Journey Levels

Integrated fare modelling with strategy-based transit assignment

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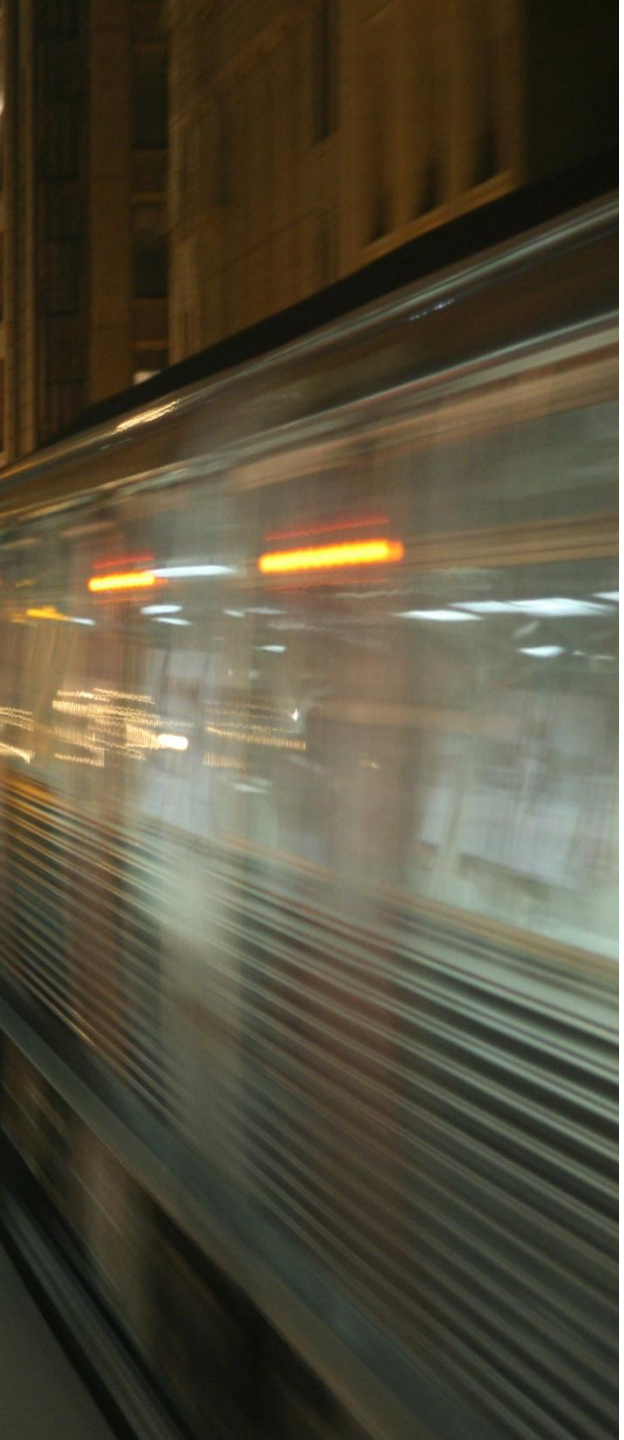
Strategies and states

- Strategy transit assignment is Markovian - no ‘history’
  - Integrated fares required network construction
  - Hard to limit or force mode combinations
- Journey levels
  - Add traveler state to strategy-based method
  - Can directly model network-wide integrated fares
  - Can directly force mode(s)

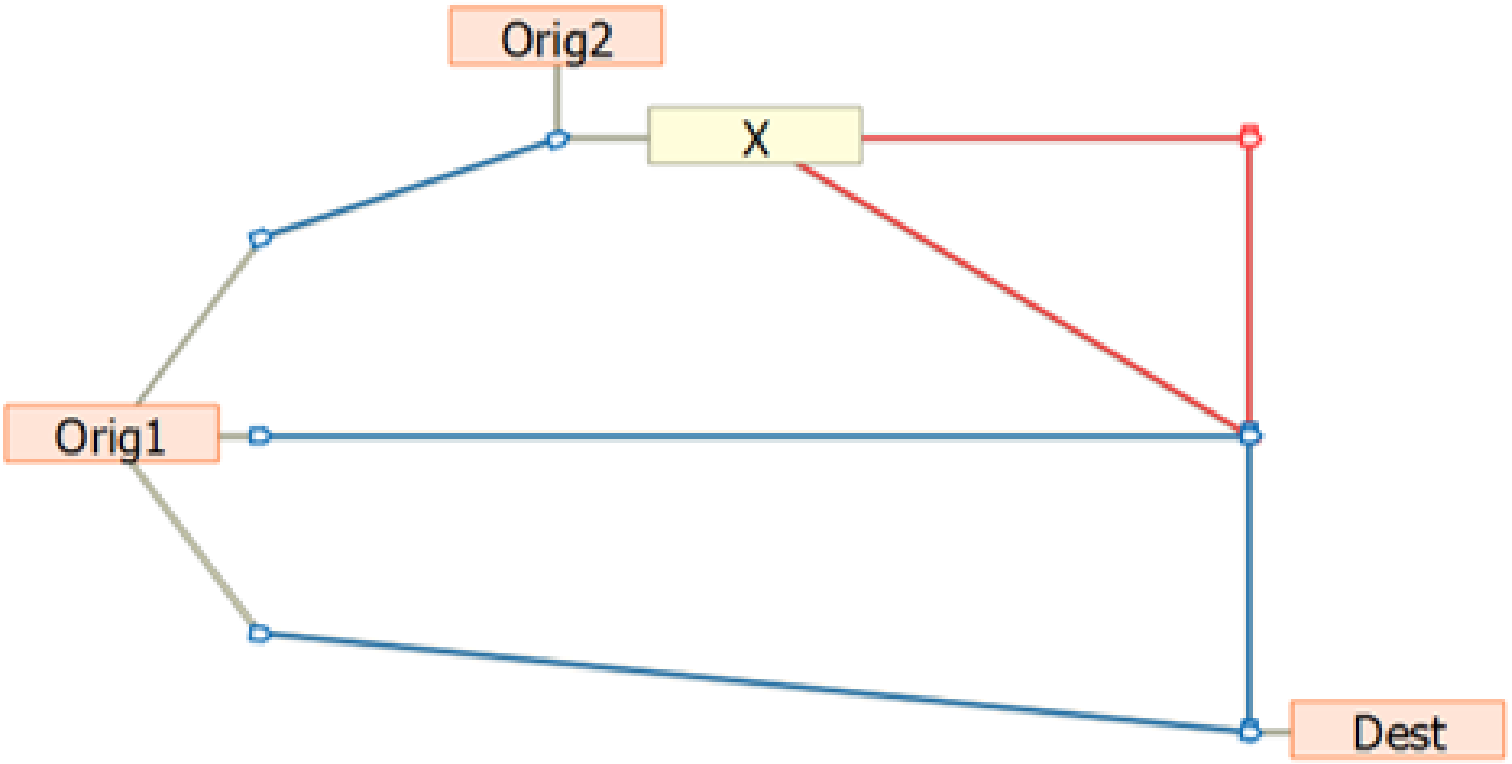


Background

The original strategy-based transit assignment

- Does not remember nor need to know how travelers arrived at a node:
  - Did they walk from their origin?
  - Which transit mode(s) did they already board?
- Uses the same boarding/waiting parameters to determine how they will leave that node
  - Attractive lines and/or walk link(s)
  - Resulting impedance to destination

