International Journal For Technological Research In Engineering
Volume 8, Issue 4, December-2020 *ISSN (Online): 2347 - 4718*

STUDY ON EFFECTS OF ORIENTATION CHARACTERISTICS COMING STABILITY OF 2-AXIS AUTOMOBILE

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ABSTRACT

There are many causes of instability to the orbital motion of the automotive turnaround. Cause destabilize the rotation direction is: Characteristics direction; Road surface state (bad roads, good, dry, wet, ...); Transmission of the vehicle. Other factors such as structural suspension, differential, proactive; driving techniques; ... The angle is deflected by the elastic deformation of the wheel that the driver felt very clearly when the phenomenon appeared oblique stab floss instability leads to orbital motion of the automobile.

To study the effect of the characteristic direction using flat two models of cars wound to study two axes. Orbital motion simulation of automotive turnaround affected the characteristics of the user. Results achieved when running simulation programs can help manufacturers design, improved stability of the automotive turnaround, thus helping to improve road safety issues.

I. INTRODUCTION

Nowadays, many traffic accidents happen mainly due to the loss of driving force. The stability of the car is the ability to ensure that the motion trajectory required by the driver is maintained in all different motion conditions. Depending on the conditions of use, the car can stand still, move on the road with a vertical angle, horizontal tilt, brake or turn around on different types of roads.

In particular, the deflection that the driver feels very clearly leads to the oblique stabbing, flossing phenomenon, when the car appears, the phenomenon of flossing does not comply with the driver's intention will cause a dangerous traffic accident. This is one of the causes of loss of control. The property of changing the direction of motion due to the effect of objective factors (except for the steering wheel rotation of the driver) is called the direction characteristic.

II. RESEARCH METHODS

Document search method: find and read relevant documents, scientific research topics, master's thesis, domestic and foreign sources from magazines, books, from the internet.

Theoretical analysis method: analysis and reasoning in the direction of the theory of cyclic stability based on the background knowledge that has been equipped in the process of undergraduate and graduate studies.

Application method Matlab software to calculate simulation.

III. STABLE ROTATION

1. Basic relations

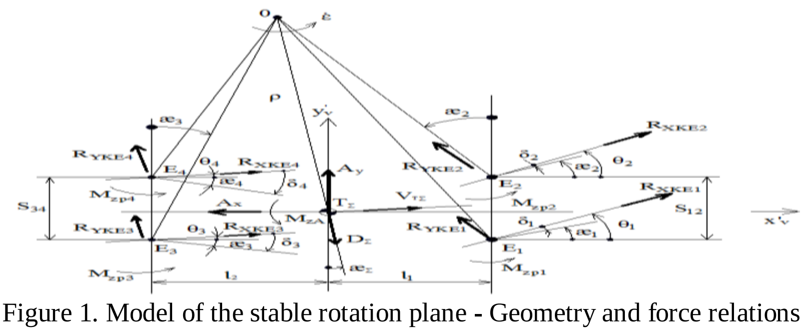

Figure 1. Model of the stable rotation plane - Geometry and force relations

Cars turn around on flat roads at a constant speed.

The entire vehicle spins around the O-axis at speed $\dot{\varepsilon}$

Vector speed $\vec{V}_j$ of any point j on the vehicle lying in a plane parallel to the road surface (X, Y), perpendicular to the radial vector $\vec{\rho}_j$ and valuable $V_j = \rho_j . \dot{\varepsilon}$.
If j is a point substance with mass mj, it will be subjected to a force acting inertia

$$D_j = m_j V_j . \varepsilon = m_j . \frac{V_j^2}{\rho_j}$$

At the center of the vehicle T_v has centrifugal force D_v , at the center of the wheel and suspension T_{Ki} has a centrifugal force effect D_{Ki} .

For the center of gravity of the vehicle's body, there is usually an aerodynamic effect $\vec{A}$ and aerodynamic moment $\vec{M}_A$.
The forces mentioned above must be in balance with the forces exerted from the road surface R_{XKHi} , R_{YKHi} , R_{ZKHi} with Hi are the contact points between the wheel and the vertical plane.

