# Universidad Nacional de Asunción

## Facultad Politécnica

# Table of Data and Results

Key information to understand the problems process and results included in *"Ubicación de casilleros para comercio electrónico. Un enfoque multiobjetivo"* research.

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# 1    Data section.

Tabla 4.5: Información de los barrios utilizados para el caso $n = 20$.

| N° | Acrónimo | Localidad |
|----|----------|-----------|
| 1 | BÑ | Bañado |
| 2 | OB | Obrero |
| 3 | PS | Pettirossi |
| 4 | RO | Republicano |
| 5 | SV | San Vicente |
| 6 | GD | Gral. Díaz |
| 7 | SR | San Roque |
| 8 | CT | Catedral |
| 9 | EN | Encarnación |
| 10 | DF | Dr. Francia |
| 11 | RB | Ricardo Brugada |
| 12 | TB | Tacumbú |
| 13 | MC | Mburicaó |
| 14 | SJ | Sajonia |
| 15 | LM | Las Mercedes |
| 16 | CN | Ciudad Nueva |
| 17 | PZ | Pinozá |
| 18 | RP | Roberto L. Petit |
| 19 | BC | Bernardino Caballero |
| 20 | ML | Mcal. López |

Tabla 2: Datos estimados de los clientes potenciales para el caso $n = 20$

| Localidad | EP | F | K=$EP \cdot F$ |
|:---:|:---:|:---:|:---:|
| 1 | 8.374 | 0.29 | 2.428 |
| 2 | 19.823 | 0.76 | 15.065 |
| 3 | 11.380 | 0.15 | 1.707 |
| 4 | 8.429 | 0.54 | 4.552 |
| 5 | 15.412 | 0.78 | 12.021 |
| 6 | 6.068 | 0.81 | 4.915 |
| 7 | 6.355 | 0.49 | 3.114 |
| 8 | 3.673 | 0.43 | 1.579 |
| 9 | 4.928 | 0.87 | 4.287 |
| 10 | 10.925 | 0.62 | 6.774 |
| 11 | 10.455 | 0.84 | 8.782 |
| 12 | 13.366 | 0.29 | 3.876 |
| 13 | 7.691 | 0.2 | 1.538 |
| 14 | 14.873 | 0.66 | 9.816 |
| 15 | 4.827 | 0.92 | 4.441 |
| 16 | 8.584 | 0.23 | 1.974 |
| 17 | 6.621 | 0.84 | 5.562 |
| 18 | 20.201 | 0.62 | 12.525 |
| 19 | 8.128 | 0.47 | 3.820 |
| 20 | 5.025 | 0.95 | 4.774 |
| $\Sigma$ | 195.138 | | 113.550 |

Figure 1: Matriz $MC$ para el caso $n = 20$.

