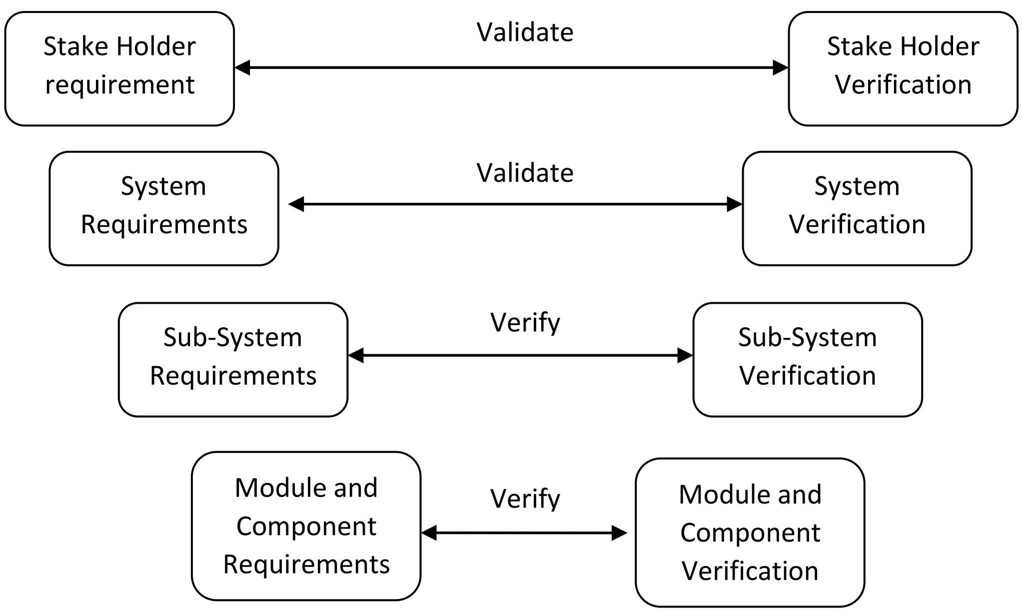


Fig. 5.3.8 Swing Arm

5.4 Industrial design control documentation:

Validation Model



5.4.1 Module and Component

1. Motor is tested by giving a load more than the load it would be required to handle. This is ensures that apt factor is safety is maintained.
2. Camera module is tested under varied lighting conditions. This ensures that there is best visibility in any situations.
3. There shouldn’t be any mating problems after fabrication of gears; this is ensured by designing spur gear mechanism.
4. High range sensors are selected with accuracy and best possible resolution.

5.4.2 Sub-System

Braking

1. It is required to stop the vehicle within a reasonable time from the time of actuations of the system. This is achieved through an affective and practical stopping distance of about 4m which verifies that the requirement is met.
2. The vehicle should be jerk free. This requirement is verified by providing a system where the vehicle showcases a linear braking output.
3. There shouldn’t be any skid and due system failures, which in turn is again verified through a braking wherein locking is ensured at proper timing only.

Steering

1. The vehicle should steer itself. This is ensured by designing an autonomous steering system which shall ensure this requirement.
2. Least possible load on the driving motor, this is achieved by designing a gear mechanism which shall ensure that by having a ratio of 2:1.
3. It shouldn’t take much time for the vehicle to take a turn this ensure by setting a steering system with only 2 end to end rotation of the column.

Perception

1. All the ambient data should be aptly collected and adequately represented. This is ensured by selecting the best quality sensors.
2. A camera with highest possible resolution with an adequate shutter speed has been selected.
3. The vehicle shouldn’t hit any obstacle, be it an asset or a living entity, this is ensure by installing ultrasonic range sensors capable of detecting the obstacle at a prescribed distance thus ensuring this requirement.

Processing

1. The vehicle should respond simultaneously and aptly respond to all possible environmental and ambient conditions, this can only be ensured by selecting a processor capable of handling multiple computations. This is done.
2. A controller board must have enough peripherals to support the sensors to be used. Raspberry Pi supports the same.
3. The processor should not have any kind of lags like processing lag, graphics lag and storage lag.
4. The processor should be checked for noise levels and magnetics fields before placing the controller in its location.
5. The processor should not malfunction because of noise or magnetic fields.

Wiring

1. All grounds are shorted so that short circuits are minimized.
2. Colour codes are maintained while wiring.
3. Jumper wires are used to connect sensors with controller so that loose contacts are avoided.
4. High DC current lines should not pass by sensors.
5. Wire ties should be used to bind the wires.
6. Live wires should properly be insulated so that contact with the vehicle is avoided.
7. Proper power sources are kept at proper locations.
8. High current sucking devices like motors should be kept away from controller.
9. Proper heat dissipation should be provided.
10. Proper enclosure should be provided for the controller.

Chapter 6

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Chapter 7

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