Cant Deficiency, Curving Speeds and Tilt

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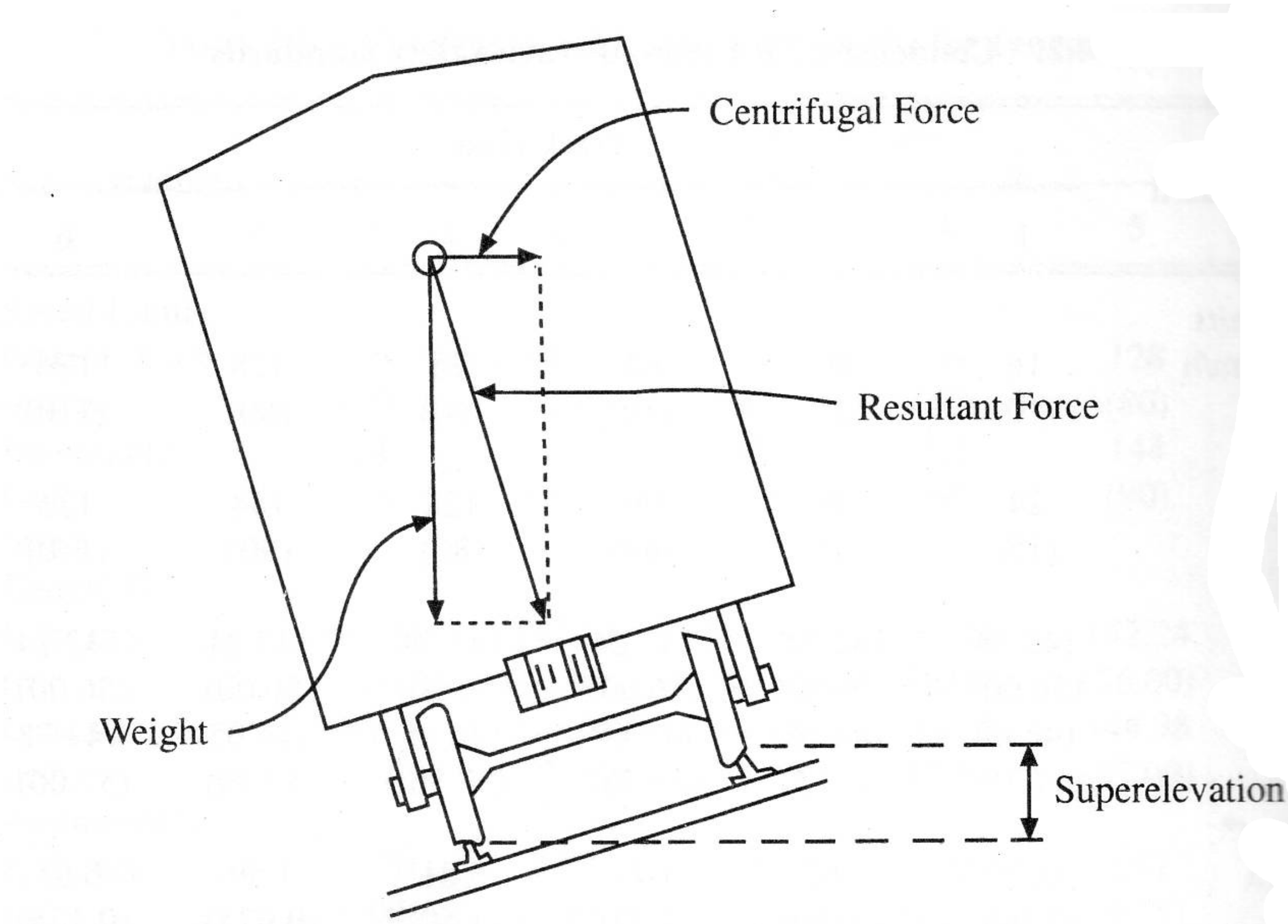
Topics

Cant Deficiency

- Definition of Cant Deficiency
- Benefits of Operating at Cant Deficiency
- Effect of Cant Deficiency on Rail Vehicle Performance
- Use of Tilt at High Cant Deficiency

