What Makes a Good Driver? The Impact of Gender, Age, Athletics, Video Games, and Confidence on Novice Drivers

Nancy L. Wayne, Gregory A. Miller

If you're on the road in Los Angeles, chances are you'll see plenty of bad driving. According to the California Office of Traffic Safety, LA ranks third of 14 major California cities in fatal and injury vehicle collisions (and the top two are nearby Anaheim and Santa Ana). Teenagers and young adults are likely behind much of it — their age group statistically produces the most crashes, and it's fair to expect a new driver to struggle more than an experienced one.

But of course, not all new drivers are bad drivers. Some novices behind the wheel quickly surpass their cohort in skill level. Are there demographic or cultural factors that make some people better at learning to drive?

LA's Westside has some of the worst traffic bottlenecks in the United States. Learning and practicing in the area is especially challenging for novice drivers (and their instructors). Through our involvement in the Westwood Driving School near UCLA, we set up a study to test how different beginners performed on the roads.

We collected data on 50 females and 50 males who each had less than five hours of previous experience driving. The study was conducted during the course of regular lessons on the Westside, and all the subjects were taught and evaluated by the same driving instructor.

Prior to the start of the lesson, the students were asked to rate their confidence in driving. The instructor was blind to this rating. Their driving skill was then assessed during a two-hour lesson using the school's 1-4 rating system — "1" being in need of much more practice and instruction and "4" being ready for the California Department of Motor Vehicles (DMV) road test.

At the end of the lesson, the students were informed of the study and asked for their consent to participate. Based on our anecdotal observations of students at Westwood Driving School and building on other studies, we hypothesized that students who participated in sports and/or played video games would be better drivers. To address these two points, we asked two questions:

- Do you currently participate in any sports or organized athletics, or have you previously? If so, which sports?
- Do you currently play video games, or have you previously?

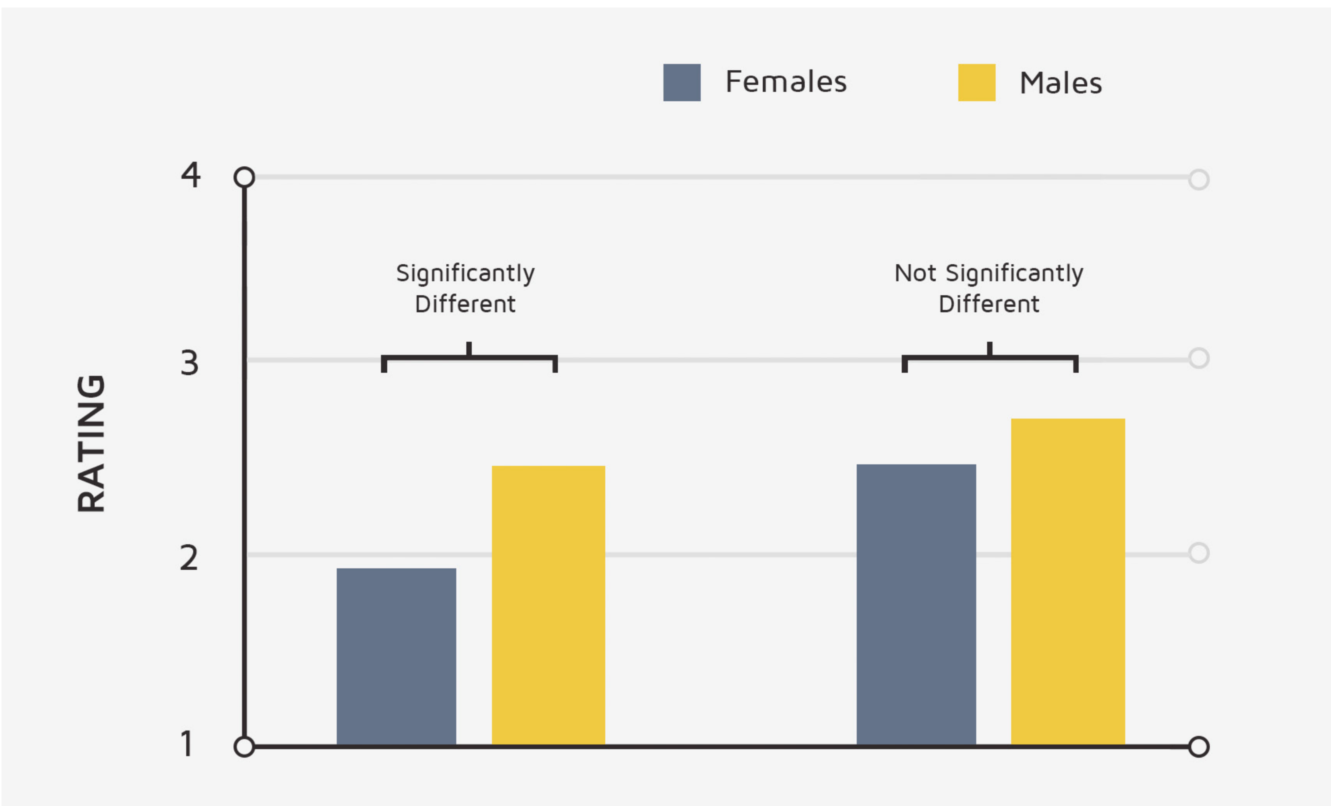
Here's what we found.

Gender and confidence

From the instructor's point of view, there was no difference between the driving skill ratings of males and females (see Figure 1). However, females were initially less confident with their driving skills than males, and their confidence was associated with how well they drove — the more confident, the better the driving skill rating. This was not the case for males: Self-confidence was not correlated with skill level. Further, female drivers' confidence was positively correlated with hours behind the wheel prior to the lesson — the more hours behind the wheel, the more self-confident the female driver.

This gender confidence divide is familiar. Numerous studies have shown that females tend to underestimate their math and chemistry exam test scores relative to males, while males tend to overestimate their test scores relative to females. Our work shows that the "confidence-competence conundrum" for females extends to the realm of driving.

Figure 1. Comparison of self-confidence and driving skill ratings



Age and skill

A surprising outcome of our study was that younger male novice drivers had a higher skill rating than older males new to driving. This counterintuitive trend was also present in female drivers but did not achieve the same level of statistical significance. In Figures 2 and 3, the downward trend lines show that for both males (Figure 2) and females (Figure 3) the older the novice driver, the lower the driving skill rating. However, this was only statistically significant for males (notice the steeper slope of the trend line). There are fewer than 50 visible data points because x-y coordinates of many values were identical and therefore overlapping, and the average age of novice drivers for both genders is 18.

