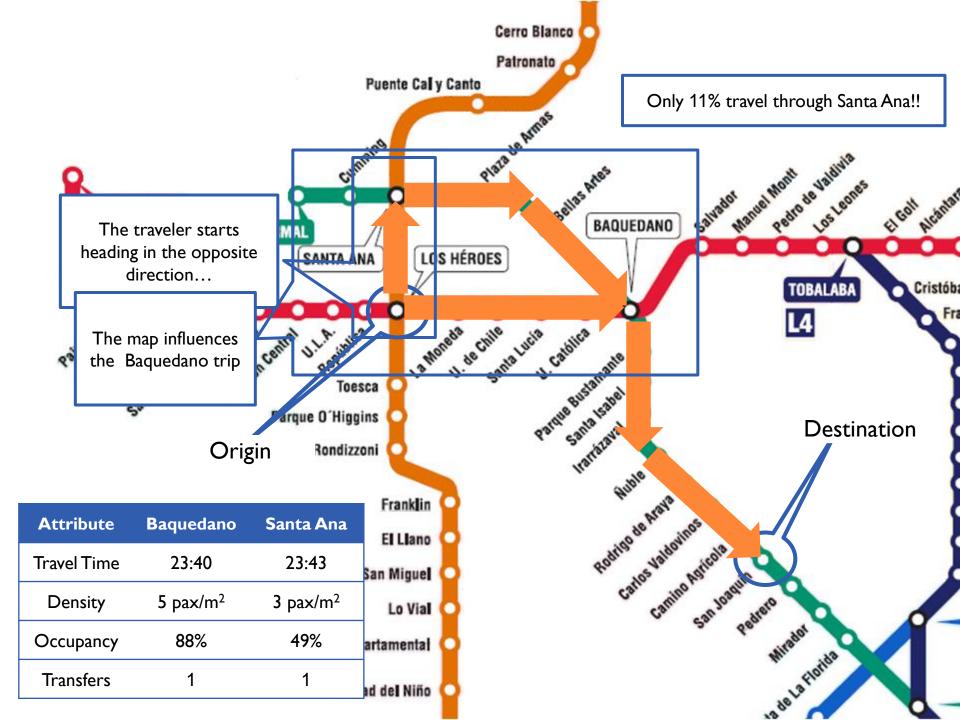
LT5: Modeling reliability, cost, travel times, safety, comfort and other relevant variables of modal choice

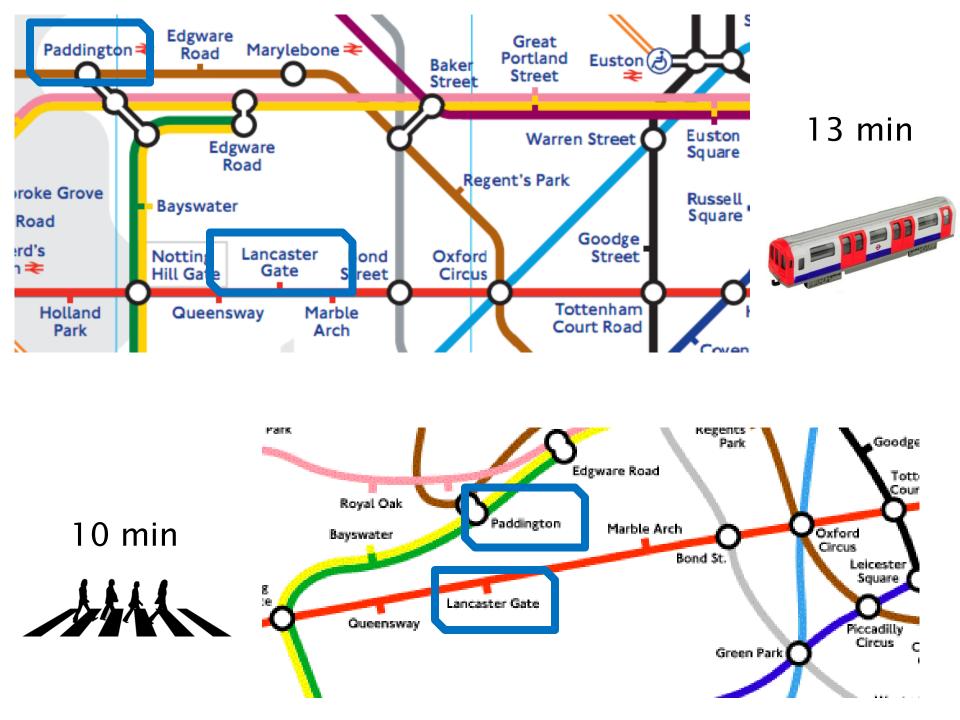
Juan Carlos Muñoz, Juan de Dios Ortúzar, Nigel Wilson

and Sebastián Raveau

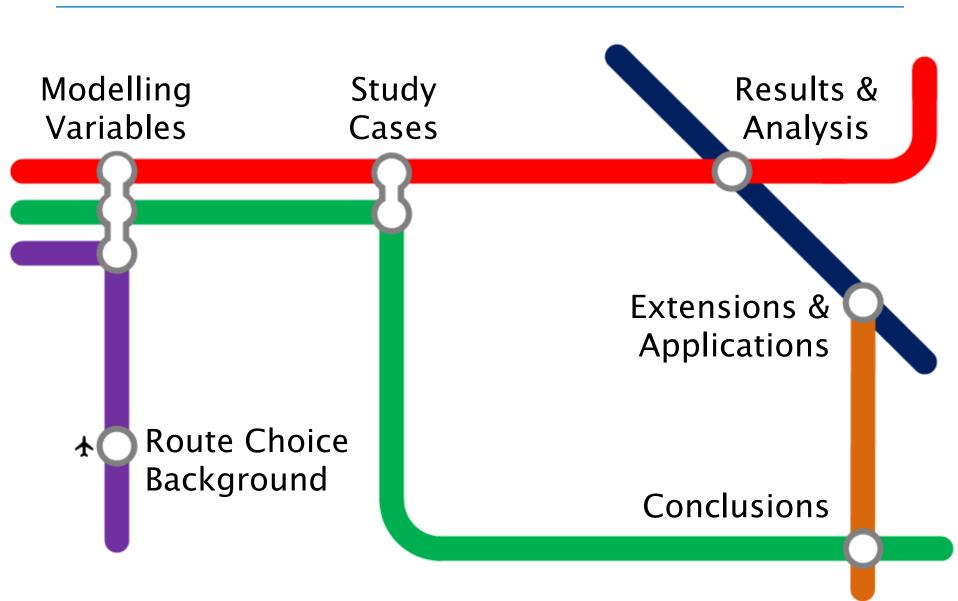


Departamento de Ingeniería de Transporte y Logística Pontificia Universidad Católica de Chile





