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**College of Engineering**

**Department of Mechanical Engineering**

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## **Senior Design Project Report**

### **Design & manufacture a Lightweight vehicle**

**Team Members**

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## **ABSTRACT**

In this modern world the use of vehicles and cars has been part of our daily routine. The vehicles are used to carry people and goods from one place to another in minimum time. There are different types of vehicles depending upon their capacity to be driven on the areas like plain roads and rough roads. Later one vehicles which can be drove in the rough and patchy roads are called off road vehicles. These vehicles are from normal vehicles. Off road vehicles have body which have the ability to have more stability in the hills and desert areas. A number of designed constraints are involved to manufacture this type of vehicle.

This is senior design project which aims to design and fabricate an off road vehicle. The main objective involved to design the roll cage of the vehicle and related components. This was achieved by thorough study of the literature review. Old work was seen and accordingly select the best materials and design variables for the vehicle. The design of the vehicle was prepared in the solid works. Schedules and budgeting was done by preparing plans for the whole project which helped a lot to systematically achieve the goals of the project. A total of 5000 SR was costed on the whole project which makes the project very economical.

## **Acknowledgments**

We are feeling pleasure in paying regards to Dr. Mohamed Elmehdi Saleh for guiding us at every step our work. He worked from day one until the last day to fulfill this project. We have also learnt good research skills from him. Special thanks to our parents, friends, lab fellows and all other well-wishers for their consistent support during.

## List of Acronyms

Abbreviation	Name	Unit
$\sigma_b$	Bending Strength	MPa
$\sigma_y$	Yield Strength	MPa
CAD	Computer added Design	
E	Elastic Modulus	GPa
I	Moment of Inertia	$mm^4$
ID	Inner Diameter	mm
$k_b$	Bending Stiffness	
MQP	Major Qualifying Project	
ORV	Off Road Vehicle	
OD	Outer Diameter	mm
PVC	PolivinyI Chloride	
SAE	Society of Automotive Engineers	
y	Deflection in beam	mm

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# CHAPTER 1: INTRODUCTION

## 1.1 Project Definition

This project is intended to design and fabrication of a reliable and cost effective off road vehicle. This project includes designing and fabrication of chassis of the vehicle and other components will be assembled as according to the international standards and vehicle capability. First of all comprehensive study will be made to design the body of the vehicle and designing of suitable connecting systems which are necessary to be assembled to made an off-road vehicle. The objectives of the project are given in the next section followed by methodology of the project how will be the project will be carried out.

First of all thorough study will be carried out to be familiar with design and manufacturing of the project. The study will help us to know about the previous work as well as new techniques utilized in the modern designing and fabrication of vehicles.

## 1.2 Objectives of the Project

The main objectives of project are enlisted below:

- To design and fabricate an off-road vehicle
- Design of light weight vehicle
- To design a vehicle more stability and reliable driving experience
- Vehicle design must be compatible with the driver
- Maintain the desired center of gravity and safety of the vehicle

## **1.3 Project Specifications**

This section of the project deals with the components and designed constraints of the project.

Following is the short introduction of the components of the vehicle and their working.

### **Components of the Vehicle**

Off-road vehicle consists of the following component systems

1. Body structure
  2. Controls
  3. Engine
  4. The transmission
  5. The auxiliaries
- Body structure consists of the chassis, suspension system, axles and tires.
  - Steering system and braking system of the vehicle are included of the control system of the vehicle.
  - Engine of the vehicle is used to give power to execute the many functions in the vehicle.
  - Transmission systems includes the clutch and gear box mechanism. It is used to transmit the torque to the wheels.
  - Auxiliaries includes the electrical circuits and components like battery.

It is taken care that weight of the vehicle should be minimum and economical vehicle should be designed which less processing cost and low maintenance have cost.