Steady State Forces on Trains in Curves



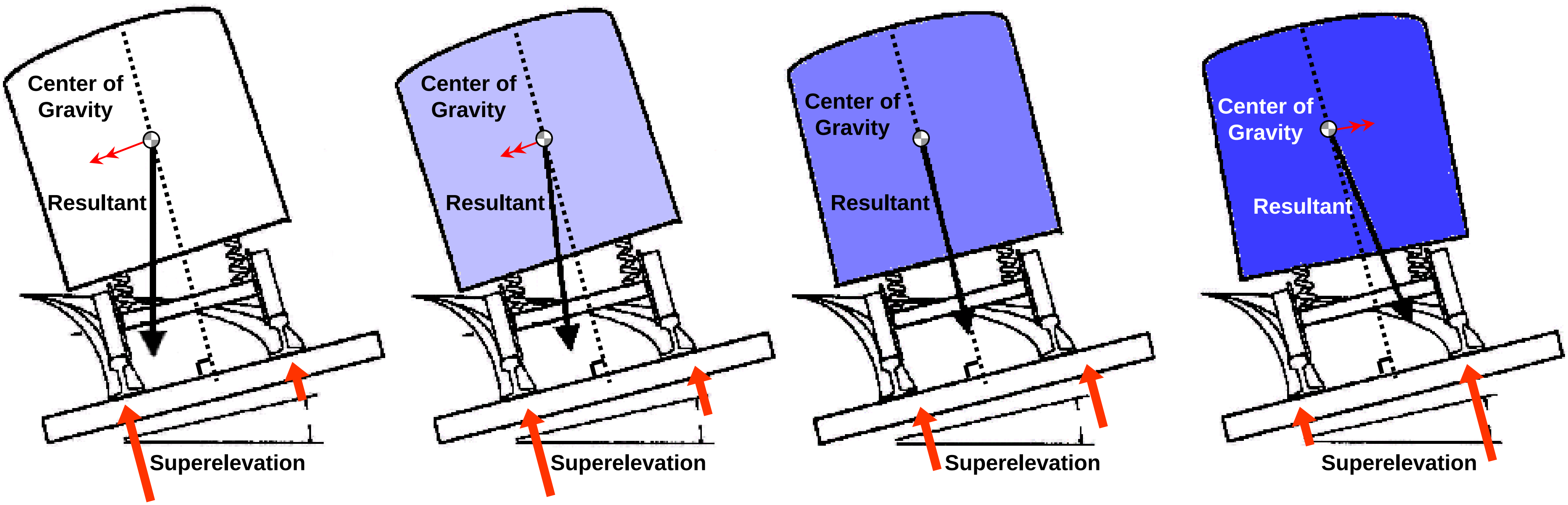
Definition of Cant Deficiency

- Trains operating in curves experience net lateral force (centrifugal force) to the outside of the curve that is a function of the velocity.
- With superelevation (cant), the centrifugal force acting on the passengers is reduced, or eliminated, by a component of the gravitational force (weight).
- Balance speed for any given curve is the speed at which the lateral component of centrifugal force will be exactly compensated (or balanced).
- Cant deficiency involves traveling through a curve faster than the balance speed and produces a net lateral force to the outside of the curve.
- Cant deficiency is measured in inches and is the amount of superelevation that would need to be added to achieve balance speed.

Definition of Cant Deficiency

Stopped | Increasing Speed →

Overbalance (Cant Excess)	Overbalance (Cant Excess)	Balance	Underbalance (Cant Deficiency)
Lateral acceleration<0	Lateral acceleration<0	Lateral acceleration=0	Lateral acceleration>0



Remove superelevation to create balance condition	Decrease superelevation to create balance condition	Superelevation counteracts centripetal acceleration	Increase superelevation to create balance condition

Benefits of Operating at CD

- Higher curving speeds V_{max}
  - Depends on curve characteristics – curvature and superelevation (cant)
- Reduce trip time without reconfiguring existing route layout
  - Strongly dependent on route makeup
  - Can improve speed on tangents as well
- Can reduce need for braking or accelerating when entering or exiting curves

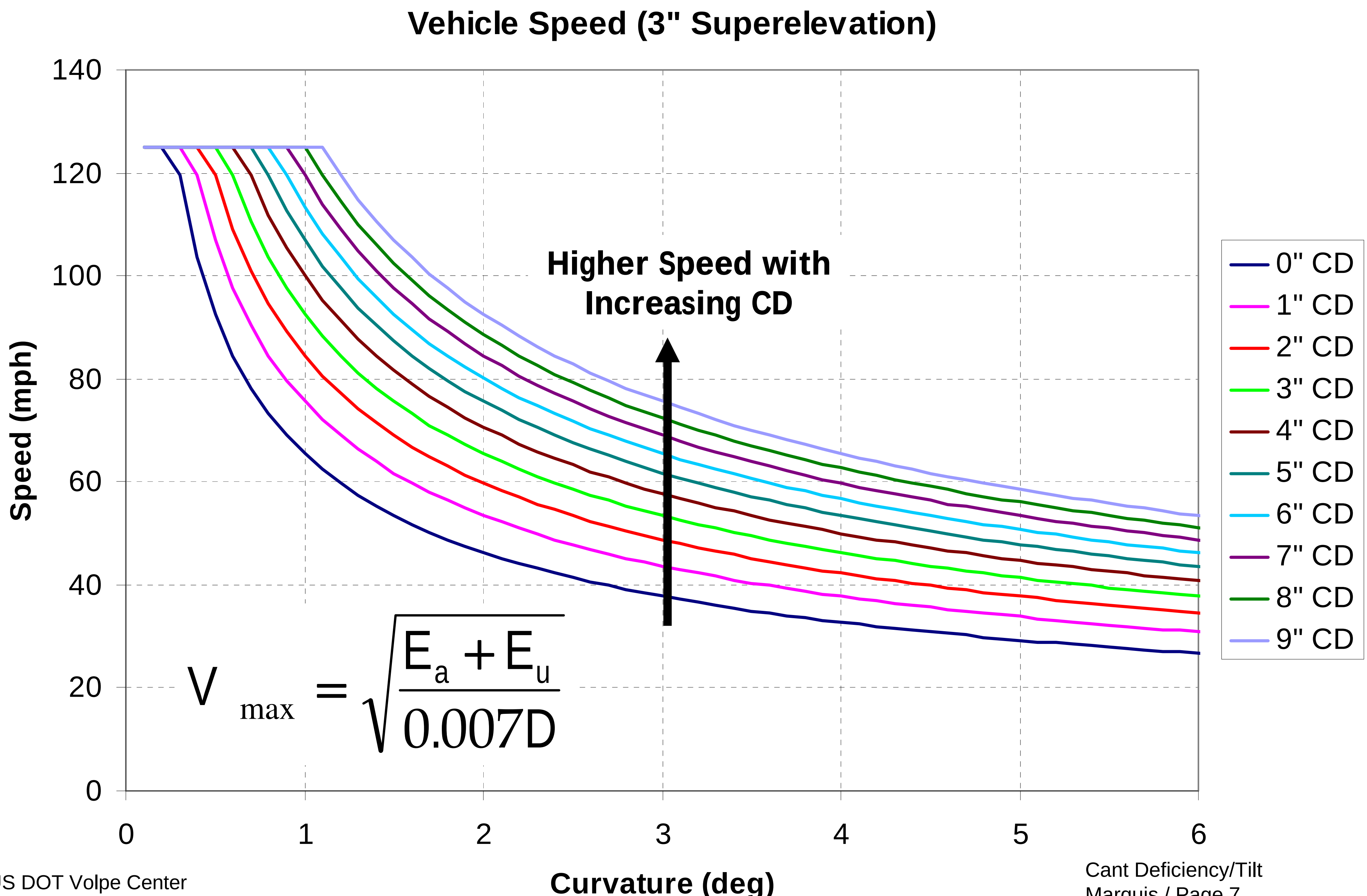
49 CFR 213.57 and 213.329
Curves; Elevation and Speed Limitations