The tires rotate at an angle to the body ϕ_i (i = 1, 2, 3, 4) and then the opposite moments appear M_{ZPi} .
As is known: horizontal force R_{YKi} and the reverse moment M_{ZPi} depends on the deflection angle δ_i , load radial R_{ZHi} and depends on traction R_{XKHi} . It mean

$$R_{YKHi} = f(\delta_i , R_{ZHi} , R_{XKHi})$$
$$M_{ZPi} = f(\delta_i , R_{ZHi} , R_{XKHi})$$

Deflection angle δ_i is the angle between the speed vector of the theoretical contact E_i of the tire with the longitudinal axis of the wheel XKi (this axis is determined by the angle of rotation θ_i)

Rotation θ_i On uncontrolled wheels depending on the precision of the wheel, wheel deviation from the vehicle body, suspension deflection. In the control wheel, of course, depends on the volant angle and steering system elasticity. All the above values are dependent on the tank stability (ψ_v , Δ_{hv} , ϕ_v) and forces R_{XKHi} , R_{YKHi} , R_{ZKHi} , M_{ZPi} .

Active force R_{XKHi} determined by the driver to achieve motion stability (v = const). Its value on each wheel depends on the differential distribution or distribution box.

Stable tank ϕ_v , ψ_v , Δ_{hv} is determined by the forces exerted on the suspension and the mounting dynamics.

Vertical jets from the road surface R_{ZHi} is determined by the value and direction of the centrifugal force, the height of the center of gravity as well as the kinetic and elastic properties of the two bridges (suspension).

Thus: the set of all the above factors in the overall problem is very complex. Usually we perform problems with simplified steps.

2. THE EQUATIONS HAVE SIMPLIFIED

When setting up the equations to calculate the longitudinal and transverse forces on the wheels in the road plane, it is practically possible to use (approximate) a flat model of the vehicle with the following characteristics: the tank does not tilt in all directions. The cylinder is vertical and goes through the center of the wheel. In addition, the entire weight of the car can be considered concentrated in the center of gravity T_Σ.

The rotation radius of center of gravity ρ and radial acceleration $d = \frac{V^2 T_\Sigma}{\rho}$ are considered as (known) input parameters when constructing force equations.

The speed vectors V_{Ei} At points Ei inclined in relation to the axes X_v corners $æ_i$, still V_{Ti} angle is inclined $æ_\Sigma$. The positive directions of these angles are shown in figure 3.1. Between the corners æ and radius ρ There are the following relationships:

$$(l_2-\rho.sinæ_\Sigma)\left(\rho.cosæ_\Sigma-\frac{S_{34}}{2}\right)tgæ_4=\left(\rho.cosæ_\Sigma+\frac{S_{34}}{2}\right)tgæ_3$$
$$(l_1-\rho.sinæ_\Sigma)\left(\rho.cosæ_\Sigma-\frac{S_{12}}{2}\right)tgæ_2=\left(\rho.cosæ_\Sigma+\frac{S_{12}}{2}\right)tgæ_1 \quad (1)$$

Because all angles æ are very small, we can write relations:

$$\frac{æ_4}{æ_3}=\frac{\rho+\frac{S_{34}}{2}}{\rho-\frac{S_{34}}{2}};\ æ_\Sigma=\frac{l_2}{\rho}-æ_4\left(1-\frac{S_{34}}{2\rho}\right)=\frac{l_2}{\rho}-æ_3\left(1+\frac{S_{34}}{2\rho}\right)$$
$$æ_1=\frac{l_1+\rho æ_\Sigma}{\rho+\frac{S_{12}}{2}};\ æ_2=\frac{l_1+\rho æ_\Sigma}{\rho-\frac{S_{12}}{2}};\ æ_3=\frac{2(l_2-\rho æ_\Sigma)}{2\rho+S_{34}}\ ;\ æ_4=\frac{2(l_2-\rho æ_\Sigma)}{2\rho-S_{34}} \quad (2)$$

All angles æi will determine if one of them is known (eg knowing æΣ). The wheels will rotate the corners θ_i in the directions shown in the figure and their deflection angle is determined:

$$\delta_1=\theta_1-æ_1\ ;\ \delta_2=\theta_2-æ_2\ ;\ \delta_3=\theta_3+æ_3\ ;\ \delta_4=\theta_4+æ_4 \quad (3)$$

