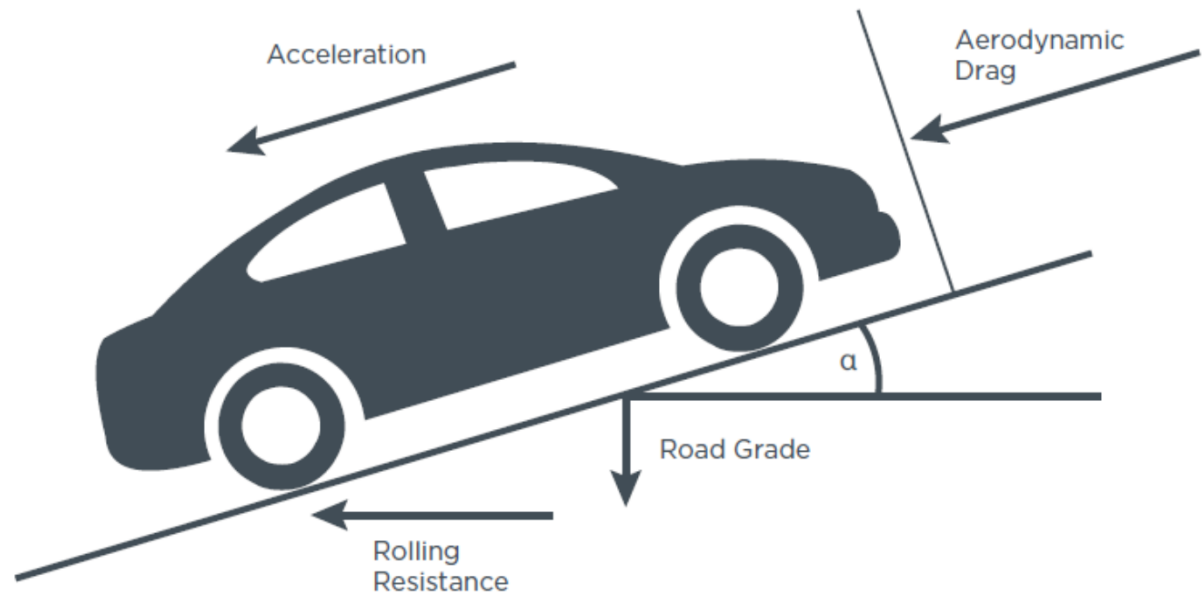


Vehicle energy balance

The driving resistances of a vehicle

- Aerodynamic drag
- Rolling resistance
- Acceleration resistance
- Slope resistance



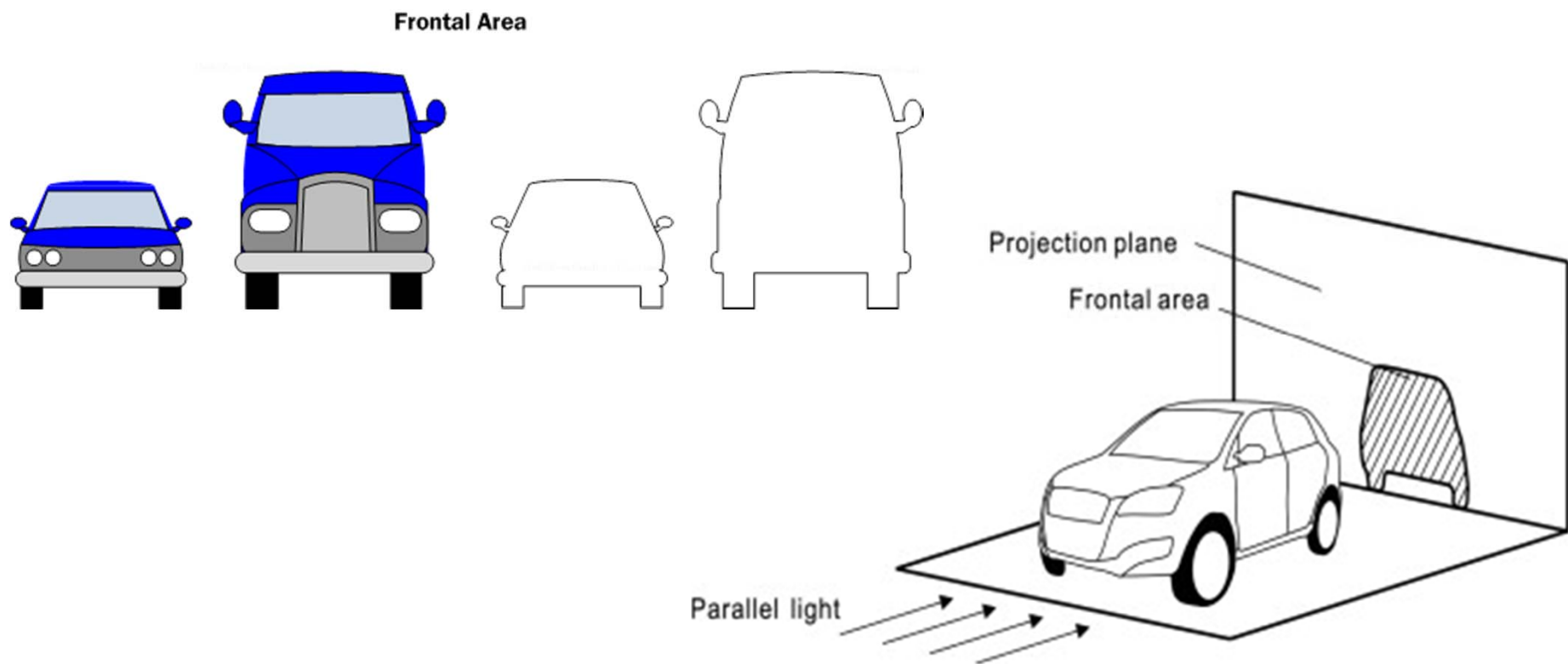
Aerodynamic drag

- $W_L = \left(\frac{1}{2} * \rho_{air} * C_d * (V + V_0)^2 * A \right)$
- $P = \rho_{air} * R * T$
- $\rho_{air} = \frac{P}{R * T}$