$$V_{max} = \sqrt{\frac{E_a + E_u}{0.007D}}$$

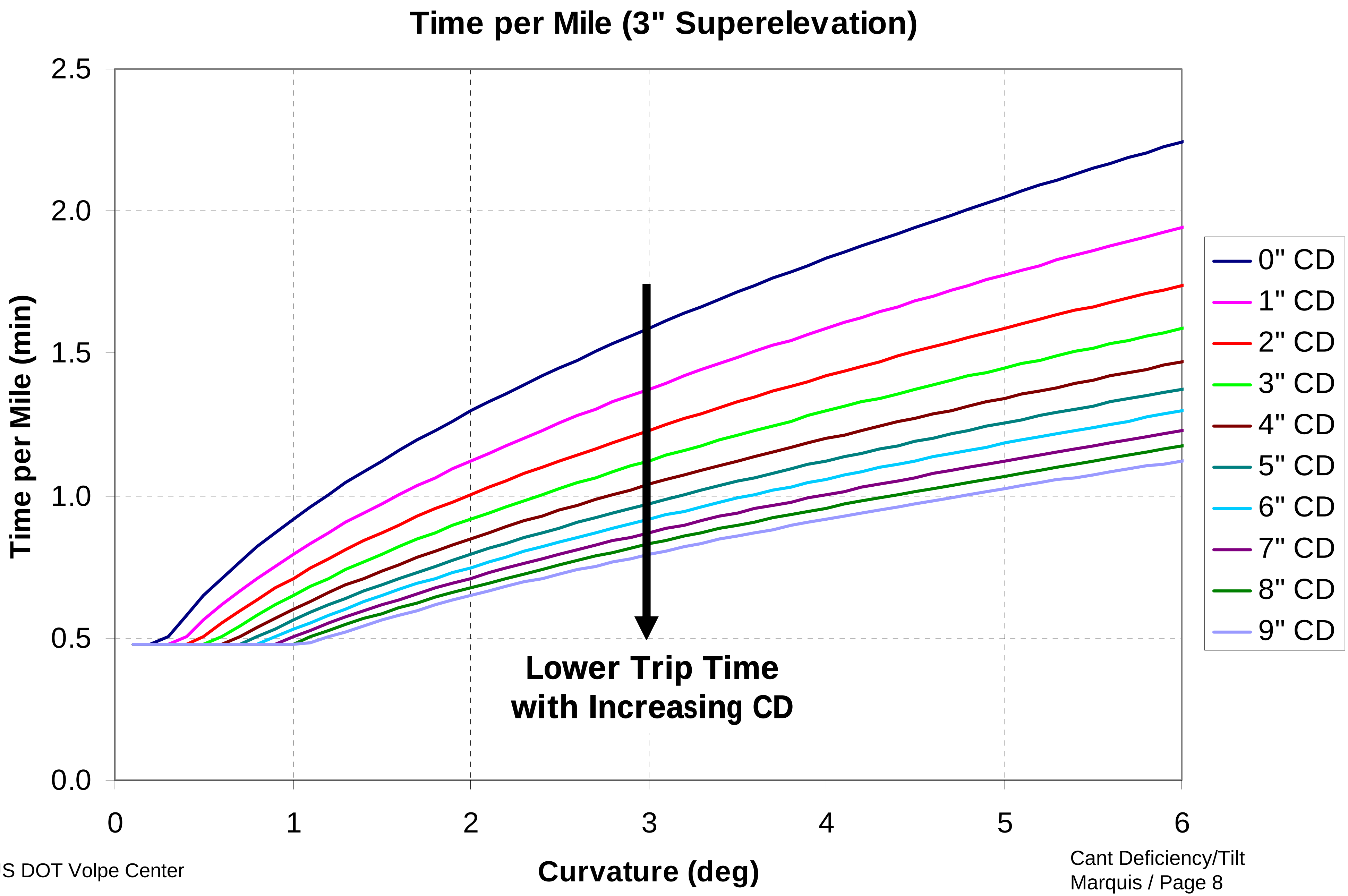
where --

V_{max} = Maximum allowable operating speed (miles per hour).
E_a = Actual elevation of the outside rail (inches)[1].
D = Degree of curvature (degrees)[2].
E_u = Cant Deficiency (inches)

