Ingeniería Industrial
PONTIFICIA UNIVERSIDAD CATOLICA DE VALPARAISO

DOCTORADO EN INGENIERÍA INDUSTRIAL
PONTIFICIA UNIVERSIDAD CATÓLICA DE VALPARAÍSO

Network Design Problems with Traffic Capture

Gabriel Gutiérrez-Jarpa

2020

Overview

- Rapid transit network design with modal competition
- Corridor-based metro network design with travel flow capture
- Bikeways and funiculars network design
- More research if we have more time.

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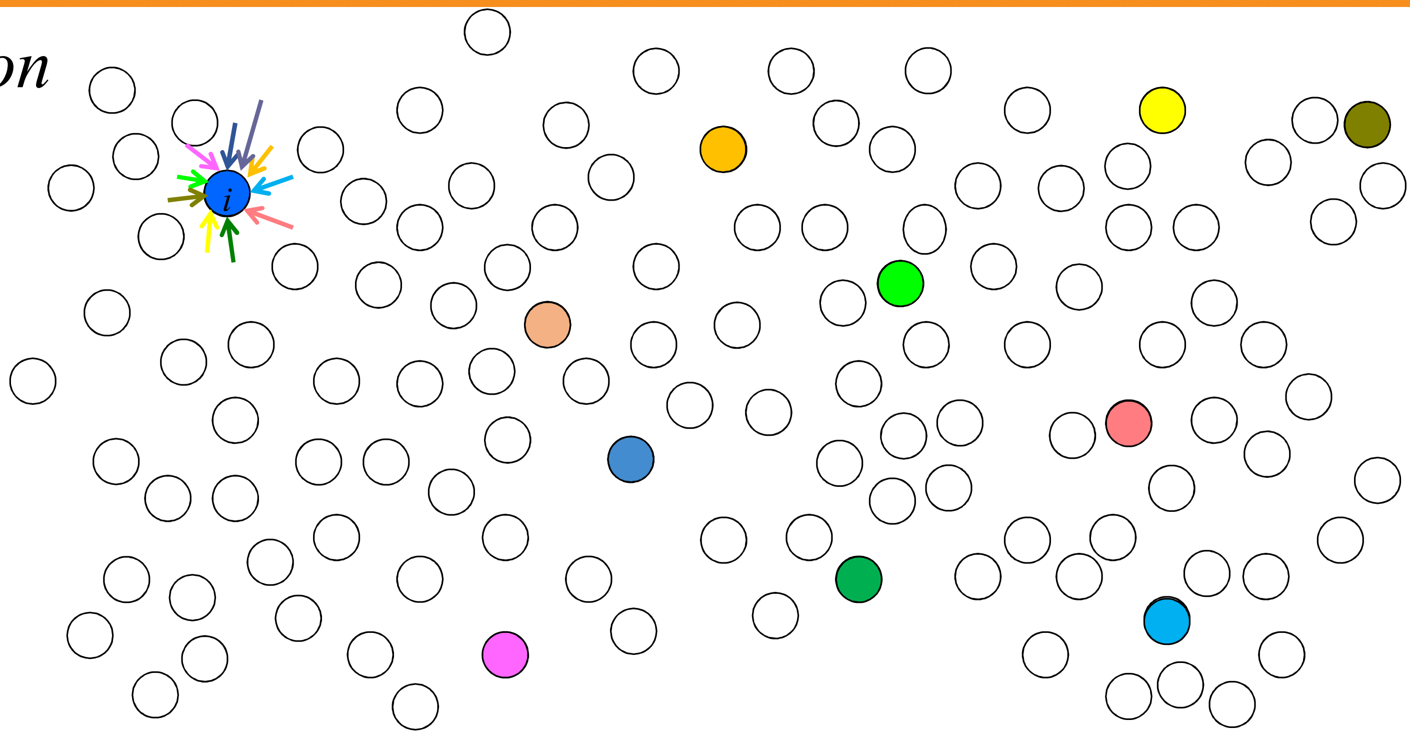
Rapid transit network design with modal competition

Luigi Moccia, Gilbert Laporte, Vladimir Marianov, and Gabriel Gutiérrez-Jarpa

Introduction

Motivation



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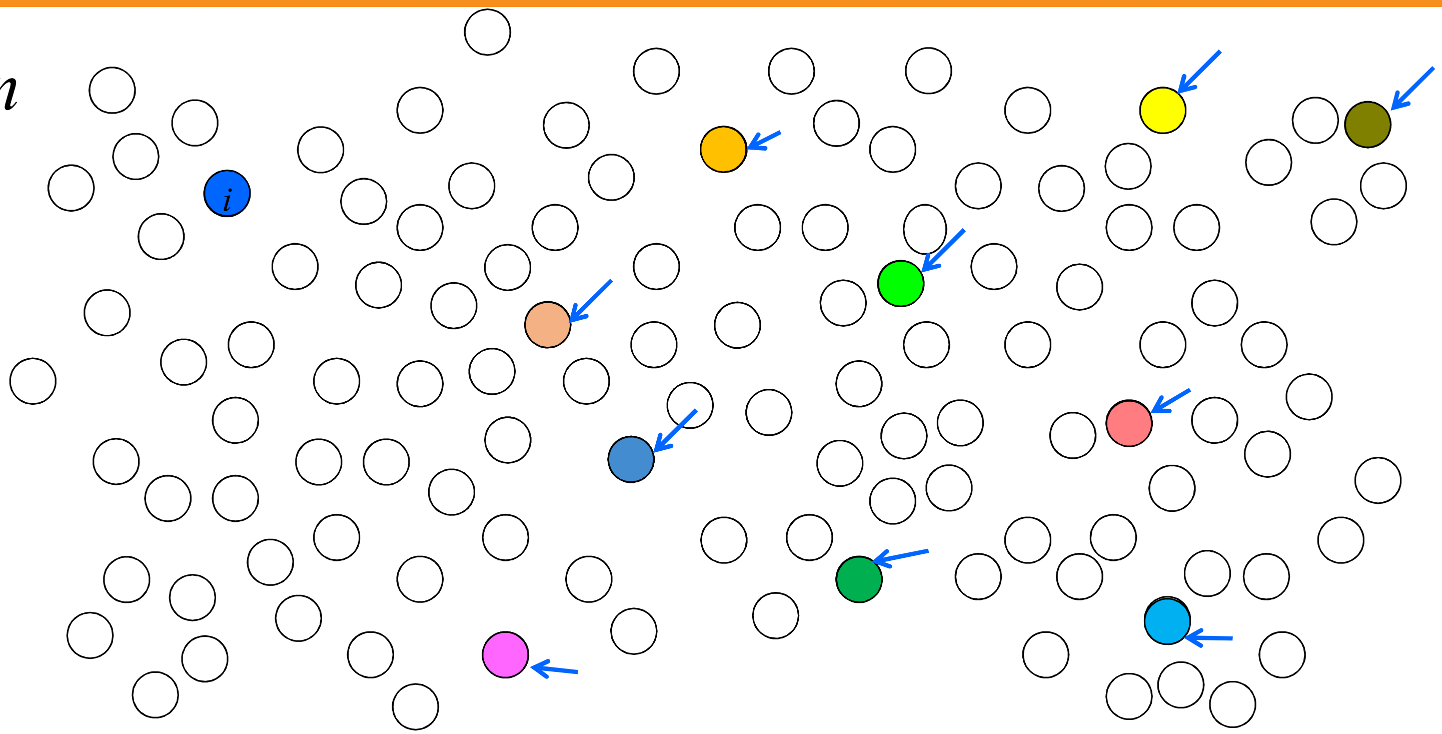

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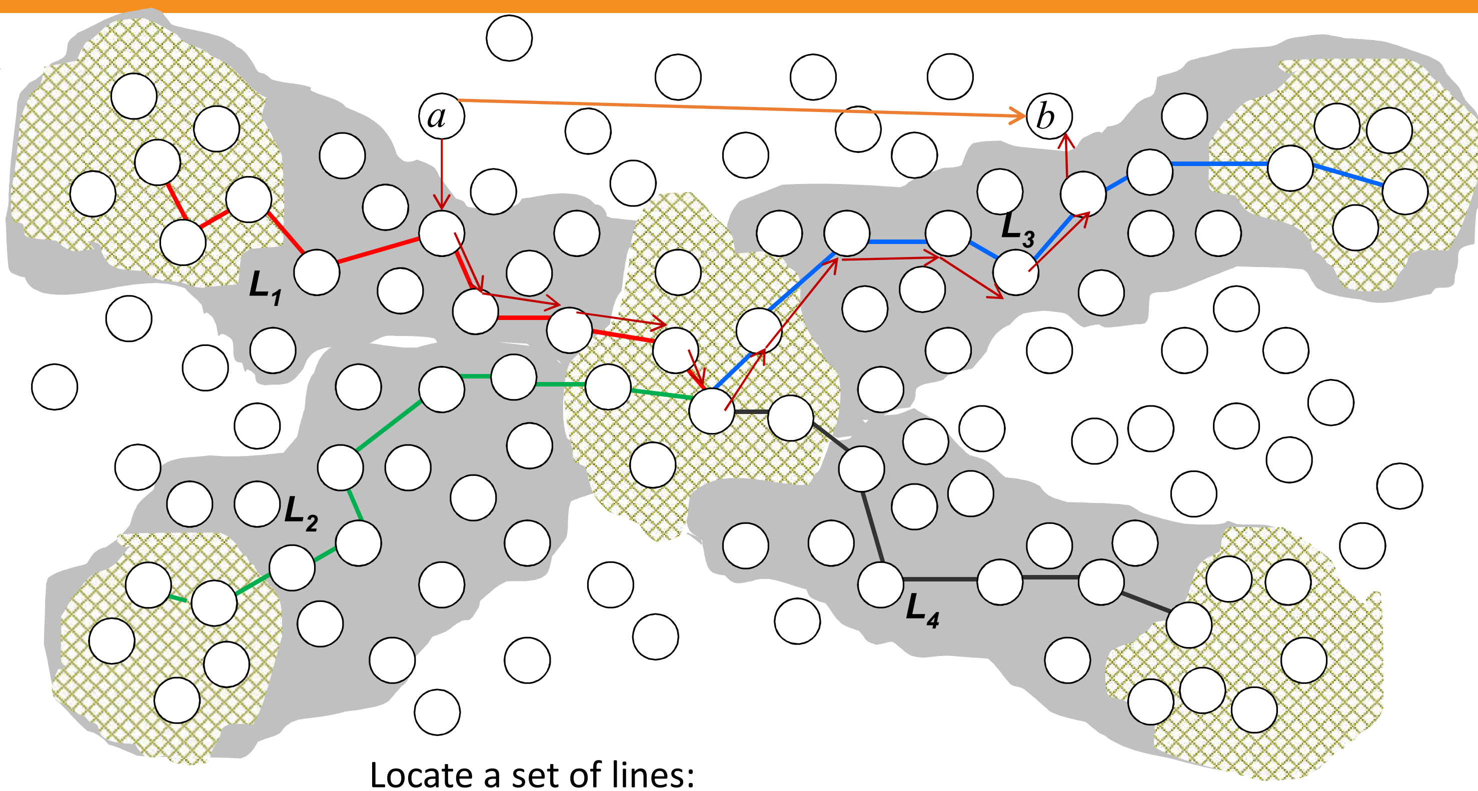

Locate a set of lines:

Maximizing traffic capture, maximizing the time savings of the captured flows, and minimizing total cost (Example: 4 lines.)