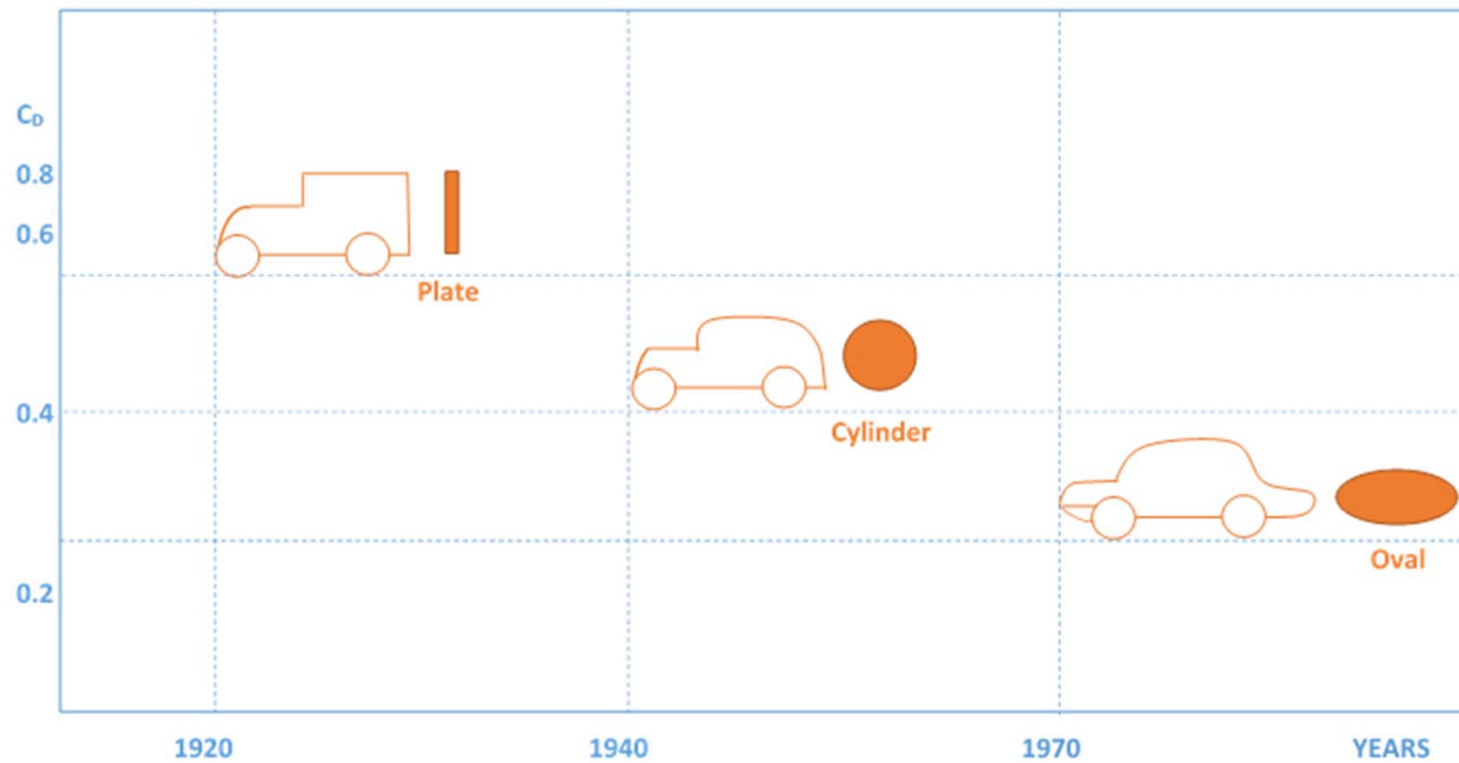
Where

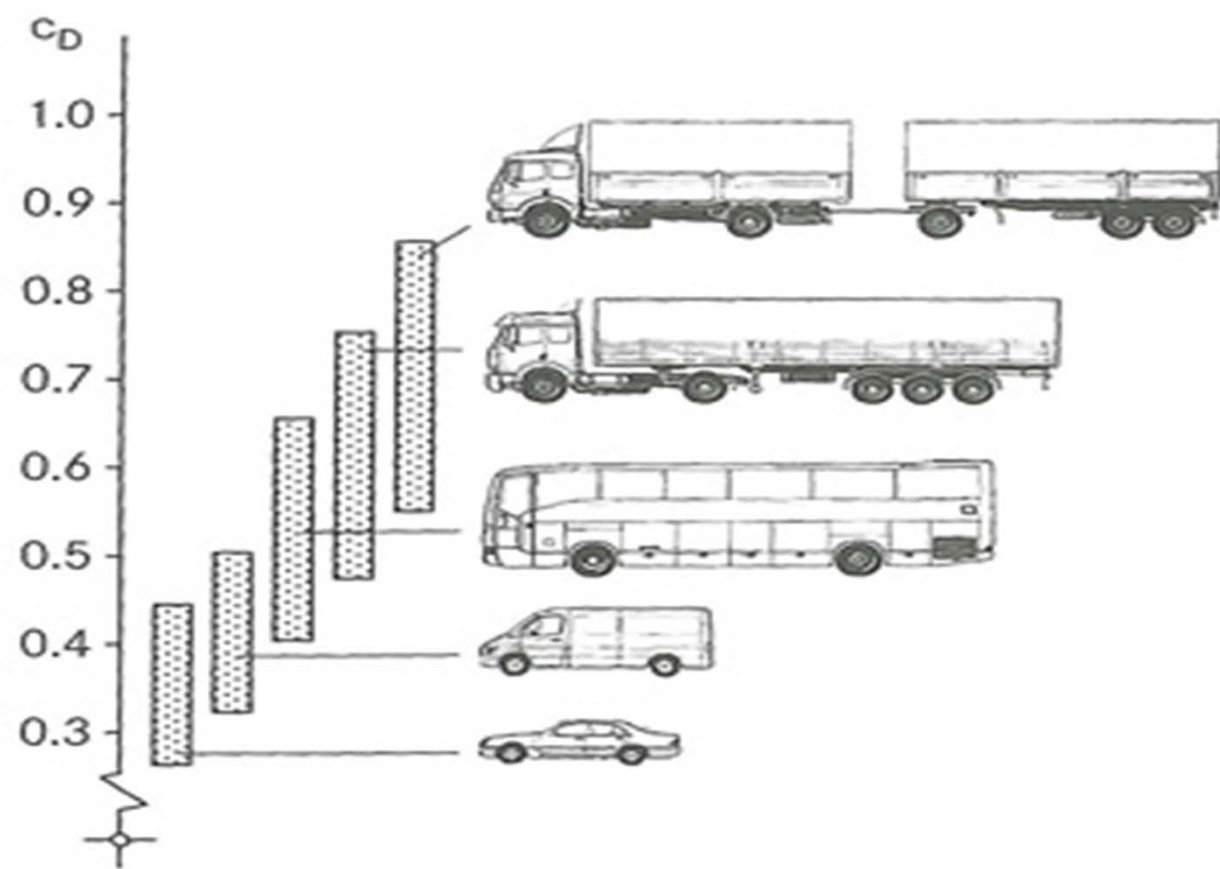
- P=Ambient pressure
- ρ_{air} =Density of air
- T=Temperature of air
- R=Gas constant of air (assuming ideal gas behaviour)
- V=Speed of the vehicle
- V_0 =Speed of wind

- A = Projected area of the vehicle.

