Kinematic Analysis of Steering Mechanism: A Review

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Abstract -Mostly, two-wheel steering (2WS) systems are used to control the vehicle. But many researchers are working in this area, for a narrow space how a car can take turn or back without any failure occurs. There are different types of drives in a vehicle such as front-wheel, rear-wheel or all-wheel drive (2 and 4 WS). But for the reason of safety, four-wheel steering (4 WS) vehicles termed as Quadra Steering System are being used. In this paper, the features of different models of car steering system used have some draw backs like failing at high speed, slipping of the tracks, higher turning radius. To overcome these drawbacks, a suitable and appropriate steering system has been proposed and it has been presented here.

Keywords: Kinematics analysis, Two-wheel steering (2 WS), Four-wheel steering (4 WS), Turning radius

I. INTRODUCTION

Steering is the collection of components, linkages, etc. which allow a vehicle (car, motorcycle, and bicycle) to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide the steering function. The mechanical 4WS uses two separate steering gears to control the front and rear wheels. The hydraulic 4WS uses a two-way hydraulic cylinder to turn both the wheels in the same direction. It is not possible to turn them in the opposite direction. The electro/hydraulic 4WS

Combine computer electronic controls with hydraulics to make the system sensitive to both Steering angle and road speeds. This system finds application in off-highway vehicles such as fork lifts, agricultural and construction equipment and mining machinery. It is also useful in passenger cars, mainly SUVs. Four-wheel steering, 4WS, also called rear-wheel steering or all-wheel steering, provides a means to actively steer the rear wheels during turning maneuvers. It should not be confused with four-wheel drive in which all four

wheels of a vehicle are powered. It improves handling and help the vehicle make tighter turns. Production-built cars tend to understeer or, in few instances oversteer. If a car could automatically compensate for an understeer/oversteer problem, the driver would enjoy nearly neutral steering under varying conditions. 4WS is a serious effort on the part of automotive design engineers to provide near-neutral steering. The front wheels do most of the steering. Rear wheel turning is generally limited to 50-60 during an opposite direction turn. During a same direction turn, rear wheel steering is limited to about 10-1.When both the front and rear wheels steer toward the same direction, they are said to be in-phase and this produces a kind of sideways movement of the car at low speeds. When the front and rear wheels are steered in opposite direction, this is called anti-phase, counter-phase or opposite-phase and it produces a sharper, tighter turn.

II.STEERING MECHANISM SYSTEM

Steering is used for changing the direction of two- or four-wheel axle with reference to the chassis, so as to move the vehicle in any desired path. Steering system is based on the following mechanism Ackerman's steering mechanism, Davis steering mechanism.
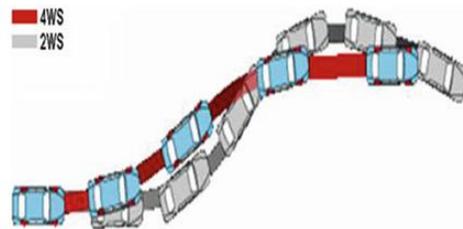

Fig.1 Movement difference between two-wheel steering system and four-wheel steering system

COMPARISON OF FOUR-WHEEL STEERING SYSTEM WITH TWO-WHEEL STEERING SYSTEM

In four-wheel directing framework, it is progressively effective and stable on cornering improved guiding responsiveness and accuracy in fast straight-line steadiness as shown in Fig.1. Prominent improvement is fast, simpler, more secure path evolving moves. Littler turning range and tight space required to moves the car at low speed, relative wheel angles and their control and danger of hitting a hindrance is enormously decreased [3, 9].