Contents



Route Choice

Background

Traditional route choice models usually consider just tangible variables related to the level of service

travel time

fare

number of transfers

These models are sometimes refined including socioeconomic variables of the travelers

Route Choice

Background

However, this approach ignores other relevant elements that influence route choice as:

comfort and safety

transfers accessibility

network topology

aesthetics

These variables are subjective and hard to quantify

Pathfinding Criteria

Thru to Urawa-misono Thru to Töbu-döbutsu-köel Thru to Kuki, Minemi-kuriheshi Thru to Toride Arakawa Line Saltama Raliway Line S Kita-ayase Shimo Öji-kamiya Machiya Molohasunuma Machiva-ekimae Chiyoda Line Jöban Line N H C Kanamachi o Öji-ekimae Akahana-lwahuet <u>s</u>z Kita-seniu Avase larita Thru to Imba-Nihon-idai 뷢 itabashihoncho Shin-' Itabashi Tabata O Airport Nishi-sugamo Minami-senju Keisel Line Keisei Wakosh Tābu Tājā Line ÖJI ě Nishigahara Minowabashi O 1. O itabashi Hikifune (Kanamachi Airport Ä i Ine Minowa H Tõbu isesaki Line Tarmir lipbashi Sugamo O Nippari Otsuka-el Nishi-nippori N 14 Tsukuba Express IN STATISTICS OF THE PARTY OF T ď6 Uguisudani Aoto Keisei-yawata Komagome Õtsuka 🖁 iriva Kelsel Oshlage Line Kelsel-takas Yamanote Lina Æ, Notoyawata 16 Sendagi Ueno Senkawa Sangoku 14 N Hon-komagome Toshimaen Shin-disuka Myögadani Hakusan 13 Oshlage Ikebukuro Kanamechő 16 H B Asakusa Nerima Keisei-ueno ŝ N Tödaimae 8 Shinozaki 2 Selbu Ikebukuro Line Æ Å Å C Nezu H Shin-okachimaet Sõbu Line Shibar Hongō-sančhôme Hanzômoi Lin Kasuga Mizue A Thru to Hannō Shin-egota 34 Higashi-ikebukuro Edogawabashi **Veno-okachimach** Ochlal-minami-nagasaki **E** Kameldo 12 6 A 1 Kuramae ž ichinge (MajiroÖ Veno H 16 Kinshichö Yushima Higashi-ikebukuro Gokokuji N M ilaica-nkachi machi Seibu Shinjuku Line Körakuen Funabori ÓWasent: Oallabo Takadanobaba Nakai Okachimach Ryágoku Higashi-öjima s Chûð Line Kagurazaka M n**ish**i-Nabar đ Asakusa bashi Suehirochö 🖁 ochial 7 Suldõbas Thru to Mitaka Òjima 🕵 6 **H** 20 16 E Ushigoma-vanacichô Ushigome-kagurazaka Akihabara Nakano Chũö Line Nishi-Diima 💈 Baraki-nakayama 🛒 Wakamatsu-kawada Thru to T0y6 Rapht L Thru to T0y6-kab S0bu Line / Nartha Line Minami-asagaya Shin-ökubo Ö E T Y N 06 06 13 10 Ochanomizu Shin-koonji 03 Jimböchö Myöden (T idahash Rakumchö Higashi-kōenji ⁰⁴ S 1 Z A 8 C 57 19 S 5 Z 5 Gvütoku 🗂 Higashi-shiniuku Akabonobashi Hig**ashi** nihombash Hamachi S Y N 04 14 09 5 03 19 Minami gyotok Shin-nakano Amalicha (G) 13 Sumiwosh O Seibu-shiniuku 푪 Kanda Ningyőchő Hönanchö niuku Lit chicava T H. A # 8 Kodemmachö H Uravasu Kudanshita Shinjuku-gyoemmae Yotsuya Suitencümae Ŧ, Shin-nihombashi Nakano-shimbashi Nakano-fulimichô 6 Z T 14 A Kiyosumi-shirakawa G Z Kasal Shiniuku M Nishi-shiniuku-oochôme M Itsuko<mark>s</mark>hima Tsudanuma O Meidaima Köjimachi lichi-kasal 卢 Yotsuya-sanchôme os Takebash Shinjuk Hanzömen 🔏 Keið Line Sasazuk C Thru to Hashimoto, Minami-sunamachi G T A H 11 E T **1**3 14 Takaosanouch Chiba O Shinanomachi Toyocho Sendaoava Kiba Aoyama-ilchôme Otemachi Kayabach Keiö Inokashira Line Monzen-Yoyogi N Z4 16 💭 Nijûbashimae Kyöbashi 🖟 A Nagatachö R H Kelyö Line Kokuritsu-kvõgi jõ Tökvö Yoyogi-uehara G 13 Taicarachô Hatchöbor Melji-jingümaı Thru to Karakida.Hon-atsugi Harajuku 👩 C R Ginza-Itchór VOSU Z Shin-kiba Akasaka-mitsuke Tatsumi G Sakuradamon Shimomichā Odakyü Line Shimo-kitazawa Yürakuchö Yoyogi-kdan Malhama ¥24 Kokkal-gijidomae 19 **X Y** E 21 16 17 ž Gaiemma Thru to Chūō-rinkan zömon i in H 10 Tsukishim Z C C Tamelke-년 연 연 Futako-tamaoawa Tökvü Den-en-toshi Line Shibuya N 문 영 A H Disney Resort Line Akasaka Kasuminaseki tenjijā O Ariake Higashi-ginza Tökyü Öimachi Line Nogizaka Roppongl-itchome x Naka-meguro Ebisu H Kachidoki Hiro-o Tōkyū Tōyoko Line Uchisalwaichő 🛃 붜 H 5 H 뵶 Line Color Roppongi 8 Kamiyachö Thru to Kikuna Jiyügaoka Tsukijishijā Toranomon Onarimon -Line Symbol Α Den-en-chöfu Tökyű Meguro Line 06 Station Number Shimbash Azabu-lüban I N 02 02 I N 01 01 I N Akabanebashi Toei Line Tokyo Metro Line Öokavama Thru to F. Shirokane-Jakanawa A Asaiansa Line G Ginza Line Meauro Shirekaneda Musashi-kosuai Hatanodai Shiodome Daimon Mita Yurikamome Lin I Mita Line Tökyü ikegami Line Mm Marunouchi Line Shibakóan Hamamateuchi Mita Lin Sengakuji S Shiniuku Lim H Hibiya Lina Rinkai Line A E Öedo Line Nishi-magome 🗛 A 04 Å T Tozai Line **A** Â Tōkyō Monorail Takanawadai Togosh Junctions 🔘 Chiyoda Line Magome Varano Gotanda പിയം Tamachi Shinaqawa Y Yürakuchó Lini JR Yamanote Line 0 Kelhin-tõhoku Line Öimach Yürzkuchó Line Tokyo Subway Pouto Ma JR Line