Figure 2. Male age vs. driving skill rating

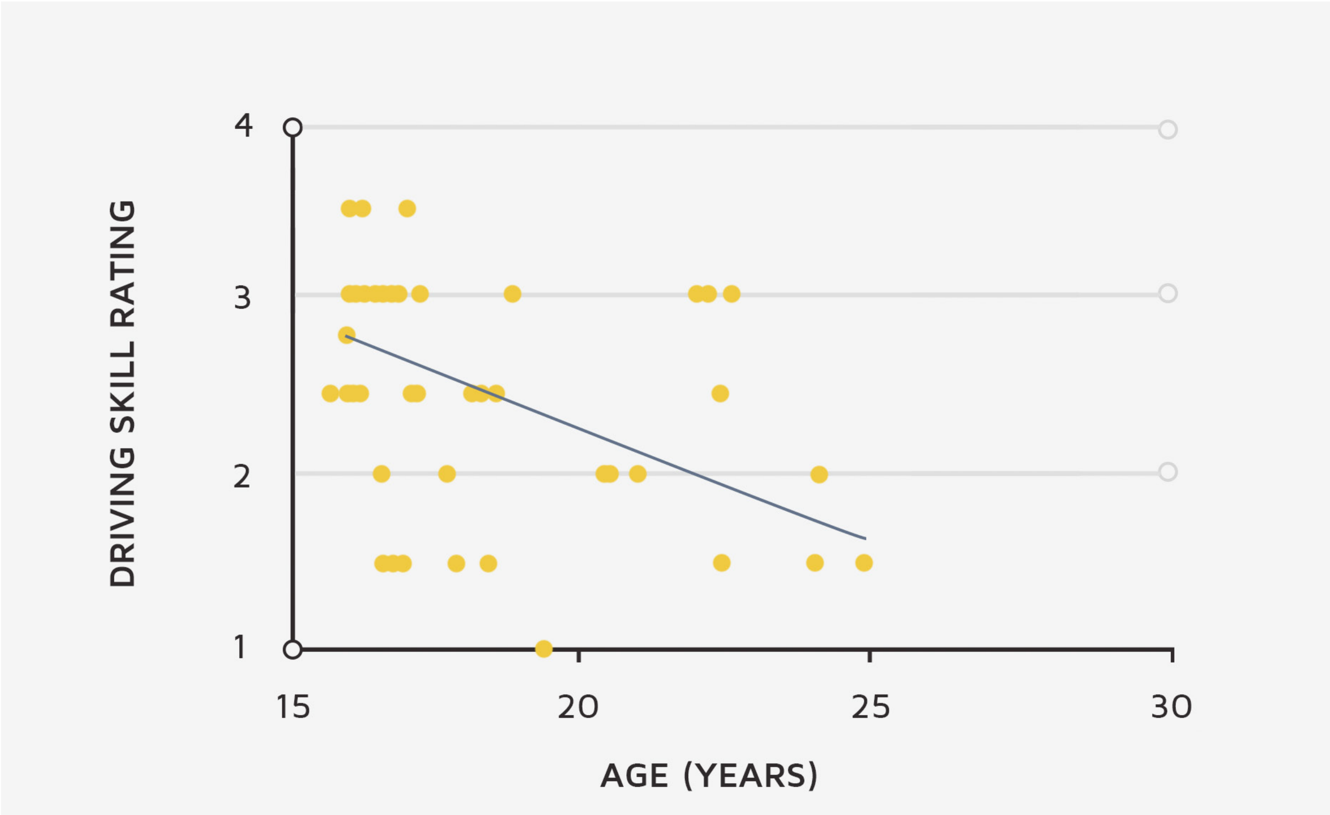
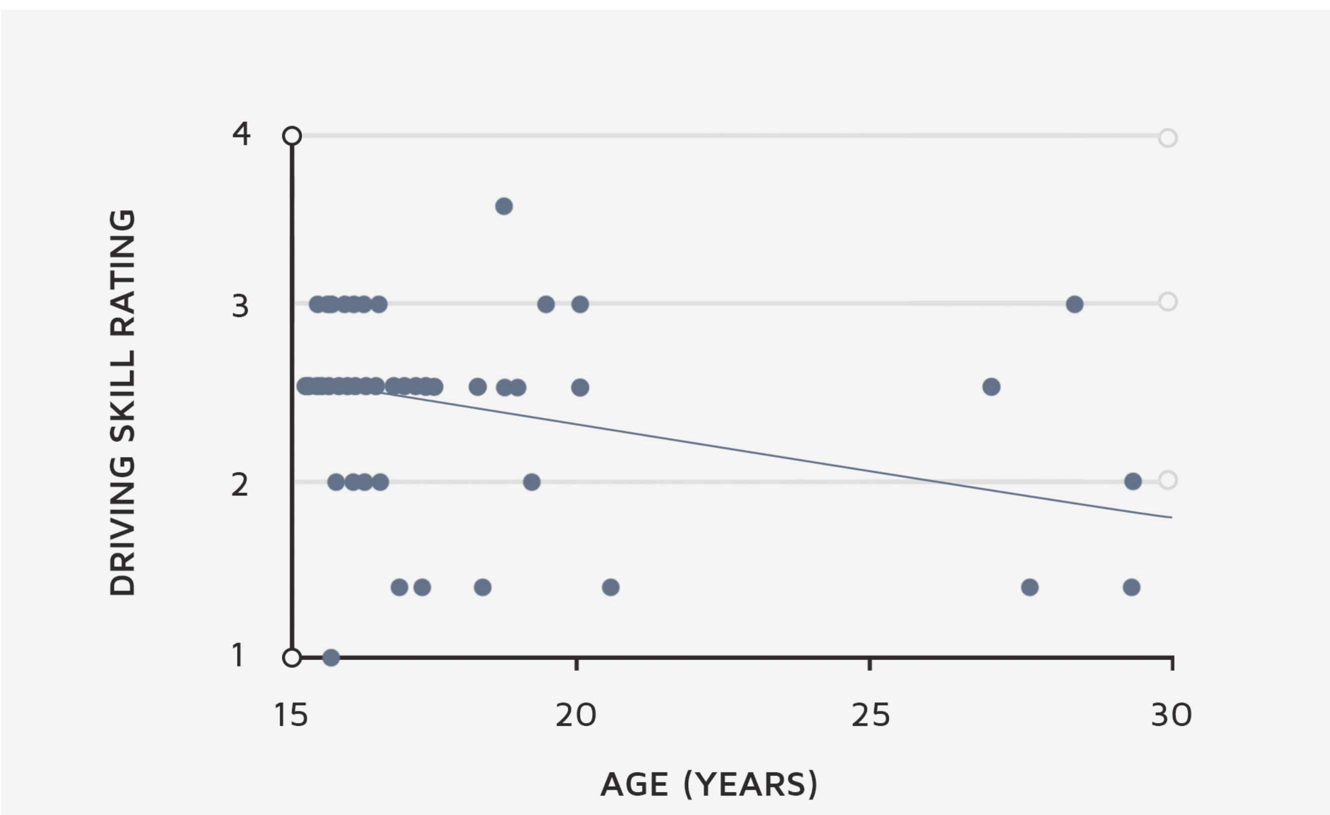


Figure 3. Female age vs. driving skill rating



While our study did not determine why older novice drivers would exhibit a lower skill score, we can speculate that people in their early-to-mid-20s have a greater fear of negative consequences while driving than teenagers, and that this fear could lead to poorer driving skills — at least at the early stages of the learning process. This trend is especially pronounced in males. Research has shown that fear-related brain activity increases during adolescence, and suggests that this continues to increase into adulthood. Further, fearful drivers make more mistakes during on-road assessments compared to control drivers. It is possible that fear is what kept many of the older drivers from learning to drive when they were younger.

We also found that there was no significant correlation between age and self-confidence in males, but there was with females: The older the novice female driver, the less confident she was in her driving ability prior to the first lesson. Therefore, the strong negative correlation between age and driving skill seen in males cannot be explained by a lack of confidence. Once again, it appears that males are more confident no matter their actual abilities.

Video games and driving skill

Earlier work with older adults has found that spatial cognition — one's knowledge and understanding of the spatial environment — is an important element in driving competency. In our study, we were surprised to find that video gaming had no impact on driving skills in either males or females, as other studies have shown that playing action video games improves spatial cognition.

We were not surprised to find that male novice drivers in the current study reported playing video games nearly four times more than females. However, this finding did not translate to any significant difference in driving skill between males and females. This was surprising given the positive relations in the literature between video gaming and spatial cognition, and between spatial cognition and driving ability.

Athletics and driving skill

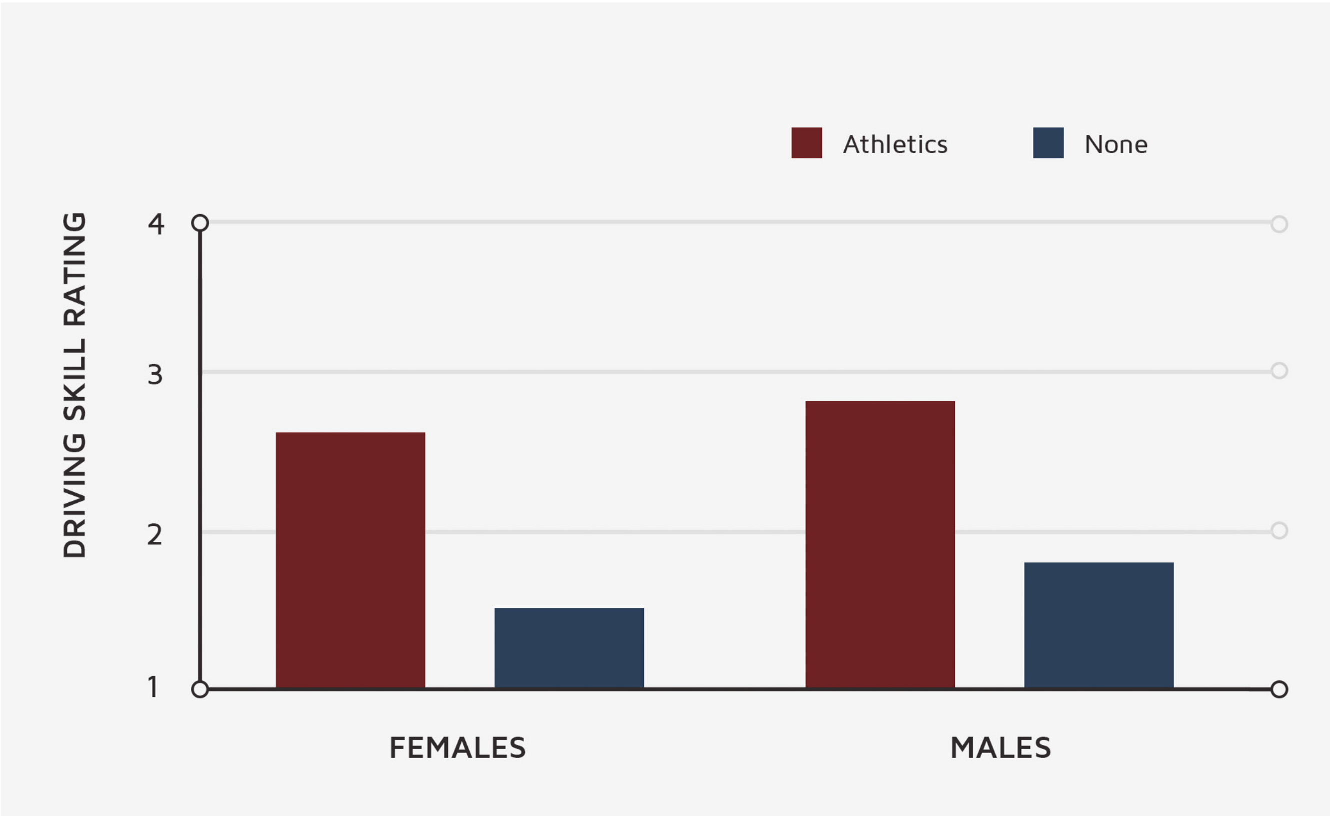
One of our key findings was that practicing organized athletics of any kind (solo or team sports, either past or present) is associated with enhanced driving skills in both females and males (Figure 4). The subjects in our study played a wide variety of organized athletic activities, including team sports such as basketball, football, and soccer, and individual sports such as boxing, skateboarding, and swimming. Many of the driving students practiced more than one sport. The Westside of LA is a sporty place: Only 13 percent of our subjects did not participate in any athletic activity.

Previous research focused on "elite" team sports players (i.e. Division I athletes) found that, compared to controls (non-elite players), elite team sports players performed slightly better across certain driving skills. It's quite possible that the control players were still athletic but just not elite, leading to less-than robust findings compared with our study featuring true non-athletes. Our study indicates that it is not necessary to play sports at an elite level to gain the benefits of sports including better driving — any organized athletic activity will do.

What is it about sports that is associated with better driving skills? There are two possibilities. Research suggests that people who play sports have better peripheral vision and spatiotemporal functions — the ability to process both space and time — compared to those who don't, and that these functions can improve driving ability. Spatial cognition has also been shown to play an important role in driving competency in older drivers, and that skill can be learned and/or developed by participating in any kind of athletics.

Perhaps there is a causal relationship between sports and driving, where participating in sports confers skills in spatiotemporal and visual acuity that translate to the road. The other possibility is a non-causal, coincident relationship: that whatever innate skills attract someone to sports also make them better at driving.