DESIGN OF TWO-AND FOUR-WHEEL STEERING SYSTEM

It is to be recalled that both the controlled wheels do not turn a similar way, since the inward wheels travel by a more drawn out separation than the external wheels, as portrayed in Fig.2. Ackermann two- and four-wheel directing framework geometries are a geometrical game plan of various linkages in the two- and four-wheel guiding arrangement of vehicles intended to take Care of the issue of wheels within and outside of a go expecting to follow out circles of various radii. The two- and four-wheel directing framework support focuses are joined by an inflexible bar called the tie pole which is a piece of the two- and four-wheel guiding framework components. In immaculate Ackermann, the middle purpose of the majority of the circles followed by all wheels will lie at a typical point at any edge of two- and four-wheel controlling frameworks. It might be quite hard to integrate or break down this component for 2 and 4 WS framework over the full scope of (2 and 4 WS) frameworks' points. Because of such sort of troubles, presently day's planner does not utilize Ackermann (2 and 4 WS) frame work in four-wheelers, since this component overlooks through parameter like dynamic and consistent impacts. In resentment in this course of action, the component
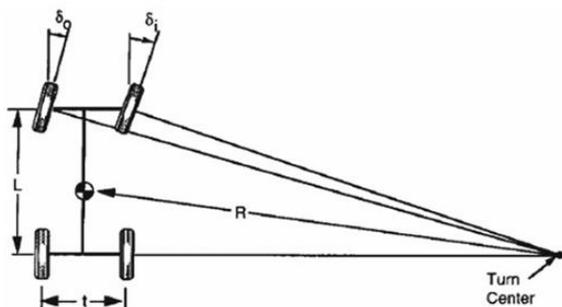
Ackerman two- and four-wheel steering system mechanism.

Is thorough for low-speed developments, and the privilege and left wheels do not turn by a similar point, in any encompassing paces. It implies a very hard for vehicles with self-sufficient (2 and 4 WS) framework. The wheels cannot be positively given the exact Ackerman turning points. It would legitimately trouble the dynamic treatment of the vehicle, making it hard to control appropriately. Four-wheel steering system is employed in vehicles to achieve better manoeuvrability at high speeds, reducing the turning circle radius of the car and to reduce the driver's steering effort.

III. ANALYSIS

Here, the main objective is to reduce turning radius. Turning radius is the difference of angles from initial position to the final position of front wheels. A vehicle with an incorrect turning radius will drag the wheels around a corner causing very fast tire wear. In this paper, turning radius will reduce the wear of the vehicle using 4 WS system for easy to turn and safety of the driver. According to the analysis of this system, a kinematic link will lie between the front and rear axles. Such a mechanism is learned by the kinematic analysis of the steering system's geometry. Now, he will calculate the turning radius of a vehicle with the help of geometry of the mechanism. Figures 3 to 6 used from his (Arvind) paper for comparative study between our prototype and ALTO 800 and FORD FIGO.

Fig.3 to 6 A. Turning measurement of vehicle. B Bicycle model of measuring turning radius. C. Four-wheel steering system. D. Bicycle model for four-wheel steering system.
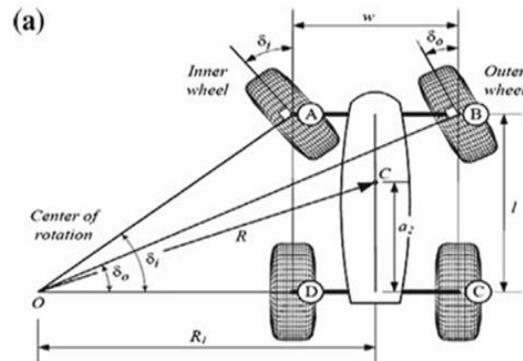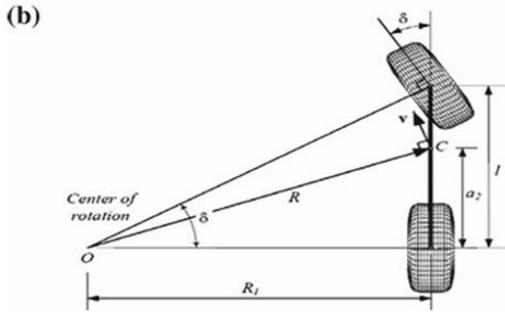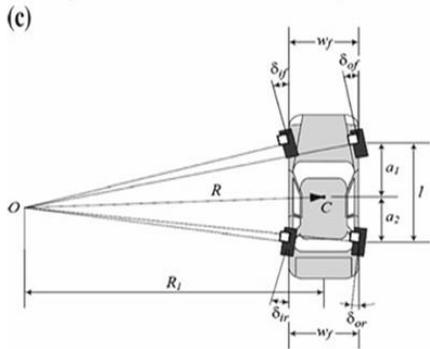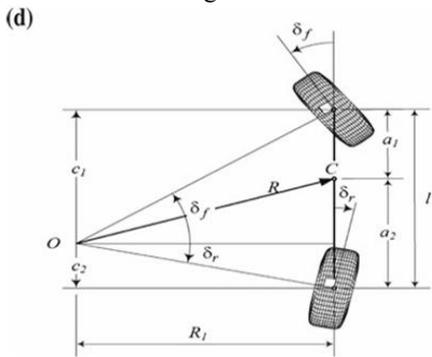

