

RE-PROGRAMMING MOBILITY

The Digital Transformation of
Transportation
in the United States

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INTRODUCTION

The Need for Better Transportation Futures

For decades, transportation experts have anticipated a sweeping technological transformation of the way Americans travel, and the transportation system they use to do so. That transformation has arrived, as the same digital technologies that have reshaped other sectors of the economy, from finance to retailing, are rapidly re-wiring the networks that provide mobility to hundreds of millions of Americans. The changes associated with these innovations are being felt at all scales – from individual trip planning to the design and management of regional mass transit systems.

In a distinct shift from the last 50 years, when transportation innovation in the United States was shaped by big public infrastructure projects like the Interstate Highway System, this transformation is being driven by the private sector. These companies are investing in infrastructure for mobility on a similar scale, but using very different technology. For instance, by 2014 mobile carriers have spent over \$500 billion building out the nation’s cellular communications grid – about the same cost of the Interstates. All but invisible to planners and citizens alike, this new communications network is the most important transportation infrastructure of our era, enabling us to re-invent the how our roads, transit systems, and freight and logistics networks function.

We call this process **re-programming mobility**. In lieu of large civil infrastructure projects, transportation systems are increasingly being augmented with a range of information technologies that make them smarter, safer, more efficient, more integrated. Over the next twenty years, the hints of change that we see today will accumulate, challenging our assumptions about how Americans travel – where they go and why, how they get there, and how the answers to both change the way we use land, the way we plan our communities, and in so doing the very role of government itself in shaping infrastructure and land use.

The hidden nature of these new mobility infrastructures – tiny devices in our pockets communicating over invisible radio waves with algorithms running on servers in the cloud – has conspired to conceal the important public policy and planning issues that their mass adoption raises. While we now recognize the critical importance of understanding how new information technologies will change transportation, there is great uncertainty about how this process will play out.

Key questions facing transportation research include:

- » What new technologies and services will have the broadest impact on mobility? Which will have more focused, but transformative, impacts on niche markets?
- » How will new mobility technologies and services impact land use patterns?
- » What kinds of organizational changes will transportation regulators,

funding agencies, and planning institutions need to begin preparing for now, and what kinds of skills and practices will transportation planners need in the future?

To shed light on these questions, over the last year, our research team conducted a comprehensive horizon scan of current debates about the nature and impact of these new technological innovations. Our analysis draws on more than 150 documents – research articles, case studies, news reports, and opinions and essays – produced by transportation experts, technology experts, journalists, and amateur observers. (A complete source bibliography can be found at on our website at www.reprogrammingmobility.org/sources). From these source materials we have identified hundreds of new technologies, new scientific discoveries, forecasts and speculation, and indicators of emerging conflicts. Some of these documents helped us identify patterns in the emerging discourse and speculation around trends in transportation, others provided expert insights and recent research findings with major implications for the future.

As a body of foresight, these sources offer a stunning diversity of expectations – hundreds of compelling and plausible explanations for how certain technologies may develop, and the impact they could have on transportation in the United States. However, many fall short due to a variety of shortcomings:

- » **Too short of a time frame:** Even overnight successes take time to develop. Much of the discourse about the impact of new technologies is overly optimistic about rates of adoption, market size, and the potential to displace existing market players or public institutions. Often, these types of forecasts rely on assumptions of inevitability that ignore or dismiss public policy choices that would push towards a different future.
- » **Too long of a time frame:** Conversely, many scenarios set 20 or more years in the future are so disconnected from the present and any action we might take today, that anything outcome is possible. They often rely upon technological breakthroughs for which no clear path exists today, but is assumed to be solved over the long run.
- » **Too dependent on a single technology or actor:** Many perspectives on the future of transportation are built around the impact of a single dominant technology or actor. But the business opportunity in transportation, the vast variety of legacy infrastructure, and the sheer range of technologies that are being applied to exploit it, suggests that in the near-to-mid-range future of 15-20 years, the transportation landscape is likely to become more heterogeneous, not less. So while it can be useful to construct a straw man scenario where a single player or technology pulls all the levers, the most interesting ones will be the ones without a clear winner, where tensions are amplified, not resolved. These scenarios may in fact be the ones where policy and planning can play the most valuable function – in helping to choose win-

ners, or create the conditions for certain kinds of technologies to win out, or to actually encourage heterogeneity in the interest of resilience – having multiple redundant transportation networks might actually be a better strategy than a single, ruthlessly efficient one.

There is an urgent need to move beyond the techno-determinism that surrounds discussions about innovation in transportation, that have become bogged down in a Silicon Valley versus City Hall narrative, the innovative upstart versus hidebound local regulator. But how?

We believe that a more realistic, nuanced, yet equally transformative set of stories about the future of transportation are desperately needed. In this report, we present a set of four alternative scenarios set in major American metropolitan areas in the year 2030. These stories are neither too close to our present day (so that there is sufficient time for change to occur on a large scale), too far out in the future (so that they stem logically from actions taken today), too focused on a single technology or event (so that they capture the richness of technological and social co-evolution), nor too binary (so that we can consider a range of actions and outcomes). While this is by nature a speculative exercise, it is not fiction. Rather we have collected the most interesting and insightful forecasts in the public record, and woven them together into a set of coherent stories.

As the private sector takes the lead in setting the transportation agenda, the response from public sector has been largely reactionary and decidedly short-sighted. We intend that these scenarios can be used to spur and inform discussions about the key issues that the nation's transportation planners and policymakers need to anticipate in the coming decade.

Crafting Alternative Futures

The traditional approach to scenario development, pioneered in the 1970s by oil giant Shell, involves a straightforward process of first identifying the two most important and uncertain variables, two possible futures for each, and then constructing four scenarios representing the four possible permutations. For instance, we might choose population growth and the cost of energy and develop four scenarios to represent combinations of high and low growth for each variable. While this method is widely used, it has many limitations. Most importantly, since the entire exercise is driven by just two variables, if you pick the wrong ones, the scenarios may not be relevant. This method is useful for limited, bounded strategic discussions but not for exploring more complex, uncertain futures.

Our preferred approach is the alternative futures method, developed at the University of Hawaii around the same time as the Shell approach, which posits that any story about the future can be grouped into one of four archetypes:

- » **Growth:** A future in which current key conditions persist, including continued historical exponential growth in certain domains (economics, science and technology, cultural complexity, etc.) Also known as PTE, or “present trends extended”.
- » **Collapse:** A future in which some conditions deteriorate from their present favorable levels, and some critical systems fail, due to a confluence of probable, possible, and wildcard factors.
- » **Constraint:** A future in which we encounter resource-based limits to growth. A sustainability regime emerges, slowing previous growth and organizing around values that are ancient, traditional, natural, ideologically-correct, or God-given.
- » **Transformation:** A future of disruptive emergence, “high tech,” with the end of some current patterns/values, and the development of new ones, rather than the return to older traditional ones. This is a transition to an innovation-based regime of new and even steeper GROWTH.

To begin framing these scenarios, we first split the narrative into two elements: the transportation system as an integrated whole, and the individual components (technologies, products and services) that operate within it. In this framework we can start developing scenario narratives:

- » In Growth, structural imbalances in the transportation system are addressed through innovation at the component level concurrently with a limited set of systemic reforms. This is a fair reflection of present trends being extended into the future, for instance, by a continued focus on innovative vehicle technologies with a far slower rollout of smart transportation infrastructure.
- » In Collapse, rapid innovation at the component level exacerbates existing imbalances in the transportation system, creating destabilizing crises.
- » In Constraint, the inability of existing planning and governance structures to deliver transportation infrastructure and services creates the conditions for a new consensus about the need for collective planning and action. The result is a top-down redesign of the entire transportation system, including highly-targeted innovation at the component level.
- » In Transformation, a new transportation system emerges organically from a groundswell of market-driven innovation in both technology and social organization, with government providing frameworks and platforms for bottom-up change.

Into this basic structure, we then placed key narrative elements. From our source materials, we developed a several sets of signals about possible futures: a list of actual digital technologies and services currently being offered in the transportation and mobility sector market, or being developed in research labs, expert forecasts and speculation, and emerging issues and areas of conflict. This material provided the basic toolkit for constructing the scenarios – the actors and the props they use to drive each scenario forward to its conclusion.

To serve as an effective thinking tool, a set of scenarios should be:

- » A good story: with a beginning, middle and end.
- » Plausible: future outcomes must stem from events that are reasonable given present conditions and emerging trends. The scenarios need to be convincing.
- » Specific: cause and effect should be clear in each example used.
- » Internally-consistent: individual scenarios should not contradict themselves, though there should be contradictions between the scenarios, especially when similar events play out differently under different influences.
- » Relevant: the scenarios should address the most important and most uncertain future forces, at local and macro scales.
- » Distinct: each scenario should be distinct enough that the set spans a wide range of possible futures.

However broad our thinking, however, these scenarios represent only a small set of possible futures, not the complete universe of possibilities. They are designed to be thinking tools that challenge us to question our assumptions, ask new questions, and highlight the complex interactions between technological innovation, business, and public policy that will shape our future transportation system and the cities they serve. To this end, we have included a blank template at the end of this document for readers to develop their own alternative future scenario.

THE SCENARIOS

More and than once during the 20th century, the United States experienced significant changes to its transportation system over a 15-year stretch, the same horizon as this forecast. In the 1920s and 1930s, American cities re-organized their streets around the capabilities and needs of the automobile. The Interstate Highway system largely took shape between 1955 and 1970. Each of our scenarios describes a similar re-organization in the nature of transportation and mobility in U.S. metropolitan areas.

However, both today and in the future, focusing only on physical movement and the transportation network doesn't give us the whole picture. Transportation systems are just one enabler of mobility, which is what individuals and businesses are really after. The Forum for the Future, in a recently published global transportation forecast also set in 2030, makes the distinction that "mobility is a means of access – to goods, services, people and information. This includes physical movement, but also other solutions such as ICT-based platforms, more effective public service delivery provision, and urban design that improves accessibility." This broader view forces us to consider issues such as the growth of telecommuting and shifting trends in the housing market as we think about the transportation system.

Because of our focus on digital technology's impact on mobility and transportation, we do not dwell extensively on external factors such as energy, the economy and demographics. This is partly strategic – we do not wish to replicate the excellent forecasts done by others – and partly tactical – incorporating these variables would greatly expand the complexity of scenario development. As written, our scenarios take as a shared starting point an America that for the next five years is economically stagnant, predominantly suburban, and largely powered by the same moderately high-priced fossil fuels of the last decade.

Setting aside important concerns about future energy systems, the economy, and demographic change allows us to focus on this coming wave of technological innovation and the potential opportunities and challenges it raises. Rather than having each scenario shaped by external forces largely beyond our control, we can instead highlight the role that transportation planners and policymakers can play in anticipating and potentially steering the introduction and operation of these technologies to achieve desired outcomes. This focus allows us to home in on several key questions:

- » What technologies are working? How do they enable new forms of mobility?
- » Who is bringing them to market? How are they adopted?
- » Who is regulating them, and how? How do public sector institutions act on or respond to them?
- » What are their unintended consequences?

We explore these questions in the context of four American metropolitan areas: Atlanta, Los Angeles, northern New Jersey, and Boston. While we have sought to portray as accurately as possible current conditions and future constraints in these regions, the link between the specific backdrop for each scenario and the future outcome is not the focus of this exercise.

The illustrations accompanying each scenario, drawn by Jeff Ferzoco of [linepointpath](#), are intended to highlight key shifts in each scenario. We present these highlights as unfinished sketches, drawn in a style inspired by the popular XKCD webcomic series authored by former NASA roboticist Randall Munroe. This style was chosen to highlight the provisional nature of the future, and the need to be playful and experimental, but rooted in solid technical foundations, as we develop our forecasts.

Self-Driving Cars: The 800-Pound Gorilla of Transportation Futures

We are surprised by the speed of development in autonomous and assisted driving technologies. Over the last year, as anticipation fueled by Google's research and development in this area has grown, it has accelerated investment by the world's automakers, and stimulated a great deal of speculation about the side effects of large-scale adoption.

The self-driving car is an idea that has been with us as long as we have been building car-dependent regions. Norman Bel Geddes, the industrial designer who shaped General Motor's highly influential Futurama exhibit at the 1939 World's Fair in New York, predicted extensive automation of private vehicles. Nearly 75 years ago, in his 1940 book *Magic Motorways*, he wrote:

Source

Geddes, Norman Bel. *Magic Motorways*. (New York: Random House, 1940).

[T]hese cars of 1960 and the highways on which they drive will have in them devices which will correct the faults of human beings as drivers. They will prevent the driver from committing errors. They will prevent his turning out into traffic except when he should. They will aid him in passing through intersections without slowing down or causing anyone else to do so and without endangering himself or others.