### **Applications**

Off-road vehicles have diverse applications. These may be used according to someone's need and environmental constraints. Some of them are as following

- There are lots of motorsports which includes off-road vehicles. These includes mud racing, desert racing, and rock crawling.
- Off-road vehicles are more common use of transportation in the areas which do not have paved roads and those which are far away from paved roads.
- These are also used on forests and hilly areas.
- These vehicles have also become an entertainment for the people who are fond of adventure. So most of the rich people spend their leisure time by travelling on off-road vehicles. These are also common in the beaches and other vast entertainment places.

## CHAPTER 2: LITERATURE REVIEW

### 2.1 Background

An off road vehicle is the one which is having the ability of driving over the paved and unstable lands. These types of vehicles have different characteristics as compared to ordinary vehicles. These vehicles have big tires, wide treads and have flexible suspension system. Due to the versatility of these vehicles they are becoming more popular in the whole world (Polaris, 2012). Initially they were designed for single person but now with innovation they also have double and triple seats. One of the main design is shown in the figure 1.



Figure 1 Simple off-road vehicle

As it is already mentioned in the previous chapter that off road vehicles has been used for recreational purposes most of the time. For specific use it is been used in the areas which are far away from the highways and proper fine roads. But in the last 50 years the use of off road vehicles for recreational activities has been increasing. Due to the versatility and innovations in the off road vehicles many motorsports have been developed which uses off road vehicle. These sports includes the rock crawling, desert race and mud racing (Krisirne Sowl et al., 2015).

In the west most of the people use it as the recreational activity. Most rich people drove to hilly and paved places which have peace and calm environment. Off road vehicles are also used in the

golf playing fields. As these fields are vast and have large area. Due to unbalanced and bouncy land, most of the people prefer to use off road 4 wheeler.

Although off road vehicles are used as a sport and recreational purposes but they also have some safety concerns. A number of accidents reported which includes injuries to the driver and the vehicles itself. Off road vehicles have bulky body and during curve paths and are on taking turn there are most chances of misbalance. During turn or driving on curve paths the vehicle swings on the outer edge and shifts its weight on the front parts (George B. et al., 2013). So to avoid accidents it is advised that one must drive it at slow speed and the driver must wear helmet. In this project the safety and balancing of the vehicle is main concern and all the efforts would be carried to design a reliable and stable vehicle which will ensure the safety of the driver and the vehicle itself.

Nowadays off road vehicles are mostly used for sports and recreational activities. But the initial development never had the intention of sports or entertainment goals. Somewhere between 1906 to 1916 the first off road vehicle Kegresse track was developed. It was developed and modified by Adolphe Kegresse. He was working in Czar Nicholas II of Russia. This vehicle had flexible belt. If it is used in the conventional cars and vehicles then these might be able to able to drove over rough and patchy paths. Off road vehicles were most common when the WWII was finished. Early time OVRs are jeep and lorries.

Most off road vehicles which are famous today due to their recreational activities were developed in 1960s. Those developed in 1960s were the early editions of the present vehicles. Four wheeled off road vehicles were developed in 1980s. In the west these vehicles gained popularity due to their ability to be able to be used in rough roads. Many western countries have public land fields filled with beauty which attract large number of visitors. So off road vehicles industry grows faster in these countries.

## 2.2 Previous Work

There were lots of related data and projects which had been done. Some were only experimental prototypes which were made for research purposes and others included projects of minor materials like PVC. But the reviews which are being presented here are design projects which includes specially designing of off road vehicles. In the next section we will discuss the comparison of others projects and their properties.

- One of the research team naming Denish S. Mevalwa et al. worked on the designing of the body of the off road vehicle which is called designing of the roll cage. They have designed the roll cage to ensure the safety and loading conditions. They found the performance of the vehicle depends on the roll cage design. Roll cage play crucial role in the aesthetics of the OVR. They conducted series of tests on the vehicle and found it safe and sound and found that up to 4G impact loading the vehicle was within deformation limits (Denish S. Mevawala et al., 2014).
- We found another research paper which was done by Thanneru Raghu Krishna Prasad et al. They designed the suspension system and body system. They worked on light weighting and adjusted the size of the vehicle. They designed the vehicle in such a way that size decrement did not affect the performance of the vehicle of the body. They performed FEA analysis and found all the results within design limits (Thannu Raghu Krishna Prasad et al., 2013).
- Grzegorz Szczesniak et al. discussed various aspects of vehicle production and chassis designs. They dicussed various stages which were necessary to fabricate the vehicle and were necessary to reached the final product. They discussed frame types and other components compatability with suspension system (Grzegorz Szczesniak et al., 2014).
- Nagurbabu Noorvhasha et al. worked on a project and there aim was to design a vehicle for a competition. They worked on design and fabrication of the vehicle. Their final product was

