Opportunities for Optimization in the Telecomms industry

Network Planning and Data Monetization

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Who we are

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Operations Research specialist

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Project Manager &
Operations Research specialist

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Business Director - Telecomms

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Founded July 2011 – based in Madrid

Spin-off from Universidad Politécnica de Madrid (UPM)

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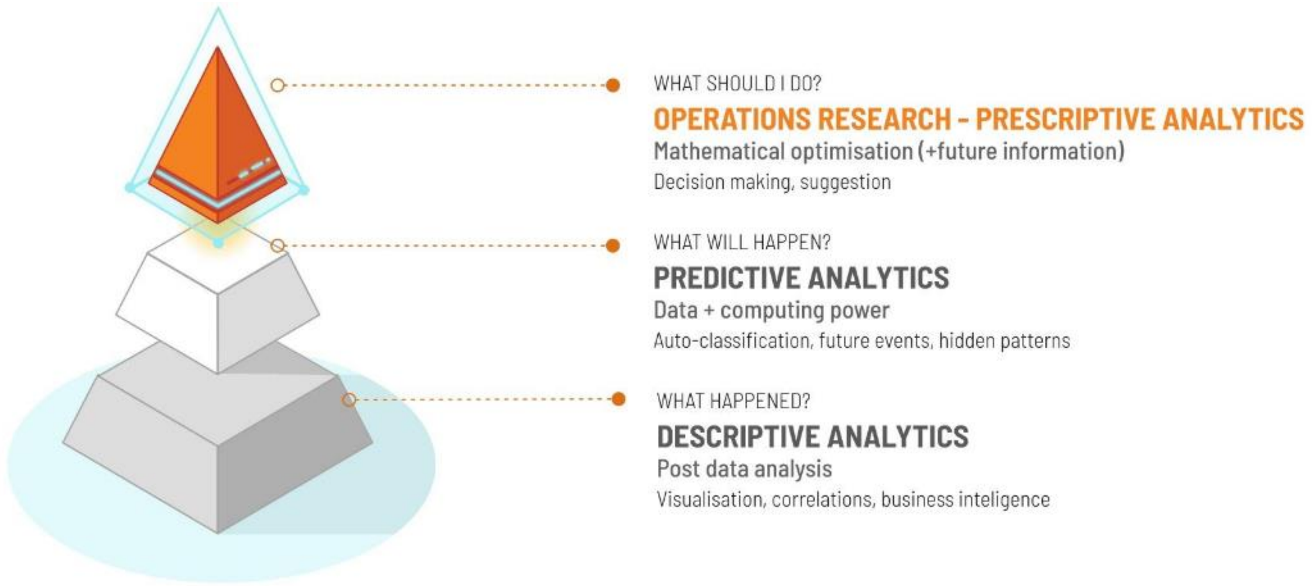

Efficient network planning using linear programming

June 2021

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Context

- Business case
- Inputs and outputs
- Optimal planning with minimum cost

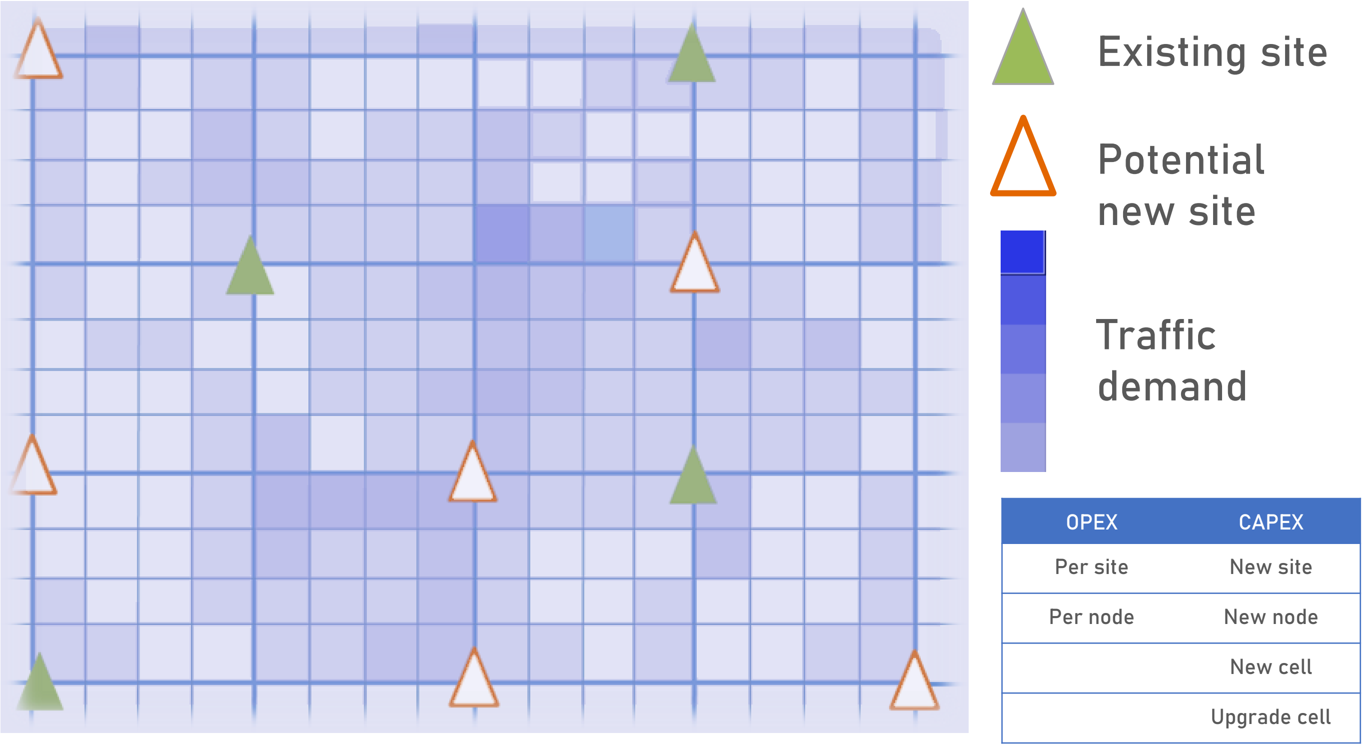
Business case

High expenditure in site leases

→ Minimize overall cost
→ Use fewer, cheaper locations
→ Reuse existing locations

Humans can find optimal solutions at small scale and good solutions at large scale.

Algorithms are necessary to find optimal solutions at large scale.



OPEX	CAPEX
Per site	New site
Per node	New node
	New cell
	Upgrade cell

Given a set of existing and candidate sites and coverage and capacity goals, we propose a mathematical model that finds the minimum cost network plan for a given area while meeting all objectives.

