Connected and Automated Vehicles – A Partial Solution to Congestion?

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Presented at:

ETC 2021, September 14, 2021

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Acknowledgements

- My co-author – Steven Landau of EBP-US.
- Participant in the original research under which the original model was built – Dr. Ira Hirschman, EBP-US
- Based on HPMS data in the USA
- The opinions expressed here are the authors' own

Abbreviations and Definitions

- CAV – Connected and Automated Vehicles
- EV – Electric Vehicles
- HPMS – Highway Performance Measurement System
- VOC – Vehicle Operating Costs
- VTT – Value of Travel Time
- TTI – Travel Time Index – defined as the ratio between the actual travel time and the free-flow travel time (regardless of trip purpose)
- For the purpose of this model, congestion is defined as TTI >= 1.5 (i.e. a free-flow ride of 30 will be 45 minutes under congestion

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Model Introduction

- The major purpose of the model is to estimate the costs of congestion under several policy variants (e.g. increased CAV penetration, while using the same infrastructure)

Estimating the Costs of Congestion and its Remedies via CAV and Added Capacity

Select Scenario	Investment if needed at TTI=1.5	Run Model					
Name of Input / Parameter	Type of input / units	Model Input	Comments	Scenarios			
Model Parameters				**Investment if needed at TTI=1.5**	**Do-minimum**	**Year by Year Investment at TTI=1.2**	**Investment if needed at TTI=1.8**
AADT/C Minimal Ratio	#	8.5	Based on FHWA graph	8.500	*	*	*
Minimal TTI	#	1	Cannot be less than 1	1.000	*	*	*
Max TTI Allowed Prior to Treatment	#	1.5	According to model document	1.500	1.800	1.200	1.800
Max TTI after add'l lane	#	1.25	According to model document - need to achieve 1.25 average at 2040	1.250	1.200	1.200	1.200
Capacity Treatment	1-Gradual (year by year); 2-Treat only when passing Max TTI; 3-Do-minimum	2	1-Gradual (year-by-year according to goals); 2-Treat only when passing Maximal TTI; 3-No Treatment (do-minimum)	2	3	1	2
Number of days in year for AADT	#	364	According to TTI Mobility Report	364	*	*	*
Discount Rate	%	7.0%	According to FHWA guidelines for grants	7%	*	*	*
Maintenance Cost	%	2.0%	as % of cumulative investment	2%	*	*	*

- The model is built on a standard economic appraisal methodology - comparison between a do-minimum to a do-something situation (such as allowing EV/CAV to grow) while keeping an option of adding lane capacity investment based on triggers.
- Works on many flexible assumptions (some are shown above)

Congestion Solutions

- Congestion can be dealt with via supply or demand or a combination of both
- Covid has the potential of assisting in the treatment of congestion (less travel, better technology, people working from home)
- Supply – building our way out of congestion –
- Demand – can be dealt with via pricing (cordon, toll roads, etc), or via administrative order (permits to drive vehicles on certain days)
- Increased usage of public transport by giving better solutions
- **This presentation will explore a new way of dealing with congestion – using the same infrastructure but allowing more vehicles to use it by use of automation – CAV and accompanying infrastructure**

CAV

A possible solution for lessening congestion

- Allows vehicles to "talk to each other" and thus keep a shorter distance between vehicles
- Is it a simple solution? No. But it has the potential of being widely accepted

Technology Beginning to Emerge	Risks to Address
• Example: Adaptive cruise control • R&D underway by various car manufacturers • Basic R&D theory: Each development is the foundation of a new development	• Security • Lack of uniform standards, not all vehicles being able to talk to each other and to infrastructure • Lack of funds • Technology not being adopted

Model Description

Considerations	• City with congestion – can be anywhere • Infrastructure – number of lanes, roads, configurations – which can increase over time • Modal split is assumed not to change significantly over time
Purpose for Considerations	• Enable estimate of the net effect from an EV policy that drives quick expansion
Presumed Outcomes	• Expanding Capacity via EV externalities • EV/CAV penetration will increase over time • For each percentage of EV there will be a distribution between the level of automation and the CAV capability

Model Description (cont.)

