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Traffic Speed Versus Roadway Capacity

Evaluating how traffic speeds affect vehicle flows and congestion costs

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Higher traffic speeds require more shy distances between vehicles and therefore road space. As a result, roadways are most efficient – they maximize capacity and minimize congestion – at moderate speeds.

Summary

This short report examines the relationships between traffic speeds and roadway capacity (vehicle flow) and identifies the speeds that maximize throughput. Because shy distances (safe separation distances between vehicles) increase with traffic speeds, capacity tends to peak at moderate speeds. Under optimal (dry, clear and level) conditions capacity typically peaks at 25-35 mph (40-60 kph) on urban arterials with cross streets and at 35-50 mph (60-80 kph) on grade-separated highways, reflecting roadway level-of-service (LOS) C to D. This indicates that moderate traffic speeds tend to maximize roadway cost efficiency and infrastructure investment value, and best reflect travel demands.

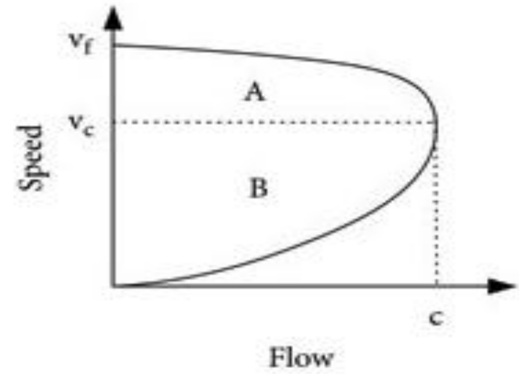
Introduction

What traffic speeds maximize roadway efficiency? Because shy distances (safe separation distances between vehicles) increase with travel speeds there are trade-offs between speed and road capacity (potential traffic flow or volumes). This study investigates these relationships.

Transportation engineers generally portray this relationship with "nose cone" graphs, such as Figure 1, that show how changes in flow (generally measured as vehicles per lane-hour or vplh) affect traffic speeds. Flow is the independent and speed the dependent variable, assuming that the goal is to optimize traffic volumes to maximize speeds. This is often used to justify roadway expansions to reduce volume to capacity (V/C) ratios, measured as higher levels-of-service (LOS).

This study examines the data from a different perspective. Rather than identifying the flows that maximize speed it identifies the speeds that maximize flow and therefore roadway efficiency (vehicles per lane-hour). This can help identify economically optimal traffic speeds that maximize roadway investment benefits.

Figure 1 **Nose Cone Graph**

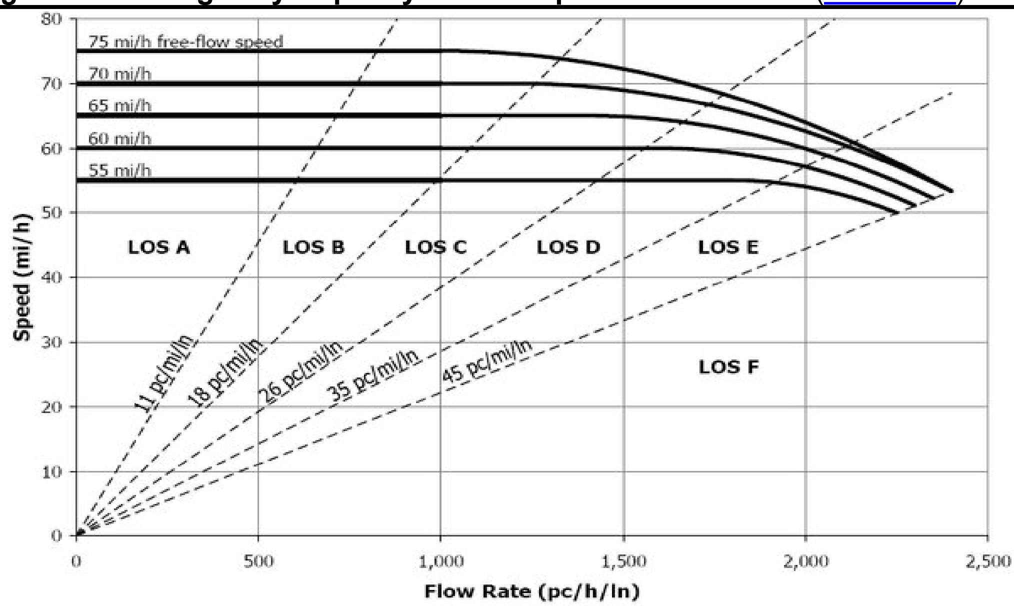


Transportation engineers usually portray speed/flow relationships with flow on the X-axis as the independent variable and speed on the Y-axis as the dependent variable, assuming the goal is to optimize flow for maximize speeds. This study rotates this graph counterclockwise to help optimize speeds for maximize flow.

Research Summaries

The figure below shows speed/flow curves published in the *Highway Capacity Manual*, a basic reference for road planning and design. It indicates that highway capacity declines at high traffic speeds.

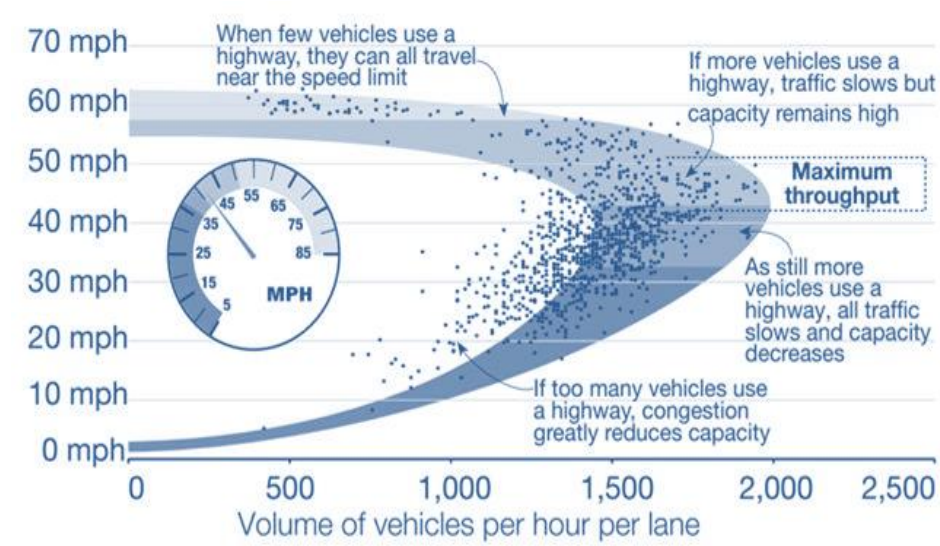
Figure 2 **Highway Capacity Manual Speed/Flow Curves** ([TRB 2010](TRB 2010))



This figure from the Highway Capacity Manual shows that maximum flow rates tend to decline as traffic speeds increase, and maximum capacity occurs at level-of-service D or E.

The figure below illustrates Washington State highway traffic speeds and volumes. At volumes less than about 1,000 vehicles per lane-hour (top left) vehicles operate at free-flow speeds; as volumes increase, moving to the right, speeds decline and tend to maximize at 40-50 mph, beyond which flow becomes unstable, causing the curve to bend backward indicating that both speeds and volumes decline.

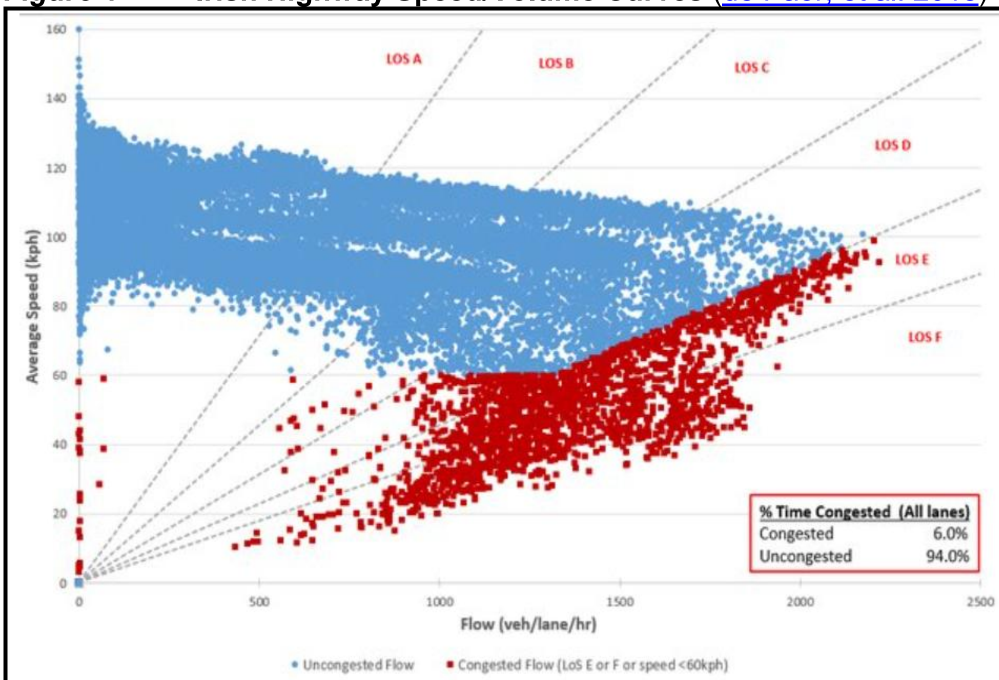
Figure 3 **Washington State Highay Speed/Volume Curve** ([WSDOT 2018](#))



This figure shows the relationship between traffic volumes and speeds on Washington State highways. The shaded curve shows the statistical pattern. It indicates that traffic capacity (maximum volumes) tend to peak at 40-50 miles per hour, 15-30% below freeflow conditions.

The figure below shows a similar pattern using Irish highway data. Red dots indicate congested traffic.

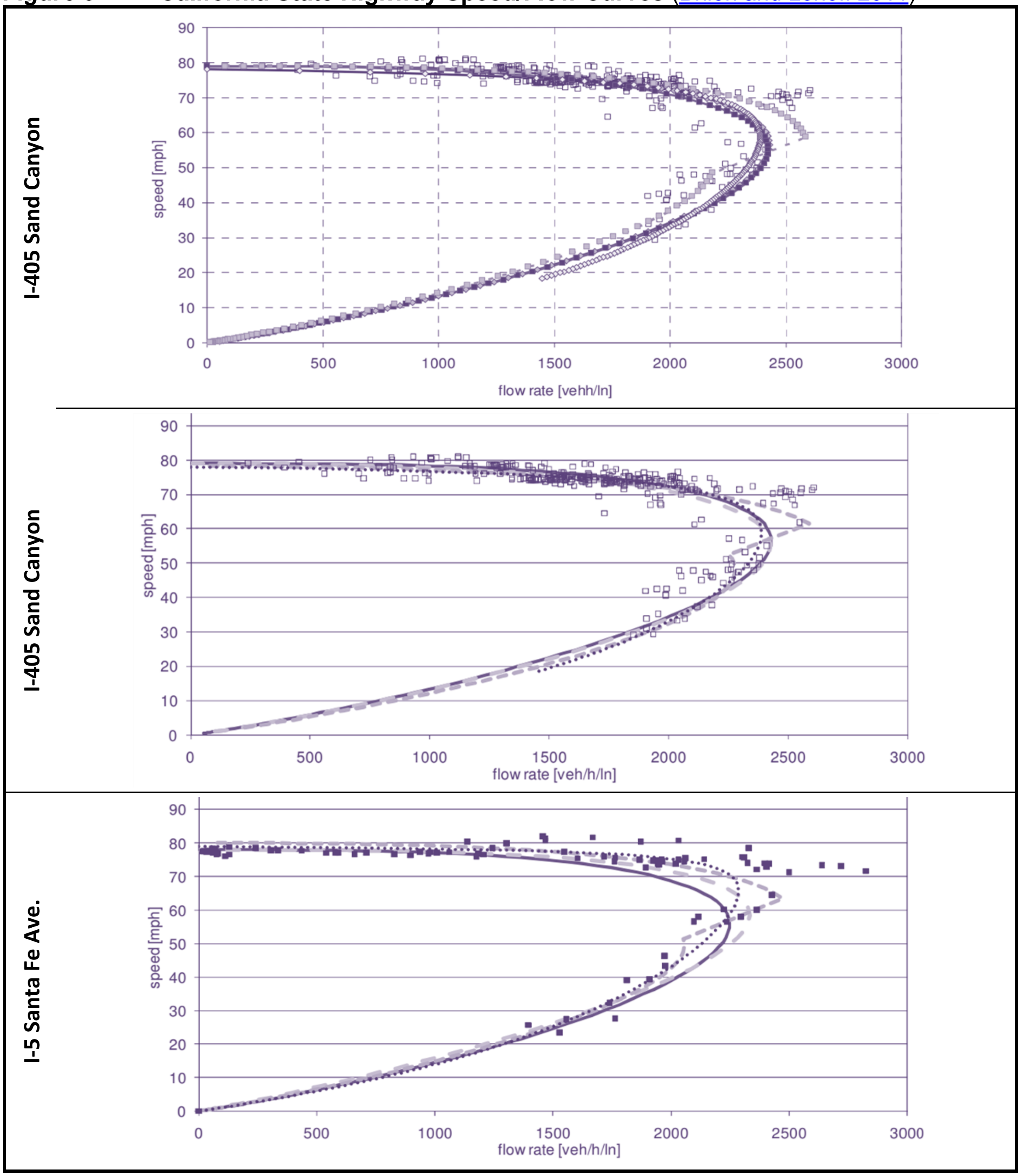
Figure 4 **Irish Highway Speed/Volume Curves** ([de Paor, et al. 2018](#))



This figure illustrates the relationship between traffic flow and speed measured on Irish Highways. Each dot reflects a particular time and location. Blue indicates uncongested flow (LOS A-D) and red indicates congested flow (LOS E-F).

The following figures show traffic volumes and speeds measured on Southern California highways. Under freeflow conditions most vehicles travel 70 to 80 mph, exceeding legal speed limits.

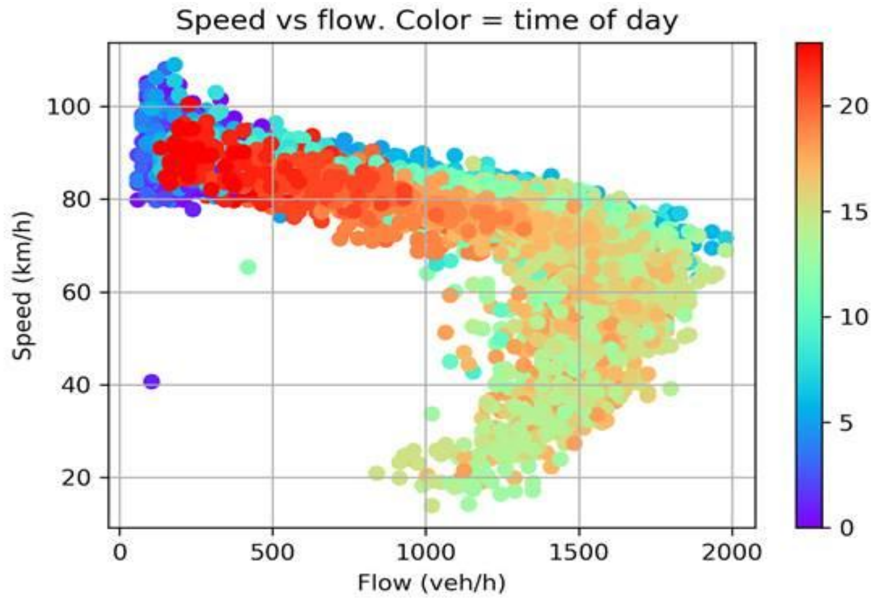
Figure 5 **California State Highway Speed/Flow Curves** ([Brilon and Lohoff 2011](#))



These graphs from Southern California freeways show that under freeflow conditions traffic speeds usually exceed legal speed limits which is 10-20% higher than flow-maximizing speeds.

The figure below shows the relationship between traffic speed and volume on Stockholm motorways. It indicates that urban highway capacity typically peaks at 60-80 kilometers per hour (35-50 miles per hour), carrying 1,200 to 2,000 vehicles per lane-hour.

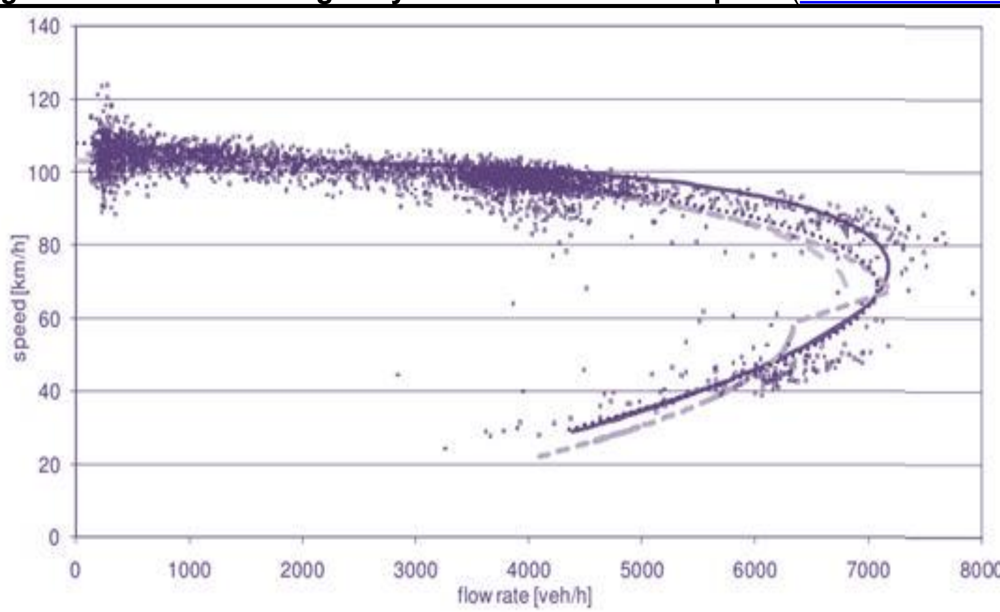
Figure 6 **Traffic Flow Versus Speed for Stockholm Motorways** (Marsh 2020)



This figure illustrates the measured relationship between traffic speed and volume on Stockholm motorways. This indicates that urban highway capacity typically peaks at 60-80 kilometers per hour (kph, 35-50 miles per hour), carrying 1,200 to 2,000 vehicles per lane-hour, 20-40% lower than freeflow speeds which average 80-110 kph.

The following figure indicates that on German highways, maximum traffic capacity typically occurs at 20-30% lower than freeflow speeds.

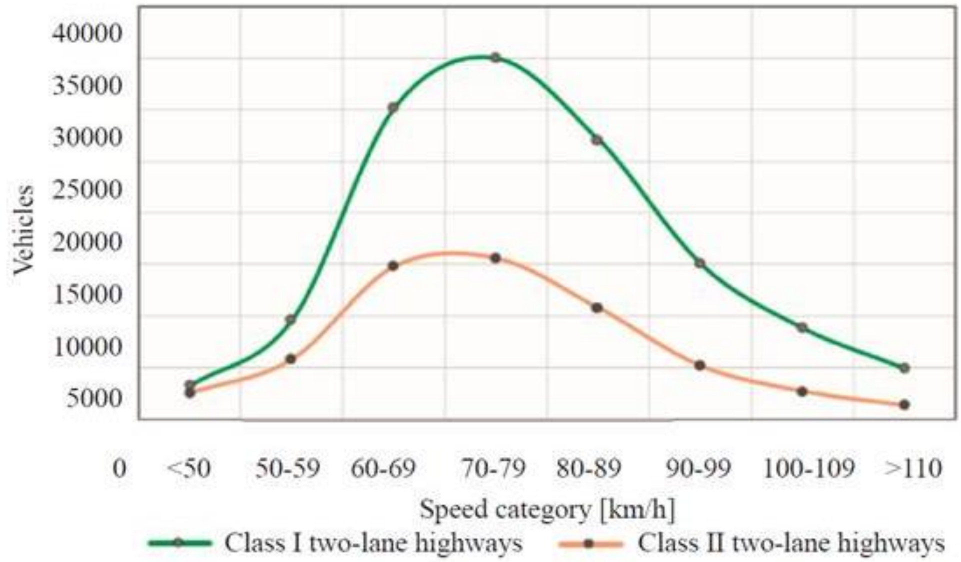
Figure 7 **German Highway Traffic Flow Versus Speed** (Brilon and Lohoff 2011)



This figure shows the relationship between traffic speed and flow (volume) on German freeways. Capacity tends to peak at 70-90 kph, 20-30% lower than freeflow speeds.

Surbian highway traffic capacity tends to peak at 70-80 kph (40-50 mph), as shown below.

Figure 8 **Serbia Highway Traffic Speeds and Volumes** (Stepanović, Tubić and Zdravković 2023)



This study found that traffic volumes (vehicles per day) peak at 70-80 kph (40-50 mph) on major highways and slightly lower on lower-grade highways.

The table below from the Australian traffic management guide shows that traffic flow increases with slower speeds and lower (worse) levels of service (LOS). LOS D and E typically accommodate more than twice the traffic volumes as LOS A and B.

Table 1 **Maximum Traffic Flow Versus Speed and Level-of-Service** (Austroads 2020)

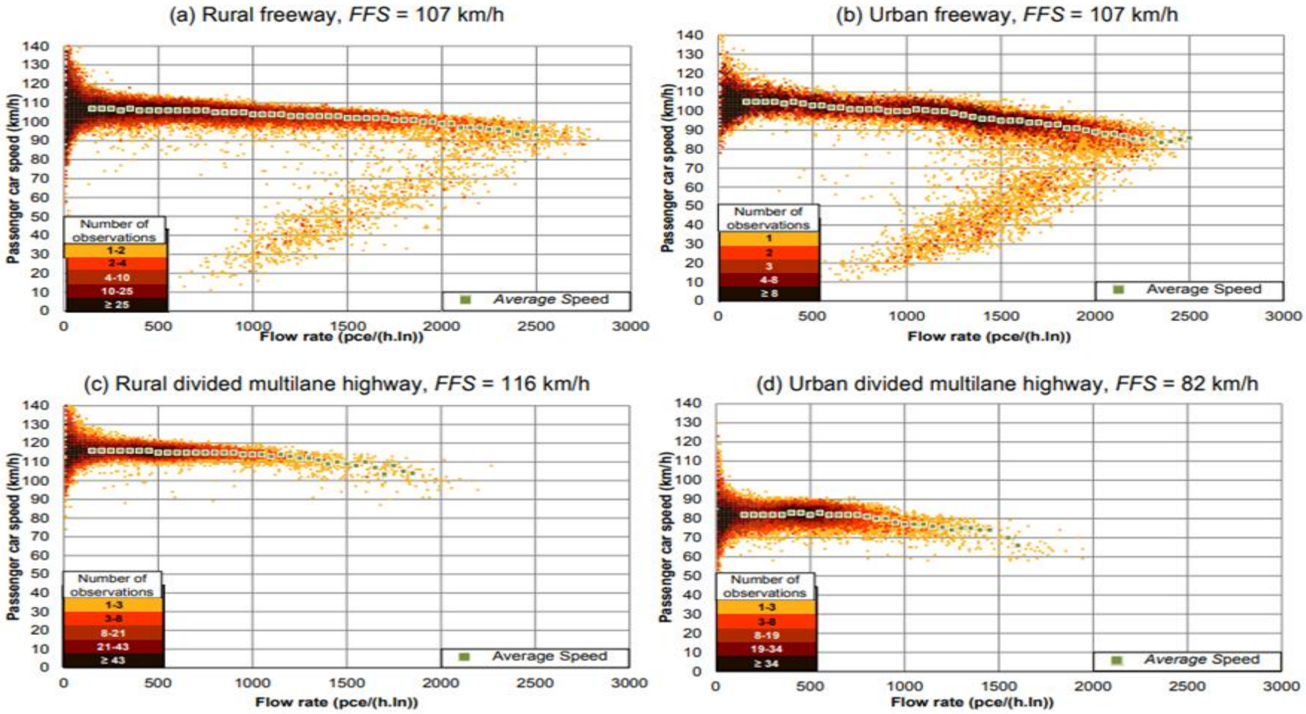
Free-flow speed	Criteria	A	B	C	D	E
100 km/h	Maximum density (pc/km/ln)	7	11	16	22	25
	Average speed (km/h)	100.0	100.0	98.4	91.5	88.0
	Maximum volume to capacity ratio (v/c)	0.32	0.50	0.72	0.92	1.00
	Maximum service flow rate (pc/h/ln)	660	1080	1550	1980	2200
90 km/h	Maximum density (pc/km/ln)	7	11	16	22	26
	Average speed (km/h)	90.0	90.0	89.8	84.7	80.8
	Maximum volume to capacity ratio (v/c)	0.30	0.47	0.68	0.89	1.00
	Maximum service flow rate (pc/h/ln)	600	990	1430	1850	2100
80 km/h	Maximum density (pc/km/ln)	7	11	16	22	27
	Average speed (km/h)	80.0	80.0	80.0	77.6	74.1
	Maximum volume to capacity ratio (v/c)	0.28	0.44	0.64	0.85	1.00
	Maximum service flow rate (pc/h/ln)	550	900	1300	1710	2000
70 km/h	Maximum density (pc/km/ln)	7	11	16	22	28
	Average speed (km/h)	70.0	70.0	70.0	69.6	67.9
	Maximum volume to capacity ratio (v/c)	0.26	0.41	0.59	0.81	1.00
	Maximum service flow rate (pc/h/ln)	290	810	1170	1550	1900

Source: Austroads (2020)

This table shows that traffic flow rates increase with slower speeds and higher (worse) levels of service.

The figure below shows that Brazilian rural highway traffic flows peak at 10-30% below freeflow speeds.

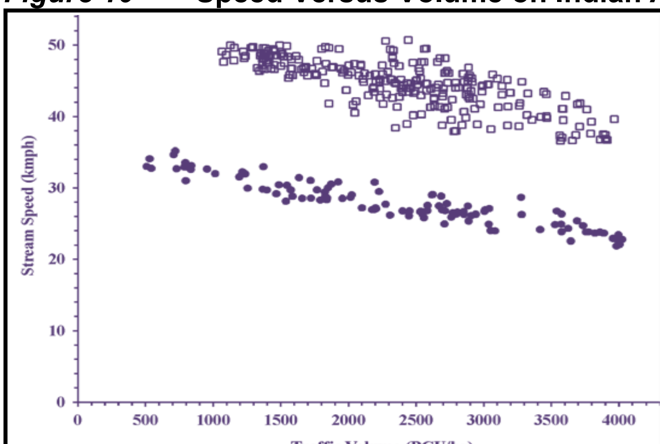
Figure 9 **Brazilian Rural Traffic Speed Versus Volumes** [(Riente de and José Setti 2014)]



Rural highway traffic flows tend to peak at 10-30% below freeflow speeds.

The figure below shows that Indian urban arterial capacity peaks at 20-30% lower than freeflow speeds.

Figure 10 **Speed Versus Volume on Indian Arterials** ([Dhamaniya and Chandra 2017])



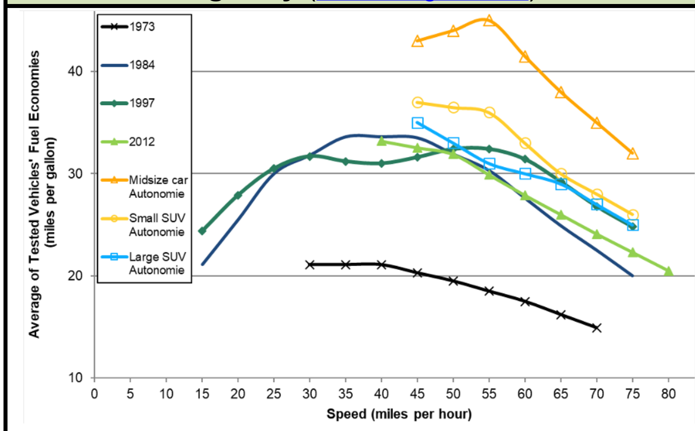
Indian urban arterials lane capacity typically peaks at 20-40 kilometers per hour (15-30 mph), 20-30% lower than freeflow speeds.

Other studies also conclude that because roadway capacity peaks at moderate speeds, urban arterials and highways designed for moderate speeds tend to be most efficient and cost effective (Analysis by Small and Ng (2012). The article, *How to Reduce Congestion I: The Optimal Speed Limit for Urban Traffic* (Benedikter 2024), finds that urban street traffic capacity and smoothness peak at about 30 kilometers per hour, making it the safest and most comfortable for drivers due to reduced traffic delay and stress.

Other factors should be considered when optimizing traffic speeds. Fuel efficiency typically peaks at 50 to 80 kilometers per hour (30 to 50 mph) on grade-separated highways and less on urban arterials.

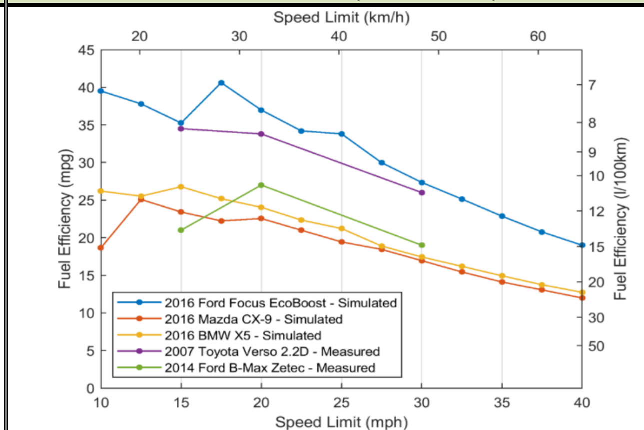
Figure 11 **Speed Versus Fuel Economy**

Highway ([Oak Ridge 2022]())



Under typical highway conditions fuel economy peaks at 30 to 50 mph (50 and 80 kph). Electric and hybrid cars use less energy but have similar efficiency curves.

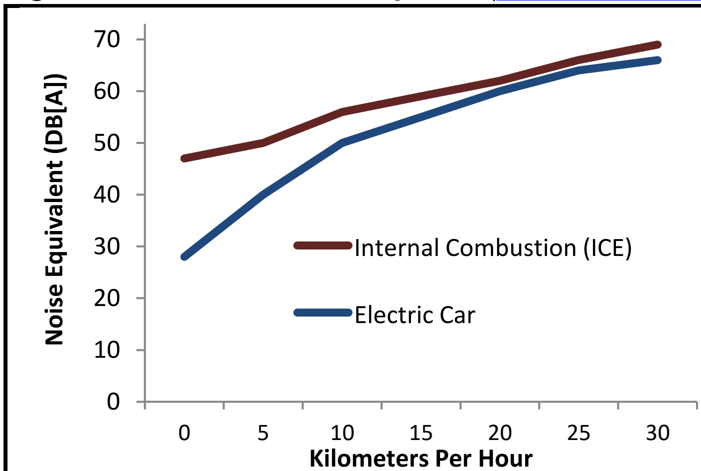
Urban Traffic ([FTR 2023]())



Under typical urban traffic conditions fuel economy peaks at 15-20 mph (25-35 kph) and declines at higher speeds.

Traffic noise also increases with traffic speeds, as illustrated below.

Figure 12 **Noise Versus Speeds** ([Salleh, Md zain & Ishak 2013]())



Vehicle noise increases with speed. Although electric cars produce less noise than internal combustion engines (ICEs), the differences decline with speed over 20 kph, as tire and wind noises increase.

To maximize traffic flow and safety many bridges and tunnels have moderate speed limits, such as 35 mph on the Holland and Lincoln tunnels, 45 mph on the George Washington Bridge, and 40 mph on the Bayonne, Goethals, and Outerbridge bridges. To optimize efficiency, safety and community livability, various professional organizations recommend 30 kph speed limits in urban areas with mixed motorized and non-motorized traffic; 50 kph in areas with intersections; and 70 kph on rural roads without median barriers to prevent head-on collisions (FTL 2024; ITF 2020; NACTO 2020; Pardo 2017).

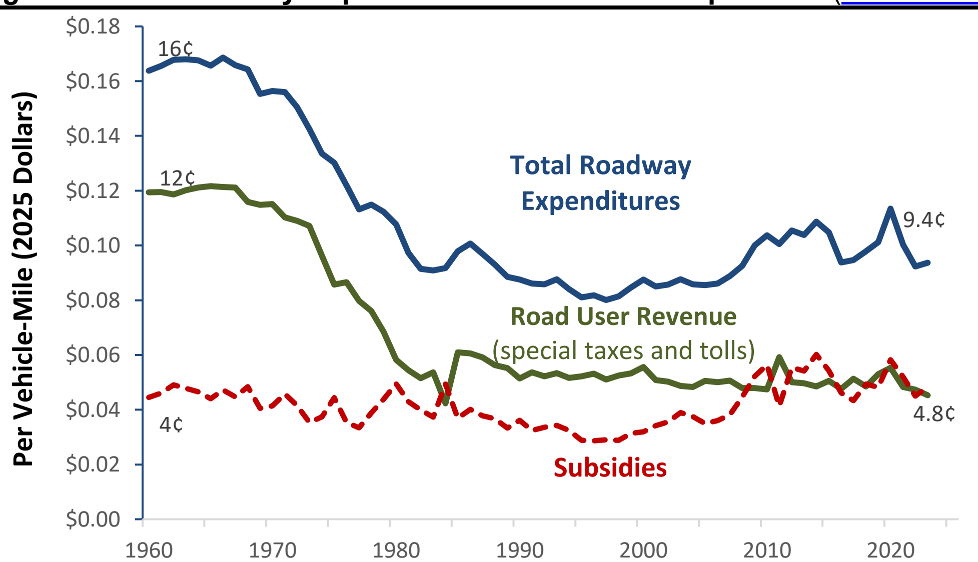
Roadway Expansion Costs and Demands

This research indicates that maximum traffic speeds typically requires that urban arterials carry less than 500 vehicles per lane hour (vplh) and highways 1,000 vplh, which is less than half the capacity at lower speeds. Adding traffic lanes to maintain such low flows on busy corridors is expensive, typically costing $10-45 million per mile on urban arterials and $15-65 million per mile on large-city freeways or $1.40 to $2.50 per additional peak-period vehicle-mile (FHWA 2023; VTPI 2025), considering just road construction costs but not additional operating costs or external costs such as more downstream traffic congestion, crash risk and pollution caused by wider roads, faster traffic and more vehicle-miles.

A basic economic principle is that economic systems are most efficient and fair if the prices consumers pay for goods reflect their marginal production costs, or as it is commonly described, consumers should "get what they pay for and pay for what they get" unless subsidies are specifically justified. This prevents governments paying more for facilities than users' perceived benefits, allows higher value trips to outbid lower value trips for scarce road space, and avoids forcing non-users to subsidize costly facilities they do not demand. Highway expansion projects that cannot be financed by user fees are economically inefficient – their costs exceed their benefits.

This creates a paradox: motorists want wider roads provided somebody else pays but not if funded by cost-recovery user fees (Litman 2024). For example, only 11% of motorists on Houston's Katy Freeway and less than a third on Miami's I95 Highway pay optional tolls to use uncongested lanes (Burris, et al. (2016)), and many toll roads have significantly lower traffic volumes and revenues than forecasted (Schmitt 2014). Since the 1960s roadway spending has plummeted; there is little evidence that motorists want higher user fees to finance major roadway expansions.

Figure 13 **Roadway Expenditures and Revenues per VMT** ([Based on FHWA data])



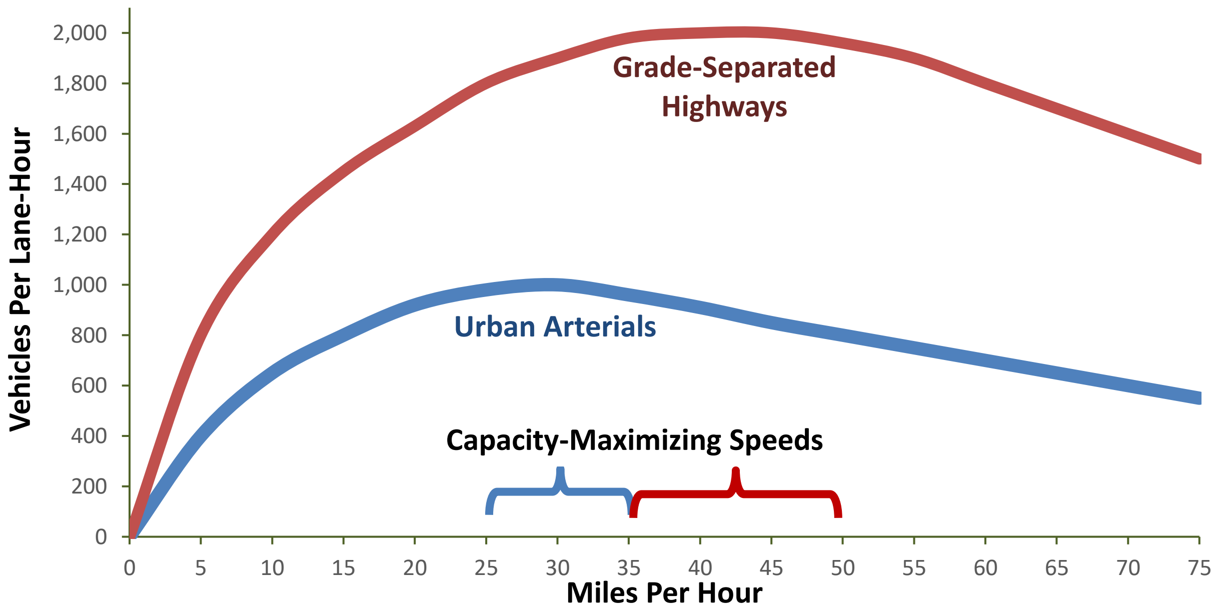
Since the 1960s real (inflation adjusted) roadway spending and user revenues declined substantially. There is little evidence that motorists want the high levels of road user fees required to expand urban roadways to reduce congestion and increase traffic speeds.

This suggests that travellers usually prefer to save money rather than time, and so prefer efficiency-maximizing (LOS C-D) rather than speed-maximizing (LOS A-B) roadway planning and performance targets.

Conclusions

This study investigates how traffic speeds affect roadway capacity and costs. Because faster traffic requires more vehicle separation, capacity peaks at moderate speeds. Under optimal (dry, clear and level) conditions capacity typically peaks at 25-35 mph (40-60 kph) on urban arterials with cross streets and 35-50 mph (60-80 kph) on grade-separated highways, as illustrated below. This is typically 10-30% lower than free-flow speeds and reflects levels-of-service (LOS) C-D. Of course, these relationships vary depending on specific conditions. Roadways sometimes achieve higher flows, but they are unstable, causing severe congestion that reduces speeds for some trips. Other factors affect traffic capacity including roadway and intersection design, fleet mix, and driver behavior; reducing speeds will not increase flow where other factors constrain capacity.

Figure 14 **Traffic Volumes Versus Speed for Urban Arterials and Highways**



Since faster traffic requires more shy distance (separation) between vehicles, roadway capacity declines as speeds increase. Under optimal (dry, clear and level) conditions capacity typically peaks at 25-35 mph (40-60 kph) on urban arterials and 35-50 mph (60-80 kph) on grade-separated highways, reflecting LOS C-D. Capacity-optimizing speeds tend to decline with more interchanges and denser traffic.

This reflects a different way of analyzing the traffic speed-flow relationships; it is a "nose cone" graph turned counterclockwise. Rather than asking, "What volume/capacity maximizes speed?" it asks, "What traffic speed optimizes traffic capacity and therefore roadway cost efficiency?"

Common planning practices assume that freeflow speeds and LOS A-B are optimal, although they usually exceed what is legal, safe and efficient, and achieving them would require large roadway spending increases, at least double current funding levels. There is little evidence that motorists are willing to bear such costs; they demand roadway expansions if subsidized but not if required to pay through tolls. More rational roadway planning uses capacity-optimizing rather than freeflow speed targets and performance indicators. All these factors should be considered when setting traffic speed targets.

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