Fast forward to the 1960s, and while much of Geddes' vision of an auto-centric American landscape was indeed playing out, driving remained a thoroughly human endeavor. But influential urban scholars, such as UC Berkeley's Melvin Webber, again foretold an all but inevitable a future of high-speed, self-driving cars and accelerated urban sprawl:

There has been a great deal of speculation about characteristics of the evolutionary successor to the automobile... it will be automatically guided when on freeways and hence capable of traveling safely at much higher speeds, but that it will continue to be adaptable to use on local streets. If bumper-to-bumper movement at speeds of 150 miles per hour or more were to be attained, as current research-and-development work suggest is possible, greater per lane capacities and greater speeds would be realized than any rapid transit proposals now foresee for traditional train systems... we are bound to experience a dispersion of many traditionally central activities to outlying but highly accessible locations. The dispersed developments accompanying the current freeways suggest the type of pattern that seems probable...

Source

Webber, Melvin. "Order in Diversity: Community Without Propinquity." In *Cities and Space: The Future Use of Urban Land*. (Johns Hopkins University Press: Baltimore, 1963) pp 23-54.

By the 1970s, the U.S. government had jumped on the bandwagon as well, forecasting the arrival of self-driving cars by 2000 in an influential report published in 1977, *National Transportation Trends and Choices*. So, while it appears that self-driving automobiles are a pipe dream that has remained perpetually just around the corner, we do need to take them seriously. After all, so was the video-phone, and today, almost overnight, we all have one in our pockets.

As we look out to 2030, then, what can we expect as these technologies are brought to market? There is little consensus. Some expect as few as 5 percent of the automobile fleet will be fully autonomous, others 15 percent or even greater. But regardless of the rate of conversion, there is a broad consensus that the conversion process to an entirely autonomous motor vehicle system will be well underway. Most likely, we'll see them arrive first in high-end auto models around 2020, in self-contained settings like college campuses and retirement communities, and in commercial fleets such as long-haul trucking and taxis.

All of this creates a tension for our scenario development. Even if self-driving vehicles do not dominate the world of 2030, by then the stage will be set for their

broader deployment to run its course. The choices that are made by markets, and by policymakers who shape them, will have a long-term impact on the transportation system - much like the clearing of America's streets for the automobile in the 1930s. But we also know that in the intervening 15 years, there will be a tremendous amount of innovation in other mobility technologies as well. We risk falling into the trap of letting our scenarios be driven exclusively by self-driving vehicles. With all of this in mind, we took two approaches to deal with autonomous vehicle technologies.

First, we tried to understand how different market and regulatory conditions could result in very different transportation and land use outcomes. In GROWTH, we forecast Google's consolidation of its Waze, Nest, Fiber, Maps and self-driving car businesses into a monolithic public-private partnership with the Georgia state Department of Transportation to manage the development of a segregated autonomous vehicle road system in the Atlanta area, connecting existing edge cities with new exurban housing developments serviced by Google technologies. In COLLAPSE, we forecast a loosely regulated yet reinvigorated automobile industry flooding the streets of southern California with a heterogeneous mishmash of assistive and autonomous vehicles that don't interoperate well - the safety benefits of self-driving cars are realized, but not the congestion-reducing ones. We believe this is an important twist on the public debate, which to date has implicitly assumed a fleet of more or less identical, or at least

highly inter-operable vehicles. Throughout the report we deliberately use a variety of terms to describe these products, (self-driving, autonomous, robot car, etc.) to highlight this issue.

Second, we looked at other modes of transportation where self-driving technology could be even more revolutionary than it will be for cars. In CONSTRAINT, we forecast the development of an expansive regional network of high-speed autonomous bus rapid transit, fed at transfer points by local networks of smart paratransit jitneys. Finally, in TRANSFORMATION, autonomous driving technology underwrites a major deployment of electric bike-sharing systems by allowing users to summon a bike to any location, and the system to automatically reposition and rebalance vehicles.

In short, Google has given the world an inspired engineering feat, but vastly over-simplified vision of how that technology will impact America's future. We hope that these scenarios will give transportation planners and policymakers permission to think far more creatively about what might play out and what we can do to guide it to a desirable outcome.

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SCENARIO HIGHLIGHTS

| | Growth | Collapse | Constraint | Transformation | |
|----------------------------|--|--|--|---|---|
| Key Characteristics | Description | A future in which current conditions persist. Also known as PTE, or “present trends extended”. | A future in which some conditions deteriorate from present favorable levels, and some critical systems fail. | A future in which we encounter resource-based limits to GROWTH. A sustainability regime emerges, slowing previous growth. | A future of disruptive change, enabling the transition to an innovation-based regime of even more rapid GROWTH. |
| | Setting | Atlanta 2028 | Los Angeles 2030 | New Jersey 2029 | Boston 2032 |
| | Headline | Doubling down on decentralization | Automation run amok | Re-inventing transit to implode the suburbs | Densification supported by automated logistics |
| | Driving Forces | Cheap solar power, passenger vehicle automation, | Low-cost self-driving vehicle imports, poor interoperability of assistive and autonomous vehicles | Fiscal crisis caused by costs of severe weather on transportation networks, public support for transit and telecommuting | Housing market shifts towards smaller, connected, single-person dwellings; widespread innovation in small electric vehicles |
| | Land Use & Transportation Impacts | Renewed exurban sprawl, consolidation and expansion of “edge cities”, abandonment of transit | Widespread gridlock; decline in walkability and walking, rise of DIY transit networks | Deployment of regional automated bus rapid transit, consolidation of suburbs around existing centers | Extensive upzoning of bikeable sheds around existing transit, rapid innovation in logistics and delivery services |
| | Outcomes | Financing Scheme | Public-private partnership | Consumer markets | Property transfer tax, dynamic demand-based transit pricing |
| Role of Planning | | Marginalized by corporate lobbying | Re-emerges to implement retrofits to infrastructure and policy, develop large-scale urban simulations | Strong, paternalistic/technocratic planning regime consolidates power | Heavily automated through software, recommendations implemented through community-based crowdfunding efforts |

GROWTH

Atlanta, 2028: Reckoning With the Snowpocalypse



GROWTH • A future in which current key conditions persist, including continued historical exponential growth in certain domains (economics, science and technology, cultural complexity, etc.) Also known as PTE “present trends extended”.

Today, the infamous “Snowpocalypse” of January 2014 is a distant memory. When just two inches of snow and ice stranded thousands of commuters in their cars overnight, the world had looked on in pity. To outsiders, it was the final, decisive verdict on the brittle success of Atlanta’s automobile-dependent, energy-gobbling sprawl.

But today, Atlanta’s economy is stronger than ever, and it is America’s greenest city, the first to receive a coveted Net Zero designation from the C200. Granted, the region’s renewed success had its downsides – hyper-sprawl exacerbated the already huge accessibility problems for the region’s poor, and new kinds of digitally-gated communities, accessible only to fully autonomous vehicles, were popping up. But Atlanta was no longer the poster child for global warming. Rather, it was a model for revitalizing the American economy.

After the Snowpocalypse faded from the headlines, debate within the region over how to deal with traffic congestion was dominated by calls for expanding transit and encouraging denser development around stations. Demand management techniques like road pricing were also considered. But the pro-growth mentality was so deeply engrained in the region’s political culture that a counterintuitive consensus quickly coalesced: the region would simply have to grow its way out of the current crisis. Sprawl wasn’t the *problem*, the thinking went, it was that

the region hadn't spread out *enough*. Sustainability wasn't top of mind, the region needed to be more resilient and able to adapt and stay economically vibrant.

The secret to Atlanta's present success was no mystery. The region simply doubled down on decentralization.

Solar-Powered, Self-Driving Sprawl

This wasn't the first time that Atlanta had tried to grow its way out of a transportation crisis. And it wasn't the first time that a winter storm had laid bare the bottlenecks in its road network. In the years following the 1982 "Snow Jam", another day-long snow-related gridlock, the region entered its greatest period of untramed sprawl. Now, as then, the region's leaders believed, the situation called for bold expansion, not a retreat from the pattern that had worked for so many for so long. Could the same strategy of inaction work again?

By the summer of 2018 - the hottest on record across the South - this thinking had taken root. But just as sustainability experts prepared to write Atlanta off, it turned out that the region had stumbled onto a formula that brought sustainability *and* growth. Sprawl, it turned out, was the ideal land use pattern for building a distributed power grid for electric vehicles.

The idea had first been put forth in an obscure academic paper, little more than a back-of-the-envelope calculation really, published in by a group half-way around the world at New Zealand's University of Auckland. As they wrote:

Source

Byrd, H., et al. "Measuring the Solar Potential of a City and Its Implications for Energy Policy."

Energy Policy. 2013.

DOI: 10.1016/j.enpol.2013.06.042

"suburbia is not only the most efficient collector of solar energy but that enough excess electricity can be generated to power daily transport needs of suburbia and also contribute to peak daytime electrical loads in the city centre... While a compact city may be more efficient for the internal combustion engine vehicles, a dispersed city is more efficient when distributed generation of electricity by [photovoltaic solar cells] is the main energy source and [electric vehicles] are the means of transport."

Atlanta unintentionally proved the authors' theory correct. Not only did solar-powered suburbs generate sufficient electricity to charge all their residents' electric vehicles, they would generate a surplus of power to fuel central cities as well. As icing on the cake for suburban politicians, they could now boast that density wasn't more sustainable, it was actually a costly luxury that would need to be made green by the surrounding sprawl. Paired with sophisticated predictive

weather models that allowed renewables to be more effectively managed, Georgia looked ready to make a transition to nearly 100% green power within the decade.

Building the G-Roads

Just as policymakers began considering how to pull off a solar revolution in Georgia, the first fully-autonomous pod cars began rolling off the assembly line at Google's massive Birmingham, Alabama plant. Much like traditional car companies, Google had quickly learned that the Deep South was a great place for heavy manufacturing – cheap labor, inexpensive electricity, and weak unions.

But what Google was doing in Birmingham was different than any car company had ever done. Taking the same approach to car design that it took to software, the plant was designed to produce a new, updated version of the vehicle every month. Part rapid prototyping, part mass production, the idea was to iterate towards an ideal design, at which point economies of scale would be brought to bear. At first, much as it had demonstrated in the spring of 2014, most of the vehicles produced in Google's plant ended up on college campuses, military, bases, airports and other kinds of self-contained communities where they could be operated at low speed.

The other part of Google's plan hatched over the next couple of years. It wasn't enough to make a great car. Much as it had done with the Internet, Google wanted to control the entire stack, and that meant taking over the roads as well. Much as it had dangled a carrot during the launch of Google Fiber a decade earlier, Google began negotiating with transportation officials around the country. And it soon became clear that nowhere was more receptive to the idea than the metro Atlanta region, which saw an opportunity to advance its decentralization agenda.

Google was busy in Washington, too, where the company was pushing hard to clear the way to export Silicon Valley's bold ideas about transportation and technology to the rest of the country. It found strong support - with the U.S. economy still stuck in its post-financial crisis coma, transportation seemed like a good place to start rebuilding.

The first step was a crash program to automate long-haul trucking. With the driver shortage that had grown throughout the 2010s, and the continued expansion of e-commerce, trucking companies were increasingly struggling to keep goods moving. Citing national security concerns, the federal government established an aggressive timetable for full conversion. Freight haulers were only too happy to comply, and tens of thousands of vehicles were upgraded, with significant cost savings, emissions reductions, and most importantly - fewer accidents. To appease the already waning Teamsters' Union lobby, the program imposed a mileage tax that would clawback some of the freight companies savings on wages to fund a re-training program for drivers put out of work.

The clear success of automated trucking cleared the way for more rapid adoption of the technology in the private auto fleet. Traffic had continued to steadily

worsen within metropolitan areas, despite the stagnation of vehicle miles travelled (VMT) nationally, mostly because people were taking more, but shorter driving trips. Traffic congestion was a significant and growing tax on the economy, contributing to global warming, and – as Atlantans knew well – could quickly become a major crisis.

By 2022, consensus was building in Washington around a bold plan being pitched by Google to rebuild the nation’s entire surface transportation network around three technologies: solar power, electric propulsion, and autonomous operation. The company was light years ahead in pulling together the necessary assets. As Google’s interest in autonomous vehicles had grown, in 2017 it had gobbled up electric vehicle manufacturer Tesla Motors, which had grown to a \$75 billion behemoth, and its sister company, sun-power giant Solar City.

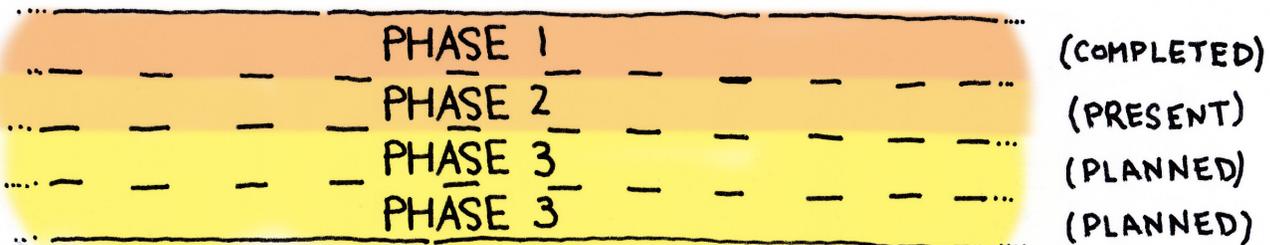
As the pieces fell into place in Silicon Valley, Georgia’s leaders faced up to the new reality long before most other regions could, or would. The finances of most states, and nearly all cities, were a disaster after years of stagnant tax revenue and staggering pension payments, even as the tech industry sat on hundreds of billions in cash. The public sector’s role in financing and managing surface transportation was coming to an end.

