A model for early positioning of emergency supplies for earthquake response in Bogotá using Python

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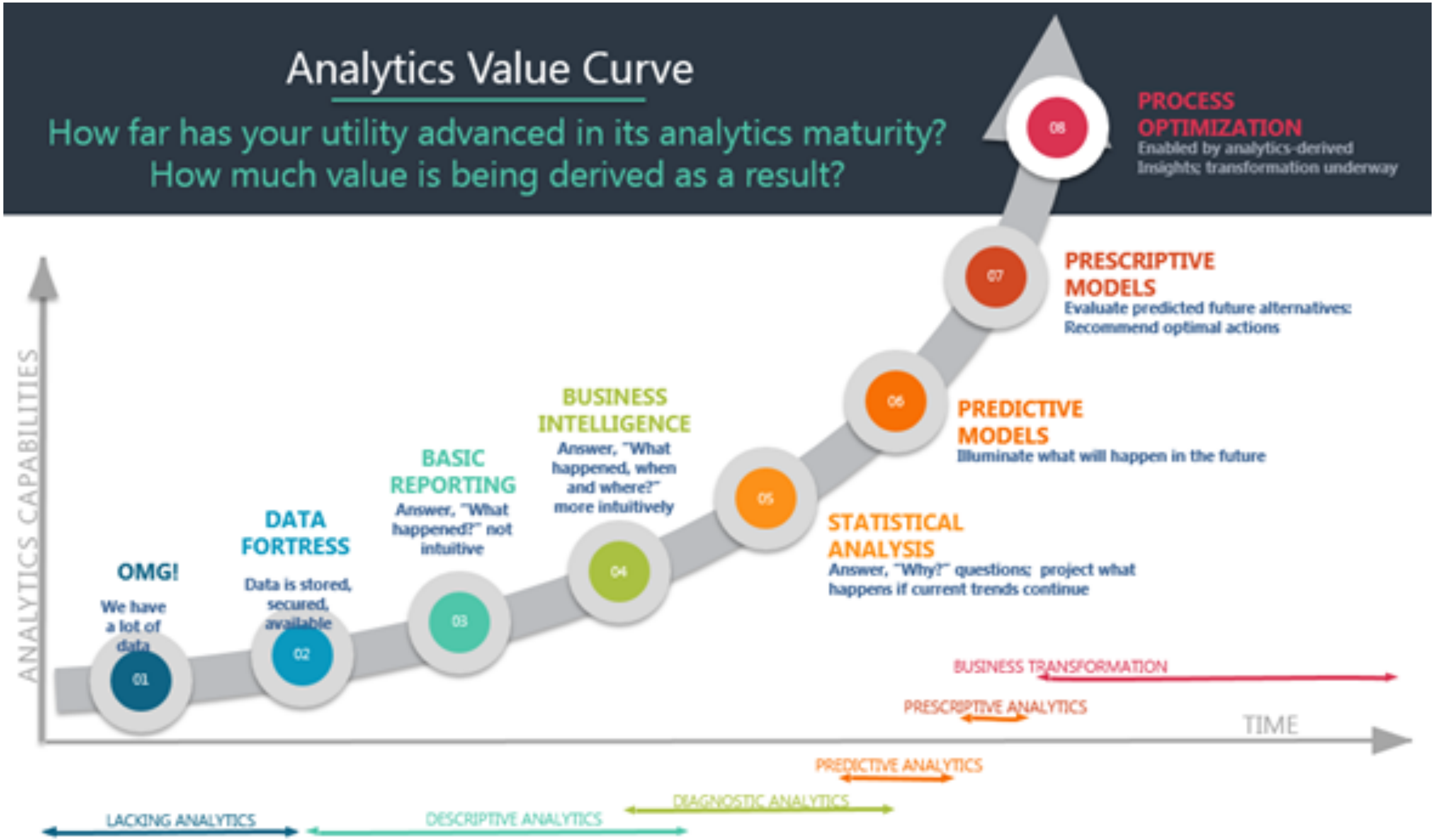
1. Motivation



