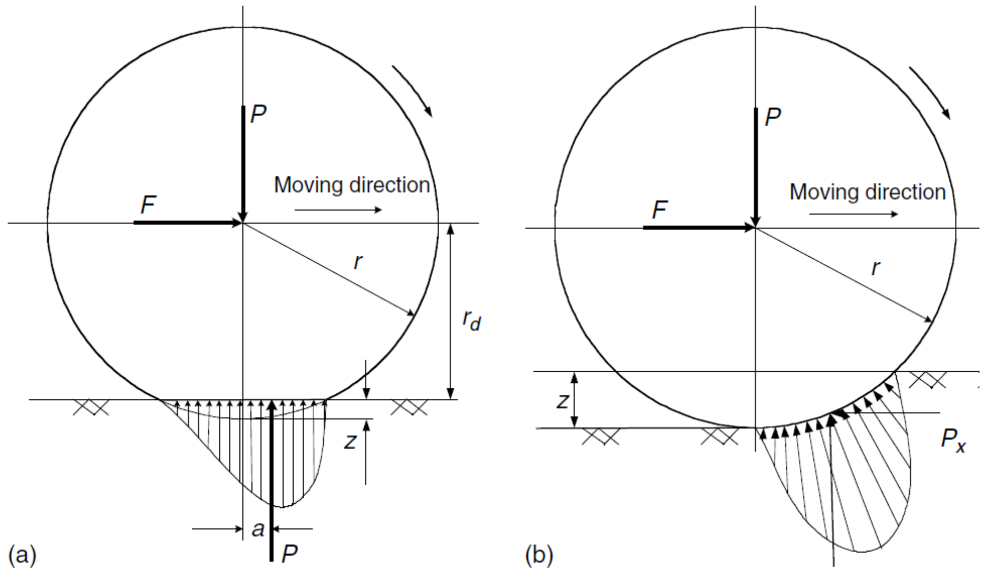
➢ Vehicle Resistance

Vehicle resistance opposing its movement includes rolling resistance of the tires rolling resistance torque T_{rf} and T_{rr}, aerodynamic drag F_w and grading resistance ($M_v\, g \sin\alpha$)

➢ Rolling Resistance



Tire deflection and rolling resistance on a (a) hard and (b) soft road surface

➢ Dynamic Equation

In the longitudinal direction, the major external forces acting on a two-axle vehicle, include the rolling resistance of front and rear tires F_{rf} and F_{rr}, which are represented by rolling resistance moment T_{rf} and T_{rr}, aerodynamic drag F_w, grading resistance F_g ($M_v\, g$ sinα), and tractive effort of the front and rear tires, F_{tf} and F_{tr}. F_{tf} is zero for a rear-wheel-driven vehicle, whereas F_{tr} is zero for a front-wheel-driven vehicle. The dynamic equation of vehicle motion along the longitudinal direction is expressed by

$$M_v \frac{dV}{dt} = (F_{tf} + F_{tr}) - (F_{rf} + F_{rr} + F_w + F_g)$$

where dV/dt is the linear acceleration of the vehicle along the longitudinal direction and M_v is the vehicle mass.

By summing the moments of all the forces about point R (center of the tire–ground area), the normal load on the front axle Wf can be determined as

$$W_f = \frac{M_v g L_b \cos\alpha - (T_{rf} + T_{rr} + F_w h_w + M_v g h_g \sin\alpha + M h_g dV/dt)}{L}$$

The friction in the gear teeth and the friction in the bearings create losses in mechanical gear transmission. The following are representative values of the mechanical efficiency of various components:
Clutch: 99%
Each pair of gears: 95–97%
Bearing and joint: 98–99%
The total mechanical efficiency of the transmission between the engine output shaft and drive wheels or sprocket is the product of the efficiencies of all the components in the driveline. As a first approximation, the following average values of the overall mechanical efficiency of a manual gear-shift transmission may be used:
Direct gear: 90%
Other gear: 85%
Transmission with a very high reduction ratio: 75–80%

The rotating speed (rpm) of the driven wheel can be expressed as

$$N_w = \frac{N_p}{i_g i_0}$$

where N_p is the output rotating speed (rpm). The translational speed of the wheel center (vehicle speed) can be expressed as

$$V = \frac{\pi N_w r_d}{30} \text{(m/s)} \qquad V = \frac{\pi N_p r_d}{30 i_g i_0} \text{(m/s)}$$

For a four-speed gearbox, the following relationship can be established

$$\frac{i_{g1}}{i_{g2}} = \frac{i_{g2}}{i_{g3}} = \frac{i_{g3}}{i_{g4}} = K_g$$

$$K_g = \sqrt[3]{\frac{i_{g1}}{i_{g4}}}$$

where i_{g1}, i_{g2}, i_{g3}, and i_{g4} are the gear ratios for the first, second, third, and fourth gear, respectively.