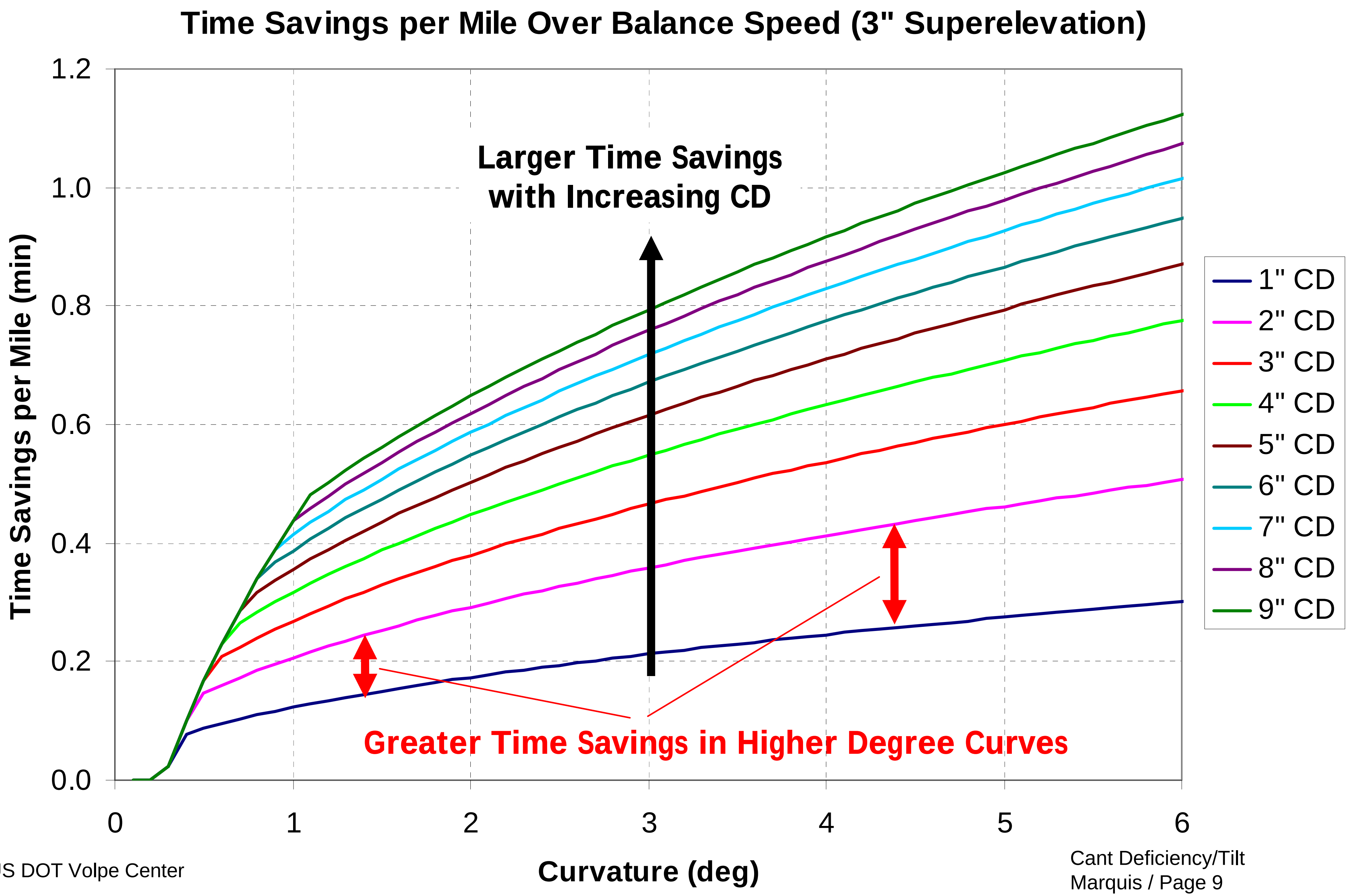
Benefits of Operating at CD



Benefits of Operating at CD



Benefits of Operating at CD

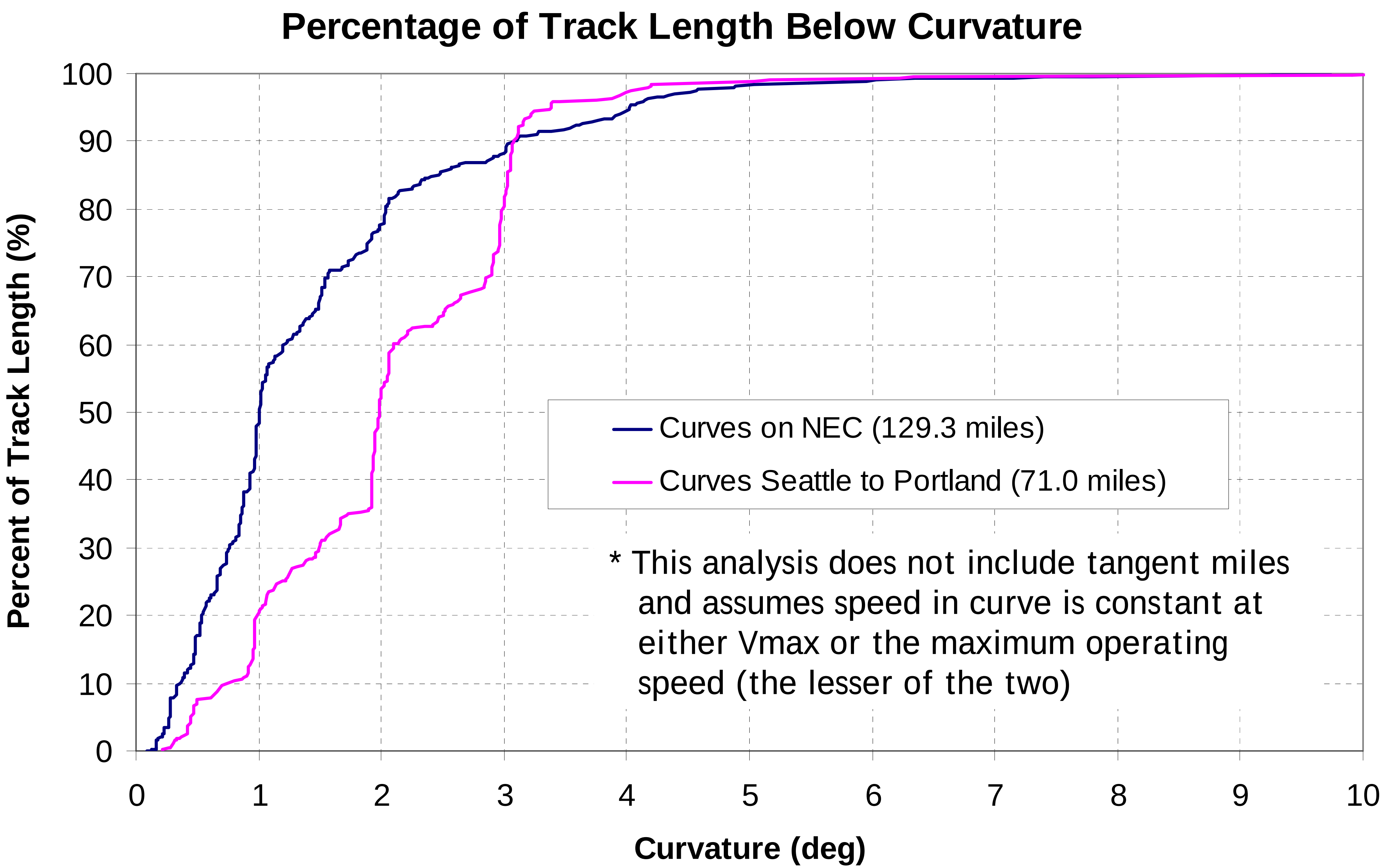


Benefits of Operating at CD

- Example Trip Time Comparison for 2 routes
