Instance generation

We consider problem instances with two, three, and four technicians, each with $|\mathcal{N}_0|$=10, 15 and 20 nodes (including the depot and customers). The node coordinates are taken from the Solomon dataset, including R and C classes. We vary the technician shift duration L, referred to as *short*, *medium*, and *long* to yield a total of 54 problem instances. Through all problem instances, we set α and ψ to 1 and β to 2. We consider three service categories, $P = \{1, 2, 3\}$, where each category $p \in P$ is characterized by a minimum and maximum amount of service time that a technician spends to repair the failure, denoted by Lb_{q_i}, Ub_{q_i}, respectively. The service category related to each customer, q_i, is uniformly selected to be one of the $p \in P$. We assume that for each customer $i \in \mathcal{N}$, the $\Psi^i_{q_i}$ is independent random variables that follow discrete triangular probability distributions.

We develop the following procedure to determine $\Psi^i_{q_i}$. We assume that the support set for each customer consists of three points, including Lb_{q_i}, Ub_{q_i}. To determine the third point, we first divide the interval $[Lb_{q_i}, Ub_{q_i}]$ into three identical subintervals, and the third point is sampled uniformly from the middle subinterval. The discrete triangular distribution corresponding to customer i is characterized by three parameters: the minimum value e_i, the mode M_i, and the maximum value l_i. To prevent zero probabilities for support points, we set $e_i = Lb_{q_i} - \lambda$, and $l_i = Ub_{q_i} + \lambda$ where λ is given. To generate more skewed instances based on the values of the supports (probabilities), we construct three discrete triangular distribution families, including *symmetric*, *positive-skewed*, and *negative-skewed*. These families are distinguished by the position of the mode, M_i. Let $M_i = e_i + \sigma(l_i - e_i)$, where σ is a parameter that specifies the proportion by which the mode deviates from the minimum value e_i. For the symmetric, positive-skewed, and negative-skewed distributions, the value of σ must satisfy $\sigma = 0, 0 \leq \sigma \leq 0.5$, and $0.5 \leq \sigma \leq 1$, respectively. In our settings, we set λ to 40 for all families, and we set σ to 0.1 for positive-skewed and σ to 0.9 for negative-skewed distributions. The skew type of the triangular distribution for each customer is determined randomly.

To establish shift duration L, we propose a model called LOPT. The LOPT is designed as a multi-traveling salesman problem that aims to minimize the total travel and service times for exactly m routes. Given m and $\mathcal{N}_0$, the LOPT with expected service times is solved, then the average route duration per technician is multiplied by factors of 0.75, 1, and 1.25. The resulting shift limits are referred to as *short*, *medium*, and *long*, respectively.

The LOPT model is as follow:

$$\min \quad \sum_{v\in\mathcal{V}}\sum_{i\in\mathcal{N}_0}\sum_{j\in\mathcal{N}_0}(\frac{c_{ij}}{\psi}+d_j)x_{ijv} \tag{1}$$

subject to:

$$\sum_{i\in\mathcal{N}_0}\sum_{v\in\mathcal{V}}x_{ijv}=1, \quad \forall j\in\mathcal{N} \tag{2}$$

$$\sum_{j\in\mathcal{N}}x_{0jv}=1, \forall v\in\mathcal{V} \tag{3}$$

$$\sum_{i\in\mathcal{N}_0}x_{ilv}-\sum_{j\in\mathcal{N}_0}x_{ljv}=0, \quad \forall l\in\mathcal{N}_0,\ \forall v\in\mathcal{V} \tag{4}$$

$$u_i-u_j+|\mathcal{N}_0|\sum_{v\in\mathcal{V}}x_{ijv}\le|\mathcal{N}_0|-1, \quad \forall i,j\in\mathcal{N}_0,\ i\ne j \tag{5}$$

$$u_i\ge 0, \quad \forall i\in\mathcal{N}_0 \tag{6}$$

$$x_{ijv}\in\{0,1\}, \quad \forall i,j\in\mathcal{N}_0,\ \forall v\in\mathcal{V} \tag{7}$$