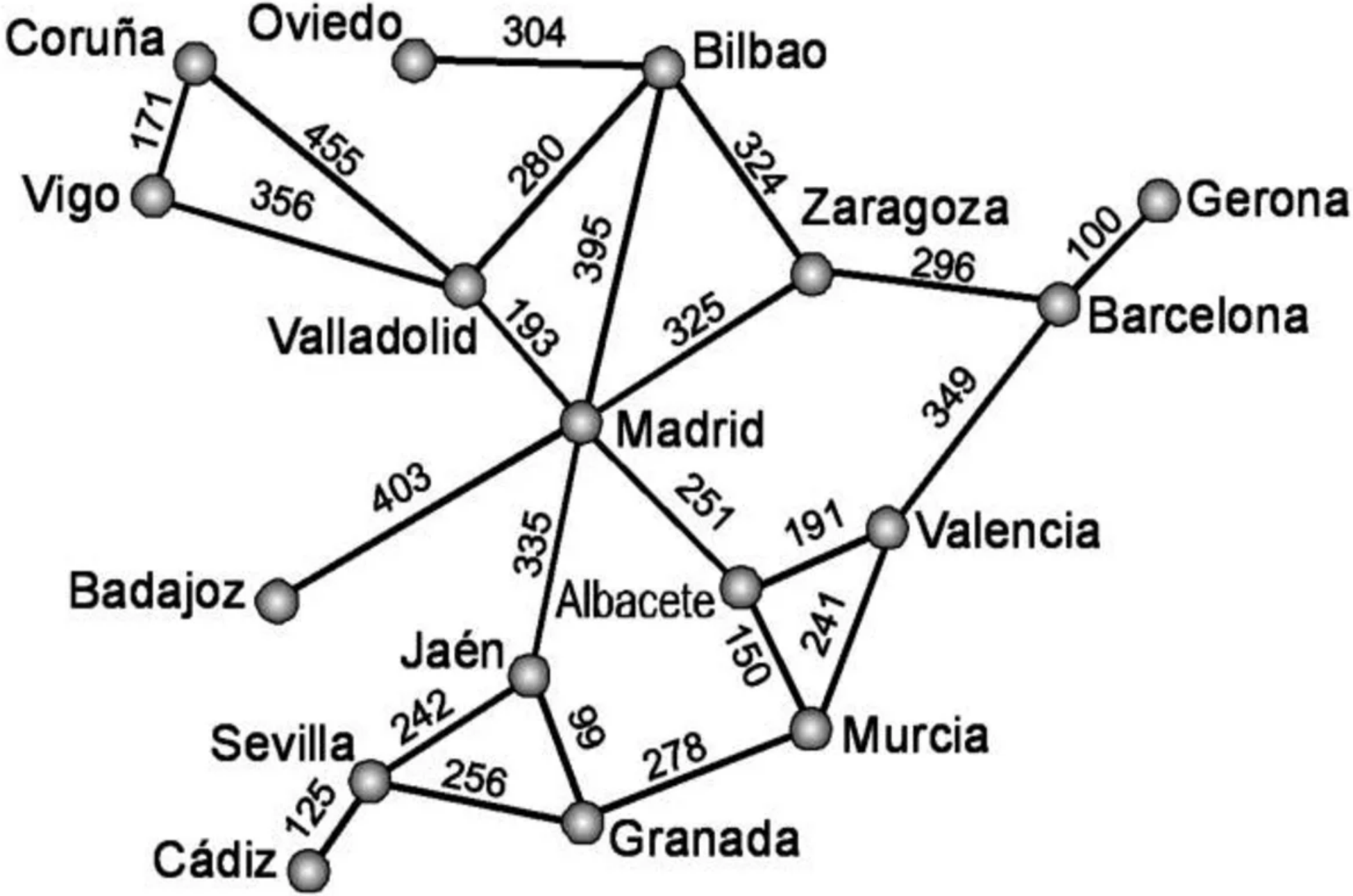
Modelos matemáticos de rehabilitación y reparto en condiciones de inseguridad para logística humanitaria

Autor: Antonio Sevilla Sastre
Tutora: Mª Teresa Ortuño Sánchez
Dpto. de estadística e investigación operativa

10 de julio de 2023


NZ 99188
NZ 99189
Anchor
blue
gracio bananas


Coruña
Oviedo
304
Bilbao
171
455
280
324
Vigo
356
Zaragoza
Gerona
100
296
395
Valladolid
193
325
Barcelona
349
Madrid
403
251
191
Valencia
335
Badajoz
Albacete
241
150
Jaén
242
66
Murcia
Sevilla
278
256
125
Granada
Cádiz

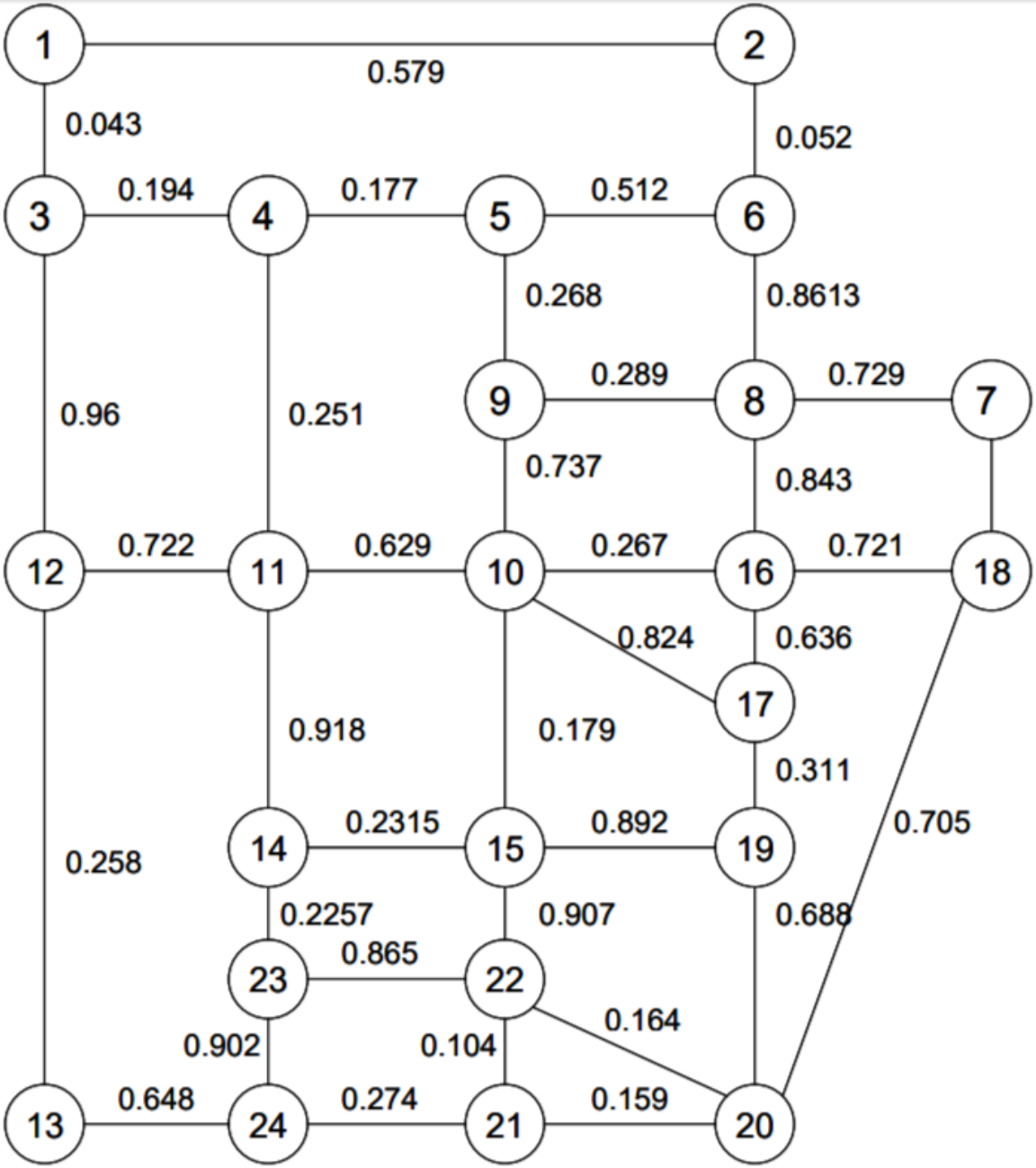
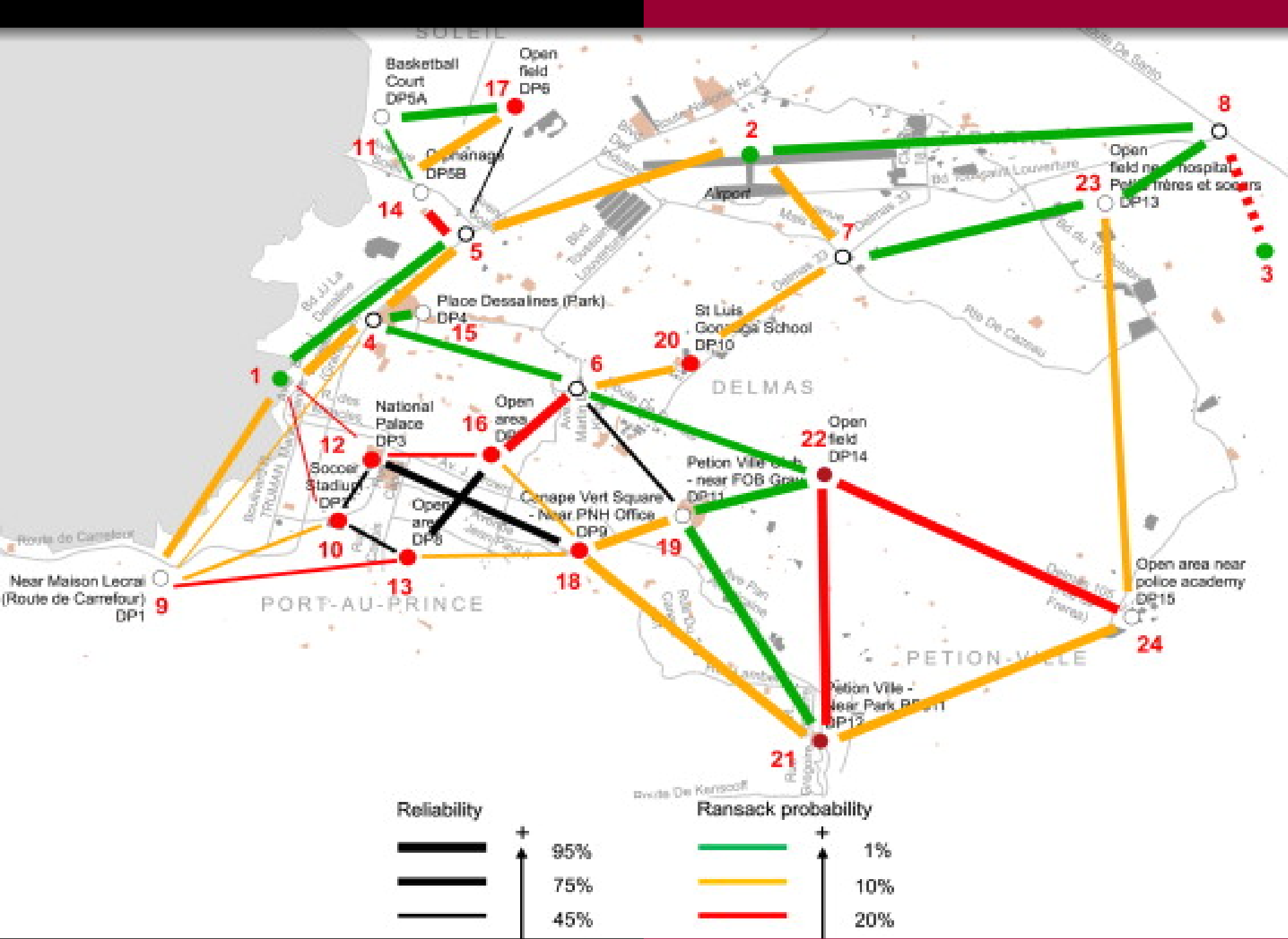