Route Choice Background

Pathfinding Criteria

Thru to Urawa-misono Thru toTõbu-dõbutsu-kõer Thru to Kuki. Thru to Toride Arakawa Line S Kita-ayase Saltama Raliway Line Minemi-kuriheshi Shimo Öji-kamiya Machiya olohasunuma Machiya-ekimae Chivoda Line N Jöban Line **C** 19 19 H C 21 18 Kanamachi O Öji-ekimae kabane Akahane-Iwabuci N 16 Kita-seniu Avase Thru to Imba-Nihon-idai larita Tabata O 붪 itabashihoncho Shin-Itabashi Minami-seniu Airport Nishi-sugamo Keisel Line Töbu Tõjõ Line ÓII Keisei Kanamachi ð Nishigahara C 16 Minowahashi O Ins the ten Hikifune O Airport itabashi Line Minowa 문 Tõbu Isesaki Line Terminal liabashi kuyakushomae Sugamo O Nippori ⊙Ótsuka-ek Nishi-nippori N 14 Tsukuba Exoress **06** Uguisudani Acto Kaisai-v Ōtsuka Komagome 🖁 iriya Az O O Kelsel Oshlage Line Kelsel-takasago Yamanote Line Senkawa 07 Ueno **Z** 14 Notovawata Sendaol Sangoku 14 N Hon-komagome Toshimaen Kanamecho os Oshlage Ikebukuro Hakusan 13 C H 16 17 G A 19 18 Nerima Keisei-ueno 🔿 Asakusa Shin-ölsuka Myögadani N Tödaimae Shibayama-chlyoda Shinozaki 3 Selbu Ikebukuro Line C Nezu E X M Ņ Shin-okachimach Hongō-sanchōme Sābu Line Kasuga Mizue 3 Thru to Hannö Shin-egola 34 Edogawabashi Higashi-ikebukuro 4-chome Ueno-okachimach Ochlal-minami-nagasaki 5 . Kameido **E** ichinoe s **A** Kuramae ¥12 MalimÖ C Yushima Uang H 16 Kinshichö M **Z** Higashi-ikebukuro N M Seibu Shinjuku Line Gokokuji Körakuen ÓWaseda Funabori **sachimachi** Oplicubo Takadanobaba Nakai Okachimach Ryögoku Higashi-õjima 🤶 M Chũð Line Waseri Kagurazaka ochial T. **5**1 Suehirochō G Asakusa bashi Nishi-wahachi Suidőbash Öjima 🐒 Thru to Mitaka M 甚 **A** Æ Wakamatsu-kawada yanagicho Ushigome-kagulazaka Nakano Chũô Line Akihabara Nishi-ojima 8 Baraki-nakayama T A Thru to Toyo Rapid L Thru to Toyo Hath Sobu Line / Nartha Line Shin-ökubo Ö Minami-asagaya E T Y N Ochanomizu Shin-Idenii ⁰³ Myöden T Jimböchö idahash Migashi-kōenii ⁰⁴ 8 1 Z C 5 M 12 07 19 A 8 S E Z S 12 13 Gvijtoku T Akebonobashi Higaehi-ehiniuka Higashi nihombash Shin-nakano ^M Hamachi 5 03 8 Y N 04 14 09 Kanda [Ę Ó Selbu-shiniuku 19 Minami-H Ningvöchö Hônanchô ichioava ME A # T. Kodemmachö 83 Urayasu Shinjuku-gyoemmae Yotsuya Kudanchib Suitenoümae Ţ 82 Nakano-shimbashi Nakano-fulimichô Shin-nihombashi 8 Z T IA 11 Kiyosumi-shirakawa G Z Shiniuku Kaesi M 99 M N 12 08 M Nishi-shiniuku-mechôme Mitsukoshimar Tsudanuma O (ishi-kasal Meidaima Köjimachi S E Yotsuya-sanchôma O Sasazuka Tochômae Hanzômon 🎄 Takebashi Shinjuku Keið Line Thru to Hashimoto, Minami-sunamachi G T A H 11 £ 12 (**T**3) 14 Takaosanguchi Chiba O Sendagava Shinanomachi Kiba Töyöchö Aovama-ilchôme Ötemachi Kavabach Keiö Inokashira Line Monzen-E N Z Y 🔓 Nijūbashimae Yoyogi Kyöbashi 10 A E Z G Tōkyō 🖪 Nagatachö Kelyö Line Kokuritsu-kvõgi jõ H Yoyogi-uehara G M 05 13 Takarachô latehőbor Melji-jingumae Thru to Karakida,Hon-atsugi Haralukuō ŝ б VOSU 2 Ginza-Itchome Shin-kiba Akasaka - milisuka Sakuradamon Shimomichë Tatsumi G Odakyū Line Shimo-kitazawa Yürakuchör Yoyogi-kdan Malhama 24 Kokkal-oliidomae 19 20 Y E 17 Gaiem Thru to Chūō-rinkar H Ta Tsukishim O Futako-tamagawa Z C G Tamelke-sannð G N M 06 06 14 Hibiya Lir 나 안 안 Z G Tökvü Den-en-toshi Line Shibuya A H 11 09 M H G **Disney Resort Line** Akasaka Kasumigaseki Hibiya tənjijā O O Ariakə Omote-sando 8 ŝ M H C Higashi-ginza Tökyü Öimachi Line Nogizaka Roppongi-Itchôme X Naka-meguro Kachidoki E Hiro-o Tōkyū Tōyoko Line Ebisu Uchisalwaichő (7) 붡 H 甚통 붶 H 05 Kamiyachô Line Color Roppongi 8 A G 10 06 Thru to Kikuna O Jiyügaoka Tsukijishijā Toranomon Onarimon -Line Symbol Den-en-chöfu O A Tõkyü Meguro Line 06 Station Number N E Shimbash Azabu-lüban I N I N 61 01 l N Akabanebashi Toei Line Tokyo Metro Line Öokavama Thru to H A 20 Shirokane A Asaiansa Line G Ginza Line Meauro Shirakanada Musashi-kosuo Hatanodai Shiodome Daimon Yurikamome Lin I Mha Line Tőkyű lkegami Line M^m Marunouchi Line Shibakõen Hamamatsuchö Mita Lin Sencakui I 04 S Shininin Lim H Hibiya Lina Rinkai Line A E Öedo Line A 04 T Tozai Line Nishi-magome 🗛 â Tōkyō Monorail Togoshi Magom Takanawadai 🔘 Chiyoda Line Junctions Jakanoh Gotanda Shinaqawa Tamachi O Y Yürakuchö Lini JR Yamanote Line Kelhin-tõhoku Line **Öimaci** Takyo Subway Pouto Ma Yürakuchó Lim JR Line

