Mitigating Urban Traffic Congestion: A Multi-modal Approach Including DRT for Jerusalem

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Possible Congestion-Mitigating Carrot-and-Stick Transport Policies for Jerusalem

Highlights:

- *Congestion charges vs parking prices*

  - Reasonable payment of 10€/day is sufficient to reduce the number of vehicles arriving to the Jerusalem city center by 25% and congestion there by 40%.
  - Congestion charges decrease the arrivals but increase car usage within the charged area
  - Parking prices are more effective than congestion charges, and can be applied locally

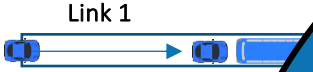
- *The perspectives of shared DRT*

  - With the current free entrance to Jerusalem city center, the DRT is mostly used by the PT users.
  - Paid entrance to the city center makes shared DRT equally attractive to the users of the private car and PT

To investigate transp… apply MATSim

Microscopic … nulations

Link 1



C… tive system … Microscopic … modeling

Home
Desired Departure 07:00

"Ca…
From Home
Work

… to
…ork

Work
Desired arrival time 14:15

Horni, A., Nagel, K., Axhausen, K. W. (2016). The … MATSim

We are at the MATSim User meeting

No need to explain about MATSim

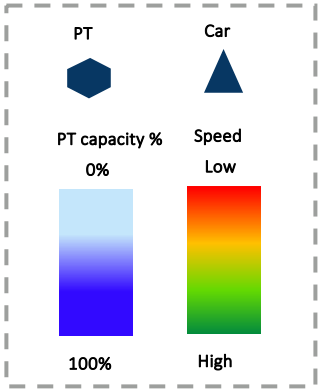
The simulated traffic

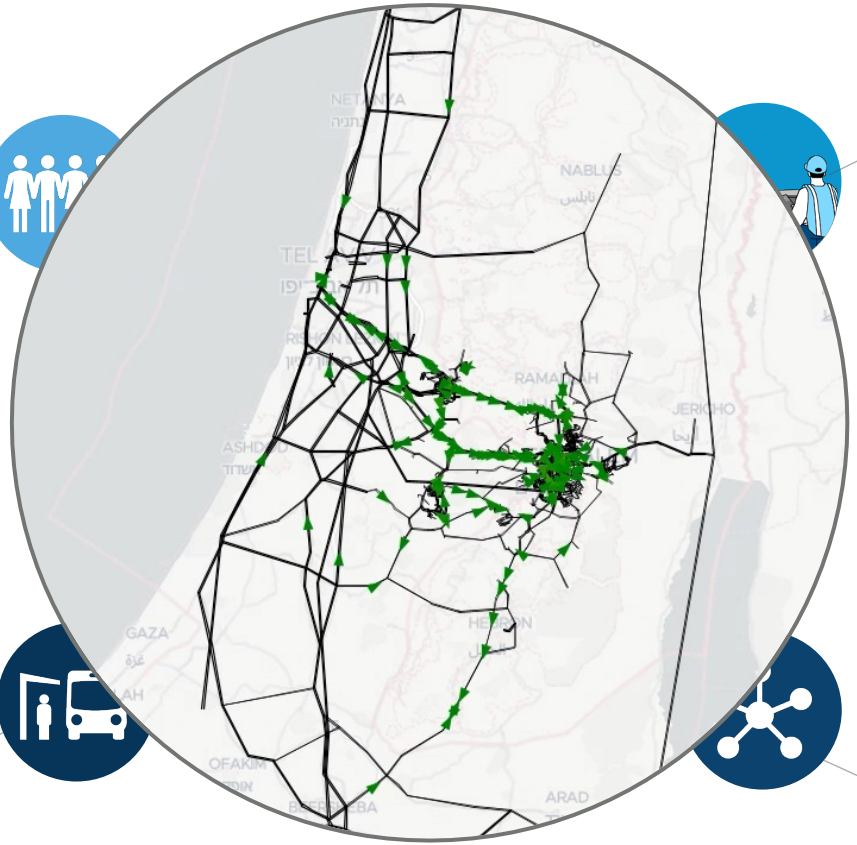
Population

434k internal agents
96k external agents

Validation - Traffic Counts

Years – 2012-2020
Count stations – 2,422
Count hours 07:00-20:00





Public Transport (GTFS)