FIGURE 5 Test Network 2: Modified Sioux Falls network


Basketball Court DP5A
Open field DP5
Campanagan DP5B
Airport
Open field near hospital Petits frères et soeurs DP13
Place Dessalines (Park) DP4
St Luis Gonzaga School DP10
DELMAS
National Palace DP3
Soccer Stadium DP2
Open area DP6
Carrefour
Canape Vert Square - Near PNH Office DP9
Petion Ville - near FOB Grau DP11
Open field DP14
Near Maison Lecrai (Route de Carrefour) DP1
PORT-AU-PRINCE
Open area near police academy DP15
PETION-VILLE
Petion Ville - Near Park DP12
Reliability
95%
75%
45%
Ransack probability
1%
10%
20%

Índices

Índice	Descripción
j, i	Nodos.
v	Tipos de convoy.
w	Cada convoy de tipo v.

Variables principales

Nombre	Índices	Descripción
X	i, j, v, w	Variable binaria que determina si el convoy de tipo v w-ésimo recorre el arco de i a j.
Y	i, j, v, w	Variable binaria que determina si el convoy w-ésimo recorre el arco de i a j volviendo.
Z	i, v, w	Variable binaria que determina si el convoy de tipo v w-ésimo reparte a i.
H	i, j	Variable binaria que determina si se habilita el arco de i a j.

Restricciones ida

(1) $\sum_i \mathsf{X}_{i,j,v,w} \geq \sum_i \mathsf{X}_{j,i,v,w}$ $\forall j, v, w \mid j > 1$

(2) $\mathsf{Z}_{j,v,w} \leq \sum_i \mathsf{X}_{i,j,v,w}$ $\forall j, v, w$

(3) $\mathsf{Z}_{j,v,w} \leq 1 - \sum_i \mathsf{X}_{j,i,v,w}$ $\forall j, v, w$

(4) $\sum_j \mathsf{X}_{i,j,v,w} \leq 1$ $\forall i, v, w$

(5) $\mathsf{Salio}_{v,w} = \sum_j \mathsf{Z}_{j,v,w}$ $\forall v, w$

(6) $\sum_j \mathsf{X}_{0,j,v,w} = \mathsf{Salio}_{v,w}$ $\forall v, w$

Restricciones vuelta

(9) $\mathsf{Ayuda}_j \leq \mathsf{dem}_j \qquad \forall j$

(10) $\sum_i \mathsf{Y}_{i,j,v,w} + \mathsf{Z}_{j,v,w} \geq \sum_i \mathsf{Y}_{j,i,v,w} \qquad \forall j, v, w$

(11) $\sum_j \mathsf{Y}_{i,j,v,w} \leq 1 \qquad \forall i, v, w$

(14) $\mathsf{Z}_{i,v,w} \leq \sum_j \mathsf{Y}_{i,j,v,w} \qquad \forall i, v, w$

(15) $\mathsf{Y}_{0,j,v,w} = 0 \qquad \forall j, v, w$

(16) $\mathsf{Salio}_{v,w} = \sum_i \mathsf{Y}_{i,0,v,w} \qquad \forall v, w$

Restricciones existencia y usabilidad

(7) $\mathsf{X}_{i,j,v,w} \leq \mathsf{E}_{i,j}$ $\forall i, j, v, w$

(8) $\mathsf{X}_{i,j,v,w} \leq \mathsf{U}_{i,j} + \mathsf{H}_{i,j}$ $\forall i, j, v, w \mid \mathsf{E}_{i,j} > 0$

(12) $\mathsf{Y}_{i,j,v,w} \leq \mathsf{E}_{i,j}$ $\forall i, j, v, w \mid \mathsf{E}_{i,j} > 0$

(13) $\mathsf{Y}_{i,j,v,w} \leq \mathsf{U}_{i,j} + \mathsf{H}_{i,j}$ $\forall i, j, v, w \mid \mathsf{E}_{i,j} > 0$

Definición criterios

(17) $\text{Ayuda}_j = \sum_v (\sum_w (\text{Z}_{j,v,w} \cdot \text{capacidad}_v)) \quad \forall j$

(18) $\text{Insatis} = \sum_j \text{Insatisaux}_j$

(19) $\text{Eq} \geq \text{Prop\_insatis}_j \quad \forall j$

(20) $\text{Prop\_insatis}_j \cdot \text{dem}_j = \text{Insatisaux}_j \quad \forall j$

(21) $\text{Insatisaux}_j = \text{dem}_j - \text{Ayuda}_j \quad \forall j$

(22) $\text{Coste\_rehab} = \sum_i (\sum_j (\text{H}_{i,j} \cdot \text{coste\_rehabilitacion}_{i,j}))$

(23) $\text{Coste\_rehab} \leq \text{max\_coste\_rehab}$

(24) $\text{Coste} = \sum_i (\sum_j (\sum_v (\sum_w ((\text{X}_{i,j,v,w} + \text{Y}_{i,j,v,w}) \cdot \text{coste\_variable}_v \cdot \text{dist}_{i,j})))) + \sum_v (\sum_w (\text{Salio}_{v,w} \cdot \text{coste\_fijo}_v))$

(25) $\text{Coste} \leq \text{max\_coste}$

Restricciones fiabilidad y seguridad

(27) $\mathsf{M} \cdot \mathsf{Usado}_{i,j} \geq \sum_{v}(\sum_{w}(\mathsf{X}_{i,j,v,w} + \mathsf{Y}_{i,j,v,w})) \qquad \forall i,j \mid \mathsf{E}_{i,j} > 0$

(28) $\mathsf{Seguridad} = \sum_{i}(\sum_{j}(\mathsf{Usado}_{i,j} \cdot \mathsf{PS}_{i,j}))$

(29) $\mathsf{Seguridad} \geq \mathsf{PS\_total}$

(30) $\mathsf{Fiabilidad} = \sum_{i}(\sum_{j}(\mathsf{Usado}_{i,j} \cdot \mathsf{P}_{i,j}))$

(31) $\mathsf{Fiabilidad} \geq \mathsf{P\_total}$

Restricciones temporales

(32) $\mathsf{t}_{v,w} = \sum_{i}(\sum_{j}((\mathsf{X}_{i,j,v,w} + \mathsf{Y}_{i,j,v,w}) \cdot \mathsf{dist}_{i,j})) \qquad \forall v,w$

(33) $\mathsf{t}_{v,w} \leq \mathsf{TZ} \qquad \forall v,w$

(34) $\mathsf{TZ} \leq \mathsf{T\_max}$

Índices

Índice	Descripción
j, i	Nodos.
v	Tipos de convoy.

Variables principales

Nombre	Índices	Descripción
Xmas	i, j, v	Flujo positivo de convoyes de tipo v en el arco de i a j.
Xmenos	i, j, v	Flujo negativo de convoyes de tipo v en el arco de i a j.
Y	j, v	Cantidad de convoyes de tipo v que reparten su mercancía en j.
Z	i	Ayuda total en toneladas repartida a i.
H	i, j	Variable binaria que determina si se habilita el arco de i a j.

Restricciones de flujo

(1) $\mathsf{Y}_{j,v} \geq 0 \qquad \forall j, v \mid j > 1$

(2) $\mathsf{Y}_{j,v} = \sum_i (\mathsf{Xmas}_{i,j,v} - \mathsf{Xmenos}_{i,j,v}) - \sum_i (\mathsf{Xmas}_{j,i,v} - \mathsf{Xmenos}_{j,i,v}) \qquad \forall j, v$

(3) $\mathsf{Xmas}_{j,i,v} = 0 \qquad \forall i, j, v \mid i \leq j \wedge \mathsf{E}_{i,j} > 0$

(4) $\mathsf{Xmenos}_{j,i,v} = 0 \qquad \forall i, j, v \mid i \leq j \wedge \mathsf{E}_{i,j} > 0$

(5) $\mathsf{Xmas}_{i,j,v} - \mathsf{Xmenos}_{i,j,v} \leq \mathsf{M} \cdot \mathsf{E}_{i,j} \qquad \forall i, j, v$

(6) $\mathsf{Xmas}_{i,j,v} - \mathsf{Xmenos}_{i,j,v} \geq -(\mathsf{M} \cdot \mathsf{E}_{i,j}) \qquad \forall i, j, v$

(7) $\mathsf{Xmas}_{i,j,v} - \mathsf{Xmenos}_{i,j,v} \leq \mathsf{M} \cdot (\mathsf{U}_{i,j} + \mathsf{H}_{i,j}) \qquad \forall i, j, v \mid \mathsf{E}_{i,j} > 0$

(8) $\mathsf{Xmas}_{i,j,v} - \mathsf{Xmenos}_{i,j,v} \geq -(\mathsf{M} \cdot (\mathsf{U}_{i,j} + \mathsf{H}_{i,j})) \qquad \forall i, j, v \mid \mathsf{E}_{i,j} > 0$

(9) $\mathsf{Z}_j \leq \mathsf{dem}_j \qquad \forall j$

(10) $\mathsf{Z}_j = \sum_v (\mathsf{Y}_{j,v} \cdot \mathsf{capacidad}_v) \qquad \forall j$