Route Choice Background

Route Choice

Background

Some people follow different criteria when deciding how to get from one point to another

the fastest way

the cheapest way

In a transit context, there are some additional factors

avoid walking

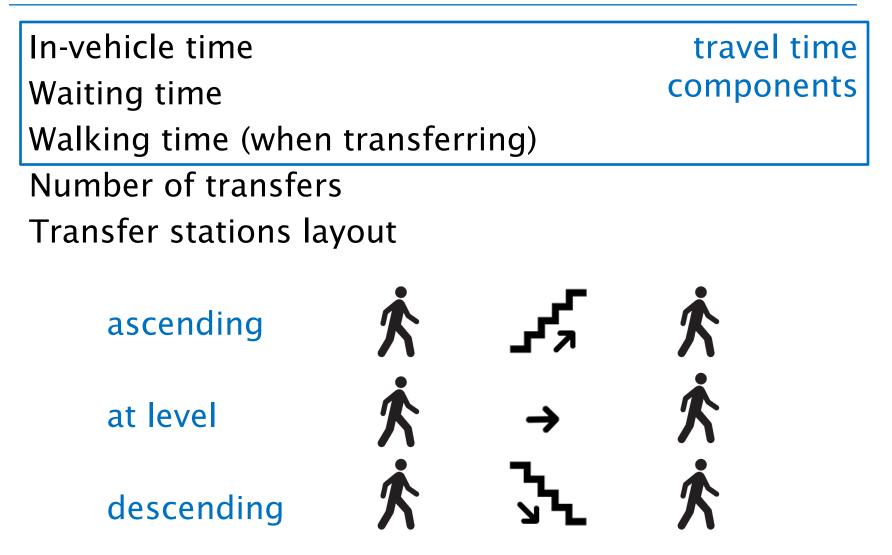
avoid transferring

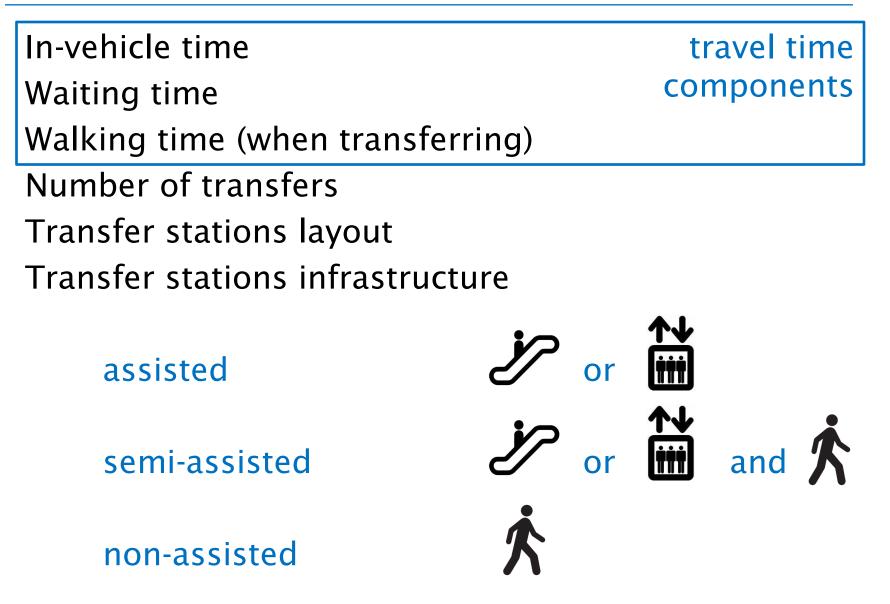
But most consider <u>many</u> factors at the same time!

