Notes:

- The steering arm angle (on the knuckle) is often set so that:

$$\text{Line through the steering arm} \rightarrow \text{Intersects rear axle at ICR}$$

- This ensures that during a turn, the wheels *automatically* satisfy:

$$\cot(\theta_o) - \cot(\theta_i) = \frac{W}{L}$$

- You **design the steering arms** to satisfy Ackermann **at the maximum steering lock** (tightest turn), or **some average radius**.
- You **accept small deviations** at other angles — it's a trade-off.

The **ideal Ackermann condition** is a **pure geometric condition** that:

- Only applies **perfectly at one steering angle**.
- Assumes **point contact**, no compliance, no dynamic effects.
- Doesn't account for **nonlinearities** in the actual linkage movement.

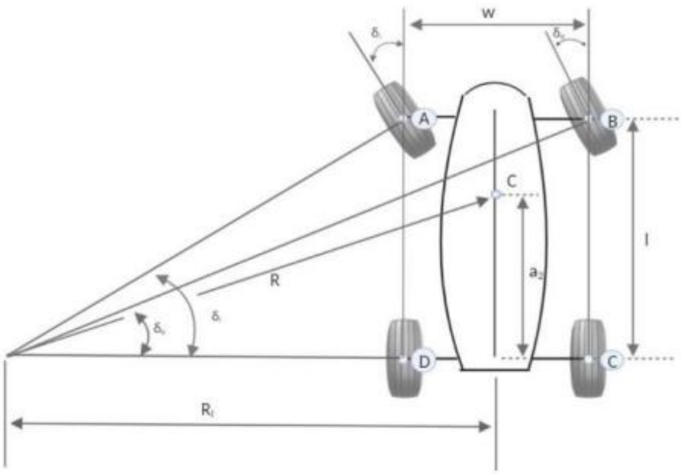
- **4-bar or trapezoidal linkages**, with finite-length tie rods and rotating arms.
- These introduce **nonlinear motion**.
- So even if you set the arms to satisfy Ackermann *at max lock*, the geometry will **deviate at intermediate angles**.

Design of a basic Ackerman Steering System

Note: Dynamic Behaviour and other vehicle dynamic perspective were not taken into that much of consideration.

For ideal Ackerman conditions:

$$Cot\delta o - Cot\delta i = \frac{w}{l} \qquad R = \sqrt{{a_2}^2 + l^2 Cot^2\delta} \qquad Cot\delta = \frac{Cot\delta o + Cot\delta i}{2}$$



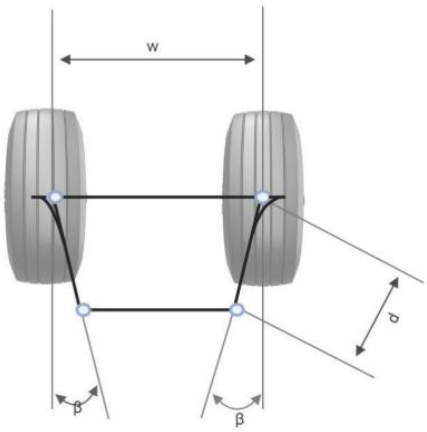
Parameters Used:

W = 1585 mm

L = 1725 mm

a = 0.4*L (Because of a heavy motor it is assumed that COM shifts at 40% of L from back)

Doubt: why are these numbers not something like: 1600 and 1700 or 1550 and 1750 or something like this round of for practical applications?