And so, the G-Road™ was born.

A power grab that would eventually put Google in control of much of Georgia’s highway system, the G-Road was built on a clever coalition. Google’s engineers had long argued that to realize the benefits of platooning vehicles at high speed, autonomous vehicles would need to be separated from other traffic. Creating autonomous-only roads seemed premature, as hardly anyone owned these vehicles yet.

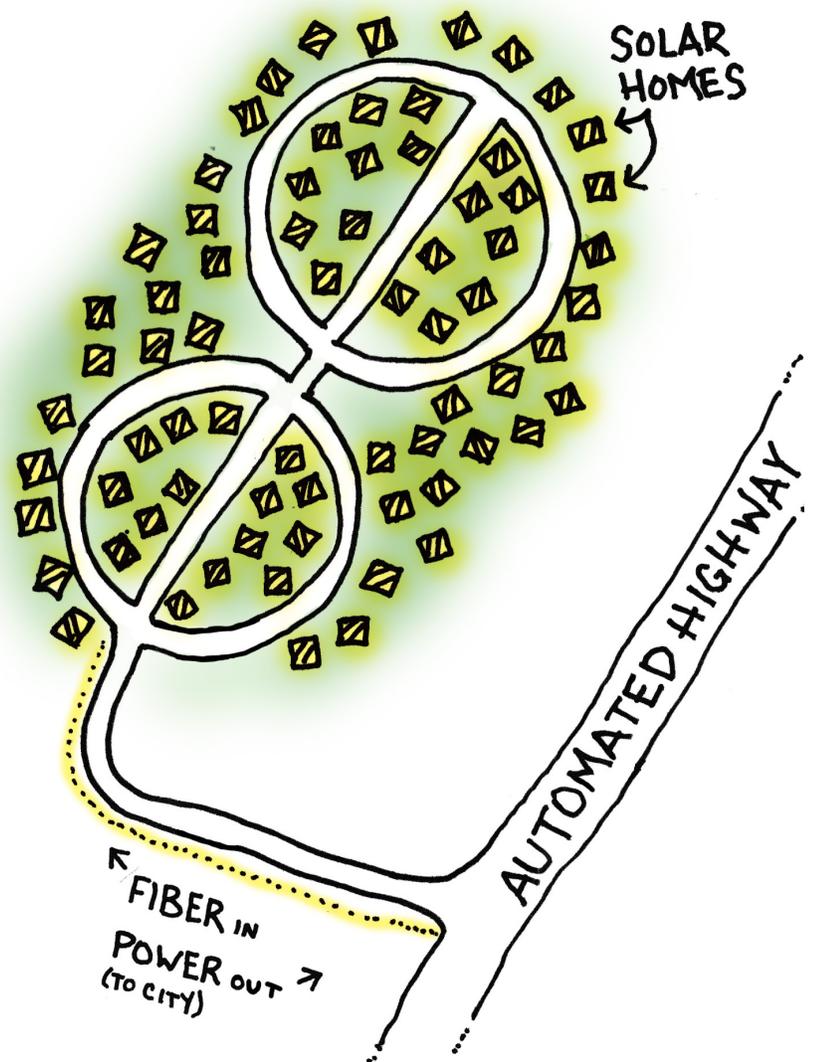
But the company had identified a handful of key constituencies that together could tip the scales. The AARP got on board to tout the benefits for Boomers who wanted to age in their suburban homes but retain access to health care and

G-Road Implementation in Progress



entertainment. A revitalized and renamed MADD (Mothers Against Distracted Driving) touted the safety benefits. Teens even organized their own massive social media campaign, to liberate themselves from dependence on their parents for mobility (though many suspect this was seeded by manipulation of search results and social media by Google). Yet another critical demographic was the region's middle class, who saw autonomous vehicles as a way to access more affordable new housing and public schools at the metropolitan fringe – a package Google's public relations campaign dubbed "the New American Dream". Much as Americans had abandoned the city via Interstate highways in the 20th century, G-Roads were portrayed as alternative beyond the bounds of the congested region.

G-Roads established a public-private partnership between Google, the U.S. Department of Transportation and the Georgia Department of Transportation that essentially handed over the region's extensive network of high-occupancy vehicle (HOV) carpool lanes to be managed by Google under state charter as a fully autonomous-only road network. Google would be permitted to charge for access based on a formula that guaranteed a certain revenue stream for ongoing expansion. It would be required to operate the road as a carrier-neutral network, accepting any vehicle certified by the National Highway Traffic Safety Administration as "Fully-Autonomous Restricted-Access Ready" (FARAR), a new designation created in 2018 to certify vehicles that could operate from entrance to exit on highways with no human intervention. But there was a crucial loophole Google would quickly exploit – it was permitted to provide toll-free transit for its



Automated Exurbs:
Affordable Living and
No-Drive Commutes.

own fleet of Uber e-taxis. With this advantage, Google was practically handed a monopoly on intra-metropolitan taxi trips of more than a few miles' distance.

Google quickly rolled out a number of programs to exploit its new position in the transportation system. Through its Solar City subsidiary, the company began offering residential solar power kits, which allowed it to solve the chicken and egg charging station problem that had dogged electric vehicles since their invention over a century ago. And with data from both vehicle fleets and solar homes, it developed lucrative partnerships with electric utilities to calibrate supply and demand for power. It made changes to the roads themselves, installing inductive charging systems that allowed new versions of the Google car to operate with a battery as much as two-thirds smaller – making the vehicles lighter, more energy efficient and less expensive, accelerating adoption. A metered pricing scheme developed by the Google Maps team was adopted with government approval, with tolls based on mileage and congestion.

By 2030, the impact of G-Roads were clearly being felt across the massive region. The number of FARAR-capable vehicles had grown steadily to about 25% of the total private car fleet, with Google capturing a respectable share of the

vehicle market alongside traditional manufacturers. With extensive use of platoons and flow controls, G-Roads only occasionally fell below full speed of 65 mph, despite carrying substantial amounts of traffic, as much as 50% at peak rush hour on the most historically congested sections. Congestion pricing helped flatten out the peaks even further. Top speeds

The stagnation in VMT that seemed all but permanent by 2022, began to rebound and was growing quickly as guilt-free, effortless automobile travel across the vast region unleashed long pent-up demand.

routinely reached 90 miles per hour, which combined with the reduced opportunity cost of driving (one could surf the web, sleep, etc.) created powerful incentives for sprawl. The stagnation in VMT that seemed all but permanent by 2022, began to rebound and was growing quickly as guilt-free, effortless automobile travel across the vast region unleashed long pent-up demand.

While road metering increased the marginal cost of driving it didn't do much to dampen travel, since the same infrastructure was powering robust economic growth – good paying jobs were putting money in people's pockets, as were their new rooftop solar panels.

A virtuous cycle emerged as revenues restocked public coffers and Google's bottom line, encouraging more investment in continued expansion of the system, and accelerating the switchover to full autonomy. Uber had captured most of the regional taxi market, and had created entirely new markets by enabling some drivers to give up their private cars. Although this part of the business fell far short of projections, it didn't matter as Google was cleaning up on tolls for private

vehicles. A road map to transition additional lanes to the G-Road system was laid out, including expansion into local arterials, with the last access for manually-driven vehicles to be phased out in 2050.

Always a poster child for unplanned urban sprawl, Atlanta was rapidly becoming a new kind of city, a low-density patchwork of suburbs stretching unbroken over hundreds of miles from Augusta in the east to Birmingham in the west (though ironically the G-Road ended at the Alabama border). In the areas of exurban expansion, Google had launched joint ventures with housing developers to build smart home communities, to which it has extended its Nest energy management platform, Google Fiber, and exclusive spurs off the G-Road network. Marketed as “door-to-door no-drive commutes” to large edge city employment centers, they unleashed a wave of housing construction that reached levels not seen since the previous peak in 2006.

Edge City Consolidation

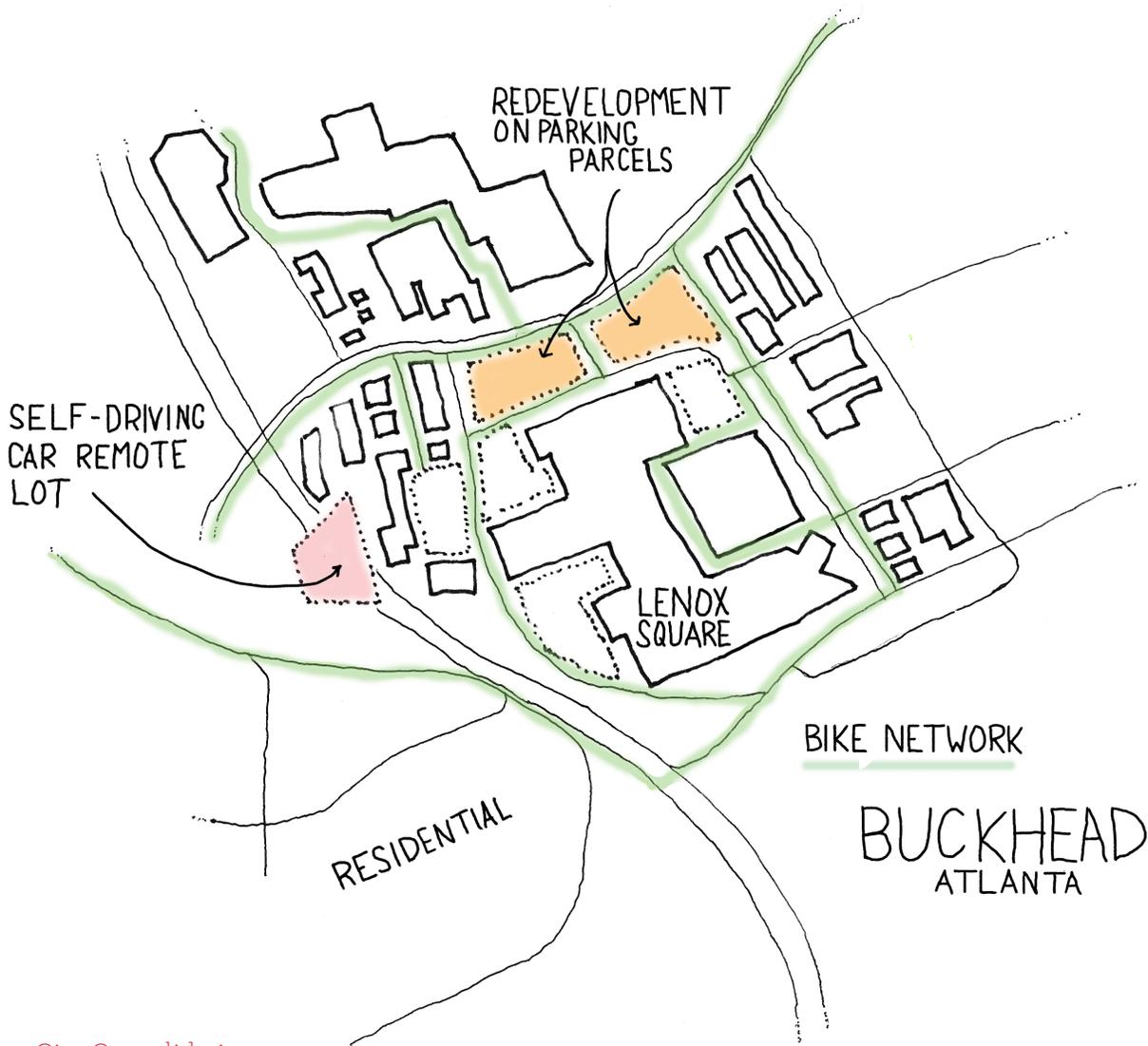
In a surprising turn of events, while the G-Roads catalyzed a new round of housing sprawl, they conspired to increase density at regional shopping and employment centers – so-called “edge cities”. Previously, the growth of these centers was limited by road capacity, on-site parking requirements, and travel times to surrounding residential communities. G-Roads changed all of that, with the help of several other transportation innovations.

Parking, which consumed as much as 50% of the land in the typical American metropolitan area, had long been ripe for Silicon Valley-style “disruption”. Edge cities took advantage of two parking schemes made possible by automation.

First, satellite parking lots for fully autonomous vehicles were built out along approach roads. Vehicles could drop off their passengers at their destination, and then park themselves just a few minutes’ drive away. They could be summoned by smart phone, and even anticipate need of their services. (e.g. “I see your movie is over, may I pick you up?”)