Understanding travelers is essential in Transportation Planning

Identify and quantify the factors that affect the transit users' behaviour

Compare the preferences of transit users in London and Santiago





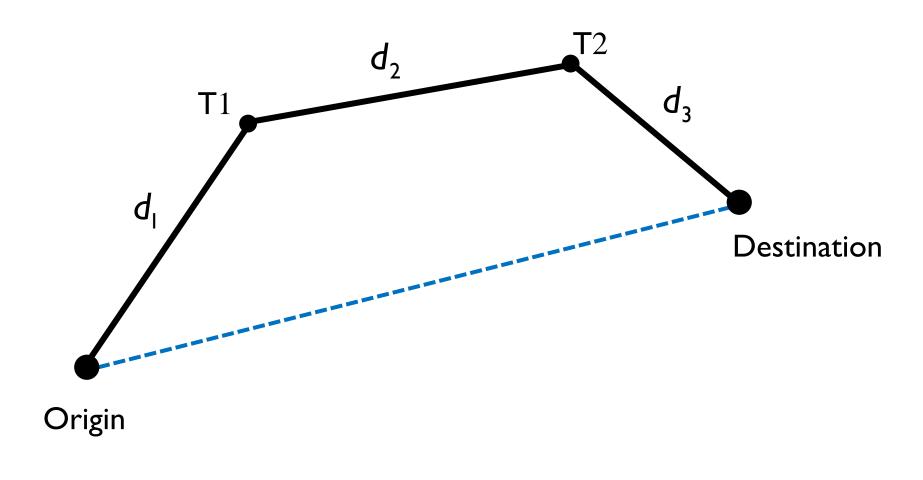
In-vehicle time	travel time
Waiting time	components
Walking time (when transferr	ing)
Number of transfers	transfer
Transfer stations layout	experience
Transfer stations infrastructu	re
Mean occupancy	
Possibility of not boarding	
in London	initial occupancy \geq 70%
in Santiago	initial occupancy ≥ 85%

In-vehicle time	travel time
Waiting time	components
Walking time (when transferr	ing)
Number of transfers	transfer
Transfer stations layout	experience
Transfer stations infrastructu	ire
Mean occupancy	
Possibility of not boarding	
Possibility of getting a seat	
in London	initial occupancy ≤ 20%
in Santiago	initial occupancy $\leq 15\%$

In-vehicle time	travel time
Waiting time	components
Walking time (when transferring)	
Number of transfers	transfer
Transfer stations layout	experience
Transfer stations infrastructure	
Mean occupancy	comfort and
Possibility of not boarding	crowding
Possibility of getting a seat	
Route distance	
Number of stations	
Angular cost	

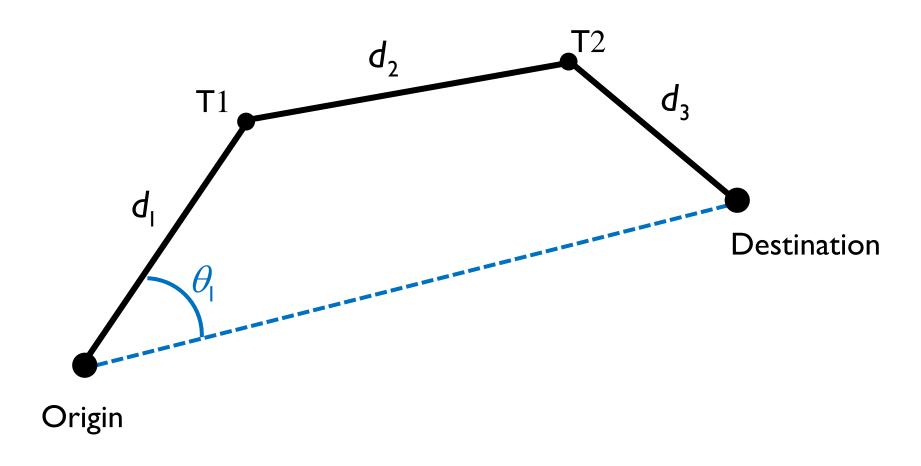
In-vehicle time	travel time
Waiting time	components
Walking time (when transferring)	
Number of transfers	transfer
Transfer stations layout	experience
Transfer stations infrastructure	
Mean occupancy	comfort and
Possibility of not boarding	crowding
Possibility of getting a seat	
Route distance	
Number of stations	
Angular cost $\sum d \cdot sin\left(\frac{\theta}{2}\right)$	