single seated, mini off road vehicle. They followed the designing guidelines of SAE and performed the relevant FAE analysis(Grzegorz Szczesniak et al., 2010).

There were number of projects and research papers which were based on this topic but we cannot write on every one.

### 2.3 Comparative Study

- Shabham S. Kapadne et al. were working on a project and they were working to design the chassis. They picked the design which is closely our design. They done similar design with very confined and little space. We're doing to increase the seating capacity and thus the design will include seating capacity of two people. Following is the Cad model of their chassis design (Shabham S. Kapadne et al., 2019) .

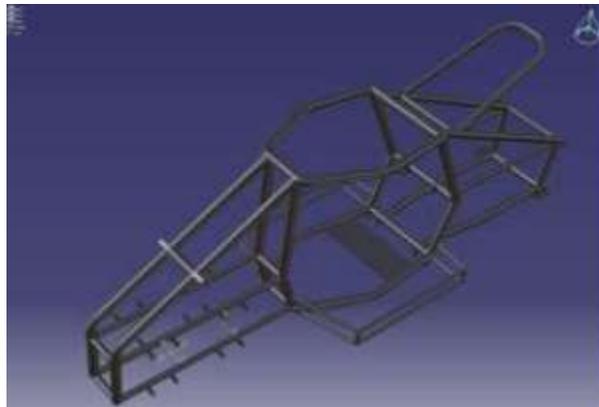


Figure 2 CAD model of Shabham S. Kapadne et al. project

- We came across another project which was competing in SAE Baja MQP. Their aim was to develop a vehicle under the given conditions of the SAE. They took the frame from the some previous models and modified it. They modified the vehicle by using differential wheel design,

manual speed mechanism with five speeds, and double wishbone suspension system. They achieved and modified the systems by using software simulations (Deep Shrivastava, 2014).

The projects presented above includes many features. Most of the research projects includes designing only one or two parts or used to modify only one or two systems. But our aim is to design and modify our vehicle and build it with best resources we have locally and software based knowledge will be implemented to best of our needs.

Next chapter is based on the designing work and it will study the basic systems.

## CHAPTER 3: SYSTEM DESIGN

### 3.1 Design Constraints

Any project which is produced on the research scale, experimental or research scale, it has some parameters which must be fulfilled. For our project some of the design parameters are given below:

- **Safety:** During the designing the chassis it is made clear that some clearance for the passenger and driver must be left. A considerable distance of about 3 inches was left if the driver and passenger wore all the equipment and sit in the car. If driver wore the helmet it has the 6 inches distance from top of the chassis. A considerable seating capacity is provided in the vehicle. These distances might be compromised depending upon the sizes of the passenger.
- **Compactness:** It was our aim to reduce the size of the vehicle by adjusting the components of the vehicle such that they cover minimum area and reducing size and having compact body.
- **Weight:** Previously it is mentioned that vehicle is made so compact that it must have reduced body than the others vehicle in the markets. It is then would have less materials and thus have less weight. The care is taken in selecting such that no additional member is framed in the vehicle.
- **Cost:** A great care is taken while selecting the material and relevant parts for the vehicle. Locally made parts according to the need and standards are purchased and some of them are manufactured. No additional components were added to the design which directly reduces the cost of the vehicle.
- **Serviceability:** All the manufacturing is done by using the simple machining processes and operations. All the parts whose manufacturing was costly and machines were not available

were purchased. Thus using the services efficiently increases the quality and effectiveness of the product.

