CO2 Estimation Models

Delta Altitude Reward Models

Force Model

Theory

Given a vehicle moving in a flat surface, there are majorly two forces acting, with other elementary forces:

$$F_T = (F_H + F_V) \cdot J \tag{1}$$

$$\begin{gathered} F_T = \text{Total force exerted} \\ F_H = \text{Horizontal Forces; dependent on load momentum} \\ F_V = \text{Vertical Forces; load and gravity only} \end{gathered}$$

$$F_H = m \cdot \frac{d^2V}{dT^2} \tag{2}$$

$$F_V = \frac{G \cdot M \cdot m}{r^2} \tag{3}$$

$$J - \text{Calibratable factor calculation, typically 1} \tag{4}$$

Forces exerted due to F_H are typically overpowered by the truck's engines, which essentially creates the movement and control of the freight in entirety. F_V is balanced by the structural integrity of the engine.

The demand of the engine is (usually defined in terms of torque requirement), defined as T_{dem}. In a normalised measurement scenario, the value of T_{dem} is 1 on flat roads.

However during ascent, the load m is shifted from F_V to F_H partly, effectively increasing net F_H. This increases $T_{dem} \geq 1$ finally. The converse is valid; during descent, the F_H is reduced since F_H is moved to F_V.

From a single body propulsion point of view, torque demand is directly proportional to the force exerted by the vehicle to counteract (1):

$$T_{dem} \propto F_T \tag{5}$$

This can be converted to a linear form:

$$F_T = k \cdot T_{dem} \tag{6}$$

These two different simple models complement each other from different directions.

Effects

From vehicle combustion point of view, torque demand is directly proportional to the fuel consumed per kilometre:

$$T_{dem} \propto Q_{km} \tag{7}$$

And similarly creating a linear form:

$$Q_{km} = k \cdot T_{dem} \tag{8}$$

With known quantities of average fuel consumption of vehicle based on class $Q_{km,avg}$, torque class T_{eng} to derive T_{dem} based on average mass in vehicle; it is possible to solve (6) to get k.

Total consumed Q_{km} can be calculated from (8) with known k and T_{dem}.

On average, CO2 production from diesel is defined as:

$$CO_{2,avg} = 3.17\text{g per g of diesel} \tag{9}$$

This is the maximum theoretical value derived from combustion of pure diesel, vehicles produce way less that aforementioned value, attributed by the after-treatment parts and active emission control devices, for example EGRs.

This lesser production can be a factor defined similar to k, since all equations $(6), (7) \text{ and } (9)$ are linear proportional values.

Known Approximations

1. Very simple force body model is used throughout the analysis: that is, a vehicle is considered a uni-body. Interacting forces are not considered, for example: momentum imbalance between load and drive-train areas of a truck, sway and other road impacts.
2. The emission systems are dependent to vary between high and low load scenarios, for example: cold-start conditions, any effects due to AECD, full-load operation and limp-mode situations.
3. The factor k is considered uniform, and approximated heavily. However this can be tuned using factor j that is controlled by the user, creating a closed loop system that does not affect the calculation chain in the middle, causing and unintended effects.
4. Many external forces are neglected: wind drag, aerodynamics of the vehicle, traffic situations, road smoothness