Modelling Variables

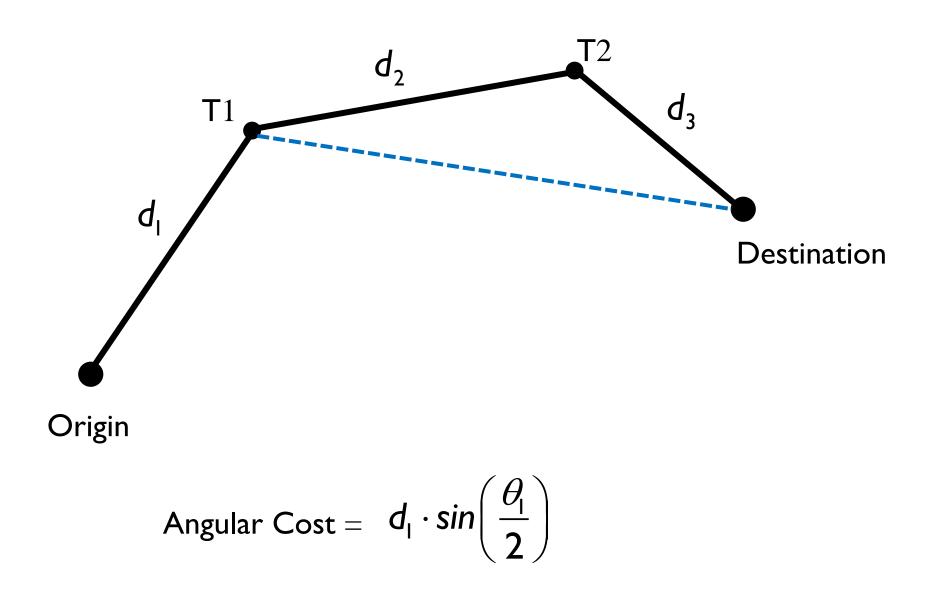


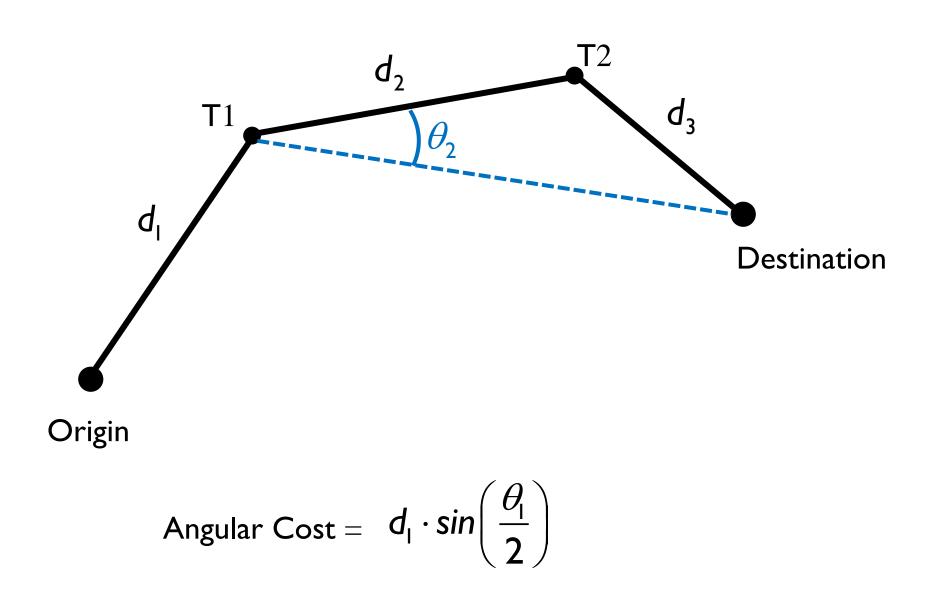
Angular Cost =

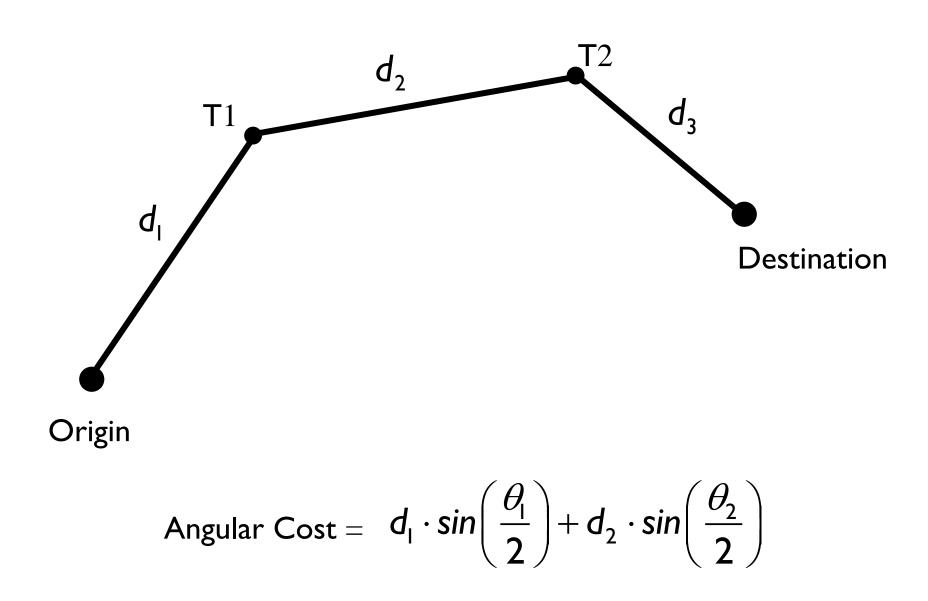
Modelling Variables



Angular Cost =

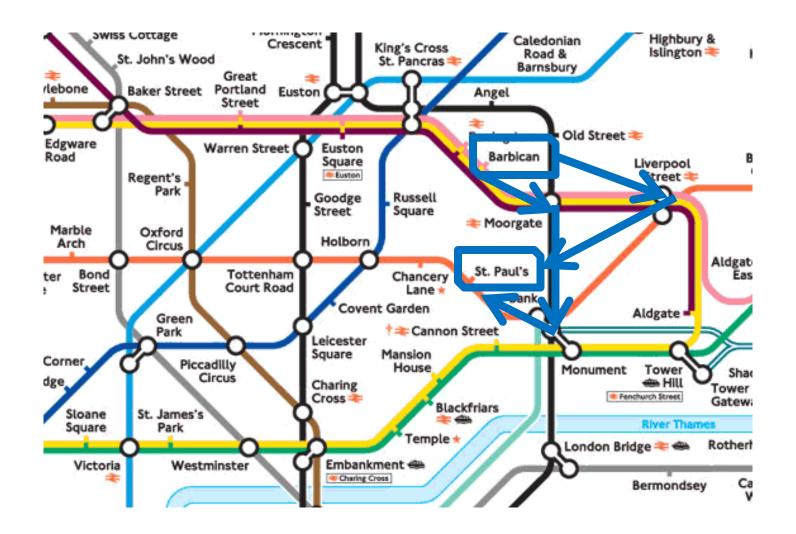






In-vehicle time	travel time
Waiting time	components
Walking time (when transferring)	
Number of transfers	transfer
Transfer stations layout	experience
Transfer stations infrastructure	
Mean occupancy	comfort and
Possibility of not boarding	crowding
Possibility of getting a seat	
Route distance	
Number of stations	
Angular cost	
Reasonable route	

turning away from the destination



In-vehicle time	travel time
Waiting time	components
Walking time (when transferring)	
Number of transfers	transfer
Transfer stations layout	experience
Transfer stations infrastructure	
Mean occupancy	comfort and
Possibility of not boarding	crowding
Possibility of getting a seat	
Route distance	topological
Number of stations	variables
Angular cost	
Reasonable route	