Definición criterios

(11) $\text{Insatis} = \sum_j \text{Insatisaux}_j$

(12) $\text{Eq} \geq \text{Prop\_insatis}_j \quad \forall j$

(13) $\text{Prop\_insatis}_j \cdot \text{dem}_j = \text{Insatisaux}_j \quad \forall j$

(14) $\text{Insatisaux}_j \geq \text{dem}_j - \text{Z}_j \quad \forall j \mid j > 1$

(15) $\text{Coste\_rehab} = \sum_i (\sum_j (\text{coste\_rehabilitacion}_{i,j} \cdot \text{H}_{i,j}))$

(16) $\text{Coste\_rehab} \leq \text{max\_coste\_rehab}$

(17) $\text{Coste} = -\sum_v (\text{Y}_{0,v} \cdot \text{coste\_fijo}_v) + \sum_v (\sum_i (\sum_j ((\text{Xmas}_{i,j,v} + \text{Xmenos}_{i,j,v}) \cdot \text{dist}_{i,j} \cdot \text{coste\_variable}_v)))$

(18) $\text{Coste} \leq \text{max\_coste}$

(19) $-\sum_v (\text{Y}_{0,v} \cdot \text{capacidad}_v) \leq \text{max\_ayuda}$

Restricciones fiabilidad y seguridad

(20) $\mathsf{M} \cdot \mathsf{Usado}_{i,j} \geq \sum_{v} (\mathsf{Xmas}_{i,j,v} + \mathsf{Xmenos}_{j,i,v}) \quad \forall i, j$

(21) $\mathsf{Seguridad} = \sum_{i} (\sum_{j} (\mathsf{Usado}_{i,j} \cdot \mathsf{PS}_{i,j}))$

(22) $\mathsf{Seguridad} \geq \mathsf{PS\_total}$

(23) $\mathsf{Fiabilidad} = \sum_{i} (\sum_{j} (\mathsf{Usado}_{i,j} \cdot \mathsf{P}_{i,j}))$

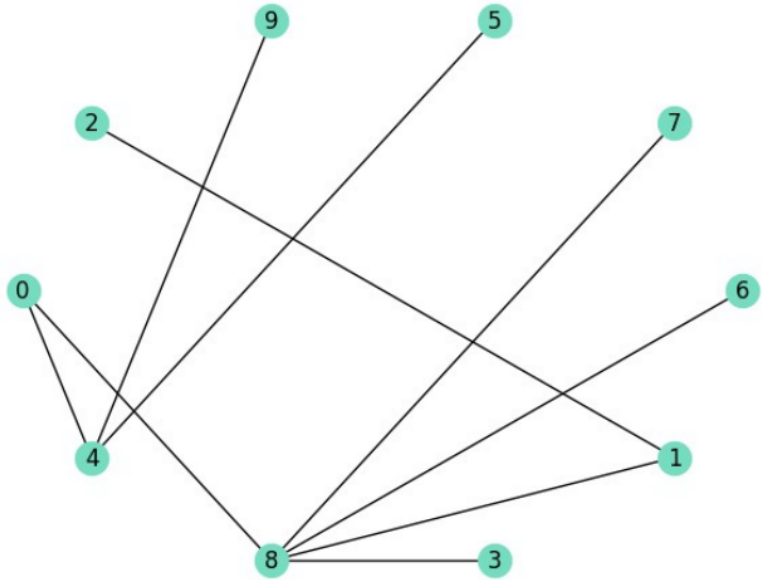
(24) $\mathsf{Fiabilidad} \geq \mathsf{P\_total}$

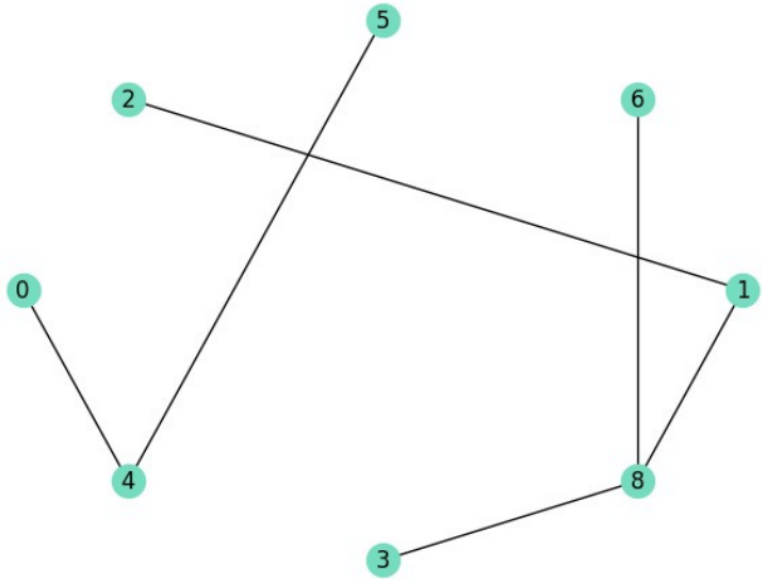
Restricciones temporales

(25) $\mathsf{TM}_j \geq \mathsf{TM}_i + \mathsf{dist}_{i,j} \cdot \mathsf{velocidad\_convoy} - \mathsf{M} \cdot (1 - \mathsf{Usado}_{i,j}) \ \forall i, j \mid \mathsf{E}_{i,j} > 0$

(26) $\mathsf{TZ} \geq \mathsf{TM}_j \quad \forall j$

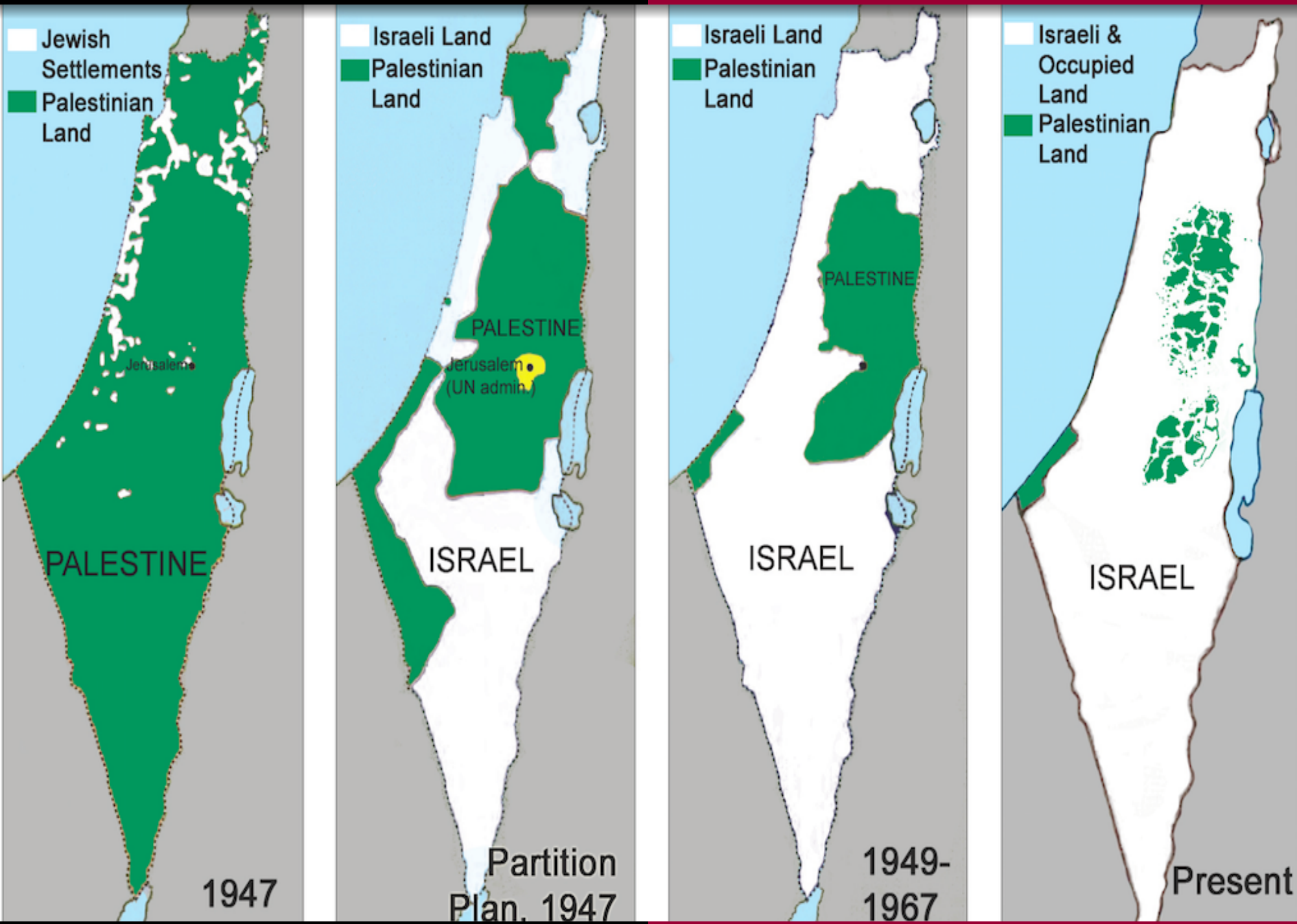
(27) $\mathsf{TZ} \leq \mathsf{T\_max} \quad \forall j$