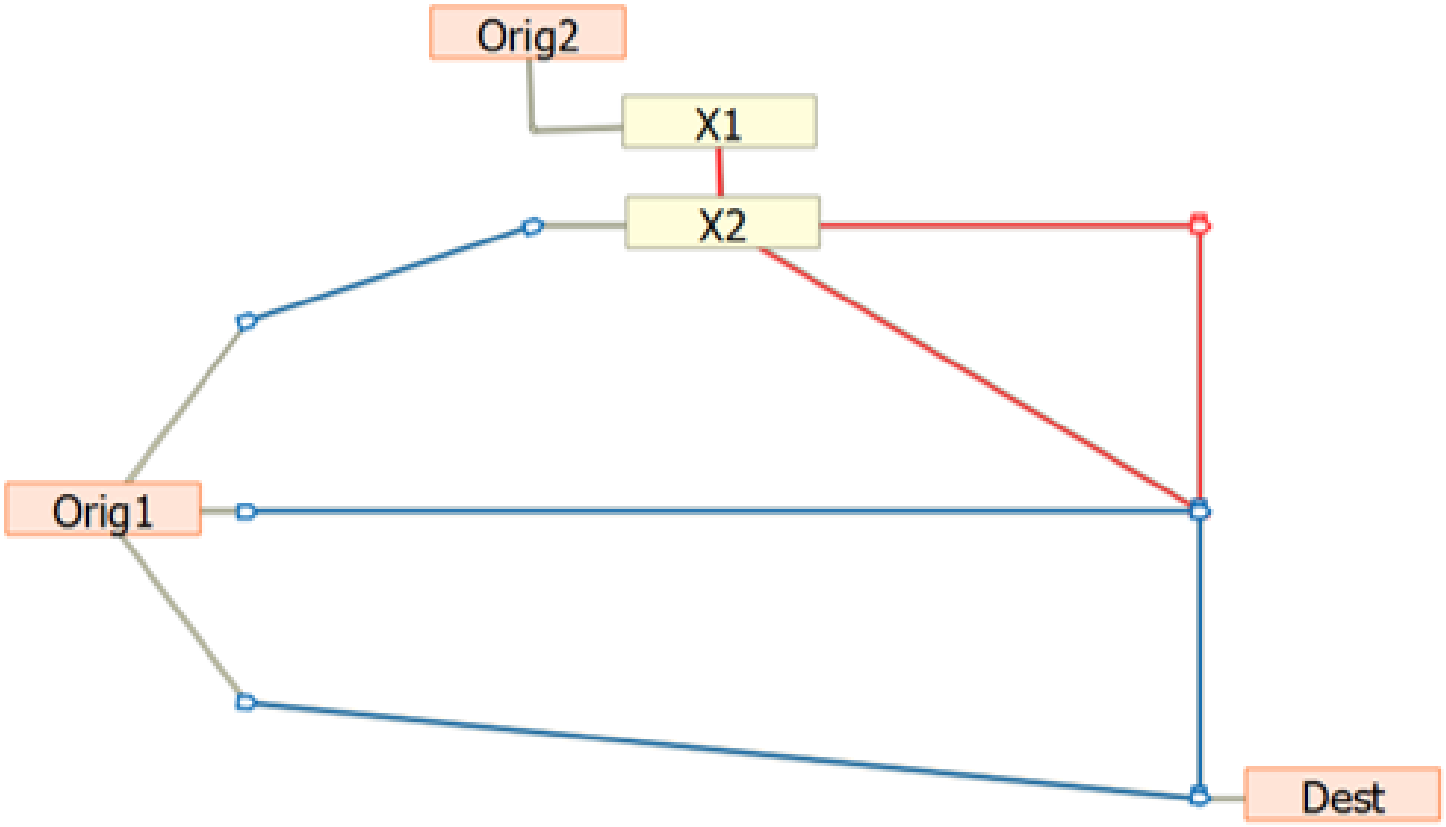
Initial vs transfer boardings at node X



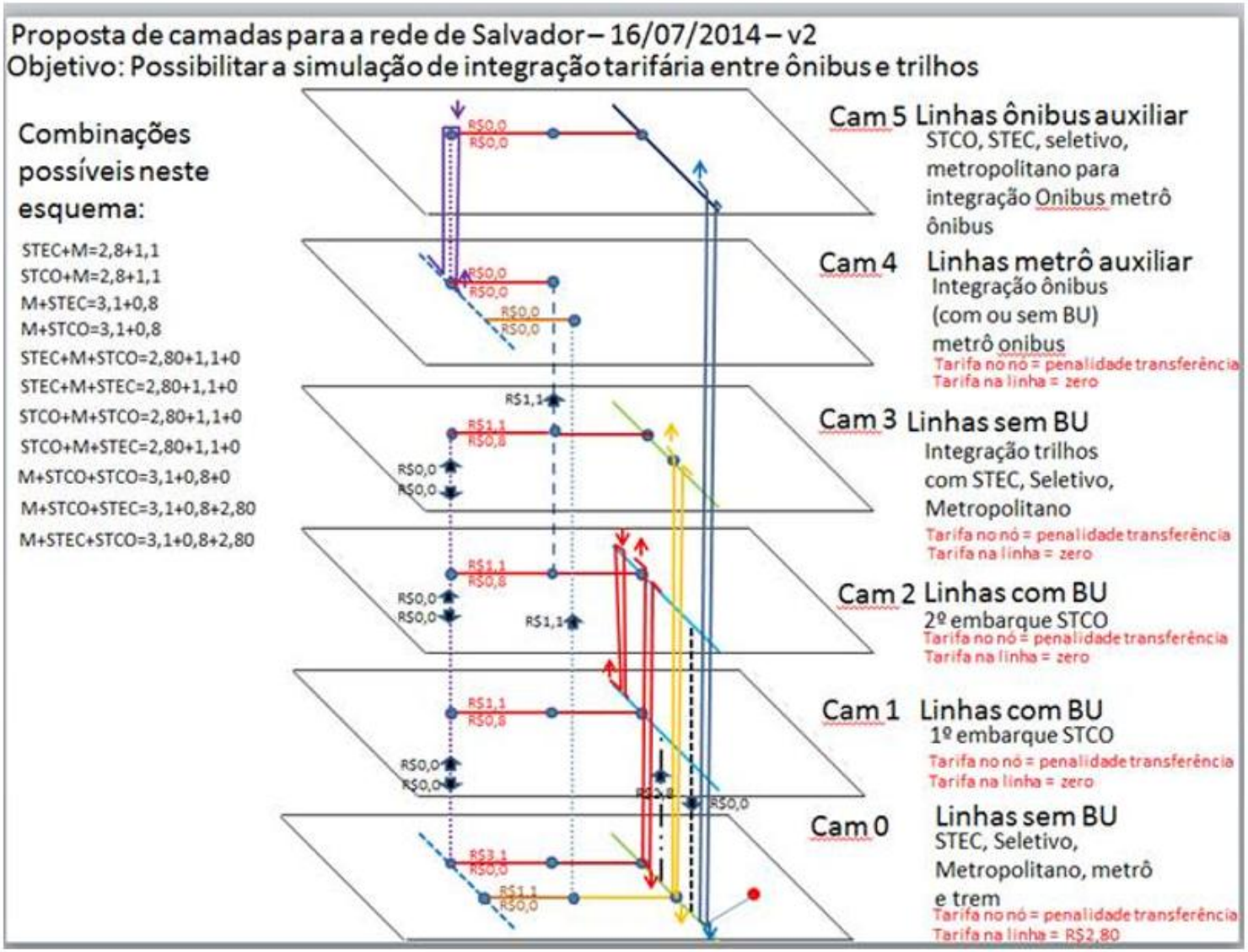
Explicit network modification

- Create several layers in order to “control” how the travelers arrive at a given node
- Apply the appropriate parameters at the node
- Requires
  - Duplicating network elements
  - Adding links/segments to connect the layers

Initial boardings at X1 / transfer boardings at X2



Can become quite complex



A new approach – "Journey levels"

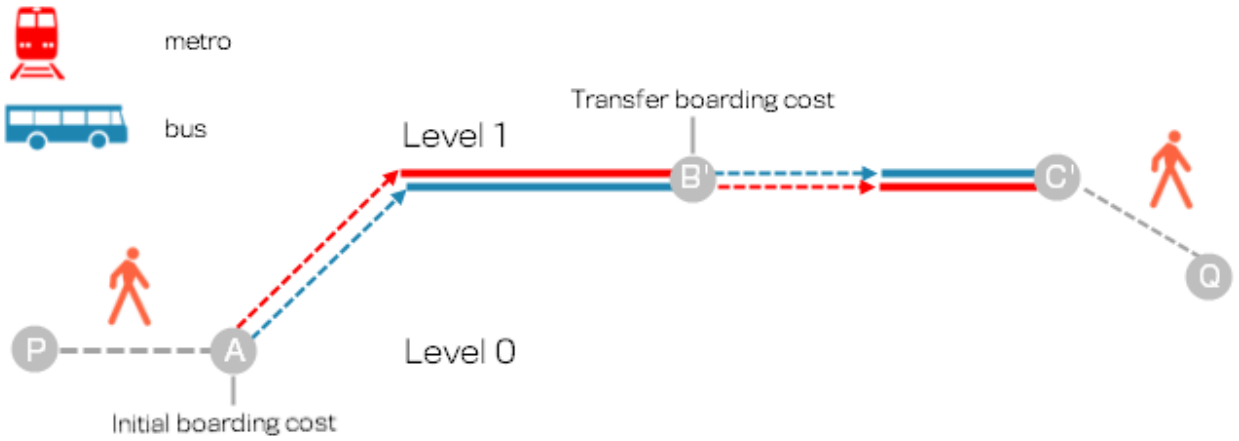
- Several "journey levels", each with distinct assignment parameters for
  - Boarding (time/cost and perception factors)
  - Waiting (headway fraction and perception factor)
  - …
- Transition rules:
  - Boarding a given transit mode may bring the traveler to another level or leave her at the same one