  - Route 1: NEC Boston to Washington DC
  - Route 2: Seattle to Portland

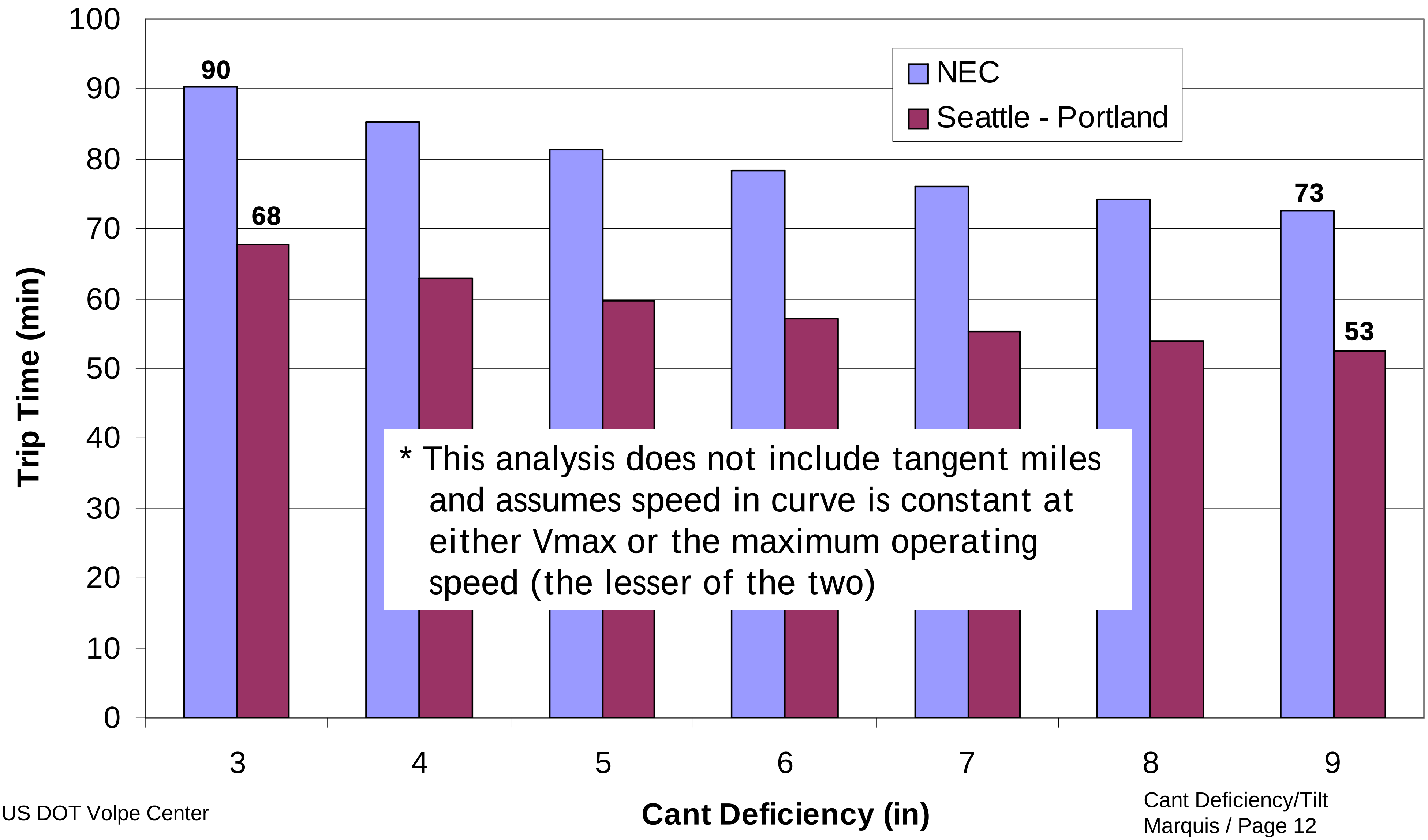
- This analysis does not include tangent miles and assumes speed in curve is constant at either Vmax or the maximum operating speed (the lesser of the two)