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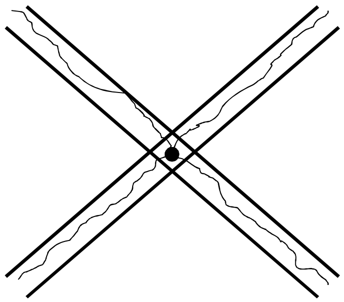
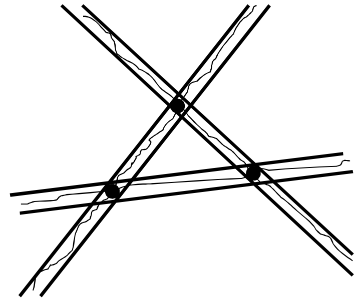
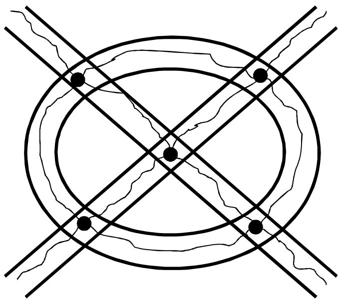


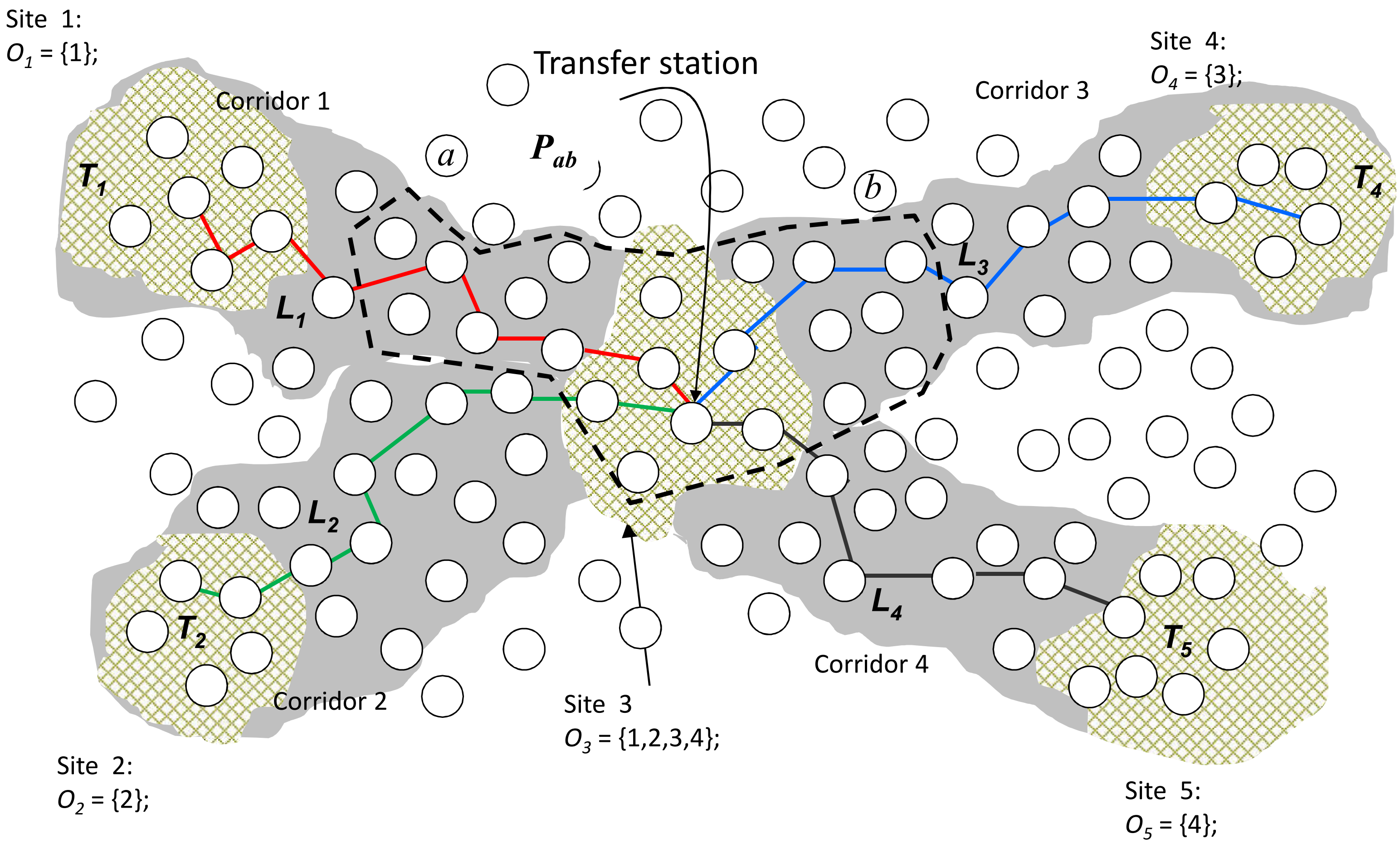
a) Four lines and one transfer point



b) Nine lines and tree transfer points



c) Twelve lines and five transfer points

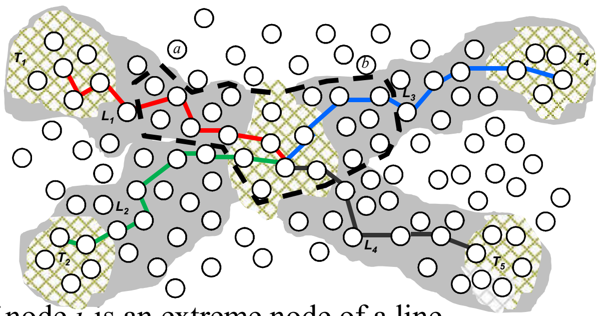


Site 1:
O_1 = {1};
Transfer station
Corridor 1
Site 4:
O_4 = {3};
Corridor 3
T_1
a
P_{ab}
b
T_4
L_1
L_3
L_2
T_2
L_4
T_5
Corridor 4
Corridor 2
Site 3
O_3 = {1,2,3,4};
Site 2:
O_2 = {2};
Site 5:
O_5 = {4};

Formulation of the RTNDC

Let $G(N,E)$, where:

N set of nodes and E set of edges.



Variables of structure

$$x_{ij}^{s}=\begin{cases}1 & \text{If edge } (i,j) \text{ belongs to the line } s\\ 0 & \text{otherwise}\end{cases}$$

$$w_{i}^{s}=\begin{cases}1 & \text{if node } i \text{ is visited by line } s\\ 0 & \text{otherwise}\end{cases}$$

$$z_{ik}=\begin{cases}1 & \text{if node } i \text{ is assigned to station } k\\ 0 & \text{otherwise}\end{cases}$$

$$y_{j}=\begin{cases}1 & \text{if node } j \text{ is an extreme node of a line}\\ 0 & \text{otherwise}\end{cases}$$

$$ws_{i}=\begin{cases}1 & \text{if node } i \text{ is a station}\\ 0 & \text{otherwise}\end{cases}$$

$$wt_{i}=\begin{cases}1 & \text{if node } i \text{ is a transfer station}\\ 0 & \text{otherwise}\end{cases}$$

Variables of traffic captured and Travel Time

$$v_{ij}=\begin{cases}1 & \text{if the demand of traffic between node } i \text{ and } j \text{ is captured}\\ 0 & \text{otherwise}\end{cases}$$

$$r_{ab}=\begin{cases}1 & \text{if travel time difference is positive,}\\ 0 & \text{otherwise}\end{cases}$$

$\beta_{ab}\geq 0,$ the travel time difference between car and transit for a passenger,

Formulation of the RTNDC

Objectives:

$$\text{minimize} \quad Z_c = \sum_{s \in S} \sum_{(i,j) \in E_s} c_{ij} x_{ij}^s + \sum_{i \in N^S} \left(cs_i \, ws_i + ct_i \, wt_i \right)$$

Construction Cost

$$\text{maximize} \quad Z_{ts} = \sum_{a,b \in N : a<b} t_{ab} \beta_{ab}$$

The time savings of the captured flows

$$\text{maximize} \quad Z_p = \sum_{a,b \in N : a<b} t_{ab} v_{ab}$$

Captured flows

$$\sum_{i \in T_k} \sum_{j \in N_s \setminus T_k} \left(x_{ij}^s + x_{ji}^s \right) \geq 1$$

$$\sum_{j \in N_s} \left(x_{ij}^s + x_{ji}^s \right) = 2 w_i^s - y_i$$

$$\sum_{i \in T_k} y_i = 1$$

$$ws_i + wt_i \leq 1$$

$$w_i^s + w_i^m \leq ws_i + 2 wt_i$$

$$\sum_{i,j \in Q} x_{ij}^s \leq \sum_{t \in Q \setminus \{q\}} w_t^s$$

Structure of the network

Formulation of the RTNDC

$$\sum_{k\in N(i)} z_{ik} \leq 1$$

$$z_{ik} \leq \sum_{s\in S} w_k^s$$

Assignment

$$v_{ij} \leq \sum_{k\in N(i)} z_{ik}$$

$$v_{ij} \leq \sum_{k\in N(j)} z_{jk}$$

Traffic capture

$$\beta_{ab} \leq \quad T_{ab} - \left[\sum_{s\in S_{ab}} \sum_{(i,j)\in P_{ab}} \tau_{ij} x_{ij}^s + \sum_{k\in N(\mathrm{a})} \delta_{ak} z_{ak} + \sum_{k\in N(\mathrm{b})} \delta_{bk} z_{bk} + \phi_{ab} \right] + M_{ab}^{-}\left(1 - r_{ab}\right)$$

