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Effect of Rear Wheel Steering on Turning Circle Diameter in Virtual Analysis

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Abstract- Turning Circle Diameter (TCD) is a critical parameter in vehicle manoeuvrability, particularly in urban environments where tight turns and compact parking spaces are prevalent. Traditional front-wheel steering systems limit the potential for reducing TCD due to geometric and packaging constraints. This paper investigates the implementation of rear-wheel steering (RWS) as a means to reduce TCD. Based on simulation and theoretical analysis, two RWS configurations — 5° and 7° rear steer angles are evaluated. Results show an approximate 8% and 12% reduction in TCD, respectively. However, mechanical constraints such as wheel envelope clearance, interference with suspension components, and vehicle loading conditions must be addressed to ensure feasibility. The study concludes that RWS can be a highly effective solution for improving low-speed manoeuvrability when integrated carefully with physical constraints.

Keywords: Rear Wheel Steering (RWS), Turning Circle Diameter (TCD), Manoeuvrability, Vehicle Dynamics

I. INTRODUCTION

Vehicle manoeuvrability refers to a vehicle's ability to execute changes in direction efficiently and safely, especially in tight urban conditions. One of the key metrics used to assess this is the Turning Circle Diameter (TCD)—the smallest diameter of a circle that a vehicle can turn within at full steering lock.

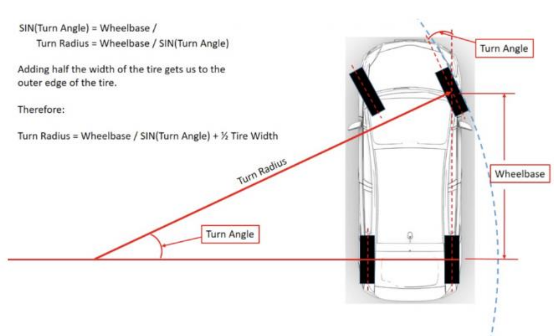

Figure 1 : Schematic of Turning Radius and Turn Angle

Image Source: https://www.theautopian.com/the-engineering-behind-why-some-cars-can-turn-tighter-than-others/

Conventional two-wheel steering (2WS) systems steer only the front wheels. This limits the minimum achievable TCD due to constraints at the rear axle. Rear-Wheel Steering (RWS), by contrast, enables the rear wheels to steer either in the same direction (at high speeds) or in the opposite direction (at low speeds) as the front wheels.

This paper explores the effect of low-speed counter-phase RWS—where rear wheels steer opposite to the front—to reduce TCD and enhance vehicle manoeuvrability. The impact of 5° and 7° rear steer angles is evaluated via kinematic modelling and analysis.

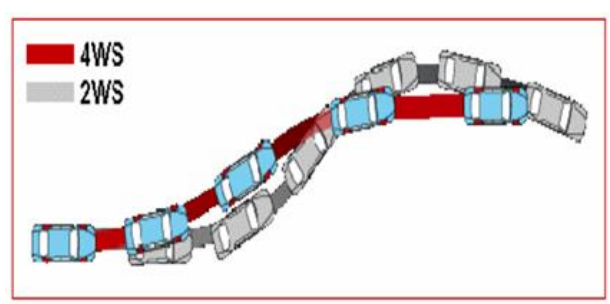

Figure 2: Illustration showing the difference in lane-change path between 2-wheel steering (2WS) and 4-wheel steering (4WS). Vehicles with 4WS maintain a tighter and more controlled path.

Source: Chaudhary, R. (2015). Study of 4 Wheel Steering Systems to Reduce Turning Radius and Increase Stability. ResearchGate.

II. METHODOLOGY

Baseline Vehicle Data

- TCD without RWS: Baseline vehicle
- Front Steering Angle (δf): Constant for analysis
- Rear Steering Angles (δr): 5° and 7° considered

Analytical Model

To estimate TCD, we use the turning radius formulas:

Turning radius without RWS: $R=L/\sin(\delta_f)$

Turning radius with RWS: $R=L/\sin(\delta_f+\delta_r)$

Where:

R : Turning radius

L : Wheelbase

δ_f : Front wheel steer angle

δ_r : Rear wheel steer angle

These equations assume ideal tyre behaviour and no slip.