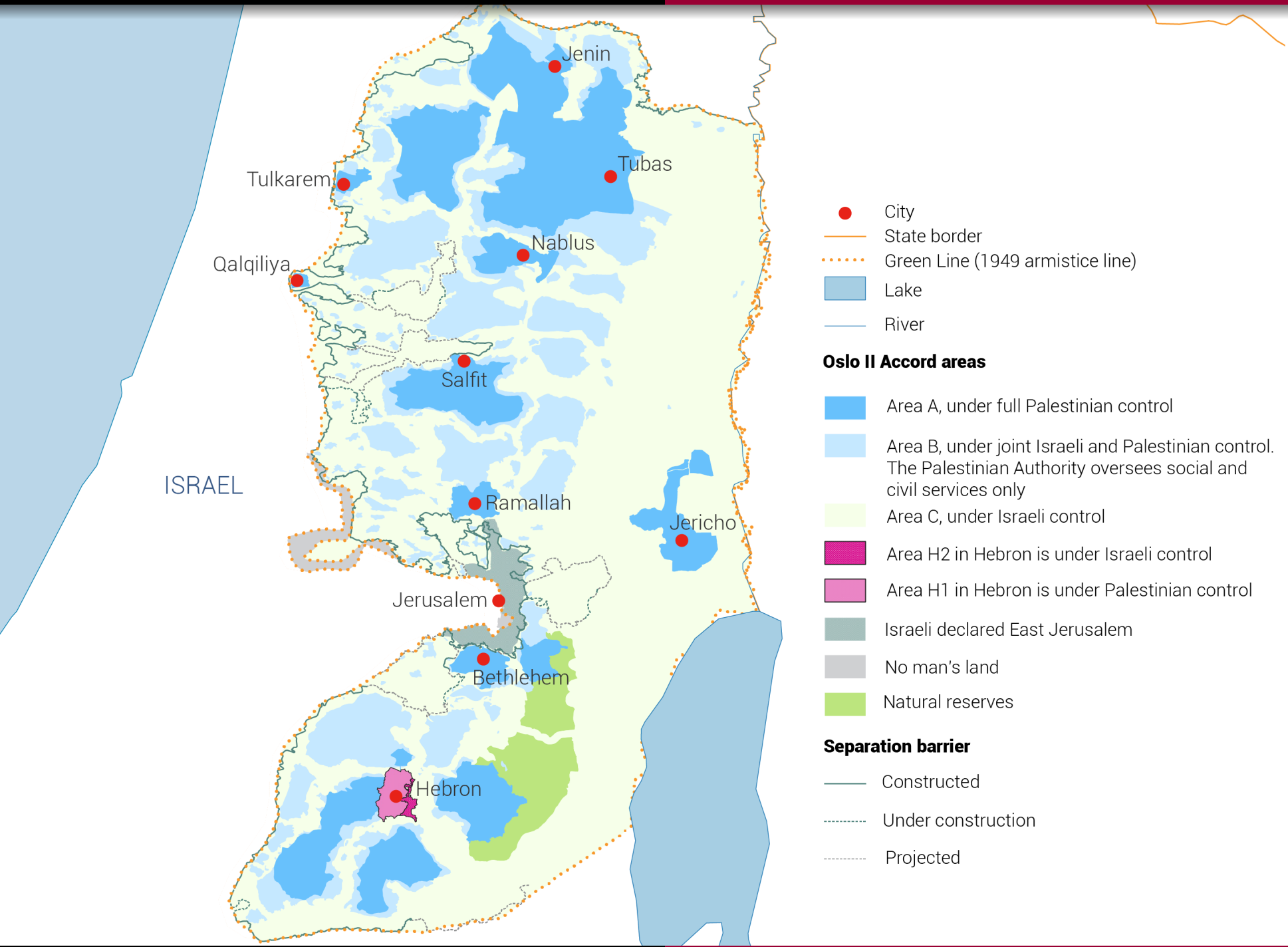

9
5
2
7
0
6
4
1
8
3

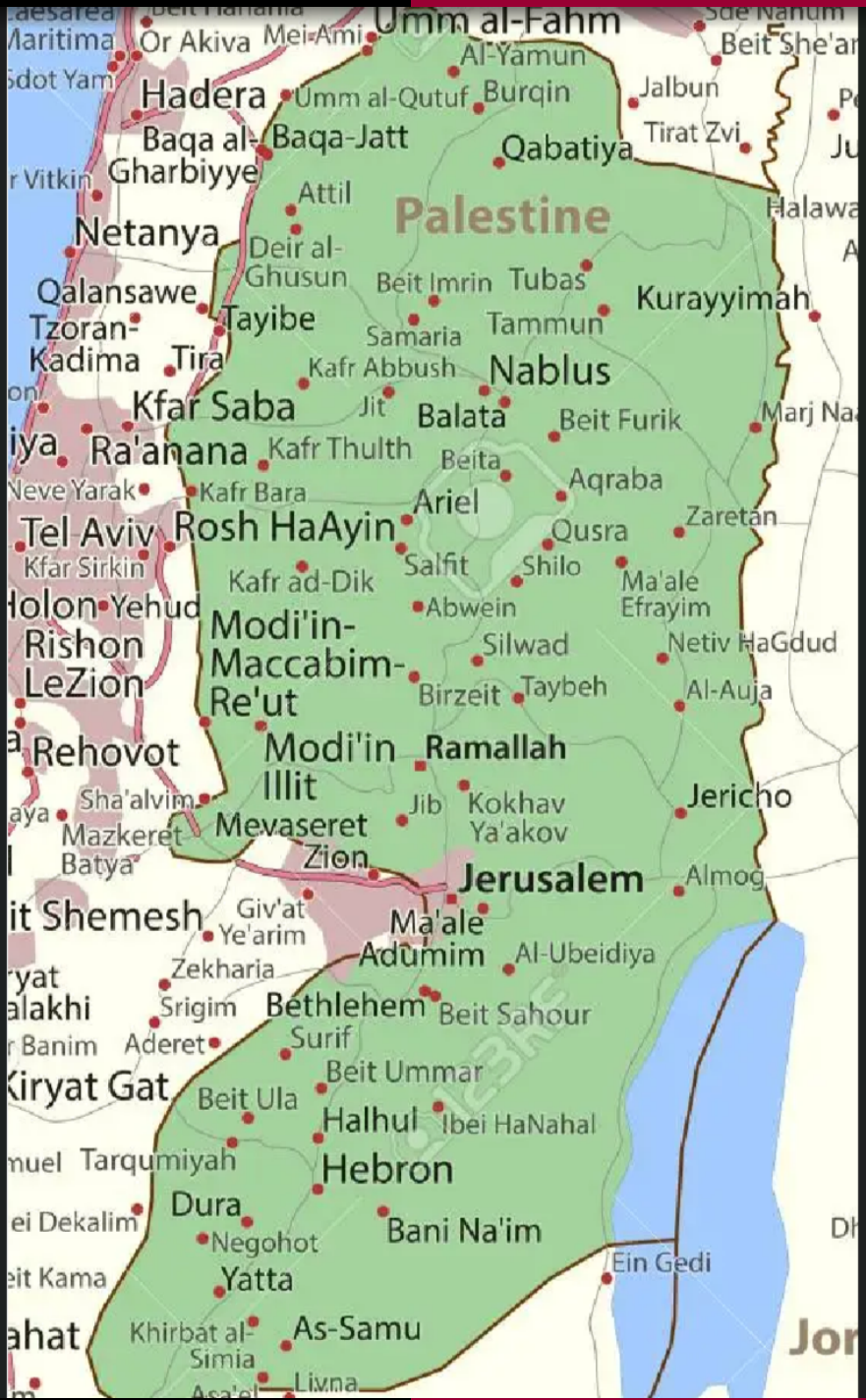

5
2
6
0
1
4
8
3

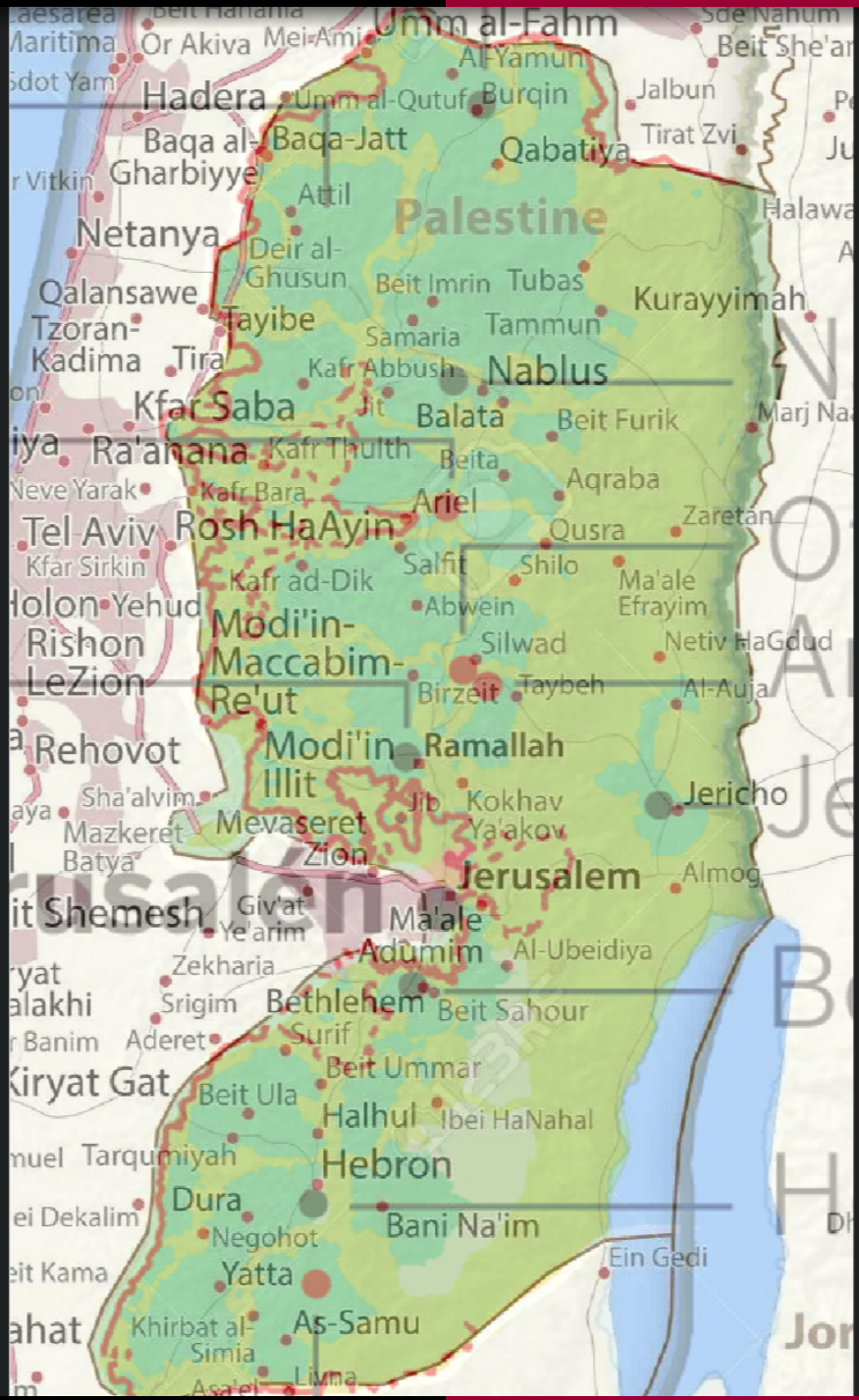
Experiencia computacional

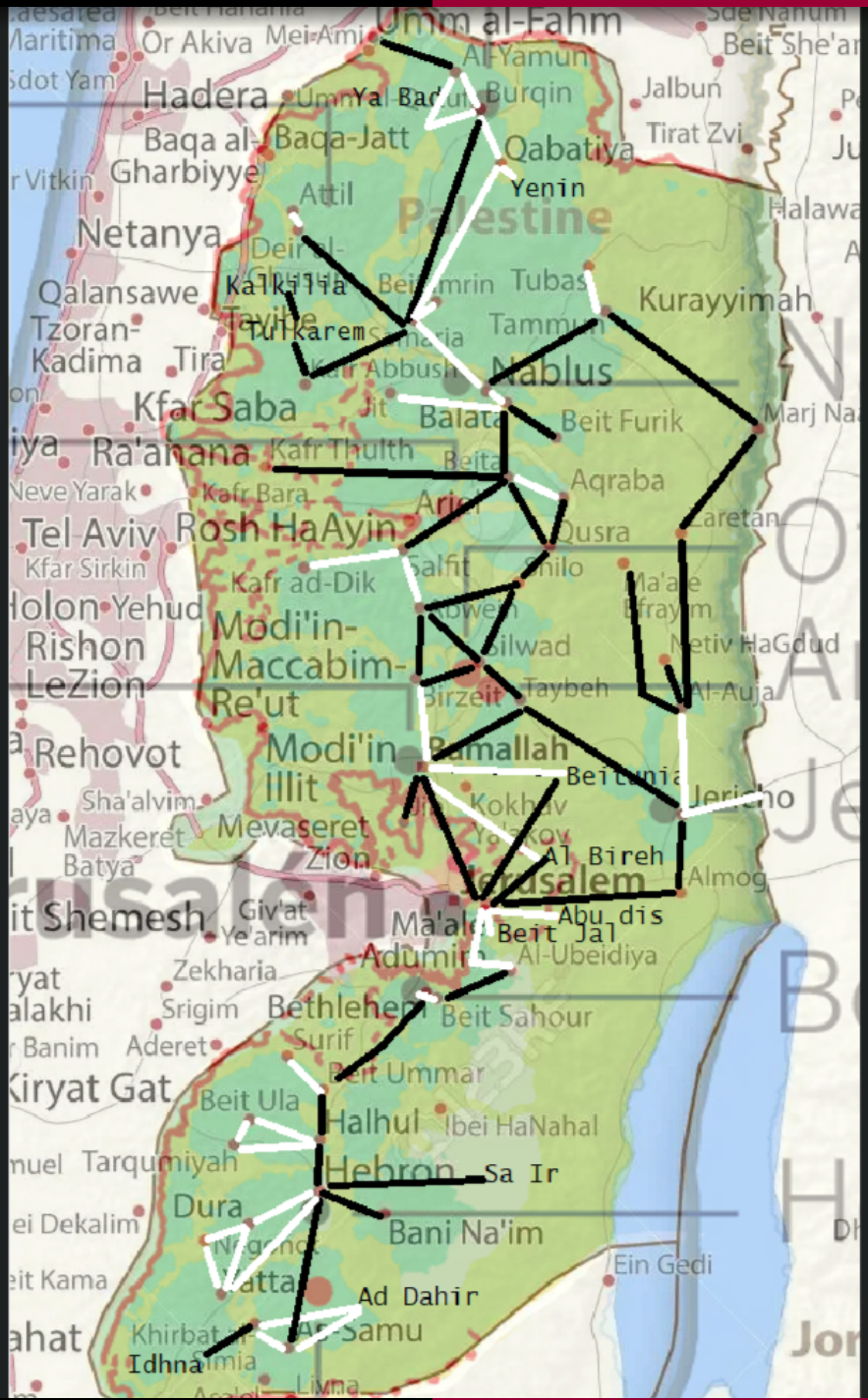
	Primer modelo	Segundo modelo
80 arcos	10 ” 6200 iters 191200 cols	2 ” 200 iters 80000 cols
200 arcos	300 ” 251000 iters 191500 cols	7 ” 750 iters 80000 cols
300 arcos	500 ” 415000 iters 193100 cols	10 ” 950 iters 80000 cols


Jewish Settlements
Palestinian Land
Jerusalem
PALESTINE
1947
Israeli Land
Palestinian Land
PALESTINE
Jerusalem (UN admin.)
ISRAEL
Partition Plan, 1947
Israeli Land
Palestinian Land
PALESTINE
ISRAEL
1949-1967
Israeli & Occupied Land
Palestinian Land
ISRAEL
Present


Jenin
Tubas
Tulkarem
Nablus
Qalqiliya
Salfit
ISRAEL
Ramallah
Jericho
Jerusalem
Bethlehem
Hebron
City
State border
Green Line (1949 armistice line)
Lake
River
Oslo II Accord areas
Area A, under full Palestinian control
Area B, under joint Israeli and Palestinian control. The Palestinian Authority oversees social and civil services only
Area C, under Israeli control
Area H2 in Hebron is under Israeli control