Inputs and outputs

Network plan

Link budget output

Coverage footprint

Traffic demand target

Node capacity

CAPEX
OPEX

Coverage goal

Capacity goal

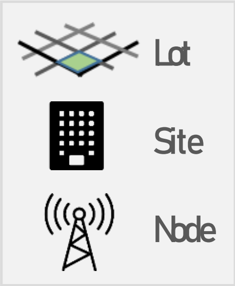
Minimum cost

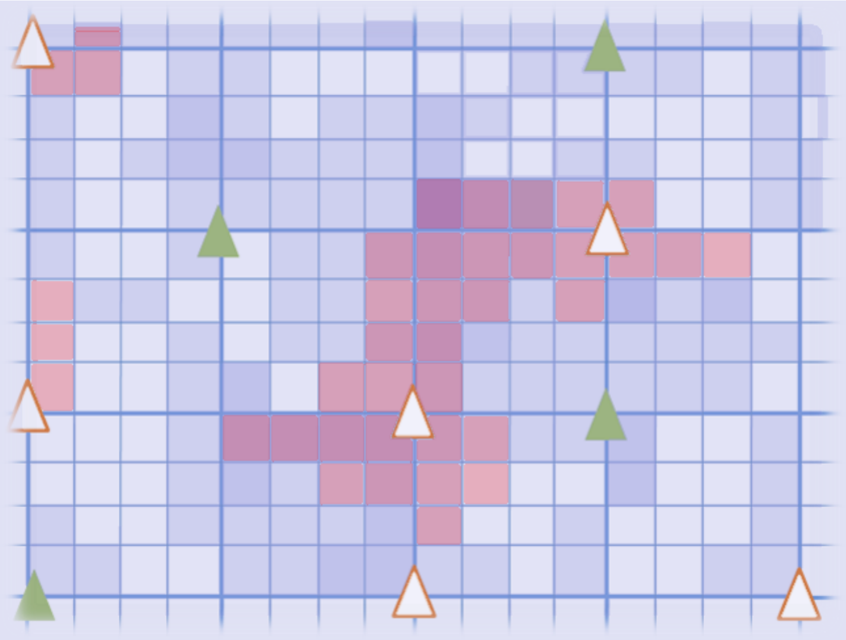
New site (with new node)

New node on existing site

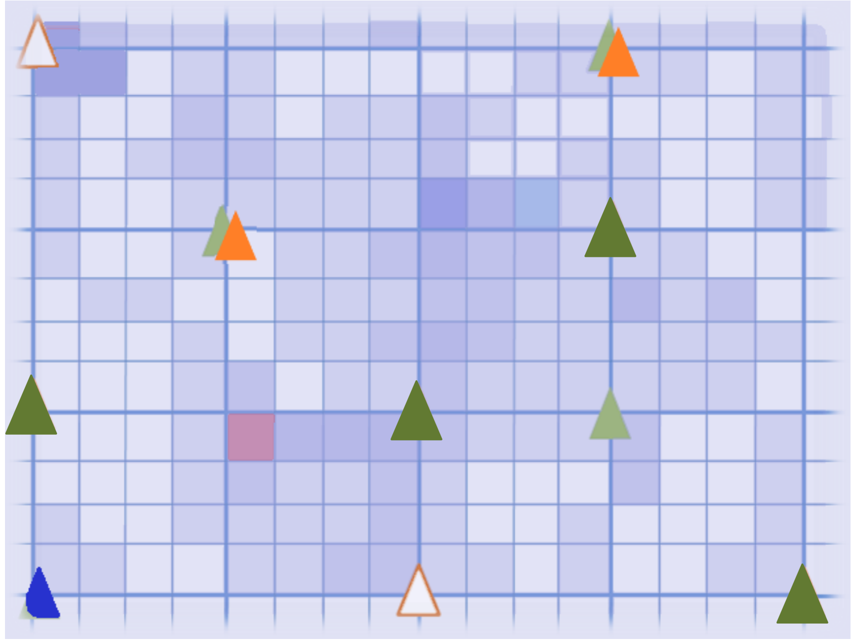
Upgrade cell capacity

Optimal planning with minimum cost





Congested state



Optimal state

Existing site

Potential new site

New node on new site

New site on existing site

Upgraded node

Contents

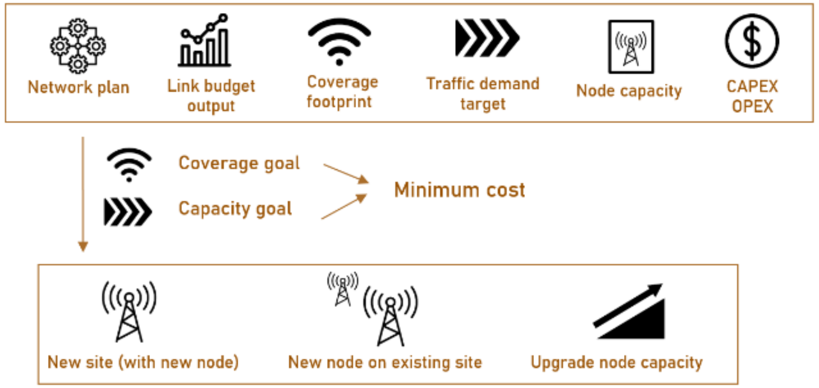
Where's the magic

- We will create the solution space that contains all the possible network plans that meet the conditions
- We will explore it and pick the plan with the lowest cost.

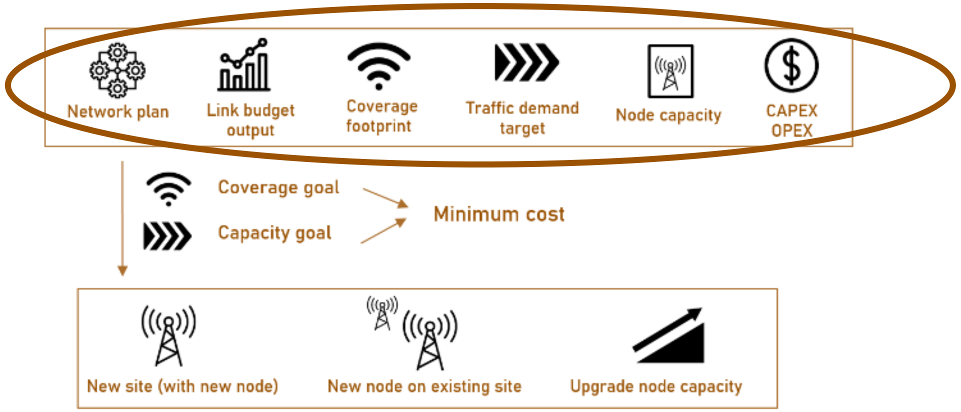
Model assumptions

- An aggregated capacity of overlapping cells is considered.
- Signal level is not considered, instead Boolean “covered/not covered” for each pair lot-cell.
- Every lot requires the same minimum signal level.
- The model does not consider interference or channel allocation.
- Site and node decommissioning is not considered for simplicity, but is obviously possible.

