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HONMA LAB.

[Design of Urban Environmental Systems]

International Center for Urban Safety Engineering

Urban Environmental Mathematical Engineering

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Design of Urban Environmental Systems

Mathematical Engineering for Sustainable Society

Urban environmental systems in present society have become large and complicated. However, by such upgrading of urban systems, lots of intractable problems are also pointed out. To tackle such problems in the society, In our laboratory, we have proposed to manage the above systems and grasp the basic structures using the “mathematical model”.

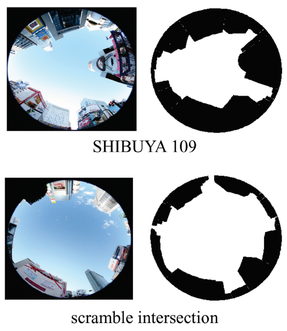
Analysis of Landscapes by Computational Geometry

The solid angle, which is closely related to the sky factor, has been used to assess urban landscapes. In this study, we propose a new algorithm to calculate the solid angles of urban landscapes.

$$R = \alpha + \beta + \gamma - \pi$$

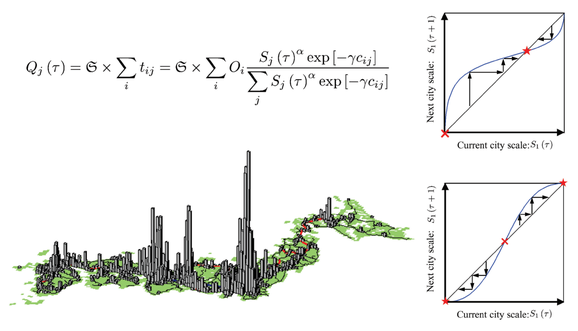
$$\alpha = \arccos\left(\frac{\cos a - \cos b \cdot \cos c}{\sin b \cdot \sin c}\right)$$

$$a = \arccos\left(\frac{\langle \overrightarrow{OB}, \overrightarrow{OC} \rangle}{||\overrightarrow{OB}|| \cdot ||\overrightarrow{OC}||}\right)$$



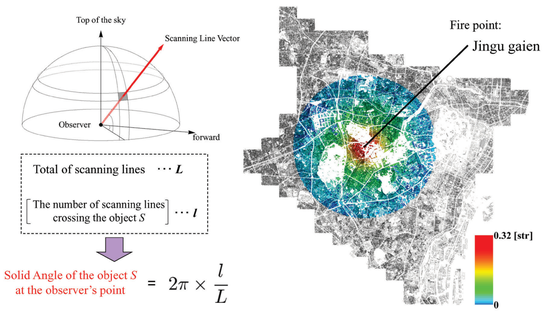
Urban Concentrations by Japanese Railway Networks

$$Q_j(\tau) = \mathfrak{S} \times \sum_i t_{ij} = \mathfrak{S} \times \sum_i O_i \frac{S_j(\tau)^\alpha \exp[-\gamma c_{ij}]}{\sum_j S_j(\tau)^\alpha \exp[-\gamma c_{ij}]}$$



In this study, we focus on the flow dynamics of urban activity distribution. Particularly, we examine how the construction of Japanese Shinkansen bullet train affects the developments of cities in Japan.

Analysis of Fireworks Using Building Data



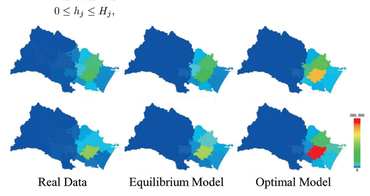
Fireworks displays are typical features of summer in Japan. In this study, we propose a mathematical model to evaluate the optimal view points for fireworks displays.

Equilibrium and Optimum Location of Housings and Jobs

In this study, we propose a new calculation method for equilibrium and optimum distribution of housings and jobs. The model could be utilized for discussion of compact-city.