Comparing Santiago and London

Study Cases

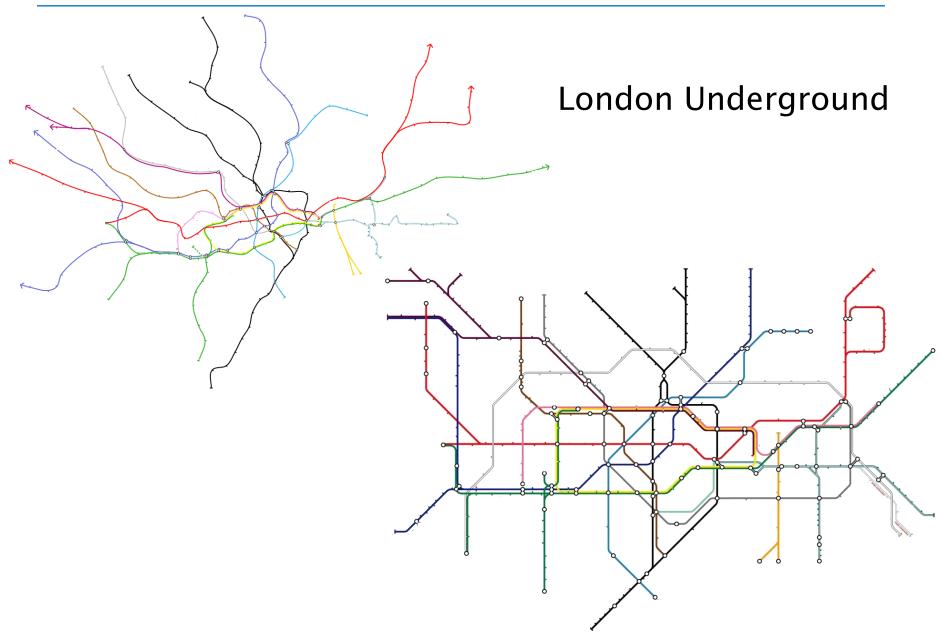
	Santiago 🐽	
Survey date	2008	1998-2005
Lines	5	11
Stations	85	255
Transfer stations	7	72
Daily trips	2,300,000	3,400,000
Survey size	28,961	16,300

Study Cases



Comparing Santiago and London

Study Cases



We use a Multinomial Logit for modeling the route choice

Probabilistic model for discrete choices

Every route has an *utility level* based on its characteristics

People choose the route with maximum *utility level*

Estimation results

Attribute	London Und	erground	Santiago	Metro
Travel Time	- 0.188	- 16.02	- 0.095	- 19.5
Waiting Time	- 0.311	- 7.39	- 0.139	- 5.07
Walking Time	- 0.216	- 6.14	- 0.155	- 8.23
Number of Transfers	- 1.240	- 4.37	- 0.632	- 4.06
				- 2.73
Developeration			ОК	n. a.
Parameter's si	gns		UK	n. a.
				n. a.
Semi-Assisted Transfers	- 0.328	- 6.83	n. a.	n. a.
Non-Assisted Transfers	- 0.541	- 6.79	- 0.262	- 6.23
Mean Occupancy	- 2 911	- 3 48	- 1 018	- 5.60
				3.41
Parameter's si	anificances	\odot	OK	
Parameter's si	gnificances		OK	- 2.97
Parameter's si	gnificances	- 5.76	OK - 0.274	- 2.97
	-			- 2.97 - 5.48 - 5.69
Map Distance	- 0.358	- 5.76	- 0.274	- 2.97 - 5.48 - 5.69 - 3.10
Map Distance Number of Stations	- 0.358 - 0.316	- 5.76 - 5.52	- 0.274 - 0.147	3.41 - 2.97 - 5.48 - 5.69 - 3.10 - 9.76 - 7.11

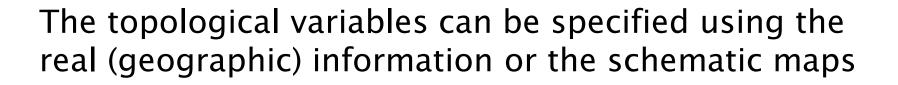
Results &

Analysis

Attribute	London	Santiago
1 min waiting	1.65 min in-vehicle	1.46 min in-vehicle
1 min walking	1.15 min in-vehicle	1.62 min in-vehicle
1 (basic) transfer	6.60 min in-vehicle	6.63 min in-vehicle
1 % of occupancy	0.16 min in-vehicle	0.11 min in-vehicle
Seating	0.52 min in-vehicle	0.97 min in-vehicle
Not boarding	2.29 min in-vehicle	3.99 min in-vehicle
1 station	1.68 min in-vehicle	1.54 min in-vehicle
Turning back	3.86 min in-vehicle	1.48 min in-vehicle
Turning away	5.15 min in-vehicle	2.37 min in-vehicle

Results &

Analysis



Statistic	London		Santiago	
	Real	Мар	Real	Мар
Corrected ρ^2	0.564	0.566	0.378	0.382
Mean Squared Error	0.348	0.342	0.613	0.611
θ_{wait} / θ_{travel}	2.44	1.65	1.98	1.46
θ_{walk} / θ_{travel}	1.90	1.15	1.94	1.62
<i>t</i> -test Angular Cost	- 1.60	- 5.87	- 4.28	- 5.48

Public transport users take into account a wide variety of attributes when choosing routes

An incomplete model specification can result in biased results, such as attributes valuations

Network's topology, and specially the way it's presented to users on a daily basis, is relevant

Due to bigger distortions in the schematic map, the topological variables are more important in London

Londoners are more willing to transfer, as it is more common to them (bigger and denser network)

Londoners are less willing to travel in crowded trains, but care less about getting a seat

Publications and working papers

- Raveau, S., J.C. Muñoz, and L. de Grange (2011) A topological route choice model for metro. **Transportation Research Part A**, Vol 45 (2), 138–147
- Raveau, S., Z. Guo, J.C. Muñoz and N.H. Wilson. (2012) Route Choice Modelling on Metro Networks: time, Transfer, crowding, and topology. To be submitted to Transportation Research Part A.
- Navarrete, F. and J. de D. Ortúzar (2012) Subjective valuation of the transit transfer experience: the case of Santiago de Chile. Submitted to Transport Policy.