Equilibrium equations can be written as follows:
According to the direction X_V :

$$D_\Sigma sinæ_\Sigma+(R_{XKE_1}-0_{f1}).cos\theta_1+(R_{XKE_2}-0_{f2})cos\theta_2+(R_{XKE_3}-0_{f3})cos\theta_3+(R_{XKE_4}-0_{f4})cos\theta_4-R_{YKE_1}.sin\theta_1-R_{YKE_2}.sin\theta_2-R_{YKE_3}.sin\theta_3-R_{YKE_4}.sin\theta_4-Ax=0 \quad (4)$$

According to the direction Y_V :

$$D_\Sigma cosæ_\Sigma+(R_{XKE_1}-0_{f1}).sin\theta_1+(R_{XKE_2}-0_{f2})sin\theta_2+(R_{XKE_3}-0_{f3})sin\theta_3+(R_{XKE_4}-0_{f4})sin\theta_4-R_{YKE_1}.cos\theta_1-R_{YKE_2}.cos\theta_2-R_{YKE_3}.cos\theta_3-R_{YKE_4}.cos\theta_4-Ay=0 \quad (5)$$

The equation of moment with respect to the axis Z_V go through the focus T_Σ :

$$(R_{XKE_1}-0_{f1})\left(+\frac{S_{12}}{2}.cos\theta_1+l_1.sin\theta_1\right)+(R_{XKE_2}-0_{f2})\left(-\frac{S_{12}}{2}.cos\theta_2+l_1.sin\theta_2\right)+(R_{XKE_3}-0_{f3})\left(+\frac{S_{34}}{2}.cos\theta_3+l_2.sin\theta_3\right)+(R_{XKE_4}-0_{f4})\left(-\frac{S_{34}}{2}.cos\theta_4-l_2.sin\theta_4\right)+R_{YKE_1}\left(-\frac{S_{12}}{2}.sin\theta_1+l_1.cos\theta_1\right)+R_{YKE_2}\left(+\frac{S_{12}}{2}.sin\theta_2+l_1.cos\theta_2\right)+R_{YKE_3}\left(-\frac{S_{34}}{2}.sin\theta_3-l_2.cos\theta_3\right)+R_{YKE_4}\left(+\frac{S_{34}}{2}.sin\theta_4-l_2.cos\theta_4\right)+\sum_{i=1}^{4}Mzp_i+Mz_A=0 \quad (6)$$

In the above equations:

In steady state the car must be driven. We assume only one bridge is active (front or rear axle) and that the differential is frictionless, it mean $R_{XKE1}=R_{XKE2}=\frac{1}{2}.R_{XKE12}$ (or $R_{XKE3}=R_{XKE4}=\frac{1}{2}.R_{XKE34}$) . So the only unknown is the traction R_{XKE12} (or R_{XKE34}).

Assumptions $\theta_3=\theta_4=0$ (ignoring the influence of rear axle suspension, wheel positioning angle, wheel rotation angle 3,4). So there are only two hidden θ_1 , θ_2 .

Rotating angle θ_m và θ_1, θ_2 driving kinetic relations. Let's say $\theta_1=\theta_2=\theta=\theta_m$

0_{fi} (i = 1- 4) is the rolling resistance at the wheels. $0_{fi}=R_{zi}.f$ (f: rolling resistance coefficient).

$R_{yi}=K_y.\delta_i$

+ K_y Direction stiffness must be chosen based on initial theory

+ $\delta_i=\theta_i\pm æ_i$, but $æ_i=f(æ_\Sigma)$

D_Σ centrifugal force at the center of gravity, $D_\Sigma=m.\frac{V^2}{\rho}=mV(\dot{æ}_\Sigma+\dot{\varepsilon})$

A_X , A_Y is the air resistance in the direction X and Y.

+ $A = 0{,}63.C_x.S.V^2$

C_x : Air resistance coefficient.

$S = 0{,}8.B_0.H$, front bump area

B_0 : the largest width of the car

H : the maximum height of the car

V : the speed of movement of the car

M_{ZPi} is the payment moment of some tire i. We have:

$M_{zpi} = C_z \,.\, \delta_i$ (Nm)

δ_i : angle of deflection of the i th wheel (rad)

C_z – the rigidity paid by the rotating tire (Nm/rad).

C_{zo} – The stiffness paid of the stationary tire is within range 2000 – 3000 (Nm/rad).