The second breakthrough in parking, automated garages, addressed the manually and semi-autonomous vehicles that still represented the majority of the cars on the road. Essentially robotic garages, these facilities operate like an ATM for cars. The vehicle is driven into a bay, the driver exits, and the car is transported into a holding area where much of the wasted space of parking structures (aisles, head area, etc.) is eliminated. These systems took off not just because of the economics – twice as many cars can fit into the same building envelope – but public safety. Nearly half of all sexual assaults committed by strangers occur in parking structures. Insurers love them too and offer discounts for customers that use them – nearly 1 in 5 crashes occurs in a parking structure.

The consolidation of edge cities around high-speed G-Roads was also enabled by Uber’s self-driving taxis. Having slashed per mile fares by 85% over their 2015 levels, Uber had captured most of the traditional taxi market, and become a



Edge City Consolidation
Creates Density, Walkability

kind of de facto transit service between edge city hubs. It was a different kind of transit though, for while shared rides were available at an even steeper discount, people usually preferred to travel in private rides. To a far more limited extent, Uber also served as a primary means of transportation for a small portion of daily commuters from the surrounding area. Edge cities are by far the most important part of Uber's business in the region, rather than the car-shunning hipsters living in older inner suburbs who were its first adopters.

The reduction in parking needs has freed up land in edge cities for in-fill development, not only making them more dense, but also creating opportunities to stitch them together into districts. Many are being retrofitted to be more pedestrian friendly, and some are experimenting with alternative transportation solutions like shared bike networks and on-demand circulator jitneys. Ironically, as the region becomes ever-more notable for its extreme sprawl, some genuinely walkable islands of urbanism are popping up.

With edge cities consolidating their role as regional centers of commerce, accessed by private car or private taxi, support for MARTA's transit operations - never strong to begin with - had diminished considerably in the last decade. Uber had once seen itself as a car-killer, making private vehicles an expensive folly, but

in an age of cheap, clean energy, and smart roads, people saw little reason to give up automobile ownership. Instead, Uber was a transit killer.

Google was slowly strangling transit in other more subtle ways. While open transit data had spurred the creation of a variety of apps that spurred steady gains in ridership in the 2010s, Google's growing presence created a monoculture in the mobility ecosystem, as the company's Maps app promoted its own services at the expense of others. Planning a journey from point A to point B with a Google app always seemed to always route you by G-Road or Uber. As a result, transit remained marginal in the big regional picture, the share of transit (non including e-taxis) was still less than 5 percent of all passenger miles - almost double what it was in 2015 but not the revolution many planners and activists had hoped for. In 2030 Atlanta it is all too clear that private autos are here to stay. An opportunity to reinvent the system had been lost, some argued.

And edge cities are here to stay too, even as telecommuting and e-commerce continue to expand. For while people may be taking fewer commuting and routine shopping trips, their time is being freed up for other activities around entertainment, education and health and wellness. Despite the rise of distance learning and telemedicine, edge cities are playing host to new kinds of institutions where these activities are clustered. What was left of old downtowns and suburban strip malls is quickly being dismantled by ecommerce and the consolidation of shopping and entertainment in edge cities.

The Rise and Fall of Planners

The years after the Snowpocalypse had been good ones for planners and progressive urbanists in the Atlanta metropolitan area. With growing troves of big data about land use and travel patterns available, a grassroots network came together to craft sophisticated and visually stunning urban simulations and social media campaigns. They simulated the Snowpocalypse, as well as a dozen past decisions about better planning that would have created a development pattern more immune to such disruptions. They identified future crisis areas, and crafted "patches" to the road network and a colossal expansion of the transit system that they framed as the region's existential crisis.

For a few years, it seemed that their efforts might be gaining ground. They were able to engage a broad set of stakeholders about the consequences of business as usual, and even entered data-sharing agreements with private transportation data holders in the local business community including mobile phone location data aggregator AirSage and logistics giant UPS. Transit funding increased, and there was talk of system expansion. Developers began asking for and getting zoning concessions for higher-density projects, following a growing national trend.

But the whole scheme fell apart as Google expanded activity in the region. As G-Roads began to take lanes away from existing traffic, transportation planners turned to every trick possible to manage demand for the remaining road space:

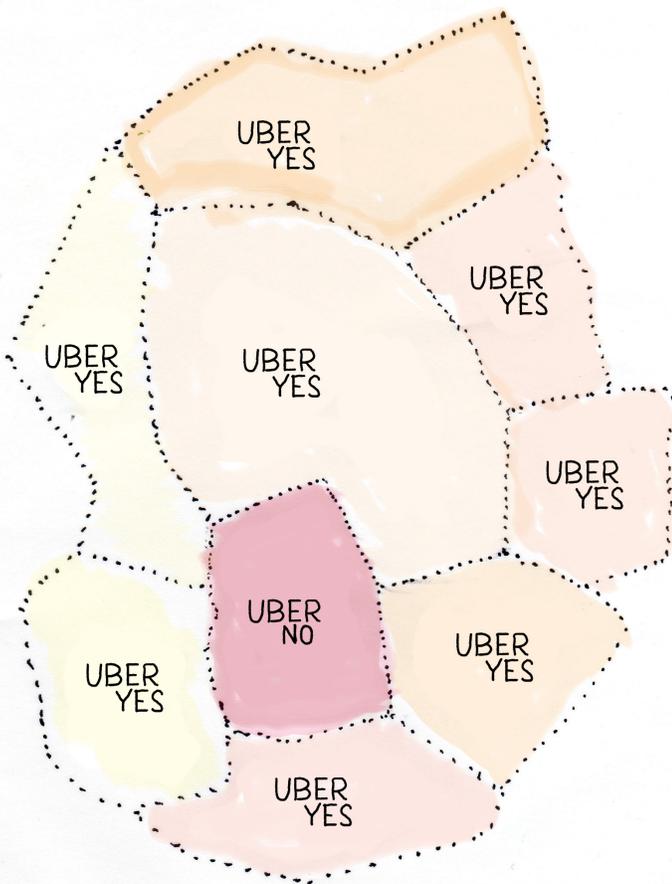
congestion pricing, shifting commercial traffic to off-peak hours, and more open data about transit operations. And they made the case, using mobile phone location data that the G-Roads were actually not delivering the benefits promised. For the average Atlantant, congestion was getting worse. The G-Roads were clearly benefitting special interests.

But it quickly became clear that Google had the upper hand. For the planners, data was a cost center. For Google, it was currency. With its stockpile of travel path data built up over the years from Waze and Uber - far exceeding anything the planners could imagine - and unmatched analytical capacity, Google knew better than anyone how to predict future travel demand. By optimizing expansion, the G-Road rollout could almost finance itself. And with its vast cash stockpile, the company had plenty of time to wait for the system to turn a profit.

Soon Google stopped even meeting with planners and started making its own plans and pitching them to political leaders directly. Throughout the 2020s as the

project played out, the region's planners found themselves with less and less to do. With the exception of their brief post-Snowpocalypse moment of glory, planners had always played a limited role in shaping Atlanta's future. Now, they had become completely marginalized. That the region seemed to be doing great without them dampened hope of turning things around.

Uber Suspected in Mobility Redlining



Prosperity and Discord

Trusting the invisible hand of the market, Atlanta found itself prosperous once again in 2030, its once-maligned sprawl given a new lease on life. It was leading a green revolution that was a new model for high-growth, sustainable development nationally. The planners who had pushed dense, walkable urbanism had forgotten the primary determinant of a city's vitality, now widely understood by urban scientists - is its ability to connect people to jobs through transportation. However humane the New Urbanism was, it was never a scalable solution for getting millions of Americans to their jobs. Atlanta had become a garden city on a once-inconceivable scale, providing millions of people access to both urban

amenities and the countryside.

Yet while Google had engineered a solution to the energy and transportation problems of sprawl, all of the other externalities of car-based decentralization worsened significantly. For instance, at the expanding frontier of the region, new residential development is consuming open space and farmland at an astonishing pace, and the state has begun to consider growth controls for the first time.

But it was the G-Road's impact on social exclusion that raised the greatest concern. Because of the greater cost of autonomous vehicles, they are seen by many as serving the elite – a privileged path from gated residential community to gated commercial community. New smart home communities often restrict access to anything less than fully-autonomous vehicles. In edge cities, this takes the form of “concierge zones”, where prime parking locations are only available to vehicles that can park themselves, or be guided by a smart parking structure. The G-Road network favored the historically more affluent communities in the northern part of the region, while only slowly expanding to the historically lower-income districts in the south. Similarly, there are still parts of the region that seem surprisingly under-served by Uber, especially low-income areas dependent on the decaying bus and rail network that cheap taxis have starved of revenue. It's not yet clear if Uber is deliberately steering drivers away from these areas because they just isn't any business there, or if it is some kind of unintended algorithmic redlining arising out of the way the service matches supply and demand. What's clear is that without a change, Uber's absence in poor parts of the city is a self-fulfilling prophecy that further discourages adoption.

Questions remained about national expansion of the project. Ironically, one of the reasons Atlanta appealed to Google as a testbed was that it rarely snowed there anymore due to global warming, and even after a decade of work the company's autonomous vehicles still had trouble operating in snow. Similarly, with solar power playing such an important role in making the whole model work, no one knew if the model would work outside the Sun Belt. Would the long-running flow of migrants to the South that had slowed during the stagnation of the 2010s and 2020s pick up steam once again? No one knew.

COLLAPSE

Los Angeles, 2030: The Future, Interrupted



COLLAPSE (n) • A future in which some conditions deteriorate from their present favorable levels, and some critical systems fail, due to a confluence of probable, possible, and wildcard factors.

Not for the first time, Southern California was where the future had gone to die. Traffic congestion had steadily worsened for decades, but around 2028, it seemed as if a tipping point had been reached and traffic speeds began to deteriorate rapidly around the clock. By the summer of 2030, congestion had reached unthinkable levels. On most freeways there were no morning or evening “rush hours” anymore, only a 16-18 hour stretch of constant stop-and-go traffic. Some 10 million vehicles of a stunning array of shapes and sizes, equipped with an assortment of assistive and autonomous driving capabilities, now competed each day for space on the region’s roads. Back in the late 2010s the public had been captivated by visions of self-driving vehicles hurtling safely forward in tightly-spaced platoons. What they actually got was a city full of smart cars that can’t quite figure each other out.

Coping with the nightmare that commuting in Los Angeles has become is a full-time job. Owners of fully-autonomous vehicles hit the road as early as 4am, where they can go back to sleep behind the wheel. There are parents who, having waited out the last of the evening traffic until 10pm, simply let their children spend the night in a garaged car, rather than rousing them to come into the house for a just few hours rest. But for most, the typical 20-mile commute might last three hours, much of it spent watching TV, working at an in-car desk, or chatting with one of the many artificially intelligent psychotherapist apps that have become California’s latest self-help craze. Through the windshield comes the whine

of autonomous electric motorcycles shrieking by, splitting the lane, bobbing and weaving with inches to spare.

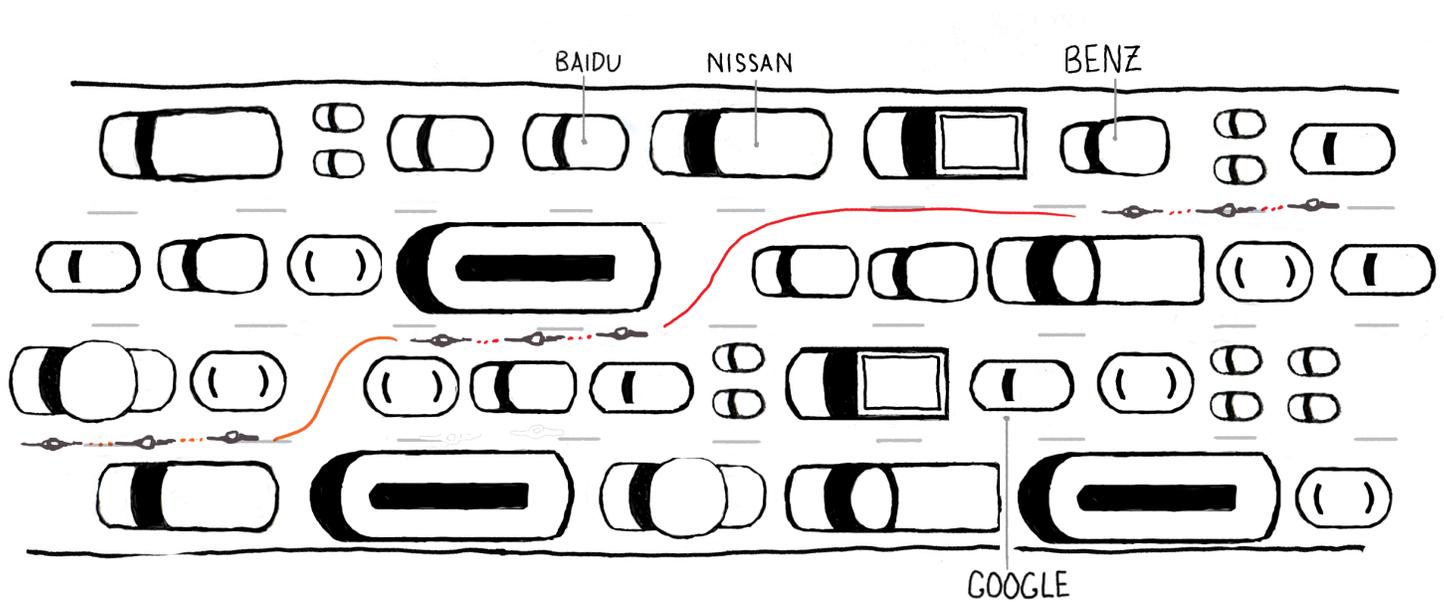
Fifteen years ago, the future seemed bright. Autonomous vehicles were going to save Los Angeles from itself, an upgrade to the region's transportation firmware that would let more cars pack onto the same road system while simultaneously improving the flow of traffic. Southern California was where the world's automakers sent their best designers to soak up American car culture, and Google's unstylish push into the transportation business had provoked a frenzy of creativity.