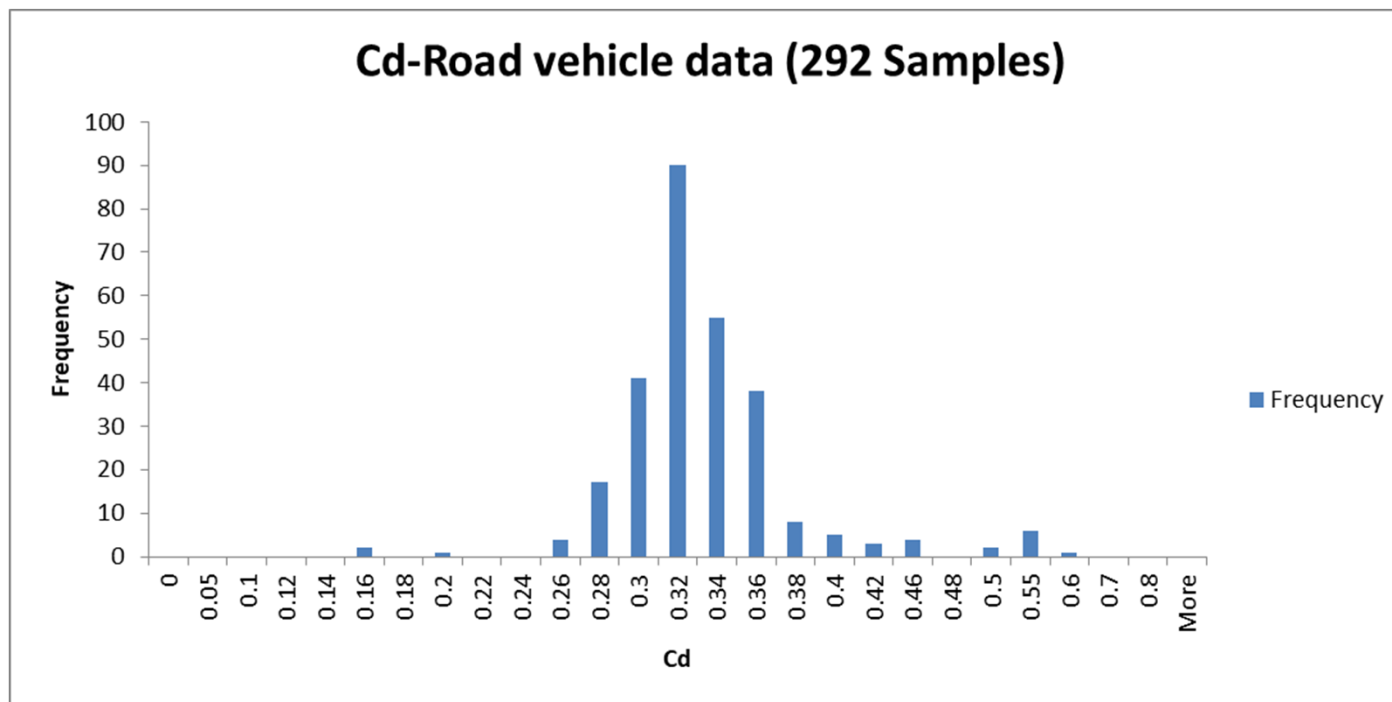


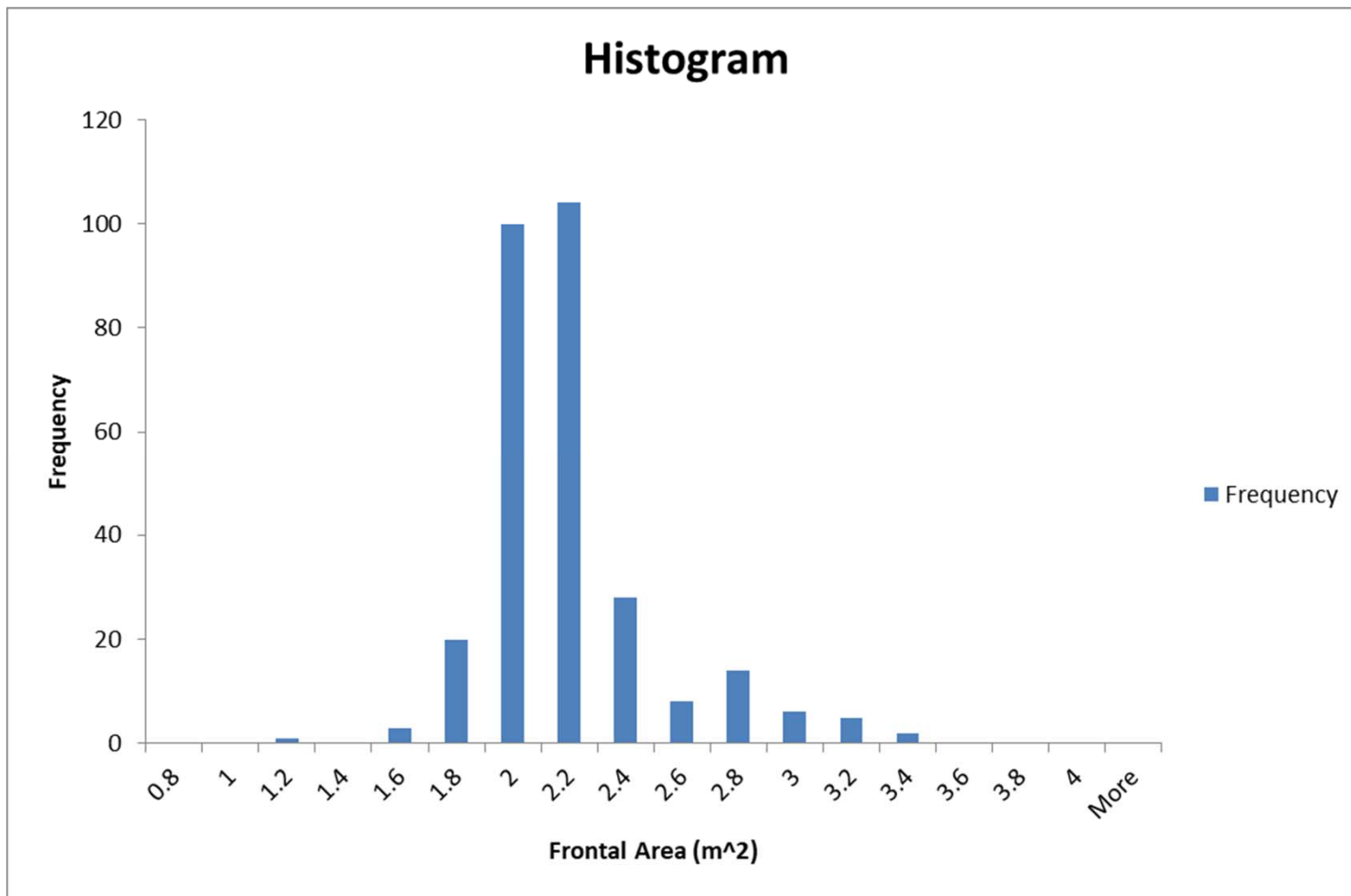
- C_d =Discharge coefficient





- Cd=Discharge coefficient







Pininfarina
ethos2
 $C_d=0.19$



GM EV1
 $C_d=0.19$



VW L1
Concept
 $C_d=0.195$
 $A=1.02$
 m^2



BMW 520
 $C_d=0.22$
 $A=2.35$
 m^2



Mercedes-
Benz A
Class
 $C_d=0.22$
 $A=2.19$
 m^2



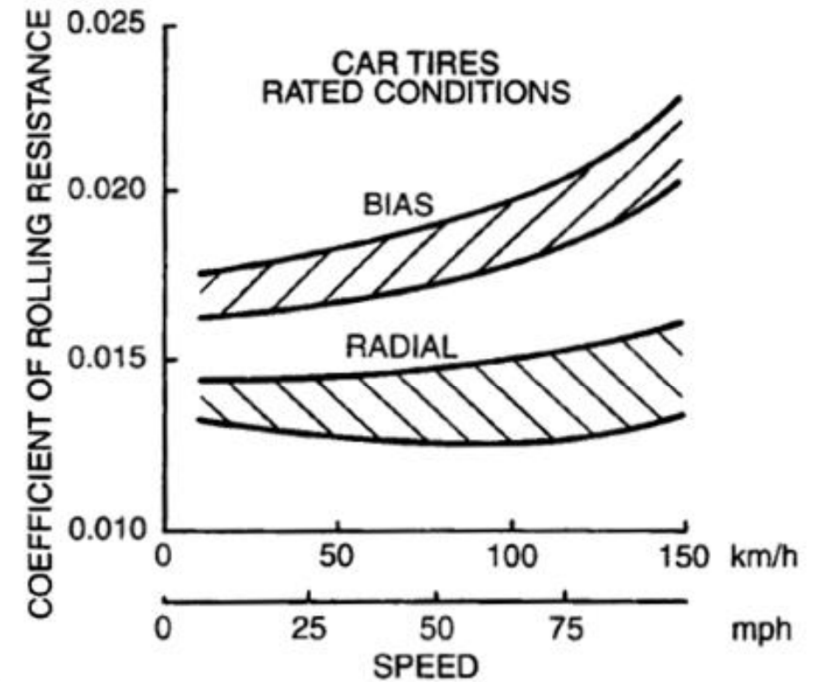
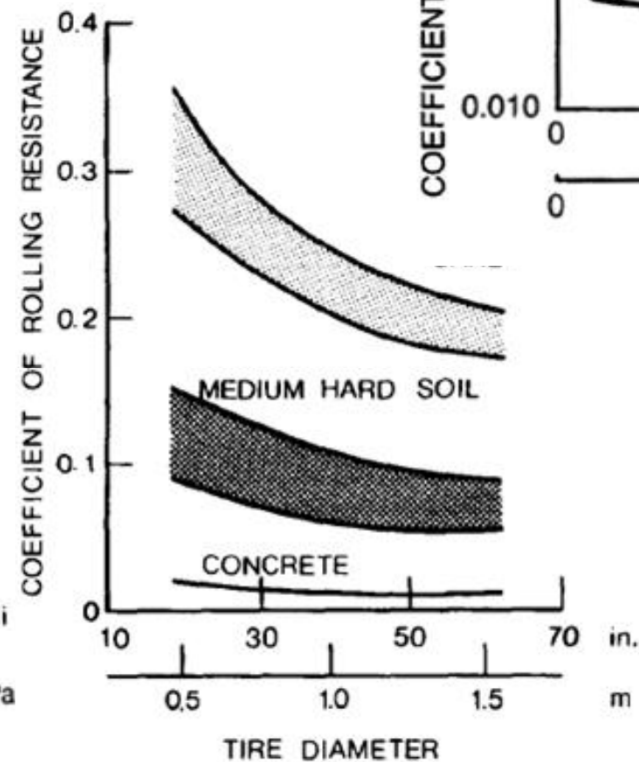
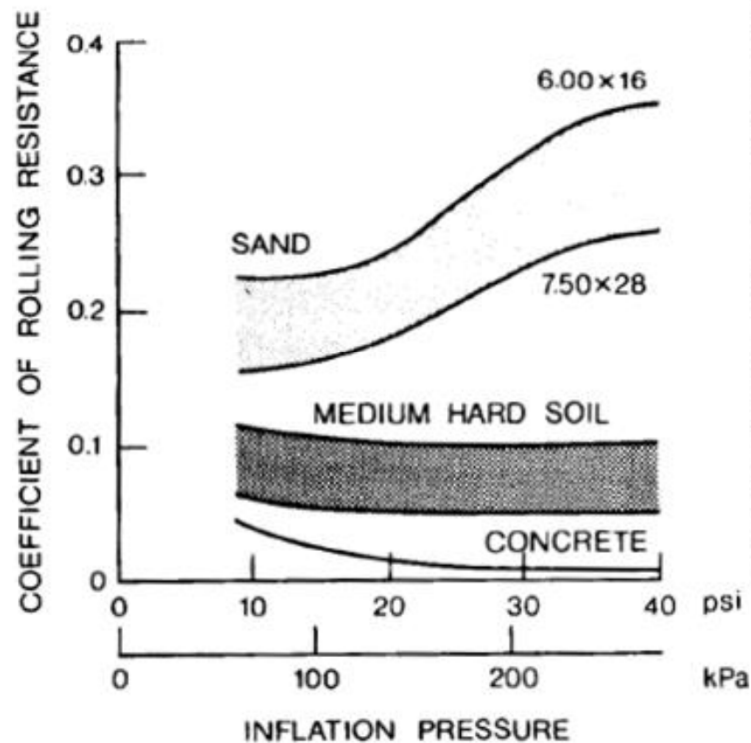
Tesla
Model 3
 $C_d=0.23$