Mathematical formulation: a MILP model



Mathematical formulation: a MILP model



Parameters

$\boldsymbol{A_s} \in \{0,1\} \quad \forall\, s$

$\boldsymbol{B_{sn}} \in \{0,1\} \quad \forall\, s, n$

$\boldsymbol{G_{snc}} \in \{0,1\} \quad \forall\, s, n, c$

$\boldsymbol{CAP^0_{snc}} \quad \forall\, s, n, c$

$\boldsymbol{CAP^{MAX}_{sn}} \quad \forall\, s, n, c$

$\boldsymbol{\Omega_{scl}} \in \{0,1\} \quad \forall\, s, n$

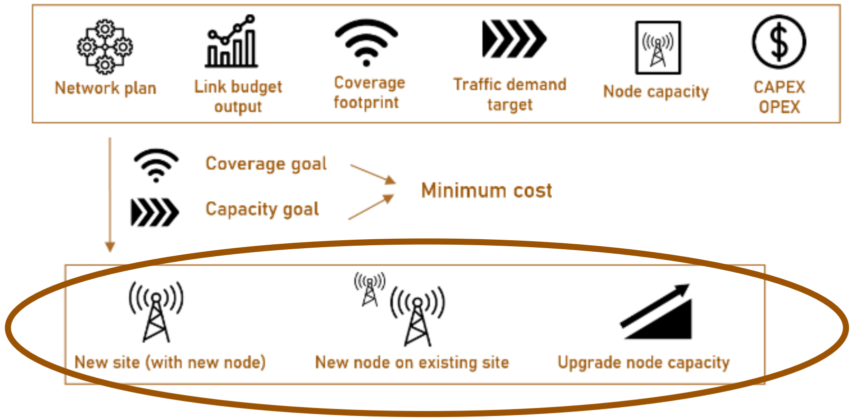
$\boldsymbol{D_{nl}} \quad \forall\, n, l$

$\boldsymbol{N_{sn}} \quad \forall\, s, n$

$\boldsymbol{C^S, C^N, C^U, C^C}$

$\boldsymbol{X_s} \quad \forall\, s$

Mathematical formulation: a MILP model



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$\beta_{sn} \in \{0,1\} \quad \forall\, s, n$

$\gamma_{snc} \in \{0,1\} \quad \forall\, s, n, c$

$\delta_{snc} \in \{0,1\} \quad \forall\, s, n, c$

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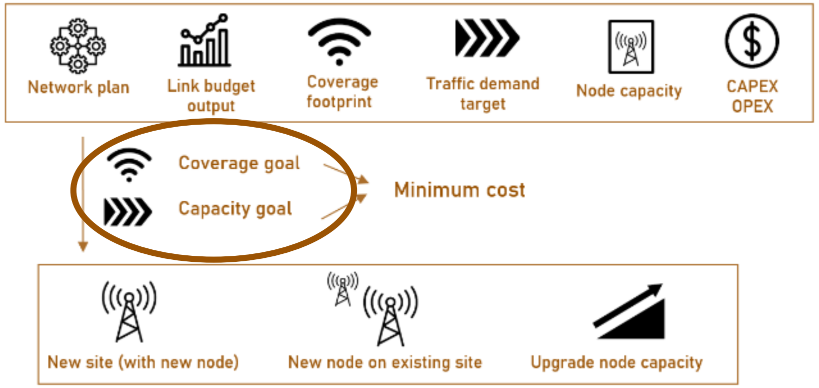
$u_{sncl} \quad \forall\, s, n, c, l$

Mathematical formulation: a MILP model



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Constraints

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$\beta_{sn} \le 1 - B_{sn}, \quad \forall s,n$

$\gamma_{snc} \le 1 - G_{snc}, \quad \forall s,n,c$

$\delta_{snc} \le G_{snc}, \quad \forall s,n,c$

$\beta_{sn} \le A_s + \alpha_s, \quad \forall s,n$

$\gamma_{snc} \le B_{sn} + \beta_{sn}, \quad \forall s,n,c$

$\sum_c \gamma_{snc} \le N_{sn} - \sum_c G_{snc}, \quad \forall s,n,c$

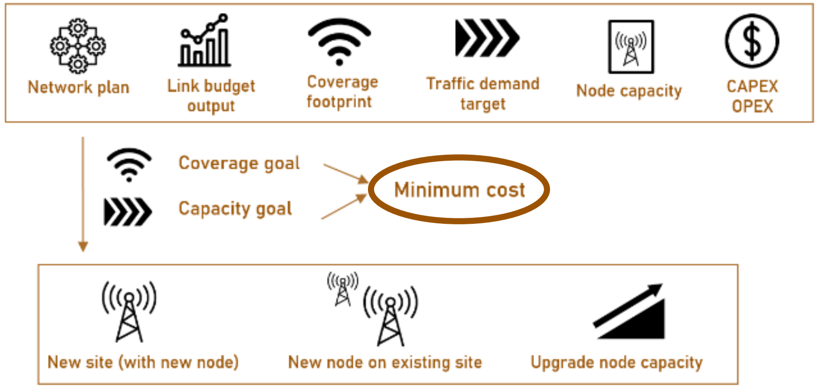
$c_{snc} \ge CAP^{0}_{snc} \quad \forall\, s,n,c$

$c_{snc} \le CAP^{0}_{snc} + (CAP^{MAX}_{snc} - CAP^{0}_{snc}) G_{snc}\, \delta_{snc} + (CAP^{MAX}_{snc} - CAP^{0}_{snc})(1 - G_{snc})\, \gamma_{snc} \quad \forall\, s,n,c$

$\sum_l \Omega_{scl}\, u_{sncl} \le c_{snc}, \quad \forall s,n,c$

$\sum_s \sum_c \Omega_{scl}\, u_{sncl} \ge D_{nl}, \quad \forall n,l$

Mathematical formulation: a MILP model



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$\sum_l \Omega_{scl}\, u_{sncl} \leq c_{snc}, \quad \forall s,n,c$

$\sum_s \sum_c \Omega_{scl}\, u_{sncl} \geq D_{nl}, \quad \forall n,l$

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C^S, C^N, C^U, C^C

$X_s \quad \forall\, s$

Variables

$\alpha_s \in \{0,1\} \quad \forall\, s$

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$c_{snc} \quad \forall\, s,n,c$