Source : Thomas D. Gillespie, Fundamentals of Vehicle Dynamics, Society of Automotive Engineers (SAE), 1992.

Section: Kinematic Steering, Ackermann Geometry

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Simulation & Estimation

Simulation models were developed using validated kinematic equations to calculate the reduced turning radius and TCD under the influence of 5° and 7° rear steer configurations.

Parameter	Units	Symbol	Value
Wheelbase	millimetres (mm)	*L*	2730
Front track width	millimetres (mm)	*Tf*	1584
Rear track width	millimetres (mm)	*Tr*	1584
Front max steering angle	degrees (°)	*δf*	~31
Rear steer angle (case 1)	degrees (°)	*δr*	0
Rear steer angle (case 2)	degrees (°)	*δr*	5
Rear steer angle (case 3)	degrees (°)	*δr*	7
Tyre	mm	*w*	225/55 R19

III. RESULTS

The following table summarises the results of the TCD reduction based on the different rear-wheel steer angles:

Rear Wheel Steer Angle (°)	TCD Reduction (%)
0 (Standard Steering)	-
5	8%
7	12%

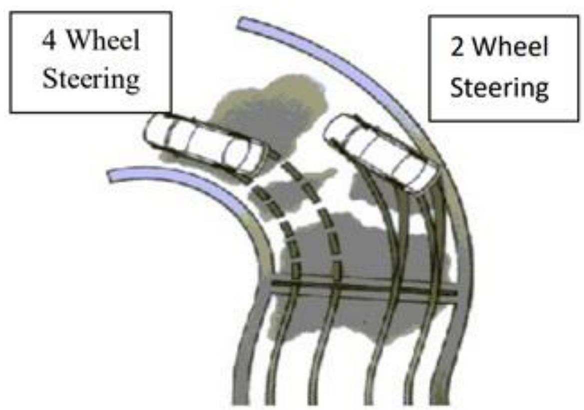

Figure 3: Visual comparison of turning radius for 4-wheel and 2-wheel steering. The 4WS vehicle demonstrates a significantly tighter turning path.

Source: Chaudhary, R. (2015). Study of 4 Wheel Steering Systems to Reduce Turning Radius and Increase Stability. ResearchGate.

These findings demonstrate that RWS, particularly at higher angles, leads to substantial improvement in turning ability.

IV. DESIGN CONSTRAINTS & IMPLEMENTATION CHALLENGES

Wheel Envelope Clearance

With RWS, the rear wheels move laterally, necessitating packaging clearances checks under:

- Bump and rebound (vertical movement)
- Steering left & right side movement along with vertical movement combination
- Cornering-induced roll
- Different loading conditions (unladen, partial load, full load)
- Presence of wheel arch liners, dampers, and suspension arms

Risk of Component Fouling

Critical interference points to assess:

- Inner wheel arch
- Dampers and suspension links
- Brake lines and wiring harnesses

A rear steer angle of even 5° increases lateral tyre movement, possibly requiring redesign of the rear body or liner.

System Complexity and Cost

- Electronic control systems for RWS increase software and diagnostic requirements.
- Weight and cost rise due to added actuators and linkages.
- Maintenance considerations must be factored in due to increased system complexity.

V. DISCUSSION

The analysis confirms that integrating rear-wheel steering significantly enhances vehicle manoeuvrability. The 12% TCD reduction seen with a 7° steer angle could allow vehicles to perform U-turns in narrower lanes, simplify parking, and reduce multi-point turns in confined spaces.

However, integration is non-trivial. The impact on rear suspension packaging, clearances, and structural envelope requires close collaboration between suspension, chassis, body-in-white (BIW), and electrical teams. Environmental durability—considering water ingress, debris, and wear—must also be validated.

VI. CONCLUSION

Rear-wheel steering is a practical and effective strategy for reducing Turning Circle Diameter and improving urban manoeuvrability. A steer angle of 7° can reduce TCD by over 12%, but implementation challenges like wheel envelope clearance, component interference, and added system complexity must be addressed, and also handling performance should be analysed and tuned for optimisation.

Future work should focus on:

- Detailed CAE envelope analysis
- Prototyping and physical testing
- Integration feasibility studies under various load and road conditions
- Effect on handling performance