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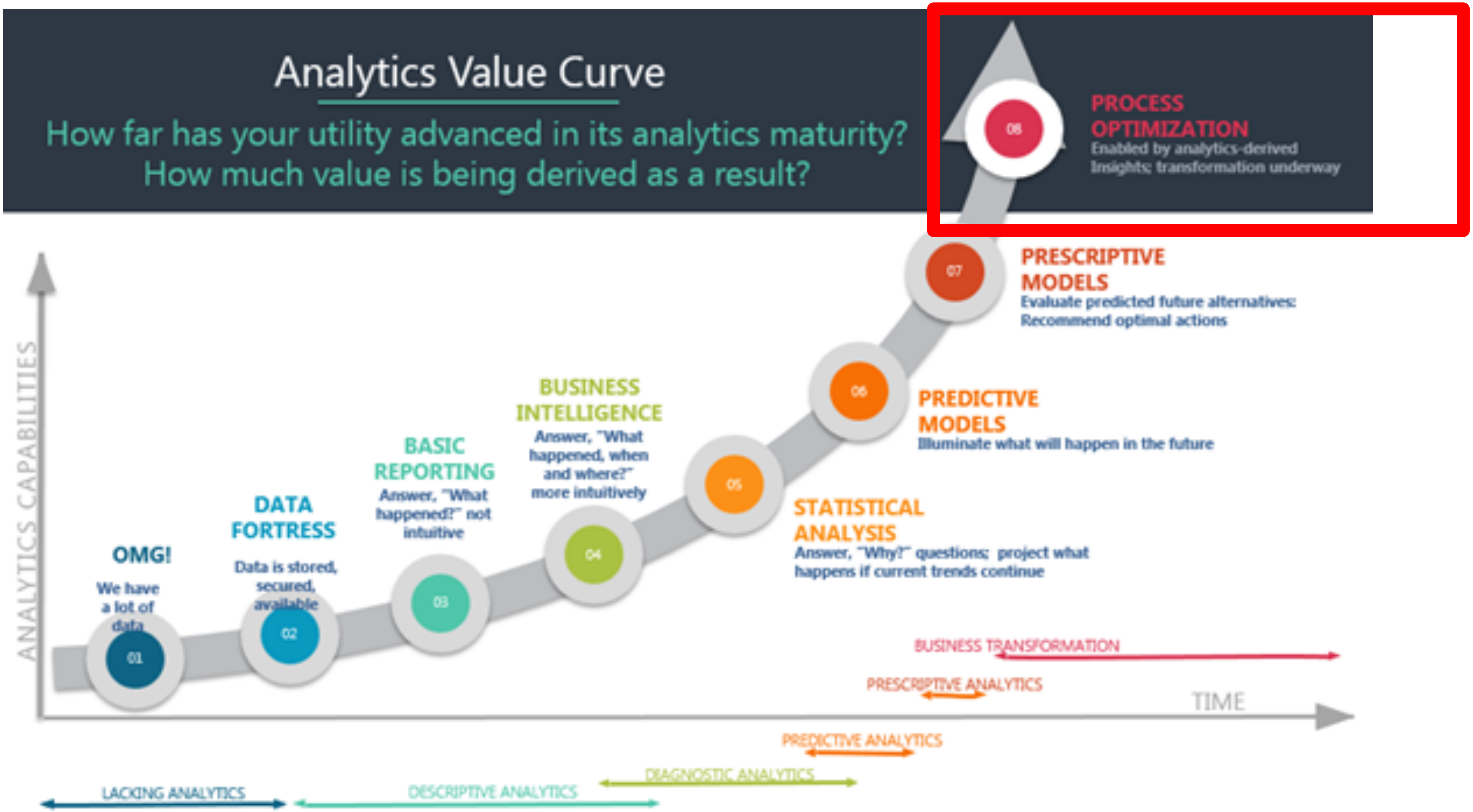
1. Motivation



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1. Motivation

- Relief and supplies response for earthquakes in Bogotá
- Phase 1: Location
- Phase 2: Distribution

19 locations

- Decision: location of warehouses of different size for storage of supply kits.
- Objective: Minimization c the total cost of distribution And location.