Car companies understood what Google did not – people didn't want pod cars. The basal, reptilian appeal of car ownership was far more ingrained than the purveyors of "disruptive innovation" appreciated. While Google fiddled around with smart golf carts, the first mostly-autonomous Nissan and Mercedes-Benz models hit the showrooms in Southern California years ahead of schedule in 2018.

At first, it seemed like both kinds of cars would find their niche. Google cars, which drove themselves entirely, but only at low speeds, were already showing up in significant numbers in and around self-contained campuses at universities, resorts and military bases. In contrast, the automakers' new models were mostly computer-driven while traversing the freeways, but manually operated on surface streets. They played off the Google car's shortcomings, targeting the luxury market and early adopters of green technology (autonomous vehicles were unbeatable "hyper-milers" even without the drafting advantage of platoons).

Automakers also lobbied hard to rig the market in their favor. They blocked state and federal legislation that would have allowed Google to begin selling fully-autonomous vehicles – those equipped with so-called Level 4 automation, requiring no active control or monitoring by a human operator. (A 2012 California law did allow such vehicles on state highways for testing purposes only, but only with a licensed operator and manual backup controls. Google's smaller pod cars operated in California under a special Low Speed Autonomous Vehicle classification which limited them to 25 mph or less). Praying on Congressional anxiety over the stagnant economy, domestic automakers also succeeded in lowering the bar for safety, closing an R&D gap with their foreign competitors. Since most car crashes were caused by a small number of high-risk drivers, they argued, autonomous and assisted-driving systems should only have to perform as good as an average human driver, not the best one. Their belief (backed up by extensive focus group research) was that an immediate and steady reduction in injuries and fatalities would validate this approach. The same research indicated that since Americans would anthropomorphize their robot cars much as they had their Roomba vacuums, they would easily accept less than perfect mechanical performance. Self-driving cars that made minor mistakes could actually be cute.

For a few years, it seemed like the automakers were winning. The world looked on in envy as Los Angeles appeared to be making a rapid transition to a more automated fleet. As key stretches of freeway became saturated by assisted-drive



cars, drivers noticed improvements in traffic flow as the self-driving vehicles were able to maintain a steadier speed and reduce spacing.

But Los Angeles was soon to become a victim of its own success. In 2024, Google's Chinese search engine rival, Baidu, entered the U.S. market with its own semi-autonomous vehicle. Pushed into car manufacturing by the exodus of electronics factories to Africa, and pulled into the U.S. market by the new, looser safety standards for self-driving technologies, a slew of new Chinese brands soon followed with their own knock-offs. The sheer scale of production led to a collapse in prices - what Chinese manufacturing had done for solar cells a decade earlier, it now did for smart cars. And drawing upon their experience in the rapid design and production cycle of the IT business, these new auto makers quickly brought new models to market for car buyers eager for innovation.

With tax incentives designed to encourage owners to replace their manually-driven vehicles, sales of Chinese smart cars snowballed. By 2030, 35 percent of the region's vehicle fleet was fully autonomous, and most of the rest had a variety of assisted-drive capabilities. But the overall number of vehicles had grown rapidly as inexpensive self-driving vehicles opened up car ownership to new markets among the very old, very young, and disabled, and new uses for driver-less vehicles were invented.

Once again, traffic ground to a halt.

Automation Run Amok

It might have been possible to manage the arrival of millions of additional vehi-

[Self-Driving Motorcycles
Hacking the Congested
Semi-Automated Freeway](#)

cles in Southern California. But a lack of regulation and standards left a number of challenges in the transition to automated roads unmet.

First, no one had really thought through how a heterogeneous fleet of millions of vehicles utilizing hundreds of different variations of assistive and automated technologies would behave as they interacted on a large scale. While a 2017 federal mandate required the installation of vehicle-to-vehicle (V2V) and vehicle-to-road (V2I) communication capabilities in all new cars by 2020, each automaker was free to decide what to do with the information received through these new channels – say, how quickly to respond to braking indication from a vehicle ahead. Some made timid cars which operated with considerable margins of safety. Others made cars that drove more aggressively, pushing the performance envelope. Automakers also sought to differentiate their products based on novel combinations of assistive and automated features, and different ways of structuring the interaction between driver and vehicles –how the car warns a driver about lane departure, for instance.

The result was mayhem. Before automation, despite the usual erratic drivers, expectations about what others could or would do behind the wheel were fairly predictable. But now, every interaction between two vehicles presented a galaxy of possibilities –between manual, assisted- and automated vehicles and their drivers. While the cars managed to avoid collisions far better than ever before, it was only because they resorted to highly defensive driving. And all the guesswork slowed traffic dramatically.

Second, new human-computer interaction challenges plagued semi-autonomous vehicles as well. Freed of much of the workload of driving, drivers became increasingly distracted by personal devices and in-vehicle media and communications systems. But the rush to market semi-autonomous features meant that the industry never really consolidated its understanding of how drivers focus and multitask while driving, and learn and forget driving skills. As poorly-designed assisted-drive system became overwhelmed by the region’s increasingly eccentric driving experience, they would panic and turn control back over to increasingly distracted drivers during a crisis – who were less than ever prepared than ever. In the same way that cockpit automation had measurably atrophied pilots’ manual flying skills, many drivers were forgetting how to drive.

Third, it turned out that the drivers who caused the most accidents and disrupted the smooth flow of traffic were the ones who resisted automation the most, e.g. bad drivers, aggressive drivers, the elderly. Their poor judgments about braking, accelerating, and changing lanes undermined the good decisions of autonomous vehicles, which had to shy away. And the continued expansion of e-commerce, along with successful resistance of automation in trucking (as the car companies colluded with the Teamsters Union to slow full AV deployment and thus thwart Google), meant that the last-mile delivery problem had become more and more profound. There were more trucks on the roads than ever, and they were a major disruptor to the formation of computer-controlled platoons that could speed the

flow of traffic. It was clear the collapse of Los Angeles' surface transportation system wasn't due to a lack of innovation, but rather too much, with poor federal oversight and unresponsive regional planning.

At first, market watchers and transportation officials celebrated the growing diversity of designs, as the market for autonomous vehicles quickly fragmented into a number of niches. Rather than the Model T future envisioned by Google, hundreds of new automated vehicle types were introduced in southern California's competitive and trend-savvy market. There were semi-autonomous models targeted at the elderly with low-floor entry and medical sensors, and others at super-commuters who spent long stretches living in their cars.

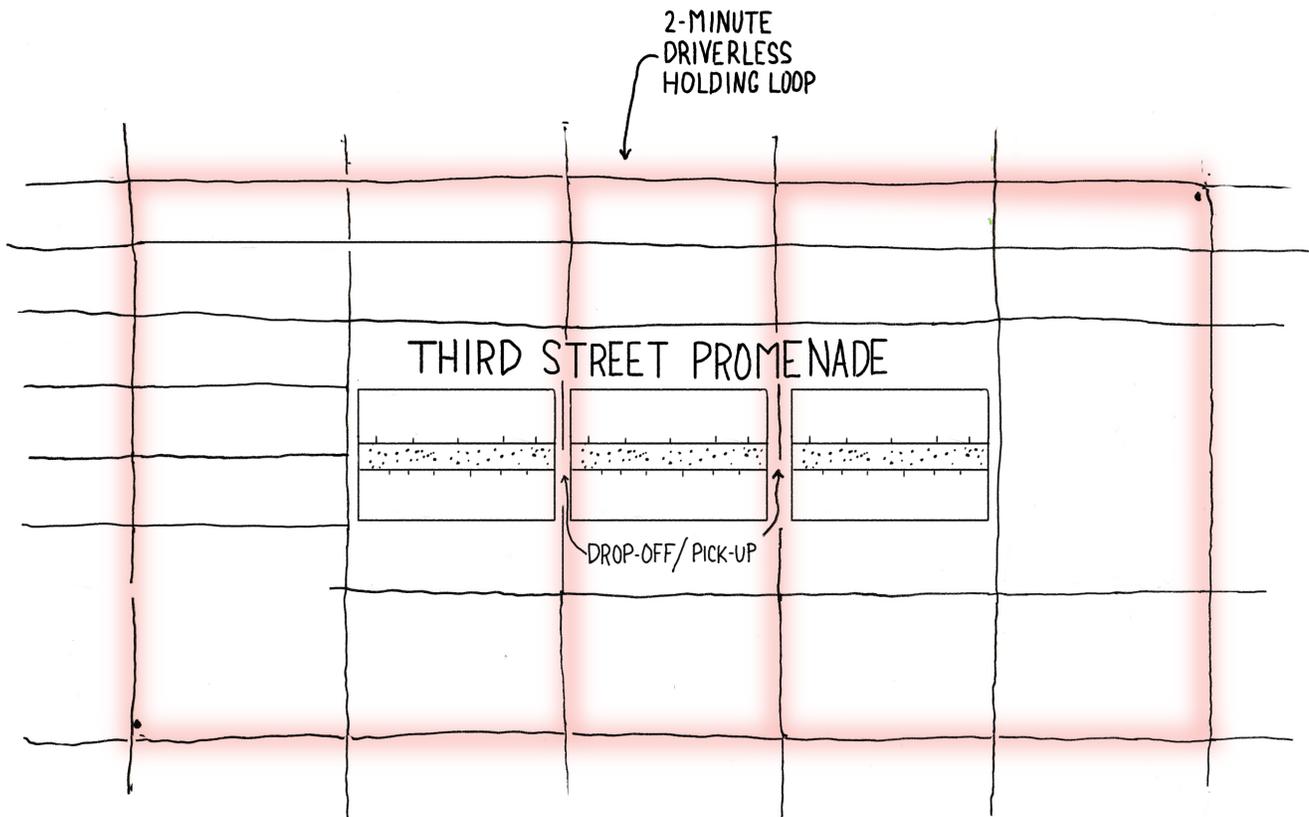
But as fully-autonomous vehicles hit the streets, new markets opened up, and the number of vehicles was projected to grow rapidly as millions of first-time car customers came online. Many of the nearly 1 million Californians with a visual disability were now buying their first car. And while the industry had lamented the declining interest in auto ownership among youth in the 2010s, as cars became more like smart phones, with extensive digital entertainment suites, the trend quickly reversed itself, pushed along eagerly by parents horrified by stories of distracted driving deaths among teens. Ironically, it turned out that just as the biggest youth generation in U.S. history came of age, and the Boomers began losing their wits, the same technology conspired to put them on the roads in record numbers.

It wasn't just innovation in the kinds of vehicles that hit the market in those years, but also the ways people used them, that contributed to the mess.

The first was that the opportunity costs of driving fell, partly because travel times (at least initially) fell on key routes, but more importantly because you could talk, text, or even sleep behind the wheel. Individual travel began to expand rapidly after more than 15 years of steady decline, as time saved from faster travel was used for additional trips for social activities, shopping, and entertainment. Those that suffered through traffic simply did so with less wasted time behind the wheel.

On a more local level, intense conflicts arose over the phenomenon of "zero-occupancy vehicles". Since fully autonomous vehicles could be directed to travel without a passenger, busy parents started using them to run errands unattended – pick up food, the dry cleaning, etc. – and in the birthplace of the drive-thru, businesses eagerly accommodated them. As transportation planners soon discovered, for a growing number of households, such unaccompanied trips resulted in a profound increase in VMT, as much as 30%. More alarming, however, was the practice of "parking" cars in traffic to avoid garage fees, by instructing a vehicle to circulate within a 2-minute travel radius while shopping. The 30 percent of local traffic known to be caused by drivers *looking* for parking was compounded

It was clear the collapse of Los Angeles' surface transportation system wasn't due to a lack of innovation, but rather too much, with poor federal oversight and unresponsive regional planning.



Drivers Avoid Parking Fees By Sending Cars to Idle Nearby

by traffic caused by cars *not looking* for parking! In Santa Monica, this practice became such a nuisance that a local ordinance was passed subjecting passenger-less vehicles to seizure.

New uses for autonomous vehicles were having surprisingly negative impacts on other modes of transportation as well.