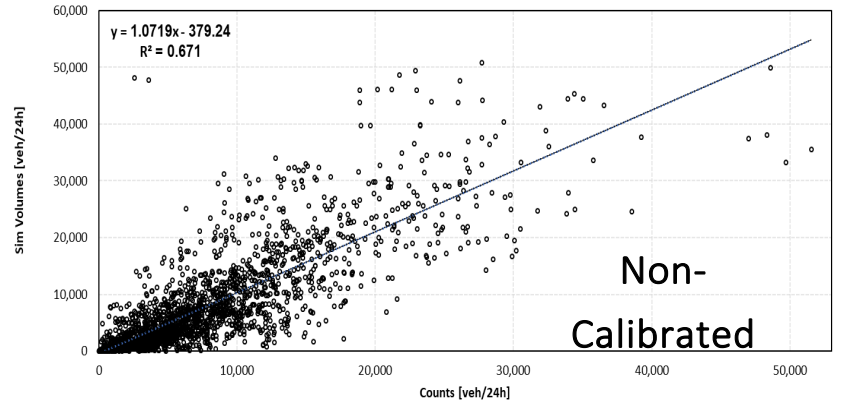
336 PT lines
2,637 Stops

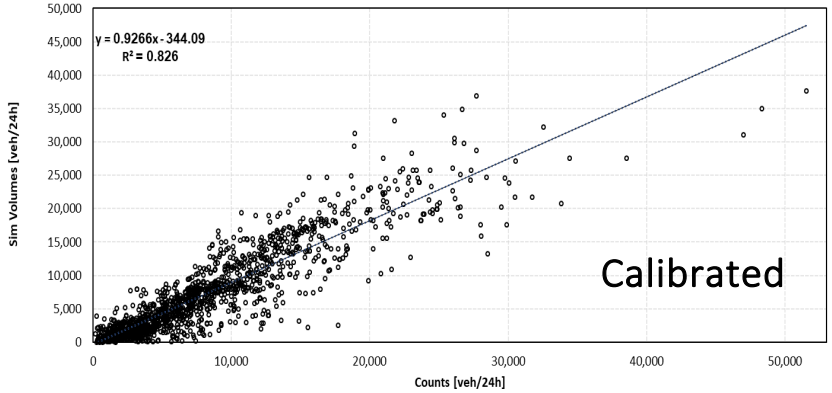
Network (EMME/2)

8,466 links
3,529 Nodes

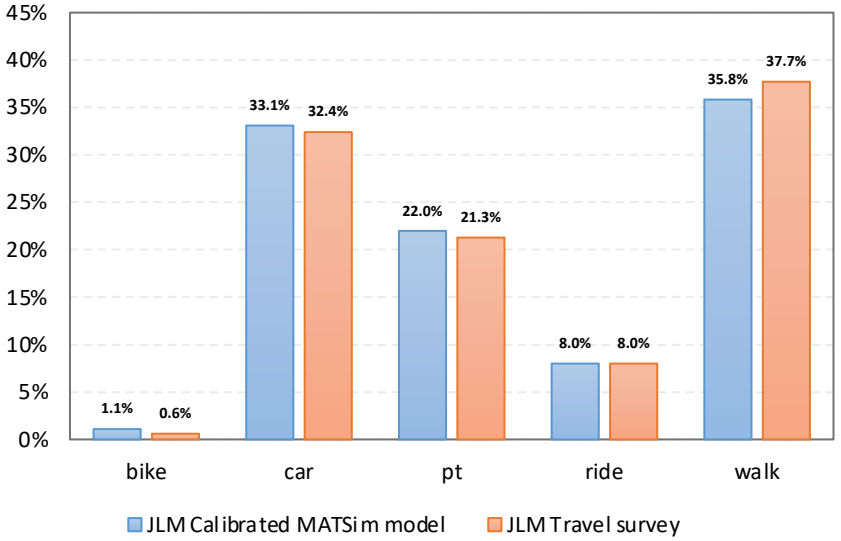
Model calibration with Berlin's parameters, adjusted to Jerusalem's income and prices

Traffic counts at 2285 points





Modal Split



The hourly match is similar to the match of the daily totals

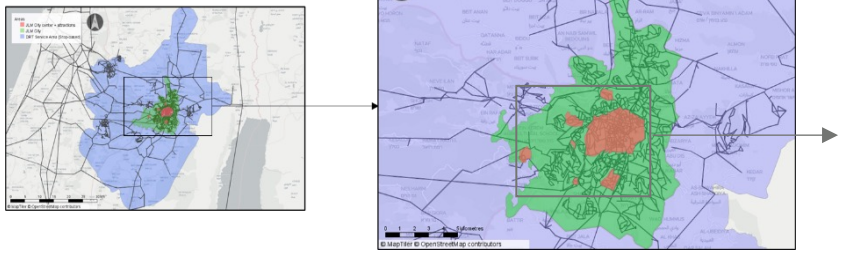
The effects of congestion and parking pricing in Jerusalem center

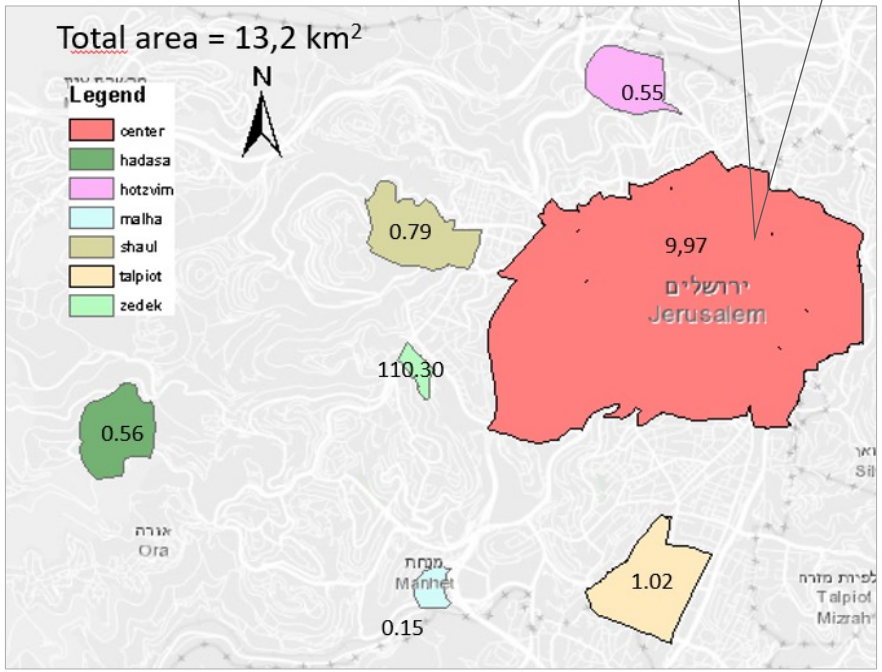
Jerusalem is highly congested, 1.3M car trips/day