$u_{sncl} \quad \forall\, s,n,c,l$

Objective function

$$C^S \sum_s \alpha_s + C^N \sum_s \sum_n \beta_{sn} + C^U \sum_s \sum_n \sum_c \delta_{snc} + C^C \sum_s \sum_n \sum_c \gamma_{sn} \sum_s + X_s \sum_s \alpha_s$$

Contents

Presentation – what it would look like

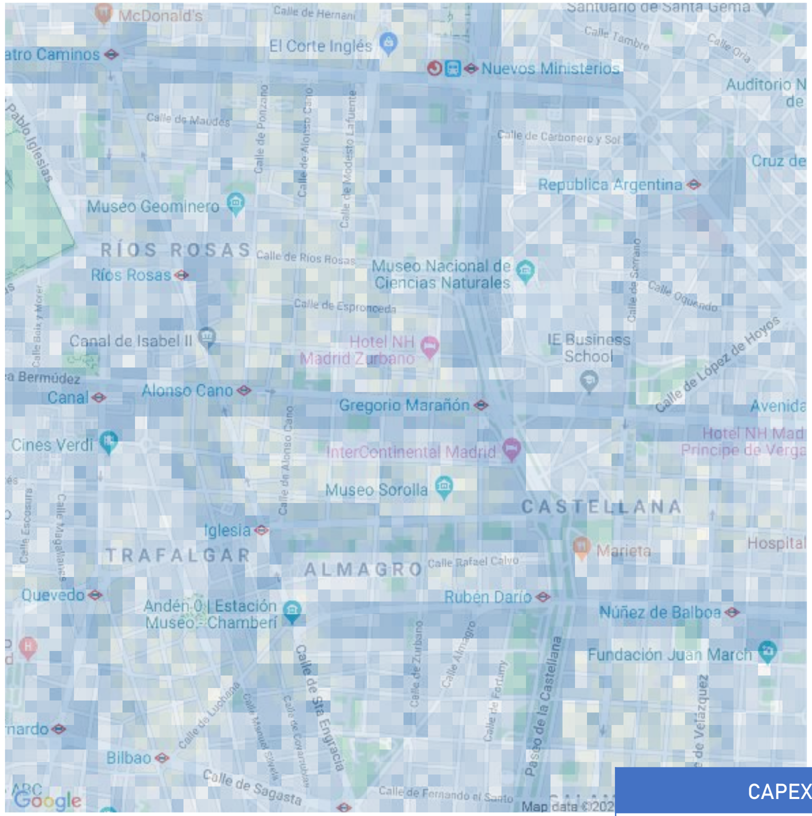
Example parameters

→ 4 square km area
→ 16 4G existing sites
→ 3 cells per site
→ 8 candidate sites

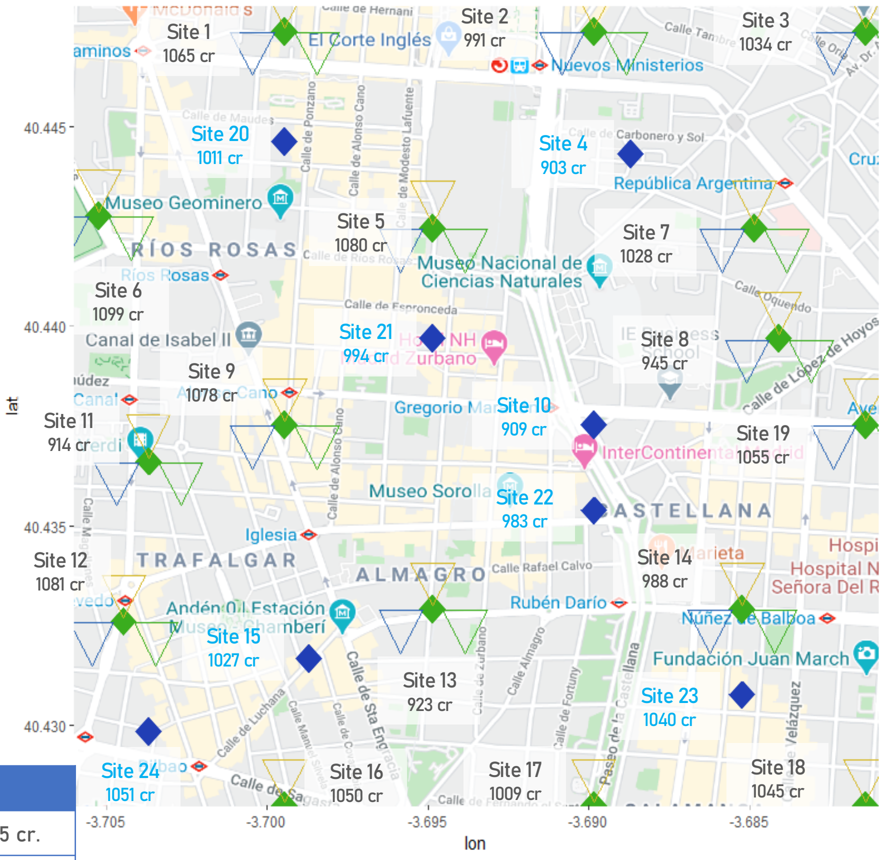
Separate OPEX and CAPEX values per site.

The algorithm provides an optimized **4G network** plan.

4G Traffic demand



Initial network plan & OPEX



Candidate sites   Active 4G nodes

CAPEX	
New site	28,855 cr.
New node	36,770 cr.
New cell	11,737 cr.
Upgrade cell	5,868 cr.