Within the region's relatively few walkable neighborhoods, an influx of cheap, self-driving taxis meant that a pickup was usually never more than 60 seconds away. People soon realized that if their time was worth money, it was cheaper to e-hail a taxi than to walk. Planners looked on in horror as walking rapidly declined, and the prevalence of so many closely-spaced vehicles intimidated those few hapless pedestrians that remained. As one American urban planner, Ian Lockwood, had predicted in 2014, "It's going to be like a machine gun spray of cars down the street." As a form of transportation in the Los Angeles basin, walking was on its deathbed. The city seemed to be entering the end stage of its addiction to the automobile.

The influx of smart cars also had a chilling effect on transit, whose traditional base of support among the poor was being undermined by cheap robot cars. Youth ridership plummeted as well, when it turned out that the main appeal of transit for youth since the mid-2000s was that it let you shift your gaze off the road and onto your tablet. As the average age of the transit customer began to

increase again the political reality became clear – transit’s role in region’s transportation future would remain limited.

Phoenix Rising: Reinventing Planning, Reinventing Transit

Los Angeles had long been at the vanguard of humanity’s reckoning with the automobile. And by 2030, the region was locked in a yet another epic struggle over the unintended consequences of mass auto ownership.

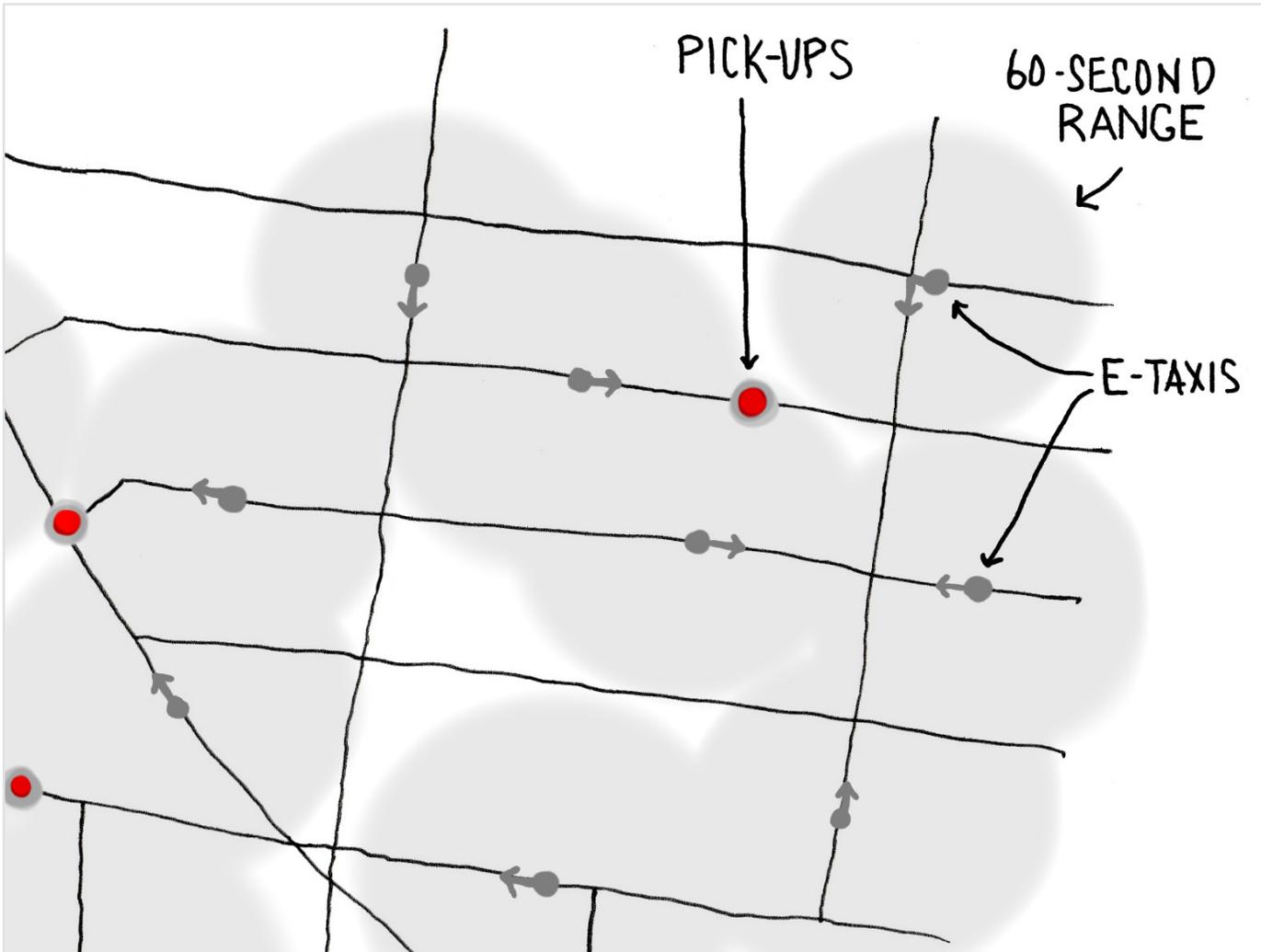
Nearly a century earlier, Los Angeles had experienced its first big smog. The cloud, which appeared on July 26, 1943, was initially thought to be a Japanese gas attack. But unlike the war, which was won in a matter of years, southern California’s battle against car-created air pollution lasted for decades. In 1976, with the formation of the South Coast Air Quality Management District, Angelenos began to rein in their cars’ pollutant-spewing ways.

Much as it had before, the region now began to mobilize to address the challenge of automation, and other cities took notice. The first step was a re-formulation of state and local transportation planning institutions and culture. The rapid pace of technological innovation in transportation driven by the infusion of digital technology had exposed the lack of agility and adaptability in transportation planning and management. Even when they were effective at anticipating needs, planning institutions had lost the public trust, and were widely seen as instruments of the elite.

To reclaim the initiative and instill public trust, CalTrans and the Southern California Association of Governments (SCAG) metropolitan planning organization began to push a four-step action plan that they hoped would break the region’s transportation and political gridlock.

First, they would decipher why the region’s traffic was so bad. According to the car companies and ITS experts, self-driving vehicles should have made it possible for the road network to accommodate the influx of new vehicles and increased travel – or at least avert the collapse that had actually occurred. Transportation scholars suspected that the complexity of interactions between so many heterogeneous automated systems was to blame, but couldn’t prove it. And so to get to the bottom of what was going on, a new, inter-disciplinary research group was established at UCLA with federal funding, charged with the task of building a computer simulation that could. But it was a huge technical challenge, as such a complicated model had never been built before. Many doubted it could be done.

The second initiative, which would build off the findings of the modeling effort, was to complete the conversion to full automation. A new statewide mandate was drafted that would require all remaining manually-driven and semi-automated driven vehicles to be retrofitted with V2V communications, and automated freeway platooning capabilities within 18 months. By prioritizing and accelerating adoption of this specific flavor of self-driving, the state hoped to break the defen-



Cheap, Ubiquitous E-hail taxis Undermine Vitality of Walkable Districts

sive-driving gridlock caused by the automakers' over-emphasis on safety, and the inconsistency of the remaining human drivers. While these upgrades were relatively inexpensive, financial aid was made available for low-income drivers.

The third step was investment in vehicle-to-infrastructure communications (V2I). The proposed California Freeways 2.0 Act of 2030 recognized that relying solely on vehicles that talk to each other wasn't enough. The state needed smart roads too. Such systems would allow warnings and other information about conditions further ahead to be spread more widely and rapidly. It would allow for top-down interventions to address chronic congestion points or crisis incidents. And it would provide the massive movement data needed to power the comprehensive regional transportation model. But mobilizing the funding and implementing this program was daunting. After all, LA's ATSAC traffic signal control system had been decades in the making before its completion in 2013.



And it was still unclear if the same tort liability exemptions that governed traffic signals would apply to V2I.

This ambitious new transportation agenda was a heavy lift, and it wasn't clear if it would succeed in whole or even in part. But it was the only visible path out of this mess.

Or so it seemed. The final piece of the plan was picking back up the transit agenda that had been abandoned 10 years earlier during the peak of the automated driving hype bubble. But given the demands of V2I on transportation spending, there was little money left over, and the system had deteriorated significantly. And with some 20 private bus operators in Los Angeles county, there had been little coordination of investment in technology.

But even as the rest of the region had collapsed into a gluttonous wave of vehicle consumption, and transit agencies failed to seize new technology to reinvent themselves, a DIY transit culture had flourished in some of the poorest immigrant-dominated parts of the city, and spawned informal alternatives to public systems. By 2029, as a growing number of second-hand fully-autonomous vans began to hit the market, they were re-combined with business models and technologies from the developing world. While the rest of Los Angeles had simply

DIY Self-Driving Dollar Vans Arise as Transit System Feeders

While the rest of Los Angeles had simply traded in their dumb private cars for smart ones, many of L.A.'s poor were taking their cue from Mexico City and Manila, and giving para-transit an upgrade.

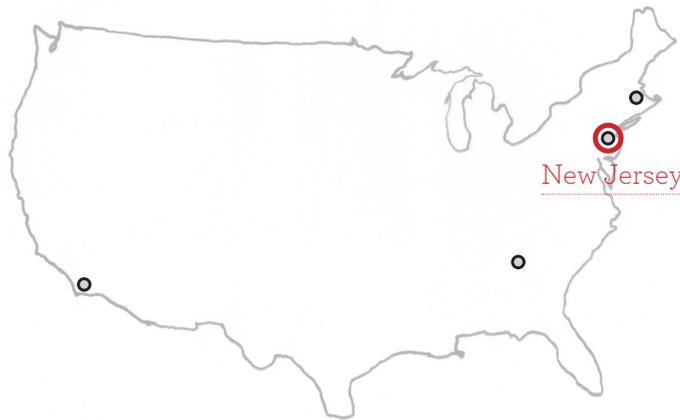
traded in their dumb private cars for smart ones, many of L.A.'s poor were taking their cue from Mexico City and Manila, and giving para-transit an upgrade.

But unlike the dollar vans of 2010s, which were always seen as an inferior alternative to private cars, these self-driving jitneys were safer, cheaper and faster. Bypassing freeways in favor of ad hoc routes along surface streets, they provided a vital link between homes and jobs for hundreds of thousands of people. The city's wealthier enclaves looked on with great interest, and soon shared e-taxis began to spread.

LA's experience is driving a rethink of the future of autonomous vehicles in the US. No one had ever considered the risks of incomplete automation and now planners everywhere are trying to figure out ways to accelerate the adoption of these technologies and avoid getting stuck in transition like LA. It wasn't clear how long it would take to fix LA, but the region had faced great challenges before, as with smog and race relations, and continued to thrive.

CONSTRAINT

New Jersey, 2029: Automated Austerity



CONSTRAINT • A future in which we encounter resource-based limits to GROWTH. A sustainability regime emerges, slowing previous growth and organizing around values that are ancient, traditional, natural, ideologically-correct, or God-given.

In 2020, one could be forgiven for avoiding the bus in New Jersey at all costs. In 2029, one would be equally hard pressed to find another way to get around. The nation's most densely populated state, which had reached the limits of sprawl ahead of all others, was now a model of planned, transit-oriented development. By crafting a novel, uniquely American approach to mass transit, New Jersey had preserved its economy and its landscape.

The trigger for this revitalization had come a decade earlier, after five successive years of brutal extreme weather. The region's transportation infrastructure was a shambles, and public finances didn't look much better. The costs of frequent track repairs had already bankrupted New Jersey Transit, the state's transit operator. Dozens of municipalities had filed for bankruptcy as a result of road repair costs. The state Department of Transportation was struggling to plug the gaps.

Meanwhile, other economic and demographic forces were pushing a broader re-assessment of mobility and accessibility in the region. Few in the know believed that the state's road network could absorb its substantial forecasted share of population growth in the New York metropolitan area, unless the switch to full autonomy could be made quickly. Yet all the market signs pointed towards a messy conversion of the private vehicle fleet taking de-

By crafting a novel, uniquely American approach to mass transit, New Jersey had preserved its economy and its landscape.

acades. The extensive rail network in the northern part of the state had an important role – but it was largely focused on moving commuters in and out of Manhattan, not between suburbs, and was already operating beyond capacity. Moreover, beginning with Superstorm Sandy in 2012, and several times again in subsequent years, rail lines and terminals along the coast had sustained heavy damage.

By 2019, consensus for a sea change in transportation planning, management and finance was growing throughout the metropolitan area. New Jersey wasn't alone, as New York and Connecticut – also under the aegis of the New York Metropolitan Transportation Council (NYMTC)– shared many of the same challenges. But while NYMTC, like other metropolitan planning organizations, played a critical role in allocating federal transportation spending, it lacked the authority to take significant actions that could change the transportation system for good. While New Jersey's legislature was ready to pass a comprehensive set of statewide land use and transportation reforms, an organization with more teeth would be needed to actually implement them.