### **3.2 Design Methodology**

Designing off road vehicles, one of the main component which is the heart of the designing work is the chassis or body of the vehicle. If it is designed correctly then all the possible constraints swing around it. In this project the main objective of the designing was body of the vehicle or roll cage. Following methodology is practiced while achieving the goal of the project.

- Material Selection
- Cross-section selection
- Use of important formulae
- CAD Model
- Design specifications
- Fabrication and Assembly

While designing roll cage the objective was to give sufficient space for the passenger and the driver. Other objective include to give space to the components of the vehicle and to provide strength to the vehicle.

For frame materials are such selected having good strength and durability and provide minimum weight to strength ratio.

### 3.3 Material Selection

It is one of the most difficult part of designing. To select material for the vehicle components it must be flexible. For roll cage material selection material must bear good strength, durability, less weight, cost effective and compactness.

In selecting material for roll cage material different strategies were used. The material must have high yield strength, good stiffness. The material must have low manufacturing cost and low material cost. On these grounds and previous research work it was decided to use the AISI 1018 for the frame or roll cage manufacturing. The tables shown below give the properties of the AISI 1018.

Table 1 Chemical Composition of the AISI 1018

Carbon	0.14-0.2 %
Iron	98.81-99.26 %
Manganese	0.6-0.9 %
Phosphorus	$\leq 0.04$ %
Sulphur	$\leq 0.05$ %

Table 2 Physical and Mechanical Properties

Density	7.87 g/cc
Poisson Ratio	0.29
Elastic Modulus	205 GPa
Bulk Modulus	140 GPa
Tensile Strength	440 MPa

Yield Strength	370 MPa
Elongation	28.2 %
Reduction in Area	40 %
Brinell Hardness	126

### 3.4 Cross-Section Selection

It is said that in circulars members and elements of a structure bending is higher when the same is compared to structural members with rectangular section. But it is experienced that to manufacture members with circular cross-section is easy. They can be adjusted and fit more easily. To have the low weight and low manufacturing cost roll cage was divided into two types. One were called primary while the other one is called the secondary members. Both of these members differ in thickness.

For roll cage the members which are constructing the main body and initial structure of the frame are designated as primary members. The members which give support to the primary members and are used in the triangular sections are termed as secondary. In the following table the thickness and diameter of each is given below:

Table 3 Chassis Design Specifications

Parameters	Primary members	Secondary members
Outer diameter	25.4 mm	25.4 mm

Thickness	3 mm	1.65 mm
Moment of Inertia	12771 mm <sup>4</sup>	

### 3.5 Formulae Used

$$(\text{Moment of Inertia} = I = \frac{\pi}{64} (O.D.^4 - I.D.^4)) \quad (1)$$

Where

OD = Outer diameter

ID = Inner diameter

$$k_b = E * I \quad (2)$$

Where

E = 205 GPa

$$\text{Bending Strength} = \sigma_b = \frac{\sigma_y * I}{y} \quad (3)$$

Where

$\sigma_y = 370 \text{ MPa}$

### 3.6 CAD Model

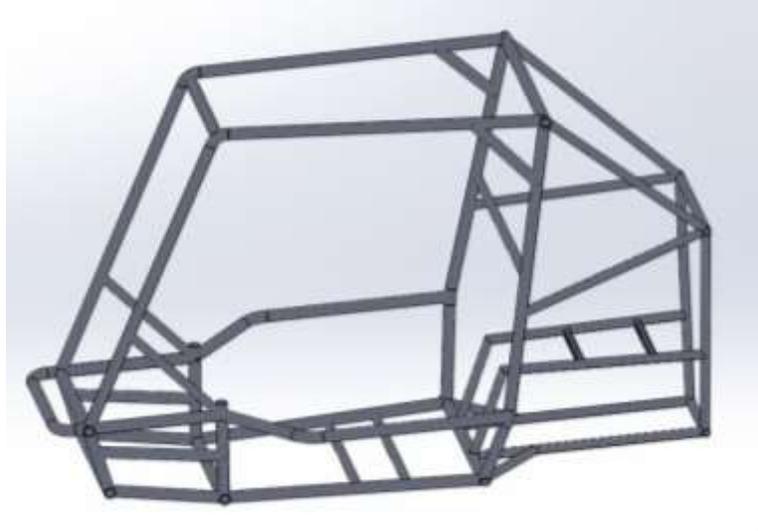


Figure 3 CAD Model

### 3.7 Design Specifications

Some of the components design specifications are given in the tables given below:

Table 4 Vehicle chassis or roll cage specifications

Type	Space Frame
Material	AISI 1018
Length	64 inches
Width	10.5 inches
Height	32 inches
Cross-section	OD = 25.4 mm T = 3 mm

Table 5 Wheel Geometry

Camber Angle	2°
Caste Angle	4°
Toe in	3 mm
Scrub Radius	110 mm

Table 6 Steering Box Specifications

Steering mechanism	Centralized steering system
Outside wheel turning angle	0.3 turns
Inside wheel turning ratio	30..9
Turning radius	2.3
Ackerman Angle	10.21

### 3.8 Fabrication and Assemblage

After the designing process the next phase is manufacture goods according to given specifications. First of all body of the vehicle was fabricated according to the designed specifications and then assembled. Tubes of the AISI 1018 were taken and cut in appropriate length according to the design of the body. Then these tubes were joined by the welding. Metal arc welding was the process through which the tubes were joined to each other.

When the roll cage had been manufactured then parts like engine, steering system, clutch, tires, seating, and other components were purchased according to capacity of the vehicle and joined in the local workshop. Our finished assembled model is shown in the given picture below:



Figure 4 Assembled off road vehicle

As the fabrication phase is completed so no testing is accomplished further in our project. So after this chapter we will directly move to the chapter project management.

## CHAPTER 4: PROJECT MANAGEMENT

### 4.1 Project Plan

This chapter deals with the how the project was executed from raw to finished form. It also includes the planning for the project and managing the project from project proposal to the final submission and presentation. So the schedule which was followed to achieve the goal of the project. All the schedules are logically in the order of first occurrence and followed throughout the time of the project.

As we know that it's a senior design project and it was planned for a semester and it approximately took 13 weeks. So in the figure below the schedule of the project is given.

<b>Project Plan</b>	
Week 1,2,3	Forming the group, Finding an Advisor and Decide which project to make
Week 4	Research began
Week 5	Drawing draft
Week 6,7,8	Designing
Week 9, 10, 11	Manufacturing
Week 12	Testing and Final adjustments
Week 13	Presentation

Figure 5 Project Schedule

### 4.2 Contributions of the team members

It was senior design project so there were five members who were working on this project. The names of the each member and their contributions to the project are given in the following tables given below:

Table 7 Name of the Team members

<b>ID Number</b>	<b>Member Name</b>
<b>201502781</b>	<b>Mohammed Alzuabi</b>
<b>201300459</b>	<b>Khalid Alfares</b>
<b>201303829</b>	<b>Abdulaziz Alqahtani</b>
<b>201002464</b>	<b>Rashed Alhadba</b>
<b>201404545</b>	<b>Hassan Almisehal</b>

Project was managed in such a way that it was divided into two parts. Part one was associated with the research, designing, methodology description and estimating the project cost. The tasks which were assigned to everyone are listed in table 7.

