|  |  |
| --- | --- |
| Set name | Elements |
| *Set of suppliers S* | *S1', 'S2', 'S3', 'S4’* |
| *Set of mobile pharmacies M* | *'MP1', 'MP2', 'MP3', 'MP4', 'MP5'* |
| *Set of hospitals H* | *'H1', 'H2', 'H3'* |
| *Set of affected areas D* | *'AF1', 'AF2', 'AF3* |
| *Set of pharmaceutical products P* | *'PI1', 'PI2', 'PI3', 'PI4* |
| *Set of demand scenarios* | *low', 'medium', 'high'* |
| *Set of candidate Mobile Pharmacy locations B* | *CL1, CL2, CL3…..CL10* |

2) B

​: weight for operational cost

​: weight for penalty cost

2 A)

**Decision Variables**

***First-Stage (Here-and-now)***

***Second-Stage (Wait-and-see, scenario-dependent)***

*=*

*= 1 if MP m is added in Stage 2 at b, O otherwise*

2F)

**Objective Function**

((This objective seeks to minimize the sum of costs from supplier setup, MP deployment, transportation, procurement))

**Constraints**

**Stage 1 Constraints (Before uncertainty is realized)**

**Activates a supplier only if selected:**

**Mobile pharmacy deployment limit (Only 3 mobile pharmacies can be deployed in the first stage):**

**Stage 2 Constraints (Scenario-dependent)**

**Hospital Demand Fulfillment**

**Affected Area Fulfillment** (Satisfy minimum coverage requirement)

**Mobile pharmacy location constraint** (Each MP can be deployed at only one location per scenario)

**Stage 2 setup condition for MP (**Additional MPs can only be deployed at extra cos)

**Flow conservation**

Items can only be shipped to affected areas if received from supplier

**MP Storage Capacity**

**MP Movement Logic** (Each MP can only deliver a limited number of items):

**Hospitals and Areas Must Be Served**

Sign Constraints:

,

2E)

The problem is best modeled as a two-stage stochastic facility location and network flow optimization problem. It involves decisions on selecting facilities (suppliers and mobile pharmacies), determining product flows through a capacitated network, and satisfying demand under uncertainty.

**2 c)**

Assumption 1:

We assumed that demand at hospitals and affected areas is known for a limited number of predefined scenarios (e.g., low, medium, high), with fixed probabilities.

Assumption 2:

We allowed extra mobile pharmacies (>3) to be placed or moved after a scenario is realized, with additional cost but no time or logistics delay.

Assumption 3:

We treated all items as fully deliverable and usable without accounting for expiration, compatibility, or storage complexity across locations.

2 d)

We applied a Two-Stage multi objective Stochastic Programming approach to solve the pharmaceutical distribution problem under uncertainty.