We investigate measures of congestion – V/C and Travel Time Ratio (TTR) = Real Travel Time / Off-Peak Travel Time

Can we reduce congestion in the center of Jerusalem?
The effect of the charged entrance to Jerusalem city center

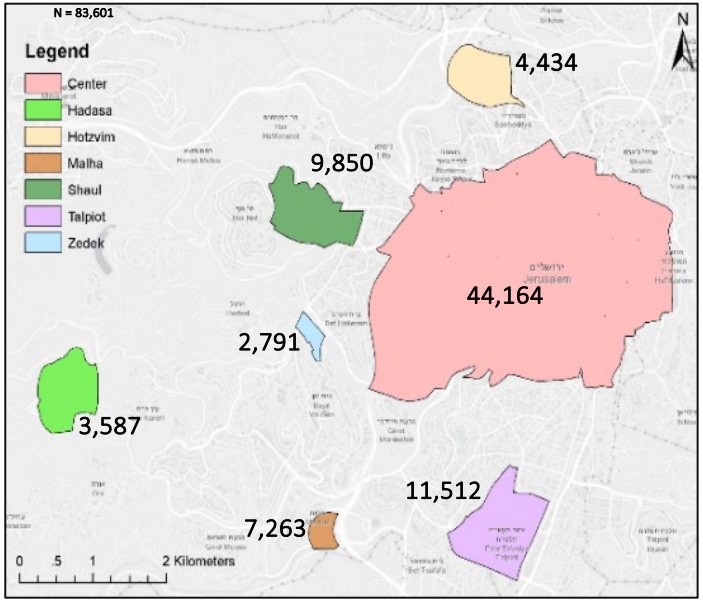
Who pays? Non-residents arriving with cars
For what? Cordon congestion charge and/or parking price
How much? Scenarios of Congestion charge x Parking price - [0€ - 20€] x [0€/h - 20€/h]



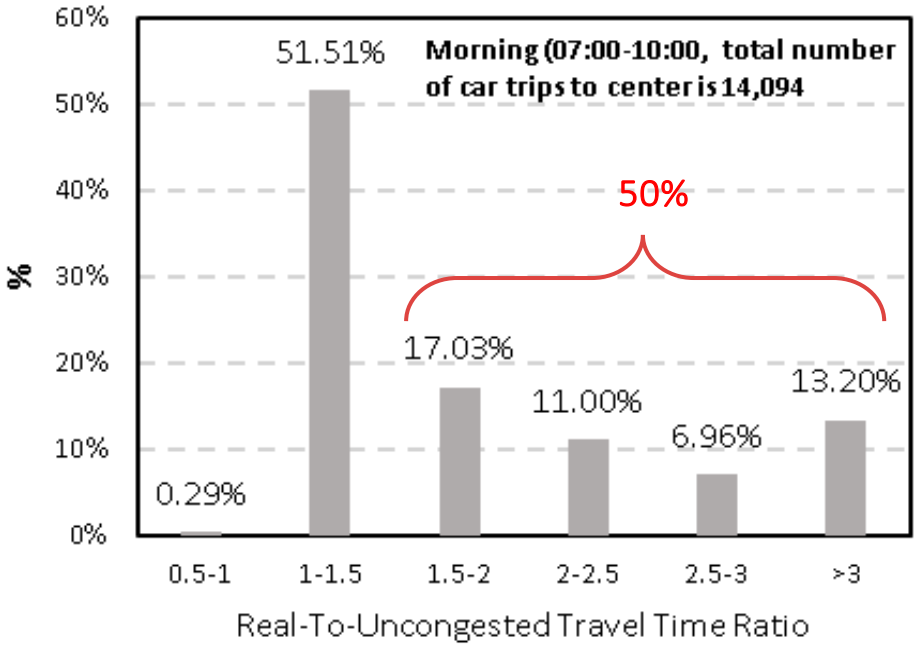


The baseline scenario (no congestion charge/parking price)

Daily car entries to the CHD



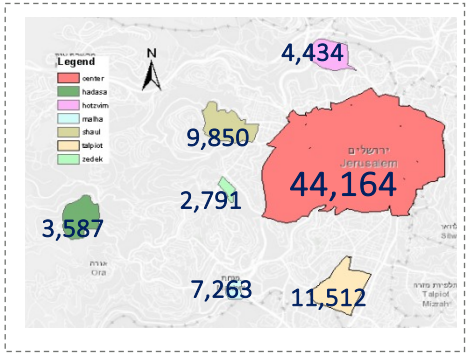
Time lost in congestion



Travel Time Ratio (TTR) = Real Travel Time / Off-Peak Travel Time

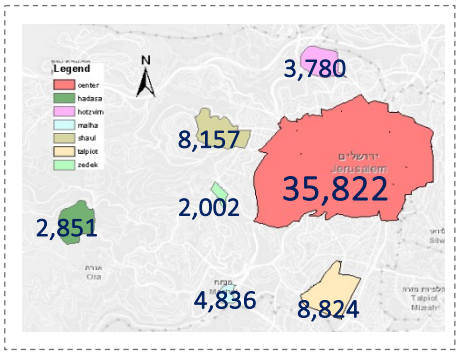
Priced entrance: 20% less cars in the city center and lower Travel Time Ratio