Area H1 in Hebron is under Palestinian control
Israeli declared East Jerusalem
No man's land
Natural reserves
Separation barrier
Constructed
Under construction
Projected

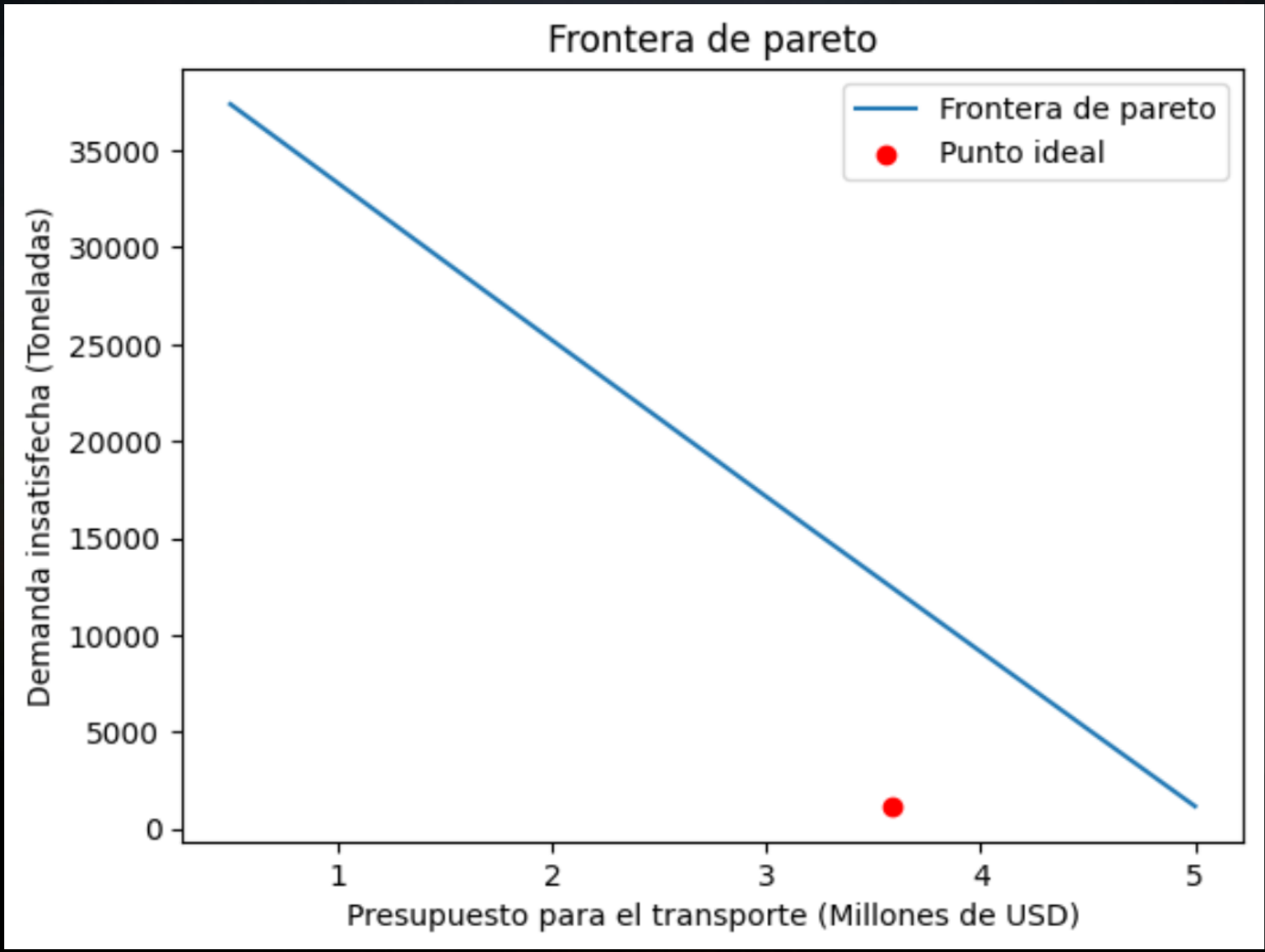

Umm al-Fahm
Or Akiva
Mei-Ami
Al-Yamun
Hadera
Umm al-Qutuf
Burqin
Jalbun
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Tirat Zvi
Attil
Palestine
Netanya
Deir al-Ghusun
Beit Imrin
Tubas
Kurayyimah
Qalansawe
Tayibe
Samaria
Tammun
Tzoran-Kadima
Tira
Kafr Abbush
Nablus
Kfar Saba
Jit
Balata
Beit Furik
Ra'anana
Kafr Thulth
Beita
Aqraba
Neve Yarak
Kafr Bara
Ariel
Tel Aviv
Rosh HaAyin
Qusra
Zaretan
Kfar Sirkin
Salfit
Shilo
Kafr ad-Dik
Ma'ale Efrayim
Holon
Yehud
Abwein
Modi'in-Maccabim-Re'ut
Rishon LeZion
Silwad
Netiv HaGdud
Birzeit
Taybeh
Al-Auja
Rehovot
Modi'in Illit
Ramallah
Sha'alvim
Jib
Kokhav Ya'akov
Jericho
Mazkeret Batya
Mevaseret Zion
Jerusalem
Almog
Giv'at Ye'arim
Ma'ale Adumim
Al-Ubeidiya
Zekharia
Srigim
Bethlehem
Beit Sahour
Aderet
Surif
Kiryat Gat
Beit Ummar
Beit Ula
Halhul
Ibei HaNahal
Tarqumiyah
Hebron
Dura
Bani Na'im
Negohot
Ein Gedi
Yatta
Khirbat al-Simia
As-Samu