Time

$$\beta_{ab} \leq M_{ab}^{+} v_{ab}$$

$$v_{ab} \leq r_{ab}$$

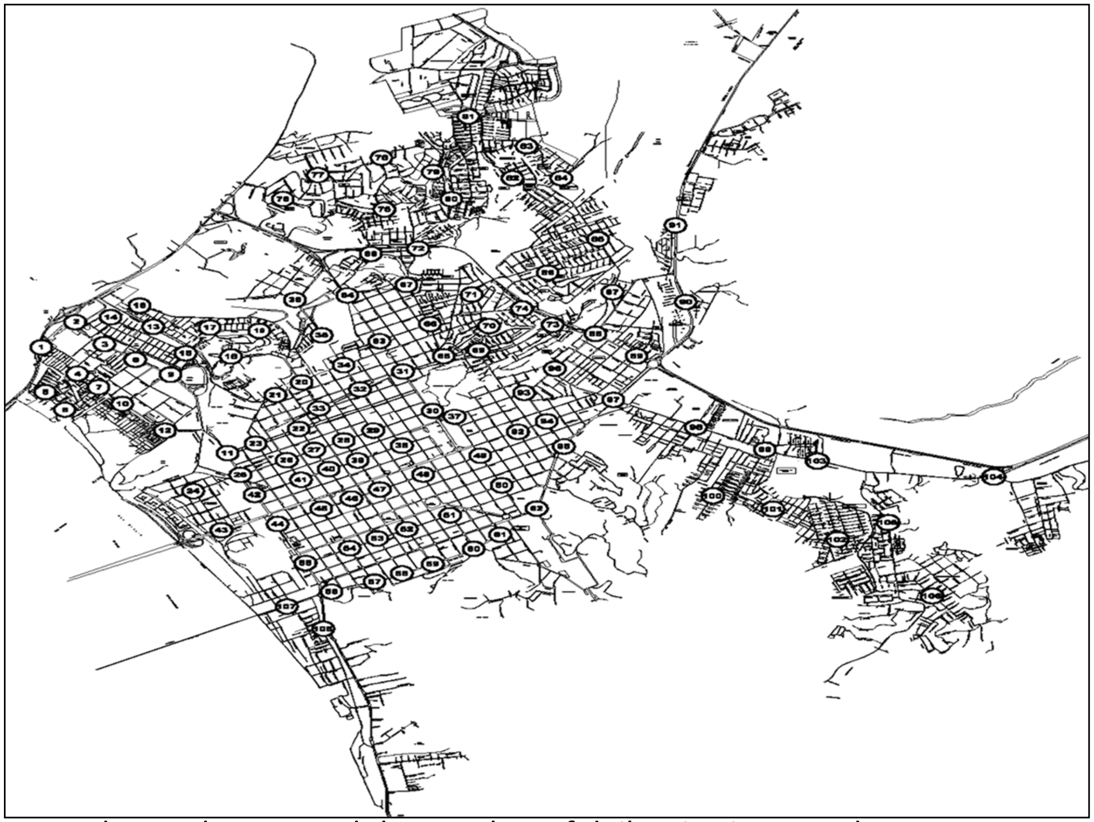
Traffic captured

Value of the variables

Result Concepción, Chile

Concepción City, Chile

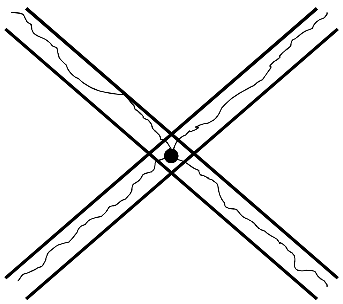
Parameter	Value	Unit of measure
Walking speed	5	km/h
Bus speed	15	km/h
Car speed downtown	10	km/h
Car speed peripheral area	20	km/h
Metro speed	40	km/h
Time length of a metro stop	60	s
Transfer time metro–metro	180	s
Transfer time walk–metro	60	s
Transfer time bus–metro	60	s



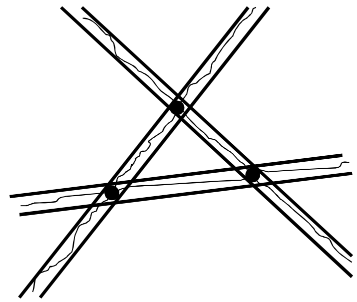
Parameter	Value	Unit of measure
Line cost	60	million US$/km
Station cost	10	million US$ per station
Transfer station cost	25	million US$ per station

108 demand zones and the number of daily trips is around 360,000.

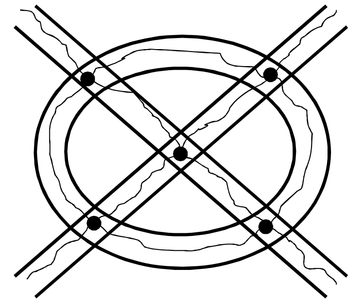
Result Concepción, Chile



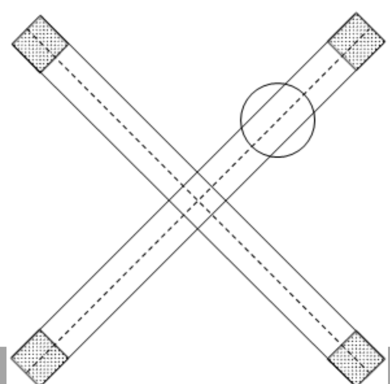
a) Start

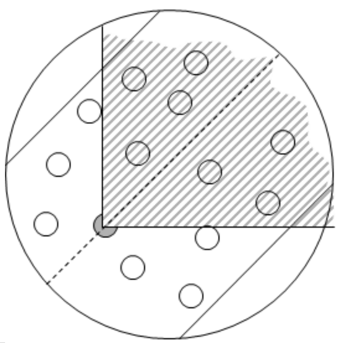


b) Triangle



c) Cartwheel





Candidate stations (hatched area) for the station depicted in grey

Result Concepción, Chile

CPLEX 12.6.1 with AMPL, on a PC Intel Core i7 at 3.4GHz, with 8 GB RAM, and Windows 7 as OS.

$$\text{maximize} \quad Z_{ts} = \sum_{a,b \in N: a<b} t_{ab} \beta_{ab} \qquad (2)$$

Or

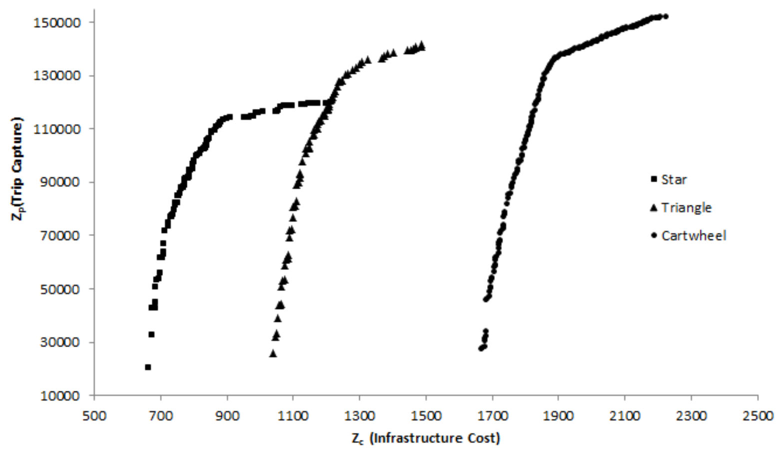
$$\text{maximize} \quad Z_p = \sum_{a,b \in N: a<b} t_{ab} v_{ab} \qquad (3)$$

$$Z_c = \sum_{s \in S} \sum_{(i,j) \in E_s} c_{ij} x_{ij}^s + \sum_{i \in N^S} \left(cs_i \, ws_i + ct_i \, wt_i \right) \leq Z_c^{\max}$$

(4) – (16), value of variables

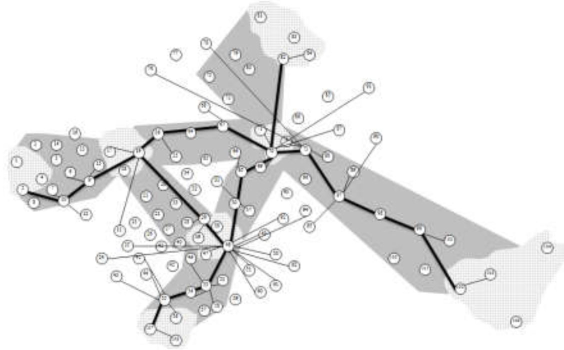
Structure	Number of variables			# constraints	Z_p		Z_{ts}	
	Binary	Continuous	Total		Inst.	Time	Inst.	Time
Star	10,457	3,788	14,245	25,462	55	2,920	12	29,809
Triangle	9,689	3,788	13,477	24,734	51	2,593	12	18,563
Cartwheel	8,966	3,788	12,754	24,029	57	2,249	12	15,756

Results (Z_c v/s Z_p)

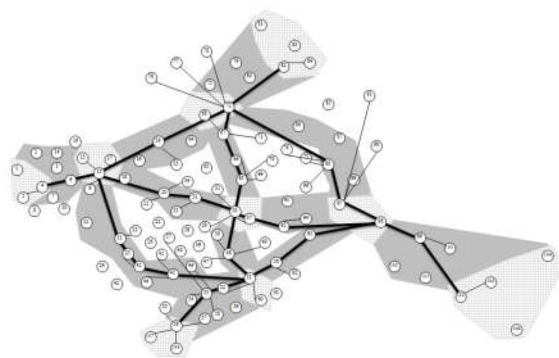


Trade-off curves, Z_p vs Z_c, for the three configurations

Z_p=113,770, Z_c=888, and Z_{ts}=89,452

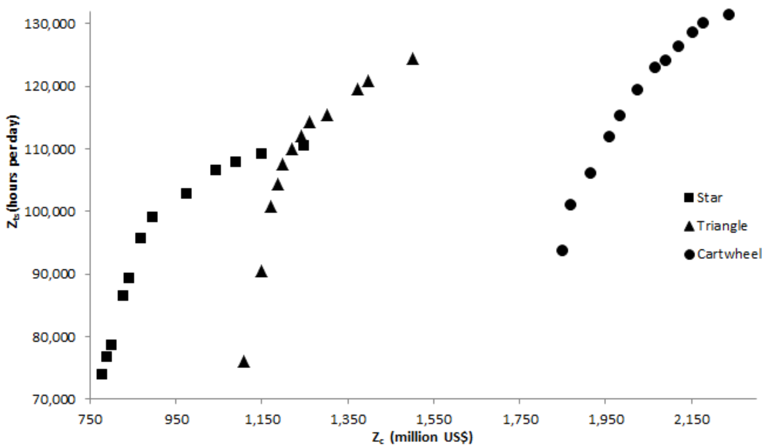


Z_p=135,240, Z_c=1,307, and Z_{ts}=107,366

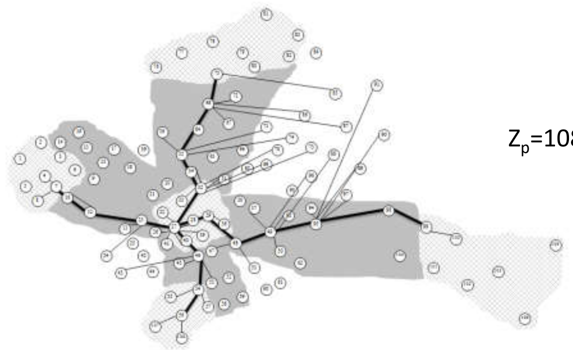


Z_p=138,208, Z_c=1,905, and Z_{ts}=105,040

Results (Z_c v/s Z_{ts})

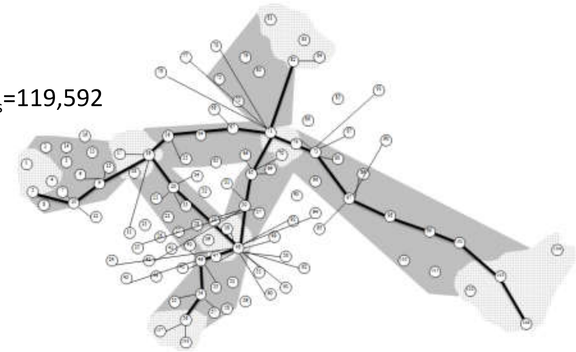


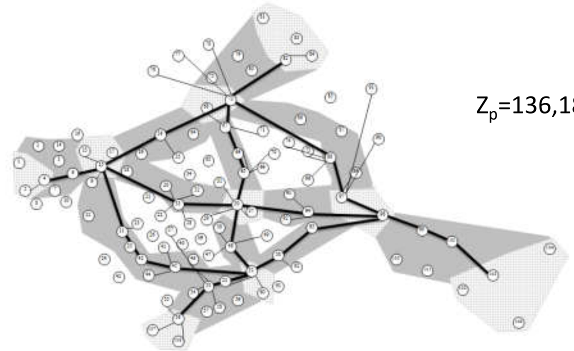
Trade-off curves, Z_{ts} vs Z_c, for the three configurations



Z_p=108,040, Z_c=894, and Z_{ts}=99,191

Z_p=132,978, Z_c=1,372, and Z_{ts}=119,592





Z_p=136,182, Z_c=1,915, and Z_{ts}=105,987

Multi-objective rapid transit network design with modal competition: The case of Concepción, Chile