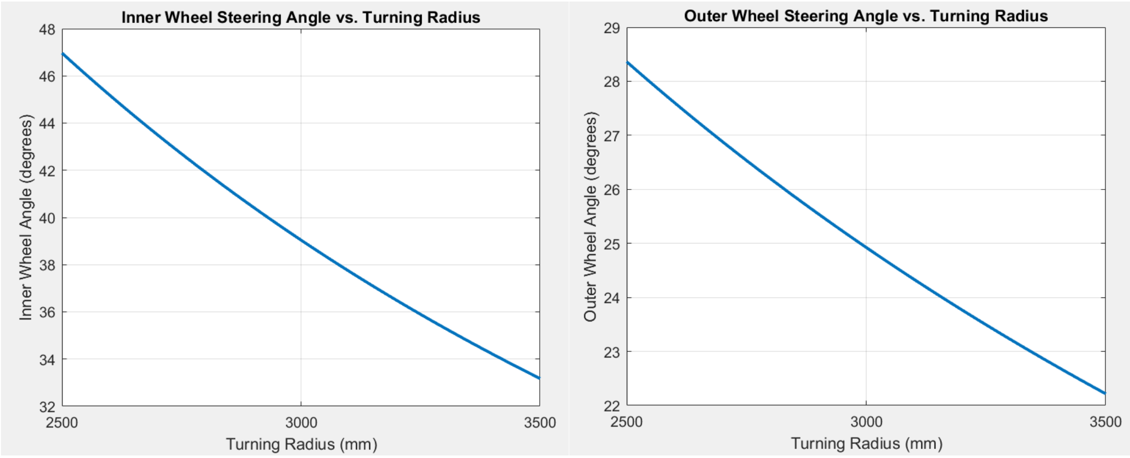


$$\beta = \tan^{-1}\left(\frac{W}{2L}\right)$$

Keep the beta as whole number for practicality

Turning Radius range: 3000mm to infinity (taking 2500mm to infinity to account for errors)

Determination of Range of Outer and Inner Turning Wheel Angles:

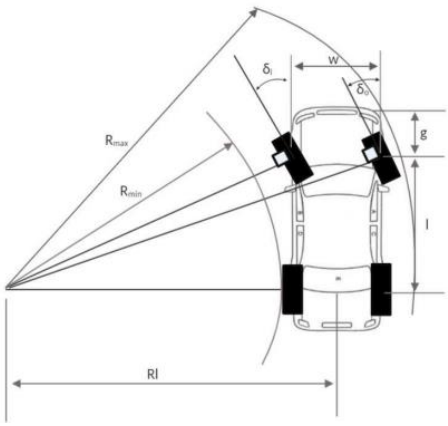


Source: Inner_Angle_Range.m and Outer_Angle_Range.m

Task1:

- This max value is not possible so we need to change the values of W and L.
- Also, one finalised the max turning angles of the wheel verify that they should not collide with any geometry.
- Also parallelly have a look if there is any rule about the packaging of the wheel while turning on any steering rule regarding this.

Vehicle Turning Space Requirement Calculation:



$$\Delta R = \sqrt{\left(\frac{l}{\tan \delta i} + 2w\right)^2 + (l+g)^2} - \frac{l}{\tan \delta i}$$

Where,

$$\Delta R = R_{max.} - R_{min.}$$

Note: Instead of 2w there should be w (you can verify by deriving it also). But take 1.2*w to be on safer side.

G = 800mm (confirm it with the chassis or suspension team)

G = distance between the maximum front part and the centre of the front wheel.

The space required should be less than any track or competition on which the car will be competing on. So, compare it with the tracks of competition.

Example: (Source: Space_Required.m)

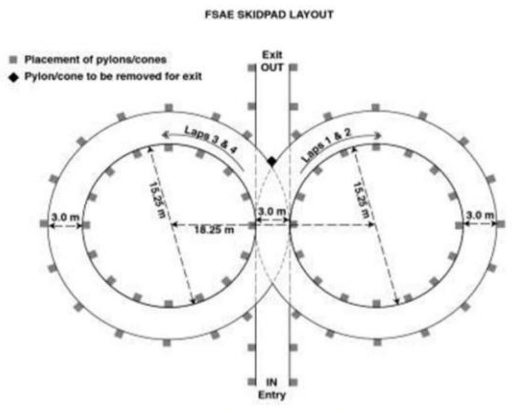
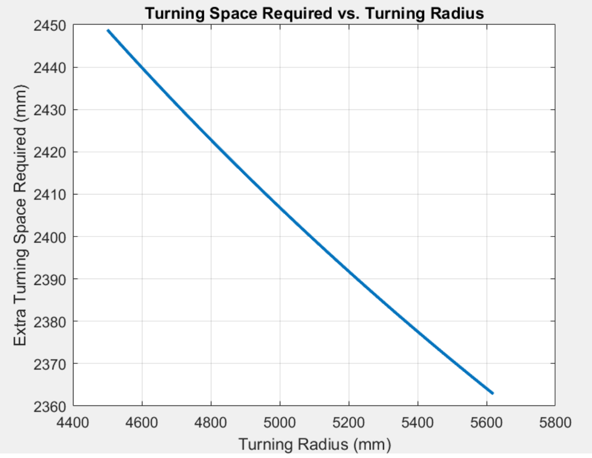