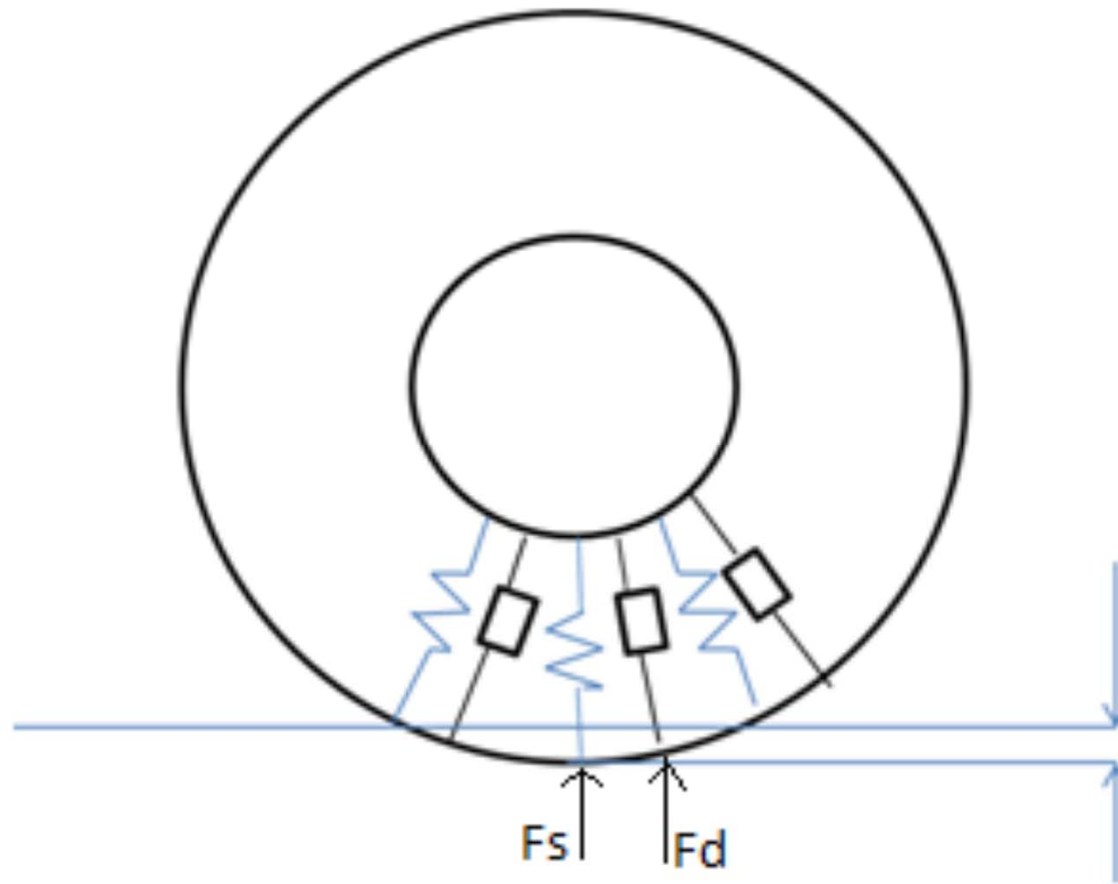
Toyota
Prius
 $C_d=0.24$

Rolling Resistance

- $W_R = f * m * g * \cos(\alpha)$



Rolling Resistance



Slope and acceleration resistances

- $W_S = m * g * \sin(\alpha)$
- $W_A = (m + m_e) * \frac{dV}{dt}$

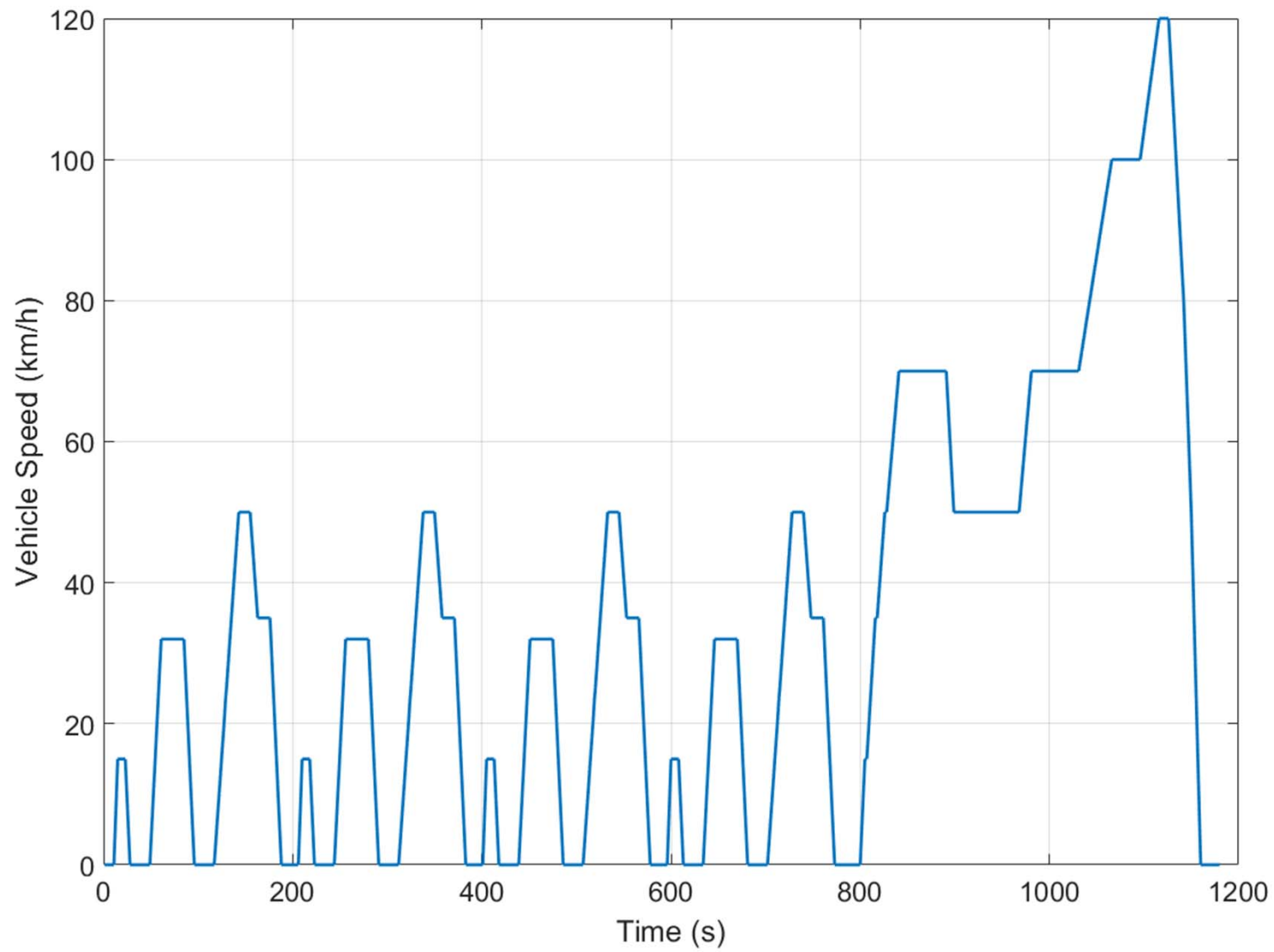
Tractive force

- $F_T = W_A + W_R + W_S + W_L$