Souce: © Copyright 2016-2019 tierracolombiana.org, https://tierracolombiana.org/localidades-de-bogota/

2. Python packages

ANACONDA NAVIGATOR

GUROBIPY

GUROBI OPTIMIZATION

Pandas

NumPy

Spyder

2. Python packages

ANACONDA NAVIGATOR

GUROBIPY

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Spyder

2. Python packages

Model Creator (API)

- PuLP
- PyOMO
- **Gurobi API (Python, java, Matlab, c++, c#)**
- .
- .
- .

Solvers

- Open:
  - GLPK
  - CBC
  - Open Solver
  - SciPy
- Commercial:
  - **Gurobi**
  - CPLEX
  - Xpress

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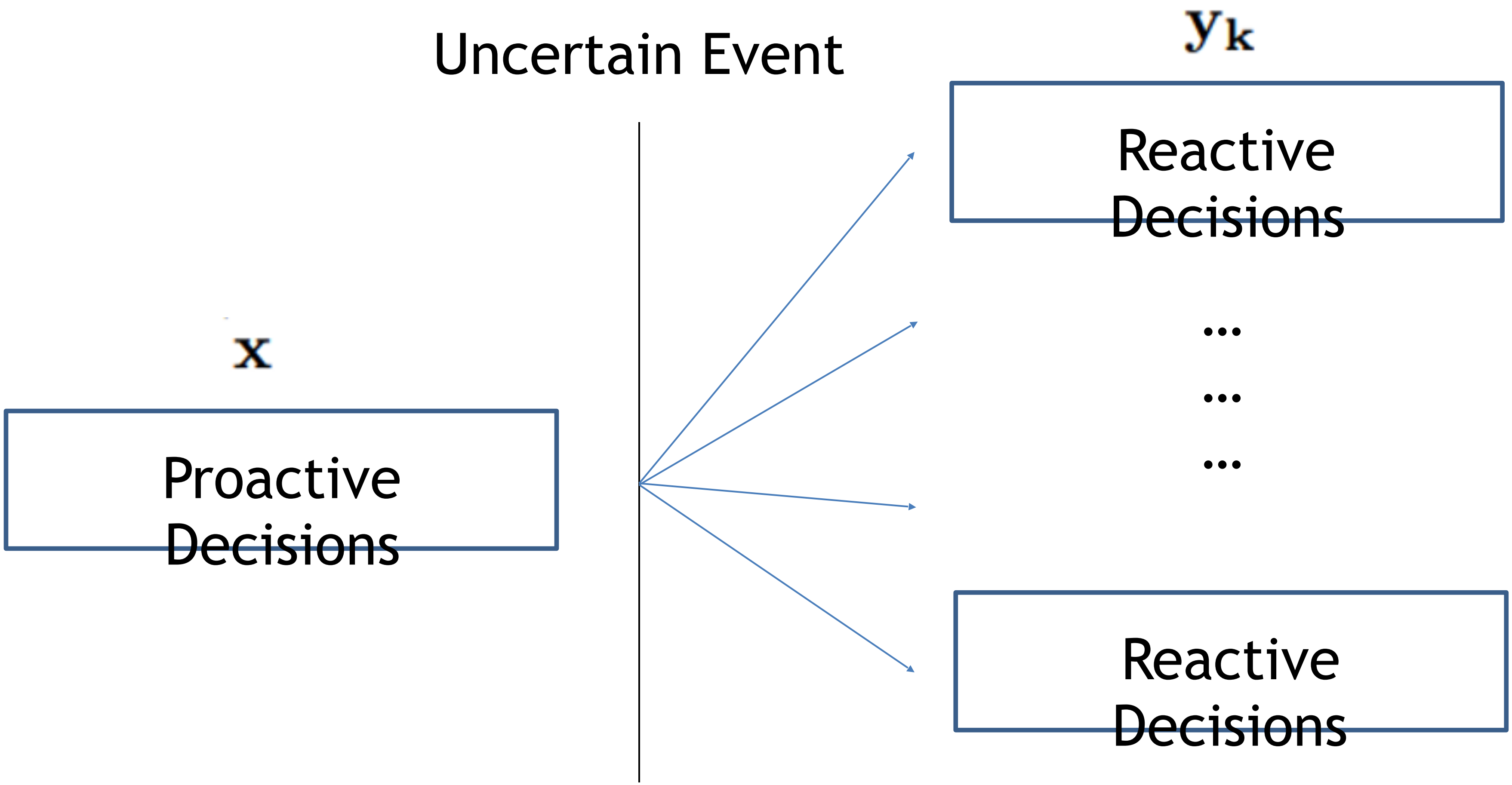
3. Methodology