Benefits of Operating at CD



Benefits of Operating at CD

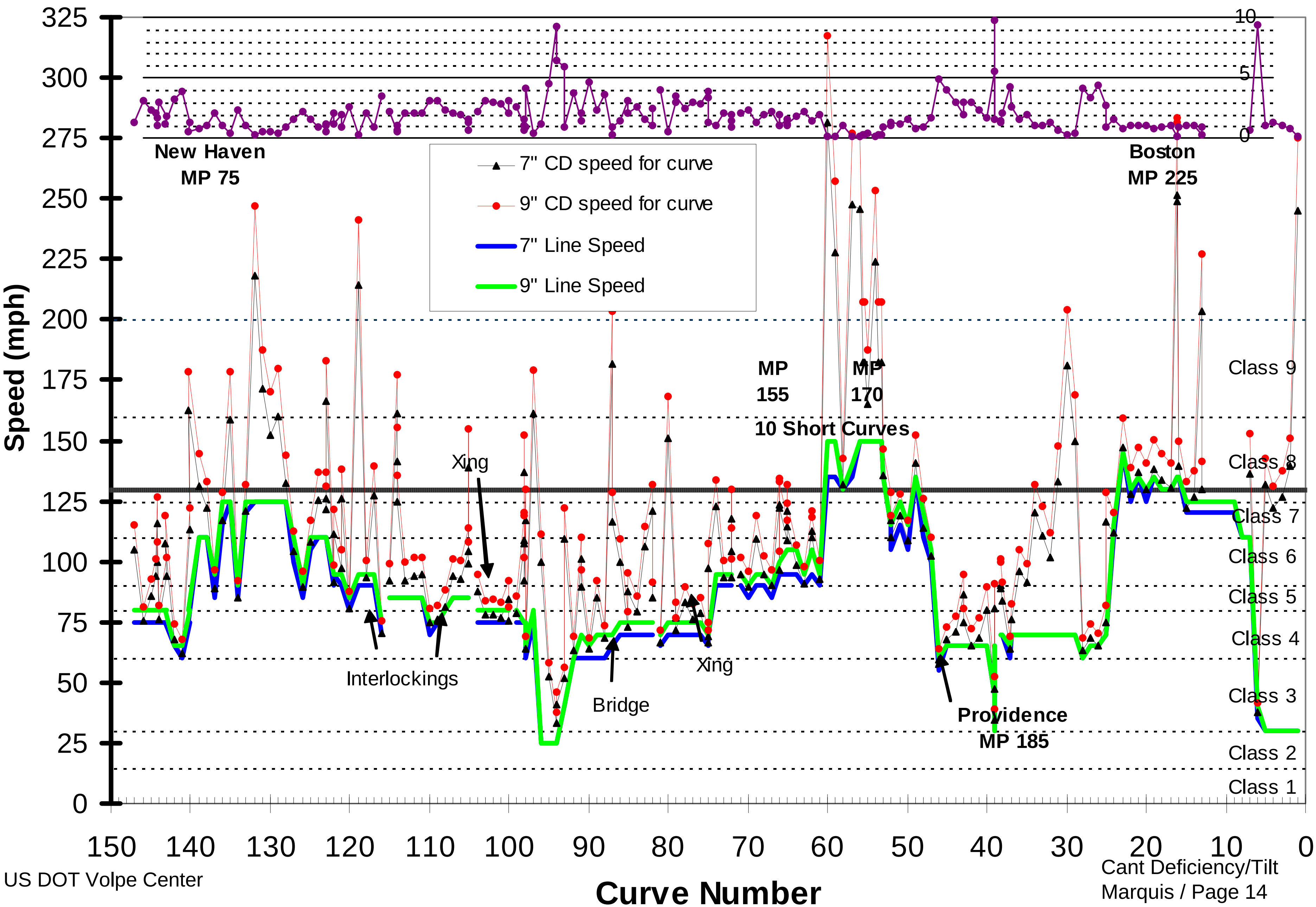
NEC: 129.3 miles, 125mph maximum speed
Seattle-Portland: 71.0 miles, 80mph maximum speed



Benefits of Operating at CD

- Estimate of reduction in trip time in previous example does not account for all factors that affect actual trip
  - Time strongly dependent on route makeup – order of curves, etc.
  - Although equipment qualified for higher CD, Vmax in a particular curve may not be achievable due to constraints of neighboring curves, etc.
  - May not want to maintain to higher track class corresponding to higher speed
  - Higher CD may permit higher speed on tangents as well
  - Reduces need for slowing down when entering a curve
  - Reduces need for accelerating when exiting a curve
  - Etc.