  - Using aux. transit modes leaves the traveler at the same level
- No network modifications required

Ex 1 – Initial vs transfer boardings

- Different boarding penalties if travelers have
  - Not boarded transit yet → “initial” (pay fare) level 0
  - Already boarded transit → “transfer” (free) level 1
- Travelers
  - Walk from their origin to their first boarding at level 0
  - Go to level 1
  - Continue their trip at level 1
    (further boardings → transfer penalty)

Ex 1 – Initial vs transfer boardings

Journey level	Boarding cost Next journey level	
	bus	metro
0 Initial state	Pay fare 1	Pay fare 1
1 Boarded transit at least once	Free transfer 1	Free transfer 1



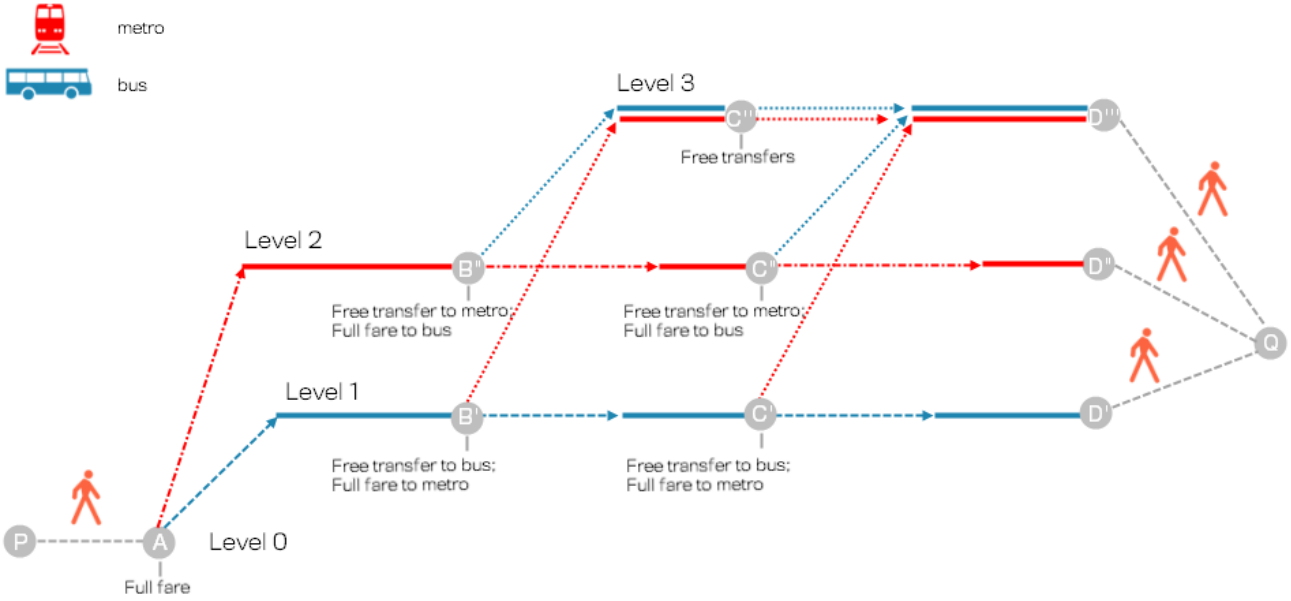
Ex 2 – Free transfers within mode

Consider the following fare scheme:

- Bus 5
  - Free when transferring from bus
- Metro 7.5
  - Free when transferring from metro

Ex 2 – Free transfers within mode

Journey level	Fare Next journey level	
	bus	metro
0 Initial state	5 1	7.5 2
1 Boarded **bus** only	free 1	7.5 3
2 Boarded **metro** only	5 3	free 2
3 Boarded **bus+metro**	free 3	free 3



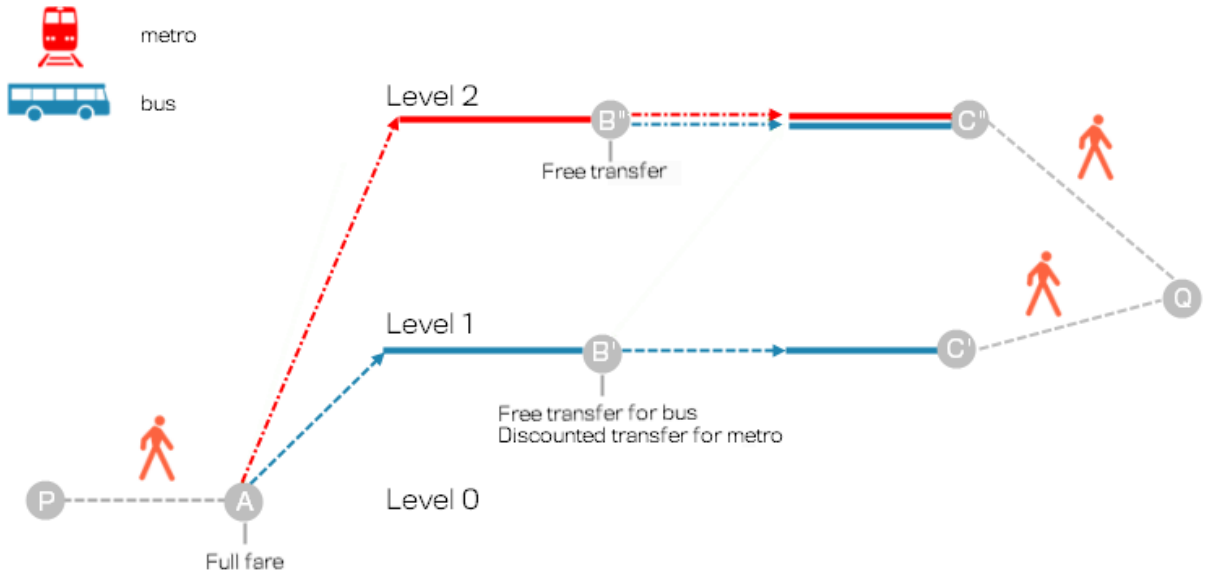
Ex 3 – Discounted transfers between modes

Consider the following fare scheme:

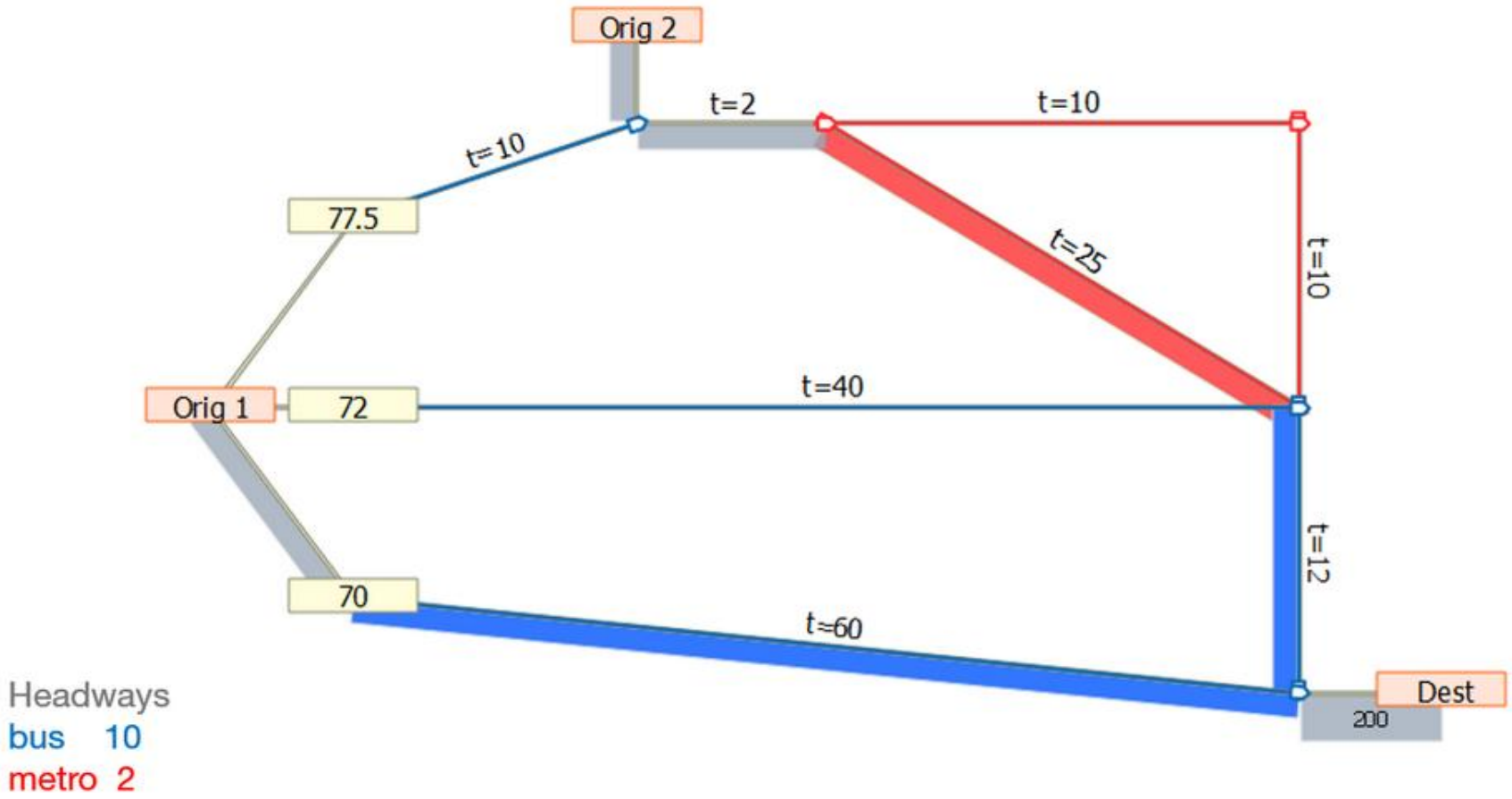
- Bus 5
  - Free when transferring from bus/metro
- Metro 7.5
  - 2.5 when transferring from bus
  - Free when transferring from metro

