Ronald Kessel, CMRE, Fuel/Energy Metric v5
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How Good are the Fuel-Reduction Measures on Your Ship?

Objective: Estimate the *expected average change in fuel consumption* due to fuel-reduction measures of *any* kind for a given ship, whether by route planning (using NAVTRONIC) or by other ship optimization.

Given:

1. Power-speed (P-V) data collected for the ship under a range of steady-state sailing conditions, *before* and *after* implementing fuel-reduction measures.
2. A customary power-law fit to each data set,

$$P = a_1 V^{b_1} \ \ before, \qquad P = a_2 V^{b_2} \ \ after \tag{1}$$

Apply the Performance Metric:

$$\overline{\Delta E_{rel}} \quad = \quad \left\{ \frac{a_2}{a_1} \overline{V^{(b_2-b_1)}} + (b_2 - 1)\overline{\Delta V_{rel}} - 1 \right\} \times 100\ \% \tag{2}$$

$\overline{\Delta E_{rel}}$ Expected average relative change of total energy (hence fuel) consumption, expressed as a percent. Its value will be *negative* ($\overline{\Delta E_{rel}} \leq 0$) when energy and fuel are *reduced*. The NAVTRONIC goal is $\overline{\Delta E_{rel}} \leq -7\ \%$ through route planning for instance. The metric (2) holds for changes $|\overline{\Delta E_{rel}}|$ smaller than 20 %. The dimensions of variables in (2) are those used in the power law (1).

P *Available* propulsion power. Typically 60 % of the total power into the propeller shaft(s).

V Forward speed of the ship through water.

(a_1, b_1), (a_2, b_2) Best-fit power-law coefficients for *before* ($_1$) and *after* ($_2$) sailing data (see equation (1) above). Special methods are required when fitting a power law to actual sailing data. See the NAVTRONIC RTD Partner Technical Note, "*Fitting a Power Law to Ship Power-Speed Data*", Apr 2013.

$\overline{V^{(b_2-b_1)}}$ Expected average ship speed V raised to the power of the difference in exponents $(b_2 - b_1)$ in future sailings. If past sailing data is believed to be representative of future sailing, and if f_i is the relative frequency of occurrence of speed V_i in a histogram of the steady-state speeds in past sailing data, then $\overline{V^{(b_2-b_1)}} \approx \sum_i f_i V_i^{(b_2-b_1)}$, with $\sum_i f_i = 1$. If future sailing speeds are expected to differ from past (because sailing constraints or modes of business have changed), then set f_i to the relative frequencies expected for future sailings. If the expected ship speeds are uniformly distributed between V_A and V_B, then $\overline{V^{(b_2-b_1)}} = (V_B^c - V_A^c)/[c(V_B - V_A)]$ with $c = b_2 - b_1 + 1$.

$\overline{\Delta V_{rel}}$ Additional average relative change in speed (throttle), *not* included in V of $\overline{V^{(b_2-b_1)}}$, instituted at the discretion of the captain for *future* sailings, perhaps in response to evidence for or against successful fuel reduction measures, perhaps in connection elsewhere with counter-piracy measures. $\overline{\Delta V_{rel}} = 0$ if no change in throttle is expected. If a 10 % average speed *reduction* is foreseen (or hypothesized), then $\overline{\Delta V_{rel}} = -0.10$. $\overline{\Delta V_{rel}}$ is dimensionless. $|\overline{\Delta V_{rel}}|$ is a assumed to be small (less than 0.2).

Disclaimer: Equation (2) was developed and is under test in NAVTRONIC. It is floated here for discussion purposes. Derivation and examples with sailing data are in NAVTRONIC deliverables.

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