All eyes turned to the Port Authority of New Jersey, which to everyone's surprise had emerged from the 2016 breakup of the Port Authority of New York and New Jersey as a highly effective, transparent public institution. Expanding the authority's charter to a half-dozen of the state's most heavily populated counties surrounding New York City, legislators tasked the organization with an ambitious agenda – implementing a statewide plan that had been adopted in 2001 merely as an advisory document. Further reforms consolidated the state's planning and transportation agencies – including New Jersey Transit and the State Office for Planning Advocacy (which was renamed the Office for Plan Administration to reflect its new jurisdiction) – under the Port Authority, which was re-named the Regional Authority. The corporation was funded by a new “planning tax” on property transfers (an additional 1% tax on homes selling for over \$1 million), providing some \$250 million in annual revenue.

The Regional Authority (RA) moved quickly, as it was clear that unless it could rapidly deliver tangible improvements in essential public infrastructure and quality of life, the backlash against reformers would be swift and severe. At the RA's offices overlooking the Statue of Liberty in Jersey City, a plan was hatched for the most rapid deployment of mass transit in world history – a project RA planners simply called “The Big Hack”. It was a reset for the region's transportation system, one which would lay the groundwork for a massive shift in land use.

The big idea, which took the transit-oriented approach from previous state plans, and added a more forceful element of withdrawing services to outlying exurban areas, was to literally collapse the suburbs into regional centers. Alongside the existing rail system, a new network of fully-autonomous buses would be deployed, with e-hailed local jitneys ferrying riders into regional high-speed bus rapid transit corridors built along existing highways and arterial roads.

The planning process for the new system was unprecedented in speed and scope. Through a partnership with AT&T Wireless and New York University's Center for

Urban Science and Progress, planners drew on billions of historical data points tracking the movement of mobile phone subscribers to model individual commuter behavior and predict demand for both jitneys and express buses. Though some tweaks had to be made, the predictions turned out to be remarkably on target.

Financing the system took a lot of radical thinking and often questionable practices. Prison labor was used extensively for station construction, a throwback to the era of chain gangs. And foregoing the separated guideways of “true” BRT for draconian enforcement of lane restrictions on private vehicles using extensive video surveillance and machine vision, raised deep concerns over privacy.

As construction began in 2021, an equally massive public relations campaign ramped up. A tongue-in-cheek retro-communist campaign spread the stark message, compelling rather than cajoling people to “GET ON THE BUS”. Online tools helped riders understand the new transportation options available to them, showing how they could use the new jitneys to get around town to local destinations, and commute across the region and into Manhattan. And to top it off, the RA tapped star appeal. Early in 2021, the first jitney rolled up in front of the Montclair, New Jersey home of nighttime television host Stephen Colbert.

Against all odds, riding the bus had become cool.

Mass Transit, Mass Expansion

Less than six months after launch of the first pilot, it was clear that the system would be a hit. A decade earlier, many would have thought it would be the geeks of Silicon Valley who would be the first to flock to self-driving buses. After all, they rode them to work every day. But it was the growing numbers of young suburbanites, increasingly poor, who had made automated public transit their own. The appeal of the e-buses was strong among this group because they have never been inculcated into car culture in the first place. What they wanted was inexpensive, on-demand, connected and social transportation. And by re-thinking the entire system from beginning to end, the RA was able to create a seamless, appealing service.

Even before you decided to take a trip, the experience was completely different. Having maintained the data-sharing agreement with AT&T from the earlier planning project, the RA had by now developed a working predictive model of the daily travel patterns of everyone in the region. As a result, there were two ways to request a pickup: you could make an on-demand electronic hail via an app, or respond to a predictive scheduler. Beginning about 24 hours in advance, the predictive scheduler would begin offering seats to the most habitual riders, working through to the most erratic regulars.

The predictive scheduler was the key mechanism underlying the e-bus’s highly sophisticated pricing model, which is very dynamic but highly transparent – essentially the same demand management scheme long used by airlines. In general, the earlier you respond to the booking request, the lower the fare. On-demand

fares were capped at 200% of the regular fare, and the base fare was priced on a combination of distance and congestion surcharges – with the exact rates adjusted on a weekly basis to keep revenue in line with budgeted spending. In addition to price-based incentives, there are public service requests similar to “spare the air day” campaigns that used to encourage people to take public transit during air quality emergencies.

For most riders, each commute starts with a jitney ride. Once booked or hailed, riders meet their jitney at a network of shelters, self-contained pods designed along the lines of bike share stations, to be simply dropped at 5-minute walk intervals along major corridors.

As jitney routes were calibrated during initial operation, the shelters could be easily relocated to more permanent positions. Estimated arrival times for each present passenger’s pickup are posted on a display.

Once aboard, payment is fully transparent, with all ticketing handled by a smart phone

tracking system. Because each ride can be linked to a specific rider, the system allows for many different kinds of subsidized pricing schemes. Pre-existing schemes for senior citizens and children are continued, but new discount pricing plans are developed through hooks from the fare billing system into means-tested programs like food stamps and unemployment, providing inexpensive mobility to disadvantaged groups.

Jitney passengers enjoy a variety of digital amenities such as high-speed wireless hotpots and displays indicating travel time to popular destinations in the local and regional network help orient the passengers and make productive use of time. Powered by electricity, the actively-stabilized jitney is clean and quiet with a smooth ride.

For many local rides, the same jitney that picked you up will drop you off at your destination, although some trips will require a transfer. Since wait time is minimal (the dispatching system juggles travel routes to allow for ad hoc passenger swaps) they are generally effortless. For longer journeys, there is a transfer at an express bus station, which has the usual food and retail concessions, but also a teleworking and coworking hub, usually operated by the local public library. Larger transfer points even have limited short-term accommodations.

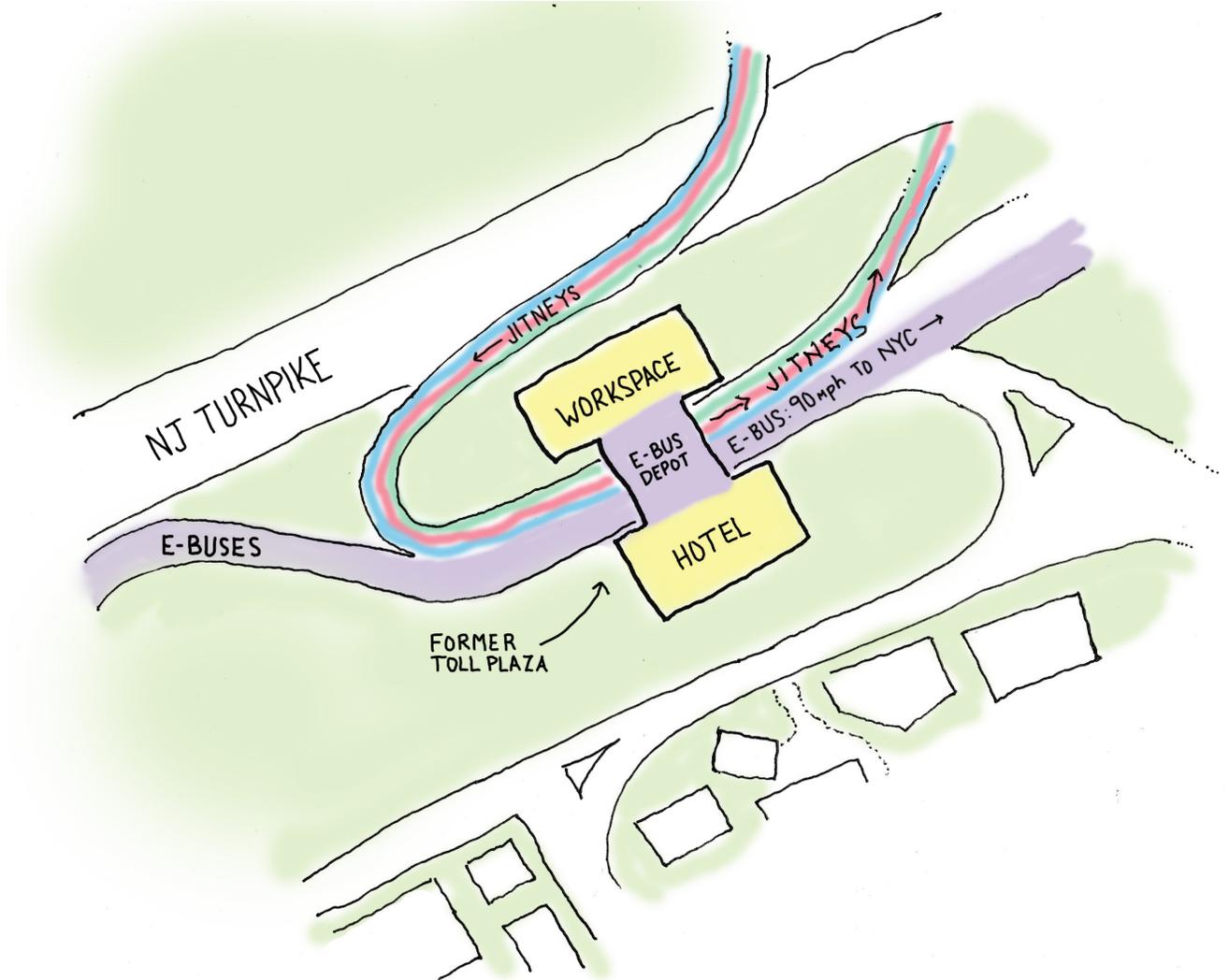
The express buses are a radically redesigned version of old inter-city buses. There are a variety of seating configurations, from traditional face-forward to pods suitable for small group discussions. Desks and tables are fitted into various pockets, making it friendly for computer-based work, and an array of new boarding schemes makes it easier for disabled persons and mothers with small

With predictive signaling and exclusive access and high-speed travel lanes, New Jersey’s smart buses have cut commute times dramatically – the run from downtown Montclair to Manhattan, which used to take 50 minutes, now takes just 30.

children to ride. With predictive signaling and exclusive access and high-speed travel lanes, New Jersey's smart buses have cut commute times dramatically - the run from downtown Montclair to Manhattan, which used to take 50 minutes, now takes just 30.

Over the next few years, the RA continued to expand the system into areas with predicted demand. Despite the high priority on public transit, there are of course still private cars, and increasingly many of them are fully-autonomous. But their numbers are dwindling fast, and they are mostly for the rich. And so the RA also wielded a big stick, phasing in ubiquitous metered road tolling in areas served by the e-bus system. The tolls are steep, and the funds are earmarked for the e-bus

Retrofitting Toll Plazas for Express Bus Transfer



system. There are waivers for some doctors and other essential personnel, but as the bus network nears completion, these too are being mostly phased out.

By 2030, the network was largely complete. In just ten years, the RA had built a network of self-driving express buses and on-demand jitney feeder networks that reached nearly 4 million residents in northern and central New Jersey, and tripled daily bus ridership to 1.5 million daily riders, for a total cost of just under \$10 billion. With its demand-responsive pricing, and low operating costs due to automation, as well as sophisticated predictive failure analytics and maintenance scheduling optimization algorithms that improve the productivity of work crews, the system is now profitable. And it has met the mobility needs of the same constituencies that many thought would drive adoption of private autonomous vehicles: the elderly, children, and disabled.

Hundreds of thousands of cars had been taken off the road, slashing carbon emissions. And the system was incredibly resilient – it could be re-routed around floods, power outages, and sinkholes – all of which had become all too routine in an era of extreme weather brought on by climate change. New Jersey had shown that smart buses could deliver the efficiencies of rail, with much of the freedom and flexibility of private automobiles, at a fraction of the cost of either. Instead of laying down corridors of steel in flood zones, the state had instead built a resilient network of lightweight infrastructure.

The “Soft Tunnel”

Betting big on buses was the biggest and most visible investment but without what Regional Authority planners came to call the “soft tunnel”, another set of digital interventions in the region’s transportation system, it would never have worked.

As the wider New York City metropolitan area continued to grow between 2015 and 2030, population growth was split roughly evenly between New York City and New Jersey. Other suburbs to the north and east in Long Island, Westchester and Connecticut never overcame their NIBMY resistance to more dense development and as a result had stagnated with an aging population and shrinking tax bases. But because Governor Chris Christie, at the height of his political power, had cancelled construction of a badly-needed third Hudson River rail tunnel in 2013, another solution needed to be found to get the booming number of New Jersey commuters to their jobs in Manhattan.

The Regional Authority’s answer involved three big technological fixes.

First, as the number of e-buses grew, they could be run in closely-spaced platoons, which both saved fuel through drafting effects, but also allowed more of them to move through the Lincoln Tunnel, increasing capacity. Similar technolo-

gy was also deployed on existing rail service, reducing headway and increasing throughput at the two existing tunnels.

Second, the Regional Authority Bus Terminal (the former Port Authority Bus Terminal) was expanded and re-designed to accommodate what might top out at 750,000 passengers per day, a nearly three-fold expansion from 2015 levels. As part of the re-design, an intelligent bus traffic control system was put in place, similar to those used at the region's airports, to sequence incoming traffic through instructions for small, automated adjustments in travel speed.