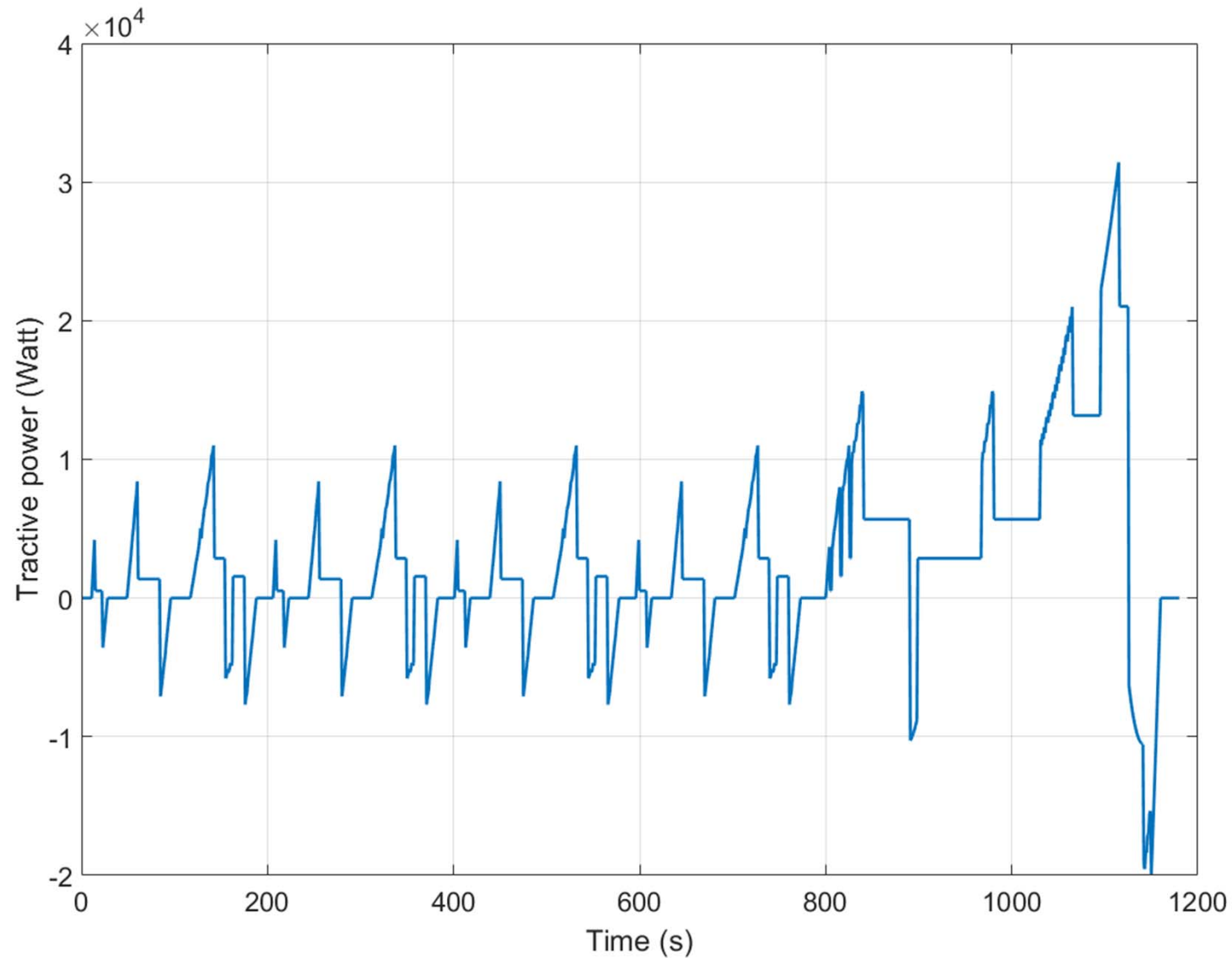
Tractive Power

- $N_T = F_T * V$
- $M_T = \frac{N_T}{2 * \pi * n_w}$

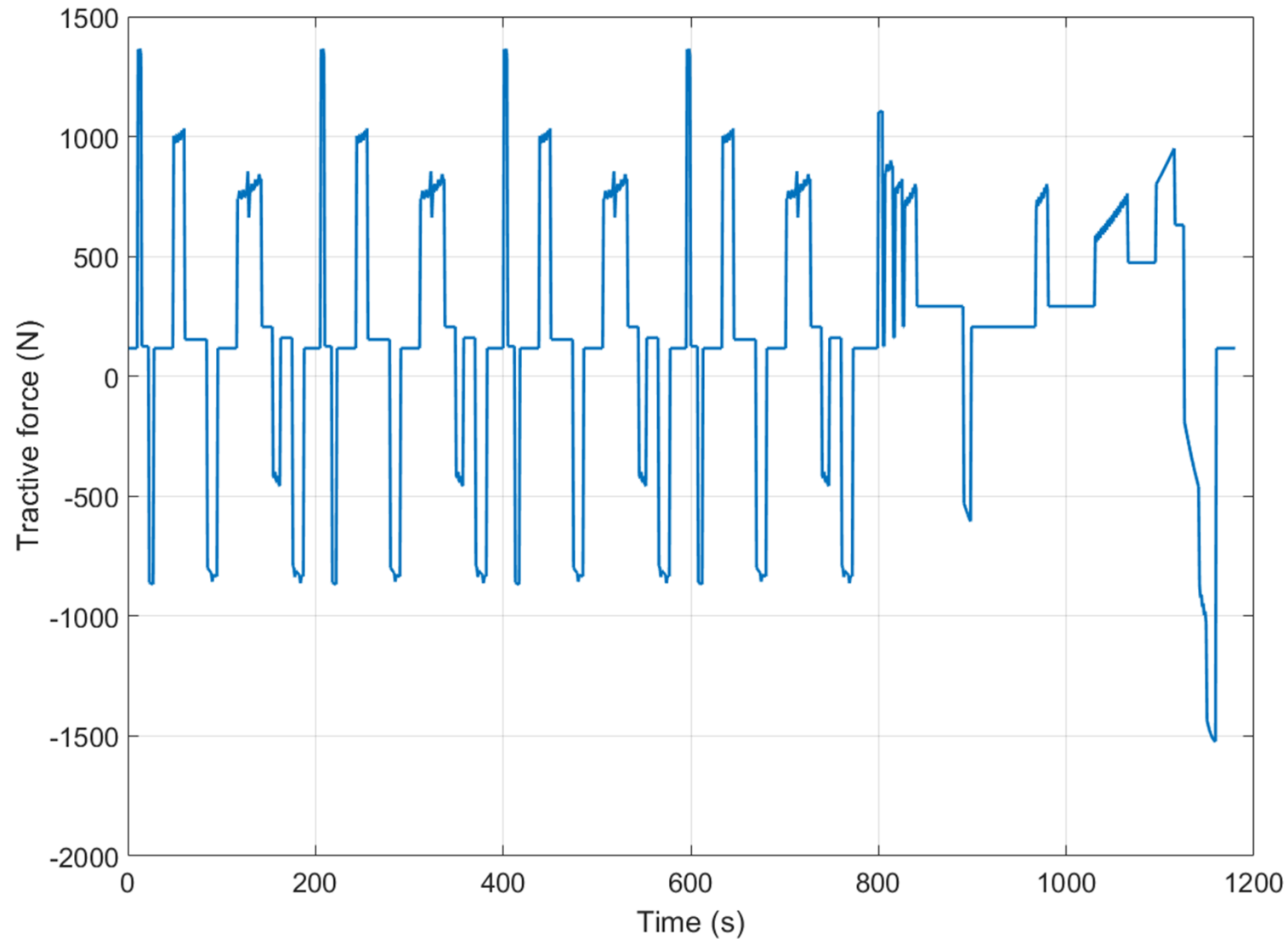
NEDC



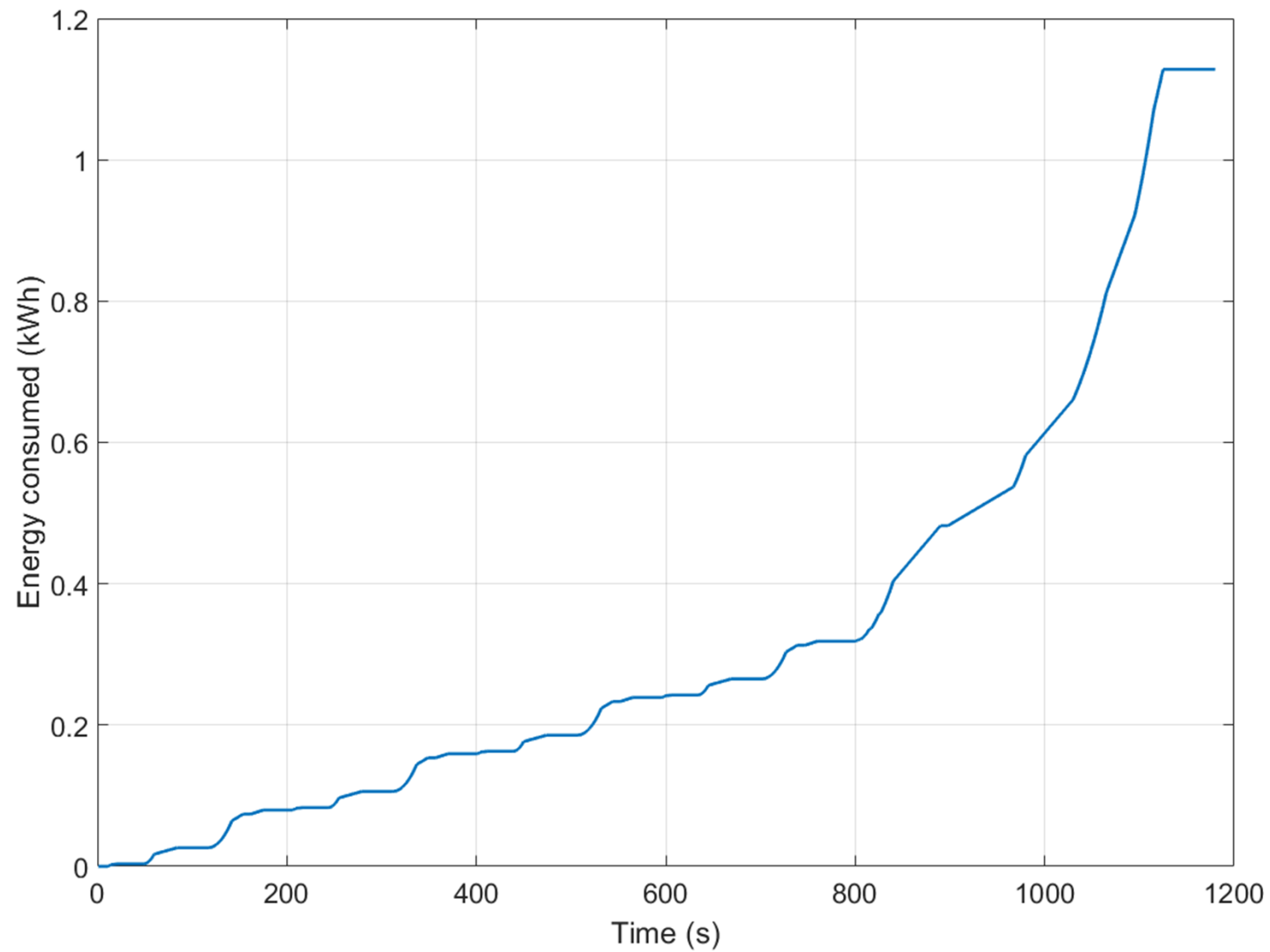
Tractive power req. for NEDC



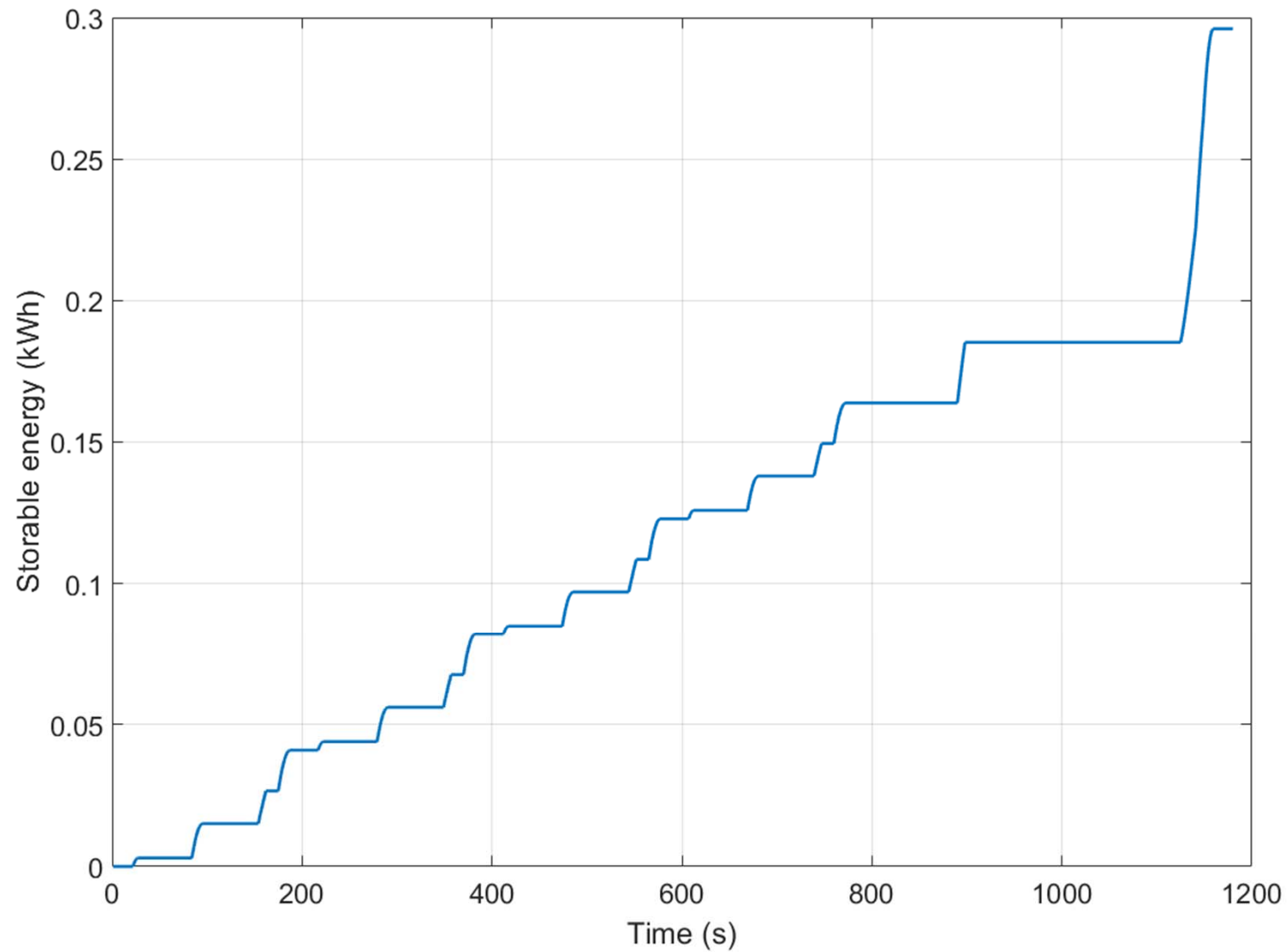
Tractive force req. for NEDC



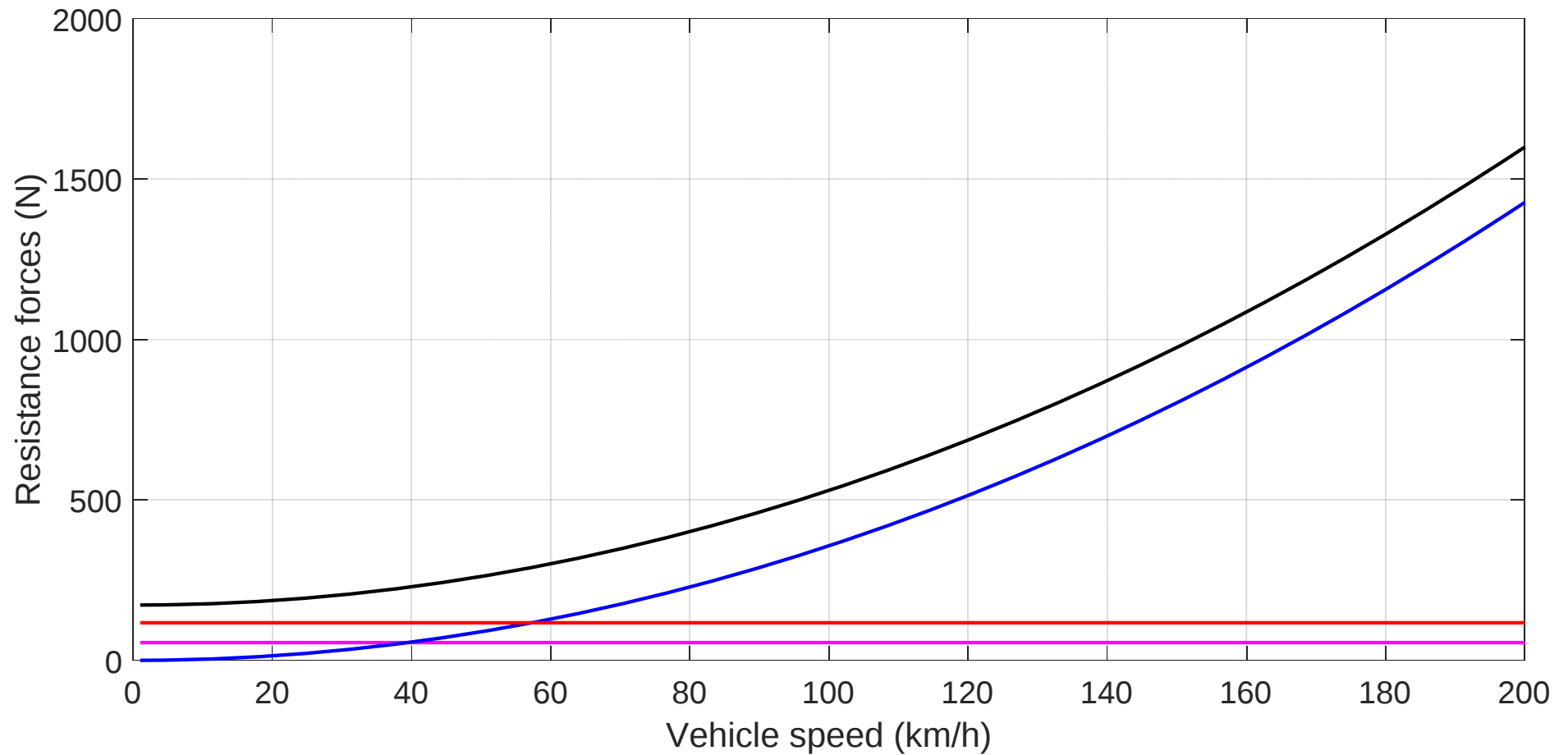
Consumed energy



