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Bryant Walker Smith

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INTRODUCTION

"Today we are well underway to a solution of the traffic problem."[1] This claim, made by Robert Moses in 1948, is as true today as it was then. Which is to say, not at all. In the middle of the last century, the preferred solution to "the traffic problem" was more cement: new highways, bridges, and lanes. Today, the sensible solution includes more sensors and better computers: highly automated vehicles that use existing roadways and roadway networks much more efficiently.[2] This automation, we are told, will make

* Fellow, Center for Internet and Society at Stanford Law School and Center for Automotive Research at Stanford (CARS); New York University School of Law (LL.M. 2009, J.D. 2008); Transportation Engineer, Strand Associates, 2003–05; B.S., Civil Engineering, University of Wisconsin, 2003. I am grateful to Sven Beiker, Ryan Calo, Todd Litman, Dorothy Glancy, the staff of the *Santa Clara Law Review*, and my partner, Chris Berneck.

1. ROBERT A. CARO, THE POWER BROKER: ROBERT MOSES AND THE FALL OF NEW YORK 918 (1974) (quoting Robert Moses).

2. "Automated" and "autonomous" are not necessarily synonymous. *See* Steven E. Shladover, COOPERATIVE (RATHER THAN AUTONOMOUS) VEHICLE-HIGHWAY AUTOMATION SYSTEMS (on file with author); *see also* Bryant Walker Smith, *My Other Car Is a Robot? Defining Vehicle Automation*,

vehicular congestion a "thing of the past."[3] As in the past, however, this prediction presumes that more capacity necessarily means less congestion. Today's transportation planners recognize that the relationship between these two concepts is much more complex.

This Article argues that automation could significantly increase motor vehicle travel and that this increase could have important consequences for the physical and legal infrastructures in which tomorrow's vehicles will operate. The next part discusses four key traffic engineering concepts: vehicle miles traveled (VMT), capacity, demand, and the time-cost of travel. Part II explains why automation could increase VMT and then shows how this increase could undermine some of the claims made with respect to congestion and emissions. Part III identifies the potential effects of increased VMT on rural and urban land use and argues that the law can help manage these effects by better internalizing the costs and benefits of motor vehicle travel. Part IV offers preliminary recommendations.

A more cautious appraisal of these likely costs and benefits in no way diminishes the immense value of the coming transportation revolution. All transportation and communication innovations—whether cars, carriages, canals, or cables—have involved great uncertainty. Innovation invites speculation.

I. SOME BASIC CONCEPTS IN TRAFFIC ENGINEERING

Motor vehicle travel is a study of supply and demand. On the demand side, vehicle miles traveled (VMT) refers to the number of miles traveled in a year by motor vehicles of all types on public roads and streets of all types.[4] This is a

CYBERLAW.STANFORD.EDU (Feb. 19, 2012, 7:45 PM), http://cyberlaw.stanford.edu/blog/2012/02/my-other-car-robot-defining-vehicle-automation. In this Article, however, both terms indicate independence from a human operator rather than independence from other vehicles.

3. Hal Varian, *Micromultinationals Will Run the World*, FOREIGN POLICY, http://www.foreignpolicy.com/articles/2011/08/15/micromultinationals_will_run_the_world (last visited May 17, 2012); *see also*, Sebastian Thrun, *Leave the Driving to the Car, and Reap Benefits in Safety and Mobility*, N.Y. TIMES, December 6, 2011, at D4.

4. *Appendix B Glossary*, BTS.GOV, http://www.bts.gov/publications/national_transportation_statistics/html/appendix_b.html (last visited May 17, 2012).

rather large and necessarily imprecise number: In 2006, for the first time, motor vehicles in the United States traveled more than three *trillion* (3,000,000,000,000) miles.[5] As historical VMT data suggest[6] (and as discussed *infra*), motor vehicle travel is somewhat sensitive to the cost of fuel[7] and to the health of the economy.[8] In broad terms, however, VMT has almost doubled since 1980[9] and is expected to reach five trillion miles in just over twenty years from now.[10]

On the supply side, capacity refers to the "maximum hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point . . . during a given time period under prevailing roadway, environmental, traffic, and control

5. U.S. DEPT. OF TRANSP., *Historical Monthly VMT Report*, (Mar. 26, 2012), http://www.fhwa.dot.gov/policyinformation/travel/tvt/history/; *see also Our Nation's Highways: 2011*, FHWA.DOT.GOV (Apr. 16, 2012 3:10 PM), http://www.fhwa.dot.gov/policyinformation/pubs/hf/pl11028/chapter4.cfm#fig45. VMT is an estimate. *See, e.g.*, Robert E. Kumapley & Jon D. Fricker, *Reviews of Methods for Estimating Vehicle Miles Travelled*, TRANSPORTATION RESEARCH RECORD 1551 (2009), *available at* http://wiki.umd.edu/transportation/images/d/dc/Review_of_methods_for_estimating_vehicle_miles_traveled.pdf.

6. U.S. DEPT. OF TRANSP., *supra* note 5.

7. CONGRESSIONAL BUDGET OFFICE, EFFECTS OF GASOLINE PRICES ON DRIVING BEHAVIOR AND VEHICLE MARKETS (2008), http://www.cbo.gov/ftpdocs/88xx/doc8893/Chapter1.5.1.shtml.

8. TEX. TRANSP. INST., 2011 URBAN MOBILITY REPORT (2011).

9. U.S. DEPT. OF TRANSP., *supra* note 5. VMT has nearly tripled since 1970. *Id.* Also since 1980, the population has increased by thirty-six percent and the number of registered vehicles has increased by fifty-seven percent. *Monthly Estimates of the United States Population: April 1, 1980 to July 1, 1999, with Short-Term Projections to November 1, 2000*, CENSUS.GOV, http://www.census.gov/popest/data/national/totals/1990s/tables/nat-total.txt (last visited Sept. 23, 2012); *Table 1-11: Number of U.S. Aircraft, Vehicles, Vessels, and Other Conveyances*, RITA (Apr. 16, 2012 3:35 PM), http://www.bts.gov/publications/national_transportation_statistics/html/table_01_11.html. Real GDP has increased by 124 percent. U.S. DEPT. OF COMMERCE: BUREAU OF ECON. ANALYSIS, CURRENT-DOLLAR AND "REAL" GROSS DOMESTIC PRODUCT, *available at* http://www.bea.gov/national/xls/gdplev.xls. VMT is forecast to continue growing three times faster than population. *U.S. Population and Highway Vehicle Miles Traveled (VMT) 2000-2030*, RITA (Apr. 16, 2012 3:49 PM), http://www.rita.dot.gov/publications/transportation_vision_2030/html/figure_01.html; *National Population Projections Released 2009 (Based on Census 2000)*, CENSUS.GOV, http://www.census.gov/population/www/projections/2009comparisonfiles.html (last visited Sept. 23, 2012); *National Totals: Vintage 2011*, CENSUS.GOV, http://www.census.gov/popest/data/national/totals/2011/index.html (last visited Sept. 23, 2012).

10. *Id.* *But see* TODD LITMAN, THE FUTURE ISN'T WHAT IT USED TO BE: CHANGING TRENDS AND THEIR IMPLICATIONS FOR TRANSPORT PLANNING (2011), http://vtpi.org/future.pdf.

conditions."[11] Although the distinction between persons and vehicles is crucial to a number of practical and abstract questions of traffic engineering, the discussion that follows focuses on the motor vehicle flow rate.

The rural highways and neighborhood streets that together make up nearly ninety percent of the nation's lane miles typically operate far below capacity.[12] By contrast, urban interstate highways, which account for only one percent of lane miles,[13] carry an average of 14,000 vehicles per day per lane,[14] or roughly 1500 vehicles per hour per lane during the daily peak.[15] In theory, a freeway operating under

11. HCM2010: HIGHWAY CAPACITY MANUAL 9-3 (2010) [hereinafter HCM2010].

12. *Table 1-6: Estimated U.S. Roadway Lane-Miles by Functional System*, RITA (Apr. 16, 2012, 3:55 PM), http://www.bts.gov/publications/national_transportation_statistics/html/table_01_06.html. The "average" vehicle lane across all highway types carries fewer than 1000 vehicles per day, which is similar to the volume on a state highway connecting two small cities. (This rough estimate of "annual average daily traffic" (AADT) is equal to (VMT / vehicle lane miles) / 365 days per year, or (2,999,970,000,000 miles per year / 8,556,585 lane miles) / 365 days per year = 961 vehicles per lane per day. *Id.*; *Table 1-36: Roadway Vehicle Miles Traveled (VMT) and VMT per Lane-Mile by Functional*, RITA (Apr. 16, 2012, 4:02 PM), http://www.bts.gov/publications/national_transportation_statistics/html/table_01_36.html.). For a list of the highways with the highest AADT (by roadway rather than by lane), see *Most Travelled Urban Highways Average Annual Daily Traffic > 250,000*, OFFICE OF HIGHWAY POLICY INFO. (Apr. 16, 2012, 4:02 PM), http://www.fhwa.dot.gov/policyinformation/tables/02.cfm. For AADT maps, see, e.g., *Traffic Counts*, WIS. DEP'T OF TRANSP., http://www.dot.wisconsin.gov/travel/counts/interstate.htm.

13. *Table 1-6: Estimated U.S. Roadway Lane-Miles by Functional System*, *supra* note 12. The number of urban interstate lane miles has, through a combination of construction and urbanization, increased by eighty-four percent since 1980. Total lane miles have increased by eight percent. *Id.* A lane mile is one mile of one lane of one roadway. *Id.* These figures exclude on-street and off-street parking facilities, which are estimated to take up "an area larger than Delaware and Rhode Island combined." Michael Kimmelman, *Paved, but Still Alive*, N.Y. TIMES (Jan. 6, 2012), http://www.nytimes.com/2012/01/08/arts/design/taking-parking-lots-seriously-as-public-spaces.html (citing Eran Ben-Joseph).

14. (474,963,000,000 miles per year / 90,949 lane miles) / 365 days per year = 14,308 vehicles per lane per day. *Table 1-36: Roadway Vehicle Miles Traveled (VMT) and VMT per Lane-Mile by Functional*, *supra* note 12; *see Table 1-6: Estimated U.S. Roadway Lane-Miles by Functional System*, *supra* note 12.

15. This, critically, assumes that the peak hour of travel handles nine percent of the AADT (K = 0.09), that the flow during the peak fifteen minutes is higher than during the peak hour (PHF = 0.95), that this volume is somewhat heavier in one direction than in the other (D = 0.55), and that the volume in each direction is split evenly among all lanes in that direction. *See* HCM2010, *supra* note 11, at 3-2–3-16, 11-24 (2010).

optimal conditions can serve a maximum of 2400 vehicles per hour per lane.[16] This corresponds to an average headway of 1.5 seconds per vehicle,[17] half the spacing dictated by the "three-second rule."[18] Under certain conditions, some freeways even have higher flow rates and hence higher capacities.[19]

Freeways can also have significantly lower capacities. A freeway's maximum attainable flow can be reduced by uniform or erratic changes in driver behavior or vehicle operation that result from geometry (narrow lanes or shoulders, on- or off-ramps, and pavement deterioration), terrain, weather, visibility, vehicle type (trucks, buses, and RVs), driver type (familiar or unfamiliar), and incidents (work zone activity, enforcement activity, crashes, and stopped vehicles).[20] Moreover, flow—as well as speeds and headways—can also be strikingly low when a queue "has backed up from a downstream bottleneck" in what is described as an "oversaturated" condition.[21]

Because a highway cannot operate above its vehicular capacity, VMT represents only the *serviceable* demand for motor vehicle travel. In other words, if a freeway's two northbound lanes have an aggregate capacity of 4800 vehicles per hour, the driver of the 4801st vehicle must either detour or wait to be processed in the next hour. This produces the classic "traffic jam" and partly explains the expansion of the peak from a "rush hour" to "rush hours."[22] A would-be driver with information and options might also choose to forgo the

16. *Id.* at 3-14.

17. *Id.* at 4-9.

18. *California Driver Handbook – Safe Driving Practices*, CAL. DEPT. OF MOTOR VEHICLES, http://www.dmv.ca.gov/pubs/hdbk/scanning.htm (last visited June 2, 2012).

19. *See, e.g.*, HCM2010, *supra* note 11, at 4-8 (2010) (I-805, San Diego, California). *But see* Shladover, *supra* note 2 ("The [California Performance Measurement System] data have shown that maximum highway capacity per lane of about 2200 vehicles per hour can be achieved over a range of speeds, up to about 100 km/h.").

20. HCM2010, *supra* note 11, at 11-1, 12, 13.

21. *Id.* at 4-8–4-9, 11-2.

22. Note also that "[a]pproximately 40 percent of total delay occurs in the midday and overnight (outside of the peak hours of 6 a.m. to 10 a.m. and 3 p.m. to 7 p.m.) times of day when travelers and shippers expect free-flow travel." David Schrank, Tim Lomax & Bill Eisele, *2011 Urban Mobility Report*, TEX. TRANSP. INST. 5 (2011), http://tti.tamu.edu/documents/mobility-report-2011.pdf.

trip or to select a different mode,[23] route, or time—another reason for the peak's expansion. But if the addition of a third northbound lane increases capacity to 7200 vehicles per hour, that driver may now be able to successfully traverse the freeway at the preferred time.[24] So too will 2399 additional drivers.

These 2400 new trips, if they materialize, exemplify a controversial concept known in a "huge and enervating literature"[25] as latent or induced demand[26]—and in popular terms as "if you build it, they will come."[27] Travel demand is at least somewhat elastic—that is, responsive to "price," which includes a driver's *perception* of her "travel time, operating costs," user charges, comfort, and exposure to injury.[28] Critically, price in this sense excludes the costs (and

23. Possible modes include single-occupancy motor vehicle, carpool, bus, train, bicycle, and foot, though many others are also possible. *See, e.g.*, Matthew Symington, *The World's Strangest Commutes*, THE TELEGRAPH (June 30, 2011, 4:23 PM), http://www.telegraph.co.uk/travel/travelnews/7863382/The-worlds-strangest-commutes.html.

24. Assuming that no secondary bottleneck impedes that driver's trip.

25. TOM VANDERBILT, TRAFFIC: WHY WE DRIVE THE WAY WE DO (AND WHAT IT SAYS ABOUT US) 155 (2008). For some sense of the empirical complexity, see, e.g., Susan Handy, *Smart Growth and the Transportation-Land Use Connection: What Does the Research Tell Us?*, 28 INT'L REGIONAL SCI. REV. 146, 146–47, *available at* http://irx.sagepub.com/content/28/2/146.

26. *See, generally*, Todd Litman, *Generated Traffic; Implications for Transport Planning*, 71 INST. OF TRANSP. ENGINEERS J. 38, 38–47 (2001), *available at* http://www.vtpi.org/gentraf.pdf; Douglass B. Lee, Jr. et al., *Induced Traffic and Induced Demand*, 1659 TRANSP. RES. REC. 68, 68 (1999); Richard Arnott & Kenneth Small, *The Economics of Traffic Congestion*, 82 AM. SCIENTIST 442, 442 (1994); David Schrank, Tim Lomax & Bill Eisele, *Can More Road Space Reduce Congestion Growth?*, TEX. TRANSP. INST., http://mobility.tamu.edu/files/2011/09/road-space.pdf. The phenomenon is also known as the rebound effect. *See, e.g.*, Litman, *supra*, at 38. The literature generally conflates latent demand and induced demand, but the distinction, if there is one, is at its core a value judgment. Consider, for example, an environmental impact statement in which a high-build alternative is projected to carry more vehicles than the do-nothing alternative. Does the lower-capacity (and hence lower-volume) alternative fail by precluding trips that should occur, or does the higher-capacity (and hence higher-volume) alternative fail by inducing trips that should not occur?

27. The actual quote from the 1989 movie Field of Dreams is, "If you build it, he will come," but a majority of the new trips in the last several decades may in fact be made by women rather than men. FIELD OF DREAMS (Universal Pictures 1989); *see* VANDERBILT, *supra* note 25, at 134.

28. DOUGLASS B. LEE, JR., APPENDIX B INDUCED TRAFFIC AND INDUCED DEMAND B-2–B-3, *available at* http://www.worldbank.org/transport/roads/rpl_docs/apbinduc.pdf; TODD LITMAN, EFFICIENT VEHICLES VERSUS EFFICIENT TRANSPORTATION (2009), http://vtpi.org/cafe.pdf (discussing the relationship

the benefits) that accrue to actors other than the particular driver, including neighbors, pedestrians, bicyclists, transit riders, and even other drivers. A key if obvious point here is that travel time can affect travel decisions.[29] Estimating the time-cost of travel is therefore important—but also difficult.[30] One particularly well-known congestion study uses a 2010 average cost of time of $16.30 per hour,[31] which corresponds to $0.27 per mile at sixty miles per hour and $0.54 per mile at thirty miles per hour. By contrast, the estimated operating costs for a passenger car range from $0.13 to $0.20 per mile.[32] These numbers suggest that drivers value their time even more than their gas.[33]

A highway project ("improvement" in the language of the past)[34] that increases vehicular capacity, free flow speed, or perceived safety can reduce the perceived price that a driver pays for using that highway, which can in turn affect that driver's travel choice.[35] In the near term, such a project might produce shifts in time, space, mode, frequency, or destination.[36] In the long term, the lower internal costs of

between fuel economy and miles traveled). This concept applies with equal force in other contexts. *See, e.g.*, Jenna Wortham, *Customers Angered as iPhones Overload AT&T*, N.Y. TIMES, Sept. 3, 2009, at B1, *available at* http://www.nytimes.com/2009/09/03/technology/companies/03att.html.

29. VANDERBILT, *supra* note 25, at 157–61.

30. *Transportation Cost and Benefit Analysis II – Vehicle Costs*, VICTORIA TRANSP. POLICY INST. 5.1 (Mar. 16, 2011), http://www.vtpi.org/tca/tca0501.pdf; Todd Litman, *Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications*, VICTORIA TRANSP. POLICY INST. (Jan. 2, 2009), http://www.vtpi.org/tca/tca01.pdf.

31. *Appendix A: Methodology for the 2011 Urban Mobility Report*, TEX. TRANSP. INST. A-13 (2011), http://mobility.tamu.edu/files/2011/09/appendix-a.pdf.

32. VICTORIA TRANSP. POLICY INST., *supra* note 30, at Table 5.1.5–5.4; LITMAN, *supra* note 30. Operating costs here include only gas, oil, maintenance, and tires and not the ownership costs (insurance, license, registration, depreciation, and financing) that are more or entirely independent of each vehicle mile traveled. *Id.*

33. This Article generally uses "driver" to refer both to the person in the vehicle and to the person who pays for the vehicle's operation.

34. Memorandum from Michael J. Wright, West Palm Beach, Fla. City Administrator, on City Transportation Language Policy (Nov. 14, 1996), *available at* http://www.8-80cities.org/Articles/City%20Transportation%20Language%20Policy.pdf. A wider road may not represent an "improvement" for the pedestrians who must cross it.

35. However, someone other than the driver—such as a company, passenger, or computer—may make some or all of these travel choices.

36. LEE, *supra* note 28, at B-6. Lee refers to these near-term changes as

motor vehicle travel might also produce changes in vehicle type, modal options, transportation policy, "residence and workplace locations," land use patterns, population, and economic activity.[37] Every one of this country's three trillion vehicle miles traveled reflects such choices.

Highway congestion is related to each of the traffic concepts discussed so far. At a freeway's functional capacity, "the traffic stream has no ability to dissipate even the most minor disruption, and any incident can be expected to produce a serious breakdown and substantial queuing. The physical and psychological comfort afforded to drivers is," not surprisingly, "poor."[38] In an objective sense, then, congestion occurs when serviceable demand approaches actual supply[39]—a common occurrence on key roadways during peak periods.[40] And in a subjective sense, it occurs when the volume of travel makes the perceived price of travel uncomfortably high.[41]

The societal cost of this discomfort is often measured in actual (rather than perceived) delay, fuel consumption, and emissions.[42] As a result of congestion in 2010, "urban Americans" traveled an additional "4.8 billion hours" and "purchase[d] an extra 1.9 billion gallons of fuel."[43] These expenditures amounted to a "congestion cost of $101 billion"[44]—a fivefold increase since 1982.[45]

"induced traffic" and to the long-term changes as "induced demand."

37. *Id.* at B-12.

38. HCM2010, *supra* note 11, at 11-6 (describing level of service E).

39. *Id.*

40. *Peak-Period Congestion on the National Highway System*, U.S. DEPT. OF TRANS., http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/nhspperiodcong2007.htm (last visited June 3, 2012).

41. Transport Research Centre, *Managing Urban Traffic Congestion*, INTERNATIONAL TRANSPORT FORUM 27, http://www.internationaltransportforum.org/Pub/pdf/07Congestion.pdf. But not necessarily intolerable; as Yogi Berra (reportedly) said, "Nobody goes there anymore; it's too crowded."

42. *See, e.g.*, TEX. TRANSP. INST., *supra* note 22, at 1.

43. *Id.* The study does not examine the delay experienced by urbane Americans, who almost certainly go out of their way. *See id.*

44. *Id.* For comparison, another study estimated that motor vehicle-related fatalities and injuries cost $299.5 billion in 2009. *See* CAMBRIDGE SYSTEMATICS INC., CRASHES VS. CONGESTION: WHAT'S THE COST TO SOCIETY? ES-2 (2011), http://www.camsys.com/pubs/2011_AAA_CrashvCongUpd.pdf; *see also* Binyamin Applebaum, *As U.S. Agencies Put More Value on Life, Businesses Fret*, N.Y. TIMES, Feb. 17, 2011, at A1, *available at* http://www.nytimes.com/2011/02/17/business/economy/17regulation.html.

II. HOW AUTONOMOUS DRIVING COULD AFFECT TRAVEL

Autonomous driving could have a dramatic, albeit gradual, effect on each of the traffic concepts discussed in the previous section. Absent other phenomena, the total cost of motor vehicle travel is likely to decrease, and demand for that travel is likely to increase faster than corresponding capacity. This section considers these potential effects in the near and long terms. It does not account for other factors—including economic state, fuel and electricity costs, the displacement of transportation by communication (through telecommuting, electronic commerce, and online entertainment), and the localization of trips (through urbanization and mixed-use development)—that could conceivably temper or negate an increase in that travel demand.

Self-driving cars that do not need human drivers or monitors may substantially increase mobility for those who cannot (legally) drive themselves because of youth, age, disability, or incapacitation. Nine percent of adults identify as blind or report "trouble seeing, even when wearing glasses or contact lenses."[46] Nearly eleven percent of Americans are between ten and seventeen years old, and nearly thirteen percent are sixty-five or older.[47] More than thirty-one percent of the total population (and thirteen percent of those sixteen or older) does not have a driver's license.[48] (Nonetheless, poverty may remain a barrier to many would-be drivers.)[49]

Truly self-driving cars will not even need human occupants. In announcing its self-driving car project, Google alluded to an earlier research vehicle "that delivered pizza

45. TEX. TRANSP. INST., *supra* note 22, at 5.

46. CTR. FOR DISEASE CONTROL, SUMMARY HEALTH STATISTICS FOR U.S. ADULTS: NATIONAL HEALTH INTERVIEW SURVEY, 2010 TABLE IX (2010), *available at* http://www.cdc.gov/nchs/data/series/sr_10/sr10_252.pdf.

47. *Age and Sex in the United States: 2010*, U.S. CENSUS BUREAU, http://www.census.gov/population/www/socdemo/age/age_sex_2010.html (last visited June 3, 2012).

48. *Highway Finance Data Collection: Our Nation's Highways: 2011*, OFFICE OF HIGHWAY POLICY INFO., http://www.fhwa.dot.gov/policy information/pubs/hf/pl11028/chapter4.cfm (last visited June 3, 2012).

49. JOHN PAWASARAT, UNIVERSITY OF WISCONSIN-MILWAUKEE EMPLOYMENT AND TRAINING INSTITUTE, THE DRIVER LICENSE STATUS OF THE VOTING AGE POPULATION IN WISCONSIN (2005), http://www4.uwm.edu /eti/barriers/DriversLicense.pdf; NICHOLE L. YUNK, THE SIGNIFICANCE OF A DRIVER'S LICENSE IN THE MODERN URBAN ECONOMY (2007), http://www.mobilityagenda.org/wiyunkpaper.pdf.

without a person inside."[50] Of the nearly 400 billion person-trips undertaken by U.S. drivers in 2008, almost forty-three percent were for "personal and family-related purposes (such as shopping trips and trips for medical care)."[51] The frequency, duration, and timing of shopping, refueling, and chauffeuring[52] trips may change as people find they can simply dispatch cars from the convenience of their home or office. In other words, as the time-cost of these trips approaches zero, demand for them is likely to increase. Recall that drivers, on average, appear to value their time even more than their gas;[53] a thirty-minute, twenty-mile trip that costs eight dollars with one human occupant (the driver) would cost less than half that without any human occupants.[54]

Moreover, the price of travel could also drop substantially for the occupants of an autonomous vehicle. Any per-mile fuel savings achieved by automation through smoother and less frequent throttling and braking, for example, would reduce the vehicle's operating costs even if the purchase price is greater.[55] A vehicle that parks and fuels itself would also reduce total trip time. And if the (well-connected) car provides an environment that is as enjoyable or productive as the home or office, the time-cost of motor vehicle travel could also drop substantially. Consider that each American currently spends an average of one hour per day in a vehicle (as either a driver or a passenger),[56] which is equivalent to:

50. *What We're Driving At*, OFFICIAL GOOGLE BLOG (Oct. 9, 2010, 12:00 PM), http://googleblog.blogspot.com/2010/10/what-were-driving-at.html; *see also Episode 8: Automated Pizza Delivery*, GRAND IDEA STUDIO, http://www.grandideastudio.com/portfolio/pt-automated-pizza-delivery (last visited June 3, 2012).

51. OFFICE OF HIGHWAY POLICY INFO., *supra* note 48.

52. For example, a family car might drive a child to school and then return home to drive a parent to work, or a shared car might operate as an autonomous taxi throughout the day.

53. *See supra* text accompanying notes 30–32.

54. Compare (0.5 hours)*($16.30/person hour) + (20 miles)*($0.20/mile) = $8.15 with (20 miles)*($0.20/mile) = $4.00. *See supra* text accompanying notes 30–32.

55. Car insurance premiums, which are generally independent of miles traveled, are a matter of considerable uncertainty. On one hand, the crash rate might decrease, and liability might shift from owners to manufacturers and service providers. On the other hand, the cost of the onboard equipment may increase. These issues are beyond the scope of this Article.

56. NAT'L HOUSEHOLD TRAVEL SURVEY, SUMMARY OF TRAVEL TRENDS 30–33, http://nhts.ornl.gov/2009/pub/stt.pdf. Some of this time may be spent as a

- An episode of The View or General Hospital (with commercials).[57]
- Twice the minimum time that an adult should spend exercising.[58]
- 15 days per year.
- $5950 per person per year.[59]
- $135,000 per year in billing potential for a partner at a major law firm.[60]
- Three years over the course of an average lifetime.[61]

In the near term, automation may reduce the typical motor vehicle capacity of roadways and intersections. An autonomous vehicle that stubbornly maintains a headway of three seconds could reduce the roadway space available to other vehicles.[62] Similarly, an autonomous vehicle that proceeds tentatively after stopping or that yields to a

passenger, and some of the time spent driving is already used, however dangerously and inefficiently, for other activities, *see* Press Release, Nat'l Transp. Safety Bd., No Call, No Text, No Update Behind the Wheel: NTSB Calls for Nationwide Ban on PEDs While Driving (Dec. 13, 2011), *available at* http://www.ntsb.gov/news/2011/111213.html. There may also be benefits to forced downtime. *See* Matt Richtel, *Digital Devices Deprive Brain of Needed Downtime*, N.Y. TIMES (Aug. 24, 2010), http://www.nytimes.com/2010/08/25/technology/25brain.html. For data specific to commuting, see U.S. CENSUS BUREAU, COMMUTING IN THE UNITED STATES: 2009 (2011), http://www.census.gov/prod/2011pubs/acs-15.pdf.

57. *The View*, ABC, http://abc.go.com/watch/the-view/167365 (last visited June 3, 2012); *General Hospital*, ABC, http://abc.go.com/shows/general-hospital (last visited June 3, 2012).

58. *How Much Physical Activity Do Adults Need?*, CDC.GOV, http://www.cdc.gov/physicalactivity/everyone/guidelines/adults.html (last visited June 3, 2012). I predict a robust market for in-car exercise equipment, including (perhaps most ironically) stationary bikes.

59. This assumes an average cost of time of $16.30 per person hour. APPENDIX A: METHODOLOGY FOR THE 2011 URBAN MOBILITY REPORT, *supra* note 31. This value may be more useful for predicting travel behavior than for actually assessing lost productivity, particularly since the nationwide figure of $1.8 trillion per year is equivalent to twelve percent of GDP. *National Economic Accounts*, BEA.GOV, http://www.bea.gov/national/ (last visited June 3, 2012).

60. This assumes 270 days per year and a billing rate of $500 per hour. *See A Nationwide Sampling of Law Firm Billing Rates*, NAT'L LAW JOURNAL (Dec. 19, 2011), http://www.law.com/jsp/nlj/PubArticleNLJ.jsp?id=1202535905815.

61. A child born in the United States in 2007 could expect to live 77.9 years. *Life Expectancy*, CDC.GOV, http://www.cdc.gov/nchs/fastats/lifexpec.htm (last visited June 3, 2012).

62. *See supra* Part I.

pedestrian will delay the vehicles behind it. Importantly, these behaviors may well be desirable: Longer headways can reduce crash frequency and severity, and drivers are legally required to yield to or stop for pedestrians in marked and unmarked crosswalks.[63]

In the long term, the widespread or universal[64] adoption of autonomous driving could actually increase system capacity. Three potential aspects of automation could drive this increase, which in turn could accommodate and ultimately foster more demand.

First, automation, particularly cooperative technology that facilitates rapid communication among vehicles ("V2V"), could increase the amount of useable road space in the longitudinal and lateral dimensions. Currently, vehicles moving at freeflow speeds on a freeway use only "11% of the length of the lane, while the remaining 89% of the lane length represents the gaps that the drivers need to maintain behind other vehicles in order to feel safe and comfortable in their vehicle."[65] More precise throttling and braking could facilitate lower vehicle headways and even accommodate closely-spaced vehicle platoons, both of which could significantly increase lane capacity.[66] Likewise, "the typical highway lane width in the U.S. is about 3.5 [meters], or 11 to 12 feet," "but even large passenger cars, vans or SUVs rarely exceed 1.8m in width. The remaining lane width is needed to accommodate steering imprecision by light-duty vehicle drivers, as well as to allow for use by heavy trucks and buses, which can be as wide as 2.74 [meters]."[67] More precise steering might permit an increase in total lanes through a reduction in the width of some of the lanes.

63. CAL. VEH. CODE § 21950 (West 2011); *see infra* note 115.

64. This is an important difference: A highway system designed for one-hundred percent autonomous vehicles could look very different from one designed for ninety percent or even ninety-nine percent autonomous vehicles. Pedestrians and bicyclists, while potentially trackable, are not automated.

65. STEVEN E. SHLADOVER, COOPERATIVE (RATHER THAN AUTONOMOUS) VEHICLE-HIGHWAY AUTOMATION SYSTEMS 2 (on file with author). This estimate is based on a freeflow speed of 100 kilometers per hour (or sixty-two miles per hour). *Id.* Vehicles may be more tightly spaced at lower speeds. *See supra* Part I; HCM2010, *supra* note 11, at 4-7–4-10.

66. *Id.*; *see also* THE SARTRE PROJECT, http://www.sartre-project.eu (last visited June 3, 2012).

67. SHLADOVER, *supra* note 65, at 2.

Second, automation could increase total functional capacity along corridors that include several parallel highways (and that therefore offer more than one potential route). Better real-time travel information could be used to route some vehicles to comparatively underutilized highways.[68]

Third, automation could reduce the number of small disruptions to vehicle flows (such as unexpected braking, lane changing, hesitating, jockeying, and rubbernecking) and the rate of crashes and other incidents.[69] The combination of smoother flowers and more useful travel information could also increase the predictability and reliability of trips, a key element of driver comfort.[70]

In other words, autonomous driving could ultimately have the same effects as adding that third, fourth, or fifth lane to the freeway.[71] And, as discussed *supra*, such a capacity expansion could lower the internal price of a motor vehicle trip, which in turn could increase both near- and long-term demand. This is the potential paradox of autonomous driving. Highways may carry significantly more vehicles, but average delay during the peak period may not decrease appreciably. Similarly, emissions per vehicle mile traveled may decrease, but total emissions (throughout the day) may actually increase. The denominator matters to these claims, and both the costs and benefits of autonomous driving must be considered on a systemic basis as well as on a per mile basis.[72]

III. HOW LAW COULD RESPOND TO CHANGING TRAVEL PATTERNS

A significant increase in motor vehicle travel could pose myriad challenges for policymakers, including changes in

68. This is actually quite tricky; what is better for all users may differ from what is better for an individual user. *See* VANDERBILT, *supra* note 25, at 161.

69. Sven Beiker, *Legal Aspects of Autonomous Driving*, 52 SANTA CLARA L. REV. 1145, 1150–51 (2012).

70. TEX. TRANSP. INST., UNRELIABLE TRAVEL TIMES – ONE OF THE CONGESTION PROBLEMS (2011), http://mobility.tamu.edu/files/2011/09/travel-times.pdf; *see* VANDERBILT, *supra* note 25, at 141.

71. Though, as noted, the near-term effect on capacity may be more akin to the construction of those additional lanes.

72. Speculation on additional measures, including the total number of crashes and the total number of vehicle purchases, is particularly difficult.

rural and urban land use, shifts in congestion, increases in certain emissions, decreases in mass transit ridership, and increases in maintenance costs for roads and bridges. This section focuses on three broad approaches to managing autonomous transportation demand and the effects thereof: internalize the costs of travel, limit suburban sprawl, and optimize urban circulation.

A. Internalize the Costs of Travel

Return to the thirty-minute, twenty-mile trip from Part II.[73] That trip imposes time-costs of about $4.15 and operating costs of about $4.00.[74] The driver pays these variable costs (plus certain variable costs from crashes), which together make up approximately half the total cost of motor vehicle use.[75] The driver also pays the fixed costs of owning the vehicle (including certain fixed costs from crashes), which make up about a quarter of the total cost of motor vehicle use.[76] The remaining quarter are costs imposed on society generally albeit unevenly through off-street parking, additional crash damages, congestion, pollution and other environmental damage, the loss of land to roadways, fuel costs not borne by the driver, and traffic services.[77]

This analysis is necessarily imprecise, exclusive of the costs and benefits of the sprawl that fosters and depends on motor vehicle travel,[78] and subject to changes in automation and propulsion. But it illustrates that drivers tend to underprice their trips, a problem that could be exacerbated by the lower cost of an autonomous vehicle trip.[79]

73. *See supra* text accompanying notes 53–54.

74. *Id.*

75. LITMAN, *supra* note 30; *Transportation Costs and Benefits: Resources for Measuring Transportation Costs and Benefits*, VICTORIA TRANSP. POLICY INST., http://www.vtpi.org/tdm/tdm66.htm at Figure 3 (last updated Mar. 16, 2011) [hereinafter *Transportation Costs and Benefits*] (aggregating previously discussed studies). The numbers in this table differ from those used in this paper's example. *See id.*

76. *Id.* On a per-mile basis, these fixed costs decrease as vehicle usage increases.

77. *Id.* at Table 16 (aggregating previously discussed studies).

78. *See* LITMAN, *supra* note 30; *Transportation Costs and Benefits*, *supra* note 75, at Table 13; THAD WILLIAMSON, SPRAWL, JUSTICE, AND CITIZENSHIP, THE CIVIC COSTS OF THE AMERICAN WAY OF LIFE 57–84 (2010).

79. *See* LITMAN, *supra* note 30; *Transportation Costs and Benefits*, *supra* note 75, at Table 13.

As the National Surface Transportation Infrastructure Financing Commission recognized, underpricing can also mean underpaying.[80] The Commission was established by Congress to "assess the [transportation] funding crisis and make recommendations to address the growing transportation infrastructure investment deficit."[81] Its final report, entitled "Paying Our Way," stressed that:

> The funding and finance framework should *cause users and direct beneficiaries to bear the full cost of using the transportation system to the greatest extent possible* (including for impacts such as congestion, air pollution, pavement damage, and other direct and indirect impacts) in order to promote more efficient use of the system. This will not be possible in all instances, and when it is not, any cross-subsidization must be intentional, fully transparent, and designed to meet network goals, equity goals, or other compelling purposes.[82]

Federal and state gas taxes—or, more precisely, "excise taxes imposed on the consumption of gasoline, diesel, and special fuels"[83]—internalize some of the cost of motor vehicle travel. Today's state and federal taxes increase the cost of a gallon of gasoline by an average of 48.8 cents, ranging from 26.4 cents in Alaska to 67.0 cents in California.[84] Assuming 27.5 miles per gallon,[85] this average tax rate amounts to just 35.5 cents for a 20-mile trip.

In 2025, however, that twenty-mile trip might cost only eighteen cents—or the equivalent of thirteen cents after inflation.[86] There are three reasons for this potentially

80. NAT'L SURFACE TRANSP. INFRASTRUCTURE FIN. COMM'N, PAYING OUR WAY: A NEW FRAMEWORK FOR TRANSPORTATION FINANCE (2009), *available at* http://financecommission.dot.gov.

81. *Id.* at 4–5.

82. *Id.* at 27 (emphasis in original); *see id.* at 28–29; *see also id.* at 233–34 (Supplemental Statement of Commissioner Donald F. Carmody) (objecting that the Commission did not apply its "common theme of 'user pays'" to transit but failing to demonstrate that motor vehicle users pay all their costs).

83. *Id.* at 100.

84. AM. PETROLEUM INST., GASOLINE TAXES (2012), http://www.api.org/statistics/fueltaxes/upload/gasoline-diesel-summary.pdf.

85. *See* Fuel Economy Standards, 49 C.F.R. § 531.5 (2011) (requiring each manufacturer to achieve a fleetwide minimum fuel economy of 27.5 mpg for each model year between 1990 and 2010); *see also CAFE – Fuel Economy*, NHTSA, http://www.nhtsa.gov/fuel-economy (discussing latest updates to CAFÉ program).

86. This estimate assumes that inflation, as measured by the average

dramatic decrease. First, in the half-century that federal fuel taxes have been used as a dedicated source of transportation funding, their rates have "increased sporadically," with the last such "increase occurring in 1993."[87] Second, federal fuel taxes are not pegged to inflation; as a result, "the actual purchasing power of the [federal] gasoline tax has declined thirty-three percent since 1993."[88] Third, the CAFE standard for 2025 will be 54.5 miles per gallon.[89] This last point is crucial: More fuel-efficient vehicles incur less per mile in motor fuel taxes—and fully electric vehicles incur none.[90]

Many solutions to this looming crisis in transportation funding have been considered.[91] These include tolling (of highways, bridges, tunnels, lanes, or urban zones),[92] VMT fees (whether based solely on mileage or "based on considerations such as time of travel, congestion levels on a facility, type of road, type and weight of the vehicle, and vehicle emissions levels"),[93] and carbon taxes.[94] Electric

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Consumer Price Index, will be the same between 2012 and 2025 as it was between 1998 and 2011. *See CPI Inflation Calculator*, BUREAU OF LABOR STATISTICS, http://www.bls.gov/data/inflation_calculator.htm (last visited June 3, 2012).

87. NAT'L SURFACE TRANSP. INFRASTRUCTURE FIN. COMM'N, *supra* note 80, at 100.

88. *Id.*

89. *President Obama Announces Historic 54.5 mpg Fuel Efficiency Standard*, THE WHITE HOUSE (July 29, 2011), http://www.whitehouse.gov/the-press-office/2011/07/29/president-obama-announces-historic-545-mpg-fuel-efficiency-standard.

90. They may, however, incur other energy taxes.

91. *See, e.g.*, NAT'L SURFACE TRANSP. INFRASTRUCTURE FIN. COMM'N, *supra* note 80, at 126–58. Indeed, this was the subject of my distant undergraduate thesis, though my team and our advisor were probably the only ones who ever "considered" our report. *See also Transportation Funding & Financing*, AASHTO CENTER FOR EXCELLENCE IN PROJECT FINANCE, http://www.transportation-finance.org/funding_financing/funding/ (last visited Sept. 5, 2012).

92. *Id.* at 126–28; U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-06-554, HIGHWAY FINANCE: STATE'S INCREASING USE OF TOLLING ILLUSTRATES DIVERSE CHALLENGES AND STRATEGIES (2006), *available at* http://www.gao.gov/new.items/d06554.pdf.

93. NAT'L SURFACE TRANSP. INFRASTRUCTURE FIN. COMM'N, *supra* note 80, at 128. Interestingly, the Commission compares VMT fees to "pay-as-you-drive insurance," which could convert a fixed expense of owning a vehicle into a variable cost of driving that vehicle. *Id.*

94. Carbon Tax/Cap and Trade Program, AASHTO CENTER FOR EXCELLENCE IN PROJECT FINANCE, http://www.transportation-finance.org/funding_financing/funding/proposed_funding_sources/carbon_tax_cap_trade_program.aspx (last visited Sept. 5, 2012); Jenny Sumner, Lori Bird, &

vehicles may ultimately force, and autonomous vehicles may facilitate,[95] greater adoption of these solutions at the state and national levels.

In addition to raising revenue, these approaches also offer the potential to internalize more of the costs of driving, including "impacts such as congestion, air pollution, pavement damage, and other direct and indirect impacts."[96] This would place driving as a whole on more equal terms with other forms of mobility, access, and activity—a wide spectrum that includes not only other modes of travel but also substitutes for travel. However, because of the likely difference in time-cost, autonomous driving would still have a significant (and justifiable) price advantage over conventional driving—an advantage that could help speed its adoption.

B. Limit Suburban Sprawl

Because of this lower time-cost, autonomous driving may nonetheless encourage suburban sprawl by increasing the acceptable commuting distance. In 2009, "[w]orkers took an average of 25.1 minutes to get to work."[97] Indeed, "[w]hether the setting is an African village or an American city, the daily round-trip commute clocks in at about 1.1 hours," as it has for some time.[98] But if workers could sleep or work in their cars, they may be willing to live further from their jobs.[99] Mass transit riders, for example, take significantly longer to reach work,[100] but are able to spend at least part of their travel time on tasks other than driving. Autonomous driving would offer a similar advantage but, unlike mass transit,[101] would not

Hillary Smith, *Carbon Taxes: A Review of Experience and Policy Design Considerations*, NATIONAL RENEWABLE ENERGY LABORATORY 21 (Dec. 2009), http://www.nrel.gov/docs/fy10osti/47312.pdf.

95. Because of the data collected, autonomous driving might be particularly conducive to VMT fees.

96. NAT'L SURFACE TRANSP. INFRASTRUCTURE FIN. COMM'N, *supra* note 80, at 27.

97. U.S. CENSUS BUREAU, *supra* note 56, at 2. Note, however, that commute times are self-reported.

98. VANDERBILT, *supra* note 25, at 131; *see also id*. at 131–32, 139–40.

99. Or, in the extreme case, to live as well as commute in an autonomous recreational vehicle.

100. *See* U.S. CENSUS BUREAU, *supra* note 56, at 11; *see also Travel Times on Commuter Rail*, N.Y. TIMES (Mar. 17, 2007), http://www.nytimes.com/imagepages/2007/03/17/nyregion/nyregionspecial2/20070318_TRAIN_GRAPHIC.html.

101. *E.g.*, CARO, *supra* note 1, at 898.

necessarily foster clustered development. Moreover, in the long term, a dramatic expansion in functional roadway capacity that increased commuting distances without, at least initially, increasing commuting times could also open additional areas to development, much as Robert Moses' New York parkways, expressways, and bridges contributed to the rapid suburbanization of central Long Island.[102]

While Long Island-style sprawl is hardly a new phenomenon, efforts to promote "smart growth" have often met more unending controversy[103] than unqualified success.[104] States (or, more likely, the municipalities or regions to which planning, zoning, and land use control are generally delegated)[105] will face two key challenges with respect to the private farmland and forestland that autonomous driving could render susceptible to suburbanization. First, what areas or corridors should be preserved (and how)?[106] Second, in those areas that should not or cannot be preserved, how and when should development occur?[107]

102. *Id.* at 898–99.

103. *Compare* Clint Bolick, *Subverting the American Dream: Government Dictated "Smart Growth" Is Unwise and Unconstitutional*, 148 U. PA. L. REV. 873, 873–88 (2000) *with* Timothy J. Dowloing, *Reflections on Urban Sprawl, Smart Growth, and the Fifth Amendment*, 148 U. PA. L. REV. 878, 889–930 (2000).

104. *See* Anthony Downs, *Smart Growth: Why We Discuss It More than We Do It*, 71 J. OF THE AM. PLAN. ASS'N 367 (2005), *available at* http://www.tandfonline.com/doi/abs/10.1080/01944360508976707; *see also* Ethan Elkind, *So Much for California's Anti-Sprawl Law*, BERKELEY BLOG (July 7, 2011), http://blogs.berkeley.edu/2011/07/07/so-much-for-california%E2%80%99s-anti-sprawl-law.

105. John R. Nolan, *Historical Overview of the American Land Use System: A Diagnostic Approach to Evaluating Governmental Land Use Control*, *in* COMPARATIVE LAND USE LAW AND GLOBAL SUSTAINABLE DEVELOPMENT (Cambridge Univ. Press 2006), *available at* http://www.law.pace.edu/files/landuse/Land_Use_System.pdf.

106. *See, e.g.*, *Environmental & Resource Economics: Agricultural Land Preservation in the United States: Fundamental Approaches and Resources*, U.S. DEPT. OF AGRICULTURE: NAT'L INST. OF FOOD AND AGRICULTURE, http://www.csrees.usda.gov/nea/nre/in_focus/ere_if_preserve.html (last updated Mar. 18, 2009); JOHN B. WRIGHT & RHONDA SKAGGS, PURCHASE OF DEVELOPMENT RIGHTS AND CONSERVATION EASEMENTS: FREQUENTLY ASKED QUESTIONS, http://aces.nmsu.edu/pubs/research/economics/TR34.pdf.

107. *See, e.g.*, TODD LITMAN, SMART GROWTH REFORMS: CHANGING PLANNING, REGULATORY AND FISCAL PRACTICES TO SUPPORT MORE EFFICIENT LAND USE (2012), http://www.vtpi.org/smart_growth_reforms.pdf; TODD LITMAN, WIN-WIN TRANSPORTATION SOLUTIONS: MOBILITY MANAGEMENT STRATEGIES THAT PROVIDE ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS (2011) [hereinafter WIN-WIN TRANSPORTATION SOLUTIONS],

C. Optimize Urban Circulation

A variation of that second question—how should a city function—applies with equal force, and even urgency, to existing communities. In the United States, the "median lifetime of commercial buildings is 70–75 years,"[108] and the average bridge was constructed in 1963.[109] Parks[110] and homes[111] are politically difficult to remove. Cities do shrink,[112] and corridors do disappear,[113] but urban infrastructure is generally a long-term investment.[114] How, then, should communities anticipate the arrival of autonomous vehicles on their streets?

Although this Article uses freeways to illustrate much of its analysis, motor vehicle trips almost always begin and end elsewhere. Urban streetscapes are complex environments that serve many types of pedestrians, bicyclists, motorists, and others users, whether mobile or stationary. Lanes may be narrow, and vehicle flows are interrupted by pedestrian crossings,[115] stop signs, and traffic signals. Because each movement at a traffic signal receives only a portion of the total "green time" each cycle, the capacity of a single lane is at most 1500 vehicles per hour and often much less.[116] Queued vehicles can also occupy large portions of a physical roadway

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http://www.vtpi.org/winwin.pdf.

108. *Buildings Energy Data Book: 3.2: Commercial Sector Characteristics*, U.S. DEP'T OF ENERGY (note 1), http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.2.7 (last visited June 3, 2012).

109. FED. HIGHWAY ADMIN., FEDERAL BRIDGE PROGRAM 11-8, *available at* http://www.fhwa.dot.gov/policy/2002cpr/pdf/ch11.pdf.

110. Citizens to Preserve Overton Park v. Volpe, 401 U.S. 402 (1971).

111. Kelo v. City of New London, 545 U.S. 469 (2005).

112. Justin B. Hollander et. al, *Planning Shrinking Cities*, *in* PROGRESS IN PLANNING, *available at* http://policy.rutgers.edu/faculty/popper/ShrinkingCities.pdf; *The Incredible Shrinking City*, N.Y. TIMES (Mar. 28, 2011), http://www.nytimes.com/roomfordebate/2011/03/28/the-incredible-shrinking-city.

113. *Why Save the Rails*, N.C. RAIL-TRAILS, http://ncrailtrails.org/web/whysavev (last visited June 3, 2012).

114. Sam Roberts, *200th Birthday for the Map that Made New York*, N.Y. TIMES, Mar. 21, 2011, at A18, *available at* http://www.nytimes.com/2011/03/21/nyregion/21grid.html; *Then/Now, a Series by David W. Dunlap*, N.Y. TIMES, http://topics.nytimes.com/topics/news/newyorkandregion/series/then-now/index.html (last visited June 3, 2012).

115. At least according to the law. *E.g.*, CAL. VEH. CODE § 21950 (West 2011). In practice, pedestrian flows are often interrupted by vehicle crossings, although autonomous vehicles could change this dynamic dramatically.

116. *See supra* text accompanying note 16.

during peak periods.[117]

Such is the environment that autonomous vehicles may encounter upon leaving a freeway. Cities, if so empowered,[118] might use tolling or parking fees to manage any increased demand generated by these vehicles.[119] But autonomous driving may also create new circulation patterns within the city that require innovative design or policy measures. On one hand, vehicle volumes in some neighborhoods could conceivably decrease if drivers no longer need to scout for parking.[120] On the other hand, autonomous vehicles, particularly those that are privately owned, will need to drop off and pick up their passengers and, in the meantime, queue, park, or circulate—the autonomous equivalent of idling.[121]

IV. PRELIMINARY RECOMMENDATIONS

The previous part sketched three broad approaches to managing autonomous transportation demand. This part offers preliminary recommendations to support these approaches in the near term.

First, researchers should seek to better understand the potential impacts of autonomous driving. With respect to demand, capacity, and time-cost, autonomous driving may require revisions to reference books like the Highway Capacity Manual[122] and Trip Generation;[123] to regional models for forecasting land use, travel demand, and emissions;[124] and to project documents like environmental impact statements,[125] traffic impact assessments, concession

117. For a discussion of queuing, see HCM2010, *supra* note 11, at 4-15–4-17

118. *E.g.*, Nicholas Confessore, *$8 Dollar Traffic Fee for Manhattan Gets Nowhere*, N.Y. TIMES (Apr. 8, 2008), http://www.nytimes.com/2008/04/08/nyregion/08congest.html.

119. *See supra* text accompanying note 92.

120. Donald Shoup, *Cruising for Parking*, ACCESS, Spring 2007, at 16, *available at* http://shoup.bol.ucla.edu/CruisingForParkingAccess.pdf.

121. *What Other Communities Are Doing*, NAT'L RES. CAN., http://oee.nrcan.gc.ca/idling/index.cfm (last updated Jan. 14, 2010).

122. HCM2010, *supra* note 11.

123. *Trip Generation, 8th Edition: An ITE Informational Report*, INST. OF TRANSP. ENG'RS, http://www.ite.org/emodules/scriptcontent/orders/ProductDetail.cfm?pc=IR-016F (last visited June 3, 2012).

124. *E.g.*, *Transportation Demand Modeling*, S. CAL. ASS'N OF GOV'TS, http://www.scag.ca.gov/modeling/ (last visited June 3, 2012).

125. *NEPA Documentation: Environmental Impact Statement (EIS)*, U.S. DEP'T OF TRANSP. FED. HIGHWAY ADMIN., http://www.environment.fhwa.dot.gov/projdev/docueis.asp (last visited June 3, 2012).

agreements,[126] and economic analyses of proposed agency rules.[127] More broadly, autonomous driving raises questions in disciplines ranging from sociology and psychology to medicine and economics.

Second, policymakers should seek to maximize the share of motor vehicle travel costs that are internal and variable as opposed to external or fixed. Although this strategy might ultimately involve some form of the VMT-based user fee described in Part III.A,[128] in the near term it could include variable tolling, management of on-street parking, and renewed efforts to index state or federal fuel taxes to inflation. Measures that do not directly affect the price of a particular motor vehicle trip might nonetheless reduce the price of an alternative. One author, for example, has identified some twenty "cost-effective, technically feasible market reforms that help solve transportation problems by increasing consumer options and removing market distortions that encourage inefficient travel behavior."[129] However, as with autonomous driving itself, any of these reforms may have unintended consequences.

Third, public and private actors should develop strategies for data protection and collection. Just as autonomous driving will require a huge amount of information, effectively managing the transportation demand that this driving creates will require a careful understanding of the who, what, where, when, why, and how of travel. The use of individual data for modeling, traffic enforcement, or variable tolling, for example, may raise privacy and security concerns that are best addressed proactively.

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126. U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-08-44, HIGHWAY PUBLIC-PRIVATE PARTNERSHIPS: MORE RIGOROUS UP-FRONT ANALYSIS COULD BETTER SECURE POTENTIAL BENEFITS AND PROTECT THE PUBLIC INTEREST (2008), *availability at* http://www.gao.gov/new.items/d0844.pdf.

127. *Guidelines for Preparing Economic Analyses*, U.S. ENVTL. PROT. AGENCY: NAT'L CTR. FOR ENVTL. ECON., http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html (last visited June 3, 2012).

128. Indeed, the autonomous driving bill just introduced in Washington, D.C. would impose a VMT fee on autonomous vehicles. *See* Mary M. Cheh, Autonomous Vehicle Act of 2012, Council of the District of Columbia (Sept. 19, 2012), *available at* Bryant Walker Smith, *Automated Driving: Legislative and Regulatory Action*, http://cyberlaw.stanford.edu/wiki/index.php/Automated_Driving:_Legislative_and_Regulatory_Action.

129. WIN-WIN TRANSPORTATION SOLUTIONS, *supra* note 107.

CONCLUSION

As autonomous and even semiautonomous technologies become more feasible, governments—and especially their planners, engineers, and lawyers—should not be idle. Autonomous driving has the potential for tremendous benefits. In the near or long term, however, some of these benefits, such as a lower time-cost of travel and a higher vehicle capacity on some highways, may actually increase certain costs associated with congestion, emissions, and sprawl. Maximizing the net benefit of autonomous driving will require researching, modeling, planning, and regulating—cooperatively, not autonomously.