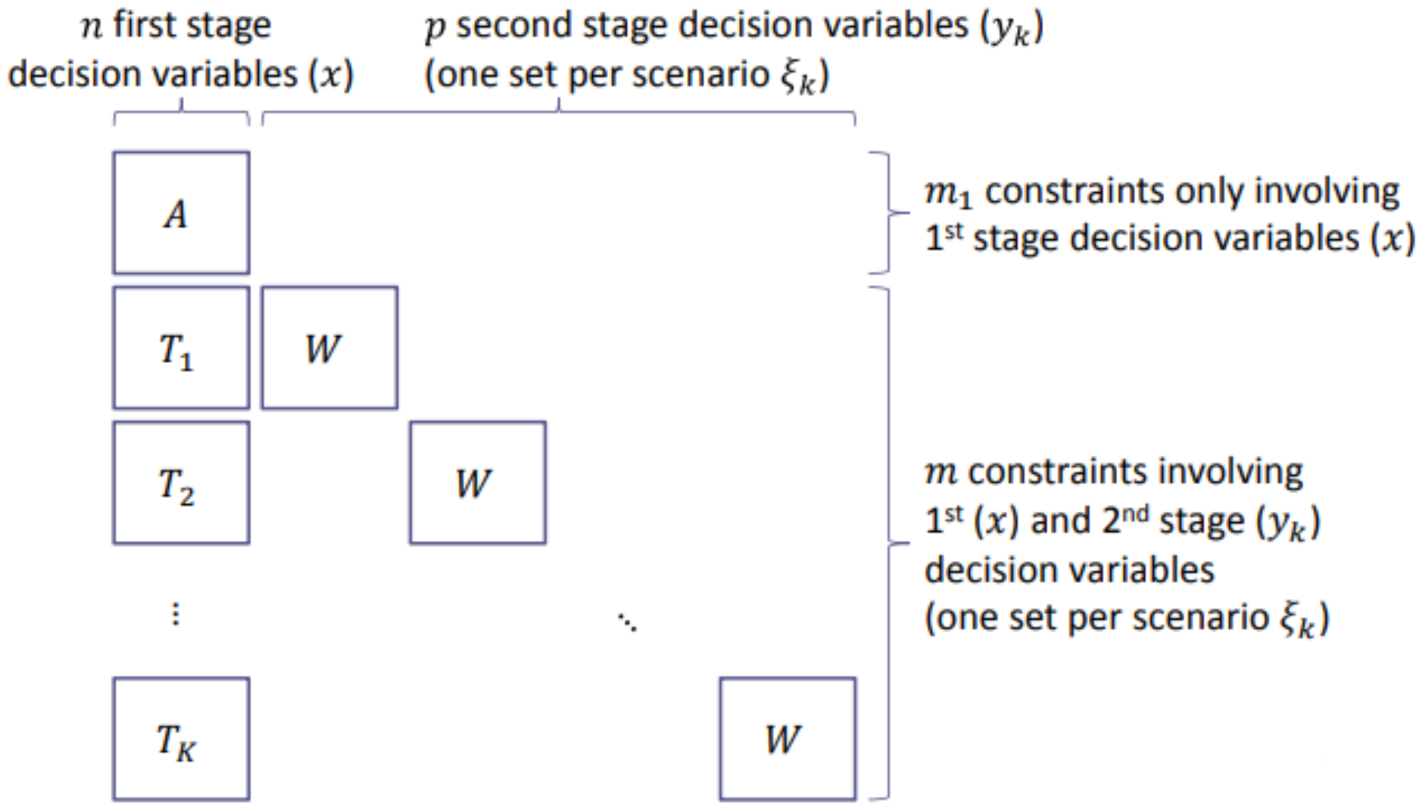
3. Methodology

- mathematical model

$$
\begin{aligned}
\min \quad & c^T \mathbf{x} + \sum_{k=1}^{K} p_k q_k^T \mathbf{y_k} & \\
& A\mathbf{x} = b & \\
& T_k \mathbf{x} + W \mathbf{y_k} = h_k & \forall k = 1, \dots, K \\
& \mathbf{x} \geq 0 & \\
& \mathbf{y_k} \geq 0 & \forall k = 1, \dots, K
\end{aligned}
$$

