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# IMechE Design Challenge

## Produce a Repeatable Car That Can Return To Its Starting Position


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## Abstract

The task of this assignment was to produce a repeatable car that can traverse a distance between 1.4 – 1.5 meters and return to its original starting point. There were many challenges that presented itself but were overcome due to the knowledge of our team. Although the design deemed simple at first, physically printing and assembling the car was much more of a challenge than we expected. Despite all of this we still came out learning essential engineering skills such as adaptability and attention to detail.

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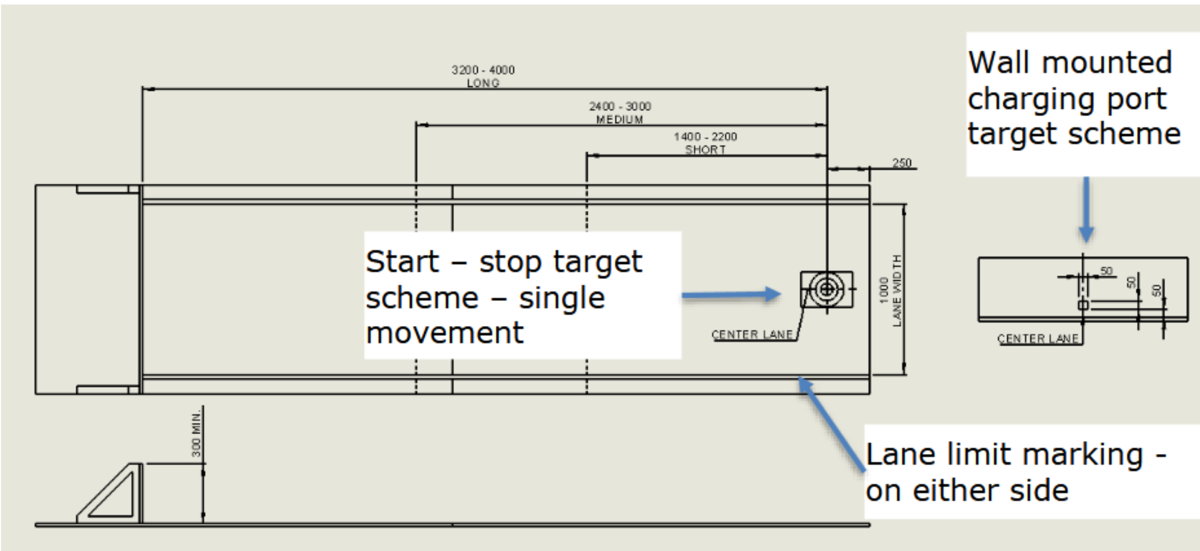
## Introduction

The main objective of this project was to build and run a device that can simulate an autonomous robotic charging device. The device should be able to go along a straight line on a horizontal track. It can be made of any type of construction but limited by cost and size. It can move by any means of transport e.g. sliding, wheels, and walking. The method of starting the car must be attached to the car itself.

### 1.1 Competition rules

There are competing rules that must be adhered to which are as follows: the device should have completed its specified movements within a deadline of 3 minutes. The device should be started off manually and should perform its movements individually without any help. It should be able to perform on real installation where there may be errors on the track. It should be able to start, stop, and return to specified designated locations. It should be able to engage with the plug simulator and simulate a battery charging engagement by keeping contact with the vertical surface for a specified amount of time.

Below is a typical lane setup:



## Product Design Specification

Safety – The design should not contain any exposed electrical connections and there should be no risk of finger trapping in moveable elements such as the belts and gears.

Size – The device should be able to fit the specified specification.