The number of the gear *ng* is known, the factor K_g can be determined as

$$K_g = \left(\frac{i_{g1}}{i_{gn}}\right)^{(n_g-1)}$$

and each gear ratio can be obtained by

$$\begin{aligned} i_{gn-1} &= K_g i_{gn} \\ i_{gn-2} &= K_g^2 i_{gn} \\ &\vdots \\ i_{g2} &= K_g^{n_g-1} i_{gn} \end{aligned}$$

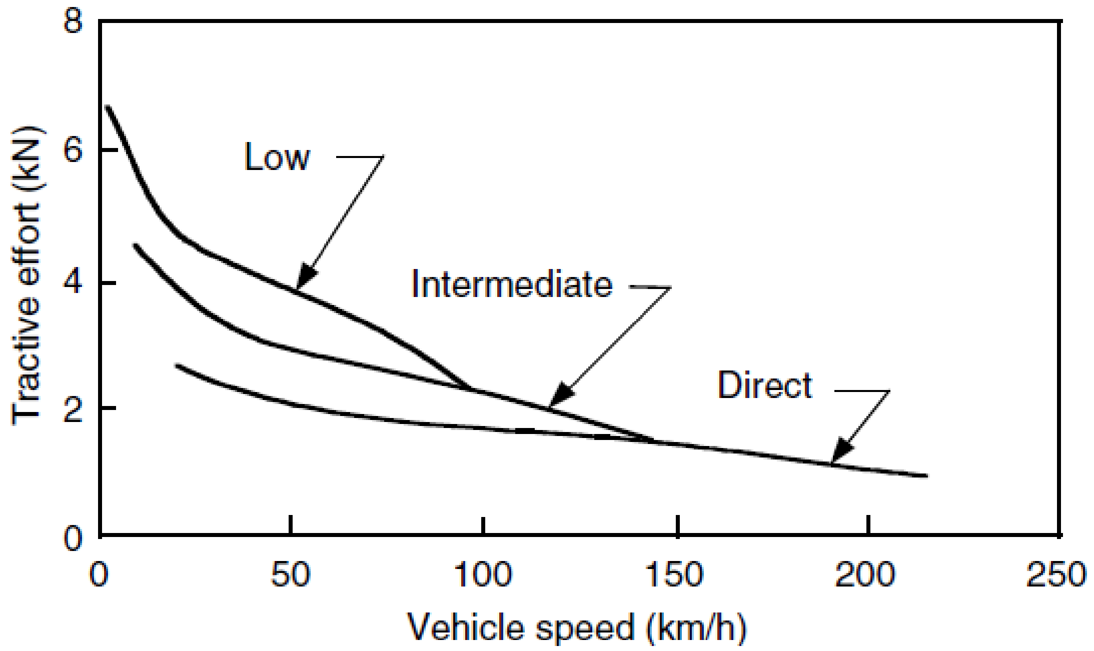
For passenger cars, to suit changing traffic conditions, the step between the ratios of the upper two gears is often a little closer than that based on upper equations. That is,

$$\frac{i_{g1}}{i_{g2}} > \frac{i_{g2}}{i_{g3}} > \frac{i_{g3}}{i_{g4}}$$

The engine shaft is usually connected to the input shaft of the torque converter, as mentioned above. That is,

$$K_e = K_{c'}$$

The matching procedure begins with specifying the engine speed and engine torque. Knowing the engine operating point, one can determine the engine capacity factor, K_e.



Tractive effort–speed characteristics of a passenger car with automatic transmission

For a particular value of the input capacity factor of the torque converter, K_{tc}, the converter speed ratio, C_{sr}, and torque ratio, C_{tr}, can be determined from the torque converter performance characteristics. The output torque and output speed of the converter are then given by

$$T_{tc} = T_e C_{tr}$$

$$n_{tc} = n_e C_{sr}$$

where T_{tc} and n_{tc} are the output torque and output speed of the converter, respectively.

$$F_t = \frac{T_e C_{tr} i_g i_0 \eta_t}{r}$$

$$V = \frac{\pi n_e C_{sr} r}{30 i_g i_0} (\text{m/s}) = 0.377 \frac{n_e C_{sr} r}{i_t} (\text{km/h})$$

