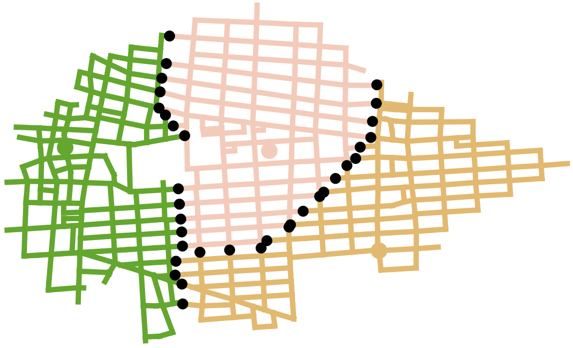

Fig. 5. Results of Voronoi heuristics. Large circles denote Voronoi generators and small circles denote boundary points between sub-networks. Number of vertices is 400 and $p = 3$.

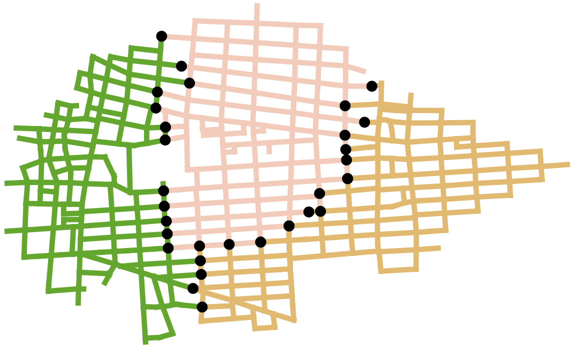

Fig. 6. Results of the linear programming method. Black circles denote boundary points between sub-networks.

$$\text{subject to} \quad 0 \le l_{i1} + x_i \le e_i, \quad i \in B, \tag{8}$$
$$x_i \in \mathbb{R}, \quad i \in B. \tag{9}$$

The objective function (7) is the sum of the absolute values of the difference between the average total edge length and the total edge length of each sub-network whose boundary points are moved by x_i. Constraints (8) ensure that the boundary point moves only along the edge.

This mathematical formulation is not an ordinary linear programming formulation. Generally, it is not easy to solve this kind formulation. However, this formulation can be easily transformed into a linear programming formulation using the additional decision variables z_k, such that

$$\left| \frac{F(N)}{p} - \left\{ L_k + \sum_{i \in B} M_{i1k}(l_{i1} + x_i) + \sum_{i \in B} M_{i2k}(l_{i2} - x_i) \right\} \right| \le z_k. \tag{10}$$

To minimize the sum of z_k is equivalent to minimizing the objective function. Therefore, we can transform the formulation to a linear programming formulation using z_k as follows:

minimize

$$\sum_{k=1,\cdots,p} z_k, \tag{11}$$

subject to

$$\frac{F(N)}{p} - \left\{ L_k + \sum_{i \in B} M_{i1k}(l_{i1} + x_i) + \sum_{i \in B} M_{i2k}(l_{i2} - x_i) \right\} \le z_k, \quad k = 1, \cdots, p, \tag{12}$$

$$\frac{F(N)}{p} - \left\{ L_k + \sum_{i \in B} M_{i1k}(l_{i1} + x_i) + \sum_{i \in B} M_{i2k}(l_{i2} - x_i) \right\} \ge -z_k, \quad k = 1, \cdots, p, \tag{13}$$

$$z_k \ge 0, z_k \in \mathbb{R}, \quad k = 1, \cdots, p, \tag{14}$$

in addition to (8) and (9).

We use the Voronoi heuristics with multiple starts to get an approximate solution, and then the linear programming formulation to improve the solution.

4. Computational Experiments

Programs were coded in Java using the optimization software package ILOG CPLEX 10.0 to solve the problem which was formulated as a linear programming problem. The programs were run on a Pentium 4, 2.53 GHz with 512 MB RAM. We made ten different network types for our experiments using the actual road network of Nagoya City in