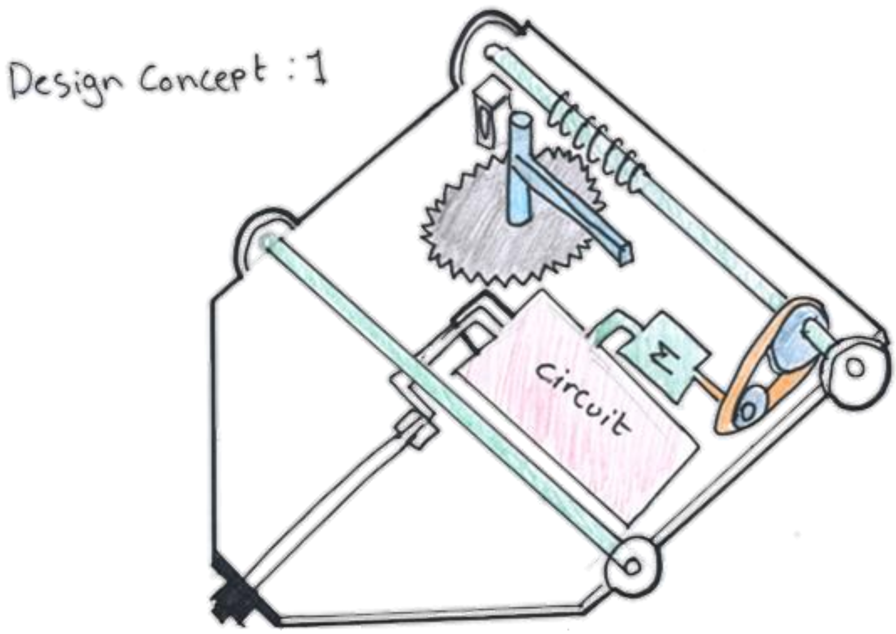
Aesthetic – Ensure that the design is simple and looks well assembled and appealing.

Cost – The expense of the device should not be able to exceed the given specified budget.

Weight – The weight should be not as heavy since it'll work more efficiently when it is light.

Durability – The car should be able to withstand pressure and weight so that it isn't fragile when it hits the wall.

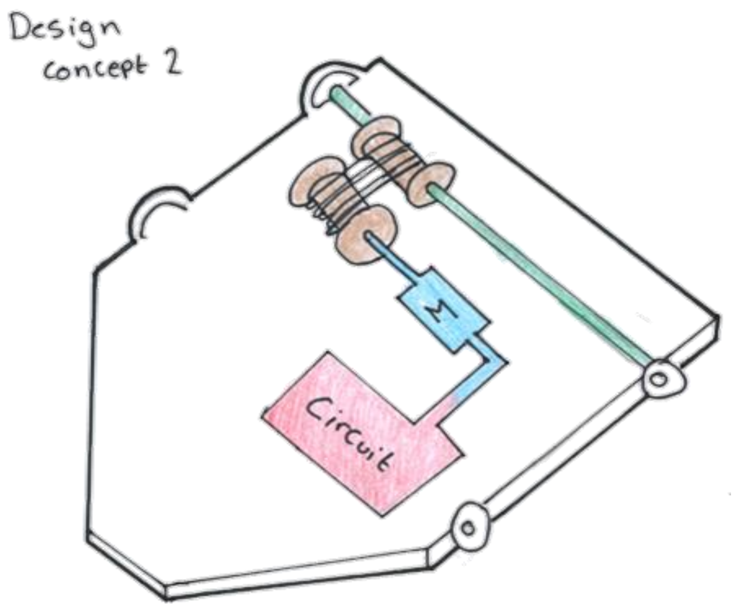
# Design Concepts




This was our first initial concept idea. Its strengths was that it contained little/no refinement however its major weakness was its costliness. It was an accurate model that did however fit the specification, but the major downside was that it contained high manufacturing costs and was complex to build.

