DRIVEN TO EXPANSION - SUBURBANIZATION, DECENTRALIZATION, AND AUTOMATED DRIVING

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Abstract
Self-driving cars have the potential to significantly shape the future of urbanization in the developed world. This project explores the effects of automated driving on urbanized areas—a topic of mutual interest to the mobility industry, and to urban designers and planners. Popular tech media variously speculates on the potential concentration and expansion effects of automated driving. As a nascent mobility form, projections about automated driving remain hypothetical and typically reveal more about current polemical debates than the functional realities that self-driving cars may portend. This project attempts to define how automated driving options might alter urbanization patterns as they penetrate the market.

Theoretically, a more dynamic set of mobility options (on-demand, self-driving, etc.), along with the consolidation of parking and fueling infrastructures, could promote denser urban clustering. Alternatively, a less-taxing form of commuting and errand runs may drive demand for typically cheaper housing further from current urban zones. To evaluate these potential changes, the project will be split into two phases. The first phase of the project will assess how the costs and benefits of automated driving technologies might be valued for the personal transportation sector. What are the cost estimates for these technologies? How will those costs decline over time? How might these costs be balanced by the potential time savings of automated travel? What are the potential interactions of automated driving with road capacity and induced travel demand? Collectively, addressing these questions through literature review and through a multi-disciplinary lens will help explore the potential economic value of traveling in self-driving cars, and thus how they might alter urbanization.

The second phase of the project will focus more on the potential for automated driving, based on the derived costs and time gains, to alter the direction of urbanization. Urbanization is defined here as the interrelated set of activities, structures, and infrastructures that alter the landscape from an undeveloped state. This definition will include a broad range of urban areas, from dense districts to remote exurb developments, and the road system that connects them. Automated driving may interact with all these areas in potentially divergent ways. To study these interactions, the project will begin with combining recent research on driver behavior from collaborating partners at the Toyota Research Institute of North America (TRINA) with existing research on urbanization trends to help predict the potential effects of automated driving.
INTRODUCTION

Drivers for change: Why is this needed?

Automation has begun to penetrate the personal transportation industry through new technological capabilities of cars. Though not likely available to the mass market until 2020, self-driving cars have the potential to significantly transform how people travel. Because of this transformative potential, the spatial, infrastructural, and economic effects of automated driving on urbanized areas arise as critical areas of study. Most current media and research interest in the automated mobility sector focuses on dense urban environments, operating under the assumption that these contexts will be the primary application of the new functionalities (for example, see Audi Urban Future Initiative). However, ongoing research by P-REX and the Center for Advanced Urbanism (CAU), in collaboration with the TRINA, documents how the suburban environment is the dominant form of urbanization in the U.S. (over fifty percent of the population, fifty-five percent of commute destinations). Past projects have looked at the economic rationale of location choices by consumers (in relationship to commuting distances, school quality and housing costs), the decentralization and polynodal structure of U.S. metropolitan areas as it relates to population and employment, and the future projections of urbanization by metropolitan planning organizations. Given the robust incentives for the current housing and employment stock in suburban areas, this form of urbanization seems poised to remain dominant.

Thus, understanding the economic and infrastructural ramifications of automated driving technologies and vehicles on suburban areas becomes paramount to projecting how urbanization patterns may evolve.

Given the unlikelihood of major alterations to the current macro level policies guiding urbanization, the research team, in collaboration with the TRINA, have begun to investigate potential ways in which the effects of automated driving on urbanization can be projected. Commuting patterns and urban development profiles are known to be critically linked. Recent studies have suggested that suburban development itself is a kind of “co-location strategy” for the working population to mitigate the costs of congestion. Commuting, along with personal travel trips in cars, accounts for about twenty percent of total U.S. greenhouse gas emissions. Thus, this project focuses on the potential changes to commuting due to automated driving as an important component of how this technological advancement might alter the energy and development profiles of urbanized areas.

General Approach on Methodology

Several critical areas will need to be investigated to formulate a robust viewpoint on the effects of automated driving in Phase 1, beginning with finding economic valuations of travel time. By assessing the value in the current mobility system, the study aims to produce a rudimentary cost-
benefit analysis for potential changes brought about by an automated driving future. What are the saved costs versus the additional costs? In order to populate these, the following resources will be reviewed:

- US DOT guidance on valuation of travel time
- willingness-to-pay studies
- travel time budget literature
- census and industry surveys
- estimates of highway, arterial, and parking-associated drive time
- estimates of additional costs of automated technologies

Phase 1 will attempt to monetize a “first wave” segment of automated driving for commuting. This valuation will then be mapped onto one or more urban areas based on existing commuting data from the American Community Survey (ACS), National Household Transportation Survey (NHTS), or more localized datasets such as the Atlanta Regional Commission Travel Survey (ARCTS) or California Household Travel Survey (CHTS). Areas with longer commutes will likely accrue greater benefits from automated driving than areas with shorter commutes due to the value of travel time. Mapping these valuations will allow comparison of different portions of urban areas based on the differential benefits of automated driving to overall commuting behavior. To formalize this calculation, several aspects will need to be researched, analyzed and documented:

- Estimated costs of automated technologies – Several industry groups have estimated these costs, projected to 2030, with some level of volume discount based on economic scaling.

- Estimated amount of commute that is “Automated Driving Available” – This step is the most research intensive as there are several methods for calculating this quantity. Industry focus on automated driving currently revolves around low-speed, congested driving, and high-speed, highway driving. This study will primarily rely on existing driving data analyzed by project partners at the TRINA to estimate those driving segments.

- Estimated amount of potential congestion reduction – Several United States’ and Canadian studies have investigated the congestion reduction capability of automated driving under different market adoption scenarios. These studies are at early stages and will be considered only as broad guides.

- Assessed potential for automated driving to increase travel due to induced travel – Since travel demand is generally considered elastic relative to highway capacity, there is a need to consider this counter or “rebound” effect of automated driving. Drivers may simply consume the extra efficiencies created by automated driving by driving/riding more. New travelers may expand the traditional driver set by allowing under age and the elderly to travel more freely.

- Monetized time savings – US DOT has published well-documented guidance on the Value of Travel Time Savings (VTTS). This resource, along with the associated academic resources on travel time valuations, will provide economic values for the commute time reductions as well as the time spent under automated driving control. Further
discussion between P-REX and the TRINA will determine whether the entire value is counted, assuming full autonomy, or it is discounted by some percentage for driver attention for partial autonomy.

- Compared costs of automated driving to the savings created – This step evaluates the amount of time/cost savings that will have to be achieved to equal the additional costs of automated driving.

Phase 2 will translate the calculated savings into an initial geography of automated driving benefits. Each unit of time saved by traveling in an automated vehicle translates to reduced costs of traveling. Mapping the savings to commute times across an urban area will reveal the differential benefits that could accrue to some areas over others. If the inner urban suburban/exurban areas are segregated, evaluation of zonal benefits from automated driving could be evaluated.

After selection of commuting data from the available datasets (ARCTS, CHTS), the calculated cost-benefit will be matched to these datasets. Ultimately, several maps of spatial zones will be produced that differentiate portions of urban areas with varying economic advantages from automated driving in the future. The overall “first-wave market” should emerge through this mapping process to identify locations where drivers will have an economic incentive to adopt automated driving.
Background purpose + Intended Audience

As an ongoing collaboration between the Center for Advanced Urbanism and the TRINA, this project attempts to analyze the effects of future mobility technology on urbanization patterns. This collaboration resulted from a combined interest in urbanization patterns and mobility automation among urban planning professionals and transportation research centers such as the TRINA. As a body of work about extant and future urbanization patterns, the potential audience is broad. The intended audience includes, but is not limited to, the following:

- Automobile manufacturers
- Mobility providers (ride share companies, transportation network companies etc.)
- Academics in the allied design/planning and urban economics fields
- Planning professionals, city managers, and politicians focused on infrastructure futures
- Automation engineers and technologists

CURRENT CHALLENGES AND OPPORTUNITIES

Conceptual Urbanism Challenges and Opportunities

Evaluating an early stage technology like automated driving inevitably involves challenges due to existing inexactitudes and unknowns. For self-driving automobiles, the challenges center on exactly how transformative the technology will be as compared to current mobility options. Will the technology penetrate a large segment of the market while maintaining the “drive alone” commuter majority? Will current transportation systems shift to a new state where ride-sharing replaces some portion of public transit options? These scenarios have fundamental ramifications that could alter the manner in which urbanization proceeds through the twenty-first century, much like affordable automobiles did in the twentieth century.

Early research efforts have attempted to include all potential options through scenario assessment. For example, Wadud, MacKenzie and Leiby divided the complex possibilities of automated vehicles into scenarios that range from a strict regulatory environment that disallows full automation on the roads, to a scenario called “dystopian nightmare” where energy use and travel demand rise to the maximum due to increased ease of travel. These scenarios are highly useful for evaluating the range of possible changes, but do not clarify the geography of change the scenarios might bring about.

To move toward a geographic translation of these scenarios, the potential benefits of automated driving will have to be mapped onto the current travel system, at least for an initial evaluation of which areas might benefit more. Therein lies a potential conundrum – assuming that current conditions will remain relatively stable while the new automated
system grows could prove erroneous. If automated driving technology rapidly penetrates the market, dramatic knock-on effects could occur in the form of vastly increased congestion, higher vehicle miles traveled, vast urban reapportionment due to parking changes and/or longer average commutes. Sifting through these various effects and their interactions reveals a complex system very difficult to forecast. This complexity is likely the rationale behind reports such as Wadud et al. offering relatively broad scenario projections.

In addition to the projection variability, extensive variability already exists in the empirical literature around the effects of reducing travel costs. The Elasticity Range graph (Figure 2) compares twenty important studies that measure long-run elasticities of VMT with respect to fuel costs and operation/maintenance costs.\textsuperscript{11} Thus, any projected changes to travel costs have to contend with 1) variation due to the range in reported elasticity values of travel demand with respect to costs, and 2) the unknown level of automation that will ultimately penetrate the market. Low-level automation (generally mapped to Levels 1 and 2 of the National Highway Traffic Safety Administration’s automation definitions) may not significantly alter driving time or perceived time costs since drivers remain in overall control of the vehicle. On the contrary, higher amounts of automation (Level 3 and 4) will have a greater range of effects on travel costs due to networking effects, greater ease of travel, and productive use of time in vehicle. The primary scope of this project will be a combination of NHTSA-defined driving standards Level 3 (conditional autonomy) and Level 4 (full autonomy) as applied to a prototypical suburban pattern of urbanization.

Because of the tremendous potential impacts of higher levels of automation, both on the consumer and mobility system levels, this research will primarily assess urbanization changes in reference to higher automation levels (most driving tasks taken over by the vehicle). However, there are few established research standards for the potential changes brought about by fully automated vehicles. For example, the "handoff problem" between the automated and human driving mode has not been solved, and currently represents a philosophical divide in automation circles.\textsuperscript{12}

If automation development proceeds through a long transitional phase at Level 3, the more drastic changes this study will investigate may be reduced in magnitude. Barriers to partial automated driving market penetration could include a push to jump to full automation by some technology developers, as expressed by Google’s self-driving focus and advocacy groups like the National Association of City Transportation Officials (NACTO). NACTO recently released a call to ban partial automated driving from city streets (and any other non-limited access roadways) due to safety concerns from driver inattentiveness in partial automated driving scenarios.\textsuperscript{13}

Furthermore, long-term effects of travel costs are poorly studied. No standard way of adjusting travel time costs for different levels of automation currently exists. For each of these research areas, the project will have to extrapolate values used in existing transportation planning practice.
Organizational and Institutional Challenges

Currently, major automated driving research reports offer only tentative thoughts on the potential expansion of urban areas through greater ease of travel. They typically list urban expansion as one of the potential negative impacts of automated driving with little contextualization or quantitative support. A WSP-Parsons Brinckerhoff 2016 report goes one step further by suggesting a potential increase in VMT as commuters could move further out due to increased speeds.\textsuperscript{14} VMT increase and possible urban expansion are the main negative outcomes listed in current discourse around automated travel with little formal characterization or quantitative estimation.

The WSP-Parsons Brinckerhoff report also suggests several known policy tools to address the potential urban expansion. These include increasing the costs of travel in private automobiles through various forms of taxing (tolls, congestion pricing, fees, VMT tax, etc.), or placing regulatory limits on land use, parking, or urban growth. This standard set of policy tools has been evaluated extensively but remains unlikely to be implemented and potentially ineffective even if parts of it are implemented.\textsuperscript{15,16,17,18} Thus, projections by this research and others need to consider the actual ramifications of potential further urban expansion rather than dismissing it as an externality that policy will counter.

Other potential difficulties in projecting the effects of automated driving are the limited availability of data and its generalizability. Data for drive traces exists, but rarely offers the type of consistent coverage required for detailed geographical predictions. Thus, predictions will likely
be limited to the census tract level at best and perhaps only to the county level. Further, the data available and travel demand studies may be valid only for certain urban regions and not applicable to others. Efforts will be made to include as much geographical diversity as possible, as well as cross-validate the elasticity estimates across multiple publications.

ADVANCED URBANISM MODELS

Advanced Principles + Theories

Historically, conceptualizations of the city have relied on a simple, mono-centric model to measure how different goods, populations, and jobs move around and are differentially priced. Mono-centrism arose in the mid-twentieth century as a general theory in urban economics to model land use and land pricing trends. As empirical realities began to erode the usefulness of the mono-centric model in describing the suburbanizing, decentralizing metropolitan structure, other theoretical frameworks began to arise. Joel Garreau described edge cities and emerging edge cities that greatly outnumbered downtowns. Dispersion and scattering of economic activities across urban space began to show up as major themes in research profiles of Los Angeles and Atlanta in the 1990s. Robert Lang, in an update to Garreau’s theory, posited that the “edgeless city” is a better descriptor of the emerging metropolitan and even megapolitan scale of urban activities. Lastly, Berger’s Drosscape mapped out a dispersion geography that trades older forms of heavy manufacturing and dense urban economic concentrations near the city center with a dispersed set of light manufacturing, logistics centers, and office/residential conglomerations in peripheral metropolitan spaces.

Collectively, this body of theoretical work formulates a picture of urban evolution that shifts some of the focus from traditional centers to the dispersing outer edges of urban areas. Mobility in that expanding urban area is partially enabled by the combined automobile infrastructure and technology systems. Shifts in that system, such as automation, that decrease the burden of driving through urban areas, are likely to reinforce dispersive economic forces. In the half-century since theorists first posited the mono-centric city models, population in the suburbs has surpassed that of central cities. The drive trace data and urbanization trend data used in this study will focus on the broader, metropolitan level space to ensure a more complete geographical context.

Precedents

As a future-oriented research project, precedents for the urbanization effects of automated driving studies are few. In addition, the focus of the few automation studies available is typically on the technologies being developed and their various potentials for energy use reductions. The primary reference point for projecting automation effects is the
Wadud, MacKenzie, and Leiby study. Another initial look at the potential for automation to reduce costs of driving was commissioned by the Eno Center for Transportation and conducted by Daniel Fagnant and Kara Kockelman. These research papers and various consultant reports on specific aspects of automated driving will be the primary starting points for this project.

**Project Vision + Goals**

As a near future technology, automated driving will likely alter the mobility networks and decisions of entire urban and metropolitan zones. How will these changes be distributed? This project aims to evaluate this question from the standpoint of current economic decision-making as it might adjust to the new technologies. Easier time spent in transit, more flexible trip-making, and potentially productive use of travel time could prove to be important economic enablers. If so, this project will provide a first-order look at how that economic expansion might precipitate into real urban development. Within that overall vision, our goals include:

- Establishing a new planning/design-based research agenda for automated driving
- Providing basic directional predictions about the potential for automated driving to expand urban areas
- Matching design and planning-based models to the econometric and automotive-based capacities to better inform automated driving projections

Implementing the Strategic Vision

The first phases of the project will collect much of the emerging literature around automated driving as a kind of library of references. This collection will document both the range of potential urbanization responses forecasted, and the conflicting futures they may represent. The project can automatically serve as a base starting point for the planning and design fields to participate in the automated driving research area by focusing more on the altered urban and suburban futures. Projecting the various urbanization possibilities will require a working knowledge of the technologies currently under development by Toyota and other mobility companies, along with the likely economic incentives/disincentives that will drive market changes associated with automated driving.

The complex interactions between transportation, housing, employment, and leisure infrastructures in future scenarios for the urban and peri-urban environment call for an extended collaboration between design and planning professionals and mobility providers. This project represents that essential collaboration. Over a longer period of time to refine the new automated mobility projections, the ongoing collaboration with the TRINA, and the relationships built between the CAU and existing city transportation and planning agencies, should help the project move toward future ground-truthing phases in actual urbanized areas.

Various manufacturers and technology companies have published plans to offer automated driving in some form by 2020. In the next four years, consumers and regulators will be deciding how automated driving will fit into the existing urbanized matrix. Without research projects that assess the suite of potential changes that automated driving will bring to that matrix, planners and political leaders will be blindly forging urban futures that may not be well-adapted. This research project is the first step in helping to inform an urban future mobilized by automated vehicles.
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