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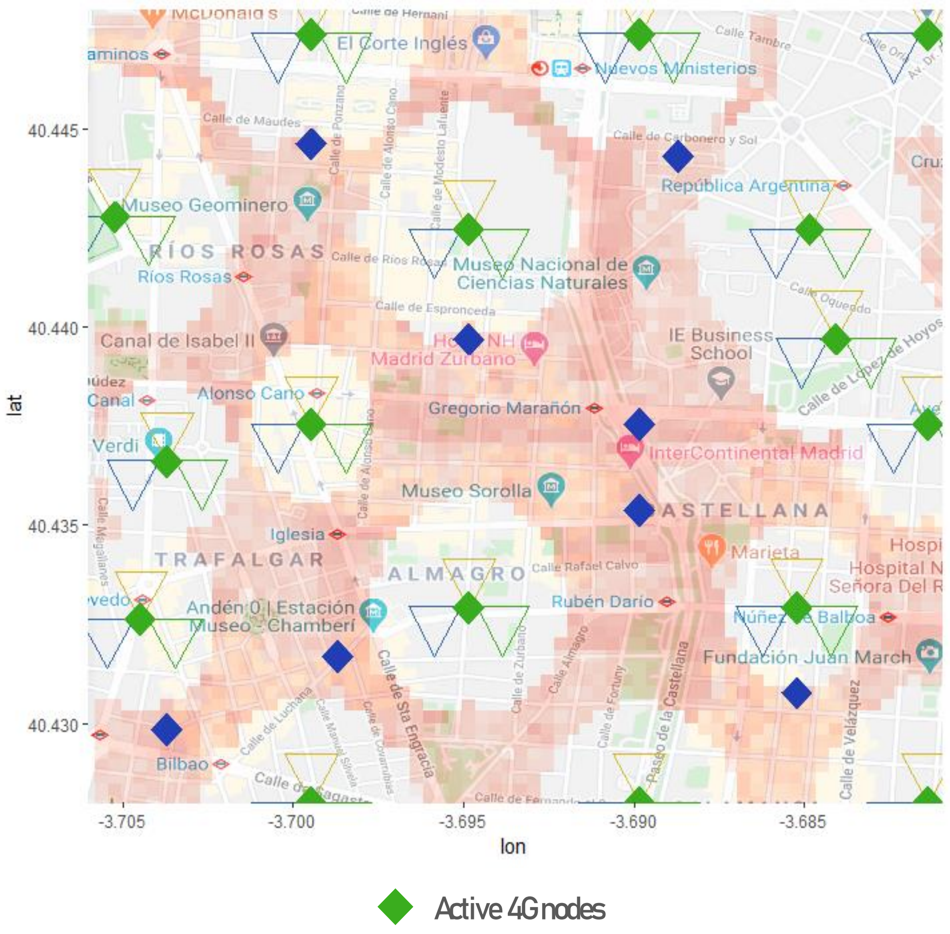
Initial state

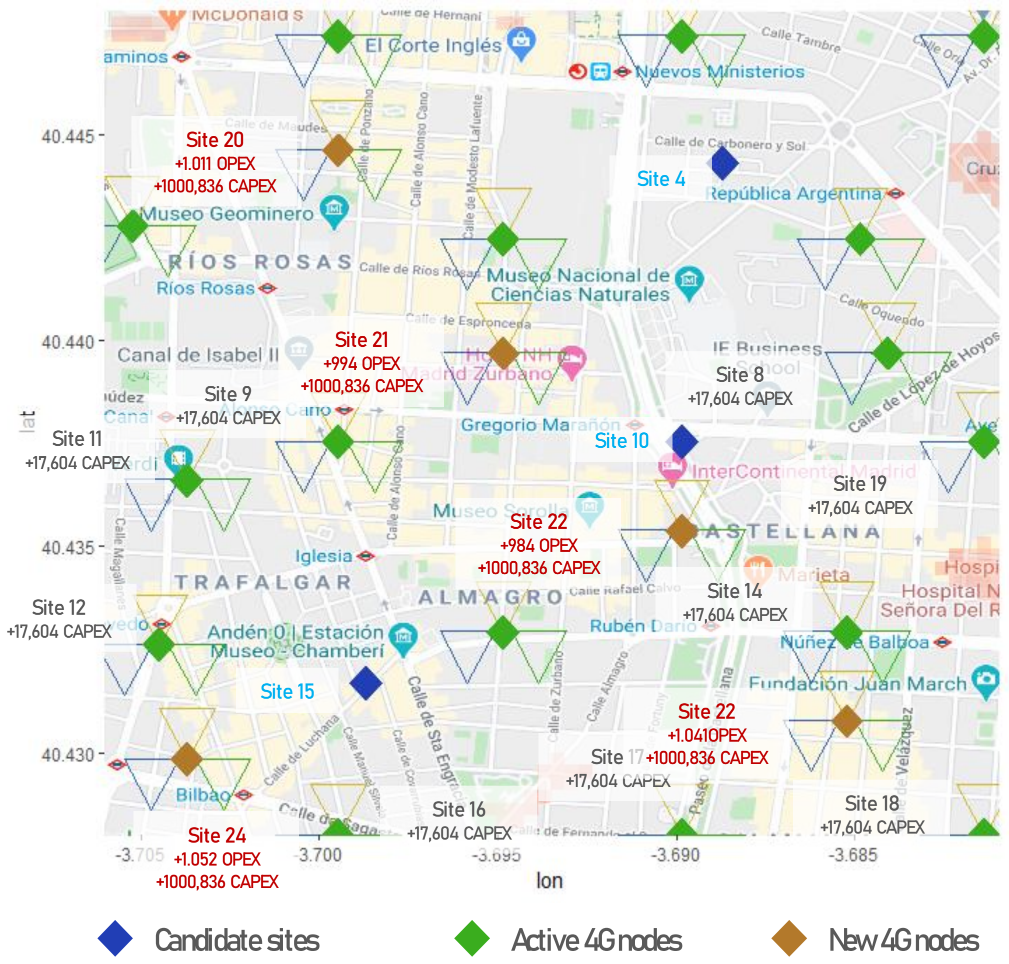
Initial 4G congestion



- This example is not using any output from a network planning tool, therefore it is simplified to highlight the mathematics.
- The example is very under dimensioned
  - For simplicity, we assumed cells could have half or full capacity.
  - Initially, all cells were at half capacity.
- In order to plot congestion, the algorithm allocates cell capacity to the nearest lots.
  - This can be refined with signal strength forecasts and by simulating power allocation algorithms.

Optimal state

Optimal 4G network plan



The algorithm proposed to:

- increase capacity in all cells (as expected)
- build 5 new nodes
- ignore 3 nodes.

With minimal increment of OPEX + CAPEX

Δ OPEX=5,082 cr.

Δ CAPEX= 662,626 cr.

Escalation techniques

Exact approaches

Problem partitioning into multiple smaller problems

Benders decomposition

Approximate approaches

Speeds the process of finding satisfactory, but non-optimal solutions

Heuristics
Metaheuristics

Contents

Conclusions and highlights

Real life network dimensioning and planning problems can be very hard to solve.
Optimal solutions require using mathematical algorithms.

The use of Gurobi MILP models in network optimization:

- Allows inspecting the whole solution space...
- ... and choosing the lowest cost plan that meets all requirements.
- Gurobi enables fast problem solving saving time and money.

Mobility data monetization

June 2021

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Context

- Business case
- Inputs and outputs
- Prospection process

Business case

Online EV charging stations maps are a good tool for EV drivers but not precise enough for EV charging network planning

The goal is to optimize the charging stations deployment using new sources of useful information and analytical methods.

- Finding the most efficient way to find and retrieve charging stations-optimized locations in an extrapolated way.
- The charging stations must be oriented to maximize the amount of served kWh either by a greater amount of chargers or faster chargers.