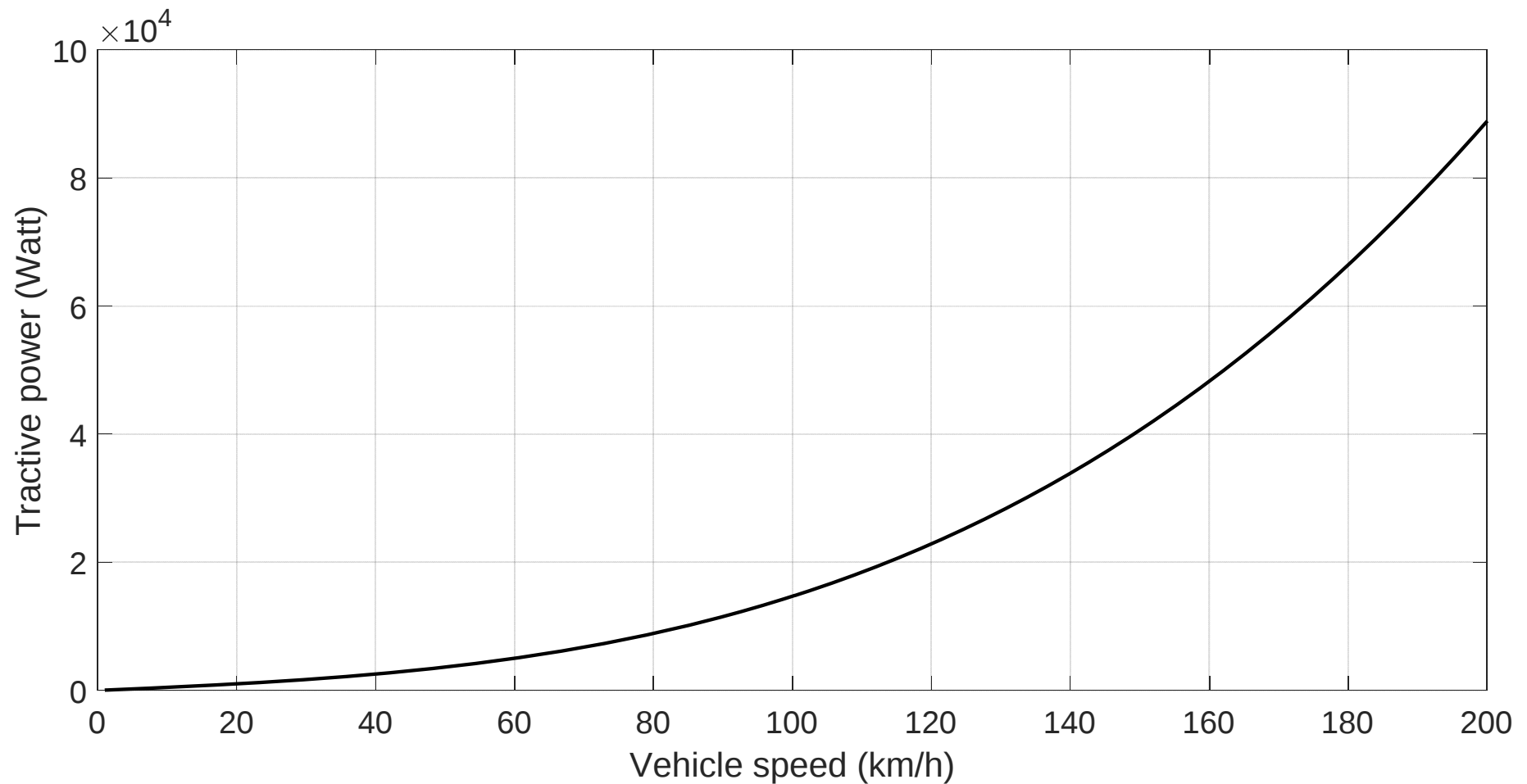
Storable/Unused energy



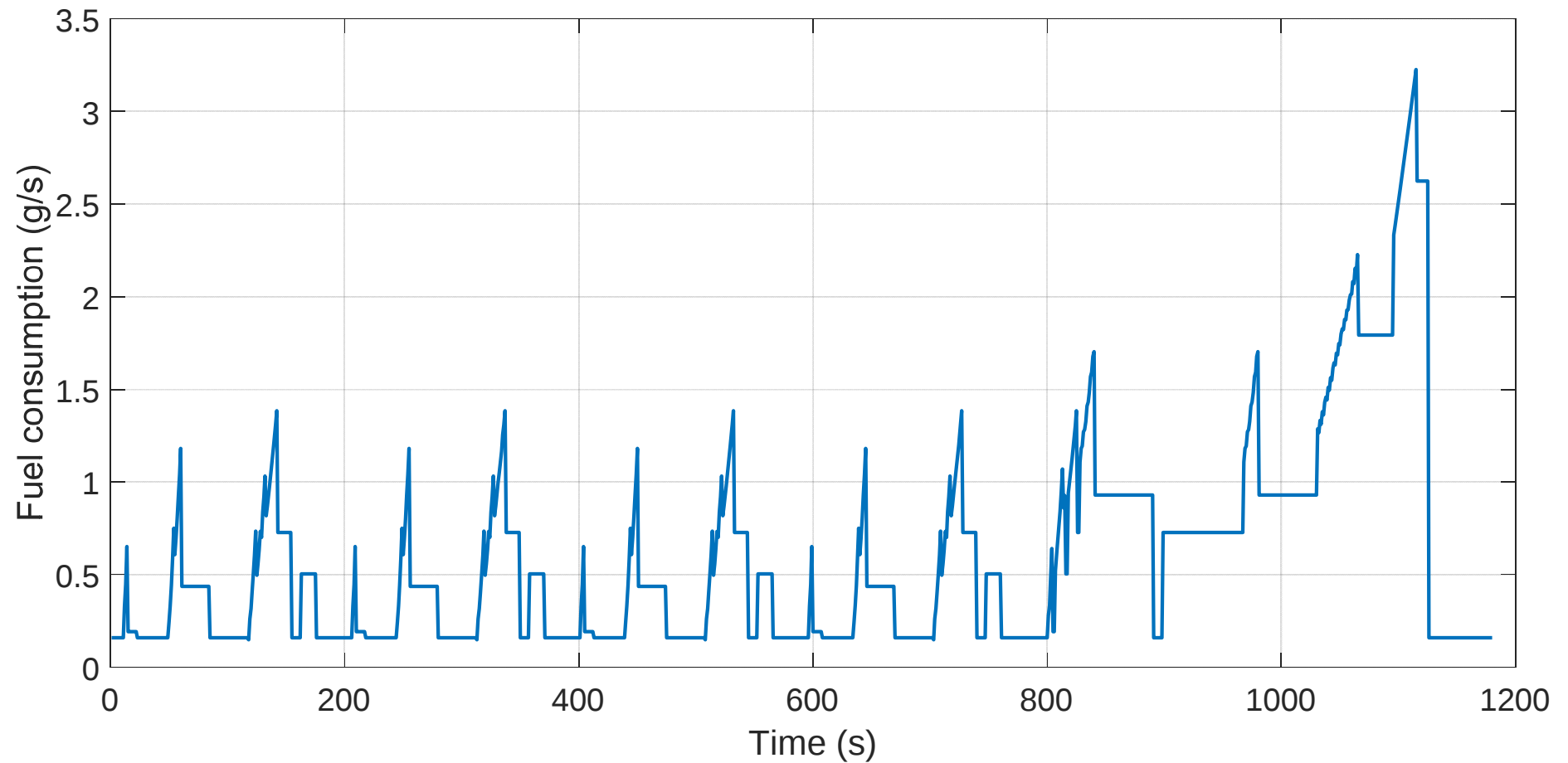
Constant acceleration condition



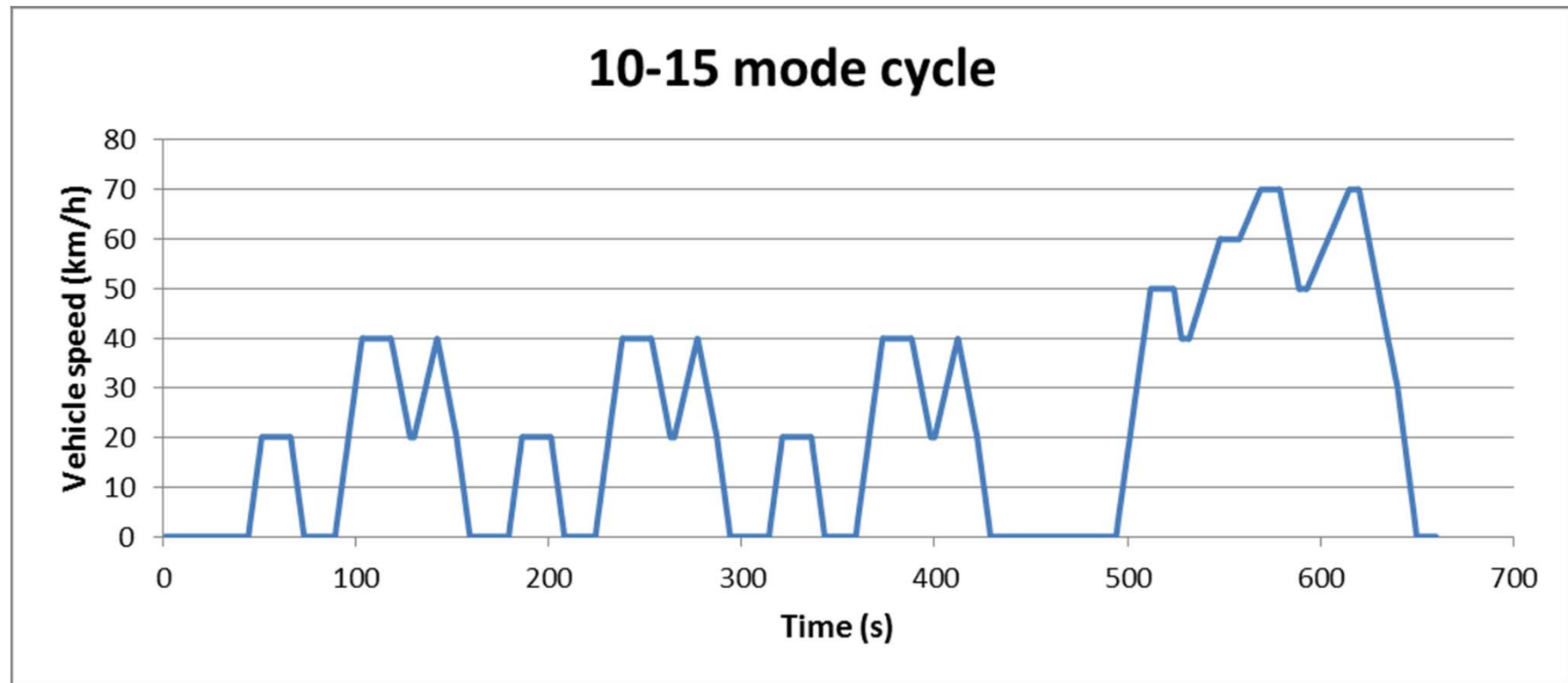
Constant acceleration condition



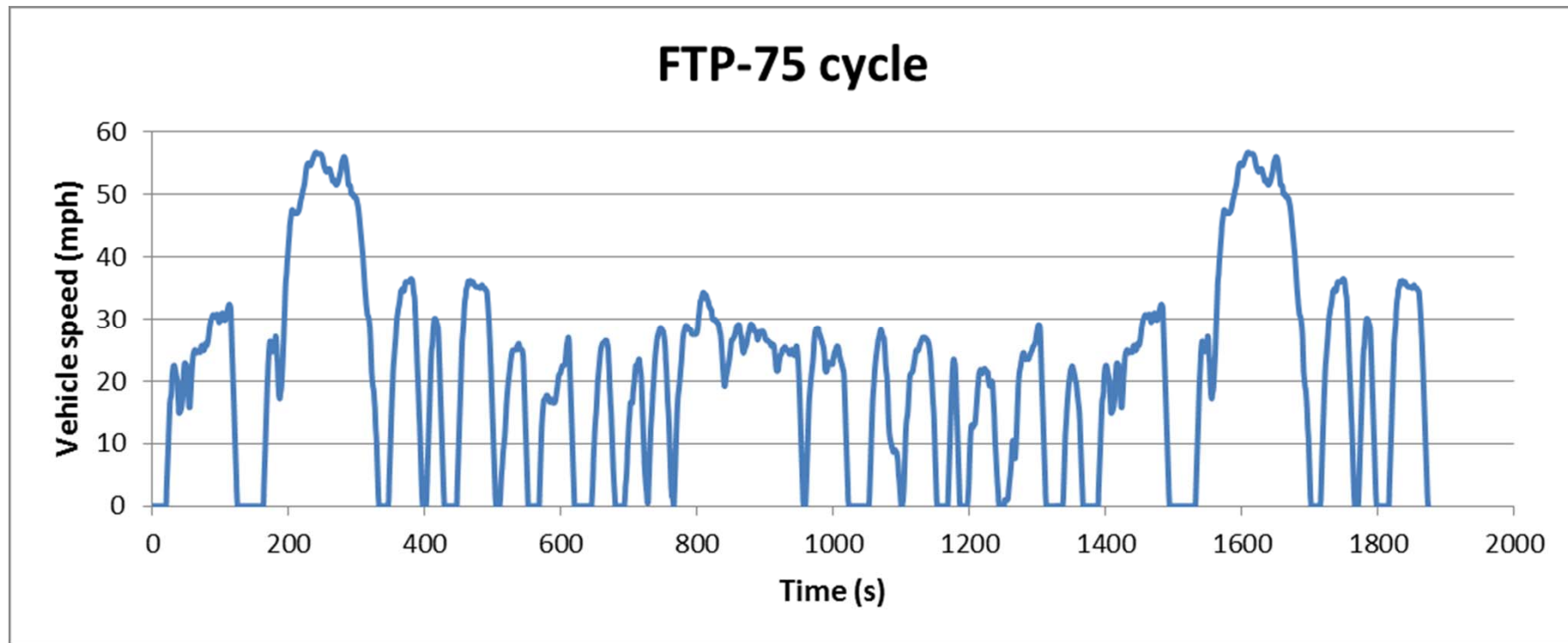
Fuel consumption NEDC



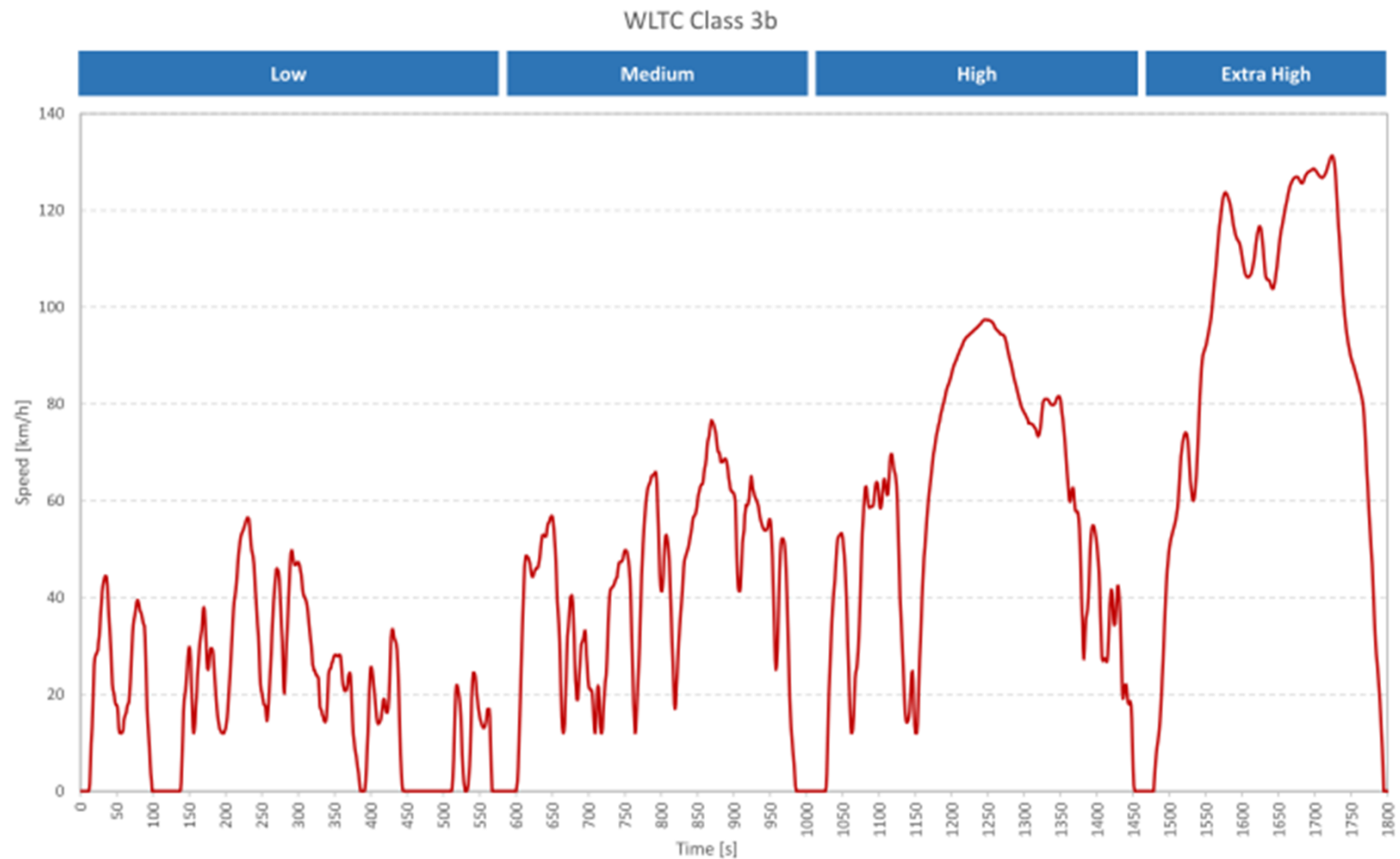
10-15 mode cycle