Benefits of Operating at CD



Effect of CD on Vehicle Performance

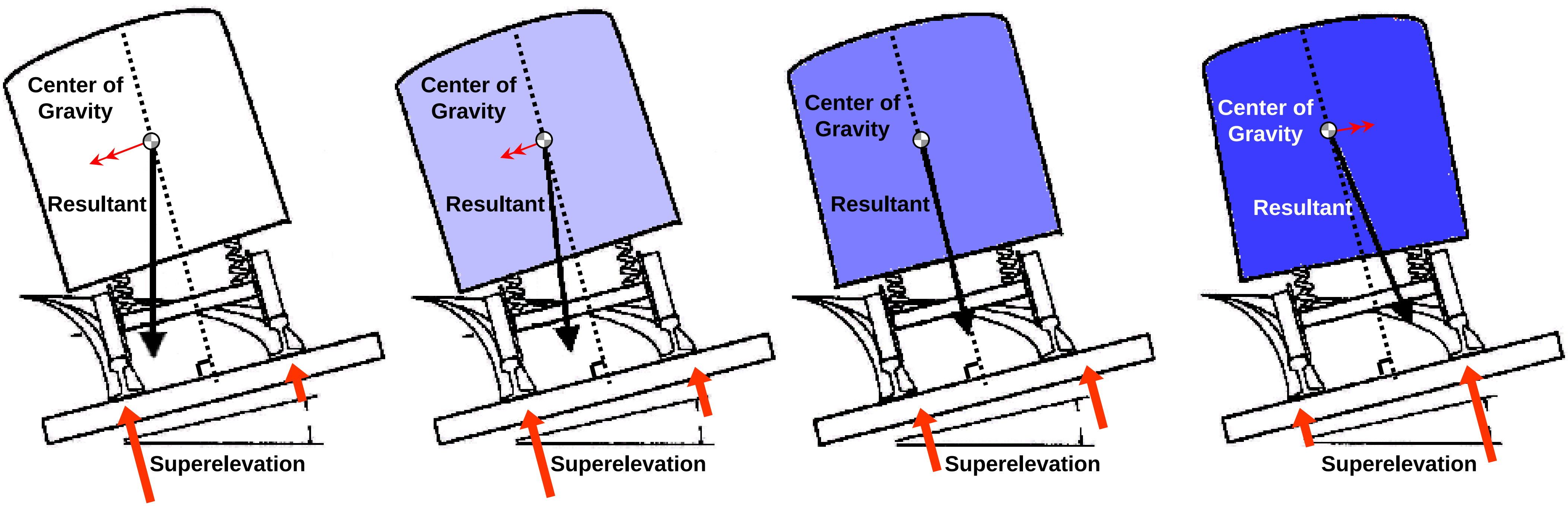
- Increase in lateral force exerted on track during curving
  - Increased deterioration of track, lower safety margin for curving, and may result in unsafe wheel force conditions
- Decrease in load on wheels on inside rail
  - Increased risk of vehicle overturn, especially if high winds present
- Reduction in margin of safety associated with vehicle response to track geometry variations
  - Suspension elements operating at performance limits
- Increase in net steady stated carbody lateral acceleration
  - Decreased passenger ride comfort
  - Tilt can be used at high cant deficiency to reduce the net lateral acceleration acting on the passengers

Effect of CD on Vehicle Performance

Stopped

Increasing Speed

Overbalance (Cant Excess)	Overbalance (Cant Excess)	Balance	Underbalance (Cant Deficiency)
Lateral acceleration<0	Lateral acceleration<0	Lateral acceleration=0	Lateral acceleration>0

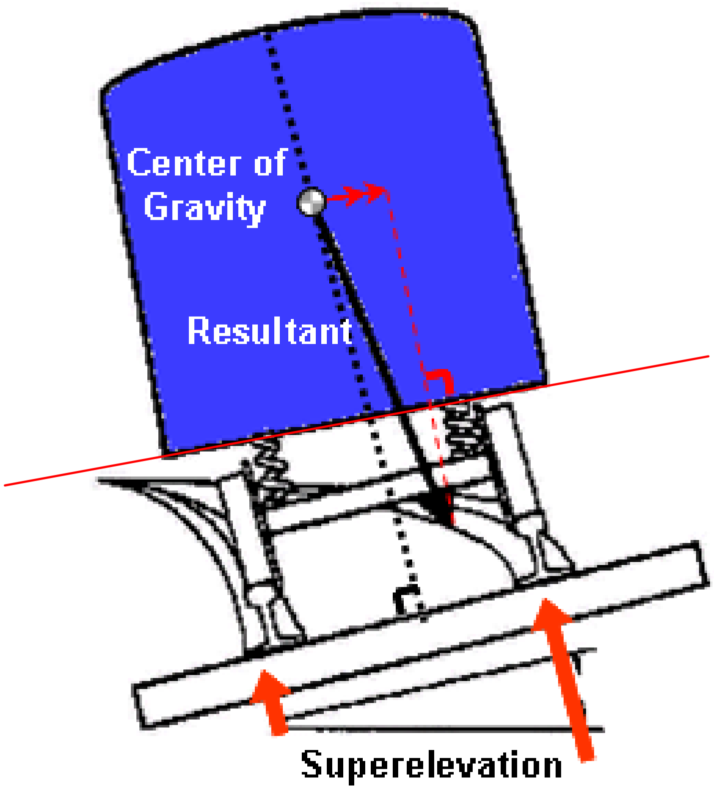


Remove superelevation to create balance condition	Decrease superelevation to create balance condition	Superelevation counteracts centripetal acceleration	Increase superelevation to create balance condition