Inputs and outputs

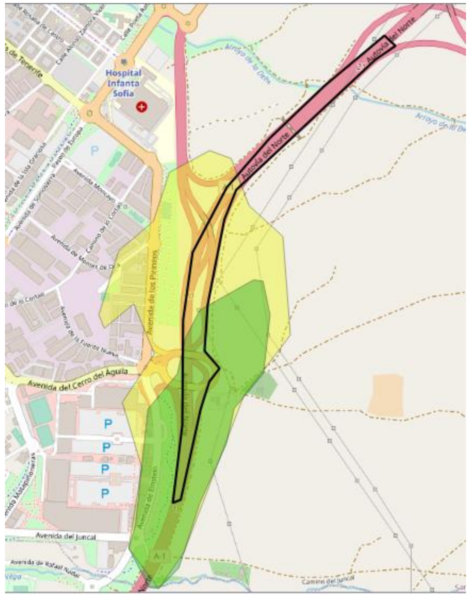
Input

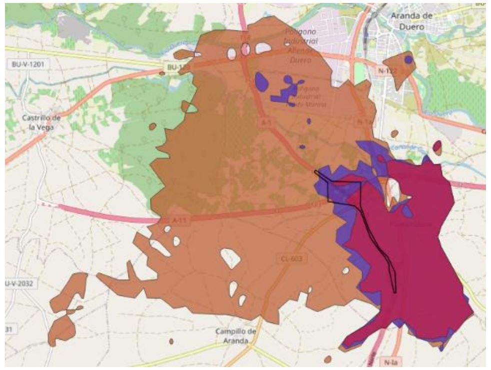
- Mobility data from Orange (Flux Vision):
  - Flow of people crossing an area of interest, by origin and destination. Hourly data.
- History of charging data from the customer:
  - Past charges.
  - kWh per charge.
- Public data from different sources:
  - Number of electric vehicles in use.
  - Number of passengers per vehicle.
- CAPEX and OPEX by type of charging station.

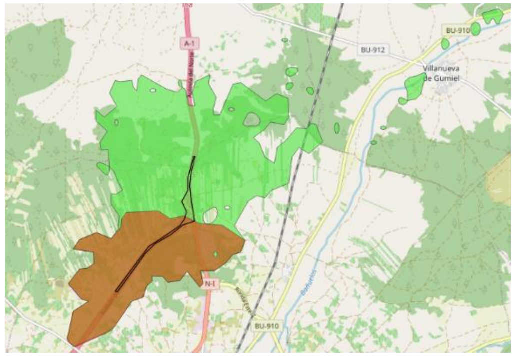
Output

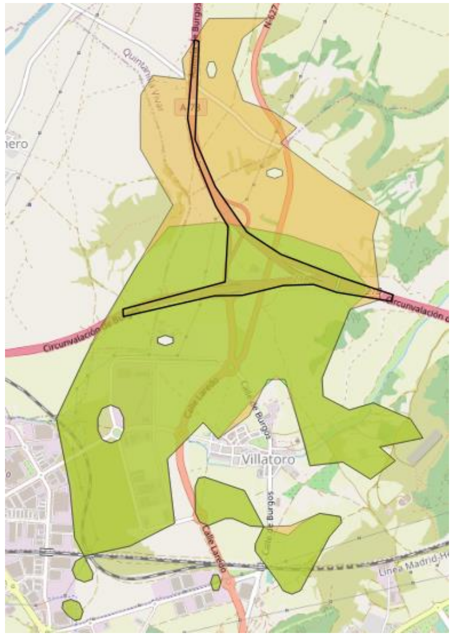
- Location of new charging stations.
- Types of chargers in new charging stations.
- Demand forecast.

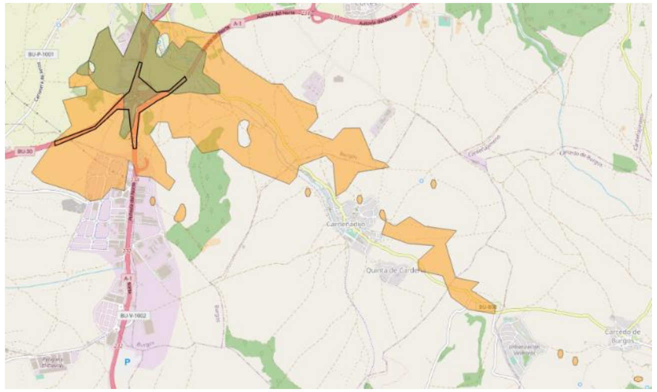
Inputs and outputs – Flux Vision

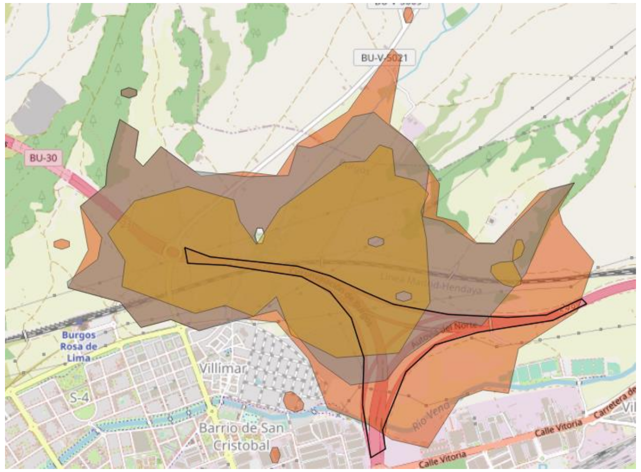


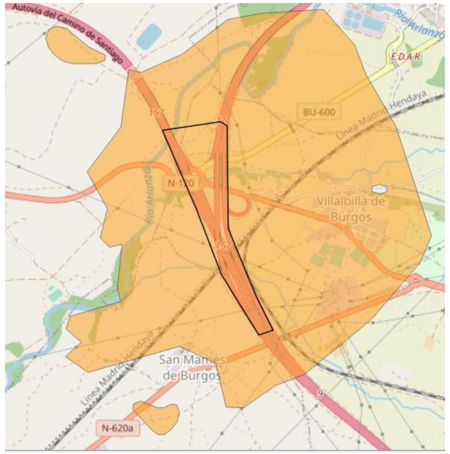












Prospection process

Target setting

Define target areas (highways, roads, cities)