0€



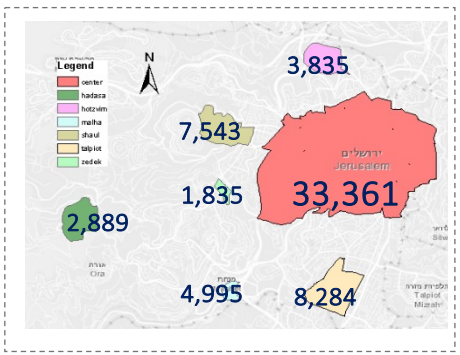
N = 83,601

Parking price 5€/h

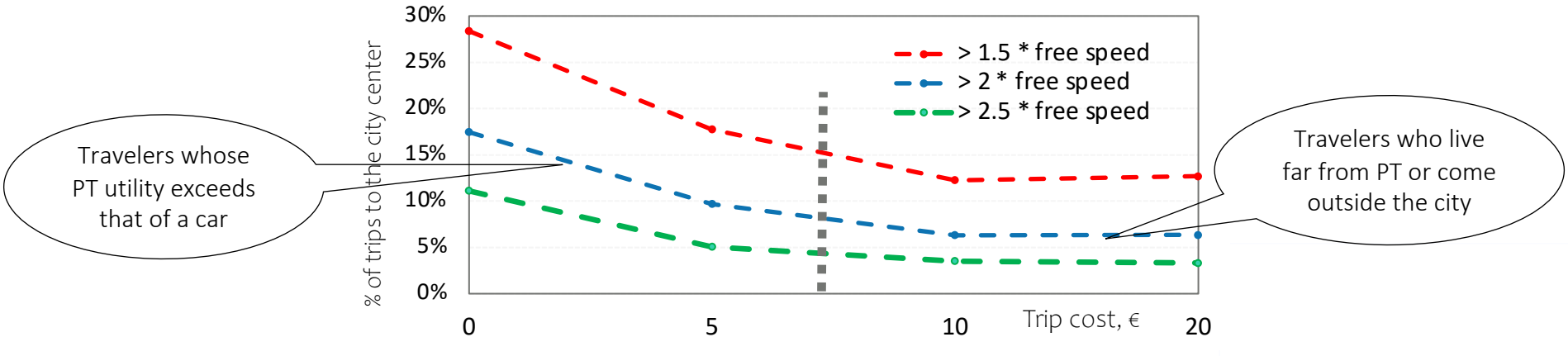


N = 66,982 -20%

Congestion price 10€



N = 62,742 -25%

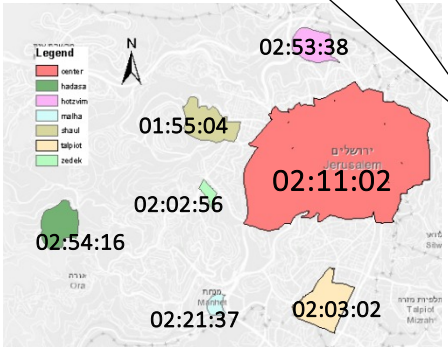


spent in Jerusalem center (wo ensive...

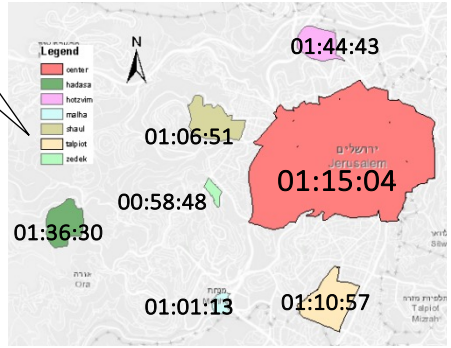
Attractive for agents with short-time activities