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Gabriel Gutiérrez-Jarpa, Gilbert Laporte, Vladimir Marianov, Luigi Moccia

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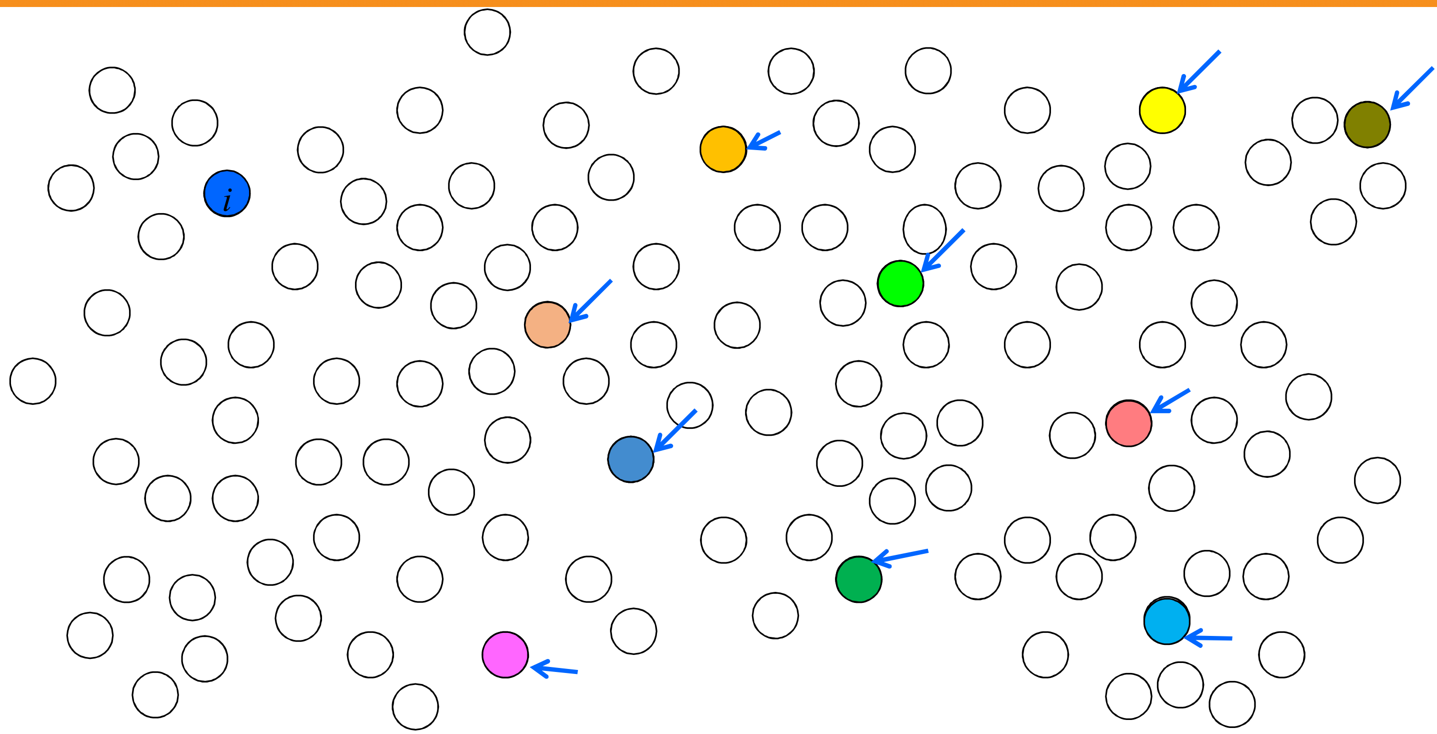
Corridor-based metro network design with travel flow capture

by

Gilbert Laporte, Vladimir Marianov, and Gabriel Gutiérrez-Jarpa

Introduction

Motivation



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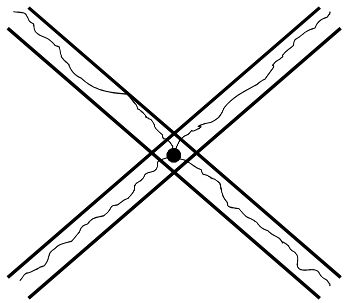

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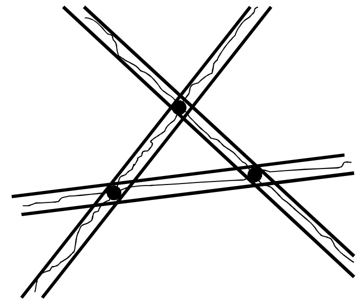

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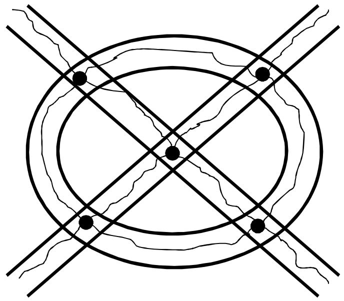


c) Twelve lines and five transfer points

Matheuristic

Stage I: Greedy generation heuristic

For each $(i,j) \in N_{EX}$, compute the travel time between each pair of nodes a, $b \in N_{O/D}$ lying inside the corridor spanned by (i,j)

Compute the traffic capture of each corridor

$S = \emptyset$

repeat

Add those corridors to S for which a set of rules holds,

until No more corridors can be added for which the rules hold.

Stage II: Estimation of O/D travel times, captured traffic and captured O/D pairs

for each O/D pair contained in the corridors in S do

Estimate the travel times between all the O/D pairs in the corridor

if Travel time by metro $\leq$ Travel time by other mode then

O/D pair is candidate to be captured

The traffic volume captured depends on the ratio of travel times by alternative modes

end if

end for

Matheuristic

Stage III: Selection of corridors and adjustment of real capture

repeat

Select the maximum capture subset of corridors using an Integer Programming Formulation (P)

z = *Solution of the IP Formulation*

Recalculate all travel times using the selected corridors, update captured O/D-pairs, and compute z_{actual} = actual capture using selected corridors. For each O/D pair, update capture using the actual capture.

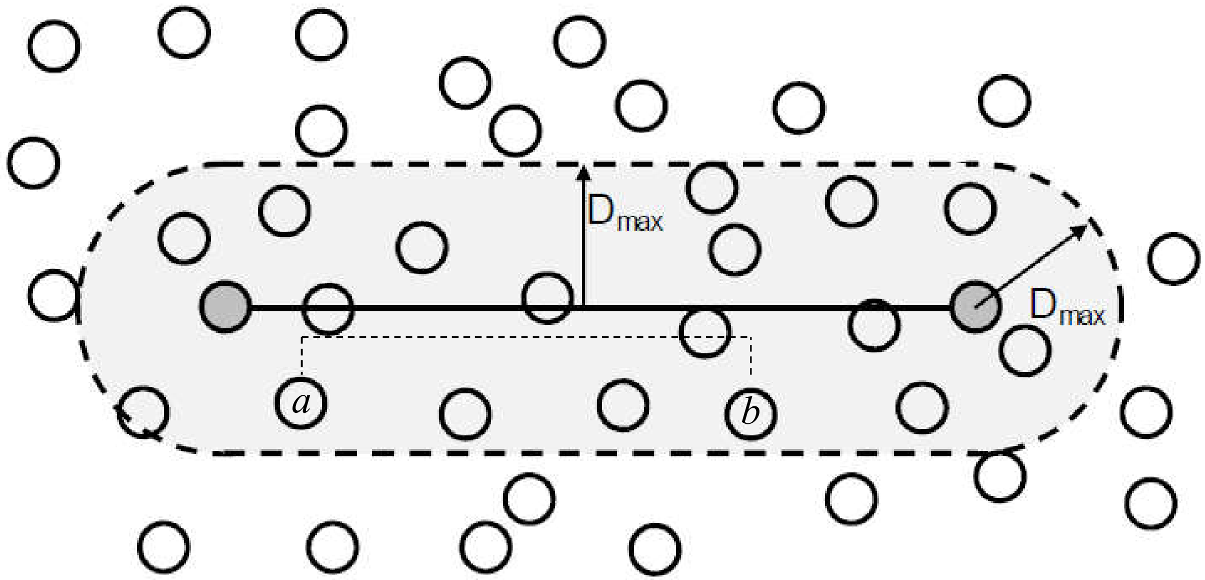
until $|z - z_{actual}|/z \leq \varepsilon$

Stage IV: Opening of transfer stations on corridor crossings

Open new transfer stations at corridor crossings.

Recalculate all travel times, captured OD-pairs demand, and z_{actual}

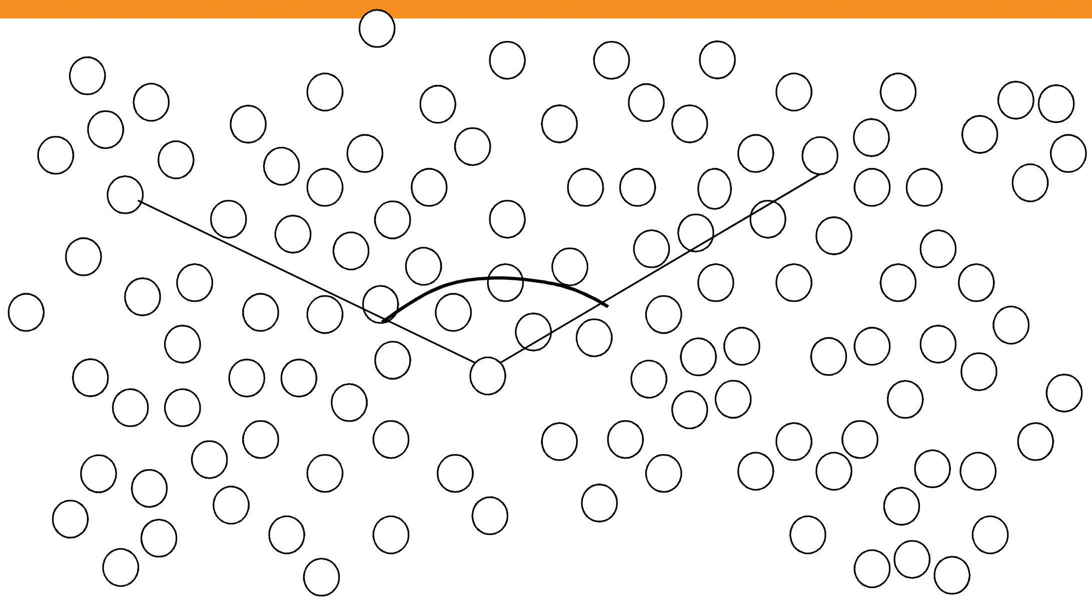
Stage I: Greedy generation heuristic



$$\beta = \frac{\text{Metro\_Time(a,b)}}{\text{Alternative\_Time(a,b)}} \quad (1)$$

$$\%\text{Traffic \_ Captured}\,(a,b) = \begin{cases} 0 & 1.00 < \beta \\ 25 & 0.75 \leq \beta \leq 1.00 \\ 50 & 0.50 < \beta \leq 0.75 \\ 75 & 0.25 < \beta \leq 0.50 \\ 100 & 0.00 < \beta < 0.25. \end{cases} \quad (2)$$