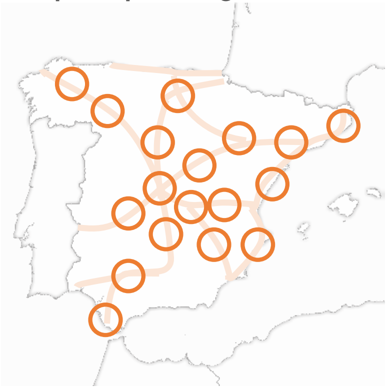
Define maximum blocking/queue time

Available budget

Nominal Plan

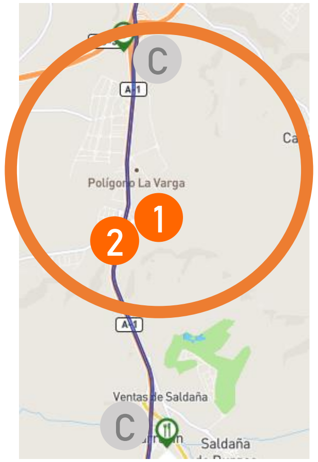
Identify and quantify traffic flows in each target area (FV)

Find areas of higher concentration of flows for prospecting



Detailed Plan

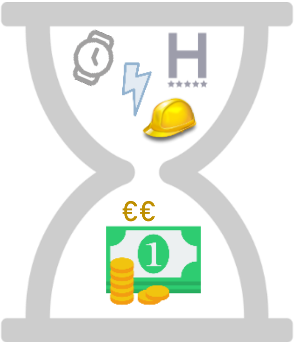
Find candidate sites in prospection areas, based on Flux Vision



ROI modelling and dimensioning

Each prospection area and candidate location will receive an ROI model

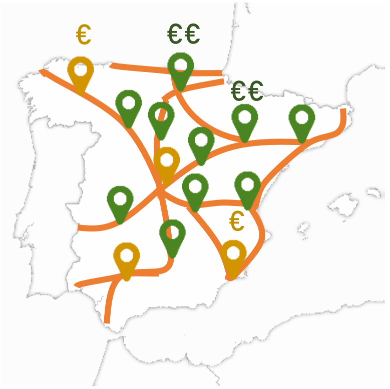
Dimensioning according to maximum blocking rate and expected traffic



Area prioritization

Allocate budget as per costs and ROI

Return detailed plan with maximum ROI within budget



ROI modelling per prospect area

Calculate vehicle flow

- Consider all flows relevant to the nominal site
- Data:
  - Flux Vision data (persons)
  - Average vehicle occupancy: 1,7 (OECD).
  - Customer data from existing charging stations

EV and PHEV consumption estimates

- Consumption estimates for each nominal point (EV and PHEV)
- Data:
  - EV penetration per province (DGT).
  - Trips, distance to previous and following stops (Flux Vision).

Market share

- Estimate customer's market share in each nominal point
- Match models to available data in each location
- Data:
  - Competition.
  - Prices.
  - Location type
  - Distance to route
  - Charging speed.
  - Customer's charging data.

ROI

- Price
- CAPEX/OPEX
  - Per charger type.
  - Per location.
    - Lease
  - Per typology
  - Power supply
- Average setup time

Contents

Model assumptions

- Investment cannot exceed the maximum budget.
- The dimensioning of the charging stations must consider peak occupancy - between 10:30 and 12:00, and 17:30 and 18:30, as seen in the Flux Vision data.
- The demand for a given study zone depends on nearby zones and the decision made for those.
- A minimum demand has to be covered.

Model assumptions

- The charging stations have to be one of the following configurations:

Installed power	Investment cost	Annual operating cost	Needs access to medium voltage	Cost of access to medium voltage	Number of charging spaces
50 kW	40,000 €	5,000 €	No	-	3
100 kW	70,000 €	10,000 €	No	-	4
500 kW	350,000 €	50,000 €	Yes	5000 €	8
750 kW	816,000 €	75,000 €	Yes	5000 €	8
1150 kW	926,000 €	115,000 €	Yes	5000 €	8

Mathematical formulation: a MILP model

Variables

$$v01AssignedStation(s) \in \{0,1\} \ \forall s \in S$$
binary variable that indicates whether a recharge station is deployed in a study zone

$$v01AssignedStationType(s,t) \in \{0,1\} \forall s \in S, \forall t \in T$$
binary variable that indicates which recharge station type is deployed in a study zone

...

$$vStudyZoneInvestment(s) \in \mathbb{R}^{+} \forall s \in S$$
non negative real variable that indicates the investment in each study zone

...

Objective function

$$\max(vTotalIncome - vTotalInvestment)$$

Mathematical formulation: a MILP model

Constraints

- One type of recharge station per study zone:

$$\sum_{t \in T} v01AssignedStationType(s,t) \leq 1 \ \forall s \in S$$

- The study area is assigned if a station type is assigned:

$$v01AssignedStation(s) = \sum_{t \in T} v01AssignedStationType(s,t) \ \forall s \in S$$

…

- Investment calculation:

$$vStudyZoneInvestment(s) = \sum_{t \in T} (v01AssignedStationType(s,t) * (pTypeInvestment(t) + pAccesNetworkCost(t)))$$

…

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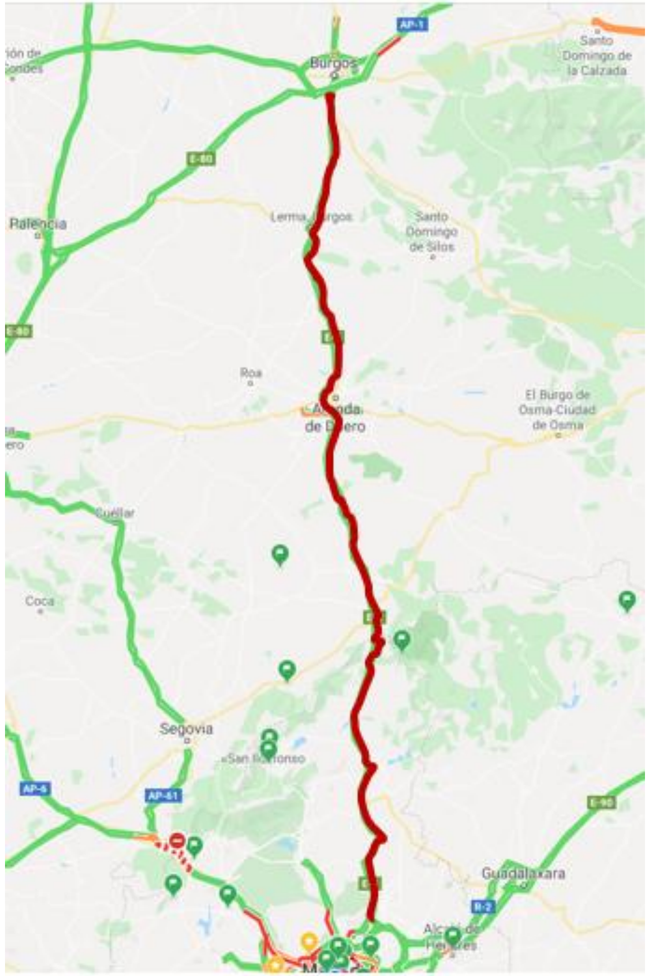
Experiments



- Study over 200km segment of a main Spanish highway.
- Four main locations with more than one study zone per location.
- Investment horizon: 10 years.
- 80% minimal demand coverage.
- 3 scenarios:
  - 3.5%, 5% and 6.5% EV penetration.