Figure 4. Impact of athletic involvement on driving skill rating



Are technically skilled drivers safe drivers?

There are at least two different sets of driving skills that make someone a good driver: technical skills and safety skills. Technical skills include steering, reflexes, smooth braking and acceleration, ability to judge distances, and other measures of the driver's ability. Safety skills measure situational and contextual awareness, including driver awareness of their surroundings, considerate use of turn indicators, obeying the speed limit, and not being distracted by cellphones and the radio. Safe driving skills require a commitment to safety over ability, and playing-it-safe is not something that teenage and young adult males are known for. Just because someone is a technically skilled driver does not necessarily mean they will be a safe driver.

The U.S. Department of Transportation reports that drivers aged 16 to 20 are involved in the greatest rate of fatal, injuring, and property-damaging crashes of any age group. Additionally, there are clear differences by gender in crash rates, with males crashing more than females at every age from 16 to over 74. This gap is especially pronounced at the youngest level.

We used the Westwood School's driver evaluation system, which encompasses both technical and safety skills. While our study examined some of the factors that impact the overall abilities of novice drivers, crash statistics suggest that technical skill does not necessarily translate into safe driving practices on the road. A different study would be required to see how the factors we selected affect driver safety over time.

Implications for policy

Our study was performed with a small group in a small area of one city, and we don't know the extent to which its outcomes can be generalized. Nevertheless, the data provide important considerations for other geographical areas and for future policy and practice recommendations.

These findings bring us to two primary recommendations. The first concerns the car insurance industry. Currently, insurance companies ask about school grades when determining the cost of car insurance, with good grades typically lowering the insurance cost for a young driver. Based on our findings that involvement in sports is a leading indicator of good driving skills, perhaps insurance companies should consider offering a similar discount for drivers who participate in organized athletics.

Second, the lower driving skills seen from older novices suggest new ways to structure driver education requirements. In California and other states, anyone under the age of 18 is required to take formal driver's education classes and a minimum of six hours of on-road driving instruction from a certified program such as ours in Westwood. Most areas of the country have eliminated free driver training in high schools, so students younger than 18 must take expensive private lessons. In California, they must also wait six months after receiving a learner's permit before they are permitted to take the DMV Driver's Road Test, making the licensing process for younger drivers significantly more expensive and time-consuming than it is for people 18 and older.

Does this age-mandated driver training really reduce crashes if it isn't required of older novice drivers? Our study showed a negative correlation between age and driving skills of novices, especially males. Perhaps California and other states with graduated driver's license programs could consider ending age-based mandatory driver's education, and focus more on safety training for all novice drivers of any age.

Although our study does not definitively show that athletics or youth make novice drivers better at driving, these factors can aid in identifying and supporting safe driving practices early on in the licensing process. The more we know about the factors that improve how people drive, the more steps we can take to make the roads safer for everyone. Considering that traffic collisions are the leading cause of death for children between the ages of 2 and 14 in Los Angeles, this really is a matter of life and death.

This article is adapted from "Impact of Gender, Organized Athletics, and Video Gaming on Driving Skills in Novice Drivers," PLOS ONE, 13(1), 2018.

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Does Light Rail Reduce Traffic? The Case of the LA Expo Line

Genevieve Giuliano, Sandip Chakrabarti

Light rail is an attractive idea, especially in famously congested Los Angeles. Why sit stuck in traffic while the light rail glides by?

Light rail projects are booming around the United States. Reports from the National Transit Database show that between 1991 and 2012, light rail transit capacity increased from 27 million to 99 million service miles nationally. Light rail service, in fact, has grown at a higher rate than bus, subway, and other public transit modes. Los Angeles is part of this trend. LA Metro has the most ambitious urban rail transit development program in the US: Projects worth approximately $8 billion are currently under construction. The first segment of the Los Angeles Expo Line, between Culver City and Downtown LA, opened in 2012 as part of this widespread recent investment.

One of the common justifications for investing in light rail is its potential to reduce roadway traffic congestion. Yet, little evidence exists to support this claim. There are many studies of the impacts of light rail, but few have examined its impacts specifically on traffic congestion.

We took advantage of a unique data set to analyze how the Expo Line affected transit ridership and road traffic in the corridor — and found that the project has had a positive impact on the former, but not much effect on the latter. Our results indicate that the real benefits of rail transit investments are not in traffic reduction, but rather in increasing the accessibility and popularity of transit within high-demand corridors.

We identified three conditions that must be satisfied for a light rail system to decrease corridor-level traffic congestion:

- A net increase in transit service and accessibility, relative to previous transit services within the service corridor, in order to attract new passengers rather than those who already used transit. The increase must be large enough to be perceived by individual travelers.

- Potential demand for transit travel within the corridor must be enough to generate more passengers. Specifically, enough existing travelers must be willing to shift to transit and new travelers must be willing to choose transit over other modes if quality transit service such as light rail is introduced within the corridor.

- The new transit system should not interfere with or slow down roadway traffic within the corridor.

If these conditions are met, light rail systems can attract new riders by promoting car-to-transit shifts, and thereby reduce congestion, improve mobility and reliability of travel, and increase person throughput across their service corridors.

“A natural experiment”

The first operating phase of the Expo Line connected Downtown Los Angeles with Culver City (Figure 1), running east-west for nearly nine miles through a dense and congested part of the city. The line is roughly parallel to the I-10 freeway, and both the corridor and several parallel arterials have extensive bus transit service: Metro’s local and rapid buses, Culver CityBus, and Santa Monica’s Big Blue Bus routes. As the corridor suffers from heavy peak-period traffic, Metro marketed the Expo Line as a means to increase transit mode share along I-10 between downtown and the Westside, noting that it would provide Angelenos “real options for parking their cars, hopping on the bus or train and beating high gas prices.”

Figure 1. Expo Line Phase 1 alignment

We wanted to answer two questions about the Expo Line: Did it significantly increase transit ridership within the I-10 corridor? And did it reduce traffic congestion and improve travel time reliability along the I-10 freeway and nearby parallel arterials during weekday peaks?

The Expo Line addition resulted in a small increase in transit service supply within its corridor — about 4 percent more vehicle hours of service. A subsequent net increase in transit ridership along this service increase is a necessary but not sufficient condition for any measurable impact on traffic. Even if transit ridership increased, we needed to determine whether the increase was enough to affect traffic performance, which depends on the magnitude of transit service increase and where the new passengers come from. If new passengers are mainly previous car users, this could signal more of a potential traffic benefit than if they were previously using other transit routes or modes, biking, walking, or not traveling at all.

So what happened after the line opened? Expo saw around 20,000 average daily boardings in the three-month period immediately after the opening of the line. Comparatively, the annual average daily traffic on the I-10 freeway within the corridor is about 300,000 vehicles.

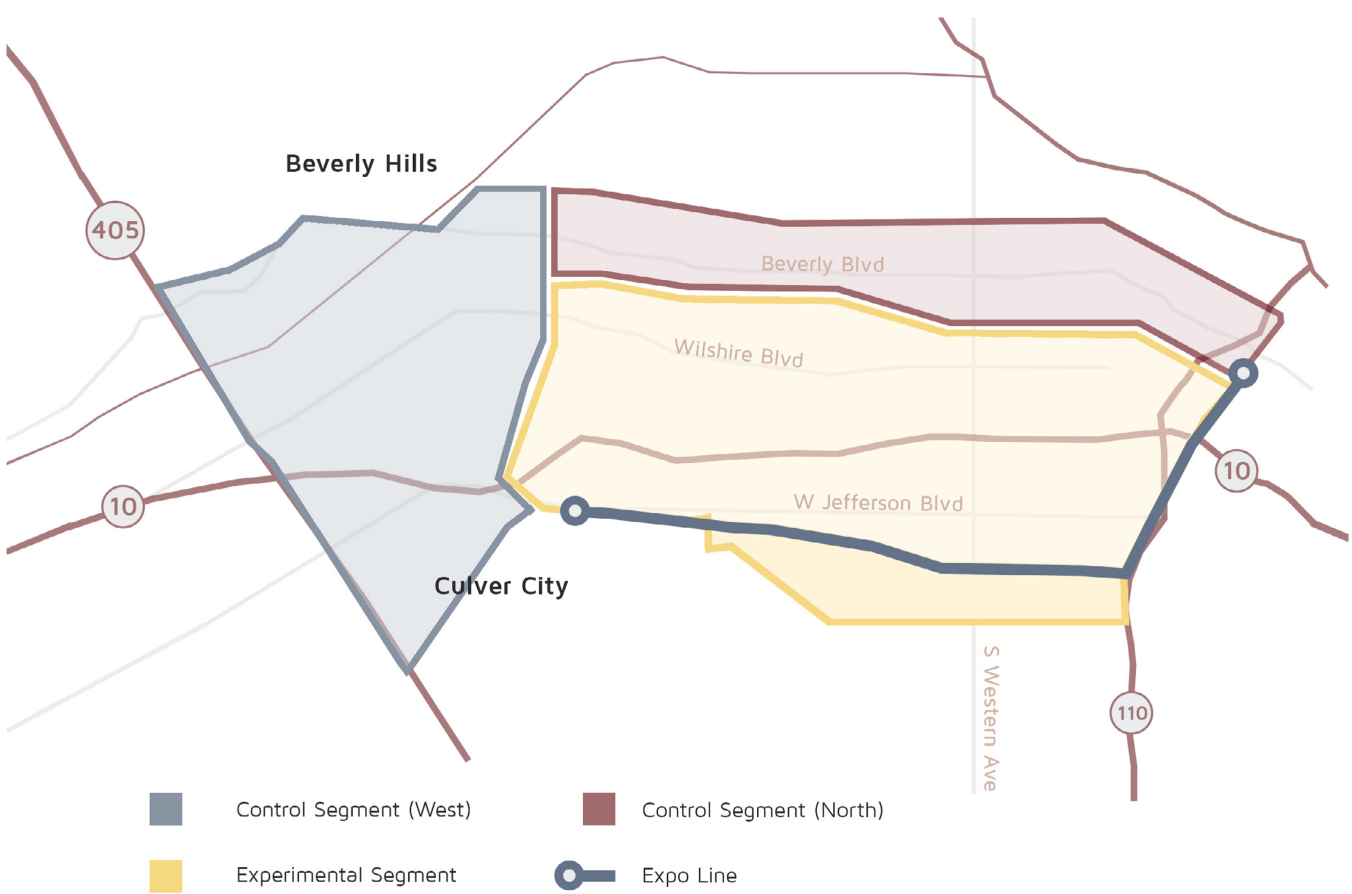
Given such a difference in scale, we did not expect dramatic shifts in traffic as a result of the Expo Line. We knew that measuring small changes in traffic performance and attempting to attribute those changes to the Expo Line would be challenging. All the other changes taking place in the corridor, such as traffic signal timing or fluctuations in fuel price, would affect the measurements, too.

Challenges aside, the Expo Line opening was a "natural experiment," giving us the opportunity to evaluate corridor changes. In order to isolate the new line's effects, we used a research design that compared transit use and traffic system performance in the corridor before and after the line's opening, relative to changes in a control corridor. For our control, we identified two similar locations not affected by the opening and performed the same before/after comparison (Figure 2). Our data covered two three-month periods, one before the opening (November 2011 to January 2012) and one after (November 2012 to January 2013). Expo Line service began in June 2012.

We selected control corridors that were comparable to the experimental corridor in terms of baseline conditions as well as in changes to transit demand and traffic system performance. We used three different measures of traffic system performance:

- Average speed, which indicates level of congestion
- Standard deviation of speed, an indicator of day to day variation
- Average buffer time, which, according to the Federal Highway Administration, "represents the extra time (or time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival."

Figure 2. The experimental and control corridors



How we asembled our Big Data

In 2010, our research team at the USC METRANS Transportation Center partnered with LA Metro to develop the Archived Data Management System (ADMS), a massive volume of geocoded and time-stamped streaming data from a variety of highway and transit sources. The system allows researchers to conduct detailed studies that were previously either impossible or extremely costly to perform. Examples include the impacts of new transportation investments such as subway line construction, policy shifts such as fare increases, and exogenous shocks such as gas price changes.

ADMS served as the principal data source for this study. Across the traffic corridors, 74 freeway and 1,066 arterial sensors provided traffic performance data on speed, volume, and occupancy roughly every 30 seconds. These were aggregated into 15-minute averages to smooth out the random fluctuations in traffic patterns while still capturing short-term changes in performance.

The final set included more than 816,000 freeway data points and more than 15 million arterial data points, across both the before and after periods. The transit data from LA Metro included configurations of bus and rail routes, the locations and boarding/alighting counts of stops and stations, and planned service schedules. We additionally accounted for transit network and schedule changes that are typically implemented in June and December.

Our ADMS data led us to two important findings: The Expo Line had a positive response on transit ridership, but a small and localized effect on roadway traffic. It appears that the benefits of light rail investments are in increasing transit accessibility and person throughput within high-demand corridors, not in reducing congestion.

Transit ridership impacts

Our results suggest that the Expo Line positively affected local transit ridership along its corridor. Average total weekday boardings across all bus stops and rail stations increased by 6 percent in the experimental corridor and decreased by 4 percent in the control corridors. The increase in transit supply, measured in terms of revenue vehicle hours, was greater in the experimental corridor (4 percent) than the controls (0.1 percent). Thus the ridership gain may be partially attributed to the overall increase in transit service.

We also found that weekday ridership, measured as boarding counts at each stop or station, increased by 7 percent on east-west transit lines within the Expo Line corridor. Boardings on east-west lines in the control corridors decreased by 2 percent.

We estimated that the number of people riding transit in both directions during weekday peak periods increased by 14 percent in the experimental corridor and decreased by 3 and 8 percent, respectively, in the control corridors. Finally, we found that bus boardings increased significantly near Expo Line stations with feeder bus connections — a combined effect of new transit trips and redistribution of existing transit trips induced, at least in part, by the Expo Line.

Traffic effects

A net reduction in traffic levels seemed plausible given the Expo Line's effect on transit ridership, as auto-to-transit shifts could have contributed to the observed increase in transit trips. We analyzed impacts of the Expo Line on weekday mornings from 7 to 10 a.m. and evenings from 4 to 7 p.m., monitoring peak-period traffic speed and travel time reliability for the I-10 freeway, Venice Boulevard (which runs roughly parallel to the Expo Line and is an alternate route to I-10), and other major east-west arterials. Again we compared traffic performance in the same before and after periods within the Expo Line and control corridors.

Overall, we found no significant changes in speed variability and no consistent travel time reliability impacts on the freeway. However, on Venice Boulevard, we found large relative improvements in westbound traffic speed and travel time reliability in both peak periods across the experimental segment of the roadway. These improvements, however, were largely due to worse traffic conditions in the control segments. The magnitude of this traffic deterioration is not consistent with regional trends, and we were not able to identify a satisfactory explanation. Therefore we find impacts on Venice traffic to be inconclusive.

A quick comparison of before and after weekday peak-period traffic speeds along all major parallel arterials suggests a localized positive effect of the Expo Line. Relative to an arterial (West 3rd Street) located far north of the Expo Line within a designated control corridor, we found average speeds across nearby arterials such as Martin Luther King, Jefferson, and Washington Boulevards to have significantly improved in both peak periods and in both directions.

A separate set of analyses suggest that the signal priority provided to Expo Line trains could have positively affected travel speeds on the nearby parallel arterials. The reduction in bus service that took place on the parallel arterials could also have had a positive effect, as fewer buses in mixed lanes could increase average traffic speeds for cars.

What we learned

Our research suggests that the Expo Line Phase 1 had a modest and highly localized impact on weekday peak-period roadway traffic system performance within the first 5 to 7 months of opening. The number of daily Expo Line trips was small compared to the total volume of traffic within the service corridor, so even if all Expo Line riders were previous car users, it is unlikely that the reduction in traffic volume would translate into significant improvements in speed and travel time reliability within the highly congested corridor.

In the longer term, any short-term traffic reductions on arterials would likely be offset by latent demand. When traffic improves, drivers who shifted to less preferred modes or time periods, or stopped making the trip altogether in response to congestion, will be attracted back to previous behavior, using up the available capacity and eventually any performance improvements in the corridor.

The potential of light rail to reduce congestion is indeed limited, particularly in high-demand areas such as the core of Los Angeles. But that's not a reason to abandon light rail projects. Rather, policymakers should remember that the fundamental purpose of light rail investments is to promote transit use and increase person throughput across their service corridors. Light rail can effectively contribute to urban mobility and accessibility even if it can't reduce traffic congestion.

This article is adapted from "Using Regional Archived Multimodal Transportation System Data for Policy Analysis: A Case Study of the LA Metro Expo Line." 2016. Journal of Planning Education and Research, 36(2): 195-209. This paper won the Chester Rapkin Award for the Best Paper in the Journal of Planning Education and Research in 2016.

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Worst-Case Scenarios: Flooding and Evacuation Plans in Honolulu

Karl Kim, Pradip Pant, Eric Yamashita

Like other coastal cities, Honolulu's long-term viability depends on how well it can adapt to climate change. By 2100, sea levels are predicted to rise by at least a meter worldwide alongside an increasing number of extreme weather events.

How the one-two punch of sea-level rise and more flooding hazards will affect people and infrastructure cannot be viewed in isolation but must be seen as part of a broader pattern. Sea level rise exacerbates flooding in coastal areas, which can then be compounded by extreme weather such as storm surges, tsunamis, and even fires. Policymakers and planners in Honolulu and elsewhere must understand plausible worst-case scenarios to "prepare for the worst and hope for the best."

To understand what the worst would look like, we quantified flooding risks in Honolulu due to sea level rise and severe weather events and assessed the risks and vulnerabilities of critical infrastructure. This included threats to the city's transportation system, for which we used travel demand software to model evacuation from inundated areas. Our approach provides critical information for emergency responders, transportation systems managers, planners, and developers that inform potential policies to protect the city and its residents.

Assessing hazards

The risks associated with flooding can be estimated by probability or more precisely through modeling historical events. We used both approaches. Over the long term, certain areas are susceptible to flooding even without any particular hazardous event. In April 2018, for instance, the island of Kauai recorded about 50 inches of rain during a 24-hour period, which is currently being certified as a new national 24-hour rainfall record. The flood damaged a large portion of Kauai County and portions of the City and County of Honolulu. Record flooding left several people dead in April and May of 2017 in southern Missouri and northwest Arkansas, where a study of changes in the peak stream flows since 1930 indicated consistent positive increases of up to 10 percent per year.

To locate areas in Honolulu that are susceptible to flooding, we used topographic and tidal data. First, we identified areas vulnerable to one meter of sea level rise and established a base water level in urban Honolulu, designated as the area between Pearl Harbor and Diamond Head (Figure 1).

Three hazard models then simulated flooding in addition to the base water level. One produced storm surge flood depth, flow speed, and inundation areas for a Category 4 storm similar to Hurricane Iniki, which hit Kauai in 1992. Another simulated inundation based on five previous tsunamis that had impacted Hawaii. Another model was used to generate a 500-

year river flooding, capturing inland flooding from heavy rainfall. Areas of flow inundation show the extent of the exposure to the flooding, while flood depth and flow speed illustrate the potential for damage.

Regional transport models, such as the Oahu Metropolitan Planning Organization (OahuMPO) transportation demand model, are typically used as forecasting tools to inform planning decisions. However, transportation demand models are not able to capture the nuances of the evacuation decision-making process. There are no evacuation travel surveys for Honolulu, so we used OahuMPO model estimates of expected demand for transportation infrastructure, the origins and destinations across motorized and non-motorized modes, and historical travel data to estimate how people might try to get away from each disaster.

Figure 1. Study area: urban Honolulu, Oahu

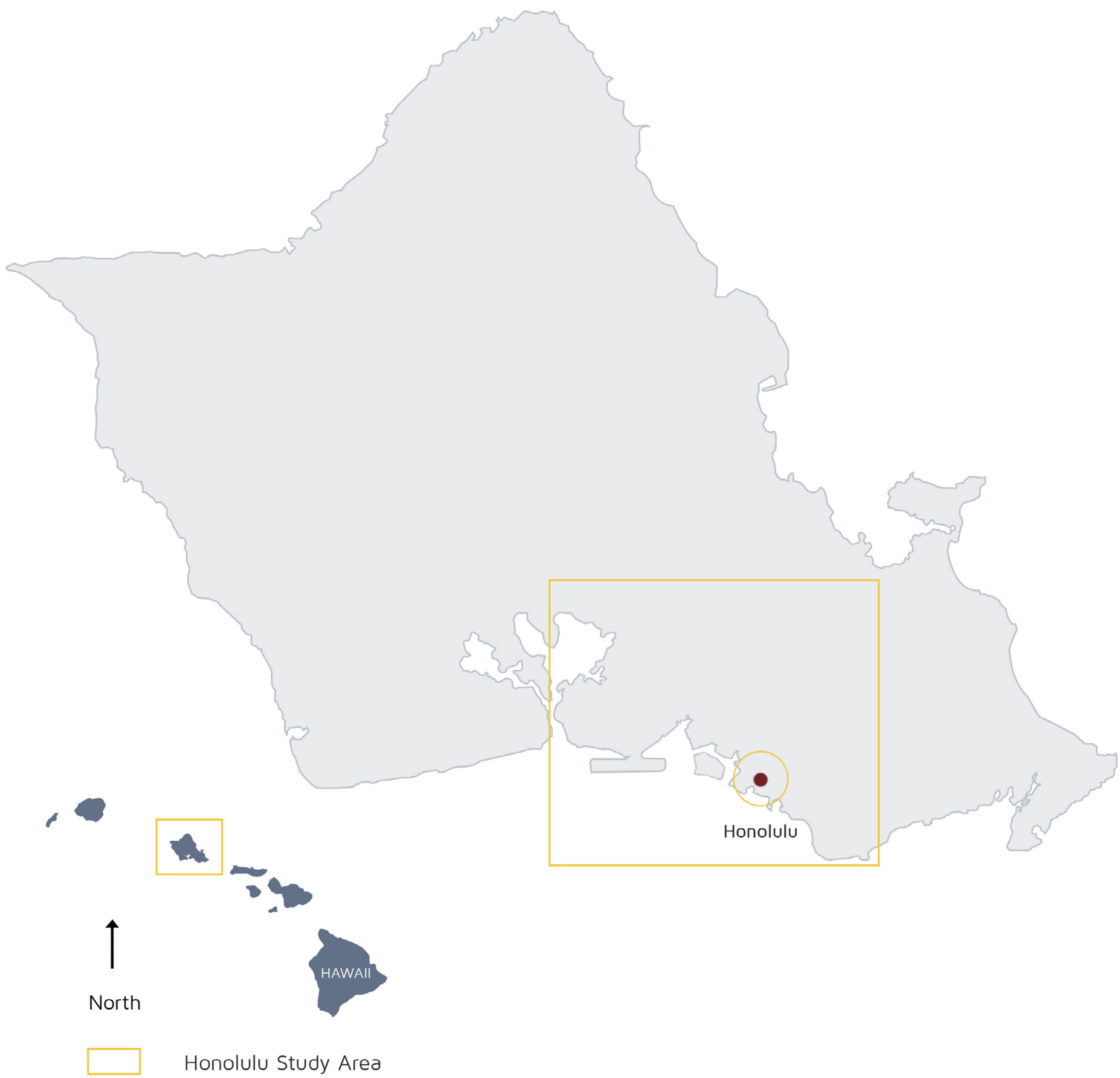


Figure 2. Inundation due to sea level rise, tsunami, and hurricane storm surge, and in-land surface flooding

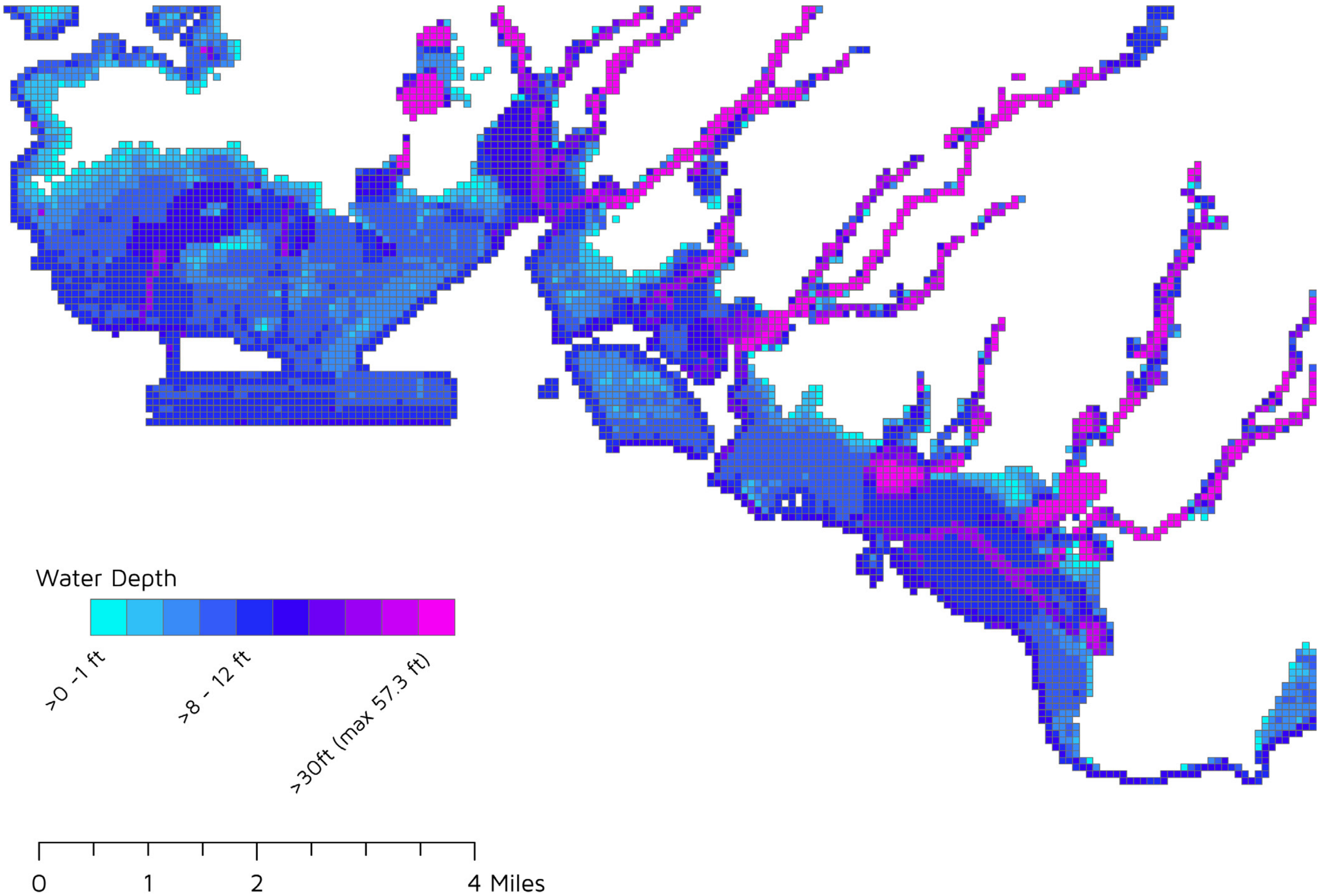
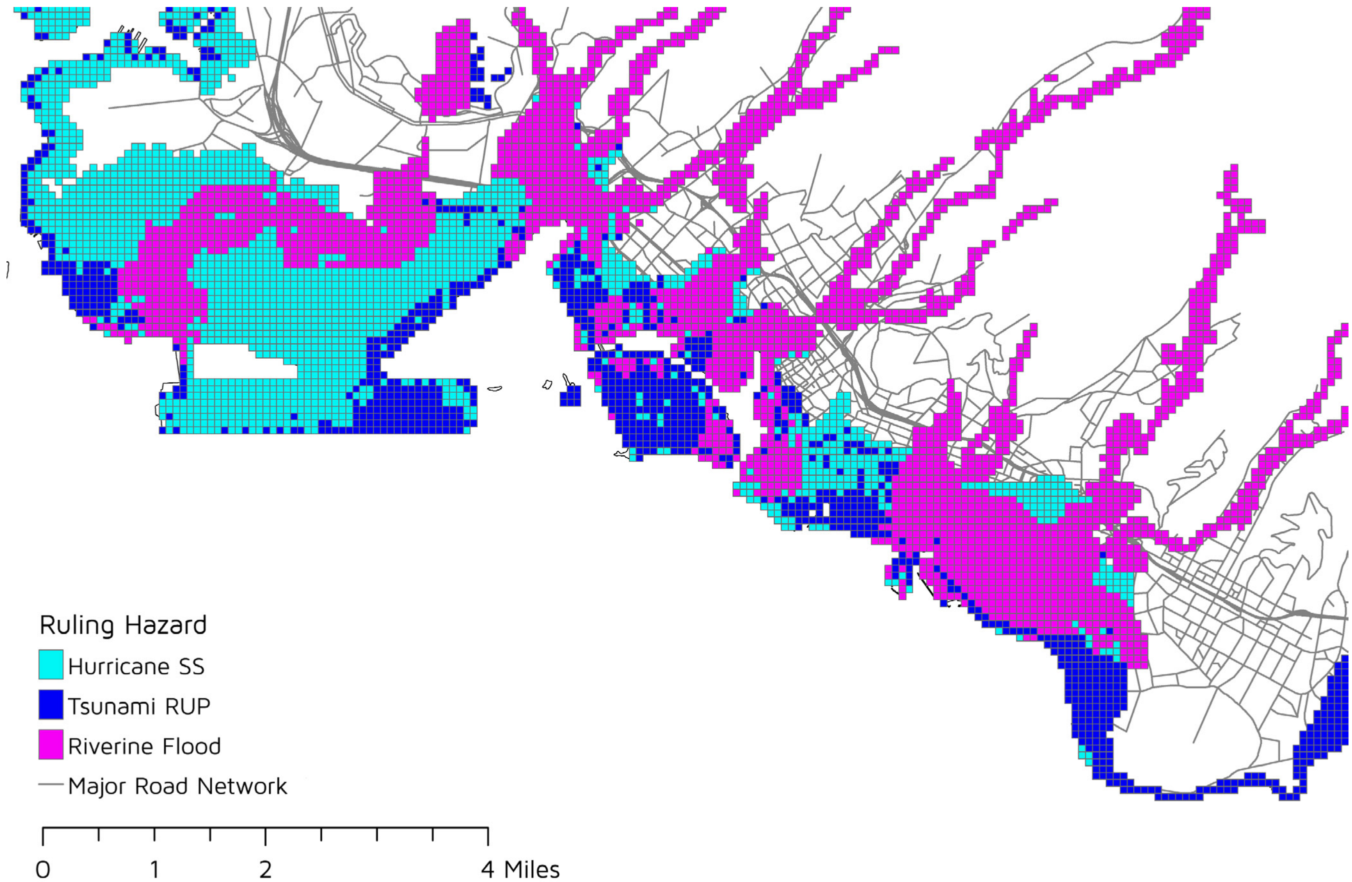


Figure 2 shows the maximum depth of anticipated flooding from sea level rise, tsunami, and hurricane storm surge, or inland river overflow in the study area. For each cell on the map, we identified the highest possible rise among the three inundation hazards — meaning if an area would flood up to three feet in a tsunami but five feet due to river overflow, we assigned it to five feet.

The "ruling hazard," displayed below is what we call the most critical flooding type for each cell. This ruling hazard analysis identified the maximum of maximums — that is, the flood type within the grid for each of the three different hazards (hurricane storm surge, tsunami run-up, riverine flooding) that causes the highest flood level for that location. This analysis indicates the predominant threat type. While deeper flooding generally means a higher risk of damage, different communities, utilities, and governments will have different responses to flooding from a tsunami versus that of a river.

Figure 3. Ruling hazards for each cell



A city exposed

The worst-case flooding scenarios would have a massive negative outcome on the people, economy, infrastructure, and emergency plans of the Honolulu area. 45 percent of the population — more than 150,000 people — would find their homes directly affected. For the 32,000 business establishments in the study area, we found that our scenarios would cost those businesses $34.8 billion, representing 80 percent of Honolulu's economy. Employment data shows that nearly 213,000 jobs, or 76 percent of the area's workforce, are exposed to worst-case flooding.

Many critical infrastructural facilities are also located in the worst flood zones, including all major electric power, oil, port, potable water, and wastewater facilities. Four out of five of the area's hazardous material sites will be affected by worst-case flooding, along with 85 percent of communications facilities. Most of these systems are not built for resiliency during a flood and could fail when needed most.

Most troublingly, Honolulu's emergency response and shelter facilities are at great risk of worst-case flooding. The city recommends that residents who live near the coastline or in older, wooden houses, evacuate to these facilities in the event of a hurricane. Half of all designated emergency operations centers, fire stations, hospitals, clinics, and highway bridges are susceptible. A quarter of police stations and nearly one-third of emergency shelters, mostly public schools, are located in the inundation zones.

Charting routes to safety

The extreme vulnerability of Honolulu's employment centers, industries, and emergency facilities makes safe, reliable travel even more vital in the event of flooding. Unfortunately, our study found that a large portion of area roadways are currently exposed to worst-case scenarios. Using the total lengths of roadways in each cell in our inundation analysis, we found that 69 percent of arterials, 44 percent of highways, 40 percent of local streets, and 38 percent of freeways would be impacted.

While arterials represent the highest percentage of exposure, local streets face the most risk in a worst-case flooding scenario, as they comprise more than 85 percent of all roadways in the study area — potentially rendering most roads in Honolulu impassable. And the worse the flooding gets, the more dangerous local streets become. Only a few miles of other road types would be exposed to flooding after water levels exceed eight feet, compared to the additional 32 miles of flooded local streets.

Overlaying Oahu's travel demand model onto the flooding hazard grid reveals the extent to which flooding would shut down travel around Honolulu. Around three-quarters of all transit trips (assuming typical operations are still in effect, as largely happened in Houston during Hurricane Harvey in 2017) and more than 60 percent of trips by car would be affected, disproportionately affecting low-income households who use transit the most and have the lowest levels of car ownership. Clearly, normal travel would be significantly disrupted. But the important question for policymakers to consider is how everyone would be evacuated.

To provide a picture of what evacuation routes might look like, we calculated the distance and time by car from the center of the flooded grid to the nearest designated un-flooded evacuation center — that is, the shelters not in the inundation zone.

Assuming evacuees would opt for the closest available shelter, in a minor flooding scenario we found that around 15,000 people will have to travel a total of 7,000 miles taking nearly six minutes per person. For the worst-case floods, more than 150,000 people will travel a total of nearly 120,000 miles at 20 minutes per person, more than three times that of minor flooding.

Table 1. Exposure of road miles by water depth

Depth (feet)	Freeway	Highway	Arterial	Local Streets
0-1	6%	5%	6%	7%
1-3	10%	12%	24%	14%
3-8	16%	21%	34%	13%
8-16	4%	5%	4%	5%
16-24	1%	1%	0%	1%
24-30	1%	0%	0%	0%
30+	0%	0%	0%	0%
Flooded %	38%	44%	69%	40%

Conclusions

The analysis provides key lessons for disaster mitigation planning and evacuation planning in Honolulu and beyond. First, there is a great need to reduce the flooding exposure of the population, economy, and infrastructure by locating development away from hazardous areas. The evacuation analysis showed that time and distances needed to evacuate would be significant during a severe flooding scenario. A near-source tsunami could reach coastal communities within 25 to 30 minutes of an earthquake, so swift evacuations are key. Moreover, evacuation shelters should be assessed for their ability to withstand secondary impacts from disasters (i.e. high winds and earthquakes) and to accommodate the anticipated demand.

Currently, Honolulu has defined tsunami evacuation zones along its coast. Although coastal areas are most susceptible to flooding hazards, this study shows that the evacuation of inland communities adjacent to the drainage channels can also be a challenge during severe flooding. The April 2018 flood in Kauai resulted in the helicopter evacuation of 475 people, some stranded at inland evacuation centers due to high flood waters. Hawaiians would benefit greatly if policymakers get better at identifying safe shelters for evacuation and disseminating pre-disaster information more widely.

Shelter identifications for each of the flooded communities using the location-allocation approach, and accounting for shelter capacity and logistical constraints advocated in the study, could be instrumental in saving lives during a disaster. The process also generates individualized evacuation routes to allow residents to evacuate quickly and efficiently. Short-notice evacuation is an important consideration for a city vulnerable to a near-shore tsunami event, like Honolulu. The study found 17 shelters will be in the flooded zones at the most severe flooding scenario, demonstrating the need to review existing shelter locations. Since Honolulu is prone to flooding from a multitude of hazards, staging areas, refueling locations, transfer stations, and other procedures for ensuring the safe and efficient evacuation of people from flooded homes and businesses are all essential. This may require investment in flood-proof or "safe to flood" infrastructure.

Our study also highlights the vulnerability and the susceptibility to flooding damage of the Honolulu transportation system. Transportation and emergency management decision-makers should identify critical road networks and reduce their vulnerability to natural hazards. In preparing for a disaster, transportation policies should not only focus on making evacuations quicker and safer, but work towards building a resilient transportation system that can withstand the worst possible threats of climate change and sea level rise.

This article is adapted from "Evacuation Planning for Plausible Worst Case Inundation Scenarios in Honolulu, Hawaii." 2015. Journal of Emergency Management, 13(2): 93-108.

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Converting Garages for Cars into Housing for People

Anne E. Brown, Vinit Mukhija, Donald Shoup

The United States has a large supply of residential garages that could be converted into affordable apartments. Unfortunately, off-street parking requirements prohibit converting most of these garages for cars into housing for people.

Converted garages in single-family neighborhoods are variously called second units, accessory dwelling units, garage apartments, granny flats, and backyard cottages. To convert a garage into an apartment, off-street parking requirements typically force a homeowner to replace the two garage parking spaces with two new parking spaces, plus an additional off-street parking space for the new apartment. These parking requirements make it almost impossible — financially and physically — for most homeowners to legally convert garages into housing.

To make conversions easier, some cities have removed parking requirements for second units. Although garage apartment residents are less likely than others to own cars, many do, and some of their cars are parked on the street. Thus, converting a two-car garage into an apartment can add three cars on the street, justifying the neighbors' fears that the conversions will congest on-street parking.

Residential parking permit districts can resolve the on-street dilemma. We propose that cities remove off-street parking requirements for single-family homes with second units, and limit the number of on-street parking permits at that address to the number of cars that can park in front of the property. Managing on-street parking in this way can reduce fears that converting garages into housing will flood the street with parked cars.

Not in my neighbor's backyard

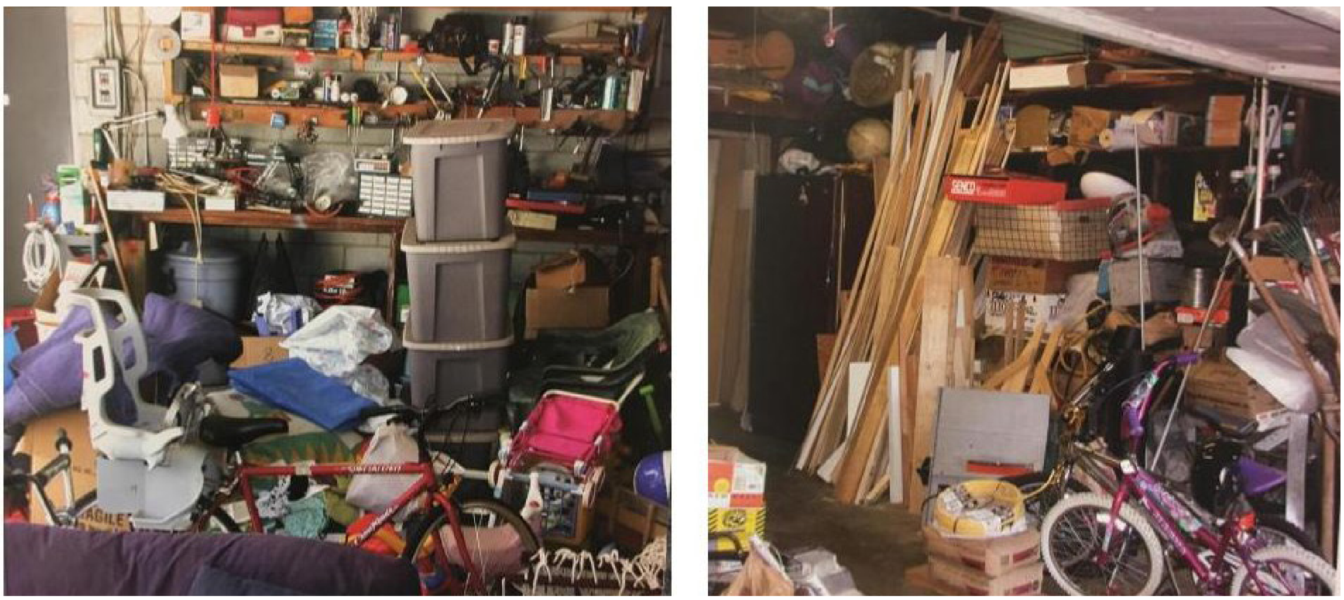
Despite the need for affordable housing in cities across the country, many homeowners oppose garage conversions in their own neighborhood. Explaining why she opposed garage apartments, one planning commissioner in a Southern California city said that she bought her house in a neighborhood "where I wouldn't have to worry if I was going to be able to park in front of my own house." Garage conversions face severe political opposition if local officials fear that the new residents will create parking problems.

This fear is exaggerated. A study of single-family homes in Los Angeles found that 75 percent of garages were used to store old furniture or other household goods, not cars.

Figure 1 below shows two of these garages where cars are out and just about everything else is in. In addition, many older garages are too small to accommodate larger modern cars such as pickup trucks or sport utility vehicles. Garage conversions are unlikely to displace many cars from garages because many cars are already in driveways or on the streets. Nevertheless, many residents fear garage conversions will lead to overcrowded on-street parking. How can cities remove off-street parking requirements for houses with garage apartments without crowding on-street parking and arousing political opposition? Cities can better manage on-street parking rather than require off-street parking. Parking is not the only reason why neighbors may object to garage conversions, but it is a major reason and a politically powerful one.

If on-street parking problems are no longer an objection to garage apartments, other reasons for opposition (such as concerns about noise or attracting poorer residents to affluent neighborhoods) can be discussed more openly. Other zoning regulations for second units (location, size, safety, construction materials, and occupancy limits) can remain largely unchanged.

Figure 1. A look inside garages in Los Angeles



Reforming off-street parking requirements

One way to manage on-street parking is to limit the number of cars permitted to park on the street. In residential permit parking (RPP) districts, the city can limit the number of on-street parking permits for cars registered at any address with a second unit. An RPP district is necessary, but not sufficient, to prevent garage conversions from crowding the curb. Although cities create permit districts only where parking is already scarce, they can be irresponsible about the number of permits issued. For example, a political firestorm erupted in San Francisco when journalists discovered that romance novelist Danielle Steel had 26 residential parking permits for her mansion in Pacific Heights.

To solve the on-street parking problem, cities can impose an if-then condition for garage conversions: If an owner receives a permit to convert a garage into housing, then the owner accepts a limit on the number of on-street parking permits at that address. This if-then condition can be included in the zoning for single-family neighborhoods with RPP districts.

Cities can also increase the number of on-street parking spaces by issuing block-your-own-driveway permits that allow residents to park on the street in front of their own driveway, effectively creating a reserved curb space in front of every house and increasing the on-street parking supply. If residents convert their garages into housing, these block-your-own-driveway permits can give property owners a guaranteed on-street parking space for themselves, guests, home help, and service vehicles.

Legalizing unpermitted garage conversions

Off-street parking requirements in single-family neighborhoods prevent on-street parking congestion mainly by prohibiting second units. Most garage conversions that do occur are confined to the unregulated housing market rather than the formal market. Some homeowners ignore not just parking requirements, but also important safety precautions when converting their garages without building permits. These unregulated garage units often do not adhere to building codes, exacerbating existing concerns over the safety of converted garages.

Unpermitted garage conversions and other second units are surprisingly widespread in the United States. To estimate the increase in the number of unpermitted single-family housing units in the 10 largest Metropolitan Statistical Areas, we compared the number of new single-family housing units reported in the U.S. Census with the number of single-family building permits reported by the U.S. Department of Housing and Urban Development (detached inhabited garages are counted as single-family housing units in both data sets). Column 4 in Table 1 suggests that, between 2000 and 2014, 37 percent of new single-family units were unpermitted. In total, 1.7 million unpermitted housing units were added in the 10 largest metros.

Table 1. Share of unpermitted single-family units in the largest metro areas, 2000-2014

MSA	Increase in Number of Housing Units	Number of Building Permits	Percentage of New Units Without Permits	Wharton Regulatory Index - Land Use Strictness
Los Angeles	454,728	155,344	66%	0.51
New York	566,167	235,846	58%	0.63
Boston	205,337	86,102	58%	1.54
Philadelphia	317,891	153,821	52%	1.03
Chicago	514,888	292,800	43%	0.06
Miami	298,554	188,632	37%	N/A
Washington, D.C.	398,169	279,401	30%	0.33
Dallas	608,604	459,609	24%	-0.35
Atlanta	582,114	471,479	19%	0.04
Houston	581,674	526,312	10%	-0.19
Total	4,528,127	2,849,346	37%	--

The rightmost column shows the Wharton Residential Land Use Regulatory Index, which measures the strictness of land use regulation. MSAs with more regulation have higher values, and those with less regulation have lower values. The MSAs with more regulatory barriers to new housing (Boston, Los Angeles, New York, and Philadelphia) have high shares of unpermitted units in their metropolitan areas, while the MSAs with fewer barriers (Atlanta, Dallas, and Houston) have low shares. Providing a pathway to legalization can greatly reduce the number of illegal garage conversions.

The economics of garage conversions

Converting garages into housing can have far-reaching benefits for homeowners, including improved financial footing. According to Pearl Remodeling, a company that converts garages into livable space in Los Angeles, the cost of converting a two-car garage into a 400-square-foot apartment ranges from $60,000 to $80,000. If the homeowner finances the conversion at 5 percent interest over a 15-year period, monthly loan payments would be between $474 and $633 per month. Using Craigslist, we surveyed rental listings of second units in Los Angeles County in May 2016 and estimated that the average rent for a 400–450-square-foot second unit in Los

Angeles is $1,440. At this rate, the rent from a garage apartment can cover mortgage payments and give the homeowner between $602 and $793 in additional income per month. If the owner pays $60,000 for the conversion without borrowing, the rate of return on the investment is 25 percent per year and the payback period is only 3.9 years. If the conversion cost is $80,000, the rate of return is 18 percent per year and the payback period is 5.4 years.

Garage conversions and urban design

The large scale and poor design of some high-density infill projects often provoke opposition from homeowners who want to preserve their neighborhood's physical character. In contrast, garage apartments do not overwhelm existing houses and may even go unnoticed by neighbors. Garage conversions merely swap cars or storage for people, leaving exteriors virtually unchanged.

Critics cannot say that a converted garage will be out of scale in the neighborhood because the garage is already there. Garage apartments create horizontal, distributed, and almost invisible density instead of vertical, concentrated, and obtrusive density. With a garage conversion, no one has to build more housing because it's already there. The problem is that the city requires it to be reserved for cars, not people.

Figure 2 below shows single-family homes with converted garages in front of and behind the house. Both have enough parking to accommodate two, three, or more cars parked in the driveway or on the street in front of the house.

Because most garage conversions have been illegal, most of them have been in backyards where they are inconspicuous. Nevertheless, street-facing garages may be the most suitable for conversion to housing, for several reasons.

Street-facing garages:

- Already comply with zoning-required setbacks and height limits.
- Do not reduce privacy in the homeowner's or the neighbors' backyards, and provide more privacy for the garage resident with a separate entrance to the street.
- Convert more cheaply than a freestanding backyard garage, as the apartment can connect with the electricity, central heating, air conditioning, and plumbing in the main house.
- Can have a door into the main house if the apartment is occupied by a family member or caregiver.

Table 2. Cost and revenue for converting a two-car garage into a 400-square-foot apartment

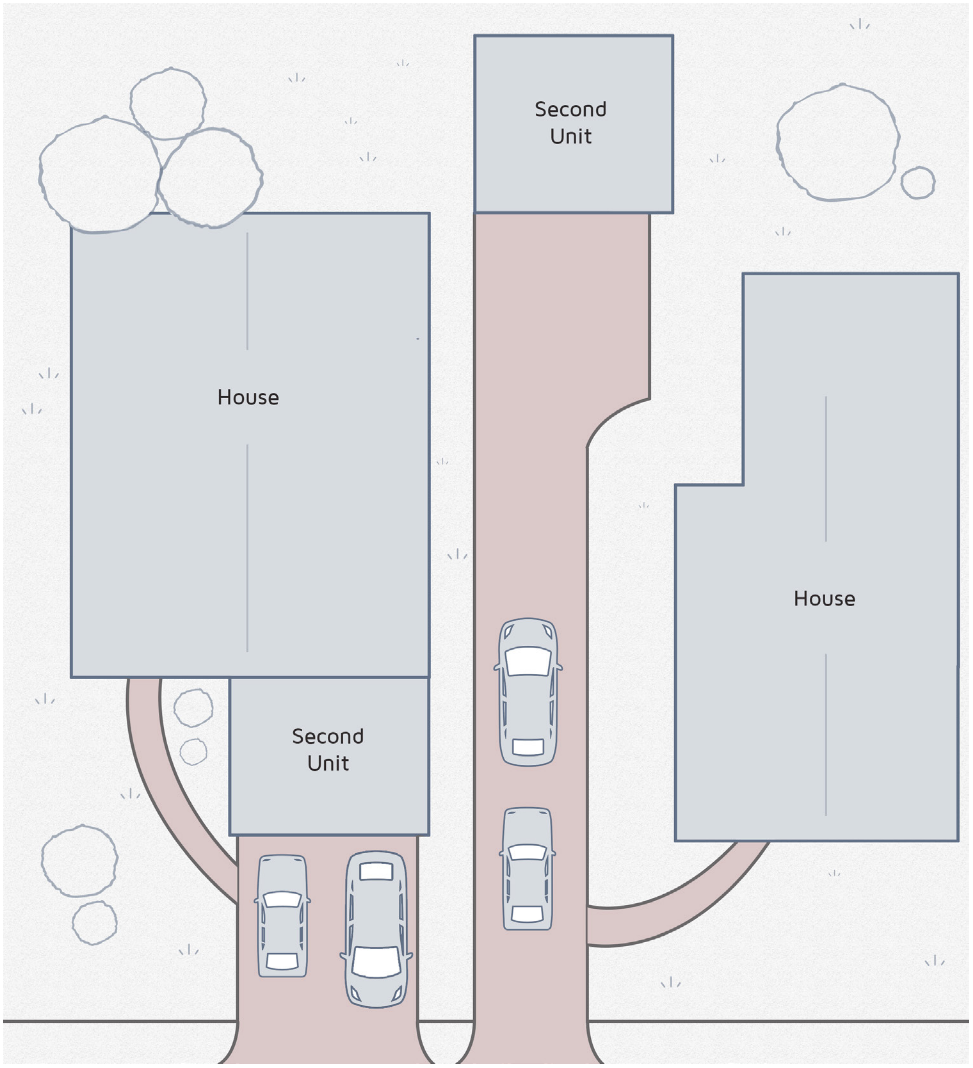
		Low	High
Construction cost	Architectural plans	$3,000	$5,000
	Permit fees	$2,000	$3,000
	Construction	$45,000	$60,000
	Fixtures	$10,000	12,000
	Total	$60,000	$80,000
Monthly cost	Mortgage payment	$474	$633
	Property tax	$50	$67
	Maintenance	$50	$67
	Insurance	$73	$73
	Total	$647	$838
Monthly rent		$1,440	$1,440
Monthly net revenue		$793	$602

- Provide fire engines or ambulances with access, removing an objection often raised against backyard cottages.
- Make homeowners feel safer while they are away, with more eyes on the street if someone is living in the former garage.
- Improve both the architecture of the house and the urban design of the street, if implemented correctly.

The two renderings on the opposite page illustrate the design improvements possible when a residential facade replaces a garage door that formerly dominated the front of a house (the entry door to the second unit can be in the side setback).

Figure 2. Garages converted to second units at the front and back of houses

Figure 3. Design improvements from street-facing garage conversions in Los Angeles



Affordable housing

Parking reforms that allow second units can provide a new supply of small, well-located, and high-quality dwellings within walking distance of local stores and public transit. Smaller apartments have lower rents and will be more affordable to tenants with lower incomes. Allowing homeowners to convert their garages into second units will allow the market to supply more housing with less parking and less traffic.

Garage conversions can reduce the demand for existing affordable housing by increasing both the number of small units and their geographical availability. If reformed parking requirements allow it, garage apartments can house communities of people with different incomes living not only within the same neighborhood, but also on the same piece of property. Garage apartments will be what has been called "naturally occurring affordable housing" (NOAH): units that are affordable without being supported by public subsidies. Because residents of new garage apartments will not be competing for the existing supply of affordable housing, the benefits of the new NOAH units will trickle sideways and benefit everyone seeking affordable housing.

All parking is political

If a city limits the number of on-street parking permits at any address with a second unit, interest groups from across the political spectrum are more likely to support reducing the off-street parking requirements for second units. Taken together, reforms for both on-street and off-street parking regulations are likely to appeal to a variety of important interest groups.

Housing advocates can see that allowing garage conversions will create affordable homes without requiring any subsidy. Environmentalists can see that it will reduce energy consumption, air pollution, and carbon emissions. Elected officials can see that it will encourage infill development and reduce traffic congestion without any new taxes.

Urban designers can see that unobtrusive micro-apartments will enable people to live at higher density without being overwhelmed by cars. Older people can see the potential to have on-site housing for caregivers or boomerang children. Opponents of illegal second units can see the potential for cities to legalize or remove these units. Homeowners can see the opportunities for guest quarters or rental income. Across the political spectrum, the left can see that garage conversions provide affordable, mixed-income housing in good neighborhoods while the right can see they are 100 percent capitalist.

A flexible path forward

By making it difficult to convert garages into apartments, off-street parking requirements put space for cars ahead of housing for people. Instead, cities should remove off-street parking requirements for houses within residential parking permit districts and limit the number of on-street parking permits at any address where a garage has been converted to housing. Limiting parking permits will prevent on-street parking congestion and help make garage conversions politically feasible. By increasing both home values and the supply of affordable housing, this parking reform can achieve both individual and collective benefits of converting garages into housing without creating costs to neighboring homeowners.

Cities can offer parking reform for garage conversions first as a pilot program in one district. Pilot programs allow cities to act fast on big ideas. By starting small, a successful policy can easily expand into other parts of the city. Because they offer flexibility and may be adopted on a piecemeal basis, parking reforms that allow garage conversions can foster gradual change at the neighborhood level. A small parking reform will enable homeowners to create affordable housing and adapt the urban landscape to a new future, one garage at a time.

This article is adapted from "Converting Garages into Housing." 2017. Journal of Planning Education and Research, forthcoming.

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Fueling Collisions: The Case for a Smarter Freight Tax

Cody Nehiba

In one form or another, most economic activity in the United States is connected to a truck. Trucking is the backbone of the American freight system — accounting for an estimated 60 percent of all freight shipped in the U.S. in 2015. But trucking and goods movement produce significant costs, including congestion, pollution, road damage, noise, and collisions. Regulating trucking's externalities is complex, and ill-informed policies may have unintended consequences.

Though they are more commonly thought of as a source of revenue for road infrastructure, diesel fuel taxes are also the main corrective measure used to mitigate damage caused by the trucking industry. The underlying assumption is that, by increasing costs, aggregate fuel consumption will decrease, which in turn will reduce the external impacts of trucking.

However, fuel taxes have an overlooked effect on freight carrier dispatching decisions. Previous research by Linda Cohen and Kevin Roth shows that as fuel prices rise, companies balance the service quality they provide, and particularly the frequency of deliveries, with the costs of transportation. Faced with a higher cost of fuel due to taxes, companies often choose to decrease their total number of shipments and increase the cargo on each shipment. In short, higher diesel fuel taxes lead to fewer, but heavier, trucks on the road. Trucks become so heavy that, according to Cohen and Roth, they cause enough additional road damage to offset the gains from reduced diesel fuel consumption. More alarmingly, my research demonstrates that the distortionary effects of diesel taxes on truck weights and mileage likely lead to more dangerous truck collisions.

This result is the culmination of several effects. Diesel taxes reduce truck miles traveled, which should reduce collisions. Diesel taxes also increase truck weight, and heavier trucks increase the number of collisions because they are less maneuverable and take more time to brake. Furthermore, heavier trucks are expected to make the average truck collision more severe. This implies that, while it is unclear whether diesel taxes increase or decrease the total number of collisions, they are expected to make collisions worse.

No one has previously investigated the link between collisions and freight truck weight, but the relationship of severe traffic collisions and passenger vehicle weight is well-documented. The literature suggests that the heavier the striking vehicle, the higher the risk of death becomes in the struck vehicle.

To better understand this, I analyzed the empirical evidence of how fuel prices affect both the quantity and severity of truck-involved collisions. I associated 3.5 billion geolocated truck weight observations from weigh-in-motion sensors onto the universe of truck-involved collisions between 2013 and 2016. Together, these data show an empirical relationship between truck weights, truck counts, and the quantity and severity of truck-involved collisions.

Combining my estimates with results from Cohen and Roth shows how fuel price increases don't limit collisions, but in fact make the roads more dangerous. While a 1 percent price increase per gallon would be expected to reduce collisions thanks to fewer trucks on the road, the gains are actually offset by nearly identical increases in collisions due to heavier trucks. What's more, the offsetting behavior favors more severe collisions, suggesting that while increased fuel taxes may decrease truck traffic, they make the average truck-involved collision more severe.

Diesel taxes are an example of a policy instrument that corrects one externality — pollution — but in the process, exacerbates other externalities — road damage and collisions. The importance of truck weight in determining the external costs of trucking suggests that a policy that directly charges trucks for their weight would better improve overall welfare. For example, an axle-weight-mile tax would tax trucks on both how far they travel and their weight.

This type of tax has three benefits. First, it would be relatively easy to implement using existing infrastructure to measure trucks and levy fees. Diesel taxes for interstate trucking are already a type of "use tax," and trucks are already required to undergo regular weigh-ins. Put simply, drivers are currently taxed by miles driven in each state and report fuel purchases and miles in each state quarterly. Oregon already uses this reporting system to apply an axle-weight-mile tax instead of a diesel tax.

Second, since this tax charges trucks for both their weight and mileage, it can alleviate pollution, collisions, and road damage. Finally, because trucks are taxed based on a per-mile and not a per-gallon basis, firms cannot avoid taxes by investing in more fuel-efficient trucks. This avoids concerns about the "rebound effect," where investing in more fuel-efficient technology increases miles driven and exacerbates other externalities. Axle-weight-taxes are easy to implement and would address both sets of externalities, encouraging more efficient truck freight transportation while avoiding more severe crashes.

This article is adapted from "Taxed to Death? The Effects of Diesel Taxes on Freight Truck Collisions," working paper, 2017.

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