Stage I: Greedy generation heuristic



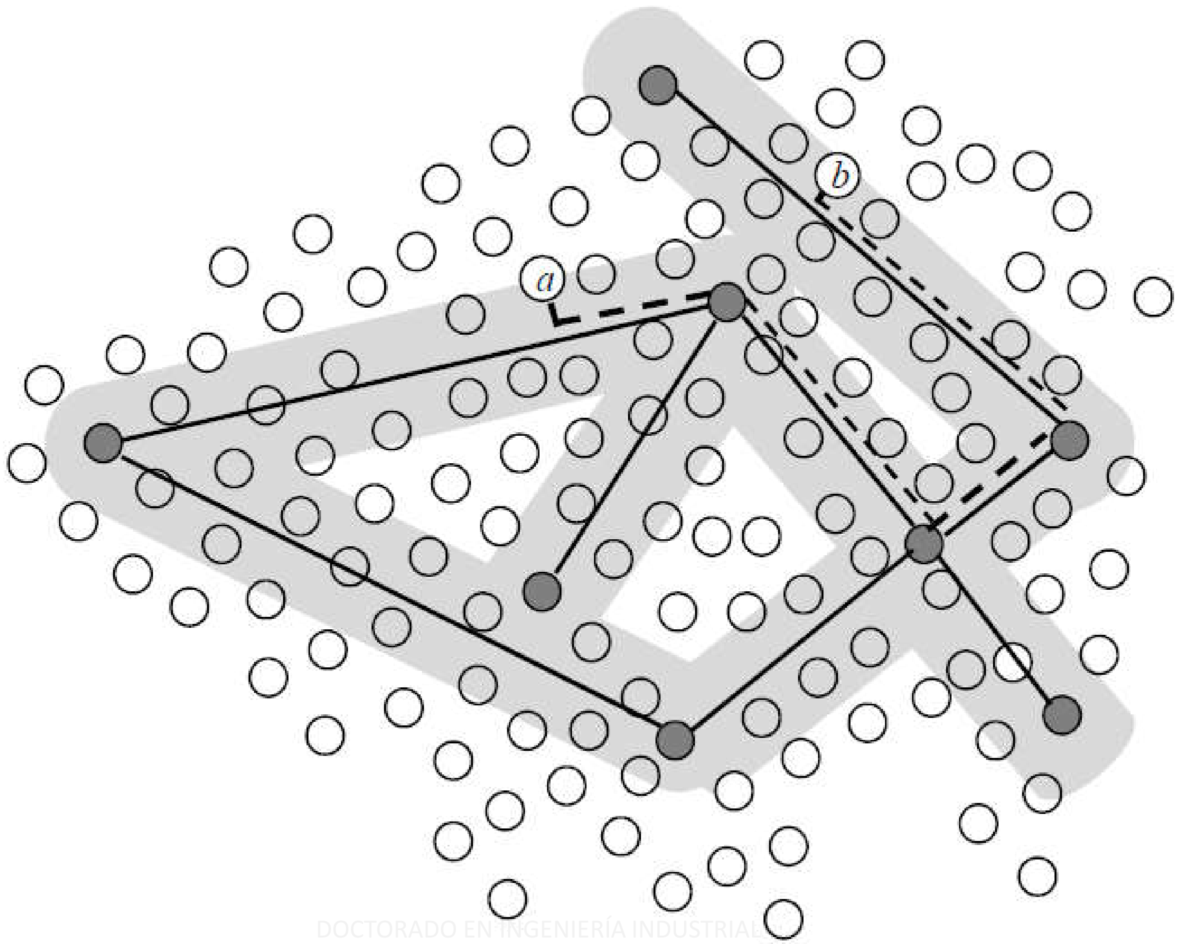
1) At least one of its extremes must coincide with an extreme of a corridor already in S,

2) The angle it makes with any of the other corridors having the same extreme nodes, must be at least equal to a prespecified minimum value θ^{min},

3) Its construction cost plus the total cost of the corridors already in S cannot exceed αC_{max}, where α is an input parameter and C_{max} is a budged, and

4) Adding any other corridor that is feasible in the sense of points 1–3 to the set, instead of s, will not result in a higher captured traffic.

Stage II: Estimation of O/D travel times, captured traffic and captured O/D pairs



Stage III: Selection of corridors and adjustment of real capture

$$(P) \text{ maximize } z = \sum_{(a,b)\in\psi} t_{ab} v_{ab} \quad (3)$$

$$\sum_{s\in S} c_s y_s + \sum_{i\in N_c} g_i w_i \leq C_{max} \quad (4)$$

$$y_s + y_m \leq 1 + w_i \quad i \in N_c, s, m \in P_i \quad (5)$$

$$h_{ms} \leq y_s \quad s, m \in S : s \leq m \quad (6)$$

$$h_{ms} \leq y_m \quad s, m \in S : s \leq m \quad (7)$$

$$r_{ab}^{sm} \leq h_{sm} \quad (a,b) \in \psi, (s,m) \in R_{ab} \quad (8)$$

$$\sum_{(s,m)\in R_{ab}} r_{ab}^{sm} \leq 1 \quad (a,b) \in \psi \quad (9)$$

$$v_{ab} \leq \sum_{(s,m)\in R_{ab}} p_{ab}^{sm} r_{ab}^{sm} \quad (a,b) \in \psi \quad (10)$$

$$\sum_{j\in N_c} f_{0j}^s = y_s \quad s \in S \quad (11)$$

$$\sum_{(t,i_s)\in A_c^0} f_{ti_s}^s + \sum_{(t,j_s)\in A_c^0} f_{tj_s}^s = y_s \quad s \in S \quad (12)$$

$$\sum_{(t,i)\in A_c^0 : t\neq i_s, j_s} f_{ti}^s = \sum_{(i,t)\in A_c^0} f_{it}^s \quad s \in S, i \in N_c : i \neq i_s, j_s \quad (13)$$

$$\sum_{(t,i)\in A_c^0 : t\neq i_s, j_s} f_{ti}^s = \sum_{(i,t)\in A_c^0} f_{it}^s \quad s \in S, i \in N_c : i \neq i_s, j_s \quad (13)$$

$$f_{i_m j_m}^s + f_{j_m i_m}^s \leq y_m \quad s, m \in S \quad (14)$$

$$f_{0j}^s \leq x_j \quad s \in S, j \in N_c \quad (15)$$

$$\sum_{i\in N_c} x_j \leq 1 \quad (16)$$

$$y_m + y_s \leq 1 \quad i \in N_c, m, s \in P_i : \theta_{ms} < \theta^{min} \quad (17)$$

$$y_s \in \{0,1\} \quad s \in S \quad (18)$$

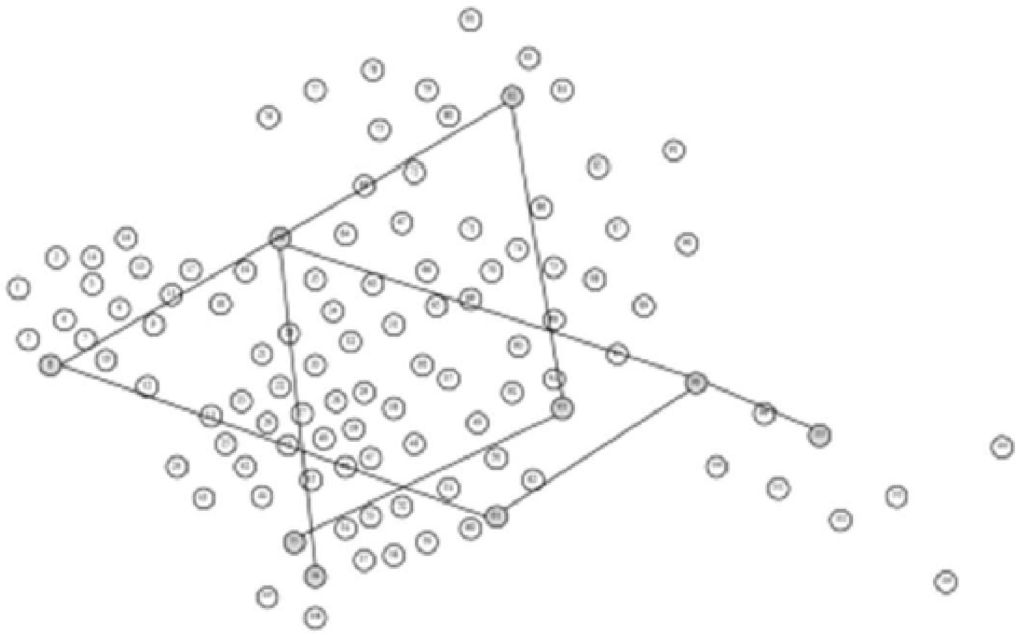
$$w_i \in \{0,1\} \quad i \in N_c \quad (19)$$

$$v_{ab} \in \{0,1\} \quad (a,b) \in \psi \quad (20)$$

$$h_{sm} \in \{0,1\} \quad s, m \in S : s \leq m \quad (21)$$

$$0 \leq f_{ij}^s \leq 1 \quad s \in S, (i,j) \in A_c^0 \quad (22)$$

Stage IV: Opening of transfer stations on corridor crossings



Result Concepción, Chile

Concepción City, Chile

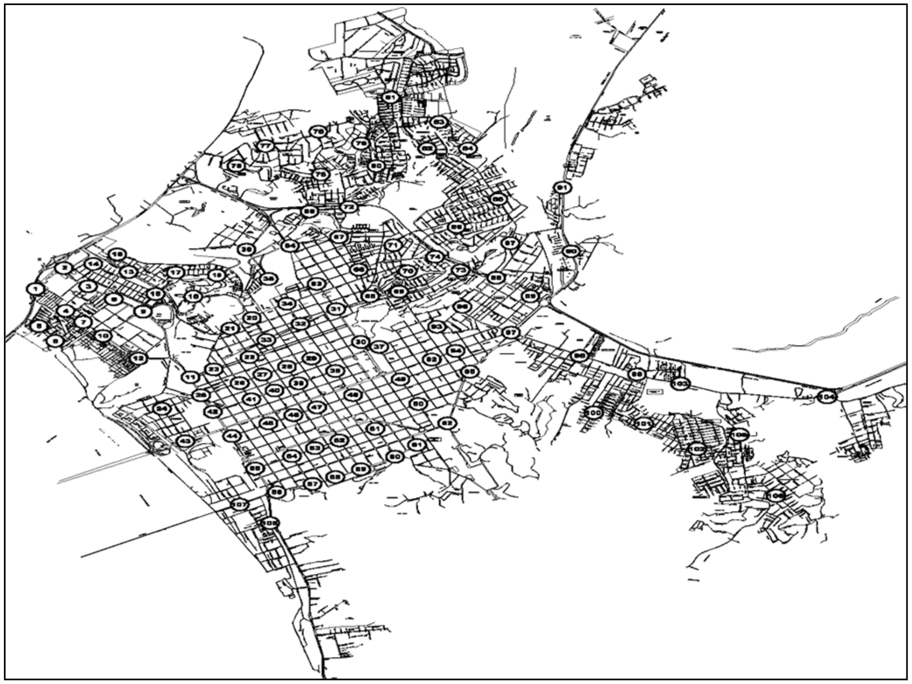


Table 1. Parameters.

Description	Value
D_{max}	500 m
L	500 m
Total time to take the metro	120 s
Transfer time	240 s
Walking speed	4 km/h
Metro speed	60 km/h
Stop time at station	60 s
ϵ	5 %
Line cost	60 millions US$/km
Transfer station cost	25 millions US$

108 demand zones and the number of daily trips is around 360,000.