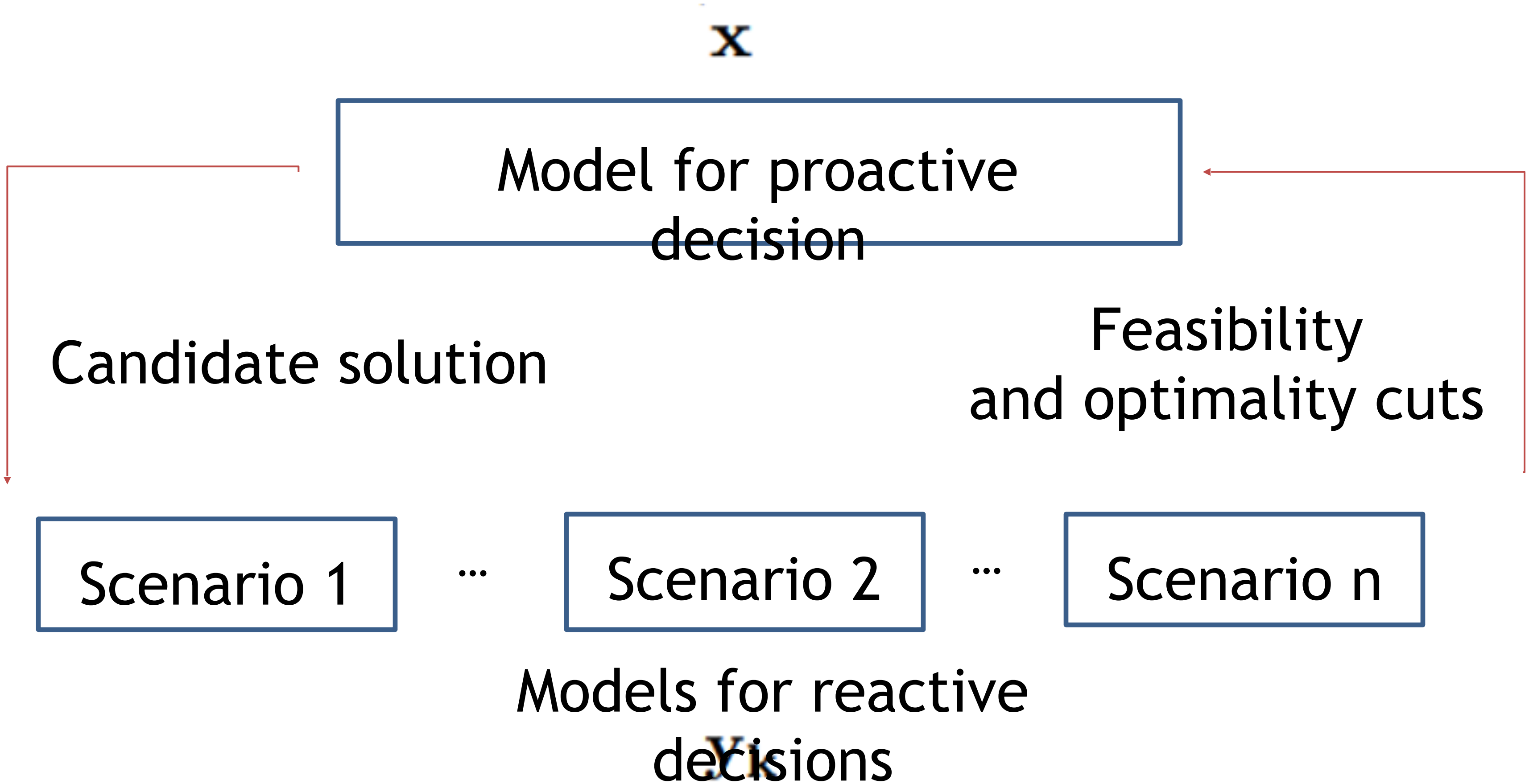
3. Methodology

- block structure of two-stage model (**primal**)



3. Methodology

Rahmaniani, R., Crainic, T. G., Gendreau, M., & Rei, W. (2017). The Benders decomposition algorithm: A literature review. *European Journal of Operational Research*, *259*(3), 801-817.



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3. Methodology

$$min\ L(\mu) = \sum_{i\in I}\sum_{l\in L} F_l y_{il} + \sum_{i\in I}\sum_{k\in K} q^k r_i^k + \theta + \sum_{i\in I} \mu_i \left(\sum_{k\in K} b^k r_i^k - \sum_{l\in L} M_l y_{il} \right)$$

$$SA:$$

$$\sum_{l\in L} y_{il} \le 1, \ \ \forall i \in I$$

$$\theta \ge E_t - \sum_{i\in I}\sum_{k\in K} e_{it}^k r_i^k, \ t = 1, 2, \ldots, T$$

$$y_{il} \in [0, 1], \ \ \forall i \in I, \ l \in L$$

$$r_i^k \ge 0, \ \ \forall i \in I, \ k \in K$$

3. Methodology

SubProblem a)

$$Min \sum_{i\in I}\sum_{k\in K}\left(q^k+\mu_i b^k\right) r_i^k+\theta$$

$$\theta \geq E_t-\sum_{i\in I}\sum_{k\in K} e_{it}^k r_i^k,\ t=1,2,\ldots,T$$

$$r_i^k \geq 0,\ \ \forall i \in I,\ k \in K$$

SubProblem b)