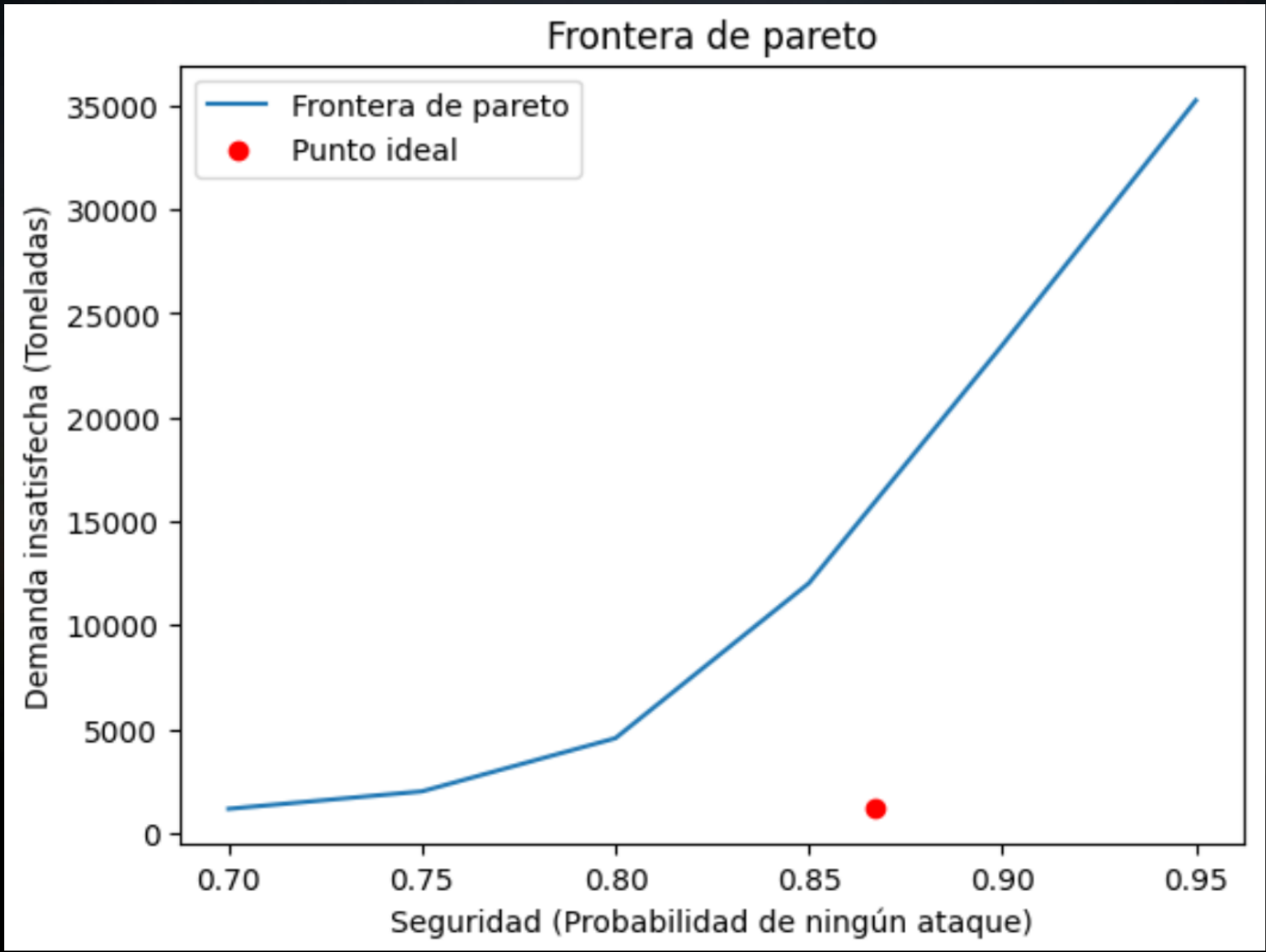

Umm al-Fahm
Or Akiva
Mei-Ami
Al Yamun
Hadera
Umm al-Qutuf
Burqin
Jalbun
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Tirat Zvi
Attil
Palestine
Netanya
Deir al-Ghusun
Beit Imrin
Tubas
Kurayyimah
Qalansawe
Tayibe
Tammun
Tzoran-Kadima
Tira
Samaria
Kafr Abbush
Nablus
Kfar Saba
Jit
Balata
Beit Furik
Ra'anana
Kafr Thulth
Beita
Aqraba
Kafr Bara
Ariel
Tel Aviv
Rosh HaAyin
Qusra
Zaretan
Kfar Sirkin
Salfit
Shilo
Kafr ad-Dik
Ma'ale Efrayim
Holon
Yehud
Abwein
Modi'in-Maccabim-Re'ut
Silwad
Netiv HaGdud
Rishon LeZion
Birzeit
Taybeh
Al-Auja
Rehovot
Modi'in Illit
Ramallah
Jericho
Sha'alvim
Jib
Kokhav Ya'akov
Mazkeret Batya
Mevaseret Zion
Jerusalem
Almog
Giv'at Ye'arim
Ma'ale Adumim
Al-Ubeidiya
Zekharia
Srigim
Bethlehem
Beit Sahour
Aderet
Surif
Beit Ummar
Kiryat Gat
Beit Ula
Halhul
Ibei HaNahal
Tarqumiyah
Hebron
Dura
Bani Na'im
Negohot
Ein Gedi
Yatta
Khirbat al-Simia
As-Samu


Umm al-Fahm
Hadera
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Yenin
Jalbun
Tirat Zvi
Netanya
Palestine
Kalkilia
Tulkarem
Tubas
Kurayyimah
Tzoran-Kadima
Tira
Nablus
Kfar Saba
Balata
Beit Furik
Ra'anana
Kafr Thulth
Aqraba
Tel Aviv
Rosh HaAyin
Kafr Bara
Qusra
Kfar Sirkin
Kafr ad-Dik
Holon
Yehud
Modi'in-Maccabim-Re'ut
Rishon LeZion
Rehovot
Modi'in Illit
Ramallah
Beitunia
Jericho
Mevaseret Zion
Al Bireh
Jerusalem
Shemesh
Abu dis
Beit Jal
Ma'ale Adumim
Al-Ubeidiya
Zekharia
Bethlehem
Beit Sahour
Kiryat Gat
Halhul
Hebron
Sa Ir
Tarqumiyah
Dura
Bani Na'im
Ad Dahir
Idhna
Ein Gedi

Matriz de pagos

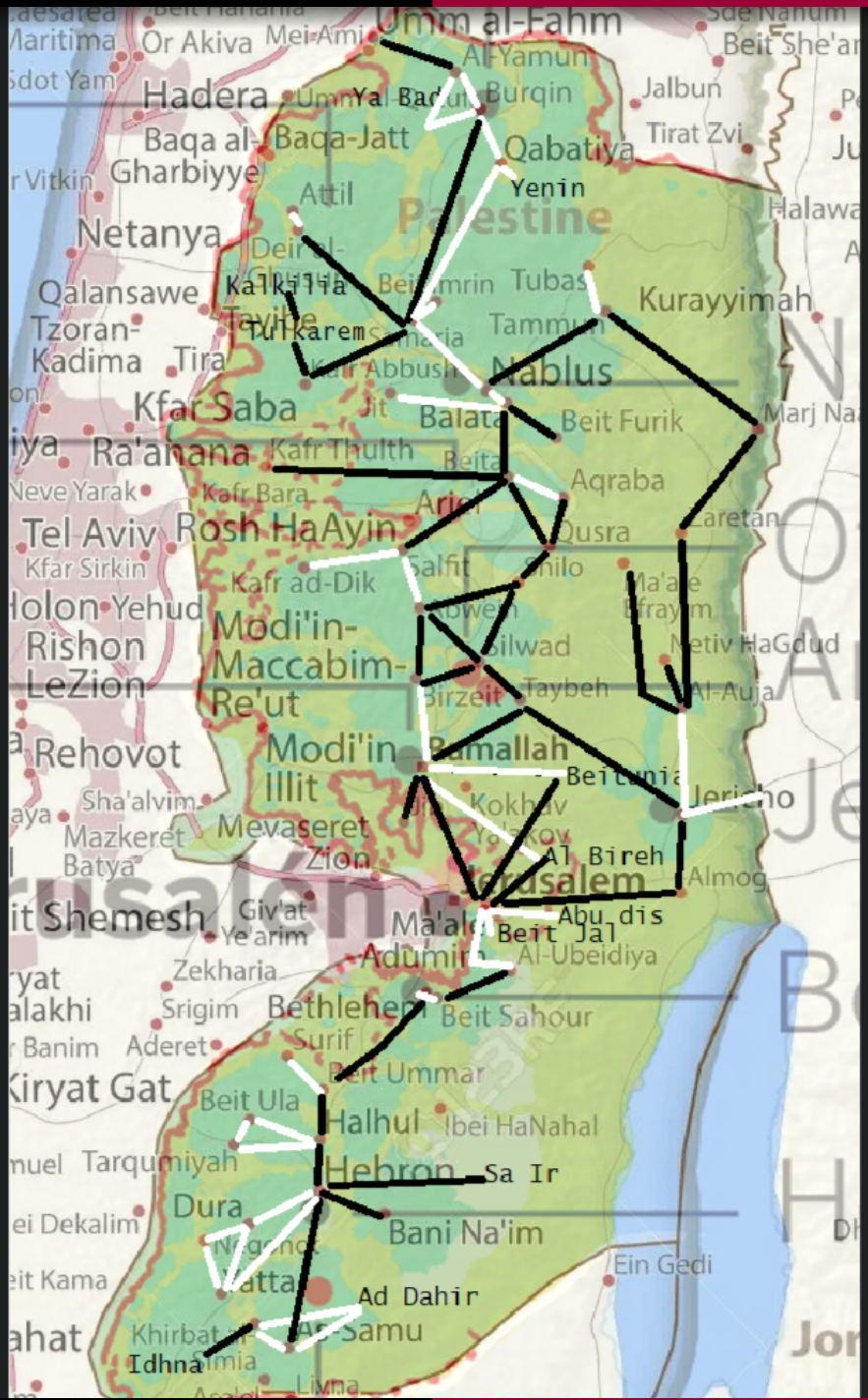
$$\begin{pmatrix} 1156 & 0{,}1078 & 4\,623\,070 & 0{,}795 & 0{,}827 \\ 1156 & 0{,}1078 & 4\,623\,070 & 0{,}795 & 0{,}827 \\ 12436 & 1 & 3\,586\,475 & 0{,}660 & 0{,}713 \\ 12449 & 1 & 3\,617\,682 & 0{,}867 & 0{,}851 \\ 12449 & 1 & 3\,607\,212 & 0{,}799 & 0{,}882 \end{pmatrix}$$