Solutions

#	θ^{min}	Stage III						Stage IV					s
		C_{actual}	Pr	z_{actual}	z	Er	Itr	NS	g_i	z_{incr}	z_{total}	%C	
1	0	4,340	0.9	120,510	120,510	0	1	5	125	54,646	175,156	45	24.2
2	10	4,537	1	144,894	144,964	0	1	7	175	37,588	182,482	26	27.8
3	20	4,616	1	170,302	170,302	0	1	7	175	43,420	213,722	26	28.1
4	30	4,438	1	163,318	163,318	0	1	6	150	48,894	212,212	30	27.1
5	40	4,494	1	117,188	117,188	0	2	4	100	29,206	146,394	25	34.1
6	50	3,644	0.8	113,688	117,126	2.9	1	4	100	43,080	156,768	38	23.8
7	60	4,077	0.9	124,956	126,892	1.5	1	4	100	39,280	164,236	31	25.6
8	70	2,354	0.5	79,534	79,534	0	1	0	0	0	79,534	0	23.2
9	80	2,950	0.6	89,464	90,570	1.2	1	2	50	11,724	101,188	13	22.6
10	90	3,574	0.8	83,558	87,764	4.8	1	1	25	10,884	94,442	13	22.5
11	100	3,960	0.9	79,480	79,480	0	2	2	50	6,996	86,476	9	35.3
	Av.	3,908	0.8	116,990	117,968	1	1	4	95	29,611	146,601	23	26.8

Table 2. Capture for $\alpha = 2$, $\beta \geq 0.75$.

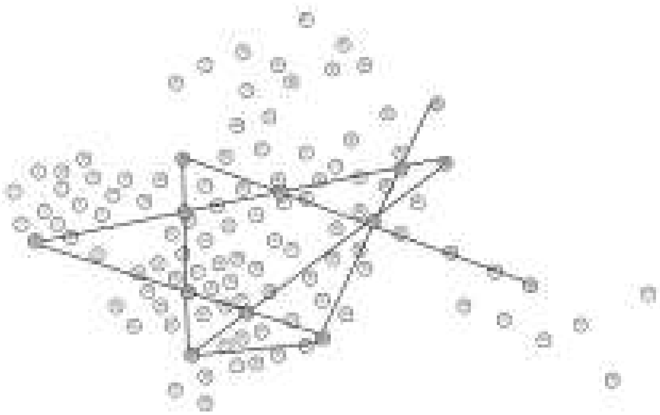
#	θ^{min}	Stage III						Stage IV					s
		C_{actual}	Pr	z_{actual}	z	Er	Itr	NS	g_i	z_{incr}	z_{total}	%C	
1	0	4,570	1	149,942	149,942	0	1	6	150	65,502	215,444	44	76.3
2	10	4,587	1	151,594	153,820	1.4	1	8	200	43,272	194,866	29	81.3
3	20	4,616	1	170,302	170,302	0	1	7	175	43,420	213,722	26	59
4	30	4,556	1	177,420	178,238	0.5	1	7	175	40,084	217,504	23	96.3
5	40	4,354	0.9	118,196	122,224	3.3	1	5	125	47,214	165,410	40	65.6
6	50	4,619	1	156,434	161,444	3.1	1	5	125	60,242	216,676	39	158.7
7	60	4,606	1	130,392	135,048	3.4	2	6	150	47,694	178,086	37	361.7
8	70	4,569	1	117,096	122,466	4.4	4	3	75	39,426	156,522	34	517.9
9	80	4,564	1	140,260	144,906	3.2	3	6	150	42,310	182,570	30	694.9
10	90	4,477	1	123,756	126,906	2.5	4	5	125	40,750	164,506	33	1,908.8
11	100	3,960	0.9	79,480	79,480	0	2	2	50	6,996	86,476	9	36.4
	Av.	4,498	1	137,716	140,434	2	2	5	136	43,355	181,071	31	368.8

Table 4. Capture for $\alpha = 6$, $\beta \geq 0.75$.

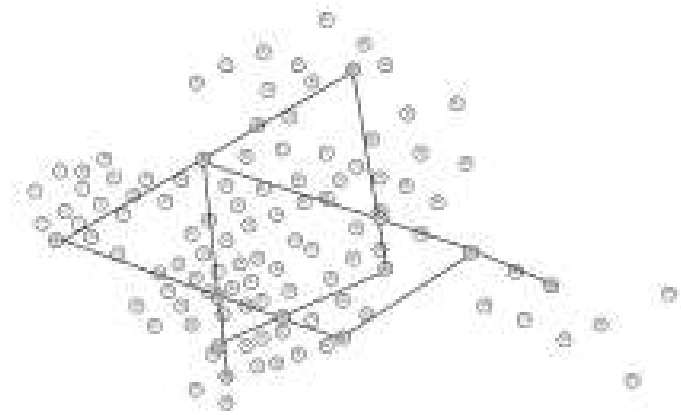
#	θ^{min}	Stage III						Stage IV					s
		C_{actual}	Pr	z_{actual}	z	Er	Itr	NS	g_i	z_{incr}	z_{total}	%C	
1	0	4,471	1	137,056	138,798	1.3	1	10	250	46,700	183,756	34	36.3
2	10	4,537	1	144,894	145,094	0.1	1	7	175	37,588	182,482	26	38
3	20	4,616	1	170,302	170,302	0	1	7	175	43,420	213,722	26	38.2
4	30	4,438	1	163,318	163,318	0	1	6	150	48,894	212,212	30	35.1
5	40	4,569	1	116,986	119,346	2	2	7	175	39,768	156,754	34	52.9
6	50	4,221	0.9	151,186	156,560	3.4	1	4	100	54,770	205,956	36	42.6
7	60	4,606	1	130,392	135,504	3.8	1	6	150	47,694	178,086	37	54.3
8	70	4,569	1	117,096	121,826	3.9	2	3	75	39,426	156,522	34	52.1
9	80	4,542	1	138,916	142,724	2.7	2	4	100	38,502	177,418	28	64.8
10	90	4,437	1	111,590	113,668	1.8	3	7	175	21,214	132,804	19	117.6
11	100	3,960	0.9	79,480	79,480	0	2	2	50	6,996	86,476	9	35.4
	Av.	4,452	1	132,838	135,147	1.7	2	6	143	38,634	171,472	28	51.6

Table 3. Capture for $\alpha = 4$, $\beta \geq 0.75$.

Network structures

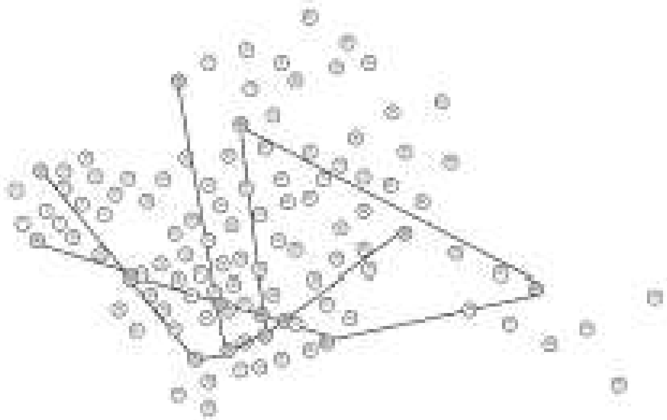


(a) $\theta^{min} = 30$, $\alpha = 2$
$z_{incr} = 48{,}894$, $z_{total} = 212{,}212$

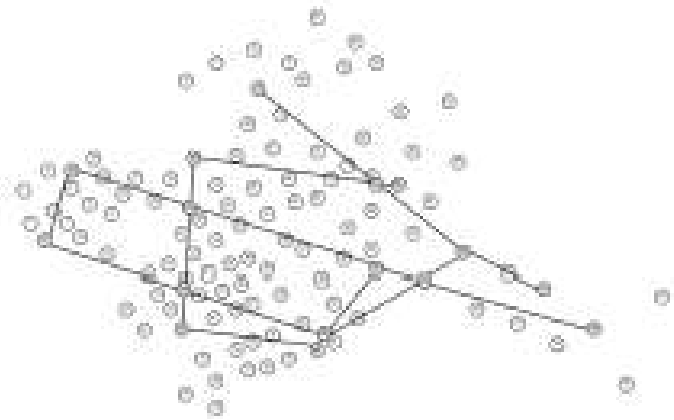


(b) $\theta^{min} = 60$, $\alpha = 2$
$z_{incr} = 39{,}280$, $z_{total} = 164{,}236$

Network structures

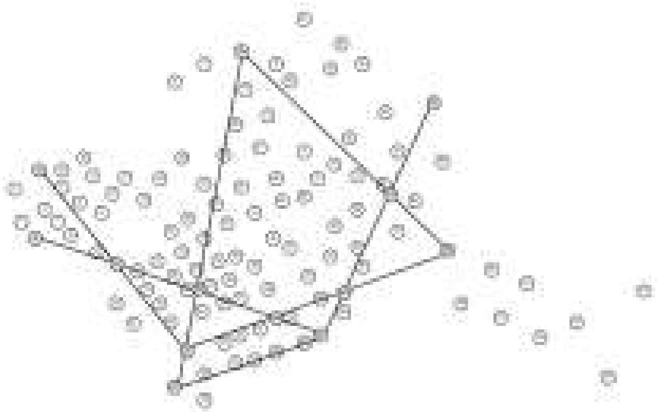


(c) $\theta^{min} = 50$, $\alpha = 4$
$z_{incr} = 54{,}770$, $z_{total} = 205{,}956$

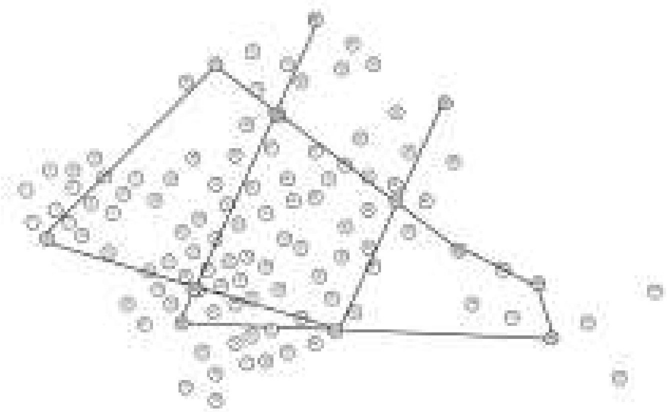


(d) $\theta^{min} = 80$, $\alpha = 4$
$z_{incr} = 38{,}502$, $z_{total} = 177{,}418$

Network structures

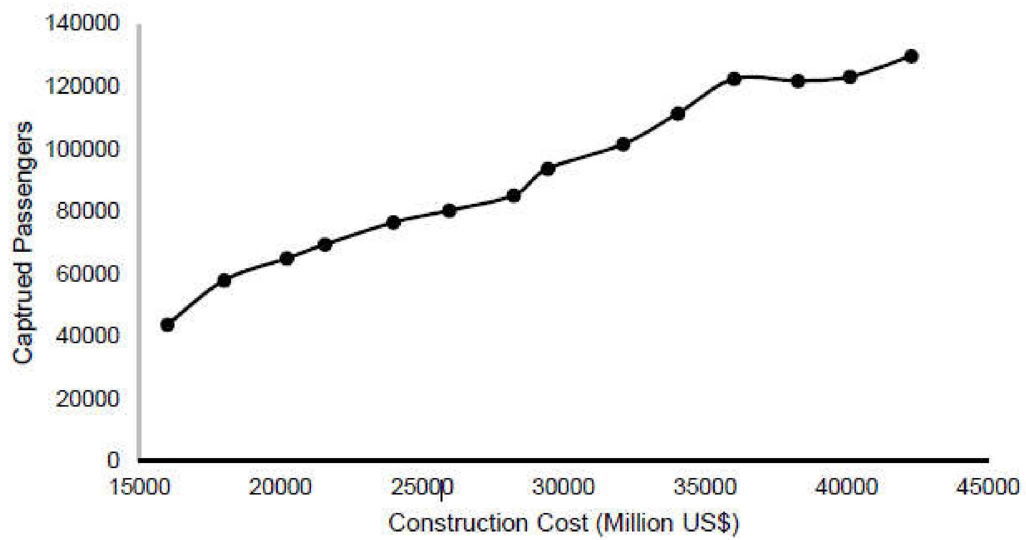


(e) $\theta^{min} = 40$, $\alpha = 6$
$z_{incr} = 47{,}214$, $z_{total} = 165{,}410$