Figure 1: FSAE skid pad layout



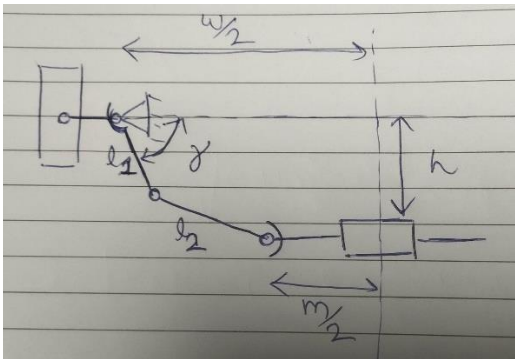
Hence with the present W, L and G we can turn the vehicle properly in skidpad event.

Task 2:

Do it for other competitions like endurance and all on which the vehicle will run during the competition.

```
r = 4500:10:5625;      % Turning radius (in mm)   -> 4625 = Turning radius for skidpad
```

Steering Trapezoidal Mechanism:



Optimisation Variables:

- γ: Steering arm angle from horizontal
- l1: Steering arm length
- h: Distance between the front axle and the rack placement

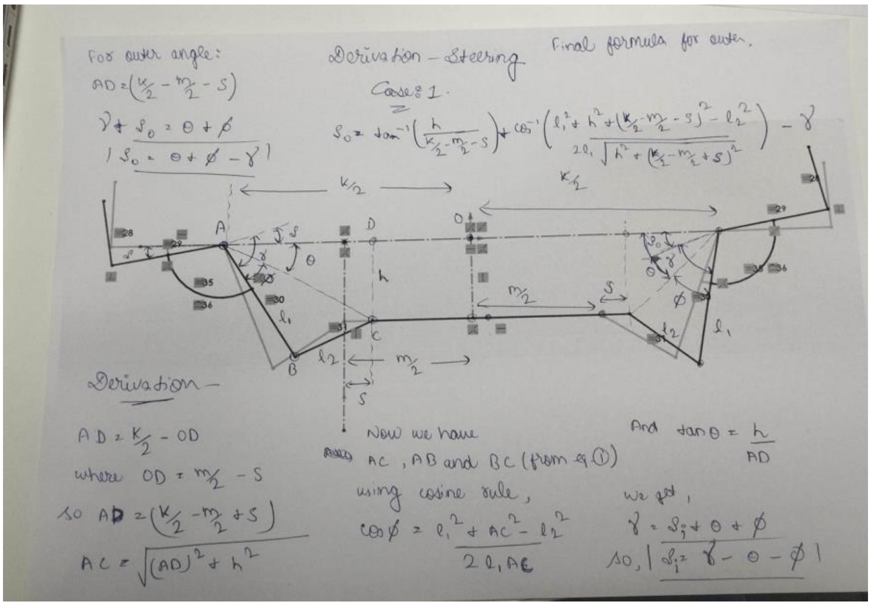
Known Variables:

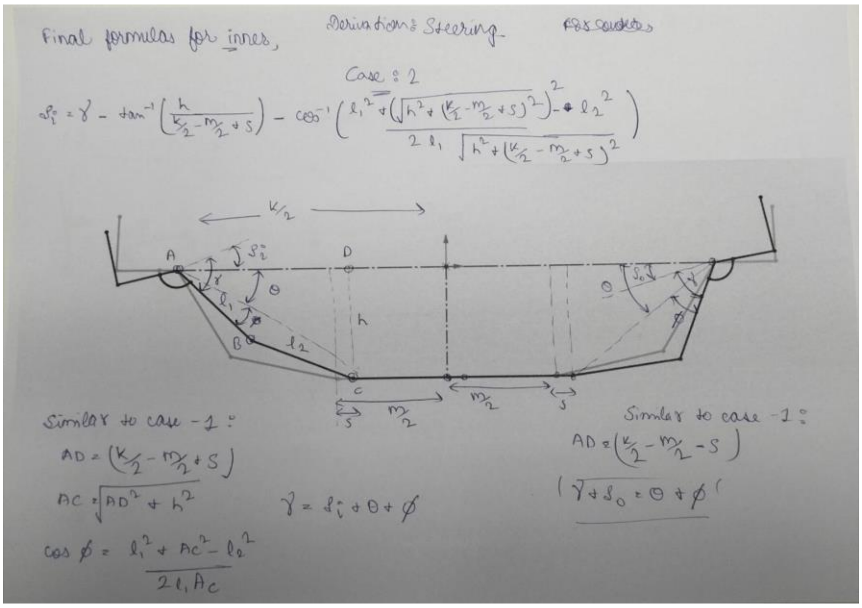
- m: Distance between ball to ball of rack and pinion
- K: Trackwidth