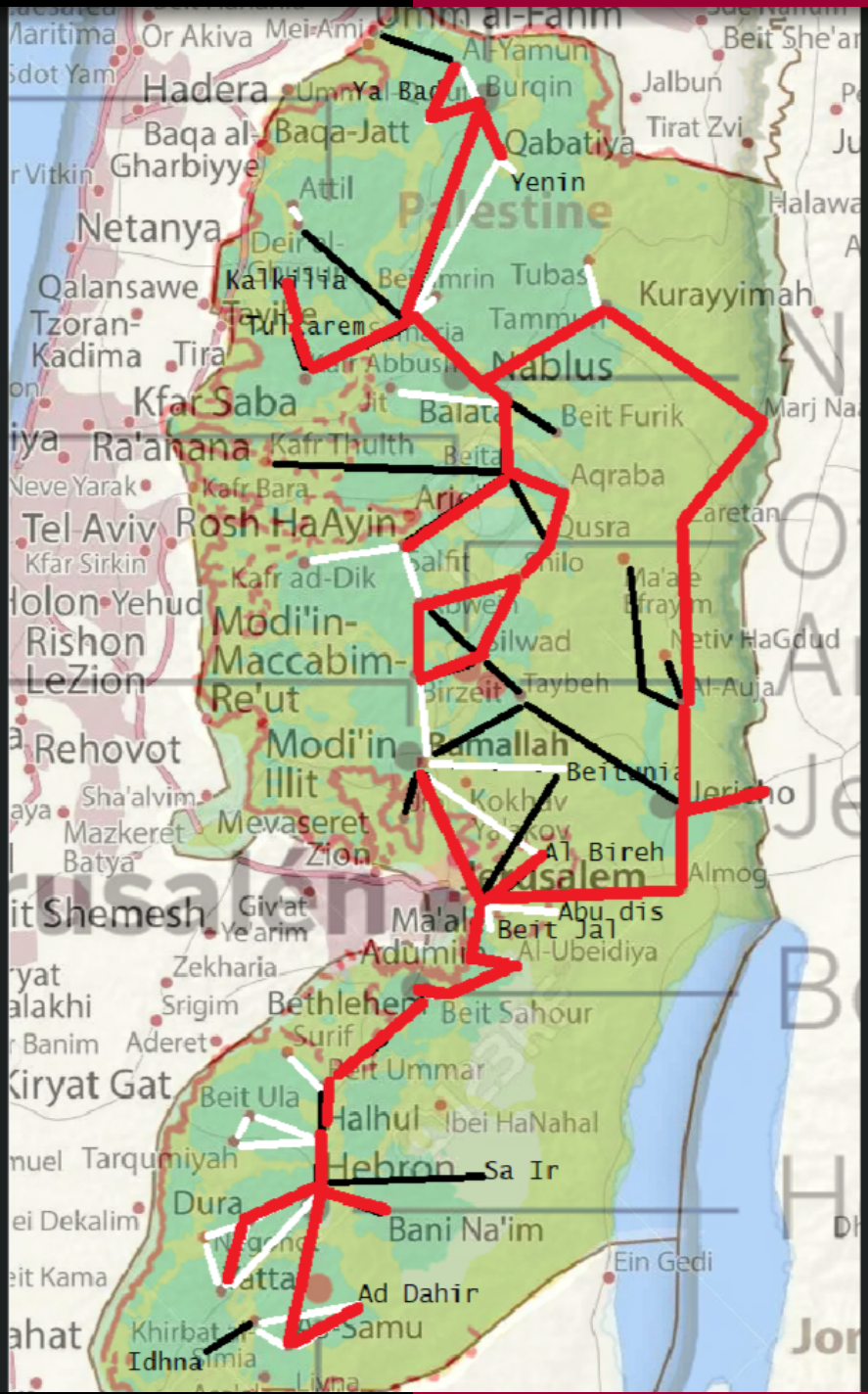

Frontera de pareto
Frontera de pareto
Punto ideal
35000
30000
25000
20000
15000
10000
5000
0
Demanda insatisfecha (Toneladas)
1
2
3
4
5
Presupuesto para el transporte (Millones de USD)


Frontera de pareto
Frontera de pareto
Punto ideal
35000
30000
25000
20000
15000
10000
5000
0
Demanda insatisfecha (Toneladas)
0.70
0.75
0.80
0.85
0.90
0.95
Seguridad (Probabilidad de ningún ataque)

Solución compromiso

Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
12016 T	1	3 681 000 USD	0.850	0.851


Umm al-Fahm
Hadera
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Yenin
Jalbun
Tirat Zvi
Netanya
Palestine
Kalkilia
Tulkarem
Tubas
Kurayyimah
Qalansawe
Tzoran-Kadima
Tira
Nablus
Kfar Saba
Balata
Beit Furik
Ra'anana
Aqraba
Tel Aviv
Rosh HaAyin
Kafr ad-Dik
Modi'in-Maccabim-Re'ut
Rishon LeZion
Rehovot
Modi'in Illit
Ramallah
Jericho
Mevaseret Zion
Al Bireh
Jerusalem
Abu dis
Beit Jal
Shemesh
Ma'ale Adumim
Al-Ubeidiya
Zekharia
Bethlehem
Beit Sahour
Kiryat Gat
Halhul
Hebron
Sa Ir
Dura
Bani Na'im
Ad Dahir
Idhna


Hadera
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Yenin
Jalbun
Tirat Zvi
Netanya
Attil
Palestine
Qalansawe
Kalkilia
Tubas
Kurayyimah
Tzoran-Kadima
Tira
Nablus
Kfar Saba
Balata
Beit Furik
Ra'anana
Kafr Thulth
Aqraba
Tel Aviv
Rosh HaAyin
Kafr Bara
Kfar Sirkin
Kafr ad-Dik
Holon
Yehud
Modi'in-Maccabim-Re'ut
Rishon LeZion
Rehovot
Modi'in Illit
Ramallah
Beitunia
Jericho
Sha'alvim
Mevaseret Zion
Mazkeret Batya
Al Bireh
Jerusalem
Almog
Shemesh
Giv'at Ye'arim
Abu dis
Beit Jal
Ma'ale Adumim
Al-Ubeidiya
Zekharia
Srigim
Bethlehem
Beit Sahour
Aderet
Surif
Kiryat Gat
Beit Ula
Halhul
Ibei HaNahal
Tarqumiyah
Hebron
Sa Ir
Dura
Bani Na'im
Ein Gedi
Ad Dahir
Samu
Idhna

Solución por metas ponderadas 1

Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
8416 T	1	4 112 400 USD	0.814	0.851

Solución por metas ponderadas 1

Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
8416 T	1	4 112 400 USD	0.814	0.851

Solución por metas ponderadas 2

Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
8296 T	0.787	4 142 600 USD	0.663	0.660

Solución por metas ponderadas 1

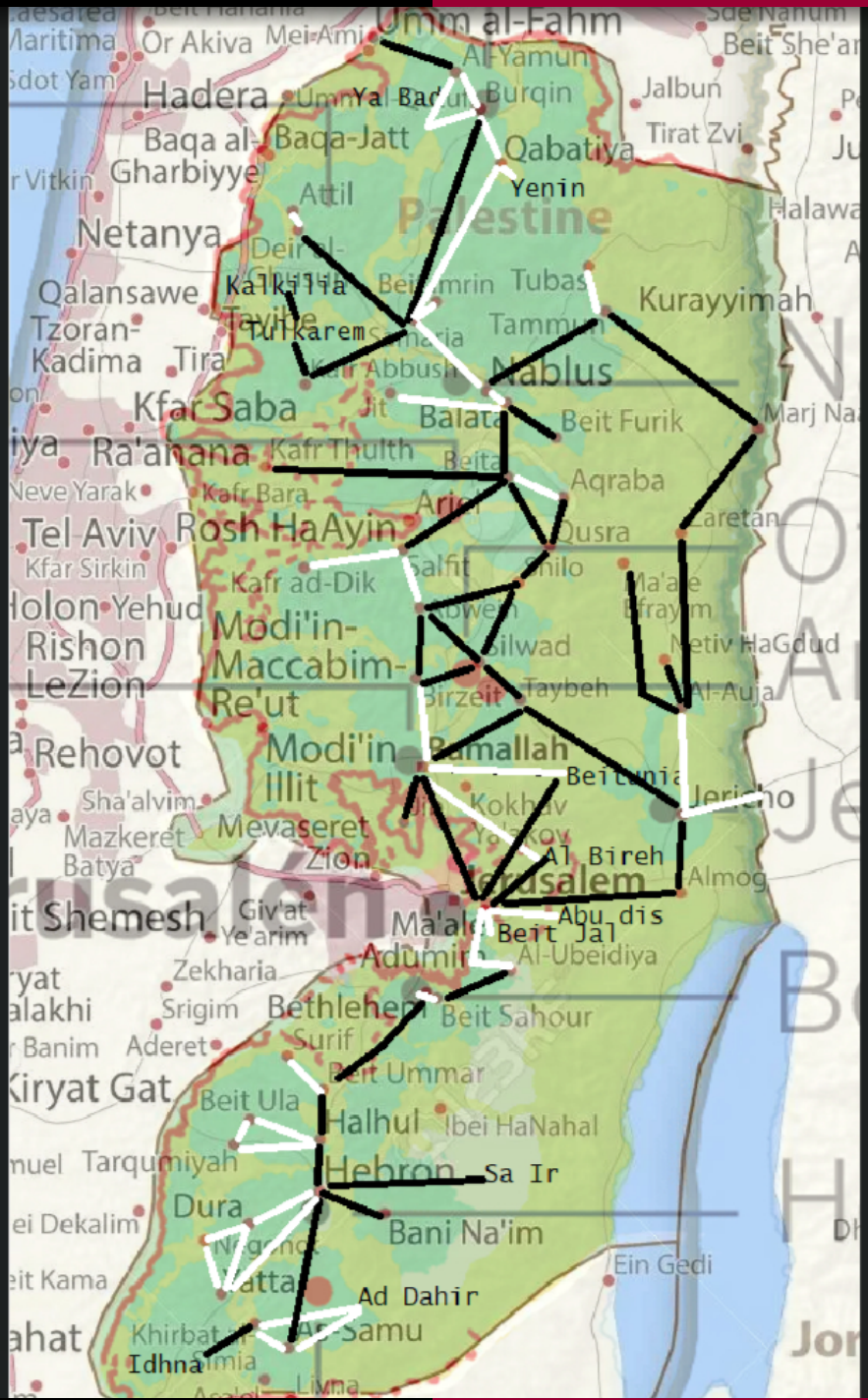
Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
8416 T	1	4 112 400 USD	0.814	0.851