| | BÑ | OB | PS | RO | SV | GD | SR | CT | EN | DF | RB | TB | MC | SJ | LM | CN | PZ | RP | BC | ML |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BÑ | 1 | 0.38 | 0.15 | 0.87 | 0.65 | 0.04 | 0.64 | 0.5 | 0.55 | 0.6 | 0.3 | 0.61 | 0.73 | 0.67 | 0.1 | 0.26 | 0.87 | 0.45 | 0.35 | 0.3 |
| OB | 0.88 | 1 | 0.68 | 0.4 | 0.26 | 0.64 | 0.3 | 0.27 | 0.66 | 0.03 | 0.41 | 0.25 | 0.37 | 0.32 | 0.61 | 0.06 | 0.07 | 0.51 | 0.72 | 0.45 |
| PS | 0.89 | 0.46 | 1 | 0.09 | 0.65 | 0.38 | 0.22 | 0.86 | 0.12 | 0.28 | 0.31 | 0.86 | 0.36 | 0.18 | 0.61 | 0.64 | 0.7 | 0.07 | 0.73 | 0.82 |
| RO | 0.1 | 0.2 | 0.1 | 1 | 0.11 | 0.7 | 0.6 | 0.64 | 0.14 | 0.17 | 0.14 | 0.56 | 0.14 | 0.65 | 0.15 | 0.32 | 0.21 | 0.36 | 0.46 | 0.63 |
| SV | 0.18 | 0.79 | 0.12 | 0.46 | 1 | 0.16 | 0.49 | 0.34 | 0.45 | 0.59 | 0.03 | 0.03 | 0.14 | 0.19 | 0.16 | 0.27 | 0.49 | 0.75 | 0.3 | 0.75 |
| GD | 0.42 | 0.53 | 0.87 | 0.76 | 0.72 | 1 | 0.42 | 0.03 | 0.52 | 0.19 | 0.8 | 0.59 | 0.36 | 0.51 | 0.77 | 0.69 | 0.43 | 0.37 | 0.62 | 0.62 |
| SR | 0.07 | 0.64 | 0.34 | 0.43 | 0.03 | 0.71 | 1 | 0.18 | 0.68 | 0.48 | 0.5 | 0.1 | 0.59 | 0.61 | 0.27 | 0.89 | 0.73 | 0.27 | 0.07 | 0.74 |
| CT | 0.86 | 0.28 | 0.02 | 0.8 | 0.35 | 0.84 | 0.75 | 1 | 0.49 | 0.05 | 0.64 | 0.09 | 0.11 | 0.37 | 0.85 | 0.24 | 0.47 | 0.36 | 0.38 | 0.26 |
| EN | 0.87 | 0.01 | 0.54 | 0.42 | 0.45 | 0.29 | 0.14 | 0.45 | 1 | 0.62 | 0.11 | 0.2 | 0.71 | 0.73 | 0.15 | 0.13 | 0.11 | 0.37 | 0.28 | 0.26 |
| DF | 0.85 | 0.29 | 0.22 | 0.47 | 0.54 | 0.43 | 0.44 | 0.86 | 0.58 | 1 | 0.23 | 0.13 | 0.53 | 0.48 | 0.44 | 0.89 | 0.79 | 0.34 | 0.25 | 0.55 |
| RB | 0.68 | 0.76 | 0.04 | 0.09 | 0.84 | 0.9 | 0.03 | 0.45 | 0.2 | 0.31 | 1 | 0.77 | 0.11 | 0.64 | 0.44 | 0.16 | 0.4 | 0.35 | 0.23 | 0.82 |
| TB | 0.37 | 0.22 | 0.64 | 0.32 | 0.7 | 0.65 | 0.36 | 0.62 | 0.41 | 0.12 | 0.13 | 1 | 0.44 | 0.34 | 0.89 | 0.73 | 0.51 | 0.42 | 0.65 | 0.17 |
| MC | 0.52 | 0.47 | 0.46 | 0.46 | 0.23 | 0.4 | 0.73 | 0.14 | 0.69 | 0.33 | 0.31 | 0.24 | 1 | 0.29 | 0.76 | 0.64 | 0.56 | 0.82 | 0.36 | 0.35 |
| SJ | 0.57 | 0.26 | 0.65 | 0.02 | 0.89 | 0.64 | 0.75 | 0.5 | 0.22 | 0.09 | 0.48 | 0.48 | 0.06 | 1 | 0.49 | 0.36 | 0.25 | 0.57 | 0.78 | 0.5 |
| LM | 0.16 | 0.39 | 0.22 | 0.73 | 0.04 | 0.88 | 0.71 | 0.82 | 0.14 | 0.5 | 0.11 | 0.39 | 0.42 | 0.05 | 1 | 0.57 | 0.07 | 0.72 | 0.8 | 0.6 |
| CN | 0.04 | 0.34 | 0.56 | 0.47 | 0.84 | 0.62 | 0.04 | 0.82 | 0.41 | 0.11 | 0.88 | 0.21 | 0.84 | 0.84 | 0.75 | 1 | 0.76 | 0.42 | 0.39 | 0.1 |
| PZ | 0.42 | 0.79 | 0.42 | 0.68 | 0.07 | 0.38 | 0.28 | 0.18 | 0.15 | 0.17 | 0.57 | 0.52 | 0.22 | 0.7 | 0.15 | 0.4 | 1 | 0.11 | 0.46 | 0.13 |
| RP | 0.63 | 0.49 | 0.62 | 0.65 | 0.44 | 0.4 | 0.43 | 0.66 | 0.23 | 0.27 | 0.13 | 0.33 | 0.54 | 0.29 | 0.78 | 0.07 | 0.08 | 1 | 0.0 | 0.16 |
| BC | 0.88 | 0.61 | 0.34 | 0.1 | 0.35 | 0.64 | 0.5 | 0.01 | 0.02 | 0.84 | 0.06 | 0.2 | 0.64 | 0.11 | 0.64 | 0.31 | 0.25 | 0.33 | 1 | 0.51 |
| ML | 0.7 | 0.79 | 0.18 | 0.66 | 0.66 | 0.28 | 0.44 | 0.39 | 0.54 | 0.41 | 0.68 | 0.69 | 0.82 | 0.42 | 0.14 | 0.51 | 0.03 | 0.8 | 0.04 | 1 |