The hardness of the tire is rotated C_z less than the paid stiffness of the stationary tire C_{zo} , This difference is approximately $C_{zo} / C_z = 1{,}5 – 2$.

M_{ZA} It is the moment of the aerodynamic drag when the vehicle turns. It mainly depends on the speed of rotation $\dot{\varepsilon}$, here can be seen $M_{\sum A} = -C_{ZA}.\ddot{\varepsilon}$.

C_{ZA} : the vehicle's aerodynamic drag coefficient in rotation around the axle z

Thus, the system of equations (4), (5), (6) is a system of differential equations describing the motion trajectory of cars.

Through the content presented above we see, when studying the steady state of the car when revolving under the influence of directional characteristics by two-track model. The two-track model allows a very detailed and complete survey of the influence of the deflection angle towards each wheel of the car and thereby the stability of the car's rotation. Investigation with a two-spot model is more complete and detailed than a single-track model.

The system of differential equations built on the basis of a two-track model allows us to survey clearly and in more detail the rotation state of a car, but it is very complicated to do a full survey. Hence here the differential equations have been simplified. Solving these simplified differential equations allows us to determine body deflection angle æΣ, body rotation angle ε, thereby assessing the steady state of car rotation when affected by the deflection angle. Direction with structural parameters, changing motion conditions.

3. SIMULATION AFFECTS THE TRAJECTORY OF MOTION

3.1 The initial input parameters of the car were used in Matlab software to solve differential equations

m = 1990 (kg) is the mass of the vehicle without load
m = 2701 (kg) is the mass of the vehicle at full load
L = 2,8 (m) is the wheelbase of the vehicle
$l_1 = 1{,}3$ (m) is the distance from the center of the car to the front wheel
$l_2 = 1{,}5$ (m) is the distance from the car's center of gravity to the rear axle
f is the rolling resistance coefficient of cars, choose the rolling resistance coefficient
$f = f_1 = f_2 = f_3 = f_4 = 0{,}015$
v is the motion speed of the car, choose the speed v = 40 (km/h) = 11,11 (m/s)
- Determine the average wheel radius

$r_b = \lambda.r_0$
λ is the selected tire strain factor $\lambda = 0,93$
$r_0 = (H.2+d)/2 = ((0,6.255).2+18.25,4 = 763,2$ (mm)
$r_b = 0,93.763,2 = 710$ (mm) = 0,71 (m)
- Coefficient of air resistance along the axial axis of the vehicle selected
$C_x = 0,35$ (Ns^2/m^4)
$Ax = 0,63.C_x.S.V^2 = 0,63.0,35.1,788.1,826.11,11^2 = 88,9$ (N)
- The horizontal axis of the air resistance of the car choose Ay = 251,6 (N)
- Car's perpendicular jet when idle

$$R_{z12} = mg\frac{(l_2 - f.r_b)}{L} - A_x\frac{h_\omega}{L} = 10556{,}45\ (N)$$

$$R_{z34} = mg\frac{(l_1 + f.r_b)}{L} + A_x\frac{h_\omega}{L} = 9343{,}55\ (N)$$

- Rolling resistance when the car is not loaded

$$0_{f1} = 0_{f2} = \frac{R_{z12}}{2}.f = 79{,}2\ (N)$$

$$0_{f3} = 0_{f4} = \frac{R_{z34}}{2}.f = 70{,}1\ (N)$$

- Auto-perpendicular jet when full load

$$R_{z12} = mg\frac{(l_2 - f.r_b)}{L} - A_x\frac{h_\omega}{L} = 14338{,}33\ (N)$$

$$R_{z34} = mg\frac{(l_1 + f.r_b)}{L} + A_x\frac{h_\omega}{L} = 12671{,}67\ (N)$$

- Rolling resistance when the car is full load

$$0_{f1} = 0_{f2} = \frac{R_{z12}}{2}.f = 107{,}5\ (N)$$

$$0_{f3} = 0_{f4} = \frac{R_{z34}}{2}.f = 95\ (N)$$

$R_{XKE12} = R_{Z12}.\varphi$
$R_{XKE34} = R_{Z34}.\varphi$
Choose $C_{z0} / C_z = 2$, with $C_{z0} = 3000$ (N/rad) therefore $C_z = 1500$ (N/rad)
$C_{zA} = 3000$
$K_y = 15$- 40 kN/rad ; choose $K_y = 40$ kN/rad
$g = 10$ (m/s^2)

3.2. The movement trajectory of the car when changing the active bridge

The survey mode is the same in terms of structure and speed parameters v = 40 km/h, steering angle $\theta = 20^0$, Vehicle testing on the road with grip coefficient $\varphi = 0,8$.