Attractive for agents with long-time activities

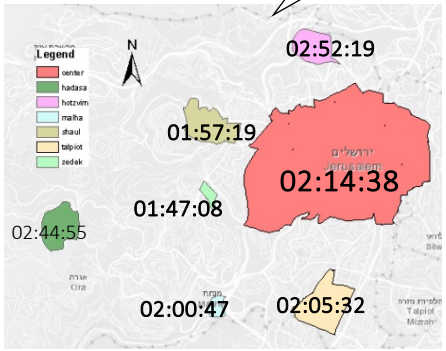
Current state, no charges



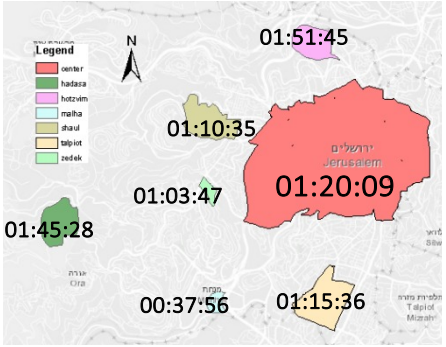
5€ Hourly parking price



10€ congestion price

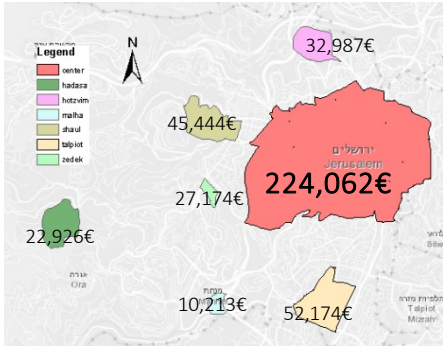


10€ Congestion price
+ 5€ hourly parking price

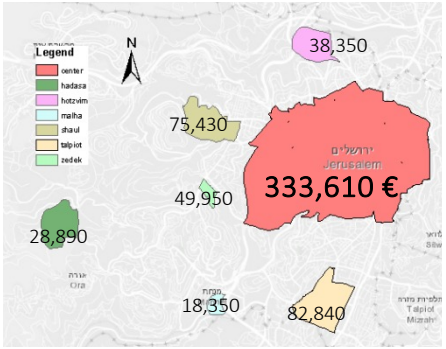


Daily tax collection

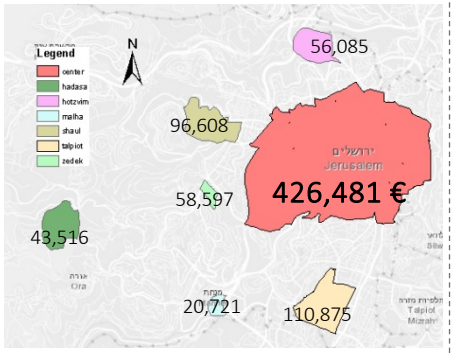
5€ Hourly parking price



10€ congestion price



10€ Congestion price
+ 5€ hourly parking price

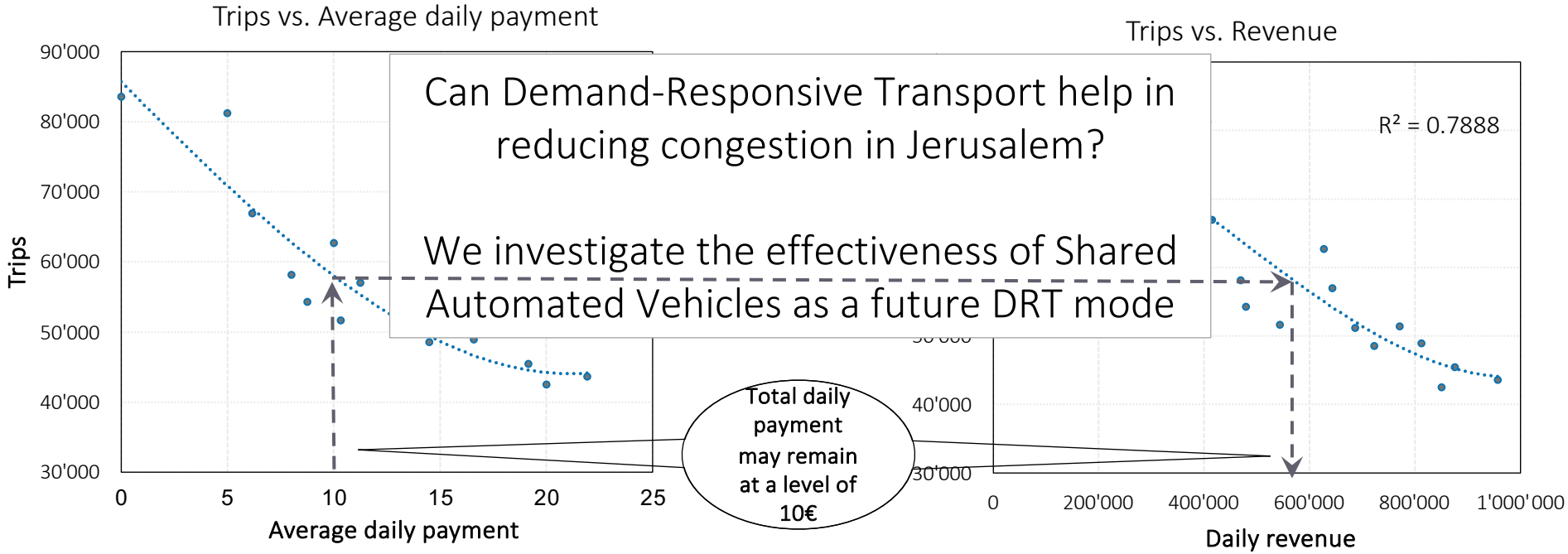


Daily revenue **414,979€**

Daily revenue **627,420€**

Daily revenue **812,883€**

The price of entering Jerusalem center should not be too high



Can Demand-Responsive Transport help in reducing congestion in Jerusalem?

We investigate the effectiveness of Shared Automated Vehicles as a future DRT mode

Average daily payment = Congestion charge + Parking price × Average dwell time

SAV vehicles must be dispatched - an algorithm

In response to the agent's request, consider all vehicles satisfying the following conditions:

1. Can arrive at the pickup point earlier than maximal waiting time t_{max}^{wait}
2. Would have a vacant seat at a pickup point
3. Would provide to a new agent a ride which duration is less than $t_{max}^{r} = \alpha * t_{direct}^{r} + \beta$
4. Would not increase travel time of any other passenger above their threshold $t_{max}^{r} = \alpha * t_{direct}^{r} + \beta$

The vehicle that provides minimal average travel time for all passengers is chosen for a service

REJECTION CONDITION:
- If none of the vehicles satisfies conditions 1, 2, 3, 4 – reject the request

NO-REJECTION ALGORITHM'S ALTERNATIVE:
- If none of the SAVs satisfies conditions 1 - 4 – assign SAV satisfying 2, 3 and 4 only, irrespective of waiting time

Bischoff et al. 2018. https://matsim.atlassian.net/wiki/download/attachments/299335682/bischoff.pdf?api=v2

Our extension of SAV Dispatching Algorithm

- SAV picks up passengers at the PT stops (and not at home locations)
- In case of rejection, an agent returns to perform its regular daily plan