# 2 Results

Tabla 3: Conjunto Pareto y frente Pareto correspondiente a la segunda instancia del problema $n=20$.

| N° | $\Omega$ | Colocar CP en | $f_1$ | $f_2$ | $f_3$ | $f_4$ |
|---|---|---|---|---|---|---|
| 1 | 01001100010001100101 | [OB, SV, GD, DF, SJ, LM, RP, ML] | 7200 | 5.36x10^-06 | 1.42x10^-05 | 8354 |
| 2 | 01011110011100100100 | [OB, RO, SV, GD, SR, DF, RB, TB, LM, RP] | 8500 | 5.22x10^-06 | 1.31x10^-05 | 6748 |
| 3 | 01011110110100100101 | [OB, RO, SV, GD, SR, EN, DF, TB, LM, RP, ML] | 9200 | 5.17x10^-06 | 1.30x10^-05 | 5121 |
| 4 | 01011100110100100101 | [OB, RO, SV, GD, EN, DF, TB, LM, RP, ML] | 8500 | 5.23x10^-06 | 1.36x10^-05 | 5930 |
| 5 | 01011100011100100100 | [OB, RO, SV, GD, DF, RB, TB, LM, RP] | 7800 | 5.29x10^-06 | 1.37x10^-05 | 7651 |
| 6 | 01011110110000100101 | [OB, RO, SV, GD, SR, EN, DF, LM, RP, ML] | 8500 | 5.24x10^-06 | 1.37x10^-05 | 5615 |
| 7 | 01011110011000100101 | [OB, RO, SV, GD, SR, DF, RB, LM, RP, ML] | 8600 | 5.20x10^-06 | 1.29x10^-05 | 6287 |
| 8 | 01011110011000100100 | [OB, RO, SV, GD, SR, DF, RB, LM, RP] | 7800 | 5.31x10^-06 | 1.38x10^-05 | 7532 |
| 9 | 01011110110100100100 | [OB, RO, SV, GD, SR, EN, DF, TB, LM, RP] | 8400 | 5.26x10^-06 | 1.39x10^-05 | 6076 |
| 10 | 01001110011000100101 | [OB, SV, GD, SR, DF, RB, LM, RP, ML] | 7700 | 5.34x10^-06 | 1.38x10^-05 | 8187 |
| 11 | 01011110010000101101 | [OB, RO, SV, GD, SR, DF, LM, PZ, RP, ML] | 8500 | 5.24x10^-06 | 1.35x10^-05 | 6077 |
| 12 | 01011110010100101101 | [OB, RO, SV, GD, SR, DF, TB, LM, PZ, RP, ML] | 9200 | 5.17x10^-06 | 1.28x10^-05 | 5582 |
| 13 | 01011100010100101101 | [OB, RO, SV, GD, DF, TB, LM, PZ, RP, ML] | 8500 | 5.23x10^-06 | 1.34x10^-05 | 6392 |
| 14 | 01011100011101100100 | [OB, RO, SV, GD, DF, RB, TB, SJ, LM, RP] | 9800 | 5.08x10^-06 | 1.20x10^-05 | 6099 |
| 15 | 01011110011001100100 | [OB, RO, SV, GD, SR, DF, RB, SJ, LM, RP] | 9800 | 5.10x10^-06 | 1.21x10^-05 | 5981 |
| 16 | 01011100011001100101 | [OB, RO, SV, GD, DF, RB, SJ, LM, RP, ML] | 9900 | 5.05x10^-06 | 1.19x10^-05 | 5546 |
| 17 | 01011100011001100100 | [OB, RO, SV, GD, DF, RB, SJ, LM, RP] | 9100 | 5.16x10^-06 | 1.26x10^-05 | 6884 |
| 18 | 11011110010000100101 | [BÑ, OB, RO, SV, GD, SR, DF, LM, RP, ML] | 8600 | 5.28x10^-06 | 1.41x10^-05 | 5569 |