After loading with the structural parameters of the vehicle, run the program with the following results:

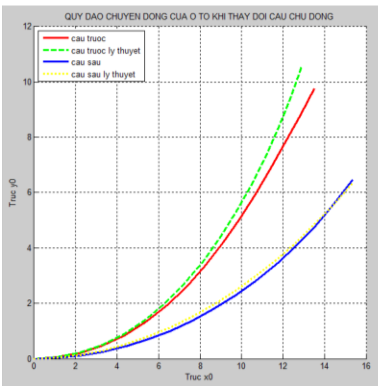

Figure 2. The motion trajectory of a car when changing the active bridge $\varphi = 0,8$

The survey mode is the same in terms of structure and speed parameters v = 40 km/h,
Steering angle $\theta = 20^0$, Vehicle testing on the road with grip coefficient $\varphi = 0,4$.
After loading with the structural parameters of the vehicle, running the Matlab program produces the following results:

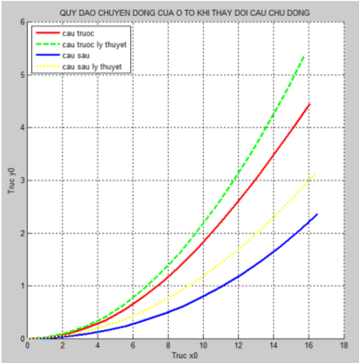

Figure 3. The motion trajectory of a car when changing active demand when φ = 0,4

Realize that the actual and theoretical orbits are different because in theoretical calculation the influence of the deflection angle is ignored. Active rear-wheel vehicles have more unstable trajectories when passing bad roads compared to active front-wheel cars and tend to lack more rotation than active front-wheel cars. The reason is due to the slip characteristic when traction R_{XKE34} slippage increases, as slippage increases the horizontal coefficient φ_y reduction, when the φ_y decrease the horizontal force R_{y34} Reducing the deflection will reduce the lateral deflection in the rear tire, then the deflection angle at the front wheel is much higher than the deflection angle at the rear wheel ($\delta_{12} >> \delta_{34}$). Therefore, active rear-wheel drive cars tend to lack more.

3.3. The trajectory of the car when changing loads

Investigate the movement trajectory of cars corresponding to different active drive such as active front wheel, active rear wheel.

The same survey mode in structural parameters, speed v = 40 km/h, steering angle $\theta = 20^0$, Vehicle testing on the road with grip coefficient φ = 0,4.

After loading with the structural parameters of the vehicle, running the Matlab program produces the following results:

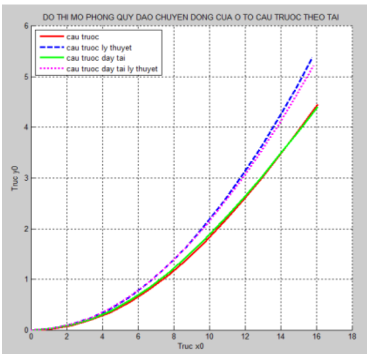

Figure 4. The moving trajectory of front-wheel vehicle is active according to load

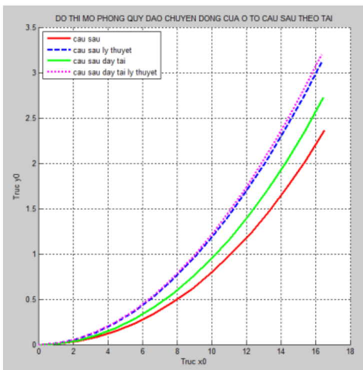

Figure 5. The moving trajectory of rear axle vehicle is active by load

Realizing that when the vehicle load changes when the motion is stable and revolving, the motion trajectory of the car between theory and reality is different with different active bridge, both front-wheel-drive cars are active. and the active rear axle has missing rotation phenomenon, the cause of this difference is due to the theoretical calculation ignoring the influence of the deflection angle. As the load increases, the actual trajectory is closer to the theoretical orbit, it is because the increased load increases the car's grip, and the car lessens slip.