Ex 3 – Discounted transfers between modes

Journey level	Fare Next journey level	
	bus	metro
0 Initial state	5 1	7.5 2
1 Boarded **bus** only	free 1	2.5 2
2 Boarded **metro**	free 2	free 2

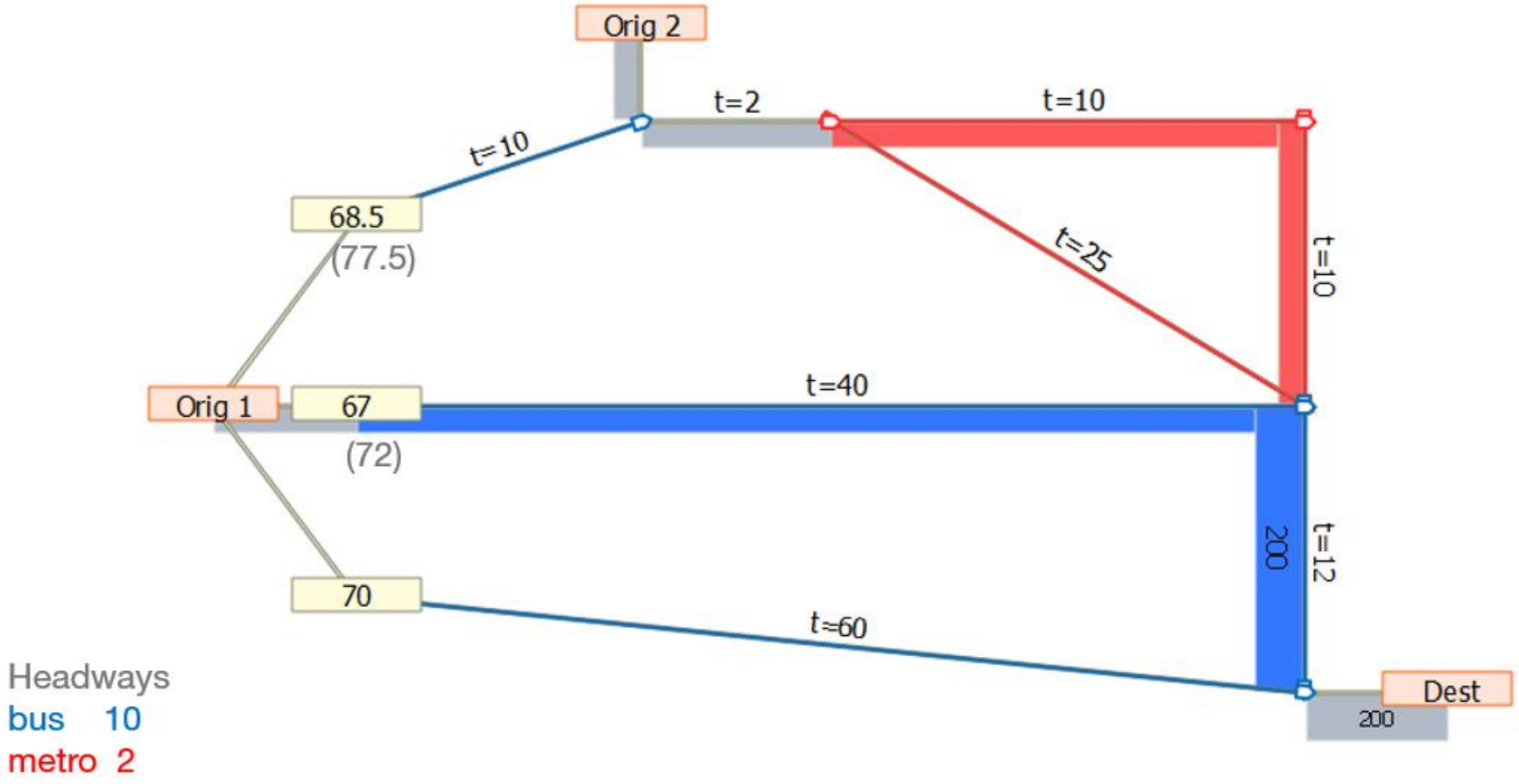


No fare integration – transfers are avoided



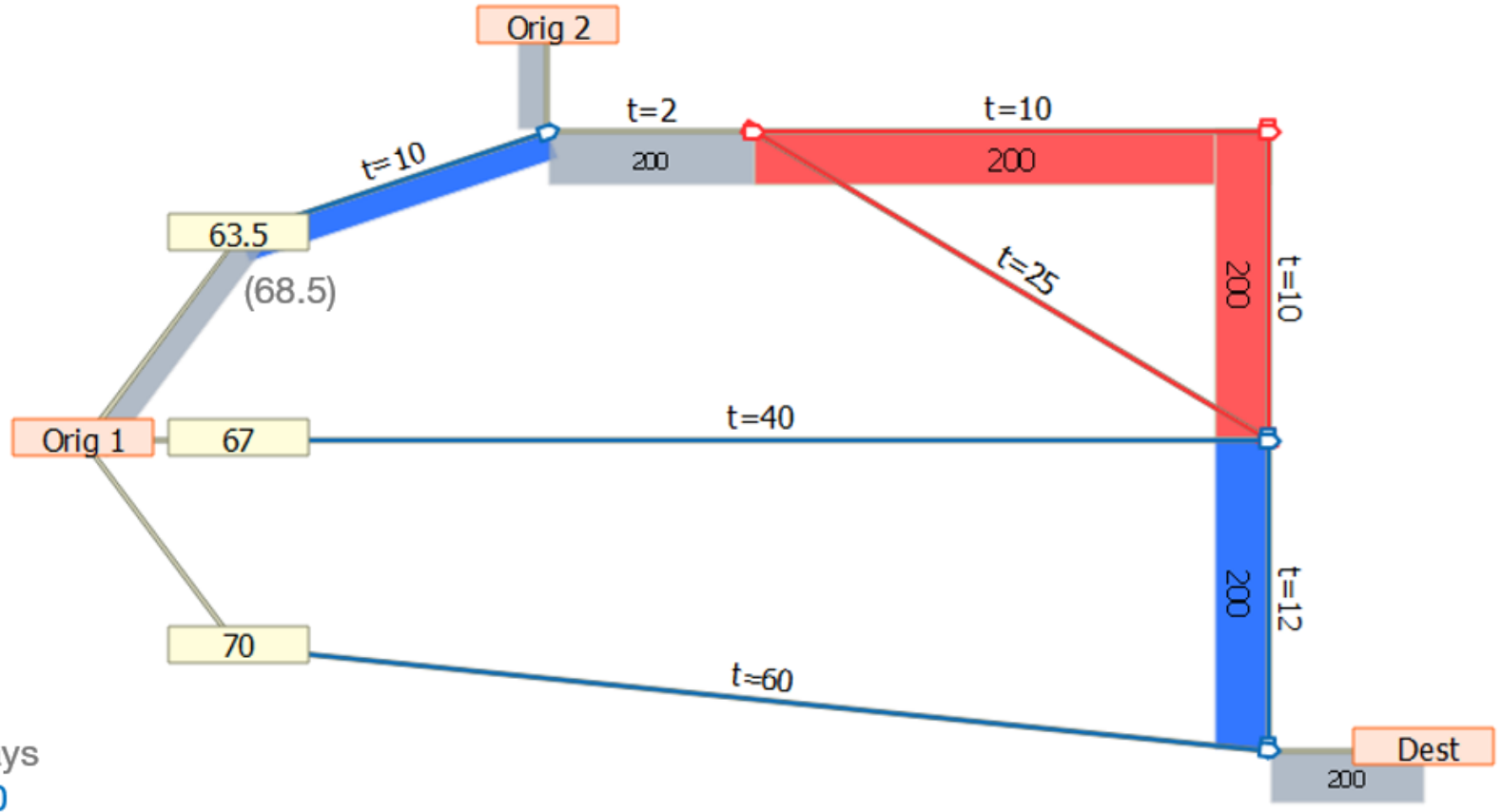
Ex 2 – Free transfers within mode

- Travelers now incur an additional (free) transfer and choose the shorter in-vehicle travel time