$$Min \sum_{i\in I}\sum_{k\in K}\left(q^k+\mu_i b^k\right) r_i^k+\theta$$

$$\theta \geq E_t-\sum_{i\in I}\sum_{k\in K} e_{it}^k r_i^k,\ t=1,2,\ldots,T$$

$$r_i^k \geq 0,\ \ \forall i \in I,\ k \in K$$

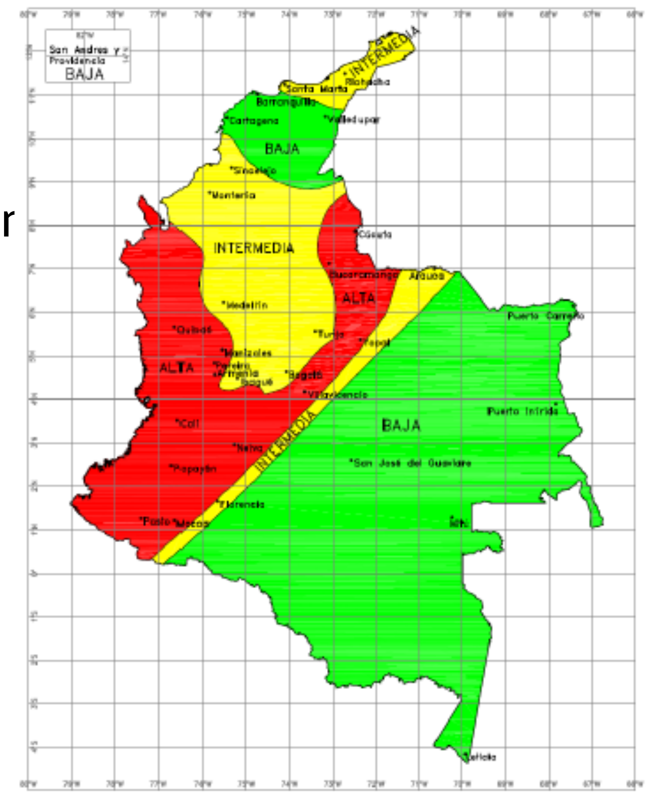
4. Case study

IDIGER (FOPAE)
Damage scenario in Bogotá due to the occurrence of an earthquake

Demand: Number of families affected

The estimated number of people affected by location. According to the 2018 census a Bogotan family is made up of approximately 3 members

$$\frac{Affected\ population}{3}$$



4. Case study

IDIGER (FOPAE)
Damage scenario in Bogotá due to the occurrence of an earthquake

$$scenarios:\ Zone^{Leves} = 256$$

Zones: Bogotá is divided into 4 zones by the quartiles of the vulnerability index.

Levels:

- Low <30% expected
- Normal
- High> 30% expected
- Extreme> 100% expected

4. Case study

National Unit for Disaster Risk Management

Help Kits:

Dimensions: 34.2 cm x 28.4 cm x 24 cm Volume = $0.0233\ m^3$
Cost: $ 93,180 COP
Leftover cost: 25% of the unit cost = $ 23,295 COP
Missing cost: 10 times surplus cost = $ 232,950 COP

Loss of disaster kits

- 30% below the damage rate.
- Expected value of the damage index.
- 30% above the damage rate.

4. Case study

Supplementary data

Warehouse:

- Prices purchase lot: Average values of m^2 by location

Trucks (2 axles):

- Freight cost:$532 COP/Km*package
- Capacity: 45 m^3

Distances and times:

Full trip cycle: Load (60 min) + one way (t_{ij}) + unload (60 min) + retunr (t_{ji})

- Daily operation time: 12 hours
- Distance between locations

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4. Results and analysis

Node	Type
Engativá	Small
Barrios Unidos	Small
Los Mártires	Small
Puente Aranda	Small

4. Results and analysis

Model	Objective Function
Expected Value (EV)	27.157.061
Expected Expected Value (EEV)	172.728.567
Deterministic Equivalent (DV)	106.322.502
Wait and See (WS)	41.051.593

Performance M

Expected Value of Perfect Information – (EVPI)

Value of Stochastic Solution – (VSS)

4. Results and analysis

Model	Objective Function
Expected Value (EV)	27.157.061
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Performance M

EVPI = DE – WS = 106.322.502–41.051.593 = **65.270.908**

VSS = EEV – DE = 172.728.567–106.322.502 = **66.406.064**

5. Conclusions

- The development of the project allows to see the flexibility that Python offers to quickly replicate complex models of the literature to evaluate and compare their performance.
- The optimization models under uncertainty applied to the location of distribution centers to respond to disasters allows facilitating decision-making (Location of distribution centers), mitigating operating costs and impact against the variability of the future.
- The different Python packages used in the project allowed the correct implementation of the model under uncertainty and an easy analysis of results, given its syntax and coding.

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Questions

Thanks!

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