The braking force can be expressed as

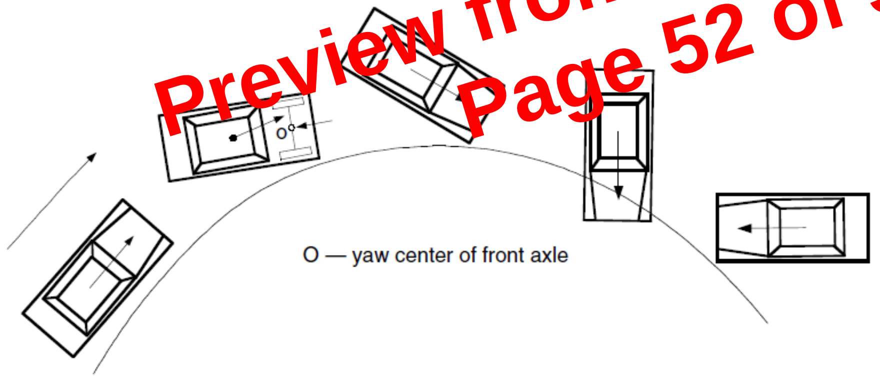
$$F_b = \frac{T_b}{r_d}$$

A maximum braking force limited by the adhesive capability can be expressed as

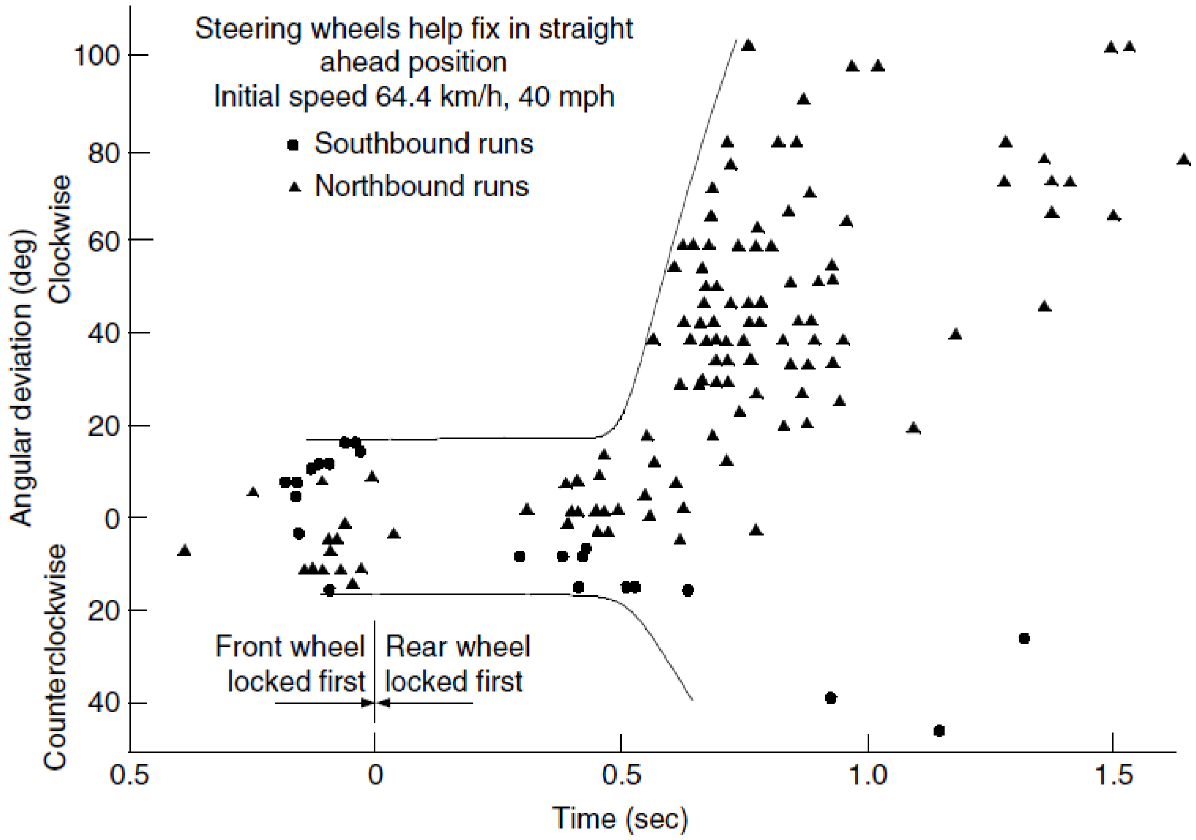
$$F_{b\max} = \mu_b W$$

where μ_b is the adhesive coefficient of the tire–ground contact.

When the rear wheels lock up first, the vehicle will lose directional stability, as shown in loss of directional stability Figure. The figure shows the top view of a two axle vehicle acted upon by the braking force and the inertia force.



Loss of directional stability due to the lockup of rear wheels



Angular deviation of a car when all four wheels do not lock at the same instant