In-progress or future research I

- Comparison of route choice models for Metro of London and Santiago. A paper should be submitted to Trans Res A this month.
- Extend the study for a route and mode choice models within a transit system. We made an 1,800 people survey in Santiago with this purpose. This research is being developed by PhD student Sebastian Raveau.
- Develop a similar survey in Bogota, Colombia to understand the role played by a BRT-based network in passengers' choices.
- Compare results between Santiago and Bogota to understand how much of a Metro service BRT provides in Bogota.

In-progress or future research II

- Build a tactic tool to predict passenger flows in a multimodal transit system. Such a model would have to deal with endogeneity since passengers flows affect travelers' choices.
- Build a tool to advise passengers how to travel in a complex multimodal transit system.
- Develop a methodology to feed our route and mode choice models with feedback provided by users of the Passenger Travel Advising Tool.

Grants obtained

 FONDEF (2012-2014). A tactic-strategic tool for urban transit systems planning and management. Total funding of US\$800,000. Involvement of Metro and Alsacia (bus operator)

Juan Carlos Muñoz and Juan de Dios Ortúzar

• PUC (2011-2012). Interdisciplinary research project to understand how to improve the users transfer experience on a transit system (US\$10,000).

Ricardo Giesen, Juan de Dios Ortúzar, Juan Carlos Muñoz, Patricia Galilea, Juan Carlos Herrera, Margarita Greene, Rossana Forray, José Allard

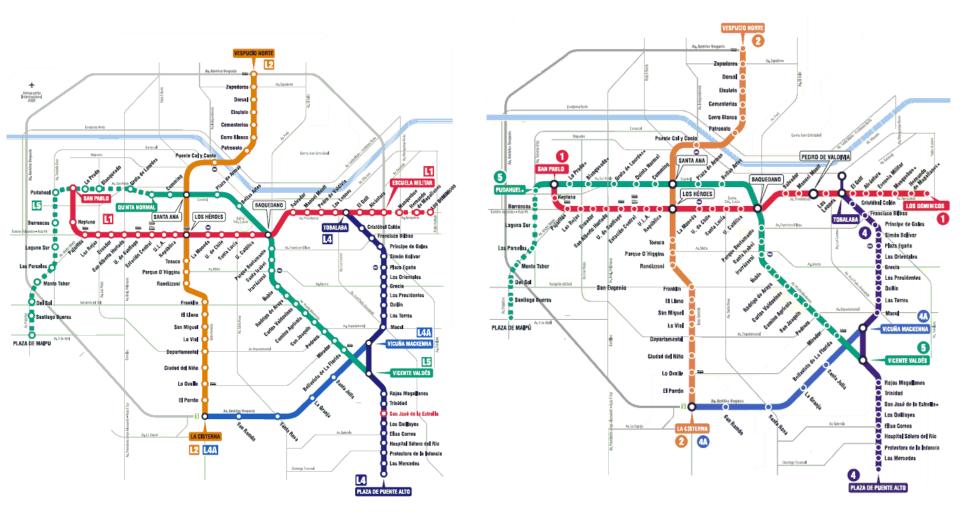
From the papers to the streets

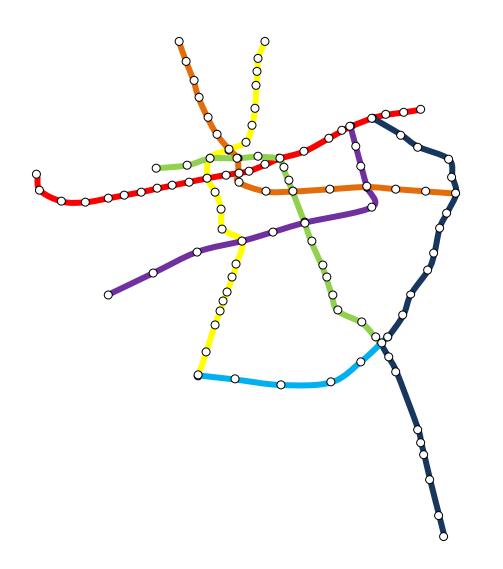
- Several interviews with the media during 2011
- Interviews with Metro and government authorities during 2011
- Metro de Santiago changed its map based on our results to induce a more socially optimal behavior

Extensions &

Applications

Change in the Santiago Metro schematic map





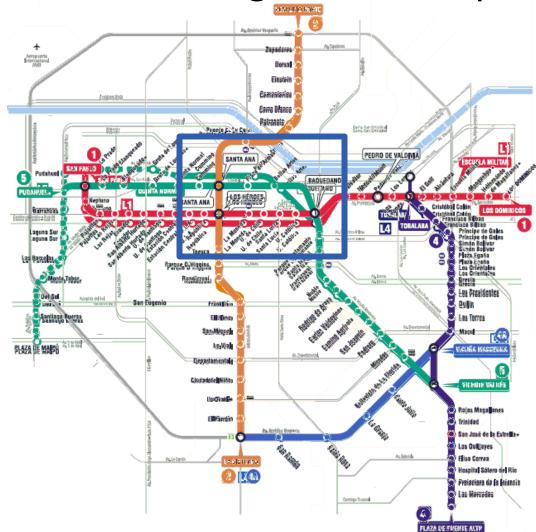
Demand analysis for the design of transfer stations

Extensions &

Applications

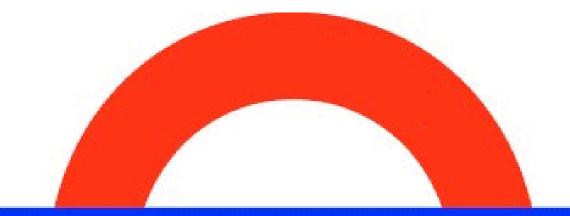
Applications

Changes in the Santiago Metro Map



From the papers to the streets

- Several interviews with the media during 2011
- Interviews with Metro and government authorities during 2011
- Metro de Santiago changed its map based on our results to induce a more socially optimal behavior
- We are now working un using our assignment model to design interchange stations and predict flows for the Metro network in Santiago that will consider two extra lines in 2016.



END OF LINE

