2.1.10 TRACK QUALITY, TRACK MODULUS, AND CONCRETE TIES (1992, 2020)

a. Higher track quality can reduce train resistance by reducing suspension losses and power losses in the wheel/rail contact area. MIT studies concluded that the level of track roughness has a considerable impact on dynamic resistance at low and moderate speeds on tangent track. On good track at high speeds, the losses are dominated by hunting, and roughness is less important. Curving resistance is less affected by track roughness, for the leading outer wheels are in flange contact beyond 2 or 3 degrees of curvature; on tangent track, roughness increases resistance by bringing the flanges into contact (Reference 5). Tests have shown that an increase in track quality from FRA class 4 to class 6 reduced rolling resistance by 0.3 lb/ton at 20 mph to 0.5 lb/ton at 60 mph on tangent track for cars with a gross weight of 104 tons. This increase in track quality reduced rolling resistance on curves of up to 2 degrees by 0.4 lb/ton for the same cars. Beyond 2 degrees little improvement was observed (Reference 6).

b. Track quality can be improved by using concrete ties instead of wood ties, using continuous welded rail instead of jointed rail, increasing the depth of the ballast section, increasing rail cross-section, and in other ways strengthening the track structure.

c. Studies have shown that train resistance can be substantially reduced when trains are operated over track with concrete ties rather than wood ties. The reduction is due to the higher track modulus which implies stiffer track. There results a decrease in energy lost in the car suspension and in the roadbed. The installation of concrete ties in place of wood ties under 132 lb rail, for example, can decrease rolling resistance by approximately 0.5 lb/ton for cars with a gross weight of 130 tons. For empty cars (25 tons), the reduction under the same circumstances is approximately 0.1 lb/ton (Reference 25).

2.1.11 ARTICULATED CARS (1992, 2020)

a. Articulated cars, defined as two adjacent cars sharing a single truck, can be used to reduce train resistance, due to fewer axles per articulated unit compared to conventional cars. Additionally, it may be possible to obtain improved aerodynamics by minimizing or eliminating air gaps between units. Examples are found in high-speed passenger trains, articulated intermodal cars and articulated vehicular (multi-level autorack) cars. Specific to high-speed passenger equipment and articulated intermodal cars, the following should be noted:

i) Articulated rolling stock is found in designs from some manufacturers for high-speed train sets integrating rolling stock and train propulsion. In this case, articulation is incorporated into a larger strategy for overall vehicle performance that is matched for specific route characteristics and commercial goals.

ii) Research has shown that optimizing loading to eliminate air gaps is key to obtaining improved aerodynamics from articulated intermodal cars.

b. To account for improved aerodynamics, when calculating train resistance for an articulated car or high-speed passenger trainset consisting of “n” articulated units, a weighted average is used. If the aerodynamic C coefficient for the leading articulated unit is Cld and the C coefficient for trailing articulated units is Ctr, the overall C coefficient for such a combination will be:

\[
C_{combined} = \frac{C_{ld} + (n - 1)C_{tr}}{n}
\]

c. Note that lower-case n above refers to the number of articulated units. As usual, upper-case N in the train resistance formula would represent the number of axles in the combination. When calculating aerodynamic resistance, sum the cross-sectional area “a” of each articulated unit over the entire combination, and then multiply by the combined C calculated above. If all units have the same cross sectional area, multiply C combined by “a x n”.

2.1.12 FOUR-WHEEL CARS (1992, 2020)

Four-wheel (two axle) cars can contribute to reduced train resistance due to fewer axles and reduced weight. The use of two-axle cars allows N to be set at 2, rather than 4 as is normally the case, in the train resistance formula. Curve resistance can be increased due to a longer rigid wheelbase, however.
These cars have seen limited use in revenue freight service in North America, although some manufacturers of high-speed train sets use four-wheel (two axle) rolling stock.

Four-wheel (two axle) cars may also be found in specialized maintenance equipment used by urban transit systems. In these cases, equipment should be evaluated against system clearance and standards before being accepted to ensure compatibility with the demanding geometry conditions often found on transit infrastructure.

2.1.13 EMPTY GONDOLA, HOPPER AND BULKHEAD FLAT CARS (1992, 2020)

As noted in the Table 16-2-3 which gives C coefficients for various car types, empty gondolas have a much higher C coefficient than loaded gondolas. This is due to the open space within the empty cars which can trap a good deal of air and cause substantial turbulence. This increase can be of the order of 150% to 200% (Reference 24). The same effect applies in the case of empty open top hopper cars but to a reduced degree.

2.1.14 HIGH-SPEED PASSENGER TRAINS (1992, 2020)

Streamlining can be used to lower the C coefficient in the train resistance formula. With a high degree of streamlining, the C coefficient for leading vehicles can be reduced by as much as 60% and that for trailing vehicles can be reduced by 33% compared with the coefficients for conventional passenger trains of the style built during the 1950's (Reference 15).

2.1.15 OTHER FACTORS (1992, 2020)

Air conditioning, atmospheric temperature, equipment weight, locomotive contour, passenger train contour, rail support, rail weight and condition, speed on curves, track conditions, and forces due to side winds are other factors which can affect train resistance.