Fig.2

Fig.3

Fig.4

Fig.5

Fig.6

Fig.7-10 1. Steered front-wheel angles measurement (FORD FIGO) [1]. 2. Modified steering wheels angles 1 (FORD FIGO). 3. Modified steering wheels angles 2 (FORD FIGO). 4. Optimum symmetric four-wheel steering (FORD FIGO).
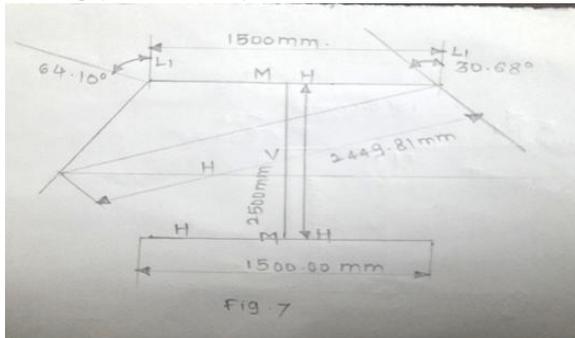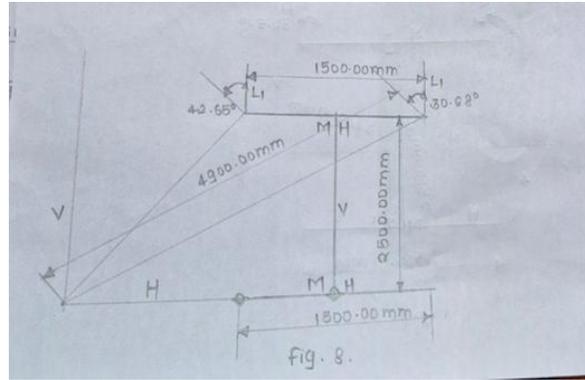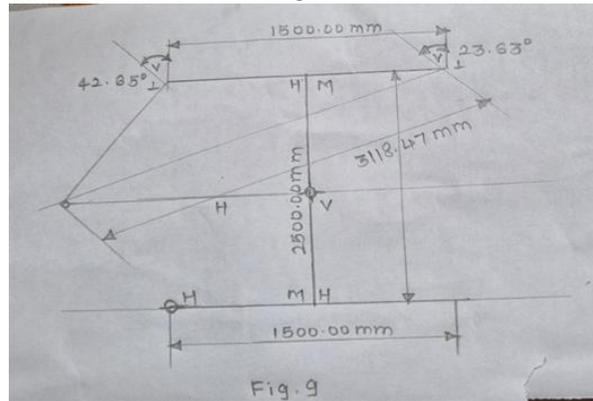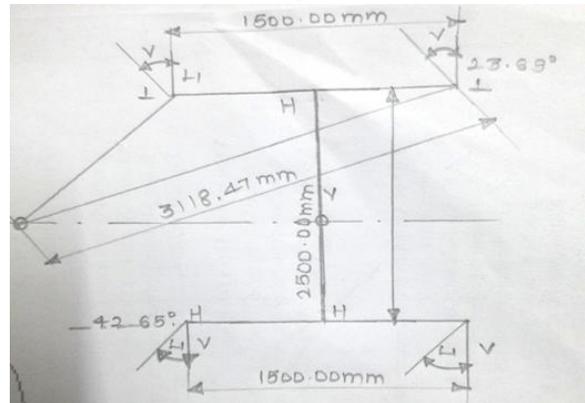

Fig.7

Fig.8

Fig.9

Fig.10

IV.   TURNING RADIUS

In steering system, when vehicle takes a turn from initial position, then the difference in the angles of the front wheels to in a turn is known as turning radius. Due to incorrect turning radius, it will strain (drag) the wheels around a junction (corners). Wearing of tyres occurs due to this reason.