| 19 | 01011110010100100101 | [OB, RO, SV, GD, SR, DF, TB, LM, RP, ML] | 7500 | 5.29x10^-06 | 1.38x10^-05 | 6750 |
| 20 | 01011110010101100100 | [OB, RO, SV, GD, SR, DF, TB, SJ, LM, RP] | 8700 | 5.18x10^-06 | 1.29x10^-05 | 6153 |
| 21 | 01011110010001100100 | [OB, RO, SV, GD, SR, DF, SJ, LM, RP] | 8000 | 5.27x10^-06 | 1.36x10^-05 | 6938 |
| 22 | 01011100010001100101 | [OB, RO, SV, GD, DF, SJ, LM, RP, ML] | 8100 | 5.22x10^-06 | 1.33x10^-05 | 6503 |
| 23 | 01011110010101100101 | [OB, RO, SV, GD, SR, DF, TB, SJ, LM, RP, ML] | 9500 | 5.08x10^-06 | 1.22x10^-05 | 5199 |
| 24 | 01001100011001100101 | [OB, SV, GD, DF, RB, SJ, LM, RP, ML] | 9000 | 5.18x10^-06 | 1.26x10^-05 | 7397 |
| 25 | 01001100011101100101 | [OB, SV, GD, DF, RB, TB, SJ, LM, RP, ML] | 9700 | 5.11x10^-06 | 1.20x10^-05 | 6902 |
| 26 | 01011100010101100100 | [OB, RO, SV, GD, DF, TB, SJ, LM, RP] | 8000 | 5.24x10^-06 | 1.35x10^-05 | 7056 |
| 27 | 01011100010001100100 | [OB, RO, SV, GD, DF, SJ, LM, RP] | 7300 | 5.34x10^-06 | 1.42x10^-05 | 7841 |
| 28 | 01001110011001100101 | [OB, SV, GD, SR, DF, RB, SJ, LM, RP, ML] | 9700 | 5.12x10^-06 | 1.21x10^-05 | 6587 |
| 29 | 01011100010101100101 | [OB, RO, SV, GD, DF, TB, SJ, LM, RP, ML] | 8800 | 5.14x10^-06 | 1.26x10^-05 | 6008 |
| 30 | 01011110010001100101 | [OB, RO, SV, GD, SR, DF, SJ, LM, RP, ML] | 8800 | 5.16x10^-06 | 1.28x10^-05 | 5693 |
| 31 | 01001100010101100101 | [OB, SV, GD, DF, TB, SJ, LM, RP, ML] | 7900 | 5.28x10^-06 | 1.34x10^-05 | 7859 |
| 32 | 01011100011000100101 | [OB, RO, SV, GD, DF, RB, LM, RP, ML] | 7900 | 5.26x10^-06 | 1.35x10^-05 | 7097 |
| 33 | 01011110011100100101 | [OB, RO, SV, GD, SR, DF, RB, TB, LM, RP, ML] | 9300 | 5.12x10^-06 | 1.23x10^-05 | 5793 |
| 34 | 01011100011100100101 | [OB, RO, SV, GD, DF, RB, TB, LM, RP, ML] | 8600 | 5.19x10^-06 | 1.28x10^-05 | 6602 |
| 35 | 01001100011100100101 | [OB, SV, GD, DF, RB, TB, LM, RP, ML] | 7700 | 5.32x10^-06 | 1.36x10^-05 | 8502 |
| 36 | 01001110011100100101 | [OB, SV, GD, SR, DF, RB, TB, LM, RP, ML] | 8400 | 5.26x10^-06 | 1.31x10^-05 | 7692 |
| 37 | 01011110010110100101 | [OB, RO, SV, GD, SR, DF, TB, MC, LM, RP, ML] | 8400 | 5.26x10^-06 | 1.35x10^-05 | 6087 |