Ex 3 – Discounted transfers between modes

- Travelers from Origin 1 use bus to access metro due to the discounted mixed mode fare rebate



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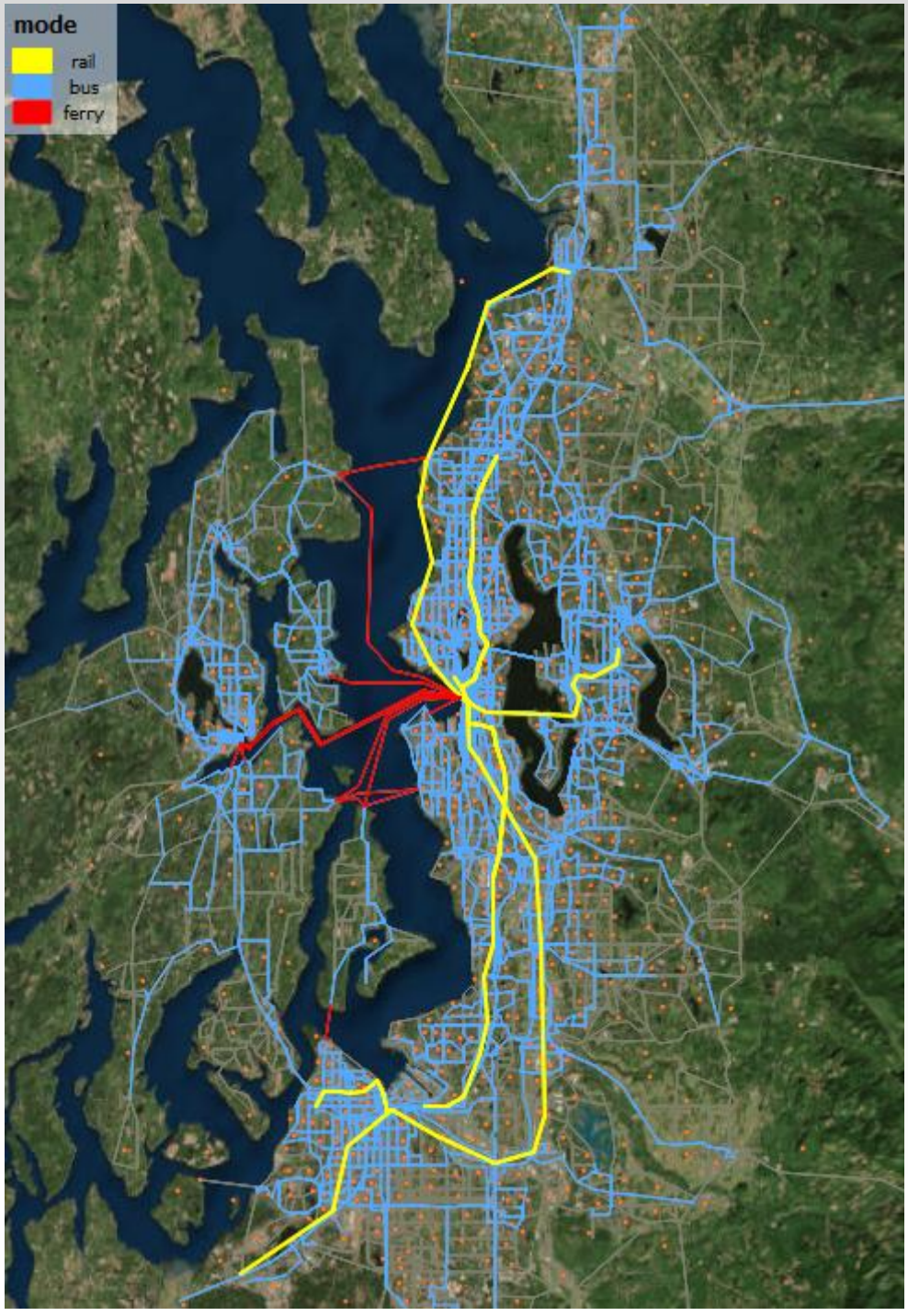
Modification to the optimal strategy algorithm

- Duplicate nodes and segments by journey level to consider different
  - Labels
  - Successors / sets of attractive lines

