Congestion function

$$\text{Congestion}_i(t) = \text{FreeFlowTime}_i \times \left\{ 1 + \underbrace{\alpha_{BPR}}_{CL_{c,i}(t)} \left[\underbrace{\sum_{c \in C} \left[\frac{\sum_{j \in F_{c,i}} \left[\frac{\alpha_c \left(\sum_{f \in F_j} \omega_f + \sum_{f_1, f_2 \in F_j} \omega_{f_1, f_2} I_{f_1, f_2} \right)}{1 + e^{-k_c (C_{c,i} - C_{0,c})}} \times \left| H_c(t) \cdot (1 + \Delta H_c^{(f)}(t)) \right| \times e^{-\lambda_c d_{ij}} \right]}{1 + e^{-\gamma_c \left(\left(\sum_{j \in F_{c,i}} e^{-\lambda_c d_{ij}} \right) - D_{0,c} \right)}} \times \prod_{m \in M} (1 + \beta_{m,c}(t)) + \varepsilon_j(t) \right]}_{TL_i(t)} \right]^{\beta_{BPR}} \right.$$

$$\left. + \left[\frac{1}{\text{Capacity}_i} \times \sum_{K=1}^{P(t)} \left(\gamma_{K,type} e^{-\lambda_{z,type} d_{iK}} \right) \right] \right\}$$

$T_{j,i}(t)$: ω_j

$TL_i(t)$: total load (Yloleal)

$CL_{c,i}(t)$: Category Load (Category Aggregation) with Density Normalization

$T_{j,i}(t)$: Facility level contribution

Predictive Replication & Advanced Variant Algorithmic Harmonization (P.R.A.V.A.H)

① by Ryan Ryu 07/02/25

Parts of Congestion Formula

$$\text{Congestion}_i(t) = \text{FreeFlowTime}_i \times \left\{1 + \alpha_{BPR}\left(\frac{\text{TotalLoad}_i(t)}{\text{Capacity}_i / R_i}\right)^{\beta_{BPR}}\right\} + \underbrace{\frac{\sum_{k=1}^{P(t)} \gamma_{k,type}\, e^{-\lambda_{z,type} d_{ij}}}{\text{Capacity}_i}}_{\text{global events term}}$$

$$\text{TotalLoad}_i(t) = \sum_{c \in C} \text{CategoryLoad}_{c,i}(t)$$

$$\text{CategoryLoad}_{c,i}(t) = \frac{\sum_{j \in F_{c,i}} T_{j,i}(t)}{1 + \exp\left(-\gamma_c\left(\sum_{j \in F_{c,i}} e^{-\lambda_c d_{ij}} - D_{0,c}\right)\right)}$$

$$T_{j,i}(t) = \overbrace{\frac{\alpha_c \omega_j}{1 + e^{-\kappa_c (c_{c,i} - c_{0,c})}}}^{\text{Category based}} \times \underbrace{\left[H_c(t) \cdot (1 + \Delta H_c^{(f)}(t))\right]}_{\text{temporal profile}} \times \underbrace{e^{-\lambda_c d_{ij}}}_{\text{Spatial decay Factor}} \times \underbrace{\prod_{m \in M}(1 + \beta_{m,c}(t))}_{\text{external event multiplier}} + \underbrace{\varepsilon_j(t)}_{\text{Stochastic Noise}}$$

(facility weight)

$$\omega_j = \sum_{f \in F_j} \omega_f + \underbrace{\sum_{f_1, f_2 \in F_j} \omega_{f_1} \omega_{f_2} I_{f_1, f_2}}_{\text{interaction term}}$$

Types:

EDUCATION
- amenity: prep_school
- "school
- "college
- "university
- "language_school
- "college
- "University
- "...

Healthcare
Retail
Government
Entertainment
Religious
Transport
Leisure
Mixed
Historic

Terminology

- facility: eg: education, mixed... (Category)
- features: eg: (landuse: commercial), ...
- F_j: Set of features for facility j
- ω_f: feature weight i.e. Eg: In education "amenity: school" and "building: College" Carry different weight.
- $\sum_{f \in F_j} \omega_f$: Sum of all contribution of all individual features of facility j
- Interaction term: Synergistic effects in religious: (amenity: Social_centre) & (building: Church) result in interaction that increases / decreases impact
- FreeFlowTime$_i$: travel time along road i under Uncongested condition
- Global events term: additional delay due to global events that affect road i (G.E.T.)
- $P(t)$: no. of such events at time t (G.E.T.)
- event k has impact $\gamma_{k,type}$ and spatial decay where d_{ik} is distance from event to road
- BPR: bureau of public road
- α_c: Scaling factor for all ~~facilities~~ features under specific facility. (Category base impact)
- $C_{c,i}$: no. of ~~facilities~~ features of Category c near road i
- $C_{0,c}$: threshold at with additional features will diminish marginal impact. eg: once count of retail exceed this traffic saturate
- K_c: Saturation Rate parameter (how quickly)
- $H_c(t)$: Baseline temporal traffic profile (how Category c varies with t)
- Climate changes: fog etc. in EEM other in TFA like seasons.
- $\Delta H_c^{(f)}(t)$: Temporal feature Adjustment. (Adjust baseline for special condition)
- $e^{-\lambda_c d_{ij}}$: Spatial decay factor eg: impact decreases of feature j as d_{ij} on road i
- $\prod_{m \in M} (1 + \beta_{m,c}(t))$: external event multiplier eg: Concerts, Sales etc.
- $\varepsilon_j(t)$: Stochastic Noise; Captures random fluctuations
- Numerator in Category Load: Sum of Contribution by each ~~features~~ facility.
- Denominator: Logistic density normalization
- γ_c: Controls steepness of normalization response.
- $\sum_{j \in F_{C,i}} e^{-\lambda_c d_{ij}}$: effective 'density' of facilities (by distance)
- $D_{0,c}$: density threshold (not over max density)
- Total Load: Global traffic Load
- C: Set of all facility
- BPR term:
  Capacity$_i$: max vehicle on road i
  R_i: Road quality factor
- $\alpha_{BPR}, \beta_{BPR}$: Calibration parameter how congestion builds up as exceeds Capacity.