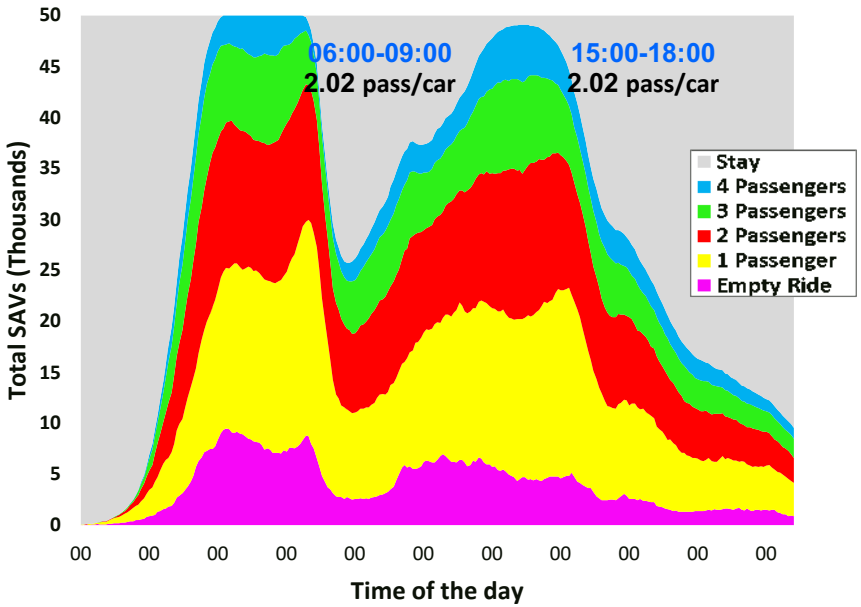
DRT service policy

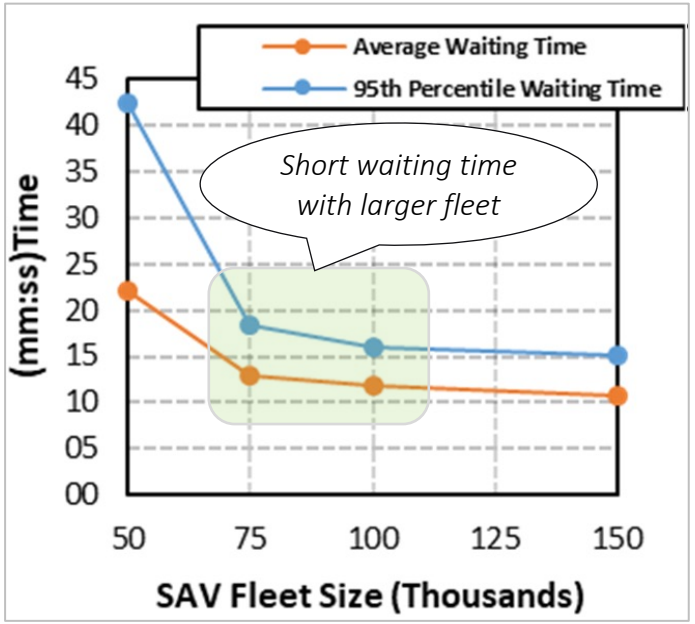
- SAV serves trips between the city center and outer area. If a trip origin is in the center, the destination must be outside, and visa versa

Technical change

- SAV dispatching algorithm is included into the HERMES simulation engine that accelerates computations more than twice

Can SAV substitute all modes (and resolve the congestion)?
Tel Aviv experiments

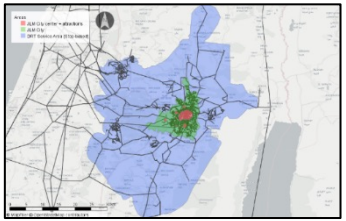


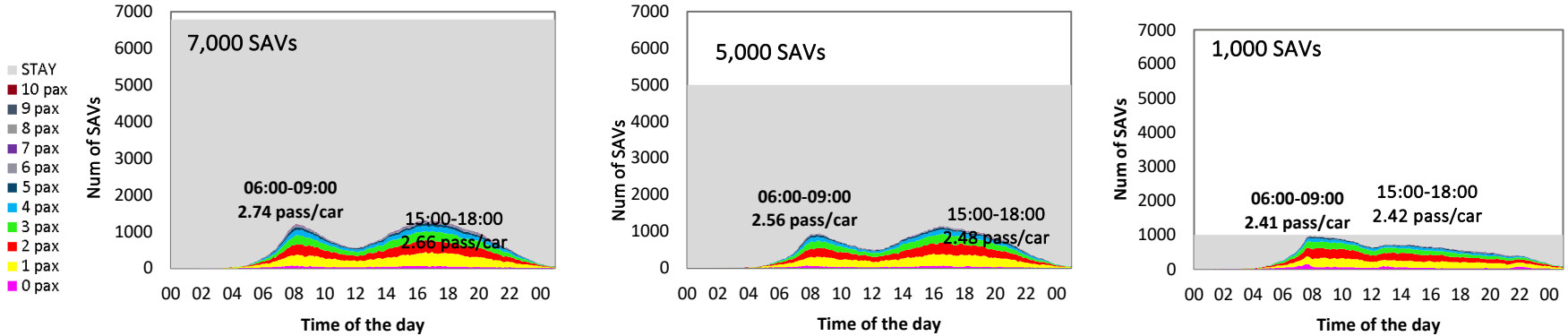


- *Good news:* Even for very high penetration, the average occupancy of SAV is below 3 (but 3 is fine!)
- *Bad news:* To guarantee high level of service, SAV fleet must be twice higher than the number of vehicles that are instantly in service. About half of the fleet would just wait for the requests.