  → Size of several vectors multiplied by number of levels
- In part 1 (compute optimal strategy to destination)
  - Apply relevant boarding penalties
  - At a node, consider alighting from segments for all possible levels
- In part 2 (assign demand on transit network)
  - Accumulate flows of all levels for a given node, link or segment for corresponding “base” element

Computational results

- Puget Sound regional network
  - 1 115 zones
  - 5 888 regular nodes
  - 20 633 directional links
  - 834 transit lines
  - 25 856 transit segments



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Impact on travelers for different fare schemes

Fare scheme	Lines per passenger	Mean impedance
Full fare	2.24	174.60
One free bus transfer	2.56	171.97
Free bus transfers	2.86	170.35
Free transfers within mode	2.87	170.46

Free transfers within each mode

Journey level	Fare Next journey level		
	bus	rail	ferry
0 Not boarded yet	5 1	7.5 2	10 3
1 Boarded **bus** only	Free 1	7.5 4	10 5
2 Boarded **rail** only	5 4	free 2	10 6
3 Boarded **ferry** only	5 5	7.5 6	free 3
4 Boarded **bus+rail**	free 4	free 4	10 7
5 Boarded **bus+ferry**	free 5	7.5 7	free 5
6 Boarded **rail+ferry**	5 7	free 6	free 6
7 Boarded all modes	free 7	free 7	free 7

Run times for different fare schemes

Fare scheme	Number of journey levels	CPU time	
Full fare	1	6.2 s	
Free bus transfers	2	9.6 s	*(x 1.5)*
One free bus transfer	3	13.0 s	*(x 2.1)*
Free transfers within mode	8	38.6 s	*(x 6.2)*

Emme 4.2 on 2 Quad CPU Q6700 @ 2.66GHz, using 3 threads for the assignments

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Computational results

- Salvador, Brazil
  - 1 055 zones
  - 13 383 regular nodes
  - 30 695 directional links
  - 1 128 transit lines
  - 150 096 transit segments

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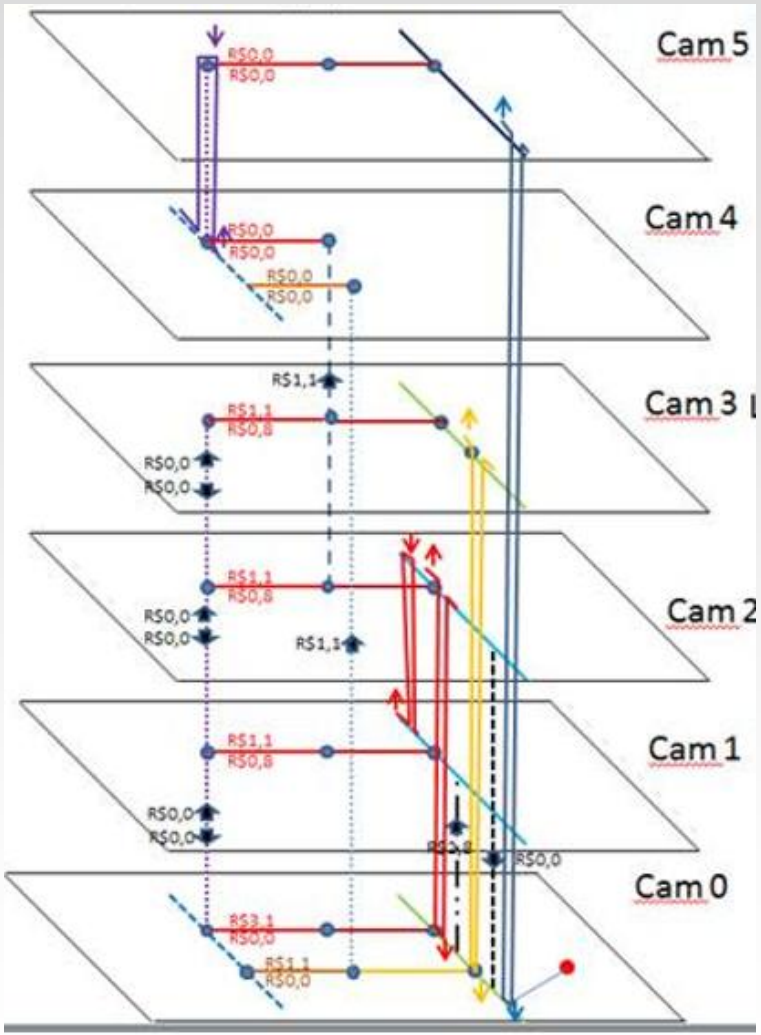
Salvador integrated metro-bus fare scheme

- Metro
  - From metro (**m**): free
  - From integrated bus (**b** or **n**): discount
- Integrated bus (**b** and **n**)
  - From metro only: discount
  - From integrated bus prior to metro: free
  - From **b** to **b**: free (only once)
- Examples
  - **b** → **n** $ 3.00 + $ 3.00
  - **b** → **b** $ 3.00 + $ 0.00
  - **b** → **m** → **n** $ 3.00 + $ 1.20 + $ 0.00
  - **m** → **n** $ 3.30 + $ 0.90