Tabla 4: Progreso del algoritmo *NSGA-II* teniendo en cuenta las 10 ejecuciones sobre la segunda instancia del problema $n=20$.

| | Generación 1 | | Generación 10 | | Generación 100 | | Generación 500 | | Generación 1000 | | Generación 1500 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ejecución | Tiempo(s) | N° de soluciones | Tiempo(s) | N° de soluciones | Tiempo(s) | N° de soluciones | Tiempo(s) | N° de soluciones | Tiempo(s) | N° de soluciones | Tiempo(s) | N° de soluciones |
| 1 | 0.90 | 1 | 18.04 | 11 | 215.48 | 23 | 1080.58 | 33 | 2179.77 | 35 | 2179.77 | 35 |
| 2 | 0.72 | 1 | 28.09 | 8 | 289.53 | 30 | 1315.25 | 35 | 2609.07 | 35 | 3818.21 | 35 |
| 3 | 0.75 | 2 | 19.42 | 13 | 216.12 | 24 | 1144.07 | 35 | 2181.65 | 37 | 3198.47 | 37 |
| 4 | 0.92 | 1 | 25.54 | 7 | 278.30 | 23 | 1279.88 | 32 | 2444.73 | 36 | 3566.76 | 36 |
| 5 | 0.67 | 2 | 17.68 | 10 | 241.08 | 24 | 1158.16 | 31 | 2217.62 | 34 | 3265.99 | 34 |
| 6 | 0.75 | 4 | 26.57 | 10 | 251.41 | 18 | 1246.56 | 26 | 2519.13 | 30 | 3704.72 | 33 |
| 7 | 0.67 | 1 | 16.27 | 9 | 195.76 | 18 | 1067.33 | 25 | 2263.28 | 35 | 3609.08 | 36 |
| 8 | 0.91 | 1 | 19.66 | 10 | 224.45 | 27 | 1222.12 | 33 | 2769.09 | 33 | 3899.61 | 35 |
| 9 | 0.66 | 2 | 16.29 | 6 | 196.61 | 30 | 1069.09 | 33 | 2151.72 | 35 | 3390.24 | 35 |