## 1.2 Evaluation

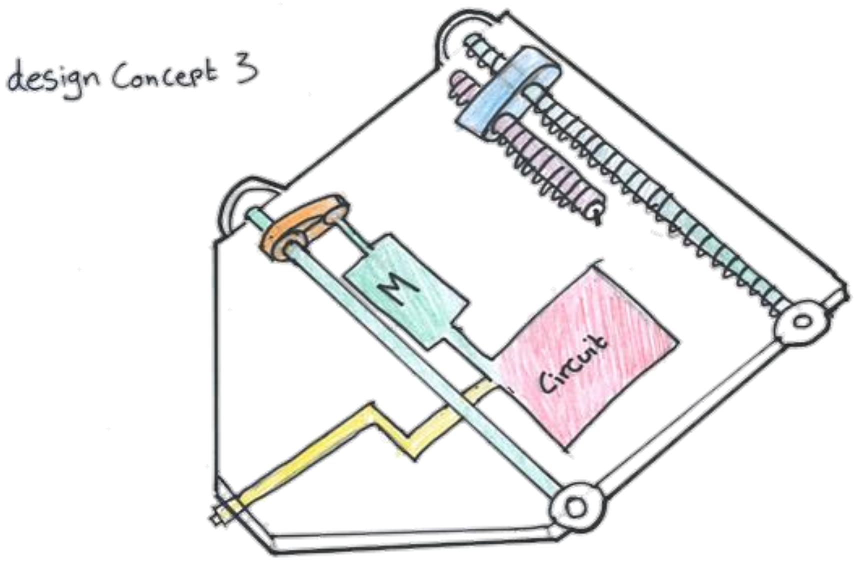
A common issue within real world workplaces is manufacturing costs. If the product is too expensive to make it won't be possible for a worldwide scale of manufacturing due to the costs. Since the product is also too expensive to build, everything will increase such as labour costs, machinery, and time. This will result in a longer time to produce the item and an increase in expenses. The positives of this design is that it does meet the required specifications as it does fit the purpose of its role.




This was our second design which was very simple and aesthetically pleasing to look at. Its major strengths was that it was simple to build and small thus resulting in extra space if we needed to exchange or swap parts out. It was a very adaptable design however the major disadvantage to this design was that it is prone easily to breakages.

## 1.3 Evaluation

The negatives of this build is that it is easily prone to breakages which is extremely unreliable. This factor is extremely important since during the testing phase it needs to pass it otherwise the car is not fit to function. If it is prone easily to breakages it will reduce its longevity over time as materials might deteriorate overtime. Since it is also a small design, there will be less space to add any improvements if need be. It is however an aesthetic build since it is versatile and is east to swap parts out if it breaks. The compactness of the build is very efficient too since it enhances the overall aerodynamics of the car and is light since it doesn't contained compact components.

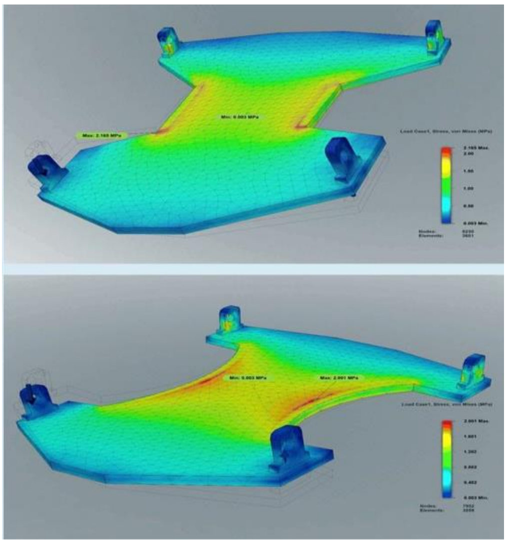



This was our final concept idea that again was like our first concept which contained little/no refinement. Its disadvantages was the cost, since it contained many different unique moving parts. It is however, a very durable but complex design but does in fact exceed the budget which is given in the technical specification

## 1.4 Evaluation

The overall budget of this design was very high since there was many different parts needed for it run which increases the manufacturing cost to make it. There was in fact a lack of refinement within this build as there was some inefficiencies within the design itself. It was also very complex which results in a difficult assembly and more chances of errors that be fixed easily if it wasn't as complex. It was however a durable and strong design which can withstand impact and can perform well.