3.4. The trajectory of a car's movement when it changes speed

Investigate the stable rotation trajectory of active front and rear axle cars with steering angle $\theta = 20^0$, in no-load mode, on the same road with a traction coefficient φ = 0,4, change the speed of the corresponding car V = 40km/h, V = 60km/h.

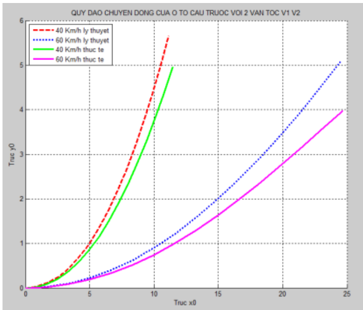

Figure 6. The trajectory of the front-wheel drive car is actively changing when it comes to speed

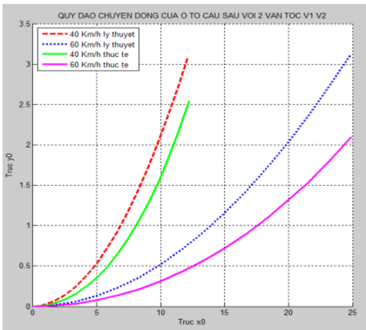

Figure 7. The moving trajectory of rear axle cars actively changes speed

The actual rotation trajectory and the theoretical motion trajectory are different. Because in the calculation ignores the influence of the deflection angle. Both the active front axle and the active rear axle have a tendency to lack rotation in comparison to the theoretical trajectory.

It is found that when the speed increases, the centrifugal force increases, making the turning radius increase, causing instability for both the active front axle and the active rear wheel.

The centrifugal force is proportional to the square of the velocity, so as the velocity increases the trajectory of a car changes very quickly. The large centrifugal force causes the vehicle to be thrown away from the large center of rotation and makes the actual trajectory further away from the theoretical orbit.

3.5. The trajectory of the car when changing the grip coefficient

Investigation of active front-wheel drive cars and active rear-wheel-drive cars in idle mode, steering angle $\theta = 20^0$, the car moves at speed V = 40 km/h, with different road surface conditions change the coefficient of grip φ = 0,8; φ = 0,6; φ = 0,4.

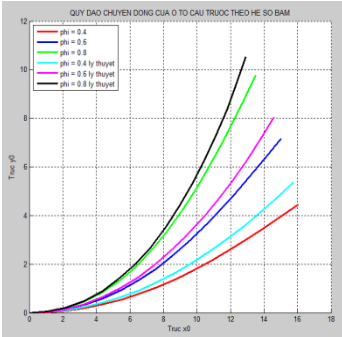

Figure 8. The trajectory of the front axle vehicle is active when changing the grip coefficient

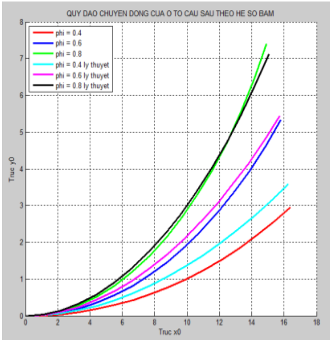

Figure 9. The trajectory of rear axle cars is active when changing the grip coefficient

Observing the graph, we can see that there are differences between the actual and theoretical orbits, the reason is that in theoretical calculation, the influence of the deflection angle has been ignored.

Cars moving on roads with a low coefficient of grip are more unstable than on roads with a high coefficient of grip, more slip, and greater turning radius.

Realized that when the coefficient of grip decreases, the actual trajectory is farther away from the theoretical orbit, the cause is that cars moving on poorly track will slide more.

Both the active front-wheel drive and the active rear-wheel drive have a lack of rotation.

IV. CONCLUDE

Using a specific set of parameters of the vehicle to calculate and survey the parameters affecting the rotation trajectory of the car, the calculation results have shown the influence of the deflection angle to the motion trajectory of the car. How dangerous is the car based on the simulation results of practical significance to improve the rotation characteristics of two-axis cars through improving structural parameters, selecting active bridges, and distributing loads will help reduce costs. the actual cost of the experiment is expensive. Helping the driver to understand more deeply about the characteristics of the vehicle he is driving, contributing to safer driving.

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