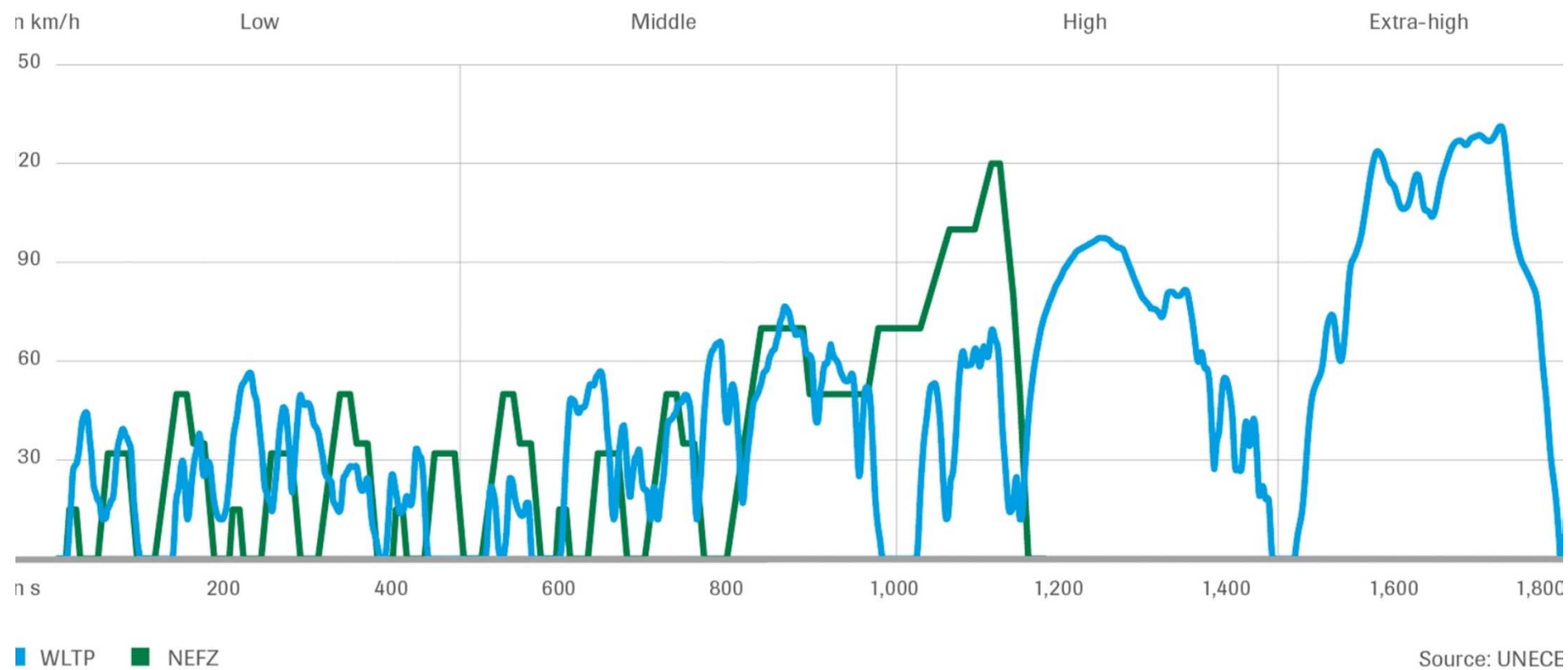


FTP-75



Worldwide Harmonised Light Vehicle Test Procedure (WLTP)





Improvements

- A greater range of driving situations (urban, suburban, main road, motorway);
- Longer test distances;
- More realistic ambient temperatures, closer to the European average;
- Higher average and maximum speeds;
- Higher average and maximum drive power;
- More dynamic and representative accelerations and decelerations;
- Shorter stops;
- Optional equipment: CO₂ values and fuel consumption are provided for individual vehicles as built;
- Stricter car set-up and measurement conditions;
- Enables best and worst-case values on consumer information, reflecting the options available for similar car models.