Results – 3.5 %

- Installed power: 400 kW.
- 10-yr peak hour energy supply: 3.65 GWh
- 10-yr peak hour demand: 4.176 GWh.
- Covered demand: 3.429 GWh. (82.1%)
- Total revenue: 1.028 M€.
- Total investment: 300 k€.
- Operating cost: 708 k€
  - 10-year Power OPEX: 400 k€
- Profit: 20 k€

Results – 5%

- Installed power: 550kW.
- 10-yr peak hour energy supply: 5.018 GWh
- 10-yr peak hour demand: 5.306 GWh.
- Covered demand: 4.259 GWh. (80.26%)
- Total revenue: 1.277 M€.
- Total investment: 400 k€.
- Operating cost: 933 k€
  - 10-year Power OPEX: 550 k€
- Profit: -66 k€

Results – 6.5%

- Installed power: 900kW.
- 10-yr peak hour energy supply : 8.212 GWh
- 10-yr peak hour demand : 6.786 GWh.
- Covered demand: 5.437 GWh. (80.13%)
- Total revenue: 1.631 M€.
- Total investment: 655 k€.
- Operating cost: 1.389 k€.
  - 10-year Power OPEX: 900 k€
- Profit: -413 k€

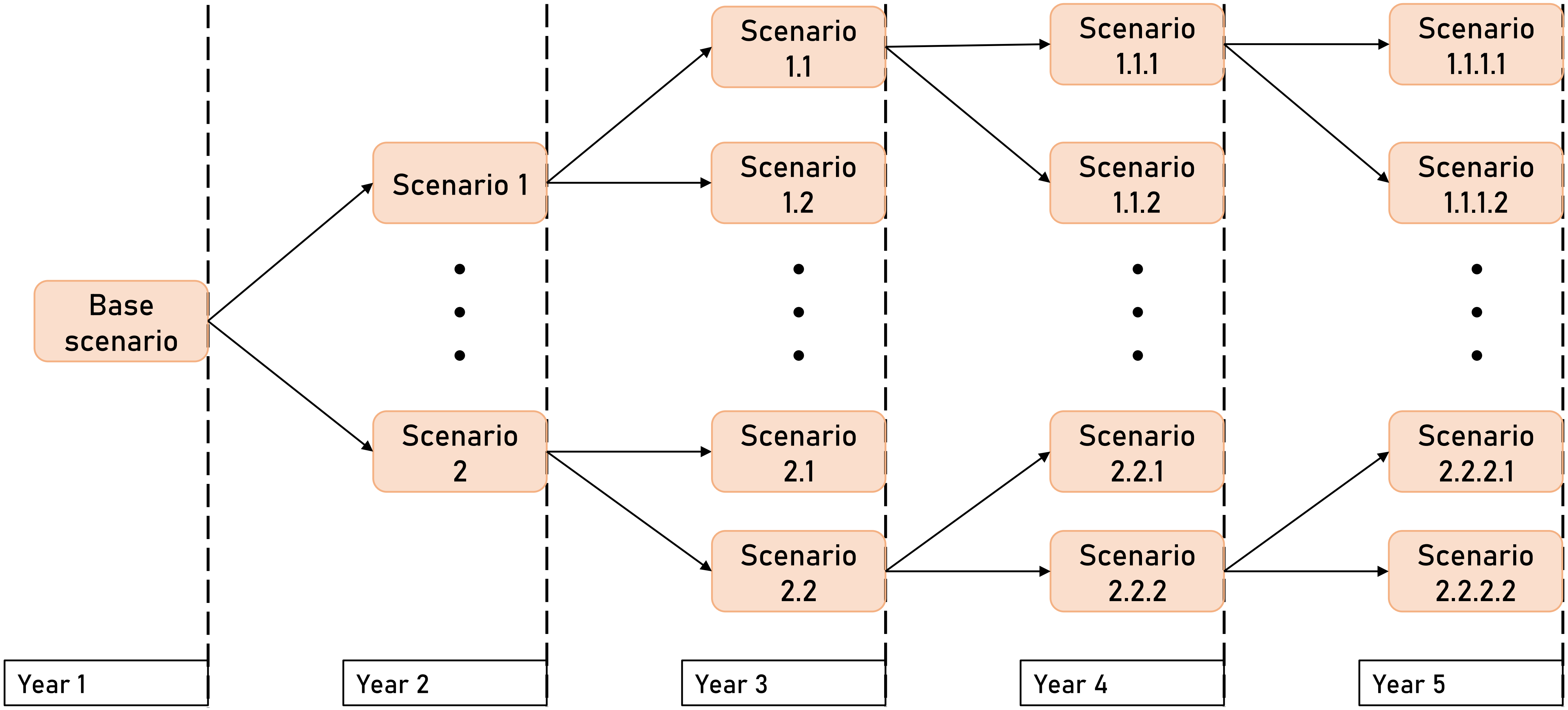
Results

	3.5% penetration	5 % penetration	6.5% penetration
Installed power	400 kW	550 kW	900 kW
10-yr supply	3.65 GWh	5.018 GWh	8.212 GWh
10-yr demand	4.176 GWh	5.306 GWh	6.786 GWh
10-yr demand covered	3.429 GWh (82.1%)	4.259 GWh (80.26%)	5.437 GWh (80.13%)
Total revenue	1.028 M€	1.277 M€	1.613 M€
Total investment	300 k€	400 k€	655 k€
Operating cost	708 k€	933 k€	1.389 M€
Installed power OPEX	400 k€	550 k€	900 k€
Supply OPEX	308 k€	383 k€	489 k€
Profit	20 k€	-66 k€	-413 k€

Remarks

- Higher EV penetration does not mean higher profits.
- Needs and costs of charging stations with more than 100kW make the investment plans difficult (example 6.5%).
- High dependency on forecast model.

Future improvements – multiyear model



Contents

Conclusions and highlights

Real life location problems can be enhanced with the use of data provided by telecom companies, this way, telecom companies can open new revenue streams and the service companies can take better informed decisions.

For this decisions, Gurobi MILP helps to model the problem and:

- Allows inspecting the whole solution space…
- … choosing the highest return that meets all requirements.
- Gurobi enables fast problem solving saving time and money.

Q&A

Thank you!

GUROBI OPTIMIZATION

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