- **This model will show that a more rapid increase in EV/CAV penetration will allow for less future investment and less disruption due to increased capacity construction**

EV	Congestion & Infrastructure
What is the expected percentage of EV? Current forecasts mention 30% by 2040	Concurrently with the increase in EV, infrastructure will be built for EV and CAV (charging stations, sensors, internet of things, etc.)
Usage of EV will also lessen fuel usage (electricity) thus having potential environmental benefits	Defining a threshold for intermediate investment in congestion alleviation – TTI = 1.5

CAV Behavioral Options

Behavioral Level 1
Conservative Vehicle and Driver
(slow and cautious)

Behavioral Level 5
Typical Legacy Vehicle
(regular)

Behavioral Level 9
Aggressive
(fast driving, minimal distance)

Source: Atkins Report for DfT (2016)

Changes in Capacity

	Penetration of CAV			
Behavioral Level	0-25%	25-50%	50-75%	75-100%
Level 1	-9.8%	-17.7%	-24.5%	-29.9%
Level 2	-6.8%	-12.6%	-18.0%	-22.1%
Level 3	-2.8%	-5.5%	-8.2%	-10.2%
Level 4	-0.1%	1.0%	2.1%	3.2%
Level 5	5.2%	11.6%	17.9%	23.8%
Level 6	8.2%	16.9%	25.7%	35.8%
Level 7	9.8%	20.0%	30.0%	43.3%
Level 8	12.3%	25.6%	39.5%	58.7%
Level 9	13.9%	28.3%	44.2%	67.3%

Source: Atkins Report for DfT (2016)

- The higher the behavioral level and the more penetration the bigger the increase in capacity
- Capacity change will be different for each country

Penetration of CAV

		Level of Automation			
		Automation Level I (current non-automated vehicle fleet)	Automation Level II (driver assistance)	Automation Level III (partial -> high automation)	Automation Level IV (full automation)
Percentage of Penetration	Base Case	100.0%	0.0%	0.0%	0.0%
	25%	75.0%	20.0%	5.0%	0.0%
	50%	50.0%	35.0%	10.0%	5.0%
	75%	25.0%	50.0%	15.0%	10.0%
	100%	20.0%	40.0%	20.0%	20.0%
	Upper	0.0%	0.0%	0.0%	100.0%

Source: Atkins Report for DfT (2016)

- Assumed geometrical growth between penetration levels
- Reflects that even with full penetration, some people will still want to utilize traditional non-automated vehicles
- Can change for each country

Capacity Increase as Function of Behavior and Penetration

	Level of Automation			
	Level I (current non-automated vehicle fleet)	Level II (driver assistance)	Level III (partial to high automation)	Level IV (full automation)
Min Behavioral Level	5	6	7	8
Max Behavioral Level	6	7	8	9
Minimal increase in capacity (0% EV)	5.2%	8.2%	9.8%	12.3%
Max increase in capacity (100% EV)	35.2%	43.3%	58.7%	67.3%

Source: Atkins Report for DfT (2016)