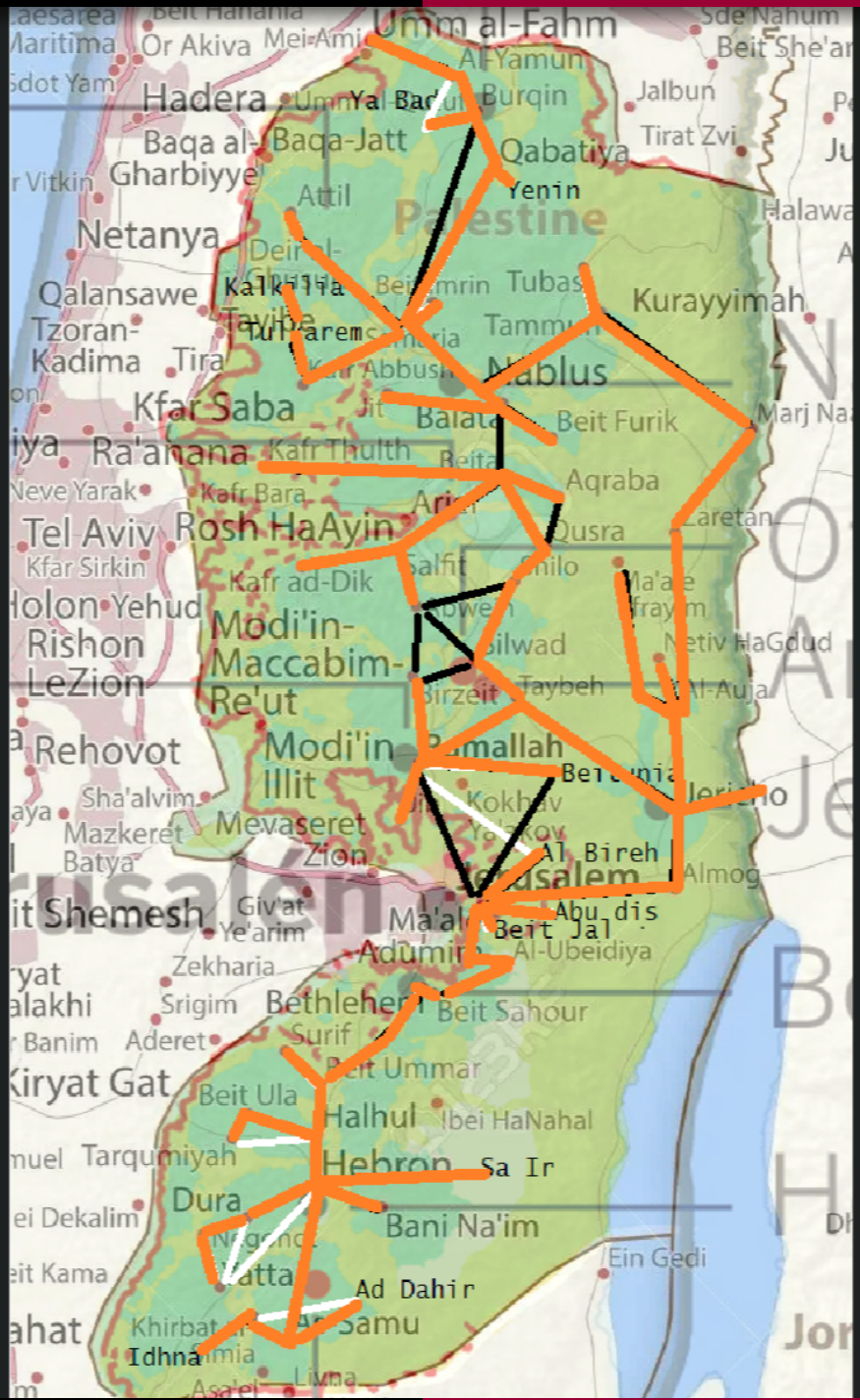
Solución por metas ponderadas 2

Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
8296 T	0.787	4 142 600 USD	0.663	0.660

Solución por metas indexadas

Demanda insatisfecha	Equidad	Coste	Seguridad	Fiabilidad
4200 T	0.120	4 671 100 USD	0.644	0.687


Umm al-Fahm
Hadera
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Yenin
Netanya
Palestine
Kalkilia
Tulkarem
Kurayyimah
Nablus
Kfar Saba
Ra'anana
Balata
Beit Furik
Aqraba
Tel Aviv
Rosh HaAyin
Modi'in-Maccabim-Re'ut
Rishon LeZion
Rehovot
Modi'in Illit
Ramallah
Jericho
Al Bireh
Jerusalem
Abu dis
Beit Jal
Bethlehem
Beit Sahour
Halhul
Hebron
Sa Ir
Dura
Bani Na'im
Ad Dahir
Idhna


Umm al-Fahm
Hadera
Baqa al-Gharbiyye
Baqa-Jatt
Qabatiya
Jalbun
Tirat Zvi
Yenin
Palestine
Netanya
Attil
Qalansawe
Tzoran-Kadima
Tira
Kfar Saba
Ra'anana
Kafr Thulth
Tel Aviv
Rosh HaAyin
Kafr ad-Dik
Holon
Yehud
Modi'in-Maccabim-Re'ut
Rishon LeZion
Rehovot
Modi'in Illit
Ramallah
Sha'alvim
Mevaseret Zion
Mazkeret Batya
Al Bireh
Jerusalem
Shemesh
Giv'at Ye'arim
Abu dis
Beit Jal
Al-Ubeidiya
Zekharia
Srigim
Bethlehem
Beit Sahour
Aderet
Surif
Kiryat Gat
Beit Ula
Halhul
Tarqumiyah
Hebron
Sa Ir
Dura
Bani Na'im
Ein Gedi
Ad Dahir
Idhna
Kurayyimah
Tubas
Nablus
Beit Furik
Aqraba
Kafr Bara
Kokhav Ya'akov
Almog
Beit Ummar
Ibei HaNahal
Livna


Gracias por su atención

Bibliografía I

Morteza Ahmadi, Abbas Seifi, and Behnam Tootooni.
A humanitarian logistics model for disaster relief operation considering network failure and standard relief time: A case study on san francisco district.
Transportation Research Part E: Logistics and Transportation Review, 75, 03 2015.
doi:10.1016/j.tre.2015.01.008.

Wadi Khalid Anuar, M Moll, LS Lee, S Pickl, and HV Seow.
Vehicle routing optimization for humanitarian logistics in disaster recovery: A survey.
In *Proceedings of the International Conference on Security and Management (SAM)*, pages 161–167. The Steering Committee of The World Congress in Computer Science, Computer . . . , 2019.

Arid Ocean Maps.
https://www.aridocean.com/sku-4b83b7-palestine-countryvectormap-
[last visited: 18/06/2023].

Bibliografía II

BM Beamon.
Humanitarian relief chains: Issues and challenges, actes de la conférence proceedings of the 34th international conference on computers and industrial engineering.
San Francisco, USA, 2004.

Bureau of Transportation Statistics.
`https://bts.gov`, [last visited: 16/06/2023].

A Charnes and WW Cooper.
Ww (1961). management models and industrial applications of linear programming.

El País.
`https://elpais.com/internacional/2017/06/01/actualidad/149631908`
, [last visited: 18/06/2023].

Ariel Alexandrino GANASSIM.
A contribuição da logística empresarial para a logística humanitária.
2017.

Bibliografía III

Human Rights Watch / Fanack water.
https://water.fanack.com/publications/water-scarcity-and-the-israeli-occupation-how-territorial-fragmentation-is-stress-in-palestine/, [last visited: 18/06/2023].

Humanitarian needs overview Palestine 2022.
https://www.ochaopt.org/content/humanitarian-needs-overview-2022, [last visited: 16/06/2023].

Gyöngyi Kovács and Karen Spens.
Identifying challenges in humanitarian logistics.
International Journal of Physical Distribution & Logistics Management, 2009.

Chen-Yang y Yuangyai Chumpol y Janjarassuk Udom Kungwalsong, Kanokporn y Cheng.
Programa estocástico de dos etapas para el diseño de redes de la cadena de suministro bajo interrupciones de las instalaciones.
Sostenibilidad, 13(5), Mar 2021.
URL: http://dx.doi.org/10.3390/su13052596, doi:10.3390/su13052596.

Bibliografía IV


F. Liberatore, M.T. Ortuño, G. Tirado, B. Vitoriano, and M.P. Scaparra.
A hierarchical compromise model for the joint optimization of recovery operations and distribution of emergency goods in humanitarian logistics.
Computers Operations Research, 42:3–13, 2014.
Multiple Criteria Decision Making in Emergency Management.
URL: `https://www.sciencedirect.com/science/article/pii/S0305054812000809`, `doi:https://doi.org/10.1016/j.cor.2012.03.019`.


NEOS.
`https://neos-server.org/neos/solvers/index.html`, [last visited: 16/06/2023].


MT Ortuño, P Cristóbal, JM Ferrer, FJ Martín-Campo, S Muñoz, G Tirado, and B Vitoriano.
Decision aid models and systems for humanitarian logistics. a survey.
Decision aid models for disaster management and emergencies, pages 17–44, 2013.

Bibliografía V

MT Ortuño, G Tirado, and B Vitoriano.
A goal programming based decision support system for humanitarian aid distribution.
TOP, 19(2):464–479, 2011.

Kasin Ransikarbum and Scott J. Mason.
Multiple-objective analysis of integrated relief supply and network restoration in humanitarian logistics operations.
International Journal of Production Research, 54(1):49–68, 2016.
arXiv:https://doi.org/10.1080/00207543.2014.977458, doi:10.1080/00207543.2014.977458.

Carlos Romero.
Teoría de la decisión multicriterio: conceptos, técnicas y aplicaciones.
Number 338 ROM. 1993.

Peter Tatham and Martin Christopher.
Humanitarian logistics: Meeting the challenge of preparing for and responding to disasters.
Kogan Page Publishers, 2018.

Bibliografía VI


Satish V Ukkusuri and Wilfredo F Yushimito.
Location routing approach for the humanitarian prepositioning problem.
Transportation research record, 2089(1):18–25, 2008.


Cristina Villalibre Calderón et al.
Concepto de urgencia, emergencia, catástrofe y desastre: revisión histórica y bibliográfica.
2013.


Begoña Vitoriano, M Teresa Ortuño, Gregorio Tirado, and Javier Montero.
A multi-criteria optimization model for humanitarian aid distribution.
Journal of Global optimization, 51:189–208, 2011.


Haijun Wang, Lijing Du, and Shihua Ma.
Multi-objective open location-routing model with split delivery for optimized relief distribution in post-earthquake.
Transportation Research Part E: Logistics and Transportation Review, 69:160–179, 09 2014.
doi:10.1016/j.tre.2014.06.006.

Bibliografía VII

worldpopulationreview . https://worldpopulationreview.com/countries/cities/palestine, [last visited: 16/06/2023].