Third, and most significant, was a bold embrace of telecommuting, financed by a grant from the U.S. Department of Transportation. In a pilot program closely watched by transportation officials from around the country, the idea was to stifle demand for access to the region's core by paying companies to keep their workers at home - in a strategy similar to federal farm subsidies that paid farmers to not grow crops when commodity prices were already too low. By providing home- or telecenter-based workplaces for employees, and submitting to remotely-sensed spot-checks to verify worker location, large employers based in Manhattan would receive federal tax credits based on the number of trans-Hudson commute trips eliminated. Valued at \$750 million, the tax credit incentive pool was designed to achieve a 20 percent reduction in New Jersey to New York commuting, from 400,000 to 320,000 daily.

Imploding The Suburbs

By 2026, with a new resilient, environmentally sustainable, and financially healthy transportation network being put in place, the Regional Authority was well-positioned to begin reigning in suburban sprawl. The suburbs began to implode in several ways.

First, e-jitney feeder systems dramatically reduced parking requirements at existing rail stations, freeing them up for development. Through a limited power of eminent domain embedded in its charter, the RA was able to seize these lands and sell them to developers. While the RA passed on a substantial portion of the proceeds to the municipalities from which it had been taken (a significant multiplier of their previous parking fee revenue), most was kept for network expansion. Municipalities benefitted primarily through a substantial increase in rateables and property tax revenue. Ironically, this was key to the whole effort - while its opponents had argued that the State Plan was a socialist no-growth agenda, it actually required growth to work. It was very much a creature of capitalism.

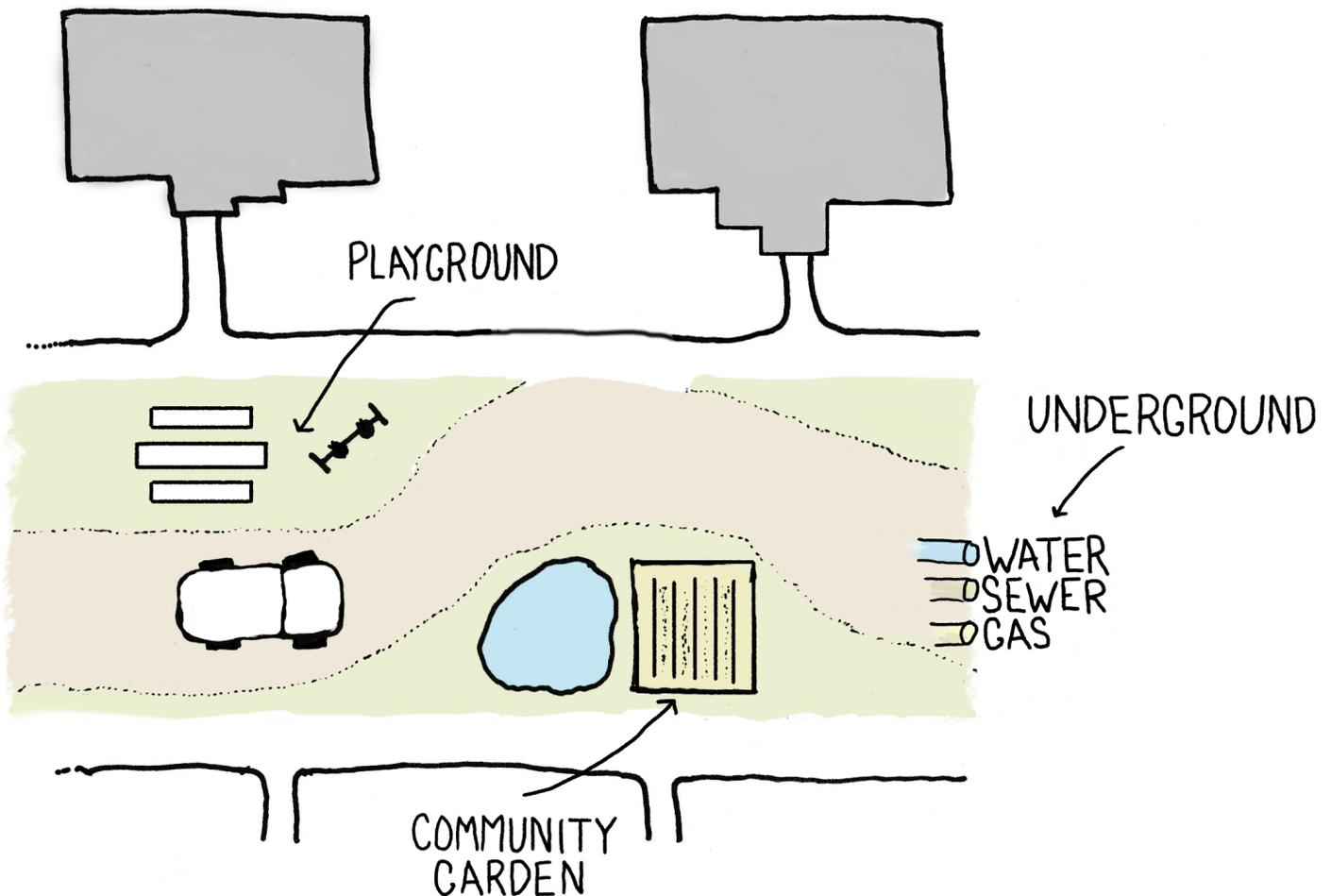
Telecommuting proved to be a revitalizing force for downtowns. Many had questioned whether the simultaneous aggressive expansion of telecommuting would actually work against the densification agenda, making it easier for people to live and work further away from transit and shopping hubs. But the opposite happened - since the 2010s, the data had shown that telecommuting rates were higher among people living in cities. It turned out that very few people

could telecommute full-time, most needed to travel to a centrally located office at least a few days per week. And it turned out they wanted to be near walkable neighborhoods with amenities - when they were working from home, it often was because they had other responsibilities such as childcare, shopping, etc. that they preferred be conveniently located near home. It turned out telecommuting and density were actually synergistic.

More broadly throughout the region, other land use changes began playing out in quick succession. Beyond the station surrounds, the character of downtowns in pre-war suburbs began to change. In addition to jitneys, shared electric bike systems, automobile bans, and expanded pedestrian amenities were put in place, maintaining high levels of mobility while freeing up even more parking for in-fill development. In post-war suburbs, a similar effect played out in shopping malls as housing, schools were built on freed-up parking sites, adjacent to new express bus stations.

By 2030, VMT per capita in New Jersey had fallen to 50% of its 2015 levels, a far greater reduction than anyone in the planning community had dreamed possible,

As Suburban Streets
go Feral, Reclaiming
Them as Shared Space



and far exceeding the RA's most optimistic scenarios. Gas stations were closing in large numbers, often finding new uses as telework centers.

As the auto-centric transportation system began to unwind and the RA's strength grew, it began to shift from simply concentrating development in transit-served areas, to more drastic measures that actively withdrew financial support for the infrastructure of sprawl. Most controversially, the RA slashed spending on road maintenance, focusing only on roads necessary for moving e-buses. The rest of the road network was left up to municipalities, which without state aid, were pressed to keep up with the constant assault of an unstable climate. As streets went feral, New Jersey's affluent suburbanites actually began to make use of their SUVs' off-road capabilities for the first time. As the asphalt crumbled, or was actively torn up, non-arterial streets reverted to a network of country lanes shared with reclaimed uses such as linear parks, bike paths, small gardens and farms, and ballfields. But amidst the new bucolic landscape, the question of how underlying sewer, gas, and storm drain networks would be maintained remained unanswered.

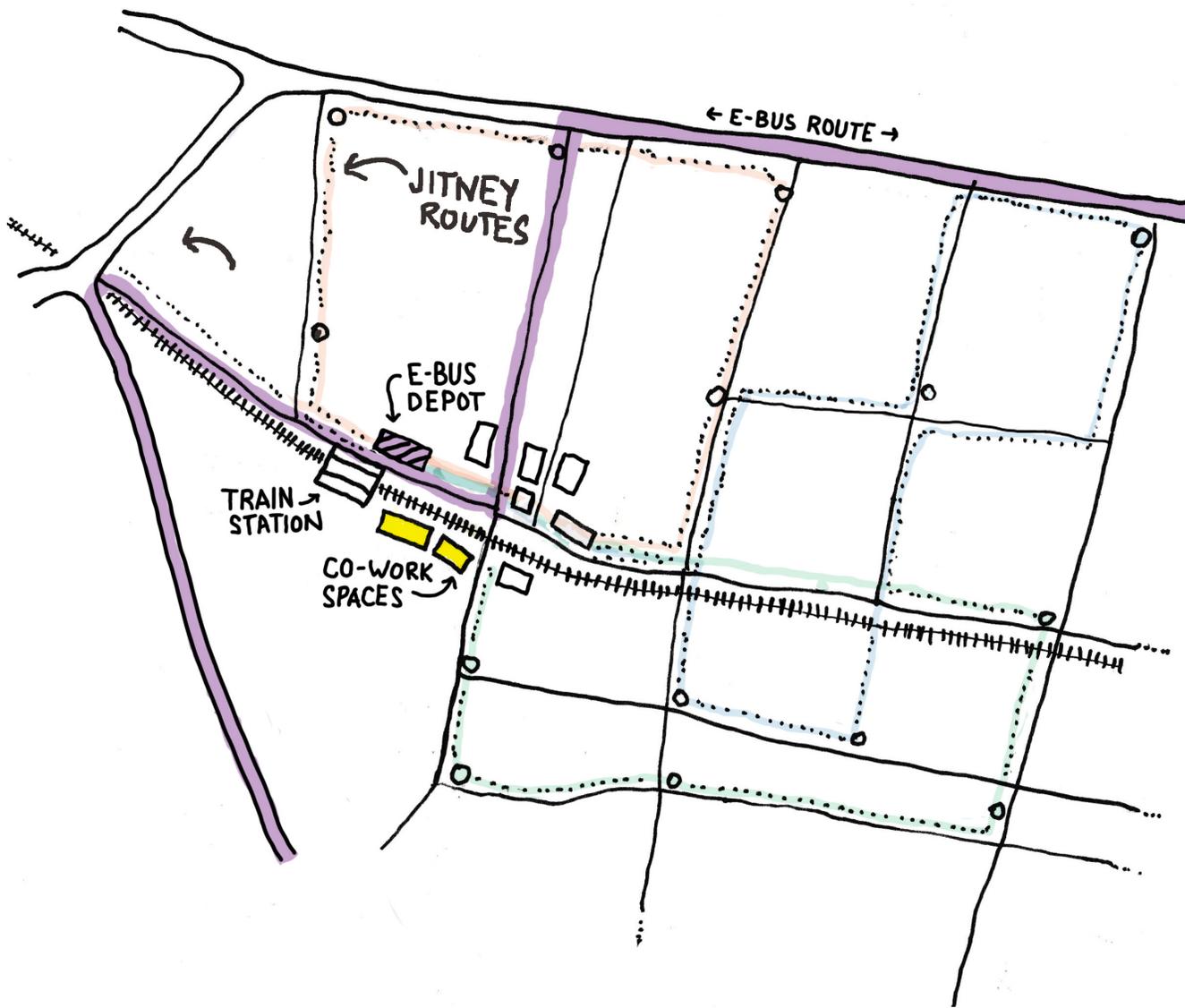
Reign of the Planners

By 2030, New Jersey was entering a golden age, having solved the challenge that still remained for the rest of the country – how to undo 75 years of auto-centric development in a way that was politically and financially feasible, environmentally sustainable, and resilient to the impacts of climate change. The transformation required an exercise of control over land use patterns that was unprecedented in the US, no less in a region so hamstrung by jurisdictional fragmentation and home rule. But the planners delivered in spades. So how did they secure the authority to make such big changes so fast?

First, there was geography. New Jersey was the first state in the country to run out of land due to suburban sprawl. While the reckoning was long overdue, it was still a shock to many when the last major tract of developable land was sold in Sussex County in 2018. For over a decade, the state had urged counties and municipalities to concentrate development around existing urban centers and transit corridors. But it wasn't working fast enough.

Second, there was a growing consensus about the need to improve accessibility to jobs for the increasingly poor population in the suburbs. Mirroring trends elsewhere in the country, New Jersey's older suburbs were growing poorer, stranding many car-less workers in places under-served by transit. As their numbers

Household income that was previously spent on cars could be spent on health care, education and local consumption, and neighborhoods were being revitalized by telecommuters.



Self-Driving Jitneys and E-Bus Networks Supplant Driving and Supplement Rail

swelled, these communities became a powerful new political constituency for an expansion of transit outside the region’s traditional urban cores.

In retrospect, it became clear that the vast expansion and improvement of transit was a boon for economic development, beyond just providing access to jobs. It propped up the housing market by allowing boomers to age in place in their suburban homes through vastly expanded paratransit services, and it provided opportunities for people to take distance learning classes on specially designed transit vehicles (like the quiet car, but the class car). Household income that was previously spent on cars could be spent on health care, education and local consumption, and neighborhoods were being revitalized by telecommuters.

While the region’s challenges all seemed to call for a heavy interventionist approach driven by comprehensive planning, it was the style of planning employed by the Regional Authority that allowed it to consolidate and hold onto power – technocratic, yet transparent and highly effective.

At the heart