Use of Tilt at High Cant Deficiency

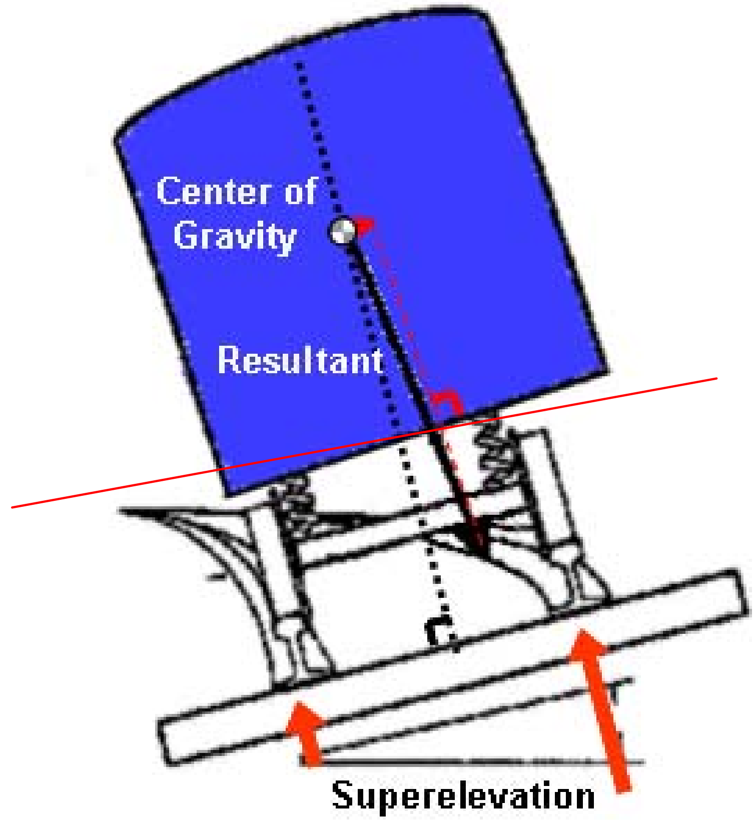
Operating at High CD without Tilt

Lateral acceleration>0.12

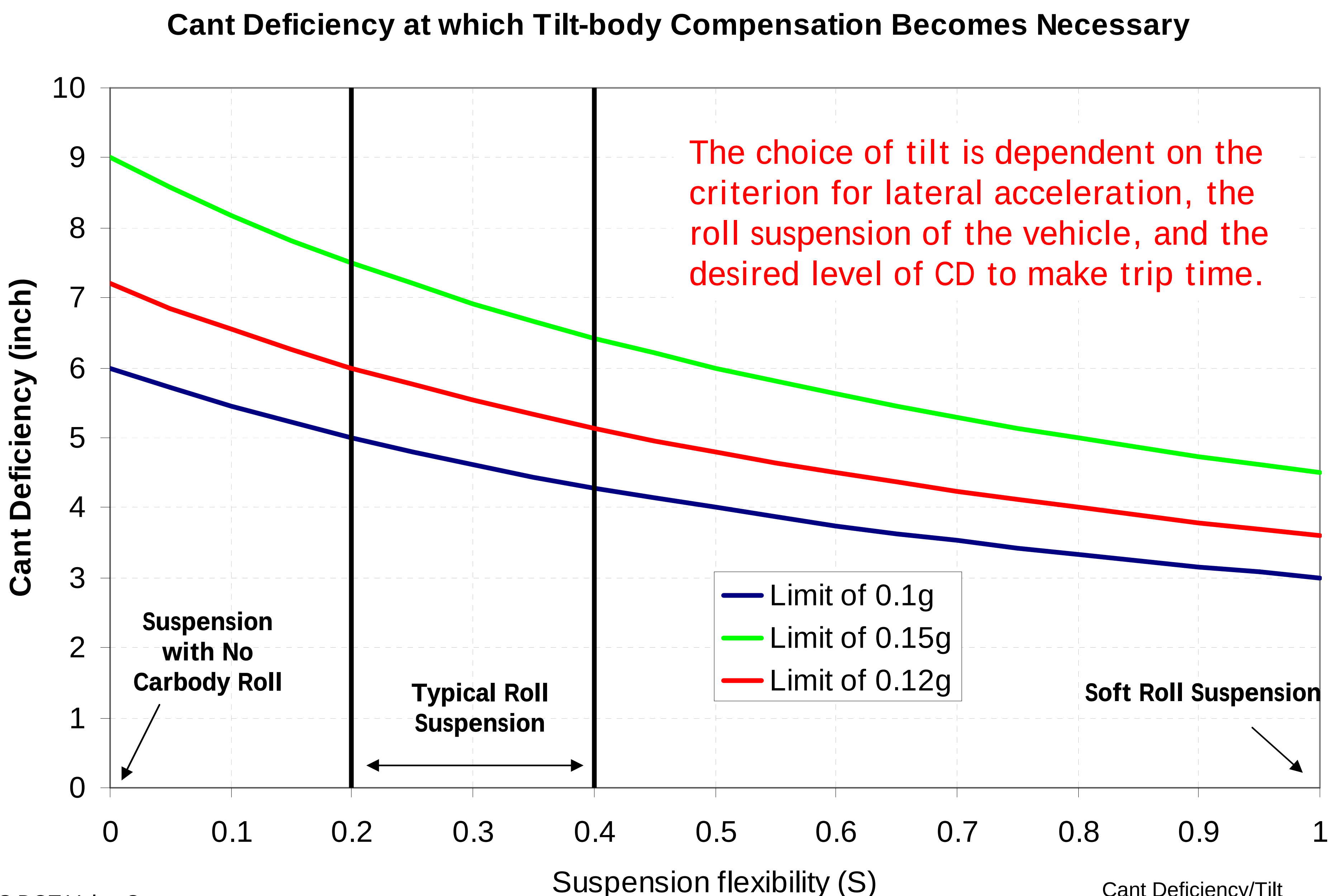


Operating at High CD with Tilt

Lateral acceleration<0.12



Use of Tilt at High Cant Deficiency



Use of Tilt at High Cant Deficiency

$$S = \frac{\theta_{Rstatic}}{\theta_{track}}$$

where

θ_{track} = angle between track plane and horizontal (superelevation)

$\theta_{Rstatic}$ = roll due to superelevation (measured relative to track plane)

Use of Tilt at High Cant Deficiency

Benefits – not a complete list

- Addresses ride comfort at higher cant deficiency
  - Reduces steady state lateral acceleration felt by passengers
- Allows operation at higher cant deficiency by meeting regulatory requirements on steady state lateral acceleration
- Has little to no effect on wheel rail forces or derailment safety

Drawbacks – not a complete list

- Compatibility with clearance envelopes for existing lines and equipment
- Increased suspension complexity and maintenance
- Motion sickness