Table 8 Task assigned in initial phase of the project

<b>#</b>	<b>Task description</b>	<b>Team member assigned</b>	<b>Progress 0%-100%</b>
	<b>Designing</b>	Khalid Alfares, Rashed Alhadba	100%
	<b>Research</b>	Hassan Almisehal, Khalid Alfares	100%
	<b>Manufacturing</b>	Mohammed Alzuabi	100 %
	<b>Estimated Project cost</b>	Abdulaziz Alqahtani	100 %

In the final part of the project, the tasks includes like manufacturing, assembling, to purchase materials and parts and hold record of the material cost, prepare report of the whole project and then final presentation to supervisor. These tasks are enlisted below:

Table 9 Tasks and final execution of the project

<b>Task description</b>	<b>Team member/s assigned</b>
<b>Manufacturing and testing</b>	Mohammed Alzuabi, Khalid alfares
<b>Material and total cost</b>	Abdulaziz Alqahtani, Rashed Alhadba
<b>Report</b>	Hassan Almisehal, Rashed Alhadba
<b>Final Presentation</b>	Mohammed Alzuabi, Abdulaziz Alqahtani, Khalid Alfares

### 4.3 Project Budgeting

This part is related to the total cost of the project which came out on the final completion of the project. Total project cost came out by summing up all the material cost, manufacturing cost, assembling cost, and all other costs like services of the technicians and tools which are used. On the final estimation we came out that our total cost sum up to 5000 SR. The Bill of the material is given in the table below which shows the cost of related item.

Table 10 Project Budgeting (Bill of Materials)

Design and Engineering	Cost (SR)
Roll Cage (Body of the vehicle)	1200
Steering Components	400
Brake Components	350
Electrical Parts	650
Tires	200

Gears and Accessories	600
Labor Cost	400
Assembling Cost	500
Miscellaneous Cost	700
Total Cost	= 5000 SR

## CHAPTER 5: PROJECT ANALYSIS

### 5.1 Life Long Learning

- It was good experience while working on this project. We learnt through many unseen things and we learned them and implemented in our project. Many new research terminologies we learnt during our time we were working on this project. Some of the experiences we came across are given in the coming lines.
- Design phase of the project was very challenging. We got a lot of ideas and many vague and impractical designs to which we draw other CAD software. In the beginning we searched for the feasible and practical designs what should we follow. There were a lots of designs which were available but we choose the most reliable design which can be completed in span of 4 to 5 months. We worked on the most of the parts and applied reverse engineering method to make them feasible for our project.
- The lesson we learned during the purchasing and manufacturing was the availability of the materials and parts about which we designed each part and assembly. It was about one must have a backup plan or you must have a plan B for everything you are designing. If one material is missing or not available in the market then you must go for another material having same properties or capacity.
- During the time we spent on the project we came across a number of software about we seek guidance from our seniors and professors. We learned these software from all the available sources and applied their possible application in our project. These includes AutoCAD, Pro-E and MS Project.

## 5.2 Impact of our project

As it has been stated in the literature review that the use of the off road vehicles has been increased and a lot of variants and editions of vehicles has been developed. The conclusion can be drawn that these have ever growing market. But we are doing an analysis what impact it is having on the economic, environmental and social grounds. These are stated below:

- **Economic:** It is stated that market of off road vehicles is ever growing industry. The use of OVRs has increased exponentially. In the west and in India the use of OVRs has spread so rapidly. There was an old estimate found by Silberman (2003) that in Arizona state that off road vehicles of worth \$3 billion were sold out. It is also stated that in deserts and muddy areas the use of off road vehicles is increasing. Thus manufacturing off road vehicles can generate opportunities for the local industries and can boost the national economy.
- **Social:** As we know that off road vehicles were used mostly in the areas which do not access to the main roads. In the hilly areas the off road vehicles are used to mostly due to their stability. These vehicles can easily access to the deserts, mud areas and can also be drove through water. Thus connecting farthest areas to communicate with the other parts of the country.
- **Environmental:** Anything which is invented in this world have some advantages and disadvantages to the environment. So there are some advantages and disadvantages of off road vehicles. Off road vehicles can be used for racing, fun rides and exploring forests, deserts and hill areas. Thus it provides entertainment to the people. But on the other hand it also has adverse effects on the environment by disturbing the ecosystems of the animals

and habitat of the birds and some of the other species. It also causes pollution to the environment which is very bad for the health of the species and for the humans too.