TURNING RADIUS OF TWO-WHEEL STEERING SYSTEM

The turning radius (R) of the vehicle is usually measured by using the formula as shown in Eqs.

$$\cot \delta_o - \cot \delta_i = \frac{w}{l}$$

$$\cot \delta = (\cot \delta_o + \cot \delta_i)2$$

$$R = \sqrt{(a_2^2 + l^2 \cot^2 \delta)}$$

$\delta_i = 42°$

$l = 32$

$\frac{w}{l} = 0.846$

$\cot \delta_0 = 0.846 + \cot \delta_i$

$\delta_o = 26.06°$

$\cot \delta = (\cot \delta_o + \cot \delta_i)/2$

$= (\cot 27.06° + \cot 42°)/2$

$=1534$

$\delta =33.09$

$a_2 = 17.3$ cm

$\therefore R = \sqrt{(17.3^2 + 32^2 \times 1.532^2)}$

$=52.04$ cm

$\therefore R = = 520$ mm

TURNING RADIUS OF FOUR-WHEEL STEERING SYSTEM

W =27.1cm

$$\cot \delta_{o_f} = \cot \delta_{i_f} = \frac{w_f}{l} - \frac{w_r}{l} \cdot (\cot \delta_{o_f} - \cot \delta_{i_f})/(\cot \delta_{o_r} - \cot \delta_{i_f})$$

$\delta_{o_f} = 35°$

$\delta_{i_f} = 39°$

$\delta_{i_r} = 40°$

$$\cot 35° - \cot 39° = \frac{27.1}{32} - (\cot 35° - \cot 39°)/(\cot \delta_{o_r} - \cot 40°)$$

$0.193 = 0.8468 - 0.846 \times \{0.193/(\cot \delta_{o_r} - 1.19)\}$

$$0.8468 \times \frac{0.193}{\cot \delta_{o_r} - 1.19} = 0.6538$$

$\delta_{o_r} = 34.77°$

$c_1 = 16.5 cm$

$c_2 = 16 cm$

$a_1 = 14.7 cm$

$a_2 = 17.3 cm$

$R = \sqrt{(a_2 - c_2)^2} + c_1^2 \cot \delta_f$

$\cot \delta_f = (\cot \delta_{i_f} + \cot \delta_{o_f})/2$

$\delta_f = 36.09°$

$R = \sqrt{(17.3 - 16)^2} + 16.5 \times 1.33^2$

$\therefore R = 21.98$ cm = 219.8 mm

PERCENTAGE REDUCTION IN TURNING RADIUS

% reduction in turning radius $= \frac{52.04 - 21.98}{52.04} \times 100$

$=57.7$

KINEMATIC ANALYSIS [USING BICYCLE MODEL]

Spentzas et al. [11] said in his paper that "A general kinematical analysis of 4WS vehicles by considering either the simplified 2WS (bicycle) or complete 4WS automobile system.

FOUR-WHEEL STEERING SYSTEM

$a = GA_f = 14..7 cm$

$B = GA_r = 17.3 \ cm$

$e = GI_m = 2 \ cm$

R=21.98cm

$\beta = 3.5°$

$$\delta_f = \tan^{-1}\left[\frac{a}{R \cos B} + \tan \beta\right]$$

$$= \tan^{-1}\left[\frac{14.7}{21.98 \cos 3.5} - \tan 3.5\right]$$

$$=36.17$$

$$\delta_r = \tan^{-1}\left[\frac{b}{R \cos \beta} - \tan \beta\right]$$

$$= \tan^{-1}\left[\frac{17.3}{21.98 \cos 3.5} - \tan 3.5\right]$$

$=36.03$

TWO-WHEEL STEERING SYSTEM

l=32cm

R=52.04cm

$$\tan \delta_f = \frac{l}{R} \cos \beta$$

$$\tan^{-1}\left[\frac{l}{r \cos \beta}\right]$$

$$\tan^{-1}\left[\frac{32}{52.04 \cos 3.5}\right]$$

$\delta_f = 31.63°$

MOTION ANALYSIS

Number of turns=5

Steering wheel angle=1800°

Wheel angle = 70

Steering ratio =Steering wheel angle/wheel angle =1800/70=25.71°

COMPARATIVE STUDY OF SOME FOUR-WHEEL SYSTEM AND OUR PROTOTYPE OF FOUR WHEELS

We are going to analyse that how the use of four-wheeler steering system will help to decrease the turning radius of commercial vehicles like FORD FIGO by keeping the practical limitation in mind and compare their results with the prototype that we design.

CASE 1- ALTO 800

A case study on the steered wheel angles of a passenger vehicle is done to find the usefulness of the symmetric four wheel steering system in reducing the turning radius of the vehicle compared to its counterpart i.e. the normal front wheel steering system in which only the front wheels are steered.

The data of the vehicle considered are as follows:-

Wheel Base: 2360mm
Wheel Track: 1300mm (approx.)
Turning radius: 4.6m
Weight (GVW): 1140kg

Initially only the front wheel steering is considered to find out the angles of the front two wheels at the given turning radius value in the car brochure considering the vehicle wheel base and track values.

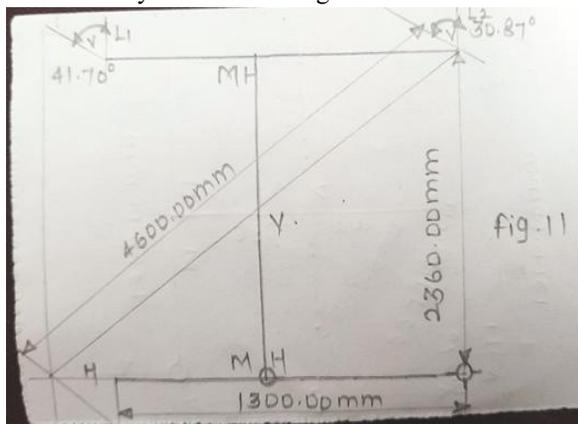Now, keeping one of the angles constant and applying four wheel symmetric steering to this

Fig.11

Vehicle and measuring the other wheel angle for symmetric four wheel steering geometry, we get the following as the resultant turning radius using this system.
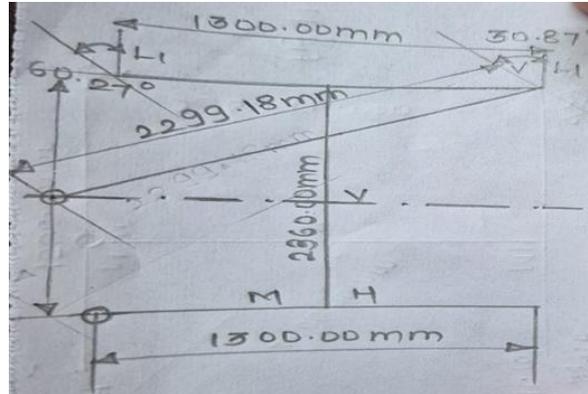

Fig.12

Now, keeping the other angle constant and applying four wheel symmetric steering to this vehicle and measuring the other wheel angle for symmetric four wheel steering geometry, we get the following as the resultant turning radius using this system.

From observations, it is evident that the this system gives the optimum turning radius without exceeding the practical limitations of the vehicle which is the turning of the inner Wheel to an angle of 60.27º to one extreme.
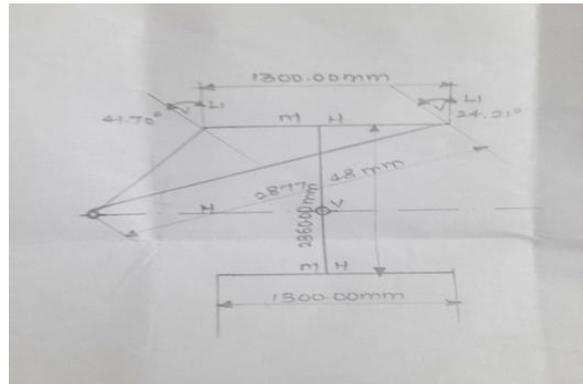

Fig.no.13

Fig. shows the optimum steering wheel angles practically suitable for a vehicle to reduce the turning radius of the vehicle. This optimum configuration gives 37% reduction of the turning radius for this vehicle.

CASE 2- FORD FIGO

Another case study on the steered wheel angles of a passenger vehicle is done to find the usefulness of the symmetric four wheel steering system in reducing the turning radius of the vehicle compared to its counterpart i.e. the normal front wheel steering system in which only the front wheels are steered.

The data of the vehicle considered are as follows

Wheel Base   :   2500mm (approx.) Wheel
Track   :   1500mm   (approx.)
Turning radius   :   4.9m
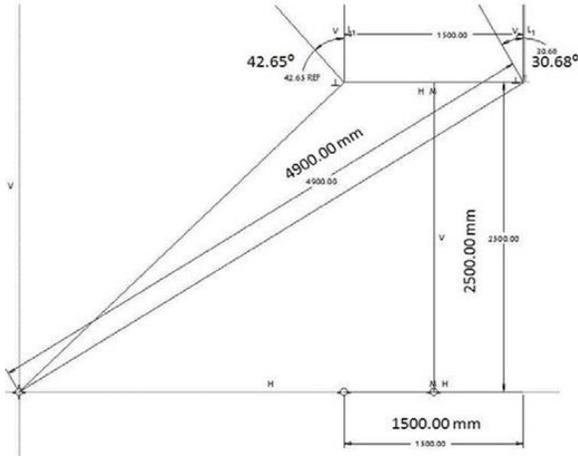Weight (GVW)   :   1500kg (approx.)

Fig.no.14

Initially only the front wheel steering is considered to find out the angles of the front two wheels at the given turning radius value in the car brochure considering the vehicle wheel base and track values.

Now, keeping one of the angles constant and applying four wheel symmetric steering to this vehicle and measuring the other wheel angle for symmetric four wheel steering geometry, we get the following as the resultant turning radius using this system.
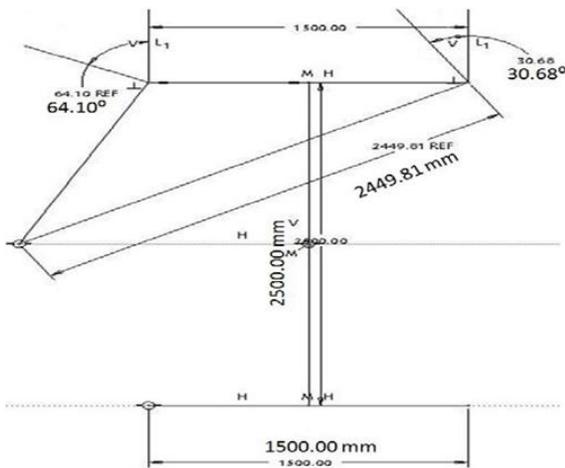

Fig.no.15
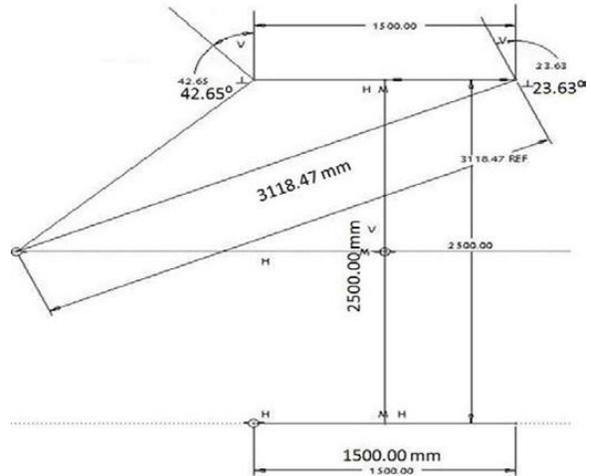
Modified steering wheels angles

Fig.no.16

Out of the two observations, it is evident that the second system gives the optimum turning radius without exceeding the practical limitations of the vehicle which is the turning of the inner wheel to an angle of 64.10^0 to one extreme.

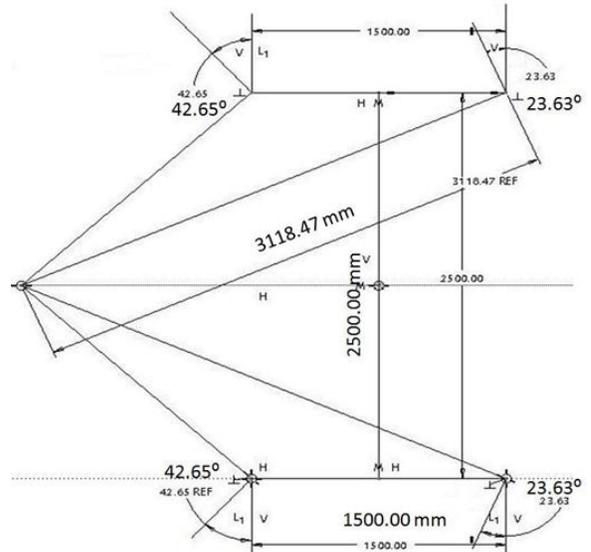Fig.no.17

Practically suitable for a vehicle to reduce the turning radius of the vehicle. This optimum configuration gives 36% reduction of the turning radius for this vehicle.

V.   CONCLUSION

From the above analysis of two-wheel and different type of four-wheel model including our prototype model shows in Table. In which this analysis is converting a steering mode from 2 WS to 4 WS the

turning radius get reduces which help auto mobile to take the sharp turn and prove to be very helpful while driving the car or at the time of changing the lane. This concept may be applied to different cars of

Model	Turning radius in two-wheel mode (in mm)	Turning radius in four-wheel mode (in mm)	% reduction in turning radius
ALTO 800	4600	2877.48	37
FORD FIGO	4900	3118.47	36
PROTOTYPE	520	219.8	57.7

Different speeds and weights. By the conservation of angular momentum, if weight and speed of vehicle increase, the then turning radius decreases. The percentage reduction in turning radius is 37% in ALTO 800 car when switching a steering mode from two wheels to four wheels, while this reduction will be 36% in case of FORDFIGO car. However, in our prototype four-wheel steering, the turning radius has reduced to 57.7%. Thus, our prototype car can turn in small space. Manufacturing cost is reduced due to small size of turning radius.

To reduce the turning radius of a Maruti Alto 800, there are a few mechanical adjustments and driving techniques that could help, though some factors are built into the car's design and can't be drastically altered without significant modification. Here's what you can consider:

VI. METHODS TO REDUCE TURNING RADIUS

Optimize Steering Components
Steering Rack Adjustment: Ensure that the steering rack is in good condition and properly aligned. Any wear and tear in the rack, tie rods, or steering linkages can increase the turning radius.
Steering Angle: Some modifications to the steering system, such as increasing the steering lock or adjusting the steering geometry, could potentially reduce the turning radius. However, this requires professional expertise and may affect the car's handling and safety.

Tire and Wheel Adjustments
Tire Size: Switching to smaller tires or wheels might reduce the turning radius slightly, as they require less space to maneuvers.
Wheel Offset: Modifying the wheel offset (how far the wheels are pushed outward) could give slightly more clearance, though it's a minor adjustment and should be done carefully to avoid any negative impacts on steering and suspension.

Suspension Modifications
Adjustments to the suspension geometry can change the dynamics of the turning radius. For instance, changing the camber angle of the wheels could improve the sharpness of turns. However, this should be handled by professionals to avoid negative effects on handling.

Weight Distribution
Reducing the weight at the front of the car, where most of the turning happens, can make the steering feel lighter and slightly improve the turning radius. This can be done by avoiding unnecessary weight on the front axle.

Driving Techniques
Three-Point Turns: In tighter spaces, using a three-point turn instead of trying to make a full U-turn can reduce the effort needed and minimize the impact of a larger turning radius.
Use Handbrake Turns (only in emergency situations): For highly skilled drivers, a handbrake turn can reduce the radius, but this is not recommended for everyday driving due to safety concerns and wear on the car.

Install Power Steering (if not present)
If your Alto 800 does not have power steering, adding it can make steering easier, allowing you to make sharper turns with less effort.

Check Alignment
Misalignment in the wheels or steering system could cause the car to require a larger turning radius. Regular alignment checks help maintain optimal steering performance. While some adjustments are possible, it's important to note that the Alto 800's design inherently limits the turning radius to a certain extent. Major modifications should be done with caution and always by a professional.

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