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Downs's Law Revisited: How and Why Expanding Roadways Reduces Congestion Despite Induced Travel

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This presentation is based on the article:

- Alex Anas, 2024. **“Downs’s Law” under the lens of theory: Roads lower congestion and increase distance traveled**. *Journal of Urban Economics,* 139, 103607.

- The article was awarded the overall best paper prize by the Scientific Committee of the 2023 annual conference of the International Transportation Economics Association.

- **Can be downloaded from:** ssrn-4331232 (1).pdf

- Journal website: “Downs's Law” under the lens of theory: Roads lower congestion and increase distance traveled - ScienceDirect

OUTLINE – FOUR PARTS

1. Background on traffic congestion

Where and why is congestion rising ?

Can more roads lower congestion?

2. The lens of theory

How urban economists modeled congestion since the 1960's.

3. Specific models

Explanation of simple models to understand the relationships between congestion, travel demand, distance traveled and urban structure.

4. Comments on road expansions and on VKT

Should there be more roads?

1. The background on traffic congestion

Where and why is congestion rising ?

Can more roads lower congestion?

Traffic congestion is of growing importance

TEXAS TRANSPORTATION IINSTITUTE (Schrank et al. 2019):

- “The trends from 1982 to 2017 show that congestion is a persistently growing problem...
- In 2017, congestion caused urban Americans to travel an extra 8.8 billion hours and purchase an extra 3.3 billion gallons of fuel for a congestion cost of $166 billion.
- The average auto commuter spends 54 hours in congestion and wastes 21 gallons of fuel at a cost of $1,080 in wasted time and fuel.”

Why has congestion in the world increased historically?

1)Urbanization: many city populations grow,

2)Car ownership grows,

3)People want to make more trips,

4)Not enough roads are built.

Congestion around the world

INRIX (2019): The most congested cities are in developing countries followed by major European capitals and large U.S. cities.

- R.L. Forstall, R.P. Greene, and J.B. Pick, 2009. Which are the largest? Why lists of major urban areas vary so greatly,.http://www3.interscience.wiley.com/journal/122302376/abstract

Metro Area 2003		Population (millions)	Area (km-sq)	Population Density(/km-sq)
Karachi	Pakistan	11.80	1,100	10,727
Cairo	Egypt	14.45	1,600	9,031
Kolkata	India	15.10	1,785	8,459
Mumbai	India	19.20	2,350	8,170
Manila	Philippines	16.30	2,521	6,466
Tokyo	Japan	32.45	8,014	4,049
Los Angeles	USA	15.25	10,780	1,415
London	UK	12.88	11,391	1,130
New York	USA	19.75	17,884	1,104

Reasons why congestion is so high in the large cities of developing countries

- Transport infrastructure is underdeveloped relative to population and car ownership growth.

- Because of the poorly developed transport infrastructure, cities cannot spread out enough.

- Densities are high because businesses and households must locate in close proximity to overcome the poor infrastructure.

William Vickrey 1996 Nobel Laureate in Economic Sciences:

"In the absence of any tolls, the best available alternative would again be to expand capacity….so as to eliminate congestion entirely."

[Vickrey, 1969, p. 257]

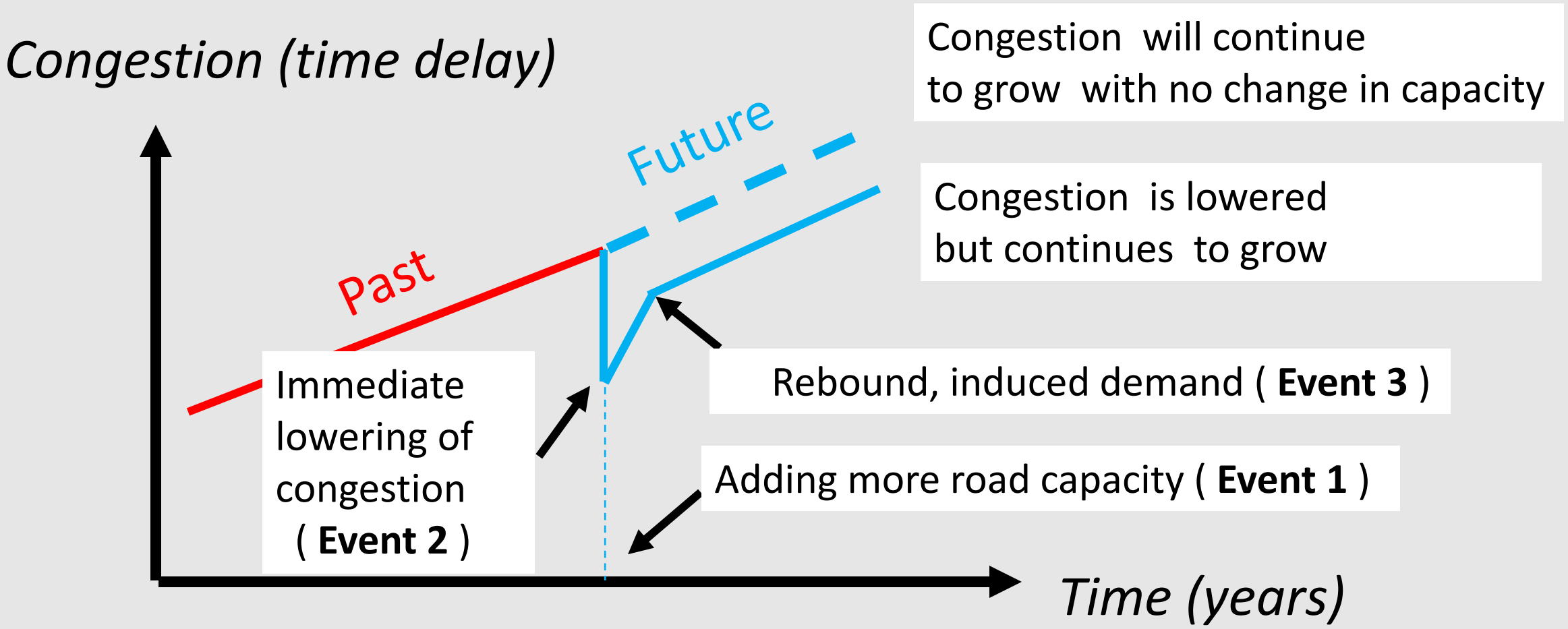
Vickrey, W.S. 1969. Congestion theory, and transport investment. *American Economic Review* 59(2), 251-260.

Matt Turner (Brown University) quoted (By Eden Weingart New York Times, January 6, 2023.) :

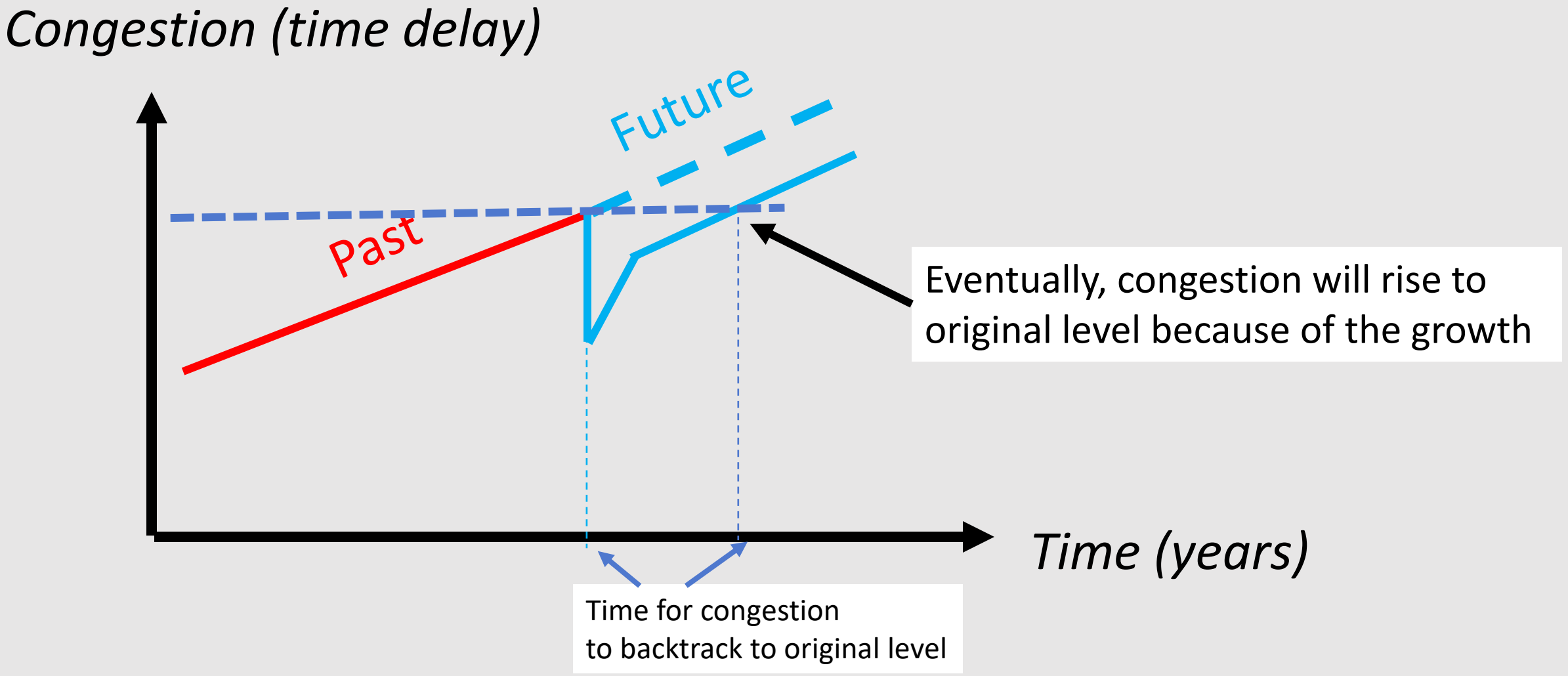
"*Widening highways doesn't fix traffic, so why do we keep doing it?*--- "If you keep adding lanes because you want to reduce traffic congestion, you have to be really determined not to learn from history."

Should we remove lanes in order to reduce congestion?

Charting congestion over time



Charting congestion over time



Downs, A. 1962. The law of peak-hour expressway congestion. *Traffic Quarterly,* 16(3): 393–409.

Anthony Downs's observations about expressways in 1962

1)Traffic flow rises to its maximum [eng'g design] level

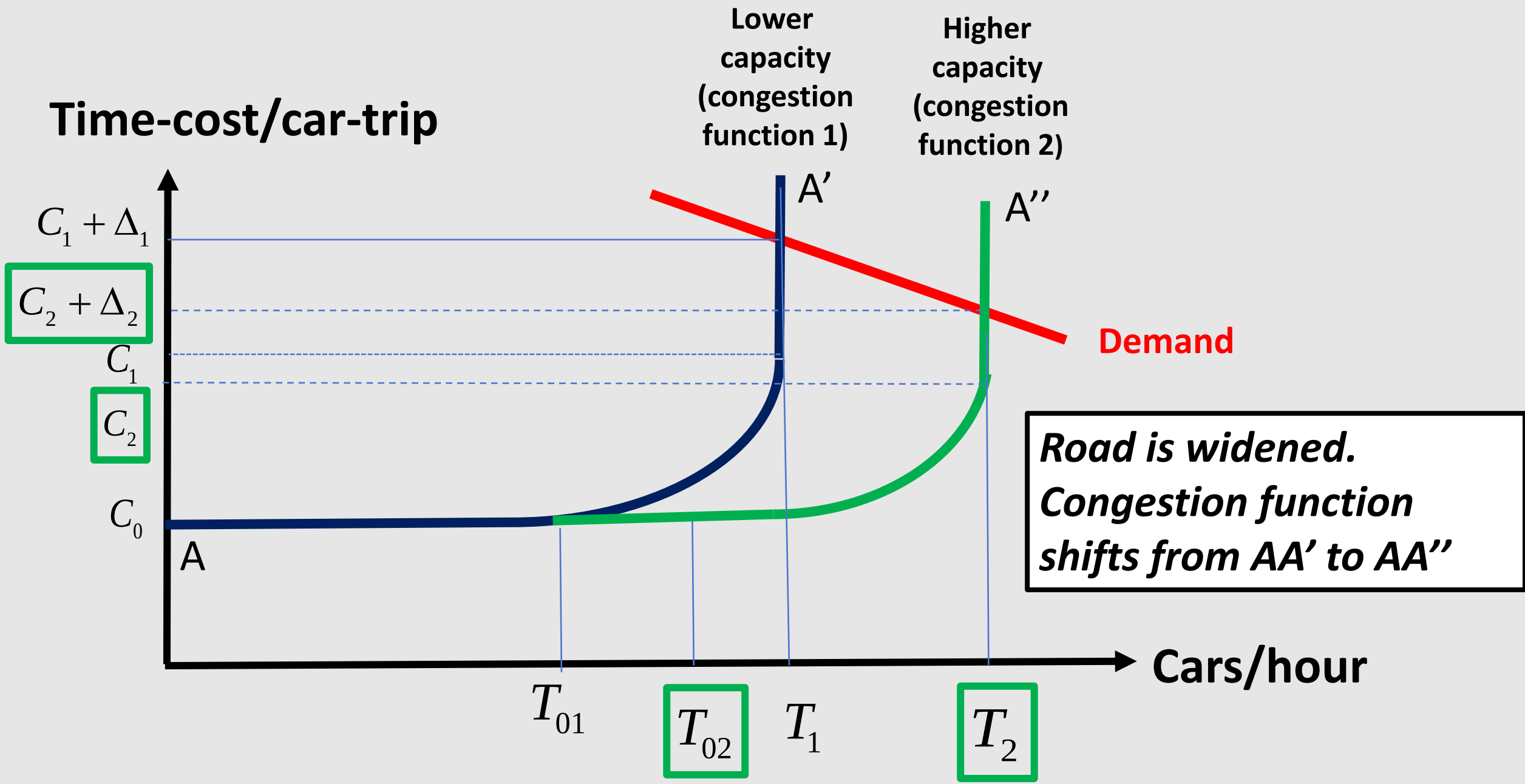
Downs's Law

2) Speed goes below its "optimal [eng'g design]"level

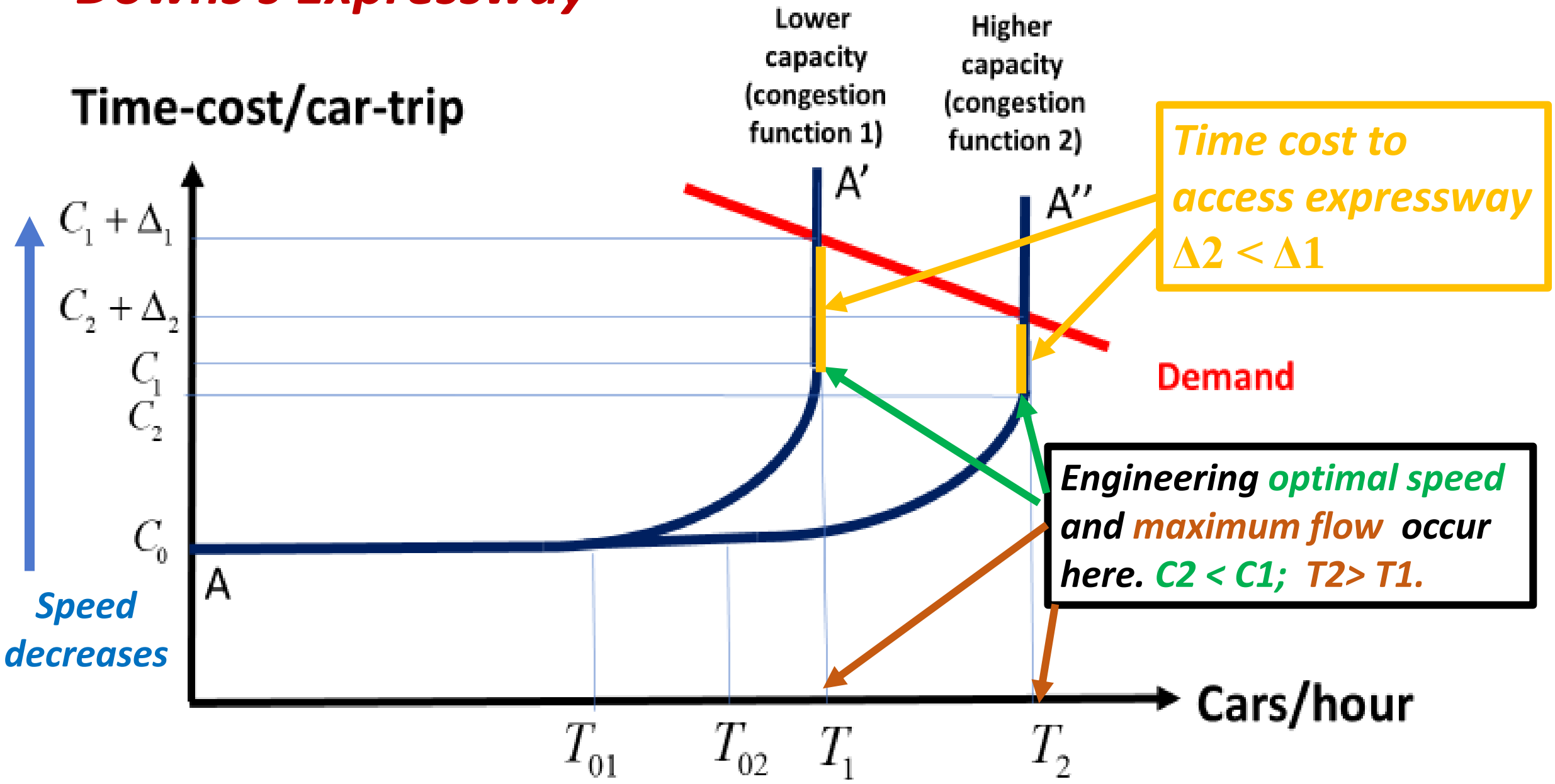
3) When capacity is added ***congestion decreases on the expressway***

Traffic equilibrium theory

4) ***Congestion also decreases on the competing streets***


Time-cost/car-trip
Lower capacity (congestion function 1)
Higher capacity (congestion function 2)
A'
A''
$C_1 + \Delta_1$
$C_2 + \Delta_2$
C_1
C_2
C_0
A
Demand
Road is widened. Congestion function shifts from AA' to AA''
Cars/hour
T_{01}
T_{02}
T_1
T_2

Downs's Expressway



Duranton and Turner (2011) (*49 years after Downs*)

Duranton, G. and M. A. Turner. 2011. The Fundamental Law of Road Congestion: Evidence from US Cities. *American Economic Review*, 101 (6): 2616-2552.

They estimated a regression equation:

$$\left(\log VKT\right) = \beta_0 + \beta_1 \left(\log ROADS\_LENGTH\right)$$

VKT : *aggregate vehicle kilometers in an MSA*

ARK : *aggregate lane kilometers of roads in an MSA*

$\beta_1 = 1$ → **% increase in ROADS_LENGTH = % increase in VKT**

THEY CONCLUDED THAT:

More road kilometers cannot decrease congestion

Duranton &Turner's congestion metric is a priori problematic

$$\frac{VKT\ \ (Vehicle\ kms)}{ROAD\_LENGTHS\ \ (Kilometers)}$$

1) VKT is not time delay, not a measure of congestion, but a measure of road utilization.

2) ROAD_LENGTHS is not a measure of road capacity.

3) Travel time delay is not included in the regression.

2. The lens of theory

How urban economists model congestion since the 1960's.

The congestion metric in urban economics

$$Time\ \ Delay\ \ = \frac{Traffic}{Road\ \ width}$$

- This metric has been used by all urban economists in the years following Downs's observations.

Some examples: Strotz (1965), Vickrey (1969), Solow & Vickrey (1971), Solow (1972), Mills (1972), Dixit (1973), Arnott (1979), Anas and Kim (1996), Wheaton (1998), Brueckner (2007).

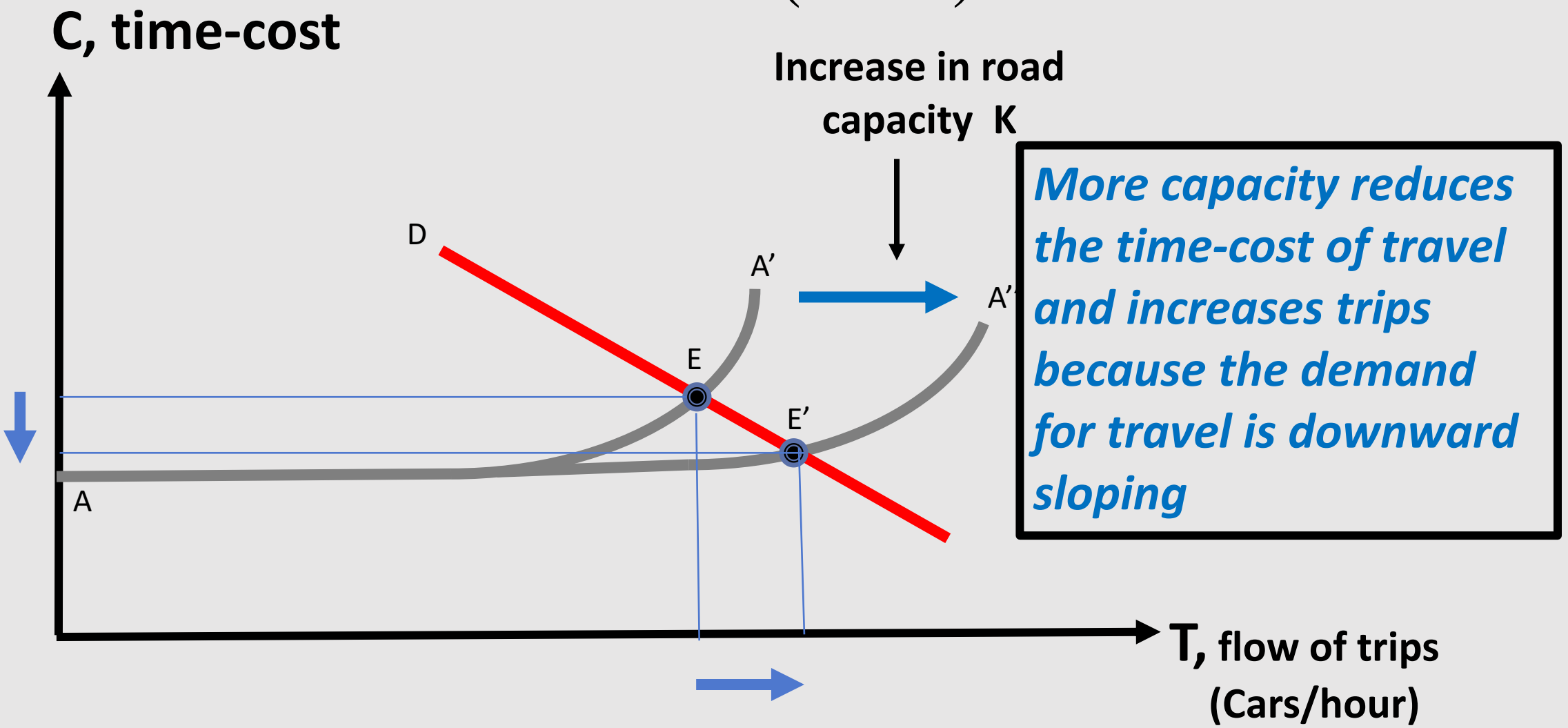
- Using the flow model of congestion we can prove that more road capacity reduces congested travel times in a variety of situations.

- The Bureau of Public Roads equation:

  T : Trips, *K*: capacity, *G*: time-cost of travel

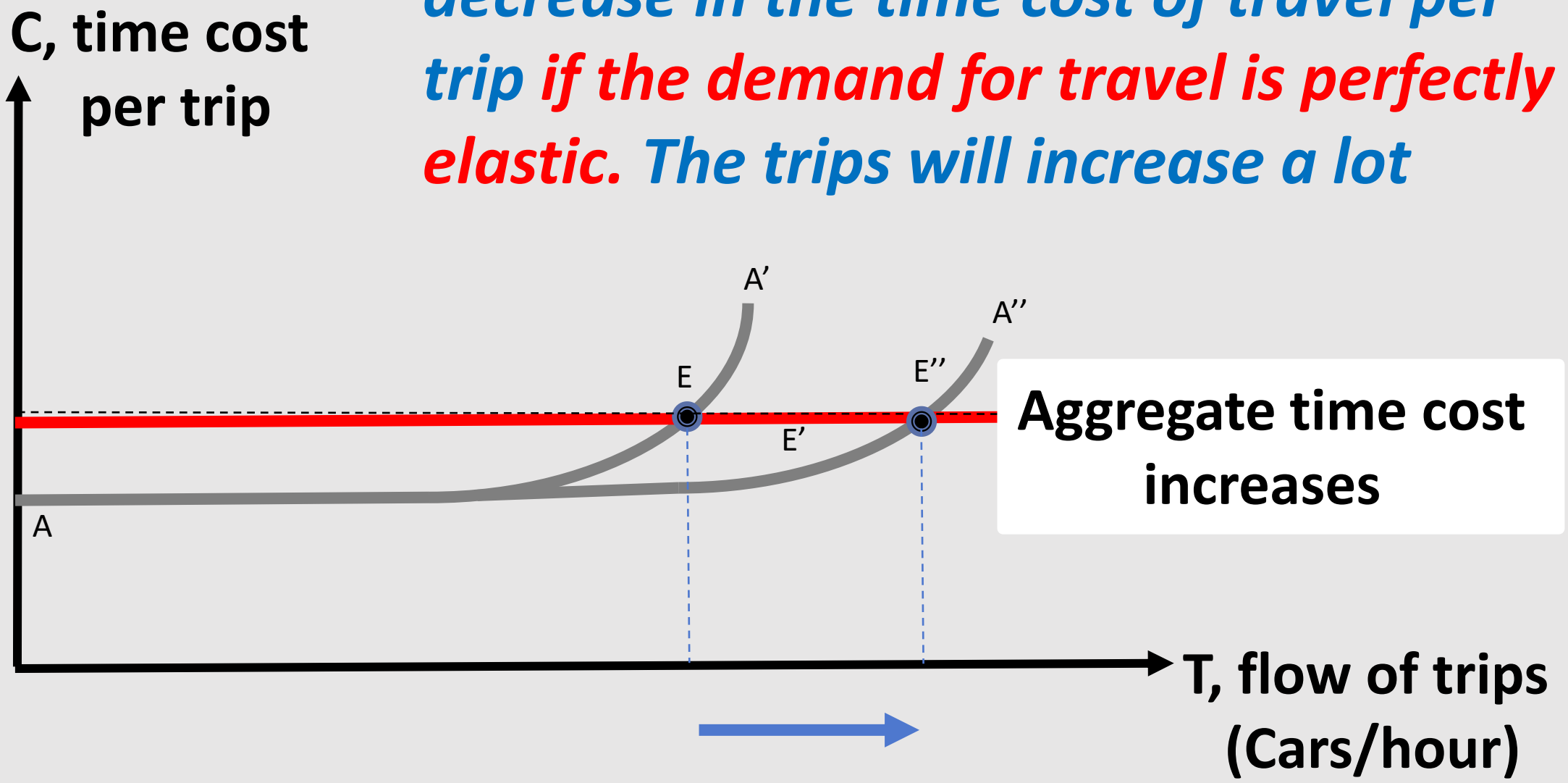
$$G(T,K) = g_0\left(1+\beta\left(\frac{T}{K}\right)^{\gamma}\right)$$

$$C = G(T, K)$$

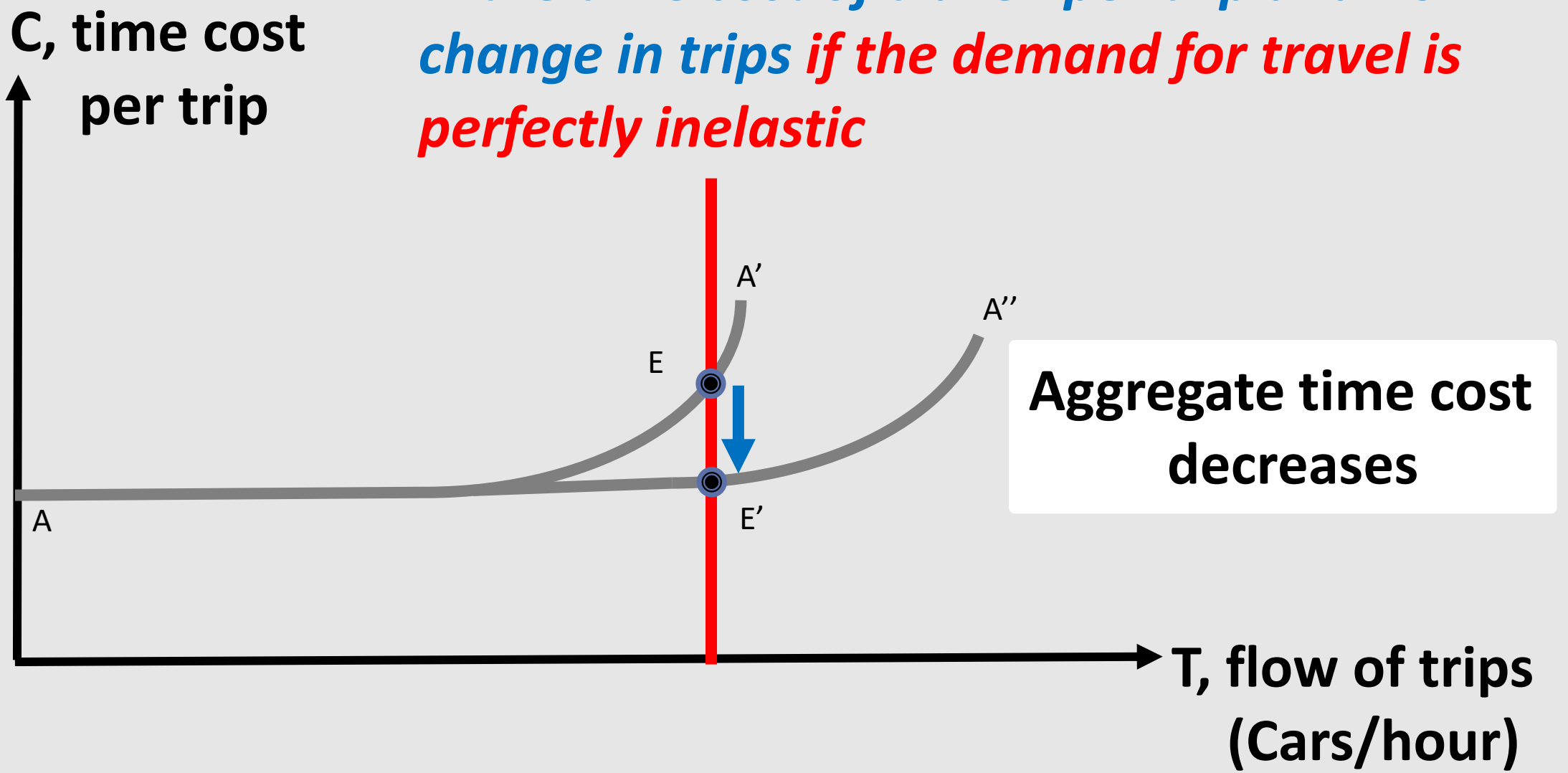


More capacity reduces the time-cost of travel and increases trips because the demand for travel is downward sloping

An increase in capacity will not cause a decrease in the time cost of travel per trip if the demand for travel is perfectly elastic. The trips will increase a lot



An increase in capacity will cause a decrease in the time cost of travel per trip and no change in trips if the demand for travel is perfectly inelastic



Aggregate time cost decreases

Empirical studies on travel demand elasticity all show very inelastic demands for travel at the aggregate level

Chan and Ou (1978):

Time elasticity: -0.8 for Boston; -0.4 for Louisville

Monetary cost: -0.5 for Boston; -0.1 for Louisville

Lago (1981), Balcombe et al. (2004), Frank et al. (2008) and Litman (2012) found as much as 10 times lower elasticities.

Numerical examples

$$G(T,K)=g_0\left(1+\beta\frac{T}{K}\right)^{\gamma};$$

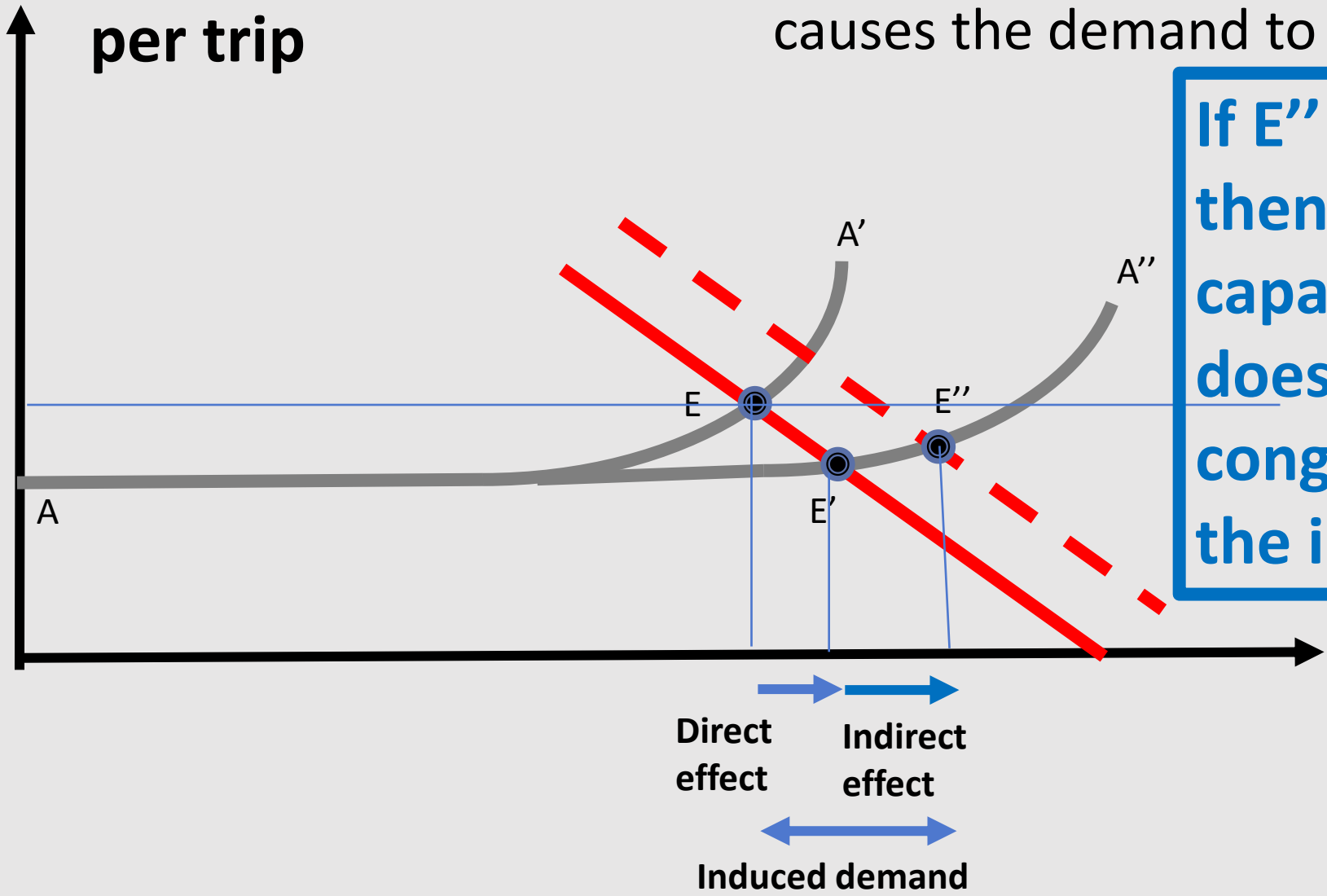
$$\beta=0.15,\ \gamma=4,\ T:trips,\ K:road\ capacity,\ G:time-cost$$

- **Suppose that K increases by 1%:**
- Travel demand elasticity = -0.5 → *T* up by 0.66%, *G* down by 1.35%, Aggregate time-cost down 0.67%
- Travel demand elasticity = -0.1 → *T* up by 0.29%, *G* down by 2.86%, Aggregate time-cost down 2.57%

SHIFTS IN DEMAND

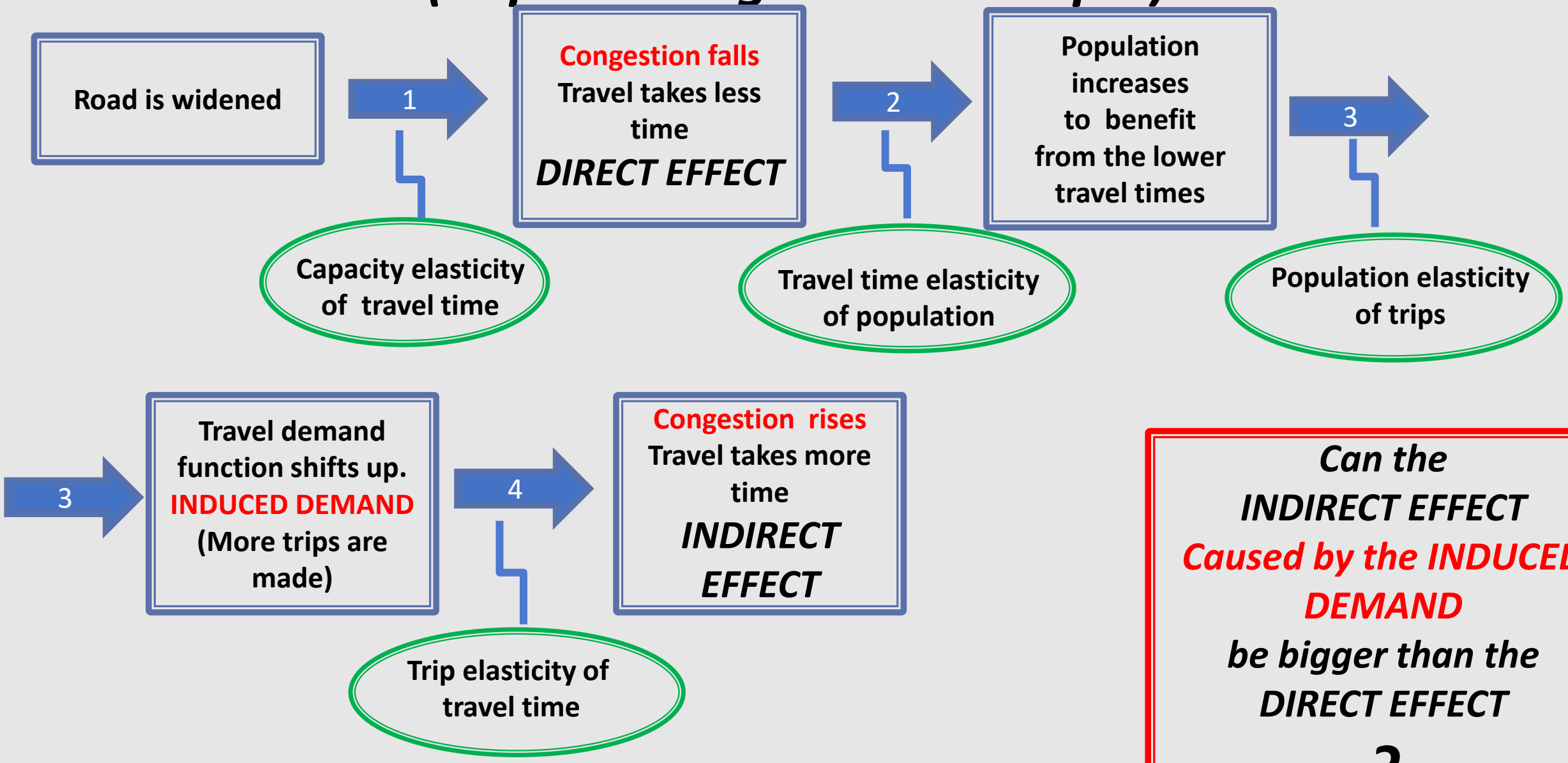
E → E’ : Direct effect of increasing the road capacity

E’ → E’’: Indirect effect if the road capacity increase causes the demand to shift from D to D’



If E’’ is lower than E, then the road capacity increase does not raise congestion despite the induced demand

There are important elasticities at work (Population growth example)



Can the INDIRECT EFFECT Caused by the INDUCED DEMAND be bigger than the DIRECT EFFECT ?

3. Specific models

Explanation of simple models to understand the relationships between congestion, travel demand, distance traveled and urban structure.

MODEL 1A Road: res. suburb (S) to bus. district (BD)

INCOME IS FIXED

- In the **SHORT RUN** the population of S is fixed. Widening the road lowers the commuting time , raises land price in S.

- **INDUCED DEMAND:** In the **LONG RUN** more residents move into S , land price in S increases more,

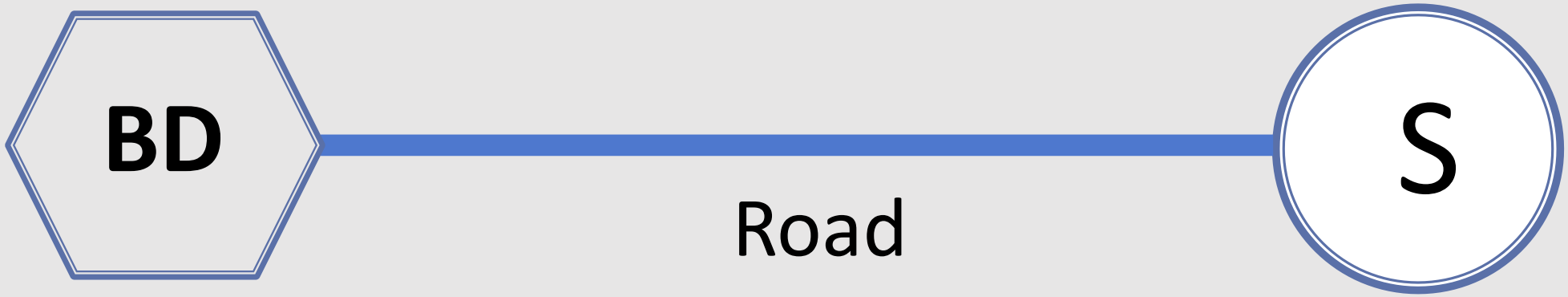
- **CONGESTION REBOUNDS but not enough to raise initial travel time.**

MODEL 1B Road: res. suburb (S) to bus. district (BD)

- In the **SHORT RUN** the population of S is fixed. ***THERE IS NO ROAD.***
- **LATENT DEMAND:** People in S want to travel to BD but cannot.
- Initial time-cost to travel to BD is prohibitively high.

➢ **When the road is built the time-cost from S→ BD falls a great deal. Travel S→BD begins.→ There is congestion but the time-cost is lower**

MODEL 2 Road: res. suburb (S) to bus. district (BD)



LABOR MARKET DETERMINES INCOME

- **INDUCED DEMAND:** In the **LONG RUN** more residents move into S , land price increases.
- **LABOR SUPPLY INCREASES → WAGES ARE LOWERED.**
- **CONGESTION REBOUNDS but not enough to raise initial travel time.**

Labor market & congestion

- Adding road capacity increases population by inducing in-migration.
- The higher labor supply after the in-migration decreases wage income.
- With lowered income, we can prove that congestion must decrease with more capacity.
- The result continues to hold when the change in income changes the value of time in travel.

MODEL 3

Roads and worker productivity

- More road capacity attracts more population, workers in BD become more productive if **Marshallian productivity externalities** are present. (Ciccone and Hall, 1996)

- Could the **positive effect of more productivity on income** overcome the **negative effect of the higher labor supply on income**? Could this increase congestion if higher incomes make more trips?

- Far from plausible because the elasticity of income with respect to jobs is too low, +0.06 or lower. The elasticity of labor supply on income is much higher.

MODEL 4

NON-WORK TRIPS

- The added road capacity attracts more population/workers.
- Each new worker adds a commuting trip and non-work trips.
- Pre-existing workers also make some more non-work trips.
- Non-work trips are about 75% of all person-trips in urban areas Nelson and Niles, 2000).
- This means that each new person adds about 3-4 trips on average.

MODEL 5

ROADS THAT ARE COSTLY TO BUILD

- More roads are needed if :
  Social Marginal Benefit (SMB) > Social Marginal Cost (SMC)

- When SMB > SMC roads are underprovided

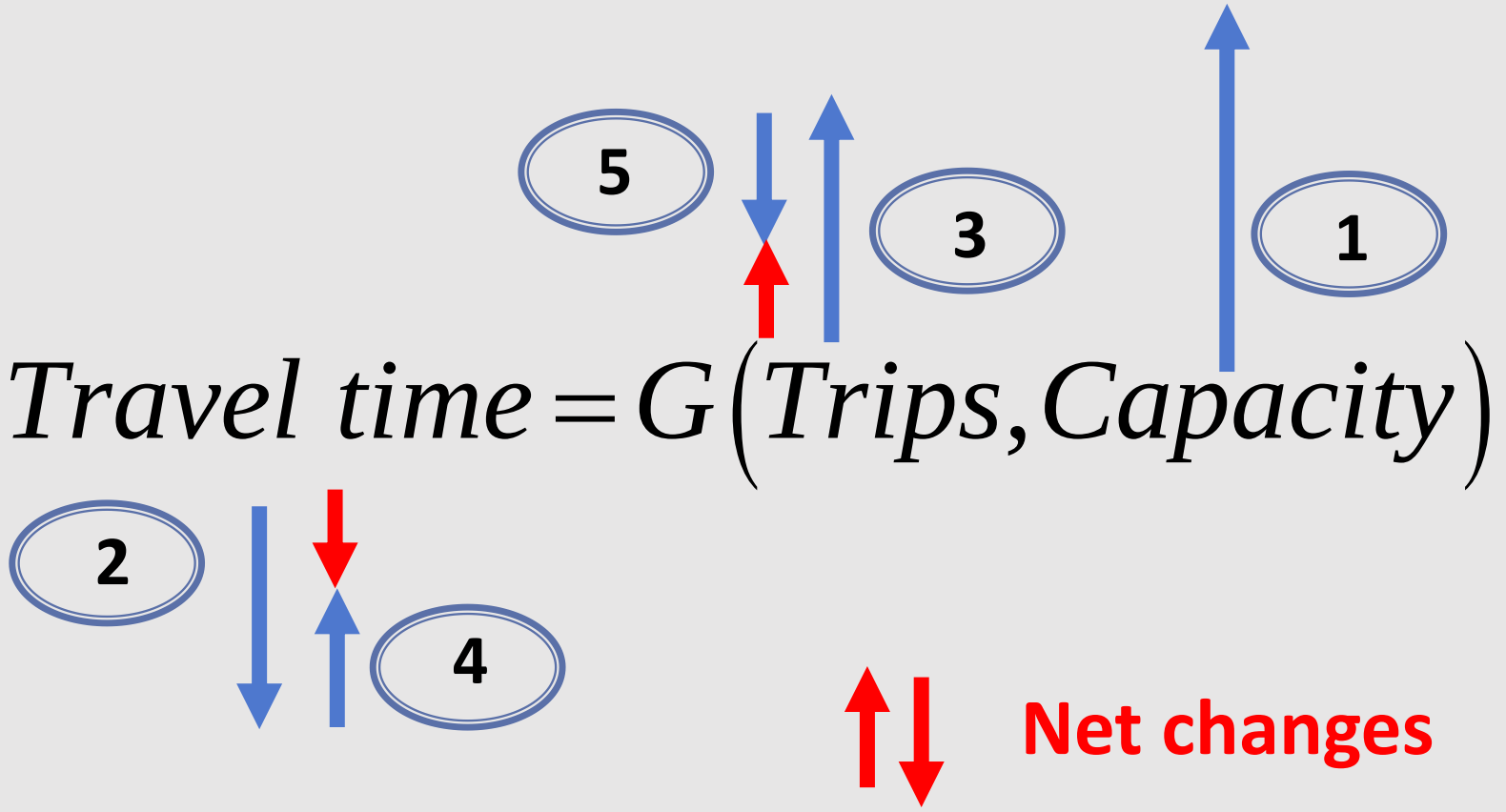
- When SMB = SMC roads are optimally provided

- When SMB < SMC roads are overprovided

More roads lower congestion, whether roads are over- under- or optimally provided.

IN ALL MODELS, INDIRECT EFFECT < DIRECT EFFECT

Travel time increase induced by more capacity is always smaller than the direct travel time decrease



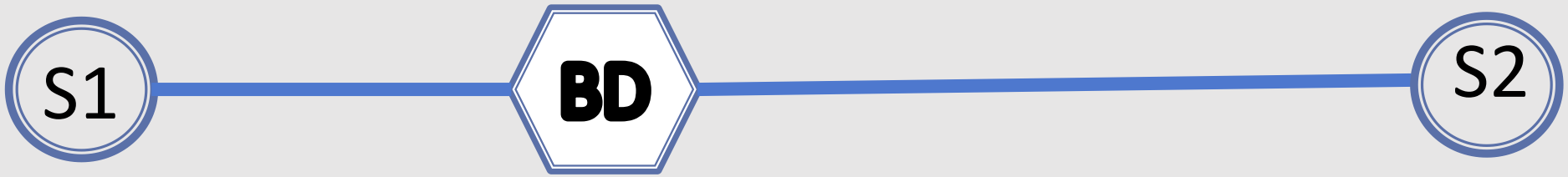
Spatially detailed models

MODEL 6 *Two competing roads connecting different suburbs to a CBD*

MODEL 7 *Complementary roads connecting inner and outer suburbs to the CBD*

MODEL 8 *An expressway competing with existing roads (Downs)*

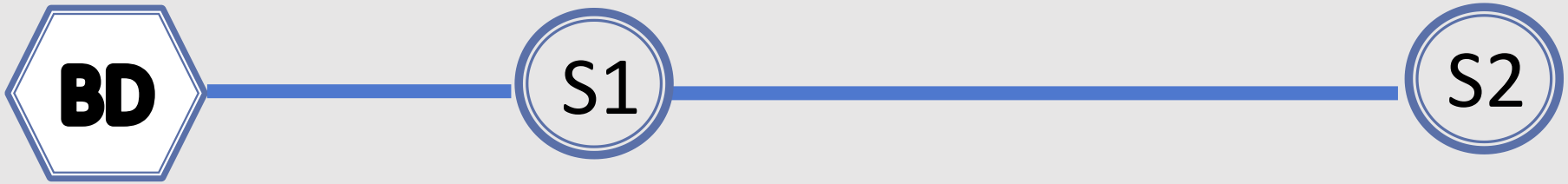
MODEL 6 ***Two competing roads connecting different suburbs to a CBD***



- Widening road 1, some people move S2→S1, congestion on both roads is lower, **VKT decreases because road 1 is shorter.** Rent in S1 increases.

- Widening road 2, people move S1→S2,congestion on both roads is lower, **VKT increases because road 2 is longer.** Rent in S2 may increase or decrease.

MODEL 7 *Two complementary roads connecting suburbs to a BD*

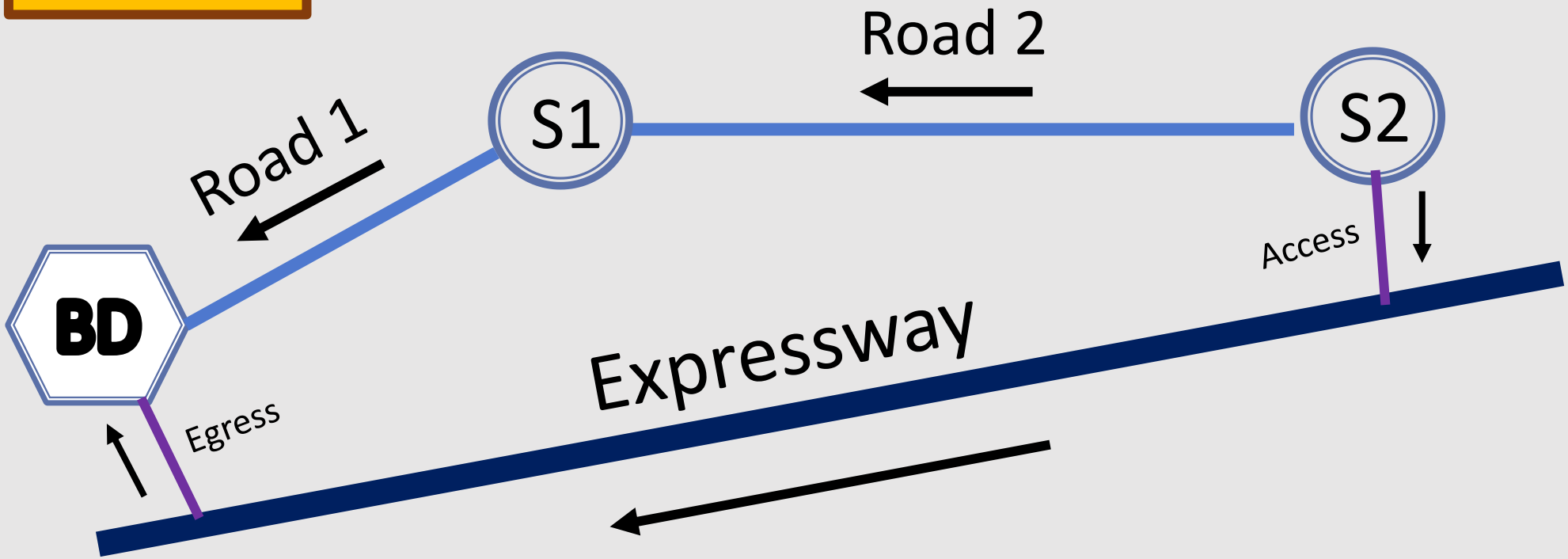


- Widening road 1, people move S2→S1, congestion on both roads is lower, **VKT decreases because of more trips on the shorter road 1.** Rent in S1 increases. Aggregate travel cost decreases.

- Widening road 2, people move S1→S2,congestion on road 2 is lower, **VKT increases because more trips on longer road** Rent in S2 may increase. Aggregate travel cost may increase.

MODEL 8

Downs's expressway competing with existing roads



Expressway reduces congestion and travel times but it can cause VKT to increase.

INSIGHTS FROM THE Regional Economy, Land-Use and Transportation Model

- <<…longitudinal Chicago simulations (Anas, 2015) with RELU-TRAN (the Regional Economy, Land Use and Transportation Model): a 20 % increase in aggregate road capacity over 30 years concentrated in the outer suburbs causes an only 2% increase in VKT over the same period, … >>

- *More roads can induce more* VKT but this happens *because more roads lower congested travel times so more and longer trips are made* (Anas, 2024)

CONCLUSIONS

- Widening road capacity lowers congestion
- The lowered congestion lowers travel times
- The lowered travel times induce a higher demand for travel, more VKT.

- Whether aggregate VKT increases or decreases depends on:
  - Whether the short or the long roads are widened
  - How many trips switch to the widened roads
  - How many new trips are induced

4. Comments on road expansion

Should there be more roads?

Costs of roads

- The Social Marginal Cost (SMC) of a road includes

- Congestion
- Noise of traffic
- Accidents
- Pollution
- Opportunity cost of land
- Neighborhood disruption

Benefits of roads

- The Social Marginal Benefit (SMB) of a road reflects

➢ Higher traffic speeds lower congestion and pollution, CO2

➢ Better access and mobility benefits consumers and businesses

➢ Latent demand is satisfied in mobility restricted situations

➢ Access to cheap land is lowered (e.g. suburbanization)

➢ More economic growth can be generated

To build or not to build a road?

- **BUILD:** when the SMB > SMC of the road
- **NO BUILD:** when the SMC > SMB of the road
- We need more roads in some places (e.g. where congestion is high, or where land is cheap enough) and fewer roads in other places.