(f) $\theta^{min} = 70$, $\alpha = 6$
$z_{incr} = 39{,}426$, $z_{total} = 156{,}522$

Construction Cost v/s Captured Passengers



Corridor-based metro network design with travel flow capture

Computers & Operations Research, Volume 89, January 2018, Pages 58-67

Gabriel Gutiérrez-Jarpa, Gilbert Laporte, Vladimir Marianov

DOCTORADO EN
INGENIERÍA INDUSTRIAL

Bikeways and funiculars network design

by

Pablo Torrealba, German Paredes and Gabriel Gutiérrez-Jarpa

Motivation

Radio Cooperativa

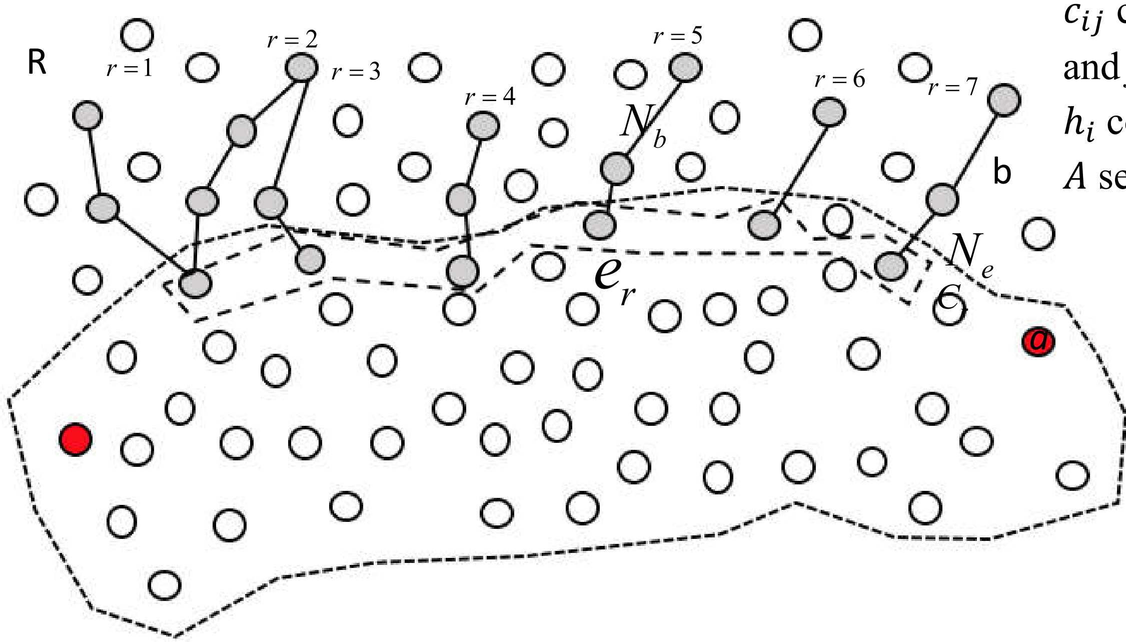
Parkin (2014) and Gonzalo-Orden et al(2014)

Motivation

Google Earth Pro

Formulation

t_{ab} flow between *a* and *b areas*

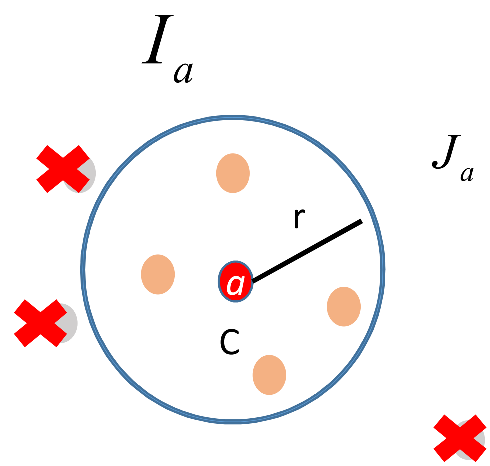


C_r construction cost of funicular r

c_{ij} construction cost of bikeway between stations i and j

h_i construction cost of bike station i

A set of edges



Formulation

$$Min \quad Z_1 = \sum_{(i,j)\in A} c_{ij}x_{ij} + \sum_{r\in R} C_r y_r + \sum_{i\in N_b} h_i g_i$$

$$Mix \quad Z_2 = \sum_{(a,b)\in\Psi} t_{ab}v_{ab}$$

$$\sum_{(i,j)\in A} x_{ij} \geq \sum_{i\in N_b}(g_i + w_i) - 1 \qquad (3)$$

$$\sum_{j/(i,j)\in A} x_{ij} + \sum_{j/(j,i)\in A} x_{ij} \geq g_i + w_i \qquad \forall i \in N_b \qquad (4)$$

$$\sum_{j/(i,j)\in A} x_{ij} + \sum_{j/(j,i)\in A} x_{ij} \leq |M_i| g_i + w_i \qquad \forall i \in N_b \qquad (5)$$

$$g_i + w_i \leq 1 \qquad \forall i \in N_b \qquad (6)$$

$$y_r \leq g_{e_r} \qquad \forall r \in R \qquad (7)$$

$$v_{ab} \leq \sum_{i\in I_a} g_i + \sum_{r\in J_a} y_r \qquad \forall (a,b) \in \Psi \qquad (8)$$

$$v_{ab} \leq \sum_{i\in I_b} g_i + \sum_{i\in J_b} y_r \qquad \forall (a,b) \in \Psi \qquad (9)$$

$$\sum_{i\in S, j\in S:(i,j)\in A} x_{ij} \leq |S| - 1 \qquad \forall S \subseteq N_b / |S| > 2 \qquad (10)$$

Binary value of decision variables

Formulation

$$\sum_{\substack{i \in S, j \in S \\ /(i,j) \in \mathcal{A}}} x_{ij} \leq |S| - 1 \qquad ; \forall S \subset N_b / 3 \leq |S| < |N_b| \qquad (9)$$

- Branch and Cut Method
- Separation algorithm to identify subtours constraints

Study Case: Valparaíso city, Chile

http://www.sectra.gob.cl/encuestas_movilidad/encuestas_movilidad.htm

220 demand zones and the number of daily trips is around 835,000

Study Case: Valparaíso city, Chile

Network

Nodes located in hills

Extreme nodes of the funiculars

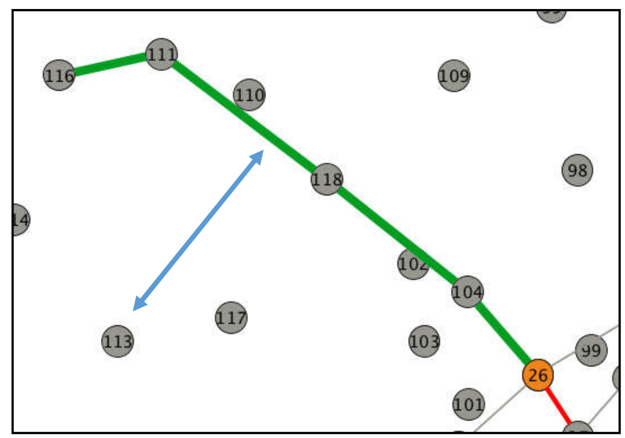
Potential nodes to locate bike stations

Study Case: Valparaíso city, Chile

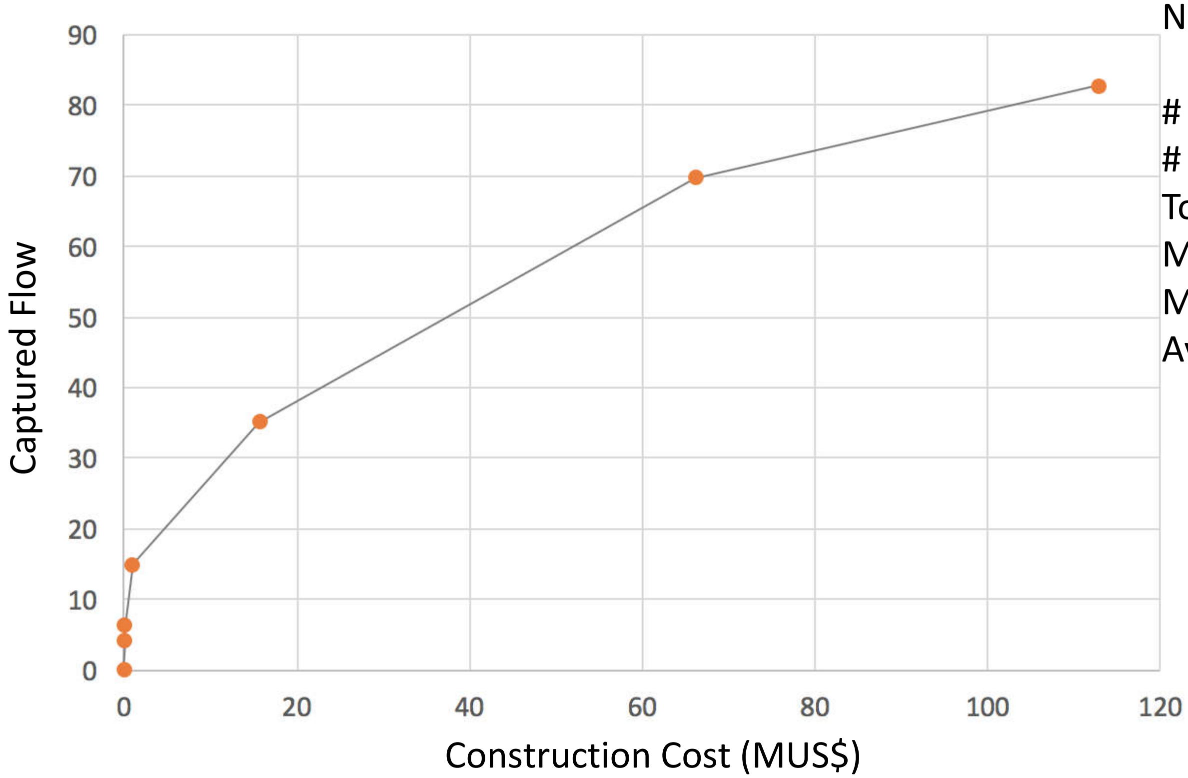
Bikeways

Funiculars

- Each funicular includes stop stations
- The distance between a node and a funicular was calculated using google map.