Layered network approach

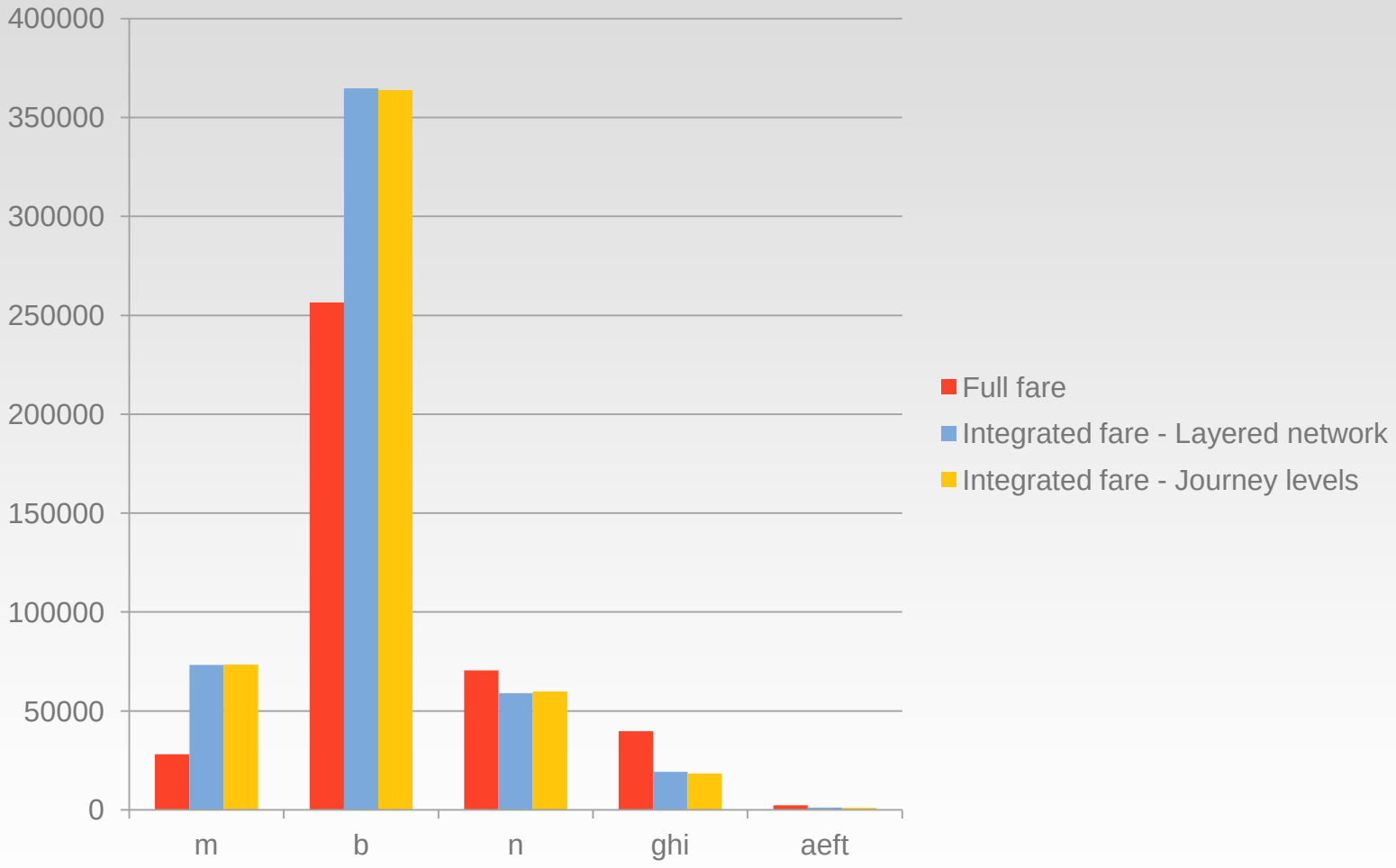
- Explicit layer creation
  - Python script using Emme's Network API
  - Network size increases
    - 13 383 → 45 861 regular nodes
    - 30 695 → 150 657 directional links
    - 1 128 → 3 356 transit lines
    - 150 096 → 985 600 transit segments
- Results interpretation is more involved/challenging



Journey level approach

Journey level	Fare Next journey level			
	m	**b**	**n**	**other**
0 Full fare must be paid	3.30 1	3.00 2	3.00 3	full 0
1 Paid full fare for **m**	free 1	0.90 4	0.90 5	full 0
2 Just boarded **b**	1.20 6	free 3	3.00 3	full 0
3 Boarded **n**, **bb** or **bn**	1.20 6	3.00 2	3.00 3	full 0
4 Boarded **mb**	3.30 1	free 0	3.00 0	full 0
5 Boarded **mn**	3.30 1	3.00 2	3.00 0	full 0
6 Boarded **bm** or **nm**	free 6	free 2	free 0	full 0

Number of passengers by mode



Execution times

Approach	Execution time (minutes)
Layered network • Layer creation • Assignment • Total	 ~ 9 ~ 2 ~11
Journey level • Assignment (7 journey levels)	 ~ 7

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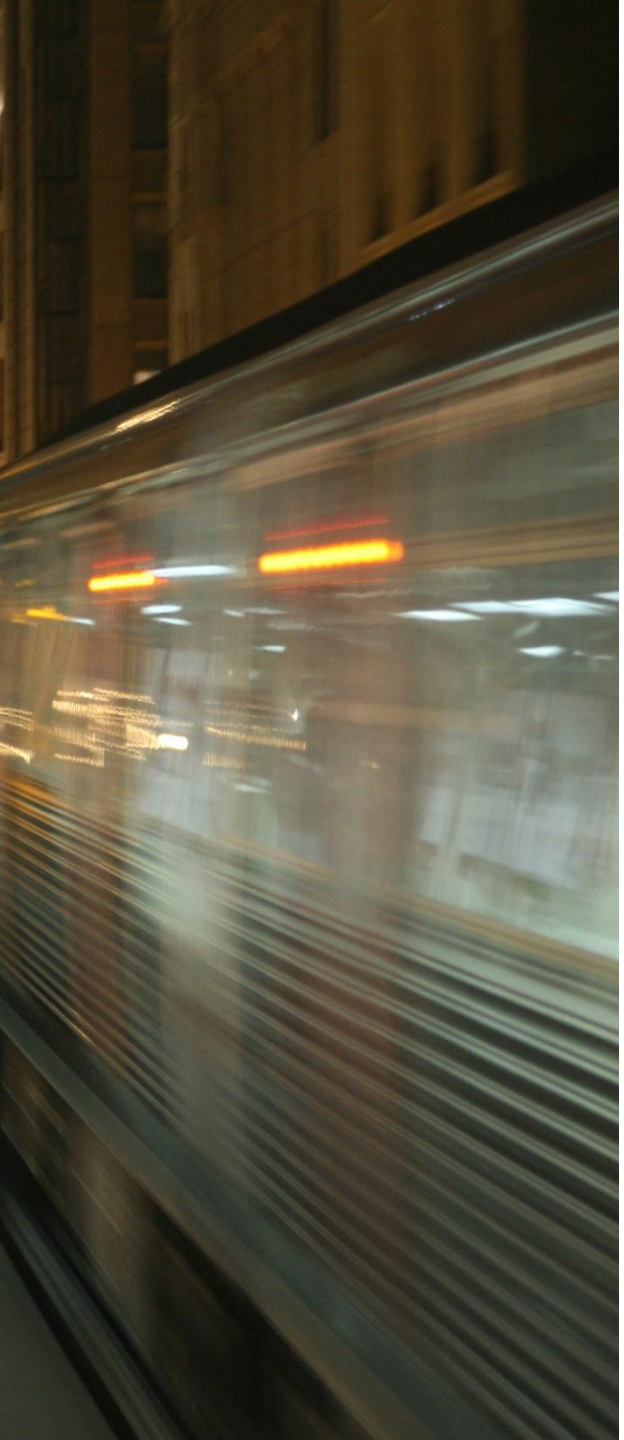

Journey levels

- Models integrated fares
- Intuitive model specification
  - No network constructions
- Computationally scalable
- Network-wide integrated fare impacts
  - Not limited to stops or stations
- Forced/must-use mode
- Available in Emme 4.2

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