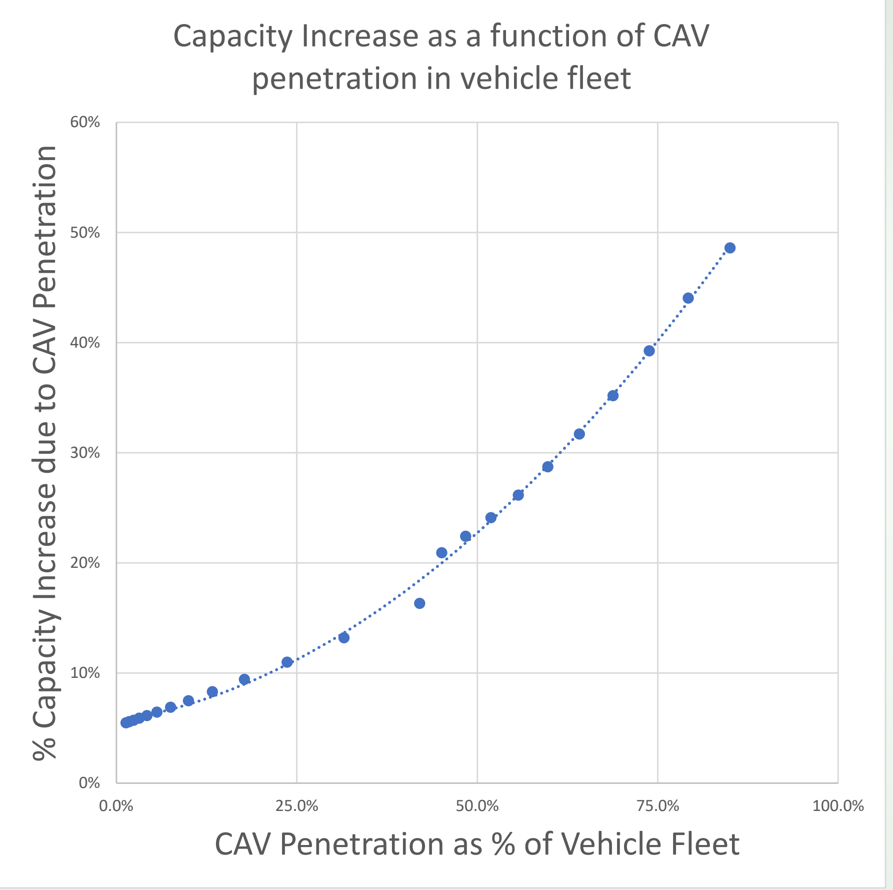
Growth parameters

- Population – each country / region / city and its own forecast
- GDP – each country and its own forecast
- Commuters – same growth as population – can be changed
- Same motorisation rate persists – obviously can be changed
- Sources of information – relevant central bureau of statistics, Moody, IMF, EU, DfT

Assumed Penetration of EV

- Current % of EV and CAV in vehicle fleet – 2% (Bloomberg)
- Several European countries have made declarations of selling only electric vehicles around 2030
- Mention of 30% penetration by 2040 – will give minimal results in terms of additional capacity
- However, for the purpose of showing what can be done to capacity if % of CAV is increased dramatically, we have assumed:
  - 42% penetration by 2030
  - 85% penetration by 2040