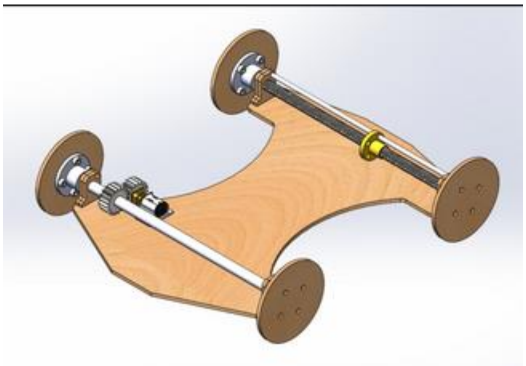
## CAD

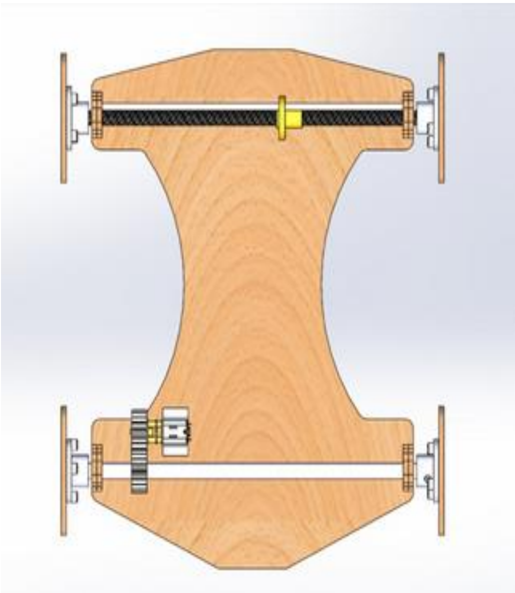


A 3D model of the base of the vehicle was created using fusion 360. From the image provided, you can see that we are showing a finite element analysis of the design of the vehicle. The colours on the vehicle represent different stresses such as yellow/red is high stress whereas green/blue is representing a low stress. There is two pictures provided that show different shapes of the vehicle. The top one is squared design, and the bottom image is a narrower design. The main reason why we chose fusion 360 was that we can input these models into the software, and it shows the max stress on each design. The top design has a maximum stress of 2.165 MPa, and the bottom design has a maximum stress of 2.001 MPa. Since the bottom design contains a lesser load for it to function, we went with this concept.

In this image provided, you can see the chassis, shafts, and bearings shown on SolidWorks. This is the mechanism that drives the car to move where the shaft is rotating to move the car. The screw threaded rod is connected to a motor which is moving the car. The motor is then spinning the rod which will then rotate the rear wheels. The wiring for this design is that the red and black wires are connected to the motor which is connected to the circuit.

This is the base layout representing an identical layout of our vehicle design. It consists of shafts and bearings. The shaft at the front shown in the image are held together by mounts. The rear shaft has a motor which is connected to it. It also contains wheels as represented within the image.





A bird's eye view of the design is shown to show the layout of the design. It also beneficial to use CAD for such projects like these as it is easier to visualise if there's enough room for wiring or attach components. This image gives a clear picture of the size that will be used to make this. When manufacturing projects such as these, it is crucial to have designs laid out on CAD software as it shows crucial parts for example where to drill/cut and gives a clean precise map on what is being built and where it is being built.

Using CAD is essential since it gives accurate and precise models of the design which you can modify and test before it is finally produced limiting out any errors that may occur. By using CAD, it speeds up the design process since you will have precise technical drawings that are accurate. By using software such as SolidWorks or Fusion 360, you reduce overall costs and enhance the overall design as you have filtered out any errors that could possibly be an issue later in the manufacturing stage.

Manufacturing Process:

Prototype 1:

Although our first prototype complied with all specifications it had certain drawbacks that ultimately affected the overall performance, durability and accuracy of the vehicle. After considered analysis we decided to change and redesign certain parts to eliminate these problems. Design for Manufacturability (DFM) was a key area we focused on, changing materials and components we used.

Chassis:

The chassis was made from 3mm plywood and laser cut to size. Plywood is lightweight and a relatively inexpensive material so thought it would be a good option however, upon building the car we discovered the plywood was ever so slightly warped and when testing we found the car would steer off to one side meaning it would not hit the required target on the wall. This was due to a multitude of reasons; it meant that the wheel alignment was now off, there is an uneven weight distribution, different rolling resistance and axle misalignment. This was an easy fix; the solution was to change the material from plywood to acrylic eliminating any possibility of natural wood defects.