| 10 | 0.68 | 1 | 33.98 | 13 | 426.08 | 23 | 1604.76 | 29 | 2765.86 | 32 | 4290.11 | 35 |
| **Promedio** | 0.763 | 1.6 | 22.154 | 9.7 | 253.48 | 24 | 1218.78 | 31.2 | 2410.19 | 34.2 | 3492.29 | 35.1 |
| **Desv est ($\sigma$)** | 0.1 | 0.92 | 5.70 | 2.19 | 64.89 | 3.95 | 153.79 | 3.31 | 232.10 | 1.94 | 533.26 | 1.04 |
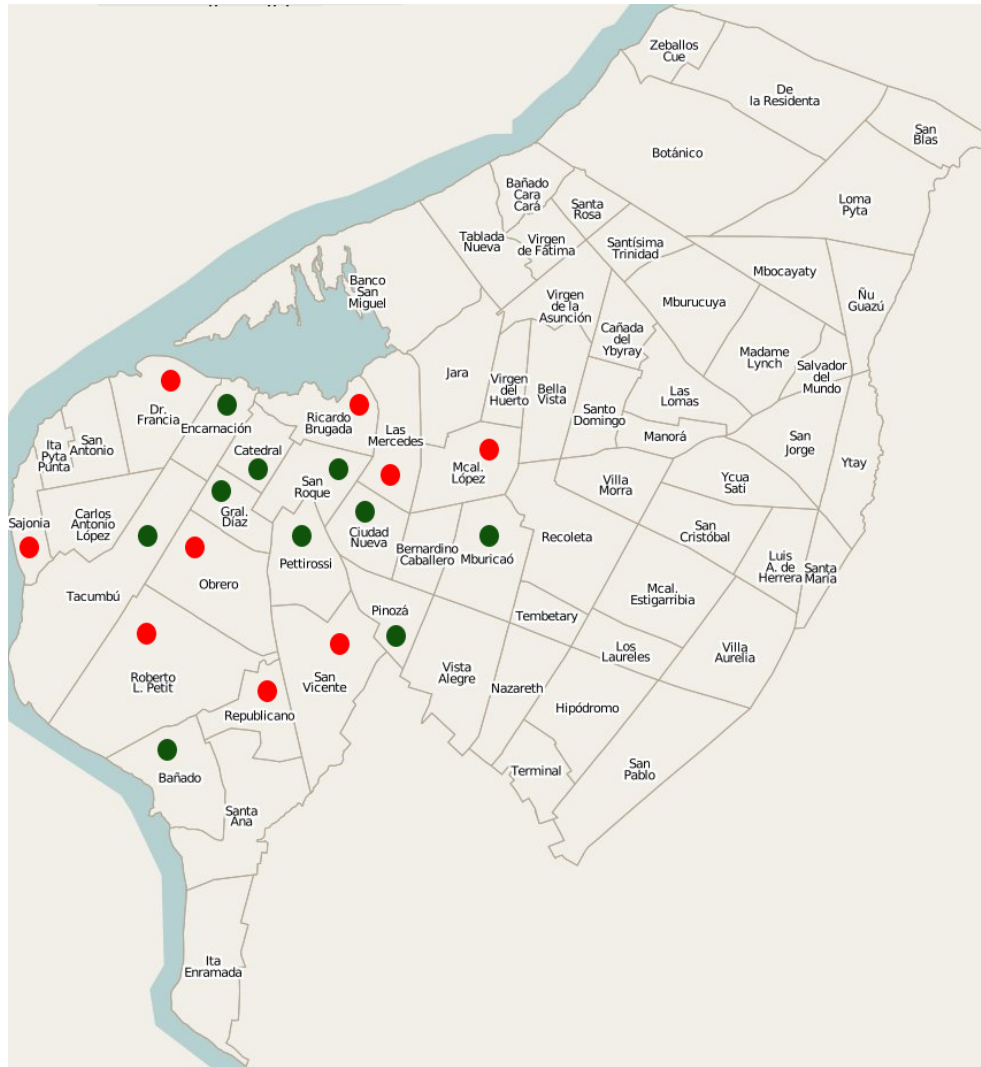
Figure 2: Solución 16 de la Tabla XI representada en el mapa de Asunción. Los puntos rojos representan la instalación de CP, mientras que los puntos verdes, ausencia de CP en las respectivas localidades.

# 3 Algoritmos

## 3.1 Exhaustivo

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**Algoritmo 1** Búsqueda exhaustiva

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1: **procedure**
2:     $leer \rightarrow n$
3:     $dominatedSet = \emptyset$
4:     $paretoSet = \emptyset$
5:     **for** $i = 1$ $to$ $2^n - 2$ **do**
6:         **for** $j = i + 1$ $to$ $2^n - 1$ **do**
7:             **if** $i \succ j$ **then**
8:                 $dominatedSet \cup \{j\}$
9:             **else if** $j \succ i$ **then**
10:                 $dominatedSet \cup \{i\}$
11:     **for** $i = 1$ $to$ $2^n - 1$ **do**
12:         **if** $i \notin dominatedSet$ **then**
13:             $paretoSet \cup \{i\}$
    **return** $paretoSet$

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