More realistic scenario: Jerusalem, SAVs coexist with the regular PT

- SAV picks up passengers at the PT stops within the service area
- Empty SAV parks at once and waits for a new request
- SAV price is the same as public transport

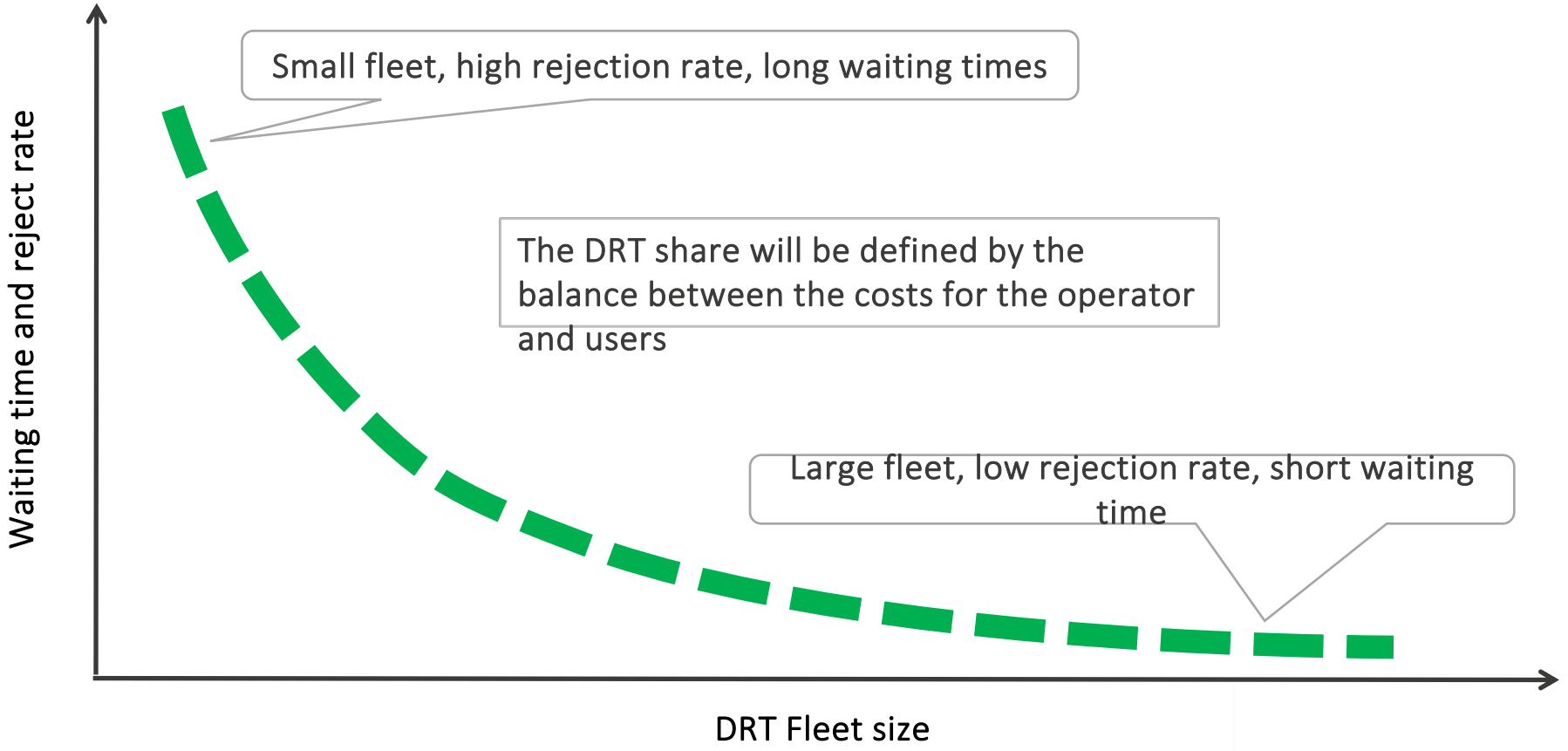




SAV Fleet size	Request rejected %	Average waiting time (min)	Waiting time 95 percentile (min)	Average in veh time (min)	Average trip distance (km)
1000	26.93%	10:07	25:18	28:23	10.39
5000	1.04%	07:06	17:02	27:41	10.38
7000	0.34%	06:59	16:52	29:44	11.90

1500-2000 SAVs seems a reasonable compromise

Unavoidable relation between the Level of Service & Cost



Can SAV effectively service the Jerusalem center?

SAV service conditions

- SAV picks up passengers at the PT stops within the service area
- SAV price is the same as public transport
- Empty SAV parks and wait for a new request at the end of the previous trip

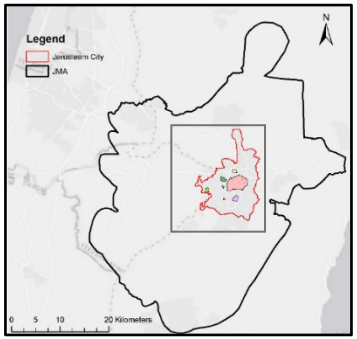
Scenarios

- Vehicle capacity – 10 seats
- SAV fleet – 250 and 1000 vehicles
- Full vs. Core-Periphery service

SMALL center vs BIG center

Full service – any request within the JMA area is served

Core-Periphery service – the origin or the destination of the request should be in Jerusalem city center (Big vs. Small)