Wheel hub:

The wheel hubs were also made from 3mm plywood and laser cut to size. The issue from these occurred with the mounting onto the chassis. We measured it by hand and glued it to the underside of it. This presented issues with alignment as we relied on the accuracy of manual human precision and judgement. Even after careful measurement the hubs were not perfectly aligned on the chassis causing problems like that of the warping. Using just glue as the joining method has its drawbacks as that area will now be weak under stress only providing strength in tensions and not in shear or peel. The surface preparation and conditions have a direct impact on the placement of these hubs especially as the chassis was warped. This didn't offer any reusability or adjustability meaning that once glued we couldn't change or undo the bond. Over time under constant load the glue joints can deform slowly reducing the accuracy of direction. Our solution to this problem was to design a new 3D printed wheel hub that slotted into the chassis from a laser cut out section. This is held in place with a dowel type joint and means no glue, manual human accuracy or measuring is needed, simply slot the hub into the chassis and its perfectly aligned and held in place without any glue.

Wheels:

Just like the chassis, the wheels were laser cut from 3mm plywood. Similar problems occurred with the warping affecting all wheels. This meant our vehicle was not travelling straight. On top of this, we had to drill the mounting holes to connect the coupling connectors, once again we were relying on human accuracy and judgement which coincidentally had the same effect, the connectors were not exactly centralised causing eccentric rotation, imbalance and uneven traction. We changed the material from 3mm plywood to 3mm acrylic to eliminate any chances of wood defects and laser cut the mounting holes to assure the hubs are dead center.

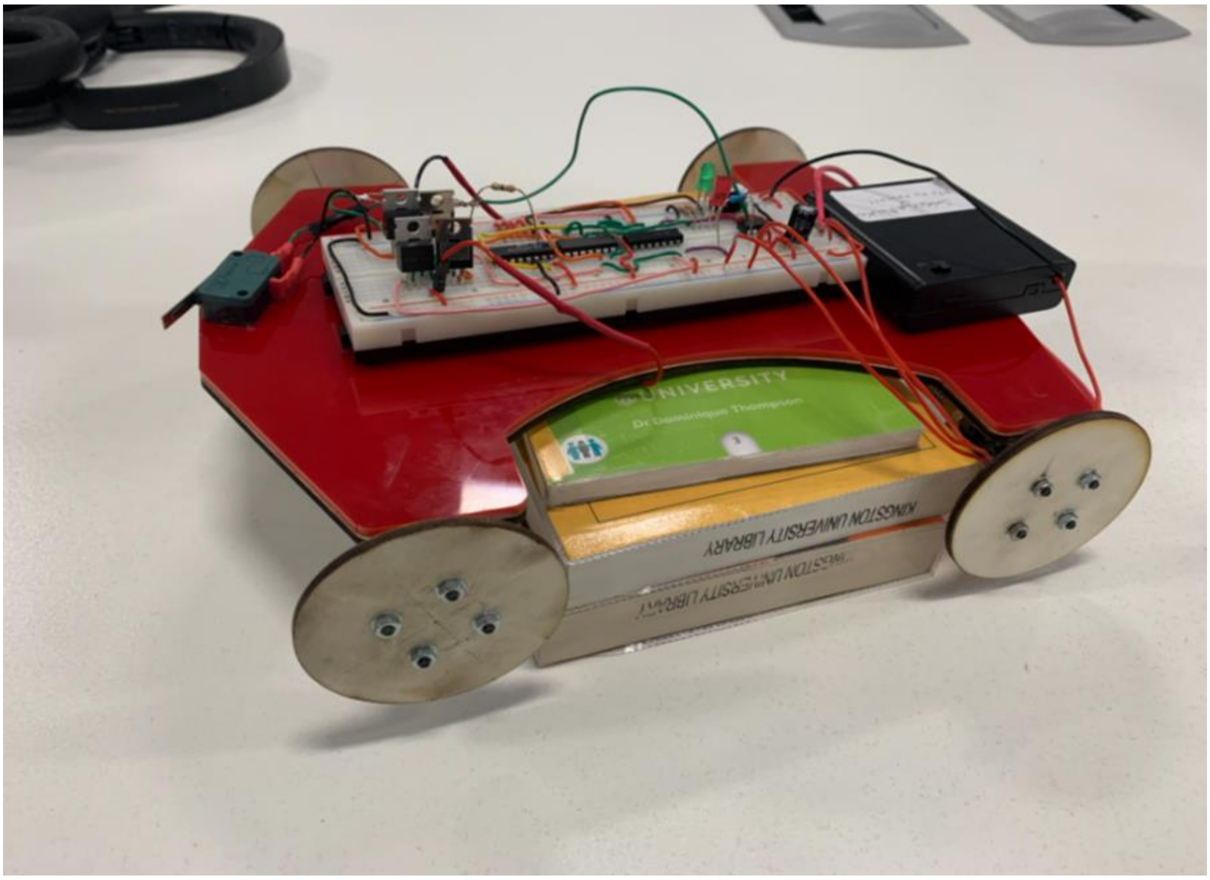
Wall target:

To accurately place the vehicle down, away from the wall and to be perfectly straight on, presented challenges. We couldn't see if it was lined up with the target meaning we didn't know if it would hit it. When doing our test run, it didn't hit the target on the wall, so we added a laser LED diode to the front of our vehicle (centralised), so from any distance we could see where it was aiming and that it would hit the target upon impact.

Circuit:

Our initial build incorporated a breadboard for the circuitry. A PCB was ready to be made but due to problems with the machine we were unable to get it printed. Switching to a PCB will make it much more reliable, wires won't fall out and connections don't move around, soldered joints create much more stability especially on a moving car. It will be smaller and more compact, saving weight and space. A PCB will allow for better performance due to lower electrical noise and better signal integrity. The overall design will look cleaner and more professional and in theory if we wanted to mass produce it, it would allow for copies to be made efficiently.

# Final design




As you can see from the picture provided of the car, you can see that we have fully manufactured a working car that follows all the guidelines and specifications that were required. The main aim of this competition was to create a device that could reach a target there and back under three minutes. The datum pointer should start in the centre of the target and move towards the wall. It should then touch the end of the wall and stay there for 15 seconds then return to the same position as before where the datum pointer started from. The device was safe to use since we ensures that all rules were carefully followed such as electrical connections not being exposed or having the car not fit within the maximum envelope.

As you can see, we received no penalties given since our datum pointer was not too high from the ground. Our front plunger was not larger that it was allowed, and it could realign between the two vertical targets. If the above was not completed it would have resulted in penalties for our team.

## Size

The size of envelope is 400x400x400mm which our device was within regulation of. The device should also be able to fit within the envelope throughout the whole competition. We ensured that the datum pointer is in a vertical position and is pointing downwards.

## Electronics

# Parts list

Parts listed for the device are stated below. Every part that was mentioned was used within the final design of the device.

- Wheels x 4
- Lead thread hub x 4
- Base x 1
- Screw and lead x 1
- Plastic tube x 1
- Thread screw x 1
- Motor x 1
- Datum x 1
- Belt x 1

Below is a list of the electrical components that was used within the device. Everything below that is mentioned was used in the final design of the device.

- 9V Battery
- 555 Timer
- 10 K Ohms Resistor
- 1 K Ohms Resistor
- 2.2 uF Capacitor
- LED red
- LED green
- 470 Capacitor
- DPDT Switch

These were parts that were essential when building the device, since we used all components, we did not waste any money which could have impacted our costs as we could have used the money to purchase better equipment/parts if need be.

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## Manufacturing process

## BOM (Bill of materials)

## Material list

## References

Design Challenge -Project Specification and Rules 2025 -V1.0 1 AUTOMATED EV CHARGING. (n.d.). Available at: https://www.imeche.org/docs/default-source/1-oscar/challenges/design-challenge/2025/imeche-design-challenge---project-specification-and-rules-2025---v1-0.pdf?sfvrsn=2.