Preliminary results

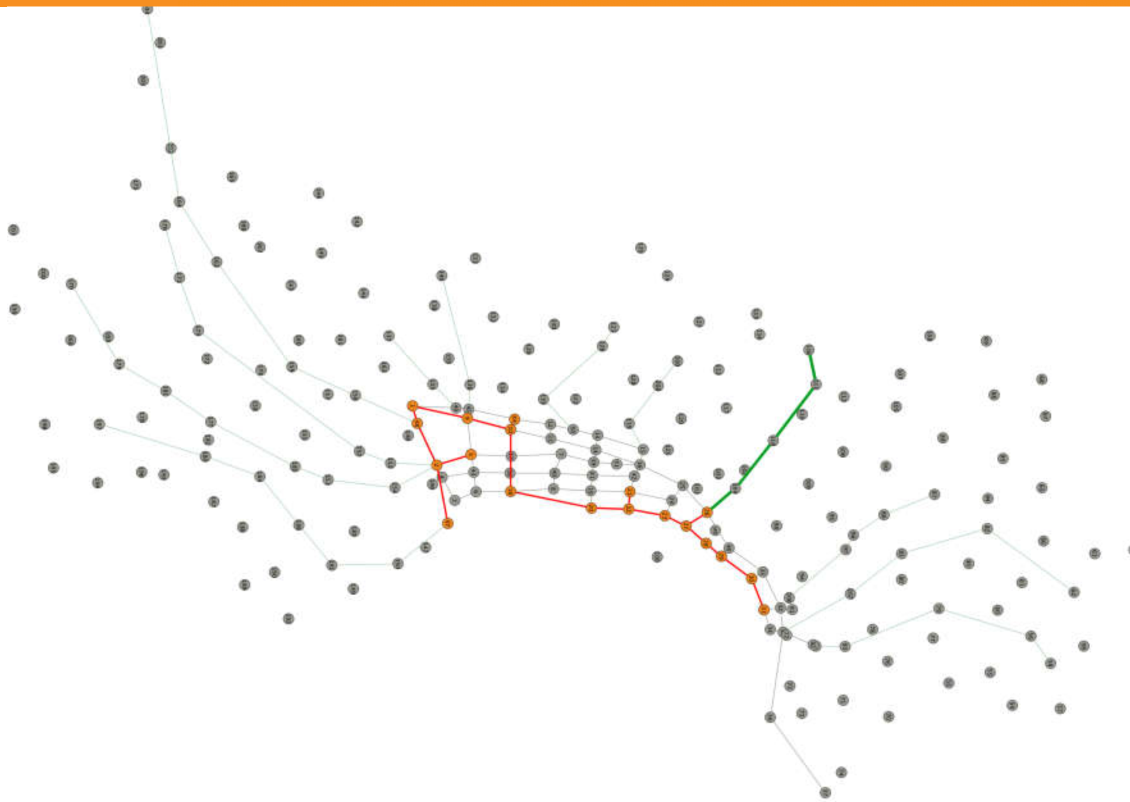


NISE Method to identify non-inferior solutions.

non-inferior solutions : 9
solved Instances : 12
Total Time (s): 81,048.
Maximum : 25,200
Minimum: 3,001
Average time : 6,754

Eclipse IDE for Java Developers, Version: Oxygen.1a Release (4.7.1a)
CPLEX 12.8.0 with AMPL, on a PC Intel Core i7-4770CPU, with 8 GB RAM, and Windows 7 as OS.

Preliminary results



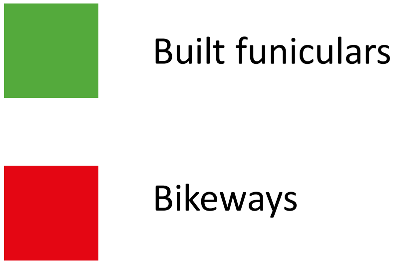
- Time: 3389.227 seconds
- Construction cost: 15.691 [MUS$]
- Flow captured: 351,130 travels

Built funicular

Bikeways

Preliminary results

- Time: 3029,227   seconds
- Construction cost: 66.1479 [MUS$]
- Flow captured: 698,280 travels



Preliminary results

- Time: 25,200 seconds
- Construction cost: 112.759 [MUS$]
- Flow captured: 827,820 travels

Built funiculars

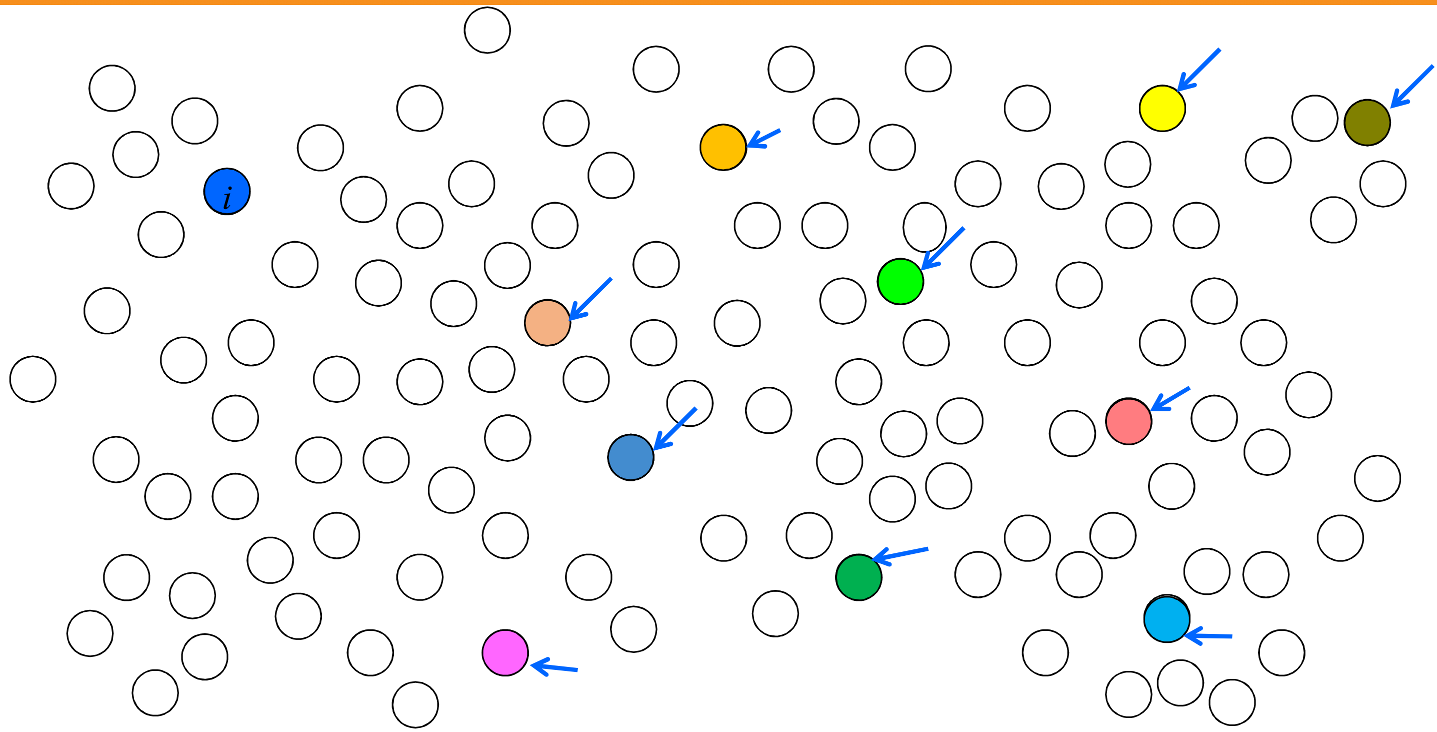
Bikeways

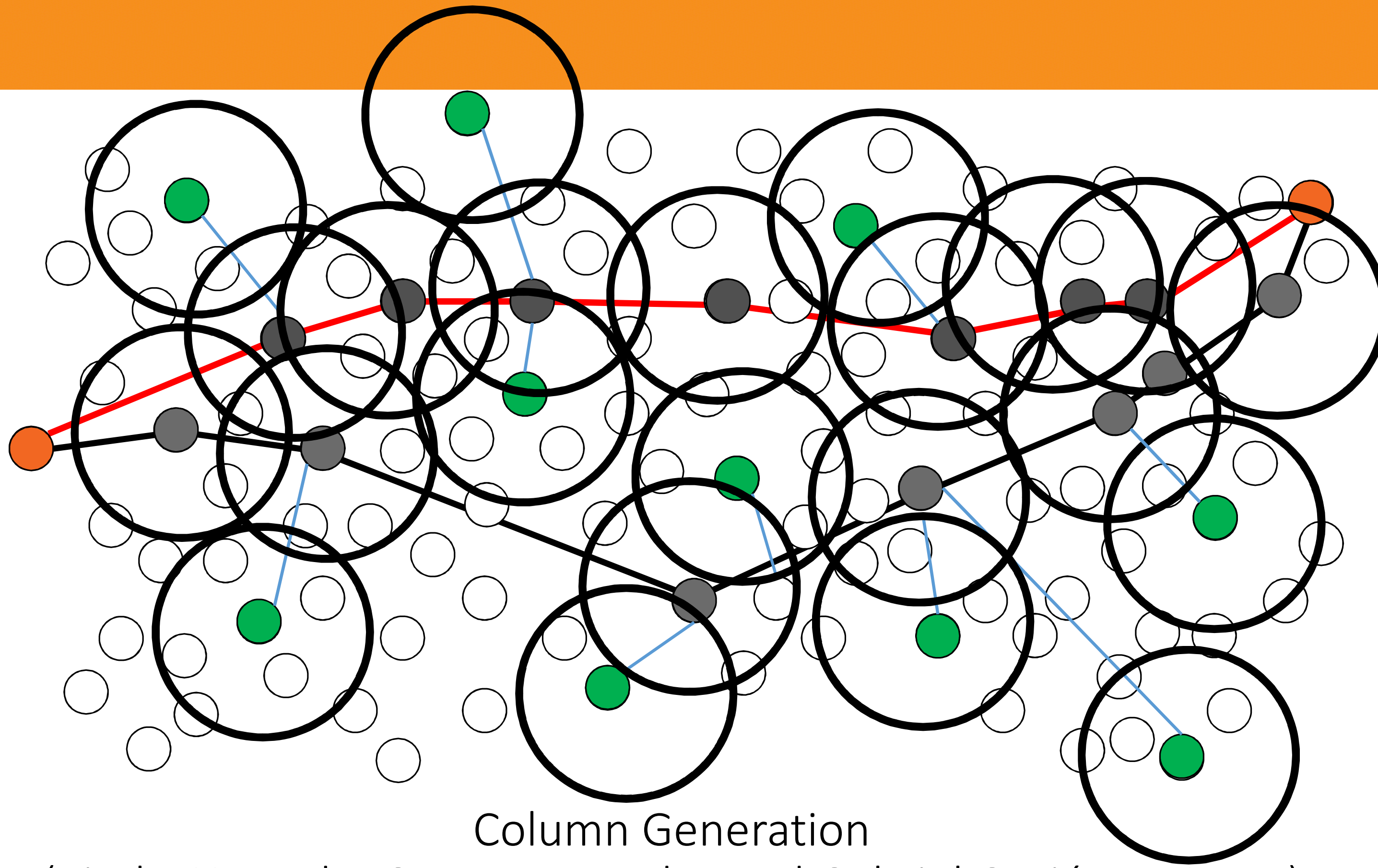
Conclusion and future research

- A first formulation was presented for bikeways and funiculars network design.
- The average time to solve the instances is too large.

FUTURE RESEARCH

- e-constraints method to identify more non-inferior solutions.
- Include competition to design the network (bus).
- Design each funicular identifying stop stations.
- Distribution network design.


i



Column Generation
(Pitehr Hurtado, German Paredes and Gabriel Gutiérrez-Jarpa)

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