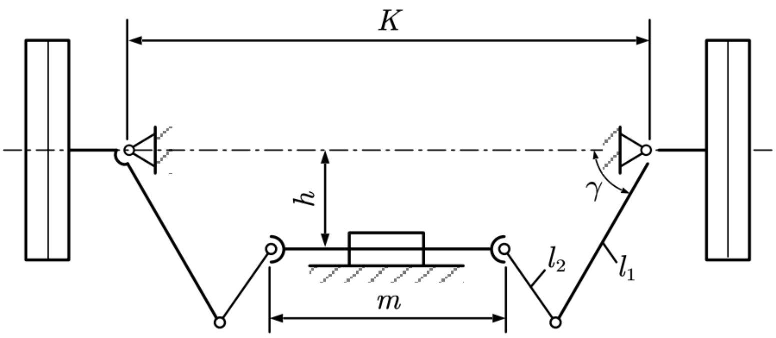
  Note: Ideally m is supposed to be extracted from the rack and pinion design using some force calculations and rack and pinion design considerations. But for simplicity we are skipping it and directly taking the selected rack and pinion from the market.

Equations derived:

$$\boxed{l_2 = \sqrt{\left(\frac{k-m}{2} - l_1\cos\gamma\right)^2 + (l_1\sin\gamma - h)^2}}$$

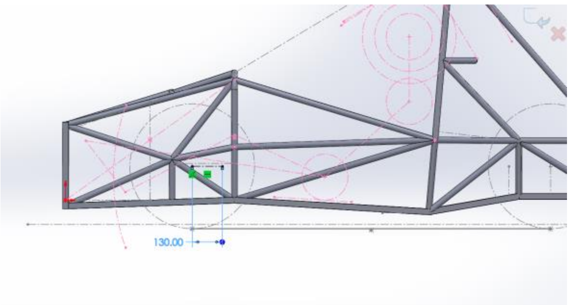






Selection of Range Values for Variables to be Optimised:

1) Range of h



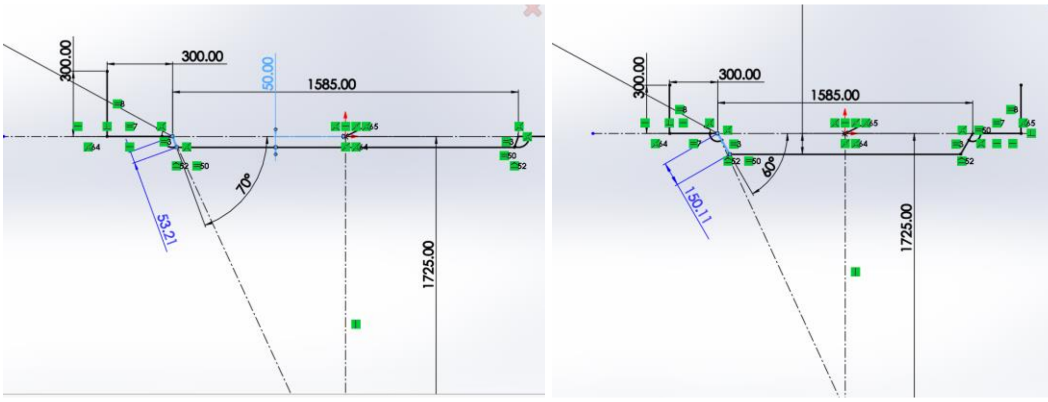
Based upon the packing possibility the max distance between the front axle and the rack and pinion can be of around 50 mm to 130mm to be on the safer side.

2) Range of γ

For a 100 percent Ackerman γ should be equal to invtan(w/2*L). So, taking +- 5 deg keeping that in mind.

γ: 65.325 +-5 that is 60 to 70 deg.

3) Range for steering arm



Taking the two extreme cases we get the range of steering arm length that is 52 mm to 150mm.

Non-Linear Parameter Optimisation: