CLEVELAND COUNTY / CITY OF NORMAN, OKLAHOMA:
PARKING STRATEGIC PLAN

Assessing an Uncertain Transportation Future

Projecting the Impact of Autonomous Vehicles and Shared Mobility Trends on Future Parking Demand

Parking Strategic Plan **-** Appendix 31

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Assessing an Uncertain Transportation Future

Assessing an Uncertain Transportation Future explores several key areas that experts warn are likely to produce "significant disruptions" to the parking and transportation industries in the coming years. Specifically, the strong emergence of autonomous vehicles (AVs) as a potentially viable reality brings with it many positive elements, including greatly enhanced vehicular safety, a dramatic reduction in automobile related deaths and injuries, reductions in roadway congestion, reductions in vehicle emissions (assuming future AVs will primarily be electric vehicles), and especially significant to this study, the potential for a dramatic reduction in parking demand. Some estimations project that once autonomous vehicles are the dominant form of personal transport, parking demands could drop by as much as 40% – 50%. There are other shifts taking place in the transportation sector such as the emergence of what is being called "shared-use mobility" which ties to the changing preferences of younger generations to purchase "mobility as a service" instead of owning a vehicle.

A key element of these issues relates to the timing of these changes and how these changes are likely to unfold. The pace of advancement in vehicle technology, lidar and vehicle sensors, and connected vehicle technology such as GPS and in-car navigation, has been dizzying. This rapid advance, and the corresponding decrease in the costs of these technologies, has created a great deal of media attention leading to a wide range of opinions and speculation about the timing and impacts of the application of these transformative technologies. To be clear, there are many conflicting opinions about the true impacts these industry changes will bring. Some argue that vehicle miles traveled (VMT) will decrease, while others argue that VMT will actually increase. Some argue that single occupant vehicle use will decrease substantially, while others warn of an emerging and even less desirable phenomenon—zero-occupant vehicles (AVs with no passengers driving from place to place to pick up customers). Some argue that vehicle ownership rates will plummet, while others suggest that while vehicle ownership may decrease, the total number of vehicles on the road will actually increase.

Beyond these uncertainties, a host of other potential issues have also yet to be addressed—legal issues, regulatory issues, insurance issues, cost issues, significant job losses in a number auto and driver-related industries and more. These could all impact the predictions of when changes will begin to impact parking demand. Another factor to consider is geography. Most experts agree that many of these pending changes will happen first in major urban areas, with adoption lagging behind in more rural areas.

This report attempts to summarize the current state of the technological and policy issues, as well as provide the projections of leading industry experts related to implementation timelines of these emerging technologies. Based on this research, we will provide a set of recommendations related to parking and access planning, specifically related to new parking development. The primary concern we are trying to address is what is right amount of parking that should be provided, both in the short to medium term (3-10 years) and in the longer term (10-40 years).

Recommended Strategies

In general terms, we are recommending a combination of strategies that attempts to bridge the gap between providing adequate parking, based on the current transportation and parking paradigms, with projections for reduced parking demand in the longer term. We are also recommending a specific approach that attempts to merge a focus on effective parking management with a more comprehensive "access or mobility management" approach to community access overall. This approach promotes an integration of parking and transportation strategies as a means to minimize parking infrastructure investment without compromising service levels for the community overall.

With a more aggressive posture related to an integrated parking/mobility management approach, which will provide less total parking an increase in mobility options will be needed in the short to mid-term timeframes, which is important because of the uncertainty of how much parking will be needed in the future. We believe that this approach can also provide significantly higher levels of customer and staff service and satisfaction levels.

A key area of focus is the adoption and integration of a range of mobility management and transportation demand management strategies which will be implemented as part of a new Transportation Management Authority. These initiatives, if well-implemented, could reduce overall parking demand significantly and reduce the amount of parking needed in the short to mid-term timeframe. Another important component to this recommendation is a monitoring and evaluation component. If this recommendation is pursued, the goal would be to establish an initial baseline of parking and modal split metrics for the downtown area and update these metrics on an on-going basis. As the transportation system evolves over the next several years and decades, this monitoring system will provide data-driven management tools to assess changes in transportation options and parking demand, and determine which transportation alternatives have proven most effective.

If the demand for parking in the future is reduced by the projected 40-50%, progressive planners and architects are proposing options that would allow for parking structures that could be "adaptively reused" for other functions. This emerging concept has garnered much attention in recent months. This document also incorporates previously submitted materials for the types of changes that would need to be considered to create adaptable, "future-proofed" parking facilities.

This report suggests that a phased parking development plan be considered (Phase 1 being the next ten-year period). The Phase one period could use traditional parking structure planning assumptions and development practices. However, any additional parking infrastructure development that may be needed beyond the next 10 to 15 years should seriously consider the adaptive reuse approaches outlined in this report. The initial phase parking facilities could also be developed using the adaptive reuse approach, but any adaptive reuse strategy will come with an initial cost premium in the 18-25% range. (This premium would cover the costs of such elements as increased floor-to floor heights, extra structural capacity, and external ramping). If these facilities were eventually adapted to other uses, such as office space, the value of this adapted space would off-set some, if not all, of the premiums associated with the design modifications. On the other hand, it is less likely that the initial garages would be candidates for adaptive reuse compared to the garages built at a later date. One caveat to this general line of thinking is that garages located more closely to certain buildings or functions might be better candidates for adaptive reuse based on their proximity to key development sites and types of development. We encourage the design team to consider the potential for garage adaptive reuse before making final garage site selections. This phased approach to parking garage development takes into account the uncertainty of the future as it may or may not affect future parking demand.

It is worth noting that this approach has already been implemented on the new Apple campus in Cupertino, CA. City code required approximately 14,000 parking spaces for the new campus. Apple built the parking, but strongly believed that future demand would be much less than the required spaces, and designed the two large rectangular parking structures to be reused for additional office space. To our knowledge, this is the first significant application of this concept for new garage construction in the country.

Overall, we are proposing a comprehensive and multi-dimensional approach to manage not only parking, but also a more robust integrated mobility management system. This approach will reduce parking demand in the initial term, reduce the potential for overbuilding parking, provide a higher level of campus access and customer service, and offer flexible strategies for meeting the parking needs of the future (whatever they may be).

Parking Structure Development Costs Update

Based on a review of several industry sources, including hundreds of completed parking structure projects of varying size, scope, and geographic location (omitting parking structures that are entirely below-grade because the cost of such structures is much higher), the national median construction cost for a new parking structure in 2017 is approximately **$19,000 – $20,000 per space or $56.99 – $59.00 per square foot**, increasing approximately 2.5% from 2015, when the median cost was approximately $18,600 per space based on historical data.

Construction cost data does not include items such as land acquisition, architectural and engineering fees, environmental evaluations, materials testing, special inspections, geotechnical borings and recommendations, financing, owner administrative and legal, or other project soft costs. Soft costs are typically 15% to 20% of construction costs.

FEATURES TYPICALLY INCLUDED IN A MEDIAN COST PARKING STRUCTURE:

- Precast concrete superstructure
- Attractive precast concrete facade, but with basic reveal pattern
- Shallow spread footing foundations
- All above-grade construction
- 8' 6" to 8' 9" wide parking spaces
- Glass-backed elevators and unenclosed stairs clad with glass curtain wall to the exterior
- Basic wayfinding and signage
- Open parking structure with natural ventilation, without mechanical ventilation or fire sprinklers
- Little or no grade-level commercial space
- Basic parking access and revenue control system
- Energy efficient fluorescent lighting

ENHANCED DESIGN FEATURES THAT COULD INCREASE CONSTRUCTION COSTS ABOVE THE MEDIAN RANGE:

- Cast-in-place, post-tensioned concrete superstructure for lower maintenance
- Attractive facade with precast, brick, metal panels, and other materials
- 8' 9" to 9' 0" wide parking spaces for user comfort
- Green Garage Certification following the Green Parking Council standards
- Energy-efficient LED lighting with occupancy and photocell computer controls
- Custom wayfinding and signage system
- Storm water management including on-site retention/detention
- Deep foundations, such as caissons or pilings
- Below-grade construction
- Enclosed stair towers due to local code requirements
- Enclosed parking structure without natural ventilation, where mechanical ventilation and fire sprinklers are required • Grade-level commercial space
- Mixed-use development where the parking is integrated with office, retail, residential, or other uses
- State-of-the-art parking access and revenue control system
- License plate recognition systems
- Parking guidance systems
- Count system with variable message LED signs
- Pay-on-foot parking revenue control stations
- Wi-Fi and cellular services

FACTORS AFFECTING PARKING STRUCTURE COSTS

People often think of parking structure development costs primarily in terms of dollars per space, however, there are many other factors that should be considered. The cost of a parking space is a product of parking efficiency (SF per space) and structure efficiency (dollars per square foot). Each component plays a critical role in determining the ultimate cost of a parking facility. Parking efficiency is the total gross area of a parking structure, inclusive of stairs, elevators, and all parking floors, divided by the number of spaces. Typical parking efficiency for an above ground, stand-alone garage is 300 to 350 SF per space. Many below-grade or mixed-use garages can have parking efficiencies of 400 to 500 SF per space. Factors affecting parking structure development costs include:

- **Geography.** Construction costs vary by location due to regional factors such as the cost of labor and availability of materials. In addition, factors such as higher seismic regions and soil conditions have a large impact on cost.

- **Number of Parking Levels.** In general, a larger-footprint parking structure with fewer levels will cost less per parking space than a taller structure with a smaller footprint. The cost per square foot of the first level at-grade is less than levels elevated above the ground. A lower-height, larger-footprint structure will have a higher proportion of the cost in the first level. Taller structures are heavier which affects the foundation cost. A taller structure generally has a less efficient parking layout, which translates into more square footage for each parking space.
- **Parking Below-grade.** Parking below-grade is much more expensive than parking above-grade. A five-level, above grade parking structure may cost $50 per square foot. If this same structure is depressed one level below-grade, the cost can increase approximately 15% to $57.50 per square foot. If the same structure is put two levels below ground, the cost increases even more because of the impacts of having to dig deeper (45% higher than the original cost or approximately $72 per square foot).
- **Structural System.** 60% to 70% of parking costs are in the structural system. As such, the type of framing system will have a significant effect on the cost of each parking space. There are two general types of framing layouts—short-span and long-span. Short span requires a column approximately every three parking spaces (27x30 feet square) to support the floor slab. Long span requires columns spaced 60 feet apart, with beams spanning over the stalls and drive aisle. Generally, short-span systems cost less per square foot, but negatively effects efficiency. Long-span systems cost more per square foot, but result in more stalls in the same square footage.

  The structural system can be cast-in-place concrete, precast concrete, or structural steel. The most cost-effective option depends on the project's location and the region's preferred construction methods. The selection of a system not common in the area will generally cause the cost to increase.
- **Foundation.** Structures built in areas with poor soil conditions requiring more expensive, deeper foundation systems will cost more. The difference between a shallow and deep foundation system can increase the price approximately 10% overall—taking the cost from $50 to $55 per square foot, for example.
- **Architectural Facade Treatment.** The appearance of a parking structure is important to the surrounding environment. The cost of making that structure more aesthetically-pleasing can affect the cost per parking space of up to 15%. If the structural system is used to create the architectural facade, the cost per square foot will be less. However, the use of architectural elements in addition to the structural system will increase the cost. If the architectural design creates an inefficient structural system, the cost could increase drastically.
- **Total Parking Spaces.** A smaller project will cost more per space than a larger project. A 200-space parking structure on a small site may cost about 30% more per square foot than a 1,000-stall structure on a reasonably sized lot.
- **Parking Efficiency.** The cost of a parking space is the cost per square foot multiplied by the square foot per space. The more square footage per stall, the higher the cost.

  Example:

– Typical efficiencies for short-span structures:	330-390 sf/stall
– Typical efficiencies for long-span structures:	300-340 sf/stall
– Typical efficiencies for mixed-use structures:	400+ sf/stall

  Example:

  Assume a 500-space structure costs $50 per square foot:

  330 sf/stall * 500 stalls = 165,000 sf * $50/sf = $8,250,000

  360 sf/stall * 500 stalls = 180,000 sf * $50/sf = $9,000,000

  The difference is $750,000, or $1,500 per stall.
- **Premium Elements.** Program elements added to parking will increase the cost per stall. A photovoltaic system covering 50% of the top level can add approximately 25-30% to the building's cost per square foot of the building. However, there may be operational cost savings that can support this type of elements. A mixed-use component will also increase the

cost per stall due to negative impacts on efficiency and the structural framing system. Special site conditions such as the need to reroute utility lines or perform substantial demolition may increase cost as well.

- **Market Conditions.** The cost of parking can be negatively and positively affected by market conditions by 10% or more. A normal bid market will generate four to six bids from qualified contractors. An aggressive bid market might see 10 or more bids, causing the price to decrease. This can also create concern if the bidders are not qualified. An impacted bid market might see one to three bidders and a price increase due to lack of competition.

In the end, most owners budget for parking in terms of dollars per space. To be as accurate as possible, it is best to understand the project in terms of parking efficiency as well as structural efficiency. Design decisions that enhance efficiency can often help make a project financially feasible.

Sources:

1. Fixr, Build a Parking Garage Cost (https://www.fixr.com/costs/build-parking-garage)
   Note: FIXR estimates a $59 per square foot cost, though their estimate of the national average stands between $50 to $70 for most projects.
2. International Parking Institute, "How Much Does a Structure Cost?" H. Dean Penny, Kimley-Horn
3. Victoria Transport Policy Institute, "Parking Costs" (www.VTPI.org)
4. Carl Walker, Inc., "Parking Structure Cost Outlook" (www.carlwalker.com)
5. *Parking Today*, "The Top 10 Issues Affecting the Cost of Building a Parking Space" by Watry Design

ASSESSING AN UNCERTAIN TRANSPORTATION FUTURE

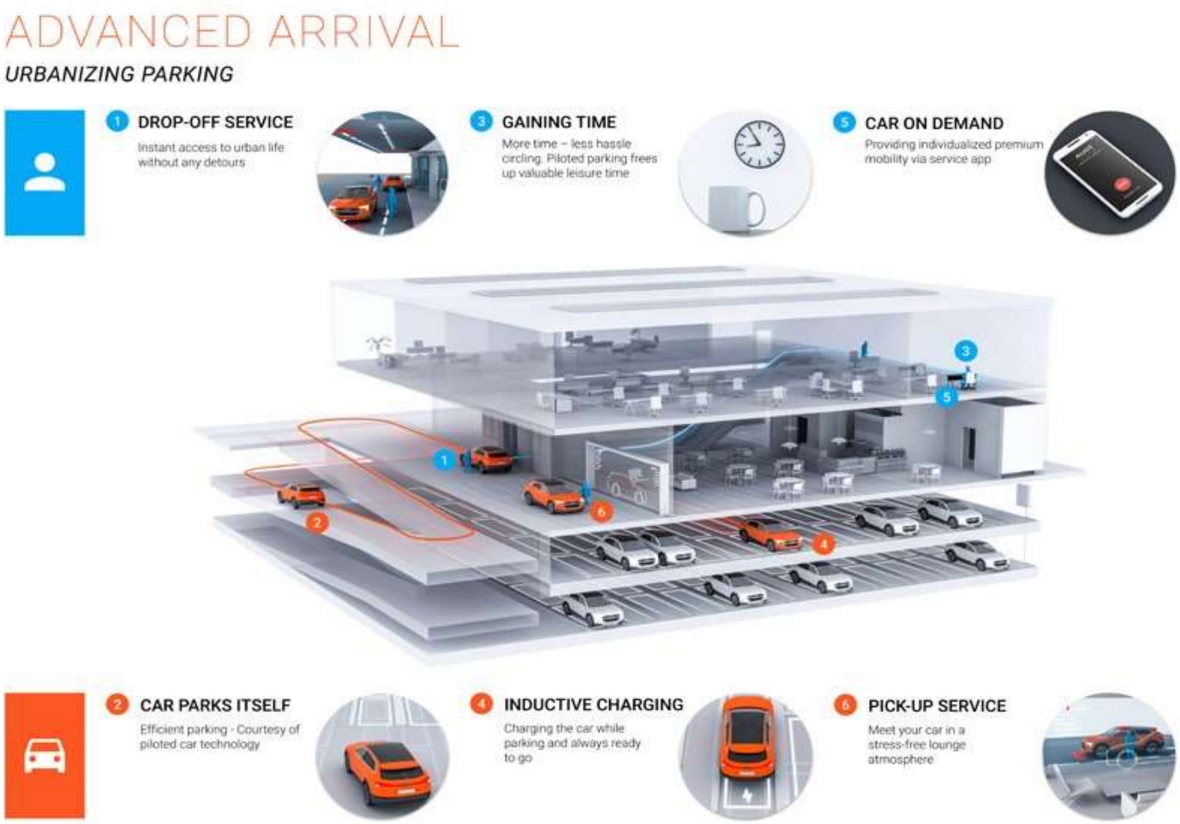
Assessing the Potential Impacts of Autonomous Vehicles and Shared-Use Mobility on Urban Transport and Parking

Overview

This section includes reviews and commentaries on autonomous vehicles and shared-use mobility, including an article written by noted transportation planner Todd Litman of the Victoria Transport Policy Institute. This article explores the impacts that autonomous (also called self-driving, driverless, or robotic) vehicles are likely to have on travel demands and transportation planning. As this is an emerging topic, general background information has been included in addition to specific issues related to the new campus.

This chapter begins with general commentary from industry experts regarding the nature and scale of the coming transformation of urban mobility, and the wide range of issues, potential disruptions, and impacts predicted. Our primary objective is to frame the national dialogue regarding these issues and create common context for the overall discussion. This overview is followed by a more detailed discussion of benefits and costs associated with autonomous vehicle (AVs), predictions related to development and implementation timelines, and explores how they will affect planning decisions such as optimal road, parking, and public transit supply.

While there are a wide range of predictions related to the timing of AV impacts (ranging from as little as five to ten years in more urban environments), Todd Litman's analysis indicates that some benefits, such as independent mobility for affluent non-drivers, may begin in the 2020s or 2030s. Most impacts, including reduced traffic and parking congestion (and road and parking facility supply requirements), independent mobility for low-income people (and the reduced need to subsidize transit), increased safety, energy conservation and pollution reductions, will only be significant when autonomous vehicles become common and affordable, probably in the 2040s to 2060s. Some benefits may require prohibiting human-driven vehicles on certain roadways, which could take longer.



Graphic courtesy of www.designboom.com

The Emerging Transformation of Urban Mobility

The following are excerpts from articles written by noted planners and industry experts related to the coming transformation of our transportation systems:

Getting Connected: What changes in technology mean for parking and municipalities in the 21st century and beyond.

Mark Braibanti | Director of Marketing, Excerpt from INRIXIPI *Parking Professional* Article, November 2016

- The growing millennial population, in combination with rapidly improving technology, is the stimulus for this change. Vehicle miles traveled decreased from 2003-2014 in the United States, but as a former traffic commissioner of New York City noted: “It wasn’t because of the recession. It was millennials. They were driving 20-25% fewer miles. That was extraordinary, and the trend was that driving and parking (for millennials) was a hassle.” As vehicle miles started to decrease, innovative technology, digitization, increased connectivity, and the millennial generation began fueling the demand for smarter, more integrated driving experiences.
- We are now is an era of data-centricity, with complex technology and algorithms improving diagnostics, navigation and hybrid vehicles. Among the technological innovations surfacing in the auto industry right now are what we call ACES: autonomous, connected, electric and shared vehicles.
- By 2020, BI Intelligence (a research service from *Business Insider*), estimates that 75% of cars shipped globally will be equipped with Internet connectivity. That equates to more than 250 million connected cars on the road in just 4 years. Compared with 25 million connected cars in 2015. This movement toward connected services represents a significant shift in technological needs for the auto industry.
- As much as real-time traffic is now viewed as being a necessity, drivers in the near future will expect their cars to help them easily find the closest and cheapest available parking, compare prices and types, and pay conveniently and seamlessly.
- Connected vehicles transmit a wide range of data that can be collected and used to predict current parking availability on city streets and at off-street parking facilities. Cars equipped with light detection and ranging sensors, usually used to let you know if you are getting too close to objects in the road, can be used to detect where open parking spaces are located as you drive.
- According to analysts at Frost and Sullivan, searching for parking costs consumers and local economies nearly $600 million in wasted time and fuel every year. The connected car will affect every facet of the transportation, parking and city planning industries. This makes connecting every component of the parking ecosystem to cars an essential part of the path forward. If not, parking lots risk being invisible to drivers if they aren’t integrated in to the next generation of connected cars. Much as cities were unprepared for ridesharing services such as Uber and Lyft, we cannot overlook the importance of connected cars. A new study by the National League of Cities recently revealed that 94% of the world’s cities are not prepared to deal with autonomous cars.

Old models for managing urban transportation are insufficient. New options demand that we think in terms of mobility.

Stephen Goldsmith | Harvard University, Contributing author to *Governing* Magazine

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- Urban mobility is undergoing its starkest transformation since the first Model T rolled off the assembly line more than a century ago. Emerging services like car-, bike- and ride-sharing have provided city dwellers with a vast—and often confusing—array of options for getting around. And it’s too early to predict the impact of technologies that are on the horizon, such as driverless cars.

- Today's changing needs demand that we find ways to bring together old and new modes of transportation so that they complement and enhance each other. With more and better data available now than ever before, we need to think in terms of true mobility management.
- That's a major departure from the traditional model in which cities or institutions might run a transportation department, a mass transit agency, a taxi commission and, perhaps in recent years, a bike-share program. That leaves individuals responsible for stitching together the various modes of transportation they need—car to bus, bus to train, train to bike and so on. As things stand, commuters can only make educated guesses about cost, duration and the likelihood of service availability and delays.
- In the new data-enabled, service-oriented model, government and institutional leaders will appoint mobility managers to enhance convenience and remove the transit deserts that plague many individuals who cannot afford cars and for whom inconveniently located bus routes provide little relief or for millennials who prefer the sharing economy approach as opposed to the vehicle ownership model of their parents. These mobility managers will help smooth transitions between public, private and shared transportation services. Individuals will be able to plan and pay for trips all in one place.

Urban Transportation's Multimodal Future: Networked alternatives for getting around are about to redefine our cities as much as the horseless carriage did a century ago.

Bob Graves | Associate Director of the Governing Institute

- The future, more and more urban transportation experts are coming to believe, lies in mobility-friendly networks in which cars are just one element—and an ever-shrinking one as we move from a system in which the personally owned vehicle is king and toward a multimodal future of on-demand driverless vehicles, ride-sharing, expanded public transit, greater reliance on human-powered transportation and other alternatives.
- How far could such a new mobility paradigm take us? Jerry Weiland, a 30-year veteran of General Motors who now leads the Rocky Mountain Institute's mobility program, believes that, over the long haul, the United States could reduce the number of urban/suburban vehicles on the road by up to 90% and in the process, redefine cities just as the horseless carriage once did.
- Whether or not this scenario plays out, it's clear that institutions and cities need a roadmap to guide the next generation of infrastructure investment decisions. Roads and bridges (and parking structures) last a long time, and new infrastructure is costly. What should city and institutional leaders be thinking about when they look at repositioning their infrastructure for the future? "The first thing cities and campuses should understand is that all of the transportation infrastructure is about networks, whether it's bike-share, whether it's light rail, whether it's roads," says Cooper Martin, co-author of a 2015 National League of Cities' report, **City of the Future: Technology & Mobility**. "One line, one bike-share station, one road doesn't cut it."
- Weiland says, "The new mobility has to offer people a complete answer, not a partial one. Otherwise you're not going to get rid of your car." It's safe to say that the best fail-safe alternative solution is a multimodal transportation system in which many options—bikes, transit, car- and ride-sharing—are readily available at a moment's notice along the direction of travel. With near real-time information, the traveler can seamlessly shift from one mode to another and choose the one most suited to his or her needs.
- Certainly, in rural communities—and no doubt many suburban ones—the personally owned car will remain the dominant transportation choice for some time. But in more urban settings, networked alternative transportation choices are already proving to be very dependable alternatives. With improving integration across transportation modes and seamless payment solutions, their growth is all but secured. Our mobility-friendly, multimodal urban transportation future may be closer that we realize.

Driverless Cars and the Disruptions They Will Bring: In planning for an autonomous-vehicle future, governments and institutions need to pay attention to the broader picture.

Bob Graves | Associate Director of the Governing Magazine

- It's easy to understand why the media is fascinated with autonomous vehicles. Scarcely a day goes by without another company's announcement of new driverless technology. The latest is Apple, which just received permission from the California Department of Motor Vehicles to test self-driving cars on the state's roadways. This brings the tally to 30 companies, not only the likes of Google and Tesla but also a long list of traditional automakers including BMW, Ford, GM, Honda, Mercedes-Benz, Nissan, Volkswagen and Subaru.
- However intriguing driverless cars may be conceptually, their integration into our transportation system will demand well informed and insightful planning. In response to this challenge, the Institute of Transportation Studies at the University of California, Davis last year launched its 3 Revolutions Policy Initiative to explore the impacts and synergies of vehicle automation along with two other disruptive technologies - electrification and vehicle sharing.
- The initiative's framing document lays out two possible future scenarios. In the first, in which the three emerging technologies are pursued in concert, "people have plentiful, accessible and affordable mobility options." We devote less precious space to parking; our air is cleaner and our communities are more livable. In the second scenario, governments allow car makers to rush gasoline-powered autonomous vehicles to market. Only the rich can afford them, and sprawl, traffic congestion and greenhouse-gas emissions worsen.
- Government planners will find Information generated from initiatives like this one critical. But there are signs that the private sector isn't likely to wait for government to exert its influence. Developers are already building what could be called "adaptable infrastructure."
- A case in point that is unfolding in Los Angeles, the nation's car capital, is described in a recent *Los Angeles Times* article. AvalonBay Communities Inc., one of the country's biggest developers, is designing a downtown residential complex for a future time when ride-sharing services and driverless cars whittle down car ownership and parking places become "expendable." Rather than building the traditional inclined floor garage, its level floors could be converted to "shops, a gym and a theater." The company also has been expanding the number of electric car charging stations in apartment complexes under construction and featuring prominent drop-off points for ride sharing.

A Big Makeover Is Coming to the Parking Garage of the Future Thanks to Autonomy: Autonomous cars will cause some substantial changes in how parking garages are designed

Urban Design Collaborative | Nashville, TN

- Back in January, Tesla Motors introduced "Summon," a feature that allows many of its newer vehicles to park themselves. Using a smartphone or key fob, car owners can remotely command their vehicles to open garage doors, enter, park themselves and shut down. When the cars are needed again, motorists can retrieve them in the same remote way.
- Other car companies are working on similar valet technologies, and the promise of cars that can park themselves is creating a ripple effect that stretches beyond the auto industry.
- Sometime later this year, excavators will start ripping into cement and construction crews will begin transforming 50 acres of an ordinary parking lot in a suburban Nashville office park into a future-minded space that brings together all the latest trends in urban planning.
- Developers intend to build a mix of retail spaces and residences that incorporate things like solar panels and green roofs. But that could describe any number of developments across the country. What makes this project most notable is that it's poised to include what is believed to be the nation's first parking structure designed for an era in which cars contain valet features like Summon and can park themselves and connect with broader transportation networks.

- Motorists might not think these drab structures would need to change in that transition. But like every other aspect of transportation being upended by technology, parking garages will be no different. Within the next two to five years, experts believe these technologies will begin to alter what drivers need from a parking garage. Further out, as that transition continues, existing structures may need to be retrofitted, and new ones rethought from the ground up. In Nashville, planners are trying to get a head start.
- “It’s not even the clients pushing us, it’s the investment group bringing the dollars to the table for the project, and they’re saying, ‘We need you to take this into consideration,’” said Brian Wright, founding Principal of Town Planning & Urban Design Collaborative, the company handling the Nashville project. “It really is a paradigm shift.”
- Autonomous cars bring the likelihood that drop-off zones will be needed for vehicle occupants at the front of the buildings. Once occupants exit cars at a designated area, the cars can park themselves. And if there’s no need for humans to exit parked cars, they can fit into narrower berths that may eventually shrink from a traditional 9-foot width to perhaps 7- or even 6.5-feet wide. Squeezing vehicles into tighter spaces in turn saves millions in costs for builders, home buyers and consumers alike. But that’s just the small stuff.
- Connected cars add another dimension to the autonomous capabilities. Whether they’re privately owned or shared vehicles, the ability to summon a ride remotely means garages may not even need to be located smack-dab in the middle of shopping districts or close to city centers. The garages can potentially be moved out of areas where real estate is at a premium. Not only does this mean big changes for parking garages, but big changes for the areas around them. Build too much parking, you generate traffic that congests your roadways.

It’s Time to Think About Living in Parking Garages

Aarian March | LMN Architects, *Wired* Magazine, November 2, 2016

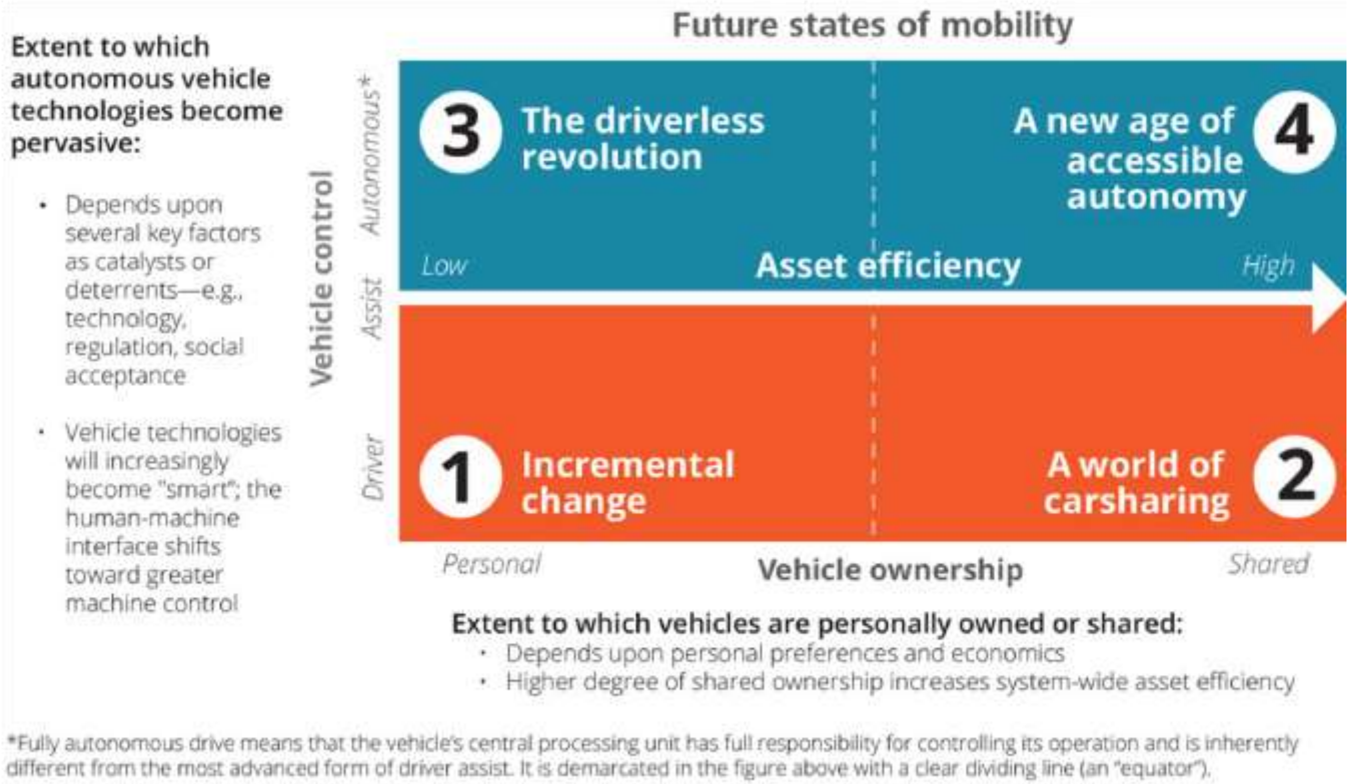
- The proposed 4th and Columbia project will include four floors of aboveground parking that can be converted to homes. The tower at 4th and Columbia will be the tallest in Seattle, a 1,029-foot, $290 million monument to the city’s recent, tech-flavored success. Residential units, a hotel, office space, retail, eight floors of underground parking. Standard, shiny city stuff. And, if the current plans are approved, the tower will include a quirky twist: four levels of above-grade parking, designed to someday take on new life as apartments and offices.
- LMN Architects, which designed the project, wants the tower to survive 50 to 100 years. “If that’s the case, we do need to make sure—I feel we do have the responsibility—that if the parking uses do change, we design to be able to adapt to that change,” says John Chau, a partner at the firm. (The project is still moving through the city approval process, and will not be completed for another two to four years.)
- The change he’s talking about is the coming transformation to a car-free-ish future. With rideshare, bikeshare, carshare, increasing transit options, and fully automated vehicles on the horizon, cities are less eager to allocate precious space for empty, parked cars. Already, places like Seattle have adjusted parking minimums, ditching rules that force developers to include parking for new projects near public transportation nodes.
- “A lot of people will start seeing a lot of these different shared services and say, ‘OK, I don’t actually need to own a car,’” says Scott Kubly, director of Seattle’s Department of Transportation. (His family has relied on shared mobility services and transit since their personal car was totaled 10 months ago.)
- For the folks designing buildings to last decades or centuries, one way to prepare for that future is to consider life in the parking garage, laying the groundwork now for a retrofit to come. And Seattle’s not the only city getting ready.

The Future of Mobility

Deloitte Planning Series Article

- It is argued that four concurrent "future states" would emerge within the mobility ecosystem, emanating from the intersection of who owns the vehicle and who operates the vehicle: incremental change, a world of car sharing, the driverless revolution, and a new age of accessible autonomy (see illustration below).

1. **Incremental Change:** This vision of the future sees private ownership remaining the norm as consumers opt for the forms of privacy, flexibility, security, and convenience that come with owning a vehicle. While incorporating driver-assist technologies, this future state assumes that fully autonomous drive doesn't completely displace driver-controlled vehicles anytime soon.
2. **A World of Carsharing:** The second future state anticipates continued growth of shared access to vehicles through ridesharing and carsharing. Economic scale and increased competition drive the expansion of shared vehicle services into new geographic territories and more specialized customer segments. As shared mobility serves a greater proportion of local transportation needs, multi-vehicle households can begin reducing the number of cars they own, while others may eventually abandon ownership altogether.
3. **The Driverless Revolution:** The third state is one in which autonomous drive technology* proves viable, safe, convenient, and economical, yet private ownership continues to prevail. Drivers still prefer owning their own vehicles but seek driverless functionality for its safety and convenience. This future will see a proliferation of highly customized, personalized vehicles catering to families or individuals with specific needs.
4. **A New Age of Autonomy:** The fourth future state anticipates a convergence of both the autonomous and vehicle sharing trends. Mobility management companies and fleet operators offer a range of passenger experiences to meet widely varied needs at differentiated price points. Taking off first in urban areas but spreading to the suburbs, this future state provides seamless mobility.



Graphic courtesy of Deloitte University Press (DUPress.com)

**Definition: By autonomy and autonomous vehicles (AV), we refer to stage 4 of the NHTSA's scale of autonomy—i.e., full self-driving automation in which the passengers are not expected to take control for the entire duration of travel.*

- **An Impending Transformation.** Our analysis suggests these changes could occur more quickly and at greater scale than many are prepared for, especially in densely populated areas. If shared and autonomous vehicles are adopted as quickly as other technologies (like smartphones, cellphones, and the Internet), our modeling finds that significant change will begin within five years and that the market for personal mobility could transform dramatically over the next 25 years (see Appendix for additional details). Population growth and the extension of transportation to the previously immobile, such as adolescents, elderly, lower-income groups, and those with disabilities, could cause total miles driven to increase by as much as 25% by 2040. Of course, if these services and technologies are adopted at slower rates more akin to electricity, the radio, or the television, the speed and magnitude of the changes will lessen accordingly and potentially significantly.

Future-Proofing Cities over the Next Decade for Driverless Cars

Leslie Braunstein | Urban Land Institute, May 25, 2017

- Driverless cars could reduce the need for up to half the nation's billion or so parking spaces over the next half century, freeing 3 million acres—an area the size of Connecticut—for development or green space to help cool overheated cities, noted ULI Global CEO Patrick Phillips during the conference's luncheon session
- Revathi Greenwood, director of research and analysis for CBRE suggests a timeline that has four stages as driverless cars become more autonomous:

– Technology development stage (2016-2020): licensed drivers with full legal responsibility for the vehicle required.

– Partial driver substitution (2020-2025): requirements for legally responsible drivers relaxed.

– Complete self-driving (2025-2029): vehicles can drive and park themselves, but drivers can intervene.

– Widespread adoption (2029 and beyond): cars are completely self-driven, and drivers have limited to no control. Car ownership will shift to a "pay-per-mile" approach, and the U.S. economy will be significantly altered.

Mary Berra | CEO, General Motors

"The auto industry is poised for more change in the next five to ten years than it has seen in the past 50."

Autonomous Vehicle Implementation Predictions

The following section quotes extensively from Todd Litman's May 2017 white paper on "**Autonomous Vehicle Implementation Predictions: Implications for Transport Planning**".

Autonomous (also called self-driving, driverless, or robotic) vehicles have long been predicted in science fiction and discussed in popular media. Recently, major corporations have announced plans to begin selling such vehicles, and some jurisdictions have passed legislation to allow such vehicles to operate legally on public roads (Wikipedia 2013).

Levels of Autonomous Vehicles (NHTSA 2013)
Level1—Function-specific Automation Automation of specific control functions, such as cruise control, lane guidance and automated parallel parking. Drivers are fully engaged and responsible for overall vehicle control (hands on the steering wheel and foot on the pedal at all times).
Level 2 — Combined Function Automation Automation of multiple and integrated control functions, such as adaptive cruise control with lane centering. Drivers are responsible for monitoring the roadway and are expected to be available for control at all times, but under certain conditions can disengage from vehicle operation (hands off the steering wheel and foot off pedal simultaneously).
Level 3 — Limited Self-Driving Automation Drivers can cede all safety-critical functions under certain conditions and rely on the vehicle to monitor when conditions require transition back to driver control.
Level 4—Self-driving Under Specified Conditions Vehicles can perform all driving functions under specified conditions.
Level 5 — Full Self-Driving Automation System performs all driving functions on normal road types, speed ranges, and environmental conditions.

Much speculation surrounds autonomous vehicle impacts. Advocates predict that affordable, self-driving vehicles will greatly reduce traffic and parking costs, accidents and pollution emissions, and chauffeur non-drivers, reducing roadway costs and eliminating the need for conventional public transit services. In this scenario, the resulting savings will be so great that such vehicles will soon be ubiquitous and everyone will benefit. However, it is possible that their benefits will be smaller and their costs greater than these optimist predictions assume. Only recently have transportation practitioners explored how autonomous vehicles will affect planning decisions such as roadway design, parking costs, and public transit demand.

Estimated Benefits and Costs

Potential Benefits

Advocates predict that autonomous vehicles will provide significant user convenience, safety, congestion reductions, fuel savings, and pollution reduction benefits. Such claims may be overstated. For example, advocates argue that because driver error contributes to more than 90% of traffic accidents, self-driving cars will reduce crashes by 90%. If they feel safer, vehicle occupants may reduce seatbelt use, other road users may become less cautious, vehicles may operate faster and closer together, and human drivers may be tempted to join autonomous vehicle platoons, which will introduce new risks and enforcement requirements.

Estimated congestion and parking cost reductions, energy savings and emission reductions are also uncertain due to interactive effects. For example, the ability to work and rest while traveling may induce some motorists to choose larger vehicles that can serve as mobile offices and bedrooms ("commuter sex" may be a marketing strategy) and drive more annual miles. Self-driving taxis and self-parking cars may increase empty vehicle travel. Although the additional vehicle travel provides user benefits (otherwise, users would not increase their mileage) it can increase external costs, including congestion, roadway and parking facility costs, accident risk imposed on other road users, and pollution emissions. Strategies, such as platooning, may be limited to grade-separated roadways, increasing congestion on surface streets by human-driven vehicles. Autonomous vehicles may also reduce public transit travel demand, leading to reduced service and stimulating more sprawled development patterns which reduce transport options and increase total vehicle travel.

Potential Costs

The incremental costs of producing autonomous vehicles are uncertain. AVs require a variety of special sensors, computers, and controls, which currently are expensive but likely to become cheaper with mass production. Because system failures could be fatal to both vehicle occupants and other road users, all critical components will need to meet high manufacturing, installation, repair, testing, and maintenance standards, similar to aircraft components, and so will probably be relatively expensive. Autonomous vehicle operation may require special navigation and mapping service subscriptions (which explains Google Corporation's interest in this technology). Simpler technologies still add hundreds of dollars to vehicle retail prices.

For example, GPS and telecommunications systems, review cameras, and automatic transmissions typically cost $500 to $2,000. Navigation and security services such as OnStar and TomTom have $200 to $350 annual fees. Autonomous vehicles require these plus other equipment and services (see box below).

Autonomous Vehicle Equipment and Service Requirements
Automatic transmissions.
Diverse and redundant sensors (optical, infrared, radar, ultrasonic and laser) capable of operating in diverse conditions (rain, snow, unpaved roads, tunnels, etc.).
Wireless networks. Short range systems for vehicle-to-vehicle communications, and long-range systems to access maps, software upgrades, road condition reports, and emergency messages.
Navigation, including GPS systems and special maps.
Automated controls (steering, braking, signals, etc.) Servers, software, and power supplies with high reliability standards.
Additional testing, maintenance, and repair costs for critical components, such as sensors and controls.

Manufacturers will need to recover costs for development, ongoing service (special mapping and software upgrades) and liability, while earning a profit. This suggests that when technology is mature, self-driving capability will probably add several thousand dollars to vehicle purchase prices, plus a few hundred dollars in annual service costs, adding $1,000 to $3,000 to annual vehicle costs. These incremental costs may be partly offset by fuel and insurance savings averaging approximately $2,000 for fuel and $1,000 for insurance per vehicle-year. If autonomous vehicles reduce fuel consumption by 10% and insurance costs by 30%, the annual savings will total about $500, which will not fully offset predicted incremental annual costs.

Autonomous vehicles can be programmed to optimize occupant comfort. Some argue that because vehicle passengers tend to be more sensitive to acceleration than drivers, and occupants use travel time to work or rest (autonomous vehicle illustrations often show occupants playing cards or sleeping), it is plausible that users will program their vehicle for slower acceleration/deceleration characteristics than human powered vehicles, leading to reduced urban roadway capacity.

Shared Vehicles

Some advocates claim that self-driving capabilities will result in more vehicle sharing, including self-driving taxis and more private vehicle ridesharing. Estimates show that by allowing household vehicles to serve multiple residents, for example, taking a commuter to work and then transporting another household member for errands, vehicle ownership could be reduced by up to 43% and travel per vehicle increased by up to 75%, but these impacts are difficult to predict. There are many reasons that motorists may prefer a personal rather than shared vehicle—keeping tools or carrying dirty loads, because driving many annual miles, needing assistance provided by human drivers, or simply, for status. Autonomous taxis are likely to incur these additional costs:

- **Vehicle travel to trip origins.** This may be a modest cost in dense urban areas where taxis are widely distributed, but likely to add 10-20% to total vehicle travel in lower-density suburban and rural areas or for specialized vehicles, such as vans and trucks.
- **Cleaning and vandalism.** Taxis and public transit vehicles require frequent cleaning when passengers litter, smoke, or spill food and drinks, and repairs when vehicles are vandalized. To minimize these risks, self-driving taxis will need hardened surfaces, electronic surveillance, and aggressive enforcement. Assuming such vehicles make 200 weekly trips, 5-15% of passengers leave messes with $10-30 average cleanup costs, and 1-4% vandalize vehicles with $50-100 average repair costs, these costs would average between $200 and $1,700 per vehicle-week.
- **Reduced services.** Drivers often help passengers (particularly those with disabilities) in and out of taxis, carry luggage, ensure passengers safely reach destinations, and offer guidance to visitors.
- **Reduced comfort and privacy.** Vehicles designed to minimize cleaning and vandalism risks will probably have less comfort (no leather upholstery or carpeted floors), fewer accessories (limited sound systems), and less reliability (since vehicles will frequently need cleaning and repairs) than personal vehicles. Passengers will need to accept that their activities will be recorded.

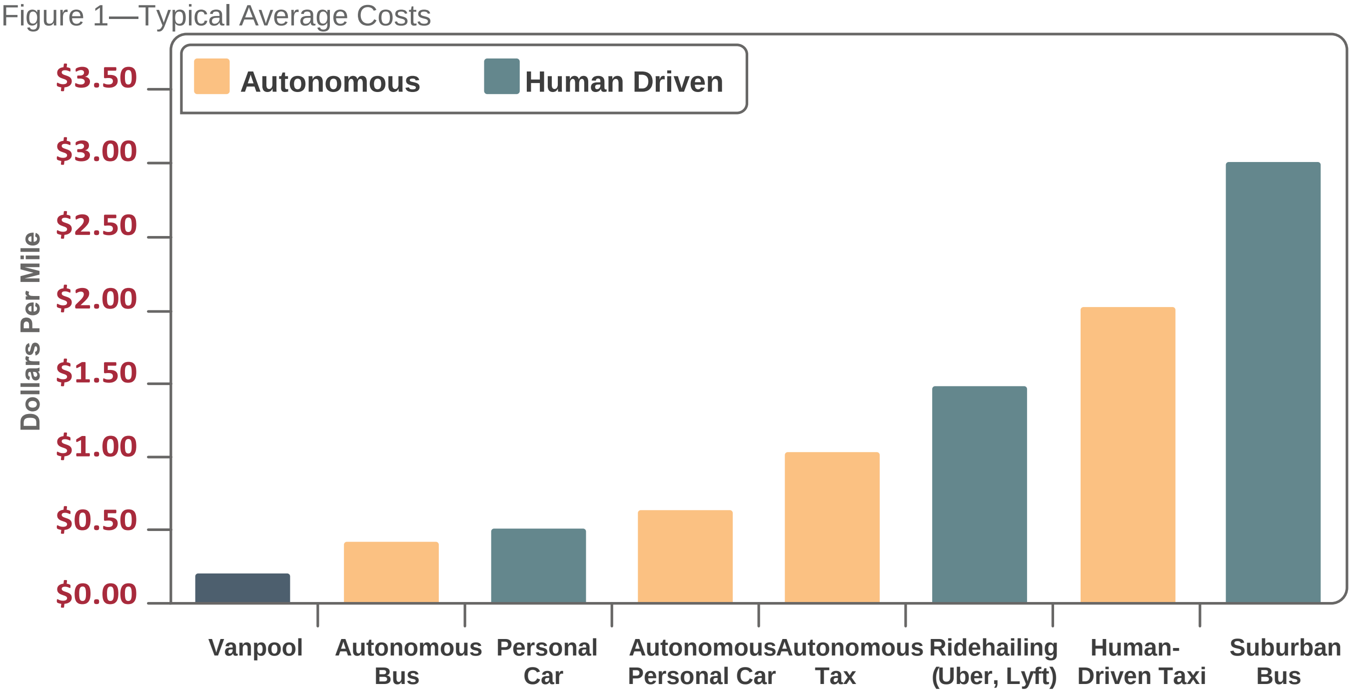
Personal automobiles typically cost about $4,000 annually in fixed expenses plus 20¢ per mile in operating costs. It is generally cheaper to use conventional taxis ($2-3 per mile) rather than own a personal vehicle driven less than about 2,500 annual miles, or rely on carsharing services ($60¢-$1 per mile) rather than own a vehicle driven less than about 6,000 annual miles. This suggests that autonomous vehicles will be a cost-effective alternative to owning a vehicle driving less than 2,500 to 6,000 annual miles, depending on cleaning and repair costs. **Table 1** summarizes trip types most suitable for self-driving taxis, a minority of total vehicle travel. Because of these additional costs, and reduced passenger comfort and privacy, it seems unlikely that most motorists will shift from owning vehicles to relying on self-driving taxis.

Table 1—Likely Uses of Self-Driving Taxis	
Suitable Uses	**Unsuited Uses**
Trips currently made by taxi or carshare vehicles. Utilitarian trips currently made by a private vehicle driven less than 6,000 annual miles.	Motorists who take pride in vehicles or value extra comfort. Motorists who drive more than 6,000 annual miles. Motorists who require special accessories in their vehicles. Motorists who often carry tools or dirty loads. Passengers who want assistance getting in and out of taxis. Passengers who place high values on privacy.

Self-driving taxis may allow some motorists to reduce their vehicle ownership, but impacts are likely to be modest and will depend on factors such as cleaning and vandalism costs, user comfort, and privacy.

Various studies have estimated that shared autonomous vehicles will cost $0.20-0.40 per passenger-mile (Bösch, et al. 2017), but these are mostly lower estimates that exclude some cost categories (such as vehicle cleaning, administration, and profits), use optimistic cost and occupancy assumptions, and ignore empty vehicle travel required for taxi services. A more realistic estimate for shared autonomous vehicle costs is likely to range from carsharing ($0.60- $1.00 per vehicle-mile, including ownership, operation and administrative costs) to human-operated taxis ($2.00-3.00 per vehicle-mile, including ownership, operation, administration and labor costs). Autonomous taxis will probably cost more per passenger-mile than transit bus service under urban conditions, but less than under suburban conditions.

Figure 1—Typical Average Costs



Vehicle costs vary depending on type, occupancy and travel conditions. Autonomous vehicles will cost somewhat more than human-powered cars, due to additional equipment and navigation systems required, but can offer somewhat cheaper taxi and bus services than those that are human-powered.

Impacts on Total Vehicle Travel

Table 2 lists various ways that autonomous vehicles can affect total vehicle travel (vehicle miles traveled or VMT). Although it is difficult to predict how these factors will interact, many studies suggest that by making vehicle travel more convenient, autonomous vehicles are likely to increase total vehicle travel unless specific demand management strategies are implemented, such as higher road user fees (Smith 2012). Trommer, et al. (2016) estimates that autonomous vehicles are likely to increase total vehicle travel 3-9% by 2035.

Table 2—Autonomous Vehicle Impacts on Total Vehicle Travel

Increases Vehicle Travel	**Reduces Vehicle Travel**
More convenient and productive travel (passengers can rest and work) will reduce travel time costs, stimulating more vehicle travel.	
Provides convenient vehicle travel to non-drivers (people too young, old, disabled, impaired, or otherwise lacking a drivers' license. Sivak and Schoettle (2015c) estimate that, accommodating non-drivers' latent travel demands could increase total vehicle by up to 11%.	More convenient shared vehicles allows households to reduce total vehicle ownership and use.
Self-driving taxis will travel more for empty back hauls.	Increases vehicle ownership and operating costs, further reducing private vehicle ownership.
Can make sprawled, automobile-dependent locations more attractive.	Self-driving transit vehicles improve transit services.
Reduces traffic congestion and vehicle operating costs, which induces additional vehicle travel.	Reduced pedestrian risks and parking demands makes urban living more attractive.
	Reduce some vehicle travel, such as cruising for parking spaces.

Self-driving vehicles can affect total vehicle travel (VTM) in various ways.

These scenarios illustrate how autonomous vehicles could impact various users travel patterns:

Jake is an affluent man with degenerating vision. In 2026, his doctor convinced him to give up driving. He purchases an autonomous vehicle instead of walking, transit, and taxis.

Impacts: An autonomous vehicle allows Jake to continue using a car, which increases his independent mobility, total vehicle ownership and travel, residential parking demand, and external costs (congestion, roadway costs, parking subsidies, and pollution emissions), compared with what would otherwise occur.

Bonnie lives and works in a suburb. She can bike to most destinations but occasionally needs to travel by car. In a city, she could rely on taxis and carsharing but such services are slow and expensive in suburbs. In 2030, a local company started offering fast and affordable automated taxi services.

Impacts: Autonomous vehicles allow Bonnie to rely on shared vehicles rather than purchase a car, which reduces her total vehicle travel, residential parking demand, and external costs.

Malisa and Johnny have two children. Malisa works at a downtown office. After their second child was born in 2035, they shopped for a larger home. With conventional cars, they would only consider houses within a 30-minute drive of the city. More affordable autonomous vehicles allowed them to consider more distant homes, with commutes up to 60-minutes, during which Malisa could rest and work.

Impacts: Affordable new autonomous vehicles allow Malisa and Johnny to choose an exurban home which increased their total vehicle travel and associated costs, plus other costs caused by sprawl.

Garry is hardworking and responsible when sober, but a dangerous driver when drunk. By 2040, he has accumulated several impaired citations and caused a few accidents. With conventional cars, Garry would continue driving impaired until he lost his drivers' license or caused a severe crash, but affordable used self-driving vehicles allow lower-income motorists like Garry to avoid such problems.

Impacts: Affordable used autonomous vehicles allow Garry to avoid impaired driving, accidents and revoked driving privileges, which reduces crash risks but increases his vehicle ownership and travel, and external costs compared with what would otherwise occur.

Table 3 summarizes the resulting impacts of these various scenarios. This suggests that in many cases autonomous vehicles will increase total vehicle mileage.

Table 3—Autonomous Vehicle Scenario Summary

	User Benefits	**Travel Impacts**	**Infrastructure Impacts**
Jake	Independent mobility for nondrivers	Increased vehicle travel and external costs	Increased residential parking and roadway costs
Bonnie	Vehicle cost savings	Reduced vehicle ownership and travel	Reduced residential parking and roadway costs
Malisa & Johnny	Improved home location options	Increased vehicle ownership and travel	Increased residential parking and roadway costs
Garry	Avoids driving drunk and associated consequences	Less high-risk driving, more total vehicle travel	Increased residential parking and roadway costs

Autonomous vehicle availability can have various direct and indirect impacts.

This analysis suggests that effects which increase motor vehicle travel are more numerous and significant than those that reduce vehicle travel. With that in mind, self-driving vehicles are likely to increase total vehicle travel, although these impacts are difficult to predict and will depend on specific autonomous vehicle implementation, such as their actual performance and user costs as well as other factors that affect vehicle travel such as fuel and road prices. Increases in total vehicle travel may be somewhat offset by reductions in per-mile costs of this incremental travel. For example, self-driving cars may impose less traffic congestion, parking costs, accident risk, and air pollution costs than human-operated vehicles per mile traveled which would counter the increased vehicle travel costs although the net effects are uncertain.

Summary of Benefits and Costs

Table 4 summarizes expected autonomous vehicle benefits and costs.

Table 4—Autonomous Vehicle Potential Benefits and Costs

Benefits	Costs/Problems
Reduced driver stress. Reduce the stress of driving and allow motorists to rest and work while traveling. ***Reduced driver costs.*** Reduce costs of paid drivers for taxis and commercial transport. ***Mobility for non-drivers.*** Provide independent mobility for non-drivers, and therefore reduce the need for motorists to chauffeur non-drivers, and to subsidize public transit. ***Increased safety.*** May reduce many common accident risks and therefore crash costs and insurance premiums. May reduce high-risk driving, such as when impaired. ***Increased road capacity, reduced costs.*** May allow platooning (vehicle groups traveling close together), narrower lanes, and reduced intersection stops, reducing congestion and roadway costs. *More efficient parking, reduced costs*. Can drop off passengers and find a parking space, increasing motorist convenience and reducing total parking costs. *Increase fuel efficiency and reduce pollution.* May increase fuel efficiency and reduce pollution emissions. ***Supports shared vehicles.*** Could facilitate carsharing (vehicle rental services that substitute for personal vehicle ownership), which can provide various savings.	***Increases costs.*** Requires additional vehicle equipment, services and maintenance, and possibly roadway infrastructure. *Additional risks.* May introduce new risks, such as system failures, be less safe under certain conditions, and encourage road users to take additional risks (offsetting behavior). ***Security and Privacy concerns.*** May be used for criminal and terrorist activities (such as bomb delivery), vulnerable to information abuse (hacking), and features such as GPS tracking and data sharing may raise privacy concerns. ***Induced vehicle travel and increased external costs.*** By increasing travel convenience and affordability, autonomous vehicles may induce additional vehicle travel, increasing external costs of parking, crashes and pollution. ***Social equity concerns.*** May have unfair impacts, for example, by reducing other modes' convenience and safety. ***Reduced employment and business activity.*** Jobs for drivers should decline, and there may be less demand for vehicle repairs due to reduced crash rates. ***Misplaced planning emphasis***. Focusing on autonomous vehicle solutions may discourage communities from implementing more cost-effective transport solutions such as better walking and transit improvements, pricing reforms and other demand management strategies.

Autonomous vehicles can provide various benefits and impose various costs.

Some impacts, such as reduced driver stress and increased urban roadway capacity, can occur under level 2 or 3 implementation, which provides limited self-driving capability, but many benefits, such as significant crash reductions, road and parking cost savings and affordable mobility for non-drivers, require that level 4 vehicles become common and inexpensive.

Development and Deployment

Table 5 summarizes the likely stages of autonomous vehicle development and deployment.

Table 5—Autonomous Vehicle Implementation Stages
(Wikipedia 2013; NHTSA 2013)

Stage	Notes
Level 2—Limited automation (steering, braking and lane guidance)	Current state of art technology, available on some vehicles.
Coordinated platooning	Currently technically feasible but requires vehicle-to-vehicle communications capability, and dedicated lanes to maximize safety and mobility benefits.
Level 3—Restricted self-driving	Currently being tested. Google experimental cars have driven hundreds of thousands of miles in self-drive mode under restricted conditions.
Level 4—Self-driving in all conditions	Requires more technological development.
Regulatory approval for automated driving on public roadways.	Some states have started developing performance standards and regulations that autonomous vehicles must meet to legally operate on public roads.
Fully-autonomous vehicles available for sale.	Several companies predict commercial sales of "driverless cars" between 2018 and 2020, although their capabilities and prices are not specified.
Autonomous vehicles become a major portion of total vehicle sales.	Will depend on performance, prices and consumer acceptance. New technologies usually require several years to build market acceptance.
Autonomous vehicles become a major portion of vehicle fleets.	As the portion of new vehicles with autonomous driving capability increases, their portion of the total vehicle fleet will increase over a few decades.
Autonomous vehicles become a major portion of vehicle travel.	Newer vehicles tend to be driven more than average, so new technologies tend to represent a larger portion of vehicle travel then the vehicle fleet.
Market saturation.	Everybody who wants an autonomous vehicle has one.
Universal	All vehicles operate autonomously.

Autonomous vehicle implementation will involve several phases.

As of 2016, many new vehicles have some level 1 automation features, including cruise control, obstruction warning, and parallel parking. Some manufactures, such as Tesla, now offer level 2 features such as automated lane guidance, accident avoidance, and driver fatigue detection. Coordinated platooning is now technically feasible but not operational because many benefits require dedicated lanes. Google's level 3 test vehicles have reportedly driven hundreds of thousands of miles under restricted conditions, including specially mapped routes, fair weather, and human drivers able to intervene when needed (Muller 2013). Some manufacturers aspire to sell level 4 automation vehicles within a few years but details are uncertain; early versions will probably be limited to controlled environments, such as freeways (Row 2013).

Despite this progress, significant technical improvement is needed to achieve unrestricted level 4 operation (Simonite 2016). Since a failure could be deadly to vehicle occupants and other road users, automated driving has high performance requirements. Sensors, computers, and software must be robust, redundant, and resistant to abuse.

Several more years of development and testing will be required before regulators and potential users gain confidence that level 4 vehicles can operate as expected under all conditions (Bilger 2013; Schoettle and Sivak 2015).

Implementation Projections

Autonomous vehicle implementation can be predicted based on the pattern of previous vehicle technologies, and vehicle fleet turnover rates.

- **Automatic Transmissions** (Healey 2012). First developed in the 1930s, automatic transmissions were not reliable and affordable until the 1980s. Now standard on most U.S. medium and high-priced vehicles, although some models have manual mode. When optional, they typically cost $1,000 to $2,000. Current vehicle market shares are about 90% in North America and 50% in Europe and Asia.
- **Air Bags** (Dirksen 1997). First introduced in 1973, this feature was initially an expensive and sometimes dangerous option (they could cause injuries and deaths). As air bags became cheaper and safer, they became standard on some models starting in 1988, and mandated by U.S. federal regulation in 1998.
- **Hybrid Vehicles** (Berman 2011). Commercially available in 1997, the prices of these vehicles were high and the performance was poor. Their performance and usability has improved but typically add about $5,000 to vehicle prices. In 2012, they represented about 3.3% of total vehicle sales.
- **Subscription Vehicle Services.** Navigation, remote lock/unlock, diagnostics, and emergency services. OnStar became available in 1997, TomTom in 2002. These systems typically cost $200-400 annually. About 2% of U.S. motorists subscribe to the largest service, OnStar.
- **Vehicle Navigation Systems** (Lendion 2012). Vehicle navigation systems became available as expensive accessories in the mid-1980s. In the mid-1990s, factory-installed systems became available on some models for about $2,000. Performance and usability have since improved, and prices have declined to about $500 for factory-installed systems and under $200 for portable systems. They are standard in many higher-priced models.

Table 6 summarizes the deployment cycles for these technologies—from first commercial availability to market saturation. Most technologies require decades of development and market growth to saturate their potential markets and, in many cases, never become universal. Airbags had the shortest cycle and the most complete market share due to federal mandates. Automatic transmissions required more than five decades for prices to decline and quality to improve, but are still not universal. Hybrid vehicles are still developing after 15 years on the market, have substantial price premiums, and modest market share. This suggests that new vehicle technologies generally require two to five decades from commercial availability to market saturation, and will not become universal without government mandates.

Table 6—Vehicle Technology Deployment Summary

Name	Deployment Cycle	Typical Cost Premium	Market Saturation Share
Air bags	25 years (1973-1998)	A few hundred dollars	100%, due to federal mandate
Automatic transmissions	50 years (1940s-1990s)	$1,500	90% U.S., 50% worldwide
Navigation systems	30+ years (1985-2015+)	$500 and rapidly declining	Uncertain; probably over 80%
Optional GPS services	15 years	$250 annual	2-5%
Hybrid vehicles	25+ years (1990s-2015+)	$5,000	Uncertain. Currently about 4%

New technologies usually require several decades between commercial availability to market saturation.

Modern vehicles are durable, resulting in slow fleet turnover. Median operating lives increased from 11.5 years for the 1970 model year, to 12.5 years for the 1980 model year, and 16.9 years for the 1990 model year (ORNL 2012, Table 3.12), suggesting that current vehicles may have 20-year or longer average lifespans. As a result, new vehicle technologies normally require three to five decades to be implemented in 90% of operating vehicles. Deployment may be faster in developing countries where fleets are expanding, and in areas with strict vehicle inspection requirements, such as Japan's shaken system. Annual mileage tends to decline as vehicles age. For example, 2001 vehicles averaged approximately 15,000 miles their first year, 10,000 miles their 10th year, and 5,000 miles their 15th year. Vehicles older than ten years represent about 50% of the vehicle fleet but only about 20% of vehicle mileage (ORNL 2012, Table 3.8).

As previously described, autonomous driving capability will probably increase vehicle purchase prices by thousands of dollars, and may require hundreds of dollars in annual subscription fees for special navigation and mapping services. Although self-driving vehicles may provide large benefits to some users (high-income non-drivers, long-distance automobile commuters, and commercial drivers), it is unclear what portion of motorists will consider the benefits worth the additional costs. A recent consumer survey found general support for the concept, but also significant concerns about privacy and safety, and relatively low willingness to pay extra for self-driving capability features (Schoettle and Sivak 2014).

Table 7 summarizes projected autonomous vehicle implementation rates based on previous vehicle technology deployment. This assumes that fully-autonomous vehicles are available for sale and legal to drive on public roads around 2020. As with previous vehicle technologies, these AVs will be imperfect initially (poor reliability and performance, and difficult to operate) and costly (tens of thousands of dollars in price premiums). As such, they will represent a small portion of total vehicle sales, with market share increasing during subsequent decades as their performance improves, prices decline, and benefits are demonstrated. Over time they will increase as a share of total vehicle fleets. Since newer vehicles are driven more than average annual miles, their share of vehicle travel is proportionately large. Without mandates, deployment will probably follow the pattern of automatic transmissions, which took nearly five decades to reach market saturation, and a portion of motorists continue to choose manual transmissions due to personal preferences and cost savings.

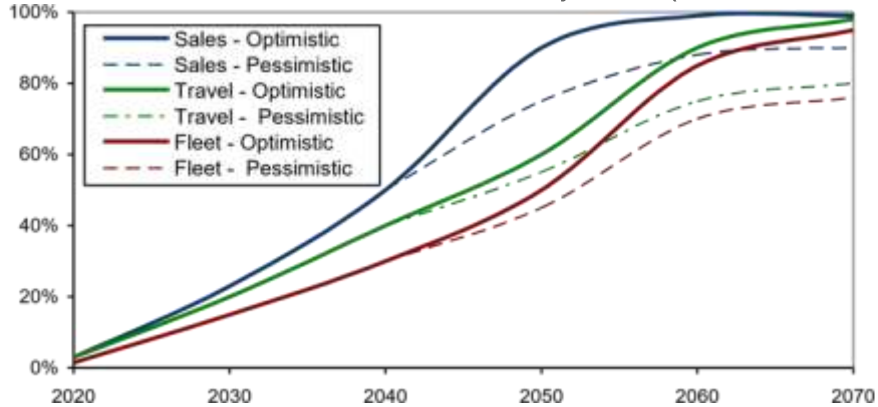
Table 7—Autonomous Vehicle Implementation Projections

Stage	Decade	Vehicle Sales	Vehicle Fleet	Vehicle Travel
Available with large price premium	2020s	2-5%	1-2%	1-4%
Available with moderate price premium	2030s	20-40%	10-20%	10-30%
Available with minimal price premium	2040s	40-60%	20-40%	30-50%
Standard feature included on most new vehicles	2050s	80-100%	40-60%	50-80%
Saturation (everybody who wants it has it)	2060s	?	?	?
Required for all new and operating vehicles	???	100%	100%	100%

Autonomous vehicle implementation will probably take several decades.

Figure 2 illustrates the deployment rates from Table 6. If accurate, in the 2040s autonomous vehicles will represent approximately 50% of vehicle sales, 30% of vehicles, and 40% of all vehicle travel in the 2040s. Only in the 2050s would most vehicles be capable of automated driving.

Figure 2—Autonomous Vehicle Sales, Fleet, and Travel Projections *(based on Table 6)*



If autonomous vehicle implementation follows the patterns of other vehicle technologies, it will take one to three decades to dominate vehicle sales, plus one or two more decades to dominate vehicle travel. Even at market saturation, it is possible that a significant portion of vehicles and vehicle travel will continue to be self-driven, indicated by the dashed lines.

Autonomous vehicle implementation could be even slower and less complete than these predictions. Technical challenges may be more difficult to solve than expected, so fully self-driving vehicles may not be commercially available until the 2030s or 2040s. They may have higher than expected production costs and retail prices, their benefits may be smaller and problems greater than predicted, and technical constraints, privacy concerns, and personal preference may reduce consumer acceptance, resulting in a significant portion of vehicle travel remaining human-driven even after market saturation.

Significantly faster implementation would require much faster development, deployment, and fleet turnover than previous vehicle technologies. For example, for the majority of vehicle travel to be autonomous by 2035, most new vehicles purchased after 2025 would need to be autonomous. New vehicle purchase rates would need to triple allowing the fleet turnover process that normally takes three decades to occur in one. This would require most low- and middle-income motorists, who normally purchase used vehicles or cheaper new models, to spend significantly more to purchase an automobile with self-driving capability. As a result, many otherwise functional vehicles be scrapped just because they lack self-driving capability.

Planning Implications

Autonomous vehicle implementation is just one of several factors likely to affect future transport demands and costs, as illustrated in Figure 3. Demographic trends, changing consumer preferences, price changes, improving transport options, improved user information, and other planning innovations will also influence how and how much people drive. These may have greater planning impacts than autonomous vehicles, at least until the 2040s.

Figure 3—Factors Affecting Transport Demands and Costs

Autonomous vehicles are one of many factors that will affect transport demands and costs in the next few decades, and not necessarily the most important.

DEMOGRAPHIC TRENDS
Aging population
More working at home
Reduced youth driver's license

PRICE CHANGES
Rising fuel prices
Efficient road & parking pricing

IMPROVED TRAVEL OPTIONS
Better walking and cycling
Improved public transit
Telework and delivery services
Car sharing

CHANGING USER PREFERENCES
Less driving
Shared rather than personal cars
More walking & cycling
More urban living

INTELLIGENT TRANSPORT SYSTEMS (ITS)
Improved information navigation
Electronic pricing
Autonomous vehicles

PLANNING INNOVATIONS
Expanded objectives
Systems operations
Demand management

Table 8 summarizes the functional requirements and planning implications of various autonomous vehicle impacts and their expected time period based on Table 5 projections. This suggests that during the 2020s and 2030s, transport planners and engineers will be primarily concerned with defining autonomous vehicle performance, testing, and reporting requirements for operation on public roadways. If several years of testing demonstrate autonomous vehicle benefits, transport professionals may support policies that encourage or require self-driving capability in new vehicles.

Parking requirements may be reduced when AVs can provide convenient and inexpensive taxi and carsharing services, reduce the need for conventional public transit services, allow more households to rely on such services, and reduce vehicle ownership. However, modeling by the International Transport Forum indicates that self-driving taxis and public transit services are complements rather than substitutes. Transit is more efficient at serving many peak period urban trips which would significantly reduce the self-driving taxi fleet size and costs.

Some benefits (higher traffic speeds, reduced congestion, and automated intersections) require dedicated autonomous vehicle lanes. This will raise debates about fairness and cost efficiency, and human drivers may be tempted to use such lanes. For example, following a platoon of self-driving vehicles would introduce new risks, regulations, and enforcement requirements, probably starting in the 2030s.

Table 8—Autonomous Vehicle Planning Impacts By Time Period			
Impact	**Functional Requirements**	**Planning Impacts**	**Time Period**
Become legal	Demonstrated functionality and safety	Define performance, testing, and data collection requirements for automated driving on public roads.	2015-25
Increase traffic density by vehicle coordination	Road lanes dedicated to vehicles with coordinated platooning capability	Evaluate impacts. Define requirements. Identify lanes to be dedicated to vehicles capable of coordinated operation.	2020-40
Independent mobility for non-drivers	Fully autonomous vehicles available for sale	Allows affluent non-drivers to enjoy independent mobility.	2020-30s
Automated carsharing/taxi	Moderate price premium. Successful business model.	May provide demand response services in affluent areas. Supports carsharing.	2030-40s
Independent mobility for lower-income	Affordable autonomous vehicles for sale	Reduced need for conventional public transit services in some areas.	2040-50s
Reduced parking demand	Major share of vehicles are autonomous	Reduced parking requirements.	2040-50s
Reduced traffic congestion	Major share of urban peak vehicle travel is autonomous.	Reduced road supply.	2050-60s
Increased safety	Major share of vehicle travel is autonomous	Reduced traffic risk. Possibly increased walking and cycling activity.	2040-60s
Energy conservation and emission reductions	Major share of vehicle travel is autonomous. Walking and cycling become safer.	Supports energy conservation and emission reduction efforts.	2040-60s
Improved vehicle control	Most or all vehicles are autonomous	Allows narrower lanes and interactive traffic controls.	2050-70s
Need to plan for mixed traffic	Major share of vehicles are autonomous.	More complex traffic. May justify restrictions on human-driven vehicles.	2040-60s
Mandated	Most vehicles are autonomous and large benefits are proven.	Allows advanced traffic management.	2060-80s

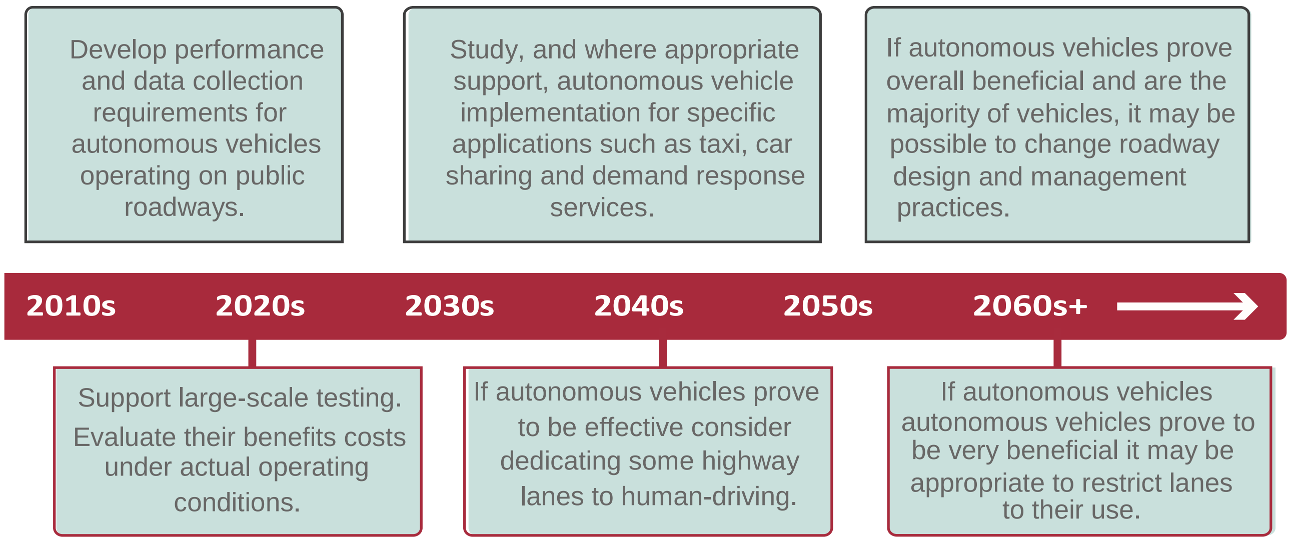
Autonomous vehicles will have various impacts on transportation planning.

When autonomous vehicles become a major share of total vehicle travel they may significantly reduce traffic risk and congestion, and parking problems, while providing some energy savings and emission reductions. Transportation professionals will be involved in technical analyses to determine their actual benefits and policy debates concerning whether public policies should encourage or require autonomous vehicles.

These impacts may vary geographically, with more rapid implementation in areas that are more affluent (residents can more quickly afford autonomous vehicles), more congested (potential benefits are greater), and have more public support.

The timeline in Figure 4 summarizes autonomous vehicle planning impact projections.

Figure 4—Autonomous Vehicle Planning Impacts Timeline



This timeline summarizes how autonomous vehicles are likely to impact transport planning.

An Analogy: Automated Banking Services

Personal computers first became available for purchase during the 1970s, the Internet went public in the 1980s, automated teller machines (ATMs) became common in the 1990s, most households were using the Internet for personal business activities by the 2000s. Similarly, banks have encouraged customers to use central call centers rather than local offices to answer questions for decades, yet these technologies have not eliminated the need for local banks with human tellers.

Automated banking can reduce the number of branch offices and employees, but customers often prefer to interact with human tellers because it can be faster and less frustrating, and therefore, more productive than automated, Internet, or telephone options. Automation has had evolutionary rather than revolutionary impacts on bank activities. Other trends—banking services, changing regulations, and management practices—have equal or greater impacts on bank infrastructure planning.

Autonomous vehicle implementation will probably follow similar patterns. Deployment will take several decades, is unlikely to totally displace current technology, will have costs as well as benefits, and will only marginally affect infrastructure planning for the foreseeable future. It is one of several current trends likely to affect road, parking, and transit demands, and these changes will probably occur gradually over several decades.

Conclusions

Recent announcements that autonomous vehicles have safely driven hundreds of thousands of miles and that major manufactures aspire to soon sell such vehicles coupled with optimistic predictions of their benefits, have raised hopes that this technology will soon be widely available and solve many transportation problems. However, there are good reasons to be cautious when predicting their future role.

There is considerable uncertainty concerning autonomous vehicle benefits, costs, and travel impacts. Advocates claim that they will provide large benefits that offset costs, but will require additional equipment, services, and maintenance costs that will likely total hundreds or thousands of dollars per vehicle-year. Moreover, many of their benefits are unproven.

Current automated vehicles can only self-drive under limited conditions. Significant technical and economic obstacles must be overcome before most households can rely on AVs for daily travel. Operating a vehicle on public roads is more complex than flying an airplane due to the frequency and proximity of interactions with often unpredictable objects, including other vehicles, pedestrians, animals, buildings, trash, and potholes. If AVs follow previous vehicle technology deployment patterns, autonomous vehicles will initially be costly and imperfect. During the 2020s and perhaps the 2030s, autonomous vehicles are likely to be expensive novelties with limited abilities, such as restrictions on the road conditions in which they may operate. It will probably be the 2040s or 2050s before middle-income families can afford to own self-driving vehicles that safely operate in all conditions, and even longer before used autonomous vehicles become affordable to lower-income households. A significant portion of motorists may resist such vehicles, just as some motorists prefer manual transmissions, resulting in mixed traffic that creates new roadway management problems.

Vehicle innovations tend to be implemented more slowly than other technological changes due to their high costs, slow fleet turnover, and strict safety requirements. Automobiles typically cost 50 times as much and last ten times as long as mobile phones and personal computers. As such, consumers seldom purchase new vehicles just to obtain a new technology. Autonomous vehicles will likely have relatively costly equipment and service standards, similar to airplanes, which may discourage some users. Large increases in new vehicle purchases and scrappage rates would be required for most vehicles to be autonomous before 2050.

Self-driving taxi costs are likely to range between carsharing ($0.60-1 per mile) and human driven taxis ($2-3 per mile), depending on factors, such as their cleaning costs. This will make them a cost-effective alternative to owning lower mileage (5,000 annual miles) vehicles. However, many motorists are likely to prefer owning personal vehicles for prestige and convenience sake. As a result, shared autonomous vehicles are likely to reduce vehicle ownership mostly in compact, multimodal urban areas, and will have little effect in suburban and rural areas.

Advocates may exaggerate net benefits by ignoring new costs and risks, offsetting behavior (the tendency of road users to take additional risks when they feel safer), rebound effects (increased vehicle travel caused by faster travel or reduced operating costs, which may increase external costs), and harms to people who do not to use the technology, such as reduced public transit service. Benefits are sometimes double-counted by summing increased safety, traffic speeds, and facility savings, although there are trade-offs between them.

Transportation professionals (planners, engineers, and policy analysts) have important roles in autonomous vehicle development and deployment. We can help support their development and testing, and establish performance standards to legally operate on public roads. If such vehicles perform successfully and become common, they may affect planning decisions, such as the supply, design, and operation of roadways, parking, and public transit. To be prudent, such infrastructure changes should only occur after autonomous vehicle benefits, affordability, and public acceptance are fully demonstrated. This may vary—autonomous vehicles may affect some roadways and communities more than others.

A critical question is whether autonomous vehicles increase or reduce total vehicle travel and associated external costs. It could go either way. By increasing travel convenience and comfort, and allowing vehicle travel by non-drivers, total vehicle mileage could be increased. Conversely, carsharing may also be facilitated, which allows households to reduce vehicle ownership and total driving. This review suggests that they will probably increase total vehicle travel unless implemented with offsetting policies, such as efficient road and parking pricing.

Another critical issue is the degree to which potential benefits can be achieved when only a portion of vehicle travel is autonomous. Some benefits, such as improved mobility for affluent non-drivers, may occur when autonomous vehicles are uncommon and costly, but many potential benefits require that most or all vehicles on the road operate autonomously. For example, it seems unlikely that traffic densities can significantly increase, traffic lanes be narrowed, parking supply be significantly reduced, or traffic signals be eliminated until most vehicles on affected roads are capable of self-driving.

A key public policy issue is how much this technology may harm people who do not use such vehicles—for example, if traffic volumes increase, walking and cycling conditions are degraded, conventional public transit service declines, or human-driven vehicles are restricted. Some strategies, such as platooning, may require special autonomous vehicle lanes to achieve benefits. These issues will likely generate considerable debate over their merit and fairness.

Summary

The selected references and excerpts above were pulled from just a few of the research documents collected for this report (a full bibliography is provided at the end). However, several common themes emerged through these expert perspectives.

- The importance of adopting a multi-modal strategy.
- An assumption of significant parking demand reductions once AVs become common place.
- General agreement that full AV implementation (and the anticipated parking demand reductions) are 20-30 years away.
- An acknowledgment that parking structures are designed for 50-75 year lifecyles and that any parking structures being built should consider new design approaches that consider adaptive reuse.
- The importance of considering changes in the millennial generation's travel preferences.
- The importance and impact of shared-use mobility options to provide a full range of mobility options.
- The importance of effective parking management that leverages new technologies to create improved user experiences.

Shared Mobility and "Mobility as a Service"

Information and communication technologies, combined with smartphone applications and location data from global positioning systems, are making feasible transportation services that have long been imagined but never realized on a large scale. These innovations include: carsharing, bikesharing, microtransit services, and most notably, transportation network companies (TNCs), such as Uber and Lyft.

These services are being embraced by millions of travelers who are using their smartphones to arrange for trips by car, shuttle, and public transit, as well as for short-term rental of cars and bicycles. These new services epitomize today's sharing economy and allow an increasing number of people to enjoy the mobility benefits of an automobile without owning one. They may also encourage others to leave their personal vehicle at home for the day, reduce the number of vehicles in their household, or even forgo having one at all.

The Transportation Research Board (TRB) recently released *Special Report 319: Between Public and Private Mobility: Examining the Rise of Technology-Enabled Transportation Services*. This report was developed by a special task force of transportation experts from industry and academia, and identified a range of research needs.

A copy of the report can be downloaded at: http://onlinepubs.trb.org/onlinepubs/sr/sr319.pdf

In a separate but related publication, Xerox's Innovator's *Brief for the Transportation Industry* recently presented "A Three Point Plan to Improve Urban Mobility". This brief highlights the fact that cities are going to get a lot more crowded. Today, 54% of the world's population lives in urban areas. The United Nations estimates that an additional 2.5 billion people could be based in cities by 2050. As our world becomes more urbanized, the issues of traffic congestion, parking, and access management are amplified. Xerox's brief focuses on three key points that can empower cities to be more sustainable and improve the quality of life for residents and tourists.

1. **Improve the efficiency of existing mobility infrastructure.**

   Adding more infrastructure is simply not an option in many urban environments. Using technology, we can move people, vehicles, and goods more efficiently through the existing infrastructure.
2. **Increase the capacity of the existing mobility infrastructure.**

   The goal here is to move more people, vehicles, and goods through the existing infrastructure.
3. **Change the behaviors of urban travelers.**

   This is about influencing the choices that travelers make toward options that reduce congestion. Agencies that implement dynamic pricing can reduce traffic congestion in all electronic toll collection and/or on-street parking situations, using pricing as a mechanism to influence driver choices. Smart parking programs help to increase space availability and reduce pollution by helping drivers get to a parking spot at their desired price point sooner. Incorporating telecommuting into the office culture helps to keep people and vehicles off the roads during the day. Providing accessible multimodal options such as ridesharing, car sharing, and public transportation via mobility apps creates opportunities to make different choices that can result in less personal vehicle usage and less congestion.

Both of these publications reinforce the integration of parking and mobility management strategies into a more comprehensive and connected platform of transportation choices.

The following section illustrates how far we have come in the evolution of shared mobility resources and options. The following list was created for the Silicon Valley "Mobility as a Service" project, where mobility aggregators integrated various services. It maps out the ecosystem of shared mobility options using the following major categories. For each category of shared mobility elements, examples of software or programs are provided.

- Enterprise Commute Trip Reduction (e.g., Luum, Ride Amigos)
- Mobility Aggregators (e.g., Moovit, Moovel, Urban Engines)
- Public Transit (e.g., bus, subway)
- Private Sector Transit (e.g., Bridj, Chariot, Go Carma, Via)
- Rideshare w/in 10 min (e.g., Lyft Carpool, UberPool, Ford Dynamic Social Shuttle)
- Rideshare w/in 24 hours (e.g., Carma, HOVee Carzac)

- Taxi-like services (e.g., Lyft, Uber, Juno, Sidecar)
- Carshare (e.g., Car2Go, Zipcar, Enterprise Car Share)
- P2P Carshare (e.g., Getaround, RelayRides, Ford Car Swap)
- Bikeshare (e.g., Motivate, DecoBike, Bcycle, NextBike)
- Personal Electric Transport (e.g., Enzo foldable ebike, GenZe electric bikes, Scoot (heavy scooter rental)) • Vanpooling (e.g., Enterprise, Vride)
- Commute Mode Detection Technologies (e.g., Strava, MapMyRide, Moves)
- Smartphone Transit Payment (e.g., Passport, GlobeSherpa, Masabi)
- Smartphone Parking (e.g., ParkMe, Parkmobile, Pay-by-Phone)
- Miscellaneous Apps (e.g., City Mapper, Transitscreen, Modify—TDM Trip Planner)
- Commuter Benefits (e.g., Commuter Check Direct,Commuter Benefits, Wageworks)
- Robotaxi (e.g., Uber with Robot Driver)
- Personal Rapid Transit (e.g., 2getthere, Ultra Global (London Heathrow))
- Niche Ride Match (e.g., Zimride, Otto (eRide Share))
- SOV Apps (e.g., WAZE Social Traffic, Twist for Rendezvous)
- Niche Transport (Ee.g., Boost by Benz, Shuddle, Hop/Skip/Drive)

This document illustrates the scope, variety, and evolution of this emerging industry area called “shared mobility” as parking and TDM programs merge to offer more comprehensive tapestries of access management strategies. Looking at this document from a different perspective reveals another dimension. Beyond the specific practices, there are broader categories—such as mobile communications, data aggregation, commute mode detection, personal transport, active transportation, private sector transit, and commuter benefits—that are driving the innovation of new approaches. In some cases, the intersections of these broader categories are generating synergistic applications and approaches that will have the potential to be both transformative and disruptive to our industry.

The promise and potential of these evolving products, applications, and strategies on our ability to improve access and mobility while simultaneously addressing other important issues—such as congestion mitigation, greenhouse gas emission reduction, and the promotion of a more sustainable transportation network—is exciting. Kimley-Horn believes it will be the City’s best interest to assess these emerging transportation options and invest in a comprehensive access management program that can improve visitor, employee and staff experiences as an integrated downtown parking and access development strategy.

Parking and Mobility Management: Monitoring and Evaluation

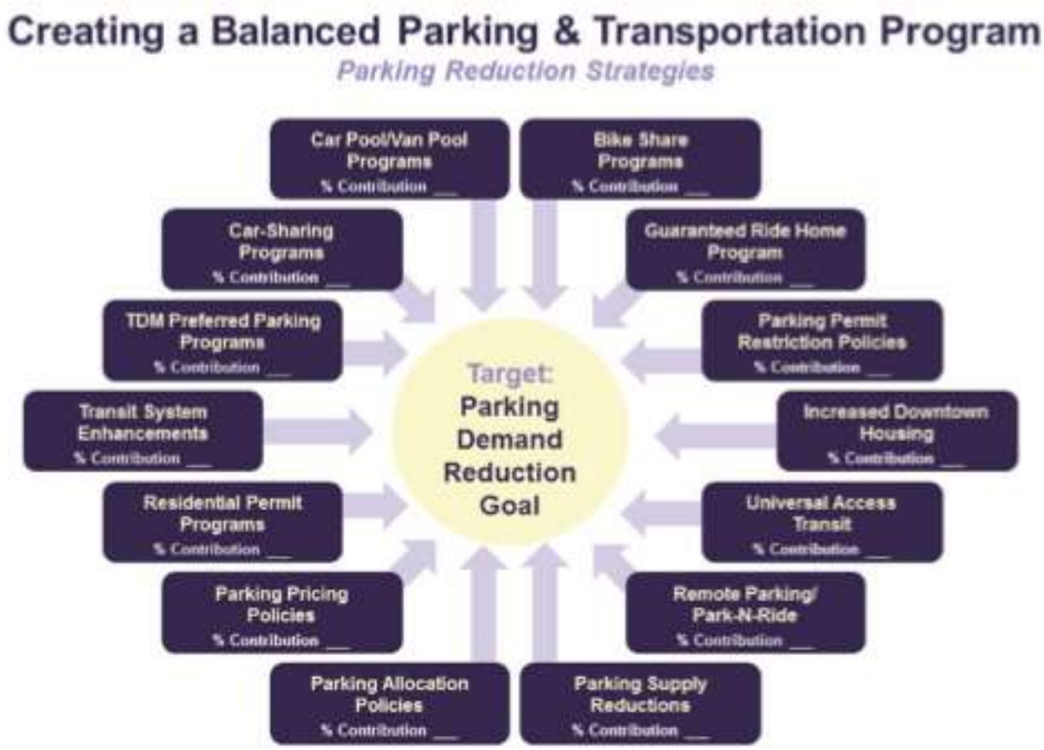
Creating a baseline of parking and transportation utilization and tracking the subsequent changes will be critical to planning for future parking, especially when considering the uncertain future of the transportation sector and the potential for significantly reduced parking needs (due to autonomous vehicles and other transportation usage trends).

Following are Kimley-Horn's recommendations for implementation within the first six months of operations:

1. Develop an automated system of documenting the number of campus employees by:
    a. Number of employees by tenant/institution.
    b. Number of employees by tenant/institution/by shift.

2. On an annual basis, conduct a "cordon count" in conjunction with a parking utilization survey. Cordon counts are counts taken at each campus access point or peripheral campus intersection while documenting the types of vehicles and their respective volumes. Kimley-Horn has had recent success conducting "cordon counts" using video which allows the surveyor to obtain specific numbers by type for each access point (cars/buses/bikes/peds). This data can also be useful to assess traffic conditions.

3. Define specific modal split targets as parking demand reduction strategy and provide ongoing monitoring. The graphic below shows a potential application of various parking demand reduction strategies along with their estimated parking demand reduction goals.



By clearly stating your parking demand reduction goals and mapping out the intended strategies, a logical TDM implementation and monitoring process can be created. The keys to success in this process are:

- Assign anticipated percentages to meet the overall demand reduction goals.
- Gather valid baseline data for comparative analysis.
- Develop effective performance measures related to each TDM program element.
- Implement an ongoing tracking and reporting process to measure progress.

Designing for Flexibility and Adaptive Reuse

Given the uncertain future of transportation and parking discussed in the previous chapters (particularly the potential for dramatic parking demand reductions) the question of whether a parking structure be designed today and adapted into something different tomorrow takes on a new significance. Thinking critically from an operational and design perspective, two key concepts emerge related to forward-thinking parking planning—developing strategies that promote maximum operational flexibility in short- to mid-term time frame, and designing future parking infrastructure with the capability of being adaptively reused should projections related to reduced parking demand prove to be on-target.

Planning for the Adaptive Reuse of Parking Structures

This report section explores the technical issues associated with the concept of adaptive reuse parking facilities. Designs must consider future direction of the industry, including:

- Migration of suburbanites to urban centers
- Millennials driving less and forgoing car ownership
- Car sharing services (e.g., Uber, Lyft, Zipcar)
- Connected and autonomous vehicles
- The drive towards reducing vehicular traffic and making communities becoming more pedestrian-friendly and walkable

Many communities are taking measures to meet the evolving parking and transportation needs of communities of today and of the future. For example, forward-thinking administrators are revising their zoning codes and moving away from the minimum to maximum parking ratios for selected land uses. In addition, most are recognizing reduction in parking demand for transit-oriented development (TODs) and shared-use parking.

Most people would agree that the need for parking structures is not going to go away anytime soon, even as technology is rapidly changing. Parking may not be the most glamorous element of a development or community but many community planners and developers recognize that when done right, it is the key to realizing their vision for an active and vibrant community and a successful development.

The service life of many parking structures designed is 50-75 years. As such, these facilities are and will continue to be fixtures of our urban landscape. We realize that mobility options and preferences are going to change over time as are the needs of the community. The last thing anyone wants is to build a structure that will be obsolete or severely underutilized.

What if parking structures could be designed to not only handle the current need but also be adaptable to better meet the evolving parking and transportation needs of communities in the future? What if we could future-proof the parking structure of today and design them to be adaptable to become say a community mobility hub, a community event center, or other land use types (office, clinical space, residential, etc.). Can this be done physically and economically?

We believe it can. It may also be possible for an existing structure to be retrofitted to a degree. Some would argue that it would be simpler and less costly to demolish the existing parking structure and replace it with a new, more suitable building. In some circumstances, and for many owners considering the long-term, this may not be the most environmentally responsible or cost-effective choice.

How do we go about doing this in a creative and economical way?

What should we consider and do today to allow parking structures to be multi-functional and adaptable in the future?

First, let's define the design challenge. Parking structures are unique building types with the following typical features:

- Open to the environment
- Designed to be storage facilities (Group S Occupancy), not conditioned, occupied spaces
- More horizontal than vertical in configuration

The primary focus of parking structure design has been to efficiently move cars in, store them, then move them out. In contrast, buildings for non-parking uses focus on making the occupied space safe, habitable, appealing, and accessible. There are a number of parking structure design features that don't lend themselves to a non-parking use, including:

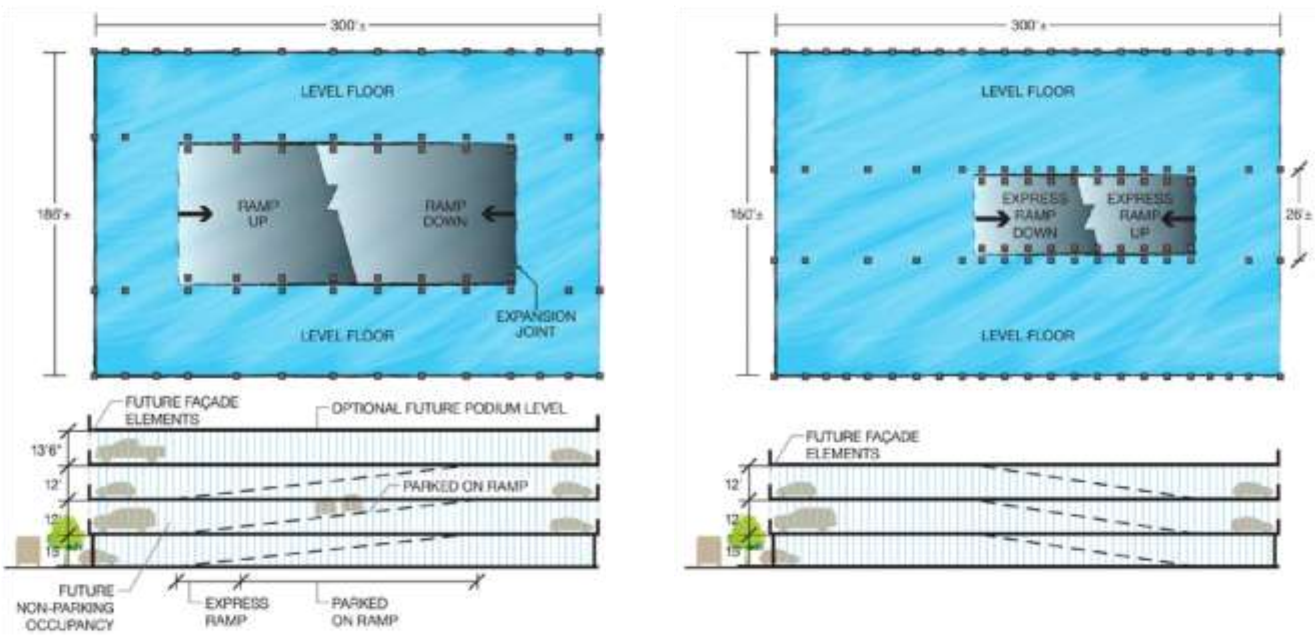
- Story (or floor-to-floor) heights. Parking structure story heights generally range between 10' 0" and 11' 6" which are not suitable for most commercial office/retail or residential use
- Sloped floors. Parking structures require sloped floors to facilitate self-parking vehicular circulation between parking levels and for drainage
- **Size, number, and layout of stairs and elevators.** Stairs are a means of egress for life safety and sized based on code prescribed occupant load factor associated with an occupancy use classification. For parking structures, the occupant load factor is 200 SF per person whereas office (Group B) and mercantile (Group M) occupancy at 100 and 60 SF person, respectively, resulting in the requirement for wider stair widths and/or additional stairs. These stairs and accompanying elevators are typically located along the perimeter of the parking structure whereas for non-parking use buildings they are typically located within the interior of the building footprint.
- **Lack of HVAC systems.** These systems are not provided for parking floor areas.
- Lack of fire protection. Many jurisdictions don't require parking structures to have fire sprinklers for fire protection whereas they are typically required for non-parking uses.
- **Lower live loading code.** The minimum code for live loading parking structures is 40 psf. For other uses such as office, retail, library reading rooms, public meeting spaces, and their corridors are between 50 and 100 psf.

Key Parking Structure Adaptive Reuse Strategies

What can be done differently when planning for and designing parking structures of the future to compensate for these conflicting design features?

- Increase floor-to-floor heights. By increasing the first story height minimum to 15 feet and the height of typical upper stories to 12 feet, the resulting first story height can be a minimum of 15 feet and the height of typical upper stories can be 12 feet. These heights are more suitable to provide higher clear heights of 12± feet for ground level commercial/retail use and 9± feet for office, community meeting, or possibly residential use. If sufficient site length is not available to provide a parked-on ramp with these story heights or more flat floor area is desired then non-parked on express ramps (with slope > 6.67%) can be provided for a portion or the entire length of ramp. These ramps can be situated near ends of the floor plate or along its sides to provide for more flat floor area.
- Design the floor framing to allow for the ramped parking bay to be more readily demolished. One way of accomplishing this is to provide double row of columns along the bay with the ramp and expansion/construction joints at the top and bottom of each floor-to-floor ramp segment. This would likely require additional framing elements for lateral load resistance and detailing to facilitate load transfer and accommodate building movement at the expansion/construction joints. While this would also add to the initial construction costs, it would provide an opportunity for modifying each floor to be a complete flat floor plate for future uses.
- Include 25-30-feet wide light-well between parking bays to provide space for construction of additional elevator and stair cores and flat floor construction for corridors within the interior of the building footprint. Foundations for these future pedestrian circulation elements could be constructed as part of the initial construction.
- The perimeter stair and elevator cores that serve the parking structure could be located outboard to the floor plate. This will allow for easier demolition of these elements if they don't adequately serve the alternate use.
- Design floor framing for additional load carrying capacity by including provision for adding columns and beams to reduce beam and slab spans or supplement conventional and post-tensioned slab and beam reinforcement to support additional floor loads. This additional load carrying capacity could accommodate a topping slab to level out the floor drainage slope.
- Impacts of floor cross slope for drainage can be reduced by providing additional floor drains.

- Building columns, walls, and foundations could be designed to accept vertical expansion and the addition of a podium level for a public plaza recreational space or a one- or two-story light-framed (Type 5 framed wood construction) building structure.
- Design for either the removal of perimeter vehicle and pedestrian guard rails or detail connections points to accept future installation of building facade elements (e.g., curtain wall/store front system, panelized EIFS, or stucco wall system), including doors and windows to fully enclose the perimeter of the structure.
- Provide additional capacity in the electrical service, sanitary sewer, and fire protection systems. Include provisions for electrical and mechanical chases to accommodate duct work and cabling, and additional space for mechanical and electrical service and fire protection equipment (e.g., fire pumps and emergency generators).



Additional structural and architectural consideration may need to be identified based on the whether the parking structure is cast-in-place concrete, precast concrete, or steel framed construction.

We recognize that not all projects will lend themselves for implementing design enhancement for facilitating future adaptive reuse but for some projects and owners, it may be beneficial to investigate the possibilities during project planning and design development. Parking structures designed to accommodate future conversion to a different use will cost more initially. The economic decision to proceed will need to be considered by community and institutional leaders and owners to determine the feasibility of such an investment.

Advancing the Concept of Parking Structure Adaptive Reuse

Given the potential of this concept and its specific relevance to the new Druid Hills healthcare campus we have attempted to advance this concept further by exploring the following key areas below:

- Preliminary Building Code Review (comparative analyses of different uses and occupancy classifications)
- The Development of Prototype Design Concepts
- Estimates of Probable Cost for Prototype Concept Designs

Preliminary Code Review

We conducted a preliminary code review of the 2012 International Building Code (2012 IBC) for the near term and potential building uses to identify the basic requirements that need to be addressed in our design concepts. Each building or portion of a building is assigned a single occupancy classification based on its intended use. Occupancy classifications reviewed include parking structure use (Group S occupancy), professional office use (Group B occupancy), mercantile use (Group M occupancy), and residential use (Group R occupancy). Tables 1, 2, and 3 present results of this code review.

TABLE 1—Preliminary Code Review
Comparison of Group S and Group M Occupancy Requirements

2012 IBC Code Section	Parking Structure Use: Group S-2 Occupancy	Retail Use: Group M Occupancy
Chap 4 – 406.4.1 Chap 12 – 1208.2	Minimum clear height is 7’-0”	Minimum ceiling height in habitable spaces and corridors is 7’-6”
Chap 4 – 406.4.3	Vehicle barriers minimum 2’-9” in height	
Chap 4 – 406.5 Chap 5 – 705.8	Openings for natural ventilation purposes: Uniformly distributed openings on two or more exterior sides. The area of such openings in exterior walls on a tier must be at least 20% of the total perimeter wall area of each tier. The aggregate length of the openings considered to be providing natural ventilation shall constitute a minimum of 40% of the perimeter of the tier.	Maximum allowable area of unprotected and protected opening is a function of the fire separation distance from property line. Refer to Table 705.8
Chap 5 – 508; 510 Chap 6 – 601; 602	Noncombustible Type 1 or Type 2	Noncombustible Type 1 or Type 2
Chap 4 – 406.5.5 Chap 5 – 503; 504.2; 506; 508.4	Maximum height allowable; area per tier; and maximum number of stories Type 1A – unlimited; unlimited; unlimited Type 1B – 160 feet; unlimited; 12 stories Type 2A – 85 feet; 78,000 SF; 6 stories Type 2B – 75 feet; 52,000 SF; 4 stories	Maximum height allowable; area per tier; and maximum number of stories Type 1A – unlimited; unlimited; unlimited Type 1B – 160 feet; unlimited; 12 stories Type 2A – 85 feet; 43,000 SF; 5 stories Type 2B – 75 feet; 25,000 SF; 3 stories
Chap 5 – 508.4, 510	Horizontal separation with assembly having fire-resistance rating of not less than 3 hours between separated occupancies	Horizontal separation with assembly having fire-resistance rating of not less than 3 hours between separated occupancies

Chap 7 – 706.4; 707; 708	Fire wall resistance rating – 2 hours Fire barrier assemblies – 2 hours Fire partition walls – 1 hour	Fire wall resistance rating – 3 hours Fire barrier assemblies – 2 hours Fire partition walls – 1 hour
Chap 9 – 903	Generally, not required in tiers classified as open for natural ventilation in mixed-use S-2 open parking structures unless required by local jurisdiction.	Required where one of the following conditions exists: Fire area > 12,000 SF fire area 3+ stories above-grade Total fire areas (all floors) > 24,000 SF Furniture/mattress sale area > 5,000 SF
Chap 9 – 905	Class I standpipes allowed with automatic sprinkler system	Class I standpipes allowed with automatic sprinkler system
Chap 9 – 907	Fire alarms and detection systems – not required	Manual fire alarm system required where one of the following conditions exists: Combined occupant load ≥ 500 Occupant load > 100 above or below the lowest level of exit discharge *Exception: When an automatic sprinkler system is installed and* occupant notification appliances activate upon sprinkler use.
Chap 10 – 1004	Occupant load = 200 SF gross per occupant	Occupant load = 60 SF gross per occupant. Basement and grade floor areas = 30 SF gross per occupant. Storage, stock, shipping areas = 300 SF per occupant
Chap 10 – 1005	Stair egress width [in.] = 0.2*occupant load (with automatic sprinkler system)	Stair egress width [in.] = 0.2*occupant load (with automatic sprinkler system)
Chap 10 – 1007	Area of refuge not required in stairways in open parking structures	Area of refuge not required at stairways in building with automatic sprinkler system
Chap 10 – 1016	Maximum travel distance to egress stair with sprinkler system = 400 feet	Maximum travel distance to egress stair with sprinkler system = 250 feet
Chap 16 – 1604	Risk Category II	Risk Category II
Chap 16 – 1607	Live load = 40 psf	Live load first/ground floor = 100 psf Live load upper floors = 75 psf
Chap 29 – 2902	Plumbing fixtures not required	Minimum # of plumbing fixtures: Water Closets: 1 per 500 occupants Lavatories: 1 per 750 occupants Drinking fountains: 1 per 1,000 occupants

TABLE 2—Preliminary Code Review Comparison of Group S and Group B Occupancy Requirements		
2012 IBC Code Section	**Parking Structure Use: Group S-2 Occupancy**	Professional Office Use: Group B Occupancy
Chap 4 – 406.4.1 Chap 12 – 1208.2	Minimum clear height is 7’-0”	Minimum ceiling height in habitable spaces and corridors is 7’-6”
Chap 4 – 406.4.3	Vehicle barriers minimum 2’-9” in height	
Chap 4 – 406.5 Chap 5 – 705.8	Openings for natural ventilation purposes: Uniformly distributed openings on two or more exterior sides. The area of such openings in exterior walls on a tier must be at least 20 % of the total perimeter wall area of each tier. The aggregate length of the openings considered to be providing natural ventilation shall constitute a minimum of 40 % of the perimeter of the tier.	Maximum allowable area of unprotected and protected opening is a function of the fire separation distance from property line. Refer to Table 705.8
Chap 5 – 508; 510 Chap 6 – 601; 602	Noncombustible Type 1 or Type 2	Noncombustible Type 1 or Type 2
Chap 4 – 406.5.5 Chap 5 – 503; 504.2; 506; 508.4	Maximum Height; Allowable area per tier; and maximum number of stories Type 1A – unlimited; unlimited; unlimited Type 1B – 160 feet; unlimited; 12 stories Type 2A – 85 feet; 78,000 SF; 6 stories Type 2B – 75 feet; 52,000 SF; 4 stories	Maximum Height; Allowable area per tier; and maximum number of stories Type 1A – unlimited; unlimited; unlimited Type 1B – 160 feet; unlimited; 12 stories Type 2A – 85 feet; 75,000 SF; 6 stories Type 2B – 75 feet; 46,000 SF; 4 stories
Chap 5 – 508.4, 510	Horizontal separation with assembly having fire-resistance rating of not less than 3 hours between separated occupancies.	Horizontal separation with assembly having fire-resistance rating of not less than 3 hours between separated occupancies
Chap 7 – 706.4; 707; 708	Fire wall resistance rating - 2hours Fire barrier assemblies – 2 hours Fire partition walls – 1 hour	Fire wall resistance rating – 3 hours Fire barrier assemblies – 2 hours Fire partition walls – 1 hour
Chap 9 – 903	Generally, not required in tiers classified as open for natural ventilation in mixed-use, S-2 open parking structures unless required by local jurisdiction.	Required when building height is greater than or equal to 55 feet
Chap 9 – 905	Class I standpipes allowed with automatic sprinkler system	Class I standpipes allowed with automatic sprinkler system
Chap 9 – 907	Fire alarms and detection systems – not required	Manual fire alarm system required where one of the following conditions exists: Combined occupant load ≥ 500 Occupant load > 100 above or below the lowest level of exit discharge *Exception: When an automatic sprinkler system is installed and* occupant notification appliances activate upon sprinkler use

Chap 10 – 1004	Occupant load = 200 SF gross per occupant	Occupant load = 100 SF gross per occupant
Chap 10 – 1005	Stair egress width [in.] = 0.2*occupant load (with automatic sprinkler system)	Stair egress width [in.] = 0.2*occupant load (with automatic sprinkler system)
Chap 10 – 1007	Area of refuge not required in stairways in open parking structures	Area of refuge not required at stairways in building with automatic sprinkler system
Chap 10 – 1016	Maximum travel distance to egress stair with sprinkler system = 400 feet	Maximum travel distance to egress stair with sprinkler system = 300 feet
Chap 16 – 1604	Risk Category II	Risk Category II
Chap 16 – 1607	Live load = 40 psf	Live load upper floors = 50 psf Live load for corridors above first floor = 80 psf Live load for lobbies and first-floor/ground floor corridors = 100 psf
Chap 29 – 2902	Plumbing fixtures not required	Minimum # of plumbing fixtures: Water closets: 1 per 25 for the first 50 occupants and 1 per 50 for the remainder exceeding 50 occupants Lavatories: 1 per 40 for the first 80 occupants and 1 per 80 for the remainder exceeding 80 occupants Drinking fountains: 1 per 100 occupants

TABLE 3—Preliminary Code Review
Comparison of Group S and Group R Occupancy Requirements

2012 IBC Code Section	Parking Structure Use: Group S-2 Occupancy	Multifamily Residential Use: Group R-2 Occupancy
Chap 4 – 406.4.1 Chap 12 – 1208.2	Minimum clear height is 7’-0”	Minimum ceiling height in habitable spaces and corridors is 7’-6”
Chap 4 – 406.4.1 Chap 12 – 1208.2	Minimum clear height is 7’-0”	Minimum ceiling height in habitable spaces and corridors is 7’-6”
Chap 4 – 406.4.3	Vehicle barriers minimum 2’-9” in height	
Chap 4 – 406.5 Chap 5 – 705.8	Openings for natural ventilation purposes: Uniformly distributed openings on two or more exterior sides. The area of such openings in exterior walls on a tier must be at least 20 % of the total perimeter wall area of each tier. The aggregate length of the openings considered to be providing natural ventilation shall constitute a minimum of 40 % of the perimeter of the tier.	Maximum allowable area of unprotected and protected opening is a function of the fire separation distance from property line. Refer to Table 705.8
Chap 5 – 508; 510 Chap 6 – 601; 602	Noncombustible Type 1 or Type 2	Noncombustible Type 1 or Type 2
Chap 4 – 406.5.5 Chap 5 – 503; 504.2; 506; 508.4	Maximum height; allowable area per tier; and maximum number of stories Type 1A – unlimited; unlimited; unlimited Type 1B – 160 feet; unlimited; 12 stories Type 2A – 85 feet; 78,000 SF; 6 stories Type 2B – 75 feet; 52,000 SF; 4 stories	Maximum height; allowable area per tier; and maximum number of stories Type 1A – unlimited; unlimited; unlimited Type 1B – 160 feet; unlimited; 12 stories Type 2A – 60 feet; 75,000 SF; 4 stories Type 2B – 60 feet; 46,000 SF; 4 stories
Chap 5 – 508.4, 510	Horizontal separation with assembly having fire-resistance rating of not less than 3 hours between separated occupancies	Horizontal separation with assembly having fire-resistance rating of not less than 3 hours between separated occupancies
Chap 7 – 706.4; 707; 708	Fire wall resistance rating – 2 hours Fire barrier assemblies – 2 hours Fire partition walls – 1 hour	Fire wall resistance rating – 3 hours Fire barrier assemblies – 2 hours Fire partition walls – 1 hour
Chap 9 – 903	Generally, not required in tiers classified as open for natural ventilation in mixed-use S-2 open parking structures unless required by local jurisdiction.	Required
Chap 9 – 905	Class I standpipes allowed with automatic sprinkler system.	Class I standpipes allowed with automatic sprinkler system.

Chap 9 – 907	Fire alarms and detection systems – not required	Manual fire alarm system required where one of the following conditions exists: Dwelling/sleeping unit is located 3+ stories above lowest level of discharge Building contains 16+ dwelling units *Exception: When an automatic sprinkler system is installed and* occupant notification appliances activate upon sprinkler use
Chap 10 – 1004	Occupant load = 200 SF gross per occupant	Occupant load = 100 SF gross per occupant
Chap 10 – 1005	Stair egress width [in.] = 0.2*occupant load (with automatic sprinkler system)	Stair egress width [in.] = 0.2*occupant load (with automatic sprinkler system)
Chap 10 – 1007	Area of refuge not required in stairways in open parking structures	Area of refuge not required at stairways in building with automatic sprinkler system
Chap 10 – 1016	Maximum travel distance to egress stair with sprinkler system = 400 feet	Maximum travel distance to egress stair with sprinkler system = 300 feet
Chap 16 – 1604	Risk Category II	Risk Category II
Chap 16 – 1607	Live load = 40 psf	Live load = 40 psf Live load for public rooms and corridors serving dwelling units = 100 psf
Chap 29 – 2902	Plumbing fixtures not required	Minimum # of plumbing fixtures: Water closets: 1 per dwelling unit Lavatories: 1 per dwelling unit Bathtubs or showers: I per dwelling unit Kitchen sink: 1 per dwelling unit Automatic clothes water connection: 1 per 20 dwelling units

Prototype Design Concepts

Concepts presented in this section have been developed under the assumption that in the near-term, this building will be a mixed-use parking structure with retail/commercial space at the street level and parking at all above-grade supported levels. In the future, portions of the building's above-grade levels would be converted to either general office or residential apartment use with the remainder of floor area used for parking.

These design concepts are not intended to address all design aspects related to future-proofing the parking structure but rather an attempt to address some key aspects to providing an adaptable parking structure. These concepts should only be considered as examples of what is possible. Additional structural, architectural, and MEP design consideration may need to be identified and addressed during design development of these concepts.

Concept 1

Concept 1 is depicted in Sheet 1A (near-term mixed-uses) and Sheet 1B (future mixed-uses) of the enclosed drawing exhibits. Key attributes of Concept 1 are summarized as follows:

CONCEPT 1A (NEAR-TERM MIXED-USES)

- Four-story building with footprint of 302 feet x 153 feet
- Total building floor area of approximately 223,260 SF which includes approximately 15,000 gross SF of ground level general retail space with a depth of approximately 60 feet
- First-story height of 15 feet and typical above-grade story height of 12 feet, building height to top of parapet of approximately 55 feet
- Single parking bay on ground level and two bays of parking on each of the above-grade levels providing approximately 431, 8.5 feet x 18 feet, 90-degree stalls. Note that this total does not account for loss of spaces due to ADA accommodations, motorcycle and bicycle parking, and utility and storage rooms.
- Single thread, non-parked on, express ramp provided along back side of building for vehicle circulation between parking levels. A single thread helix is a ramp orientation that circulates vertically one floor with each 360 degrees of revolution. This ramp has a double row of columns along its interior to allow for the ramped parking bay to be more readily demolished if it is not desired to include parking in the future mixed-use building scenario.
- Building footprint includes a 44 feet x 28 feet interior lightwell between parking bays to provide space for construction of an additional elevator and stair core, and flat floor construction for corridors within the interior of the office/residential use footprint.
- Average design parking efficiency provided is 483 SF per stall. This parking efficiency is considered poor relative to what can typically be provided (360-380 SF/per stall) with short span construction and parked on ramps. This poor parking efficiency is primarily attributed to having a non-parked on express ramp and lightwell.
- Building construction consists of conventionally reinforced (not post-tensioned) 10-inch thick cast-in-place concrete two-way flat slab with drop panels supported by reinforced concrete columns on shallow spread and wall footings. Floor framing, columns and footings are designed for increased live and dead floor loads associated with future office/ residential use on above-grade levels. Post-tensioned floor construction was not considered to allow for flexibility in the future for making penetrations to facilitate routing of MEP conduits and piping.
- Lateral loads are resisted by moment frames.
- The foundations are designed to support additional live and dead loads associated with future conversion of above-grade levels to office/residential uses.
- Catchment area per floor drain would be approximately 3,600 SF with drains located along Gridline 5. Spot floor elevation at drain locations would be on the order 8-10 inches below the floor elevation along floor exterior perimeter. This results in providing a minimum drainage cross slope of 1%.

Concept 1B (Future mix of uses)

Modifications to the near-term mixed-use concept:

- Total of approximately 48,600 gross SF of office/residential use within the upper three stories of building. The depth of office/residential space is approximately 60 feet.
- Single parking bay on ground level and the three above-grade levels and two parking bays on the top level providing approximately 293, 8.5 feet x 18 feet, 90-degree stalls. Note that this total does not account for loss of spaces due to ADA accommodations, motorcycle and bicycle parking, and utility and storage rooms. Average design parking efficiency provided is 525 SF per stall.
- An interior elevator and stair core constructed within the lightwell area providing two elevators and one stair.
- Removal of floor drains and addition of 2- to 4-inch thick lightweight concrete topping to level out the floor drainage slope on elevated levels.

- Addition of a 3-hour fire rated wall assembly along Gridline 5 to separate the parking use from the office/residential use.
- Construction of facade elements (e.g. curtain wall/store front system, panelized rainscreen, stucco wall system, etc.), including windows to fully enclose the exterior perimeter of the office/residential use floor area.
- HVAC and plumbing fixtures (water closets, lavatories, etc.) to condition and service the occupied office/residential uses.

Concept 2

Concept 2 is depicted in Sheet 2A (near-term mixed-uses) and Sheet 2B (future mixed-uses) of the enclosed drawing exhibits. Key attributes of Concept 2 as depicted are summarized as follows:

CONCEPT 2A (NEAR-TERM MIXED-USES)

- Four-story building with footprint of approximately 290 feet x 182 feet.
- Total building floor area of 254,700 SF which includes approximately 17,560 gross SF of ground level general retail space with a depth of approximately 60 feet.
- First-story height of 15 feet, typical above-grade story height of 12 feet, building height to top of parapet of 55 feet.
- Grade plus four supported levels with two bays of parking on ground level and three bays of parking on the four supported levels providing approximately 494, 8.5 feet x 18 feet, 90-degree stalls. Note that this total does not account for loss of spaces due to ADA accommodations, motorcycle and bicycle parking, and utility and storage rooms.
- Single thread, non-parked on, express ramp in switch back configuration provided along the side of building for vehicle circulation between parking levels. This ramp has a double row of columns along its interior to allow for the ramped parking bay to be more readily demolished if it is not desired to include parking in the future mixed-use building scenario.
- Building footprint includes a 28 feet x 28 feet interior lightwell between parking bays to provide space for construction of additional elevator and stair core and flat floor construction for corridors within the interior of the office/residential use footprint.
- Average design parking efficiency provided is 480 SF per stall. This parking efficiency is considered poor relative to what can typically be provided (360-380 SF/per stall) with short span construction and parked on ramps. This poor parking efficiency can primarily be attributed to having a non-parked on express ramp and a lightwell.
- Building construction consists of conventionally reinforced (not post-tensioned) 10-inch thick, cast-in-place concrete two-way flat slab with drop panels supported by reinforced concrete columns on shallow spread and wall footings. Floor framing, columns, and footings are designed for increased live and dead floor loads associated with future office/ residential use on above-grade levels. Post-tensioned floor construction was not considered to allow for flexibility in the future for making penetration to facilitate routing of MEP conduits and piping.
- Lateral loads are resisted by moment frames.
- The foundations are designed to support additional live and dead loads associated with future conversion of above-grade levels to office/residential uses.
- Catchment area of 2,700 and 3,600 SF per floor drain with drains located between Gridlines 3 and 4, and 5 and 6. Spot floor elevation at drain locations would be on the order 8- to 10-inches below the floor elevation along floor exterior perimeter. This results in providing a minimum drainage cross slope of 1%.

Concept 2B (Future mix of uses)

Modifications to the near-term mixed-use concept:

- Total of approximately 65,600 gross SF of office/residential use on the upper three stories of building. The depth of office/ residential space is approximately 120 feet.
- Two parking bays on ground level, one and one-half parking bays on three supported levels, and three parking bays on the top level provide approximately 302, 8.5 feet x 18 feet, 90-degree stalls. Note that this total does not account for loss of spaces due to ADA accommodations, motorcycle and bicycle parking, and utility and storage rooms. Average design parking efficiency provided is 560 SF per stall.
- An interior elevator and stair core constructed within the lightwell area providing two elevators and one stair.

- Removal of floor drains and addition of 2- to 4-inch thick lightweight concrete topping to level out the floor drainage slope on elevated levels.
- Addition of a 3-hour fire rated wall assembly to separate the parking use from the office/residential use.
- Construction of facade elements (e.g. curtain wall/store front system, panelized rainscreen, stucco wall system, etc.), including windows to fully enclose the exterior perimeter of the office/residential use floor area.
- HVAC and plumbing fixtures (water closets, lavatories, etc.) to condition and service the occupied office/residential uses.

Opinion of Probable Cost for Prototype Concept Designs

- Conceptual level opinions of probable cost were developed for each near-term and future mixed-use parking structure concept. The opinions of probable project costs are presented for comparative purposes in 2017 dollars for the Boise market. These costs do not include items such as land acquisition, project financing and site environmental evaluations, and owner soft costs such as site geotechnical investigations and recommendations and owner's administrative and legal costs. Escalation percentage should be established by the owner based on their assumptions as to the anticipated year of project bidding and construction.
- **Tables 4 and 5** provide an opinion of probable cost for a typical stand-alone, 4-story above-grade parking structure with long-span post-tensioned construction, 10 feet story heights, and typical facade treatments and features comparable in size to the Concept 1 and Concept 2.

TABLE 4—Typical Standalone 4-Story Above-grade Parking Structure Concept 1

Item	Square Footage	Unit Price ($/SF)	Extension
Standalone Parking Structure	223,260	$50.00	$11,163,000
Construction Contingency (10%)			$1,116,300
Design Contingency (20%)			$2,232,600
Total	**223,600**	**$65.00**	**$14,511,900**

TABLE 5—Typical Stand-alone 4-Story Above-grade Parking Structure Concept 2

Item	Square Footage	Unit Price ($/SF)	Extension
Standalone Parking Structure	254,700	$50.00	$12,735,000
Construction Contingency (10%)			$1,273,500
Design Contingency (20%)			$2,547,000
Total	**254,700**	**$65.00**	**$16,555,500**

Table 6 through 9 provide an opinion of probable cost for Concept 1 and Concept 2 for the near-term mixed-use and future mixed-uses concept scenarios.

TABLE 6—Concept 1A (Near-term Mixed-use) Opinion of Probable Cost			
Item	**Square Footage**	**Unit Price ($/SF)**	**Extension**
Parking Structure	208,260	$70.50	$14,682,000
Ground Level Retail Space Buildout	15,000	$65.50	$982,500
Subtotal	223,260	$70.16	$15,664,500
Construction Contingency (10%)			$1,566,450
Design Contingency (20%)			$3,132,900
Total	**223,260**	**$91.20**	**$20,363,850**

TABLE 7—Concept 1B (Future Mixed-uses) Opinion of Probable Costs			
Item	**Square Footage**	**Unit Price ($/SF)**	**Extension**
Parking Structure	208,260	$70.50	$14,682,000
Ground Level Retail	15,000	$65.50	$982,500
Build out Office/Residential Space	48,600	$104.00	$5,054,000
Subtotal	223,260	$92.80	$20,718,500
Construction Contingency (10%)			$2,071,850
Design Contingency (20%)			$4,143,700
Total	**223,260**	**$120.60**	**$26,934,050**

TABLE 8—Concept 2A (Near-term Mixed-use) Opinion of Probable Cost			
Item	**Square Footage**	**Unit Price ($/SF)**	**Extension**
Parking Structure	237,144	$70.00	$16,600,000
Ground Level Retail Space Buildout	17,560	$67.00	$1,176,500
Subtotal	254,700	$69.80	$17,776,500
Construction Contingency (10%)			$1,777,650
Design Contingency (20%)			$3,555,300
Total	**254,700**	**$90.70**	**$23,109,450**

TABLE 9—Concept 2B (Future Mixed-uses) Opinion of Probable Cost			
Item	**Square Footage**	**Unit Price ($/SF)**	**Extension**
Parking Structure	237,144	$70.00	$16,600,000
Ground Level Retail	17,560	$67.00	$1,176,500
Build out Office/Residential Space	65,560	$103.00	$6,753,000
Subtotal	254,700	$96.30	$24,529,500
Construction Contingency (10%)			$2,452,950
Design Contingency (20%)			$4,905,900
Total	**254,700**	**$125.20**	**$31,888,350**

Opinions rendered as to costs, including but not limited to, opinions as to the costs of construction and materials, are made based on RS Means square foot unit pricing and our experience, and represent our judgment as an experienced and qualified professional firm that is familiar with the industry. No solicitation or information from contractors was gathered.

Phased Parking Development Options

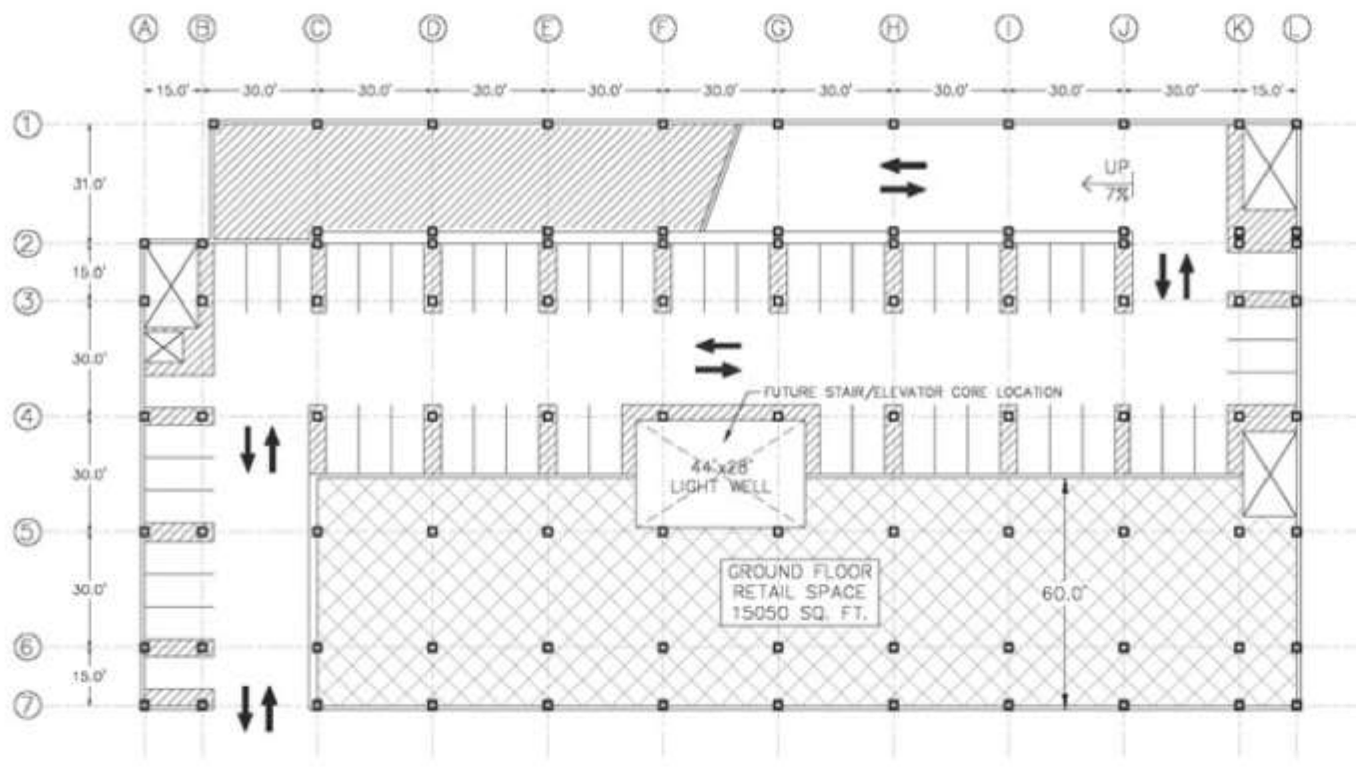
Based on the projected timeline related to the potential disruption of the current parking and transportation paradigm (e.g., autonomous vehicles, *see Chapter 4.0*), we do not anticipate a major reduction in parking demand within the Phase One development period. As such, we are recommending a phased approach to parking infrastructure development. As any new parking structure will have a design life of 50-75 years, adopting some of the strategies listed in the previous chapter could provide value even in Phase One parking development.

For parking infrastructure in the initial phases, we also recommend that these structures be designed to exceed minimum standards for ease of use. We also recommend incorporating a range of parking management best practices that will allow higher levels of service, especially for visitor and patient parking areas. This would include amenities such as:

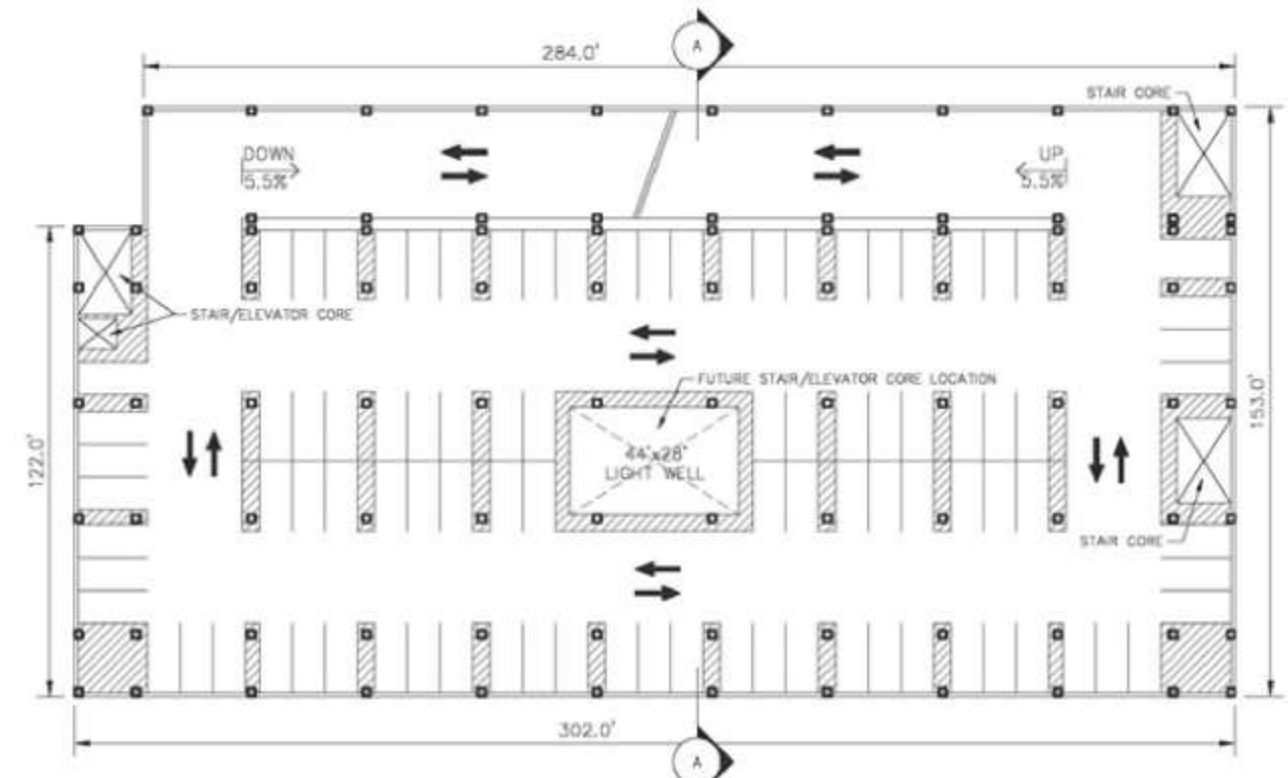
- Higher floor-to-floor heights
- White interiors
- Lighting levels that exceed IES minimums
- Glass-backed elevators
- Enhanced graphics/level theming and wayfinding

For future parking infrastructure (beyond the initial Phase of development), we recommend that CCDC develop an aggressive parking and modal split monitoring program designed to track parking demand (as well as progress on the evolution and impacts of autonomous vehicle and shared mobility). Depending on these results, the design of any additional parking structures should strongly consider parking design options that will allow future adaptive reuse (see the previous chapter for details).

CONCEPT 1: NEAR-TERM USES



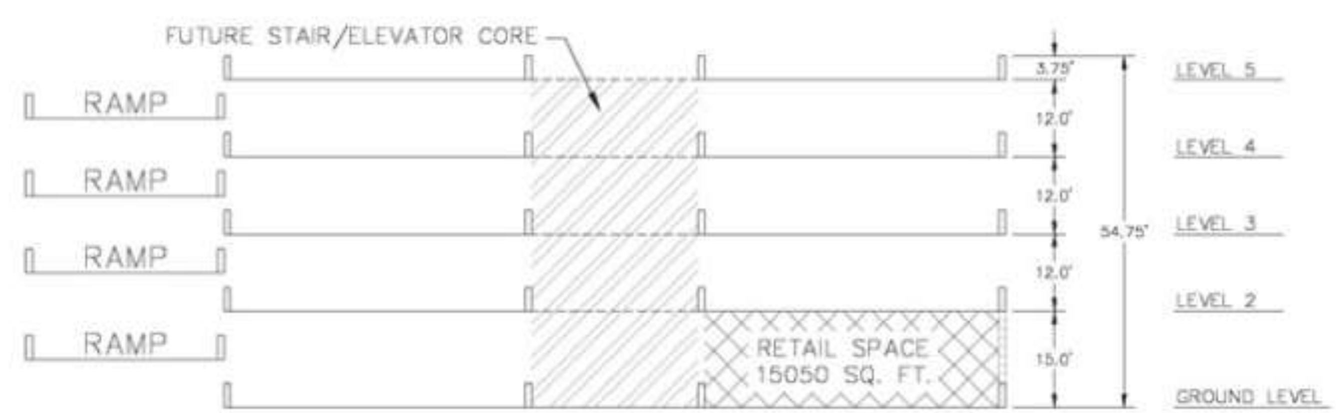
GROUND LEVEL



TYPICAL LEVEL

PARKING STALL COUNT SUMMARY				
LEVEL	SPACES (8.5'x18')	AREA (SF)	PARKING EFFICIENCY	RETAIL AREA (SF)
GROUND LEVEL	55	25615	466	15050
LEVEL 2	94	45648	486	-
LEVEL 3	94	45648	486	-
LEVEL 4	94	45648	486	-
LEVEL 5	94	45648	486	-
TOTAL	431 *	208207	483	15050

* THE TOTAL NUMBER OF SPACES HAS NOT BEEN REDUCED TO ACCOUNT FOR LOSS OF SPACES DUE TO ADA ACCOMMODATION, MOTORCYCLE PARKING, AND UTILITY AND STORAGE ROOMS.



SECTION A-A

SHEET 1A

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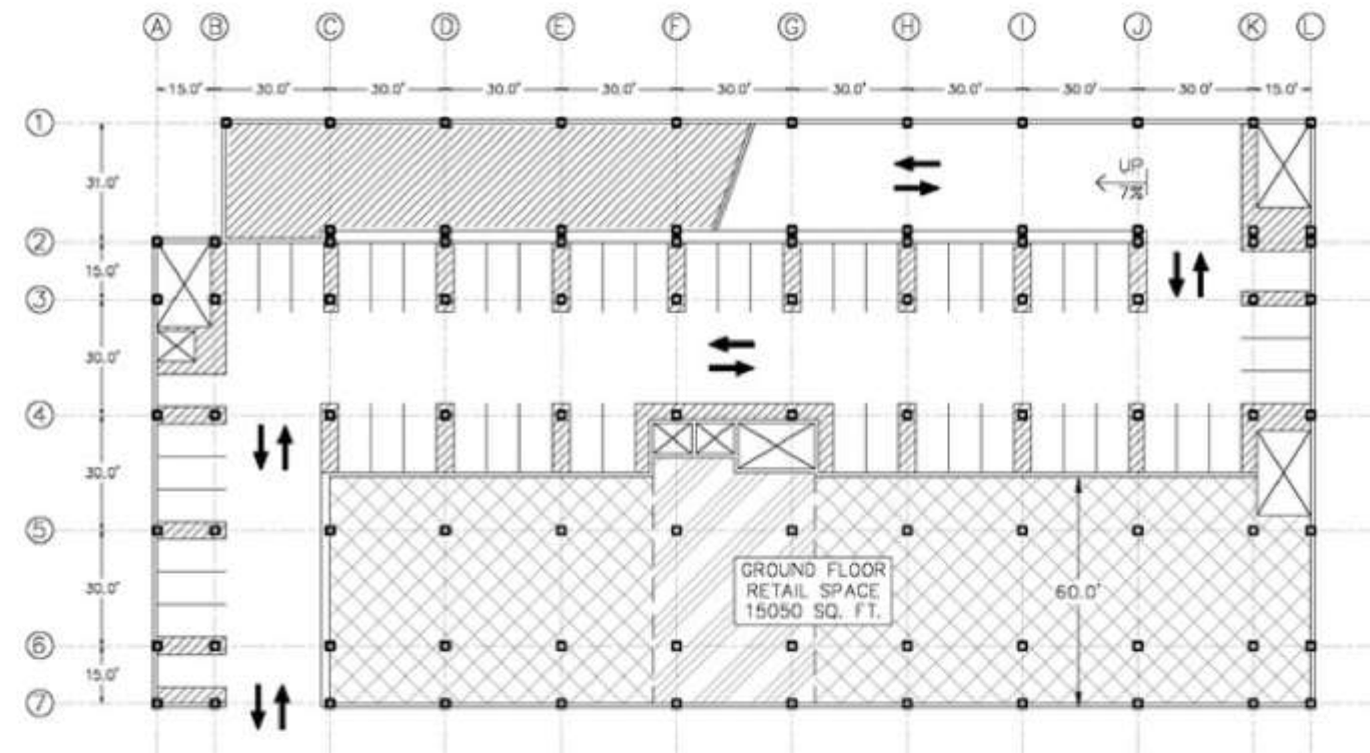
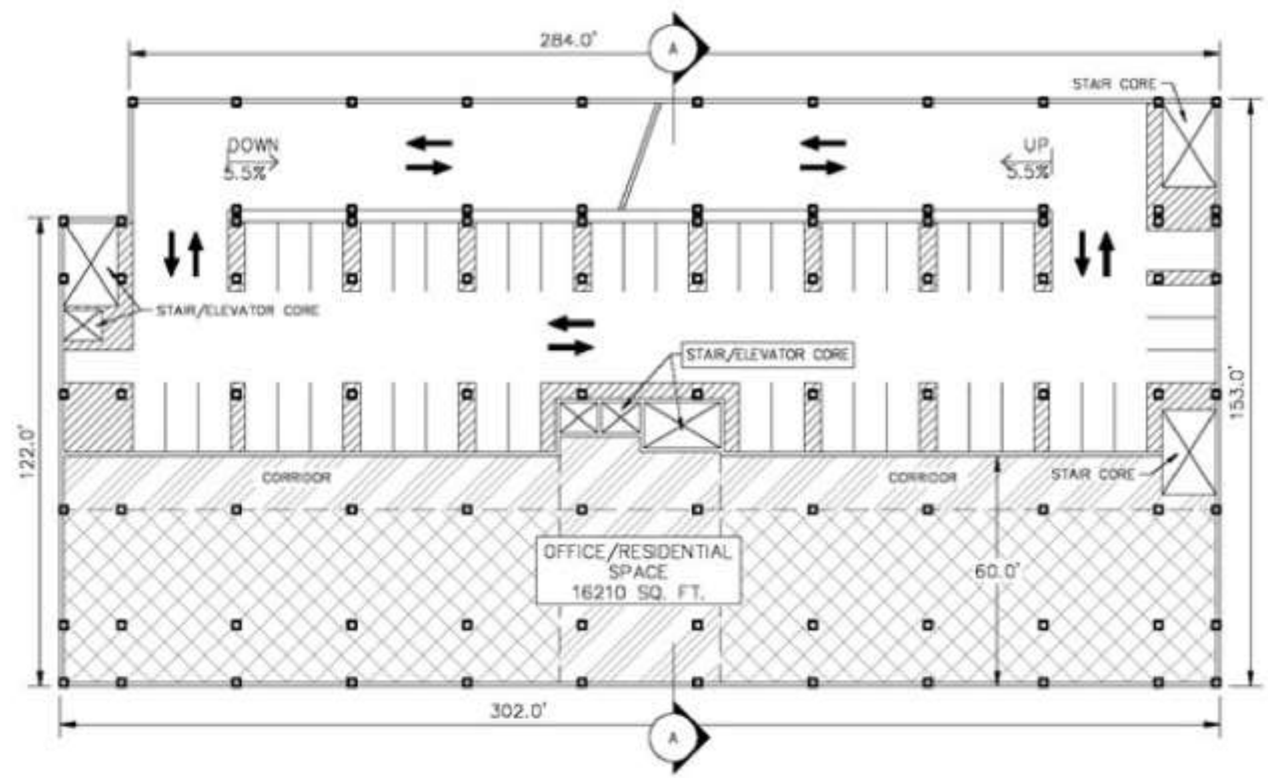
CONCEPT 1: FUTURE BUILDING USES



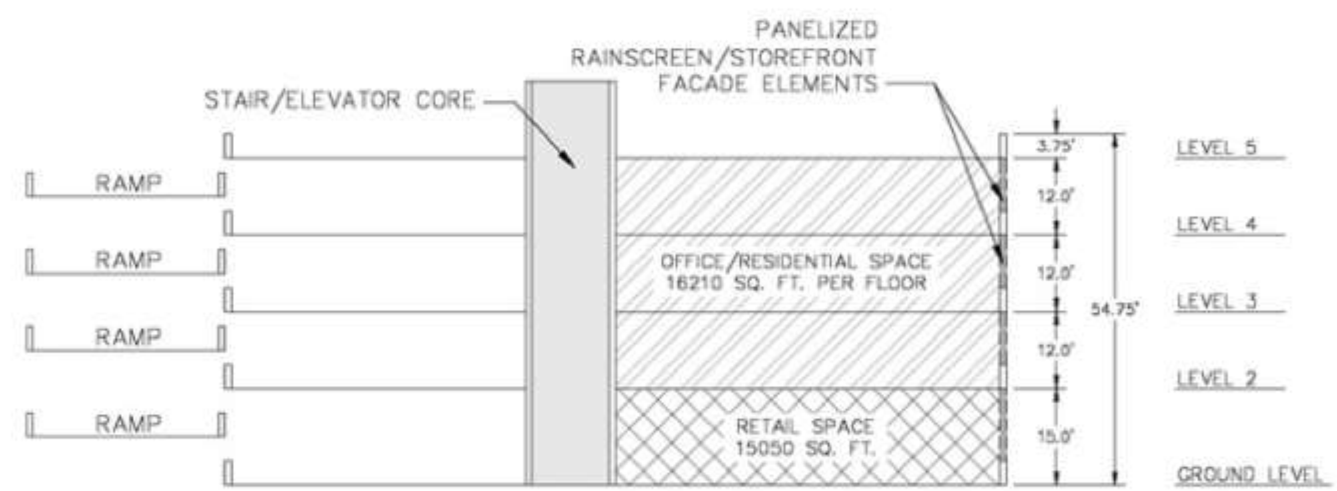
GROUND LEVEL



TYPICAL LEVEL

PARKING STALL COUNT SUMMARY					
LEVEL	SPACES (8.5'x18')	AREA (SF)	PARKING EFFICIENCY	RETAIL AREA (SF)	OFFICE/RESIDENTIAL AREA (SF)
GROUND LEVEL	55	25615	466	15050	–
LEVEL 2	48	27530	574	–	16210
LEVEL 3	48	27530	574	–	16210
LEVEL 4	48	27530	574	–	16210
LEVEL 5	94	45648	486	–	–
TOTAL	293 *	153853	525	15050	48630

* THE TOTAL NUMBER OF SPACES HAS NOT BEEN REDUCED TO ACCOUNT FOR LOSS OF SPACES DUE TO ADA ACCOMMODATION, MOTORCYCLE PARKING, AND UTILITY AND STORAGE ROOMS.



SECTION A–A

SHEET 1B

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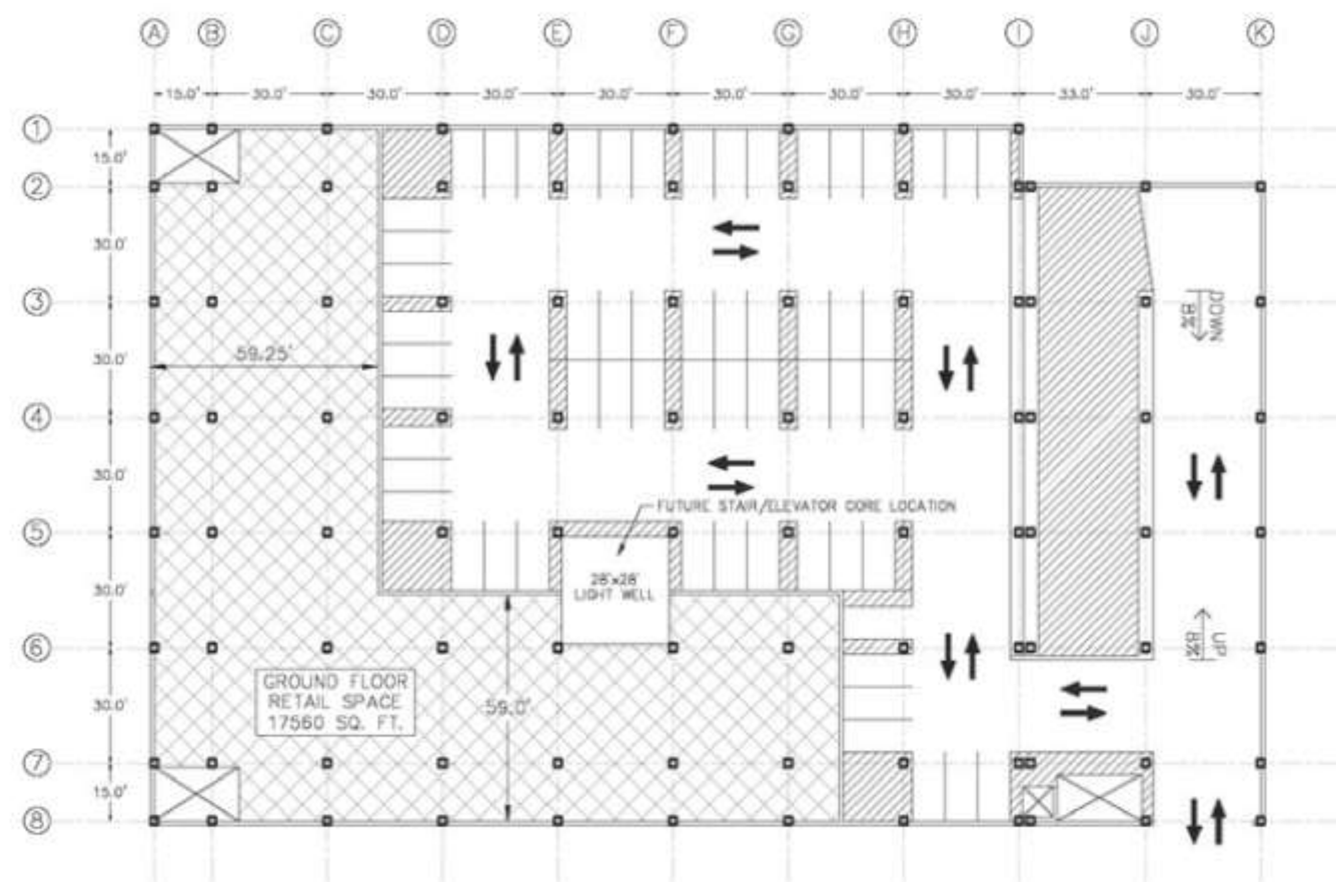
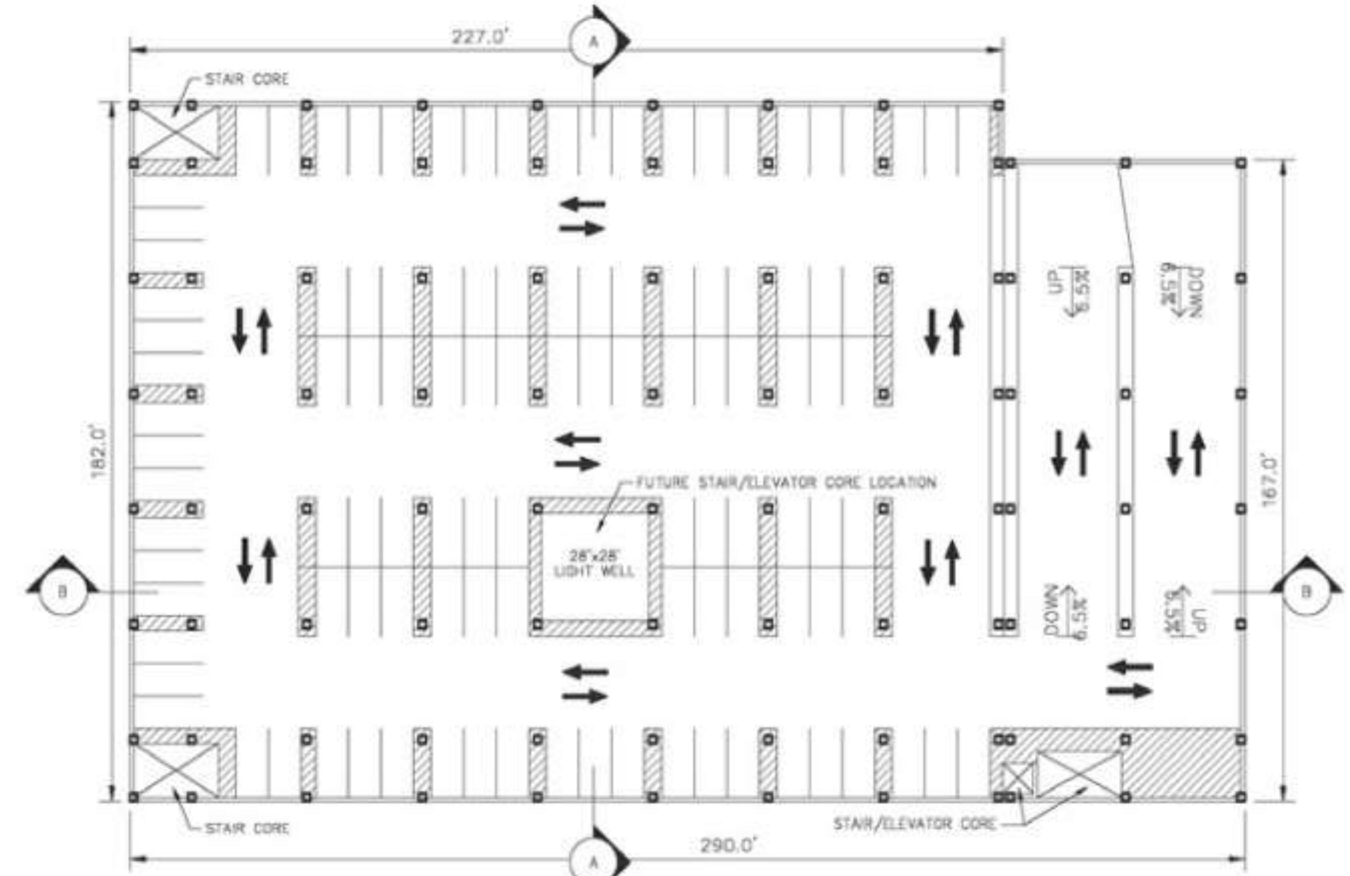
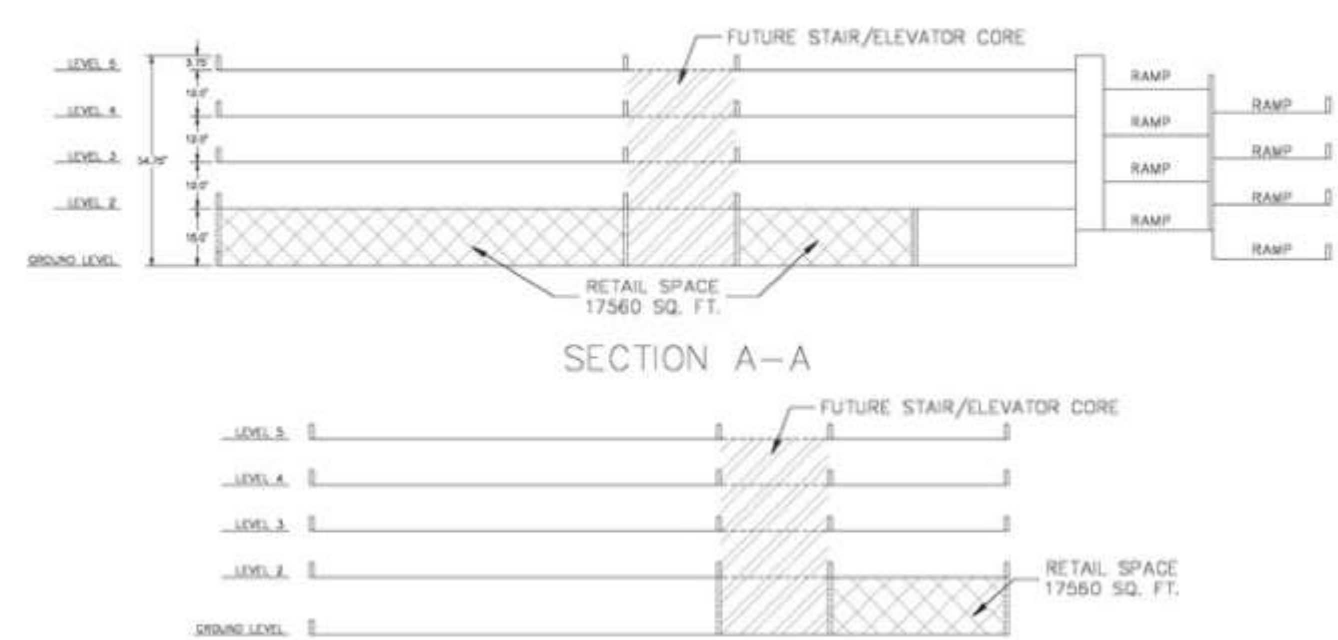
CONCEPT 2: NEAR-TERM USES



GROUND LEVEL



TYPICAL LEVEL



SECTION A–A

SECTION B–B

PARKING STALL COUNT SUMMARY				
LEVEL	SPACES	AREA (SF)	PARKING EFFICIENCY	RETAIL AREA (SF)
GROUND LEVEL	58	29804	514	17560
LEVEL 2	109	51835	476	–
LEVEL 3	109	51835	476	–
LEVEL 4	109	51835	476	–
LEVEL 5	109	51835	476	–
TOTAL	494 *	237144	480	17560

* THE TOTAL NUMBER OF SPACES HAS NOT BEEN REDUCED TO ACCOUNT FOR LOSS OF SPACES DUE TO ADA ACCOMMODATION, MOTORCYCLE PARKING, AND UTILITY AND STORAGE ROOMS.

SHEET 2A

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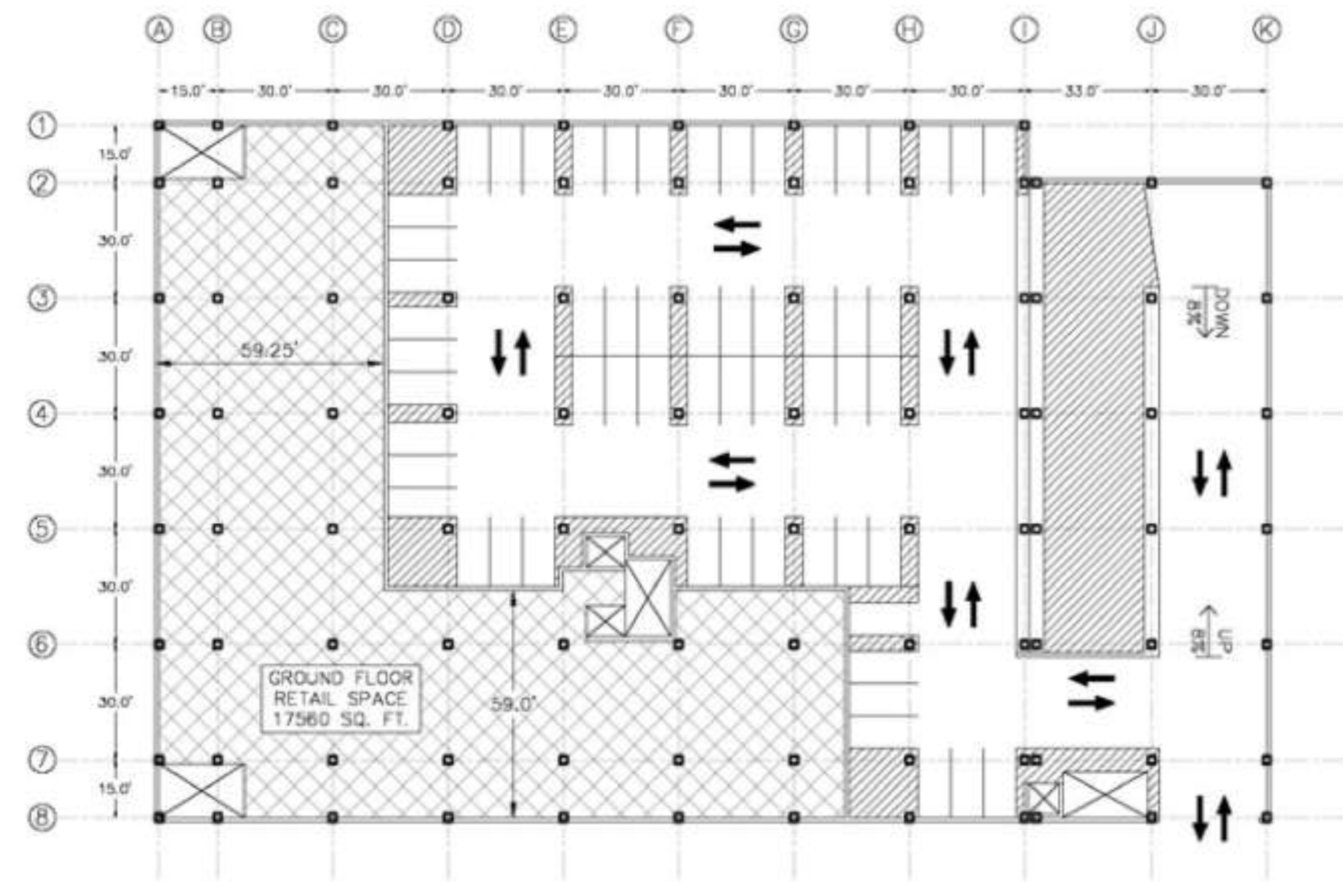
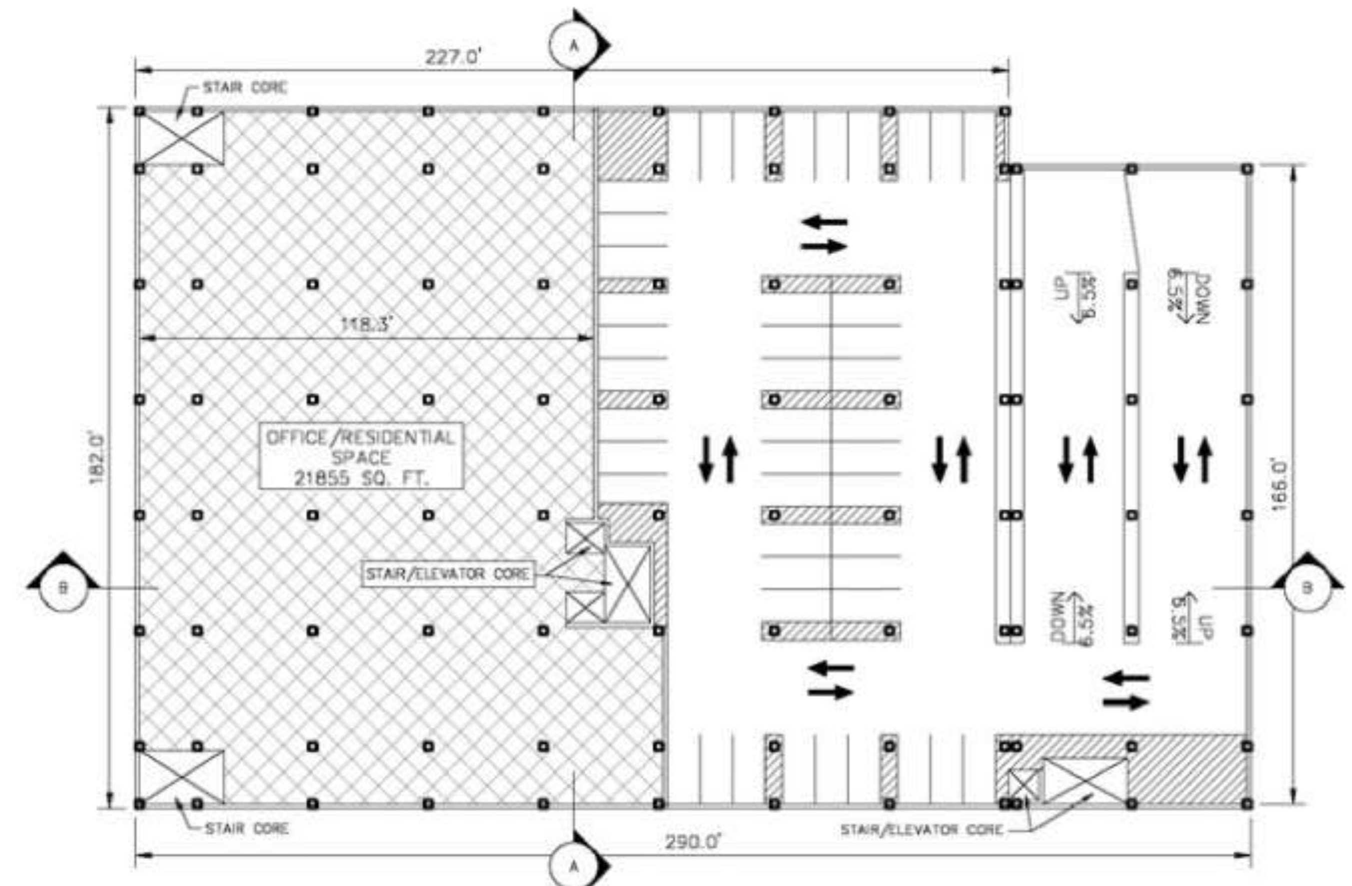
CONCEPT 2: FUTURE BUILDING USES



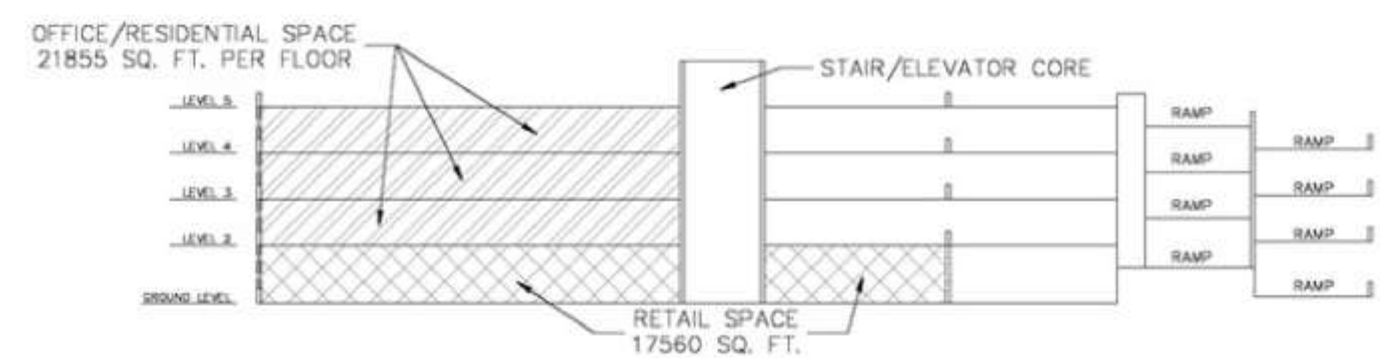
GROUND LEVEL



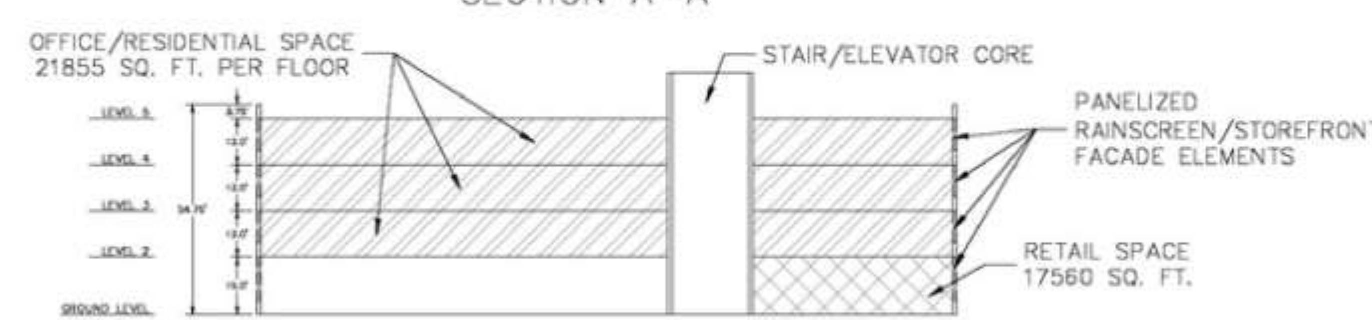
TYPICAL LEVEL

PARKING STALL COUNT SUMMARY					
LEVEL	SPACES (8.5'x18')	AREA (SF)	PARKING EFFICIENCY	RETAIL AREA (SF)	OFFICE/RESIDENTIAL AREA (SF)
GROUND LEVEL	58	29804	514	17560	–
LEVEL 2	45	29120	647	–	21855
LEVEL 3	45	29120	647	–	21855
LEVEL 4	45	29120	647	–	21855
LEVEL 5	109	51835	476	–	–
TOTAL	302 *	168999	560	17560	65565

* THE TOTAL NUMBER OF SPACES HAS NOT BEEN REDUCED TO ACCOUNT FOR LOSS OF SPACES DUE TO ADA ACCOMMODATION, MOTORCYCLE PARKING, AND UTILITY AND STORAGE ROOMS.



SECTION A–A



SECTION B–B

SHEET 2B

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