## **CHAPTER 6: CONCLUSION AND RECOMMENDATIONS**

### **6.1 Conclusion**

This project was intended to design and fabricate an off road vehicle. The must have stability with low manufacturing cost and low size and weight. These objectives are accomplished now. This goal involved a lot of research work and literature work was carried to reach the final product. The product was designed and all the parts were selected by doing critical study and hard work. The final work includes the manufacturing of the parts and assembling them to achieve the final product.

It is uniquely and efficiently fabricated with low manufacturing cost. The aim was achieved by spending less amount of time and cost. It has been clearly stated that project has been developed for two people but have a nominal size.

It was great experience to work for a project like that. We have learned how to carry on designing crucial parts. Cost effectiveness is the crucial part of the design. You have to keep in mind the cost of each part while its designing. We have learned how to do more work in less time. New software, manufacturing and assemblage technologies were learnt by us in achieving this goal.

### **6.2 Recommendations**

There are a lots of design ideas which can be done to off road vehicle design. Some of them are explained below:

- Body panels can be designed and attached to the body of the vehicles.
- Steering stability can be achieved by using customized differentials like those used in the ordinary vehicles.

- As it is said that these vehicles are damaging natural ecosystems, so one can work on the exhaust system and efficient fuel to lower this type of damage.
- One can work on more advanced materials which have more durability and have low weight.

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## APPENDIX A: PROGRESS REPORTS

<b>SEMESTER:</b>		<b>ACADEMIC YEAR:</b>	
<b>PROJECT TITLE</b>	<b>Design &amp; manufacture a Lightweight vehicle for off roading</b>		
<b>SUPERVISORS</b>			

### Month 1: September

ID Number	Member Name
201502781	Mohammed Alzuabi
201300459	Khalid Alfares
201303829	Abdulaziz Alqahtani
201002464	Rashed Alhadba
201404545	Hassan Almisehal

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
	<b>Designing</b>	Khalid Alfares, Rashed Alhadba	100%	
	<b>Research</b>	Hassan Almisehal, Khalid Alfares	100%	
	<b>Manufacturing</b>	Mohammed Alzuabi	50%	
	<b>Estimated Project cost</b>	Abdulaziz Alqahtani	75%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
	<b>Manufacturing and testing</b>	Mohammed Alzuabi, Khalid alfares
	<b>Material and total cost</b>	Abdulaziz Alqahtani, Rashed Alhadba
	<b>Report</b>	Hassan Almisehal,

		Rashed Alhadba
	<b>Final Presentation</b>	Mohammed Alzuabi, Abdulaziz Alqahtani, Khalid Alfares

## APPENDIX B: PROJECT BUDGETING

### Bill of Materials

Design and Engineering	Cost (SR)
Roll Cage (Body of the vehicle)	1200
Steering Components	400
Brake Components	350
Electrical Parts	650
Tires	200
Gears and Accessories	600
Labor Cost	400
Assembling Cost	500
Miscellaneous Cost	700
Total Cost	= 5000 SR

## APPENDIX C: DESIGN SHEETS

### Chemical Composition of the material

Carbon	0.14-0.2 %
Iron	98.81-99.26 %
Manganese	0.6-0.9 %
Phosphorus	≤0.04 %
Sulphur	≤0.05 %

### Mechanical and Physical Properties

Density	7.87 g/cc
Poisson Ratio	0.29
Elastic Modulus	205 GPa
Bulk Modulus	140 GPa
Tensile Strength	440 MPa
Yield Strength	370 MPa
Elongation	28.2 %
Reduction in Area	40 %
Brinell Hardness	126

## Vehicle Frame Specifications

Type	Space Frame
Material	AISI 1018
Length	64 inches
Width	10.5 inches
Height	22 inches
Cross-section	OD = 25.4 mm T = 3 mm

## Wheel Geometry

Camber Angle	2°
Caste Angle	4°
Toe in	3 mm
Scrub Radius	110 mm

## Steering Box

Steering mechanism	Centralized steering system
Outside wheel turning angle	0.3 turns
Inside wheel turning ratio	30..9
Turning radius	2.3
Ackerman Angle	10.21