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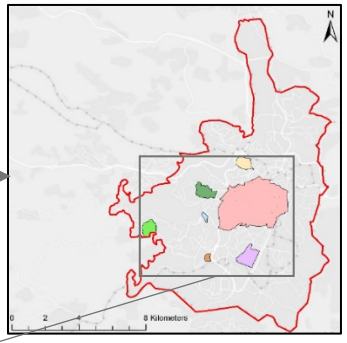
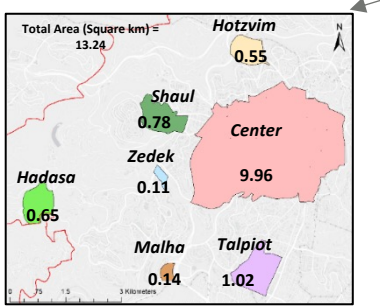
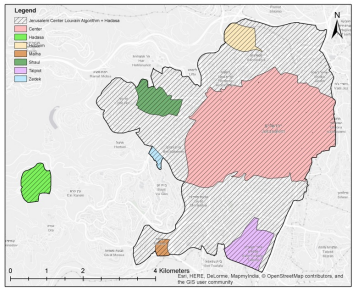


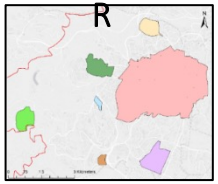
BIG





Trips to center

SMALL CENTER

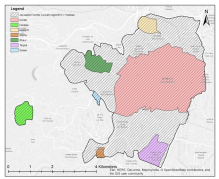


Scenario			Modal Share			N			AVG Travel Time (mm:ss)		
Scheme	DRT	Price (€)	Car	PT	DRT		Car to DRT	PT to DRT	Car	PT	DRT
-	0	0	67.5%	32.5%	0.0%	141,336	-	-	20:12	43:34	-
-	250	0	62.0%	33.7%	4.3%	139,742	1,883	3,740	21:52	46:03	38:55
Entry	0	10	49.1%	50.9%	0.0%	136,678	-	-	12:48	39:19	-
Entry	250	10	47.5%	45.9%	6.6%	134,385	4,411	4,013	13:41	43:14	34:08
Parking	0	5	49.4%	50.6%	0.0%	135,912	-	-	13:10	39:40	-
Parking	250	5	48.3%	45.7%	6.0%	133,649	3,434	4,111	13:41	43:44	34:35

Pricing reduces Car travel time to center

SAVs with no pricing takes from PT

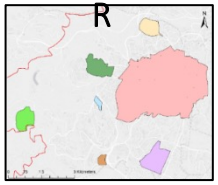
BIG CENTER



Scenario			Modal Share			N			AVG Travel Time (mm:ss)		
Scheme	DRT	Price (€)	Car	PT	DRT		Car to DRT	PT to DRT	Car	PT	DRT
-	0	0	66.3%	33.7%	0.0%	218,009	-	-	21:52	46:03	-
-	250	0	61.4%	35.4%	3.2%	215,700	2,017	4,481	19:17	43:58	41:12
Entry	0	10	56.8%	43.2%	0.0%	213,832	-	-	13:17	39:10	-
Entry	250	10	53.2%	42.7%	4.2%	210,227	4,030	4,323	13:01	43:28	40:06
Parking	0	5	46.1%	53.9%	0.0%	208,596	-	-	11:48	39:49	-
Parking	250	5	46.1%	49.9%	4.1%	203,685	3,295	4,656	13:21	43:17	38:42

Trips in center (No DRT trips in center)

SMALL CENTER

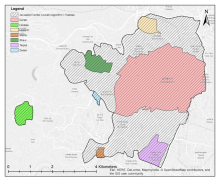


Scenario			Modal Share		N	AVG Travel Time (mm:ss)	
Scheme	DRT	Price (€)	Car	PT		Car	PT
-	0	0	44.5%	55.5%	10,963	13:13	29:46
-	250	0	43.0%	57.0%	10,680	14:36	32:22
Entry	0	10	52.8%	47.2%	10,923	05:45	25:07
Entry	250	10	47.5%	52.5%	11,100	14:36	28:49
Parking	0	5	20.1%	79.9%	10,155	05:52	26:17
Parking	250	5	25.3%	74.7%	10,069	06:41	27:46

Entry charge increase car usage in city center as internal car trips are not affect by the charge

Parking prices reduces car trip in city center

BIG CENTER



Scenario			Modal Share		N	AVG Travel Time (mm:ss)	
Scheme	DRT	Price (€)	Car	PT		Car	PT
-	0	0	56.2%	43.8%	63,014	12:50	32:00
-	250	0	52.6%	47.4%	62,212	12:07	33:04
Entry	0	10	61.4%	38.6%	62,854	06:24	27:38
Entry	250	10	55.1%	44.9%	62,905	07:33	31:39
Parking	0	5	25.6%	74.4%	58,575	05:48	26:14
Parking	250	5	31.1%	68.9%	57,295	06:27	32:05

The lessons of realistic simulations of anti-congestion policies

- DRT will never become a panacea:

The criteria of minimal rejected requests, short waiting time and minimal void vehicles' time are inherently contradictory

- DRT can be effective for serving strong flows of travelers, like Jerusalem core-periphery flows:
  - The size of the DRT fleet is defined by the balance between demand and operator's cost
  - If the entrance to the city center is not charged, most of the SAV users come from PT
  - Moderately priced entrance to the city center decreases car use in favor of the PT and makes SAV equally attractive for car and PT users.

Feasible congestion mitigation policy must balance carrot and stick measures

Acknowledgment:

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