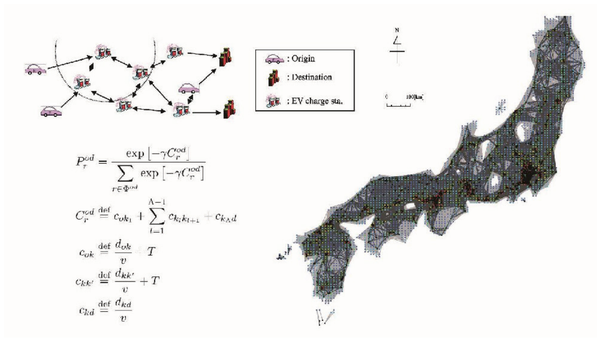
$$T = \sum_{i=1}^{I}\sum_{j=1}^{J} t_{ij}^{\mathrm{h}} \quad (1 \leqslant i \leqslant I,\ 1 \leqslant j \leqslant J),$$
$$w_i = \sum_{j=1}^{J} t_{ij}^{\mathrm{h}} \quad (1 \leqslant j \leqslant J),$$
$$h_j = \sum_{i=1}^{I} t_{ij}^{\mathrm{h}} \quad (1 \leqslant i \leqslant I),$$
$$0 \leq w_i \leq W_i,$$
$$0 \leq h_j \leq H_j,$$

$$\min.\ F_{\mathrm{UE}} = \sum_{i=1}^{I}\sum_{j=1}^{J} 2d_{ij}^{\mathrm{h}} t_{ij}^{\mathrm{h}} + \frac{\alpha}{T}\sum_{i=1}^{I}\sum_{i'=1}^{I}\frac{1}{2}d_{ii'}^{\mathrm{w}} w_i w_{i'} + \sum_{i=1}^{I}\int_0^{w_i} z_i^{\mathrm{w}}(x)\mathrm{d}x + \sum_{j=1}^{J}\int_0^{h_j} z_j^{\mathrm{h}}(x)\mathrm{d}x$$
$$\text{s.t.}\ \ w_i = \sum_{j=1}^{J} t_{ij}^{\mathrm{h}} \quad (1 \leqslant i \leqslant I)$$
$$h_j = \sum_{i=1}^{I} t_{ij}^{\mathrm{h}} \quad (1 \leqslant j \leqslant J)$$
$$T = \sum_{i=1}^{I}\sum_{j=1}^{J} t_{ij}^{\mathrm{h}}$$
$$0 \leq w_i \leq W_i \quad (1 \leqslant i \leqslant I)$$
$$0 \leq h_j \leq H_j \quad (1 \leqslant j \leqslant J)$$
$$0 \leq t_{ij}^{\mathrm{h}} \quad (1 \leqslant i \leqslant I,\ 1 \leqslant j \leqslant J)$$



Simulation — Mathematical Modelling — Optimization

Analysis of EV Movement Using Japanese Road Network

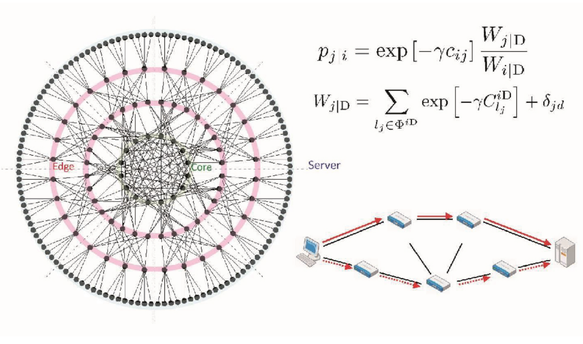


$$P_r^{od} = \frac{\exp\left[-\gamma C_r^{od}\right]}{\sum_{r \in \Phi^{od}} \exp\left[-\gamma C_r^{od}\right]}$$
$$C_r^{od} \overset{\text{def}}{=} c_{ok_1} + \sum_{l=1}^{\Lambda-1} c_{k_l k_{l+1}} + c_{k_\Lambda d}$$
$$c_{ok} \overset{\text{def}}{=} \frac{d_{ok}}{v} \cdot T$$
$$c_{kk'} \overset{\text{def}}{=} \frac{d_{kk'}}{v} + T$$
$$c_{kd} \overset{\text{def}}{=} \frac{d_{kd}}{v}$$

EV have attracted an increasing amount of attention, but the cruising distance is still insufficient. In this study, an elegant mathematical model for supporting infrastructure is proposed.

Information Network for Sustainable Environment

We present a new multi-path routing -MLB-routing-. Since MLB-routing is pure multi-path routing, it reduces the convergence on some links and also increases bandwidth utilization in the network.

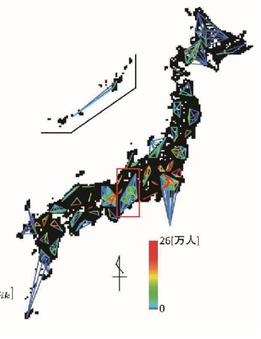


$$p_{j\,i} = \exp\left[-\gamma c_{ij}\right] \frac{W_{j|\mathrm{D}}}{W_{i|\mathrm{D}}}$$
$$W_{j|\mathrm{D}} = \sum_{l_j \in \Phi^{j\mathrm{D}}} \exp\left[-\gamma C_{l_j}^{j\mathrm{D}}\right] + \delta_{jd}$$

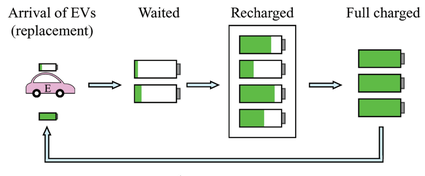
Sight-seeing Behavior Focused on Trip-chain

Analyzing sight-seeing behaveiors is important for sustainable developments of regions. In this study, focusing on the trip-chaining behavior in Japan, and estimate the number of Tourists.

$$O_i = \sum_{k \in \Phi_i} t_{ik}$$
$$M_k = \sum_{l=1}^{L}\sum_{i=1}^{I}\sum_{\{k \in \Phi_i | k_l = k\}} t_{ik}$$
$$C = \sum_{i=1}^{I}\sum_{k \in \Phi_i} t_{ik} c_{ik}$$
$$t_{ik} = A_i O_i \left(\prod_{l=1}^{\Lambda} E_{k_l} M_{k_l}\right) p_{ik} \exp\left[-\gamma c_{ik}\right]$$
$$A_i^{-1} = \sum_{k \in \Phi_i} \left(\prod_{l=1}^{\Lambda} E_{k_l} M_{k_l}\right) p_{ik} \exp\left[-\gamma c_{ik}\right]$$
$$E_k^{-1} = \sum_{l=1}^{L}\sum_{i=1}^{I}\sum_{\{k \in \Phi_i | k_l = k\}} A_i O_i \left(\prod_{l^* \neq l} E_{k_{l^*}} M_{k_{l^*}}\right) p_{ik} \exp\left[-\gamma c_{ik}\right]$$



Safety Stock in EV Battery Switch Stations



$$p_0 = \left(\sum_{n=0}^{s}\frac{(s\rho)^n}{n!} + \frac{s^s}{s!}\sum_{n=s+1}^{N}\rho^n\right)^{-1}$$
$$p_n = \begin{cases} \dfrac{(s\rho)^n}{n!} p_0 & (n \leq s) \\ \dfrac{s^s}{s!}\rho^n p_0 & (s \leq n \leq N) \end{cases}$$
$$p_N = \frac{s^s}{s!}\rho^N \left(\sum_{n=0}^{s}\frac{(s\rho)^n}{n!} + \frac{s^s}{s!}\sum_{n=s+1}^{N}\rho^n\right)^{-1} \leq \delta$$

Some company has proposed an EV operations system called ``battery switch system''. In this study, we are focusing on the infra-structure required to support the optimal operation of battery switching system.

Human