Penetration of EV and CAV

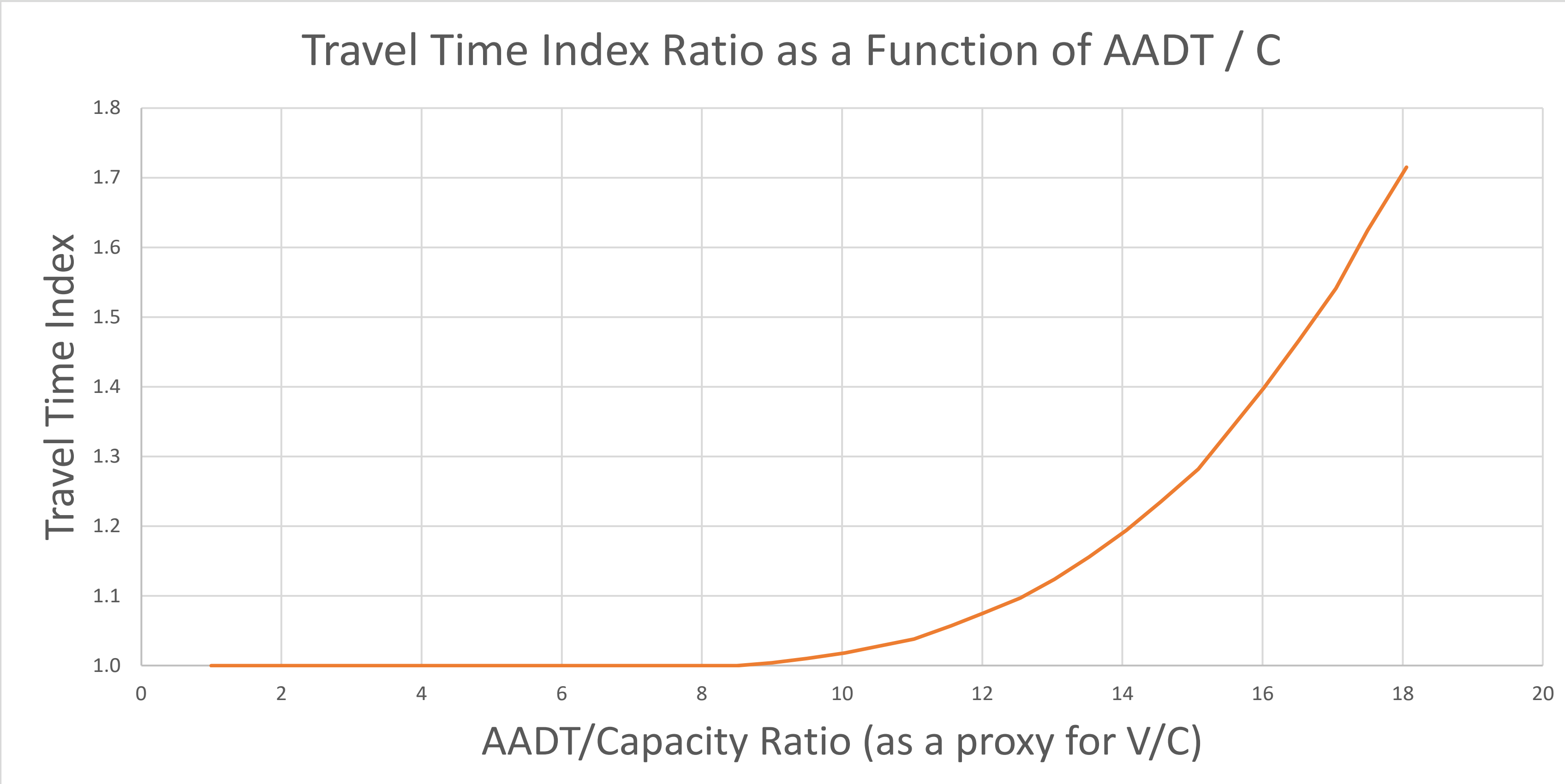


- Takes into account penetration (0-100%), internal distribution by level of automation (Level I – IV), behavior (Level 1 – 9)
- Jump close to 50% is a result of slope increase in capacity at higher levels of behavior

The "Race" to CAV

- The greater the penetration the higher the increase in capacity using the same infrastructure – 85% penetration using DfT accepted distribution can cause an increase more than 50% in capacity
- However, population will grow and GDP will also grow – more traffic
- Is the increase in capacity sufficient to overtake both population and GDP?
- We need a volume capacity curve which can be used for an entire city / region / country
- One is available from the USA

AADT / Capacity Curve



Source: FHWA with adaptations by the authors

- Works on Peak Time Travel Delay which was translated to TTI
- Implied assumption of % of peak traffic as a function of total AADT and spreading out

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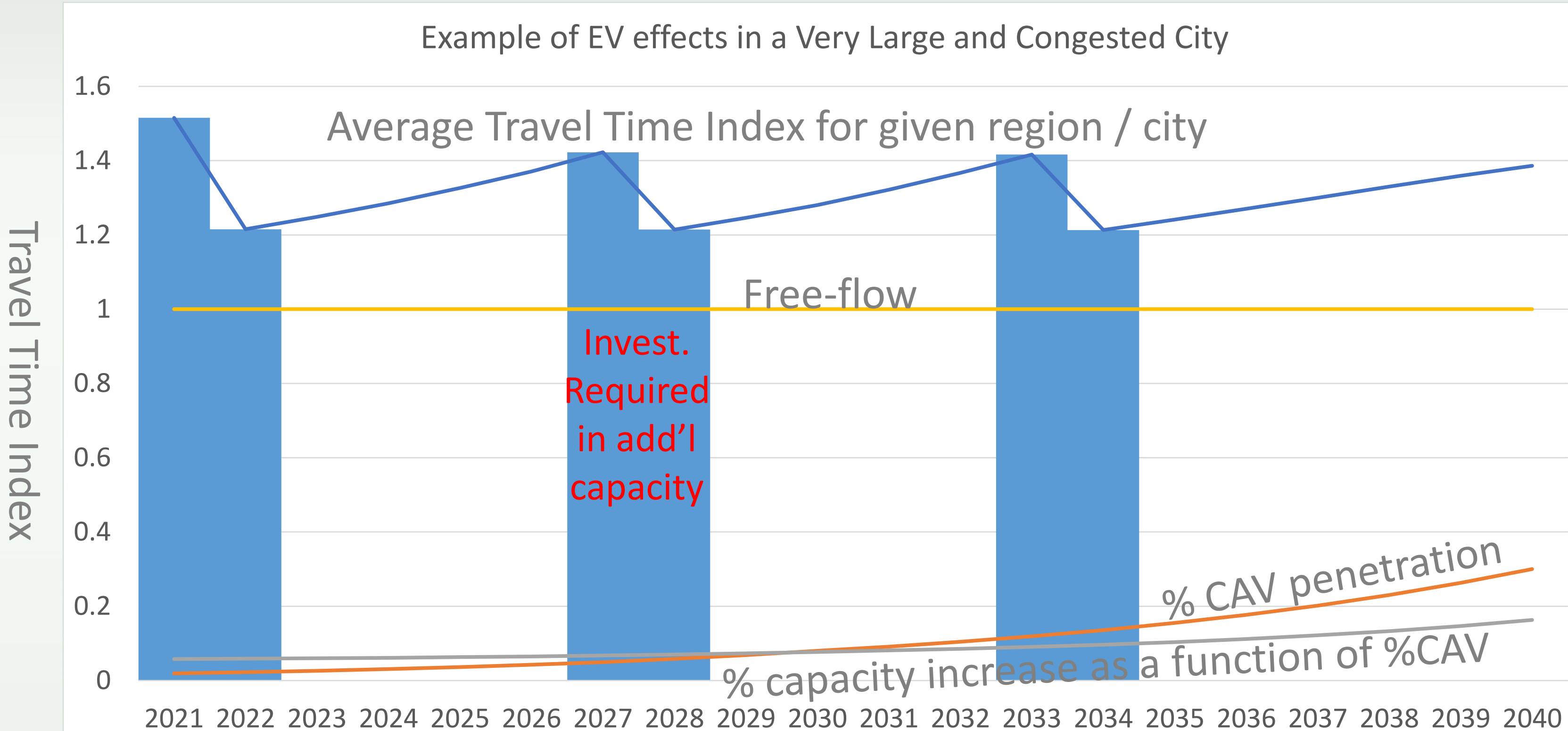
Evaluation Process

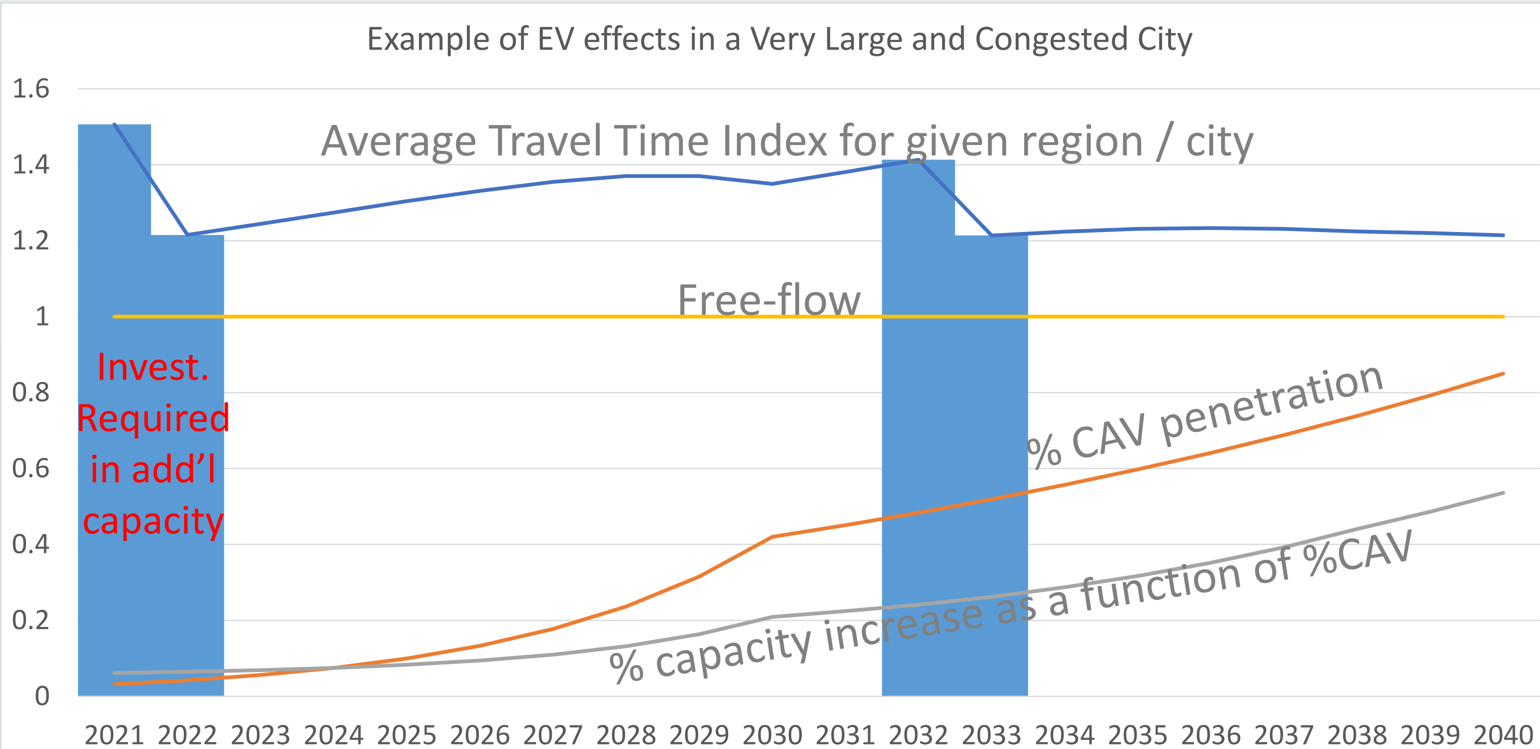
- Take AADT for given year
- Estimate TTI for initial study year (can be by study, estimate, 4-step model, activity based model)
- Increase it by growth rates (population, GDP) to find AADT in year t+1
- See increased penetration of CAV and estimate capacity increase
- Since the increase in CAV capacity is small year-to-year, then cities / regions have enough time to put in infrastructure to allow increases in capacity due to CAV. The cost of the investment in automation is considered to be small – 20% of the construction of a new lane
- If the increase in capacity is larger than the increase in GDP and population then TTI will be lower, i.e. less congestion
- However, if a threshold is reached, then additional capacity or other means should be implemented

Low Penetration of CAV



- CAV penetration is insufficient in cities of large magnitude with high congestion
- Investment in additional capacity is needed in 2021, 2027, 2033
- Capacity increases by less than 20% with 30% CAV penetration

High Penetration of CAV

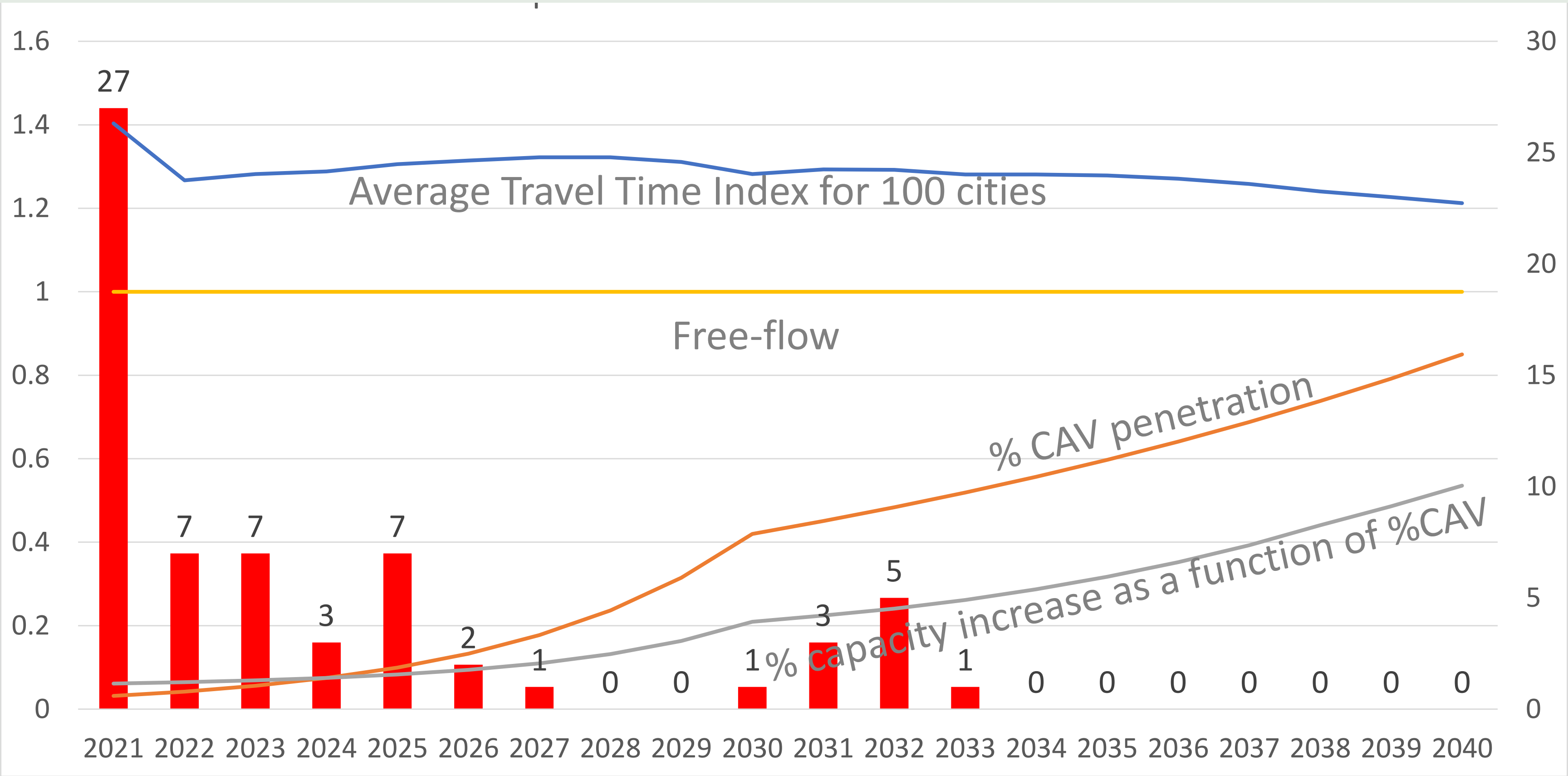


- Higher CAV penetration allows savings in at least one investment (2027)
- TTI is maintained at almost 1.2 just from capacity increase due to CAV
- Capacity increases by almost 50% with 85% CAV penetration

Conclusions

- Additional Policy Option for cities to invest in CAV infrastructure
- Will save investments in the long run and will reduce congestion with all its externalities
- Does not require major investments and can be spread out over time, and can also be less disruptive
- Can be implemented for any city / region / country as long as some data (AADT, lanes, congestion estimate, etc) is available.
- Requires action on the side of regulators, consumers, and also vehicle manufacturing companies (some have already begun)
- It is not the only means of reducing congestion – other travel demand management practices can be utilized
- Focus on the big picture

Nationwide Results



- 27 cities require capacity investment to meet "bearable" level of congestion in 2021 (at a cost of $151 billion), in future years this is dramatically reduced to 7 cities with a maximal investment of $15.7 billion, no investment needed from 2034 on
- Investment in CAV infrastructure on its own will reduce TTI to 1.2 by 2040

Thank You!

In case of questions:

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