The optimization problem is formulated as follows:

$$\begin{aligned} Min\ \ Z = & \sum_{j\in J} F_j x_j + \sum_{i\in I}\sum_{j\in J}\sum_{l\in L} Z_{ijl} A_{ijl} + \sum_{j\in J}\sum_{k\in K}\sum_{l\in L} y_{jkl} B_{jkl} \\ & + \sum_{s\in S}\pi_s \left\{ \sum_{j\in J}\sum_{k\in K}\sum_{l\in L}\gamma_{lk} Q^1_{jkls} + \sum_{j\in J}\sum_{k\in K}\sum_{l\in L}\gamma_{lk} Q^2_{jkls} \right\} \end{aligned} \quad (1)$$

Subject to,

$$\sum_{j\in J} x_j = R \quad (2)$$

$$\sum_{i\in I} Z_{ijl} = \sum_{k\in K} y_{jkl} \qquad \forall j \in J, l \in L \quad (3)$$

$$\sum_{i\in I}\sum_{l\in L} Z_{ijl} \le M x_j \qquad \forall j \in J \quad (4)$$

$$\sum_{k\in K}\sum_{l\in L} y_{jkl} \le M1 x_j \qquad \forall j \in J \quad (5)$$

$$\sum_{j\in J} y_{jkl} = D_{kl} \qquad \forall l \in L, k \in K \quad (6)$$

$$\sum_{l\in L} m_l \sum_{j\in J} Z_{ijl} \le P_i \qquad \forall i \in I \quad (7)$$

$$\sum_{l\in L} n_l \sum_{k\in K} y_{jkl} \le Cap_j x_j \qquad \forall j \in J \quad (8)$$

$$\sum_{j\in J} Q^1_{jkls} \ge D_{kl} - \sum_{j\in J} y^1_{jkls} \qquad \forall l \in L, k \in K, s \in S \quad (9)$$

$$\sum_{j\in J} Q^2_{jkls} \ge D_{kl} - \sum_{j\in J} y^2_{jkls} \qquad \forall l \in L, k \in K, s \in S \quad (10)$$

$$\sum_{k\in K} y^2_{jkls} = \sum_{i\in I} \alpha_{isl} * Z_{ijl} \qquad \forall j \in J, l \in L, s \in S \quad (11)$$

$$y^1_{jkls} = \beta_{jsl} * y_{jkl} \qquad \forall j \in J, k \in K, l \in L, s \in S \quad (12)$$

$$x_{j \in \{0,1\}} \qquad \forall j \in J \quad (13)$$

$$y_{jkl} \ge 0,\ Z_{ijl} \ge 0,\ Q^1_{jkls} \ge 0,\ \ Q^2_{jkls} \ge 0,\ y^1_{jkls} \ge 0,\ y^1_{jkls} \ge 0 \qquad \forall j \in J, k \in K, l \in L, s \in S \quad (14)$$

Equation (1) is the objective function. It minimizes the sum of investment cost at DCs, the sum of distribution cost from supplier to DCs and from DCs to customers, the sum of expected shortage cost. Equation (2) states that R is the number of distribution centers which are to be located. Equation (3) is the mass balance constraint. Constraint (4) ensures that flow can be initiated from supplier i to distribution center j if and only if distribution center j is established. Constraint (5) ensures that flow can be initiated from distribution center j to customer k if and only if distribution center j is established. In equation (4) and (5), M and M1 is a sufficiently large positive number. Equation (6) implies demand satisfaction constraint. Constraint (7) is the capacity constraint of the supplier. Constraint (8) expresses capacity constraints of the distribution centers. Constraint (9) represents amount of shortage in disruptions scenario in the first time period. Constraint (10) indicates amount of shortage in disruptions scenario in the second time period. Constraint (11) decides the amount of product supplied in the second time period due to disruptions of the suppliers in the first time period. As the suppliers suffer disruptions in the first time period, they can`t supply the normal flow amount (Z_{ijl}) in the second time period, rather some fraction of these are provided by them to the distribution centers. From the third time period, the suppliers start to supply regular flow amount as they recover from disruptions. Constraint (12) gives the amount of supply in the first time period due to disruptions of the distribution centers. Constraint (13) imposes the integrality restrictions on binary variable. And, finally constraints (14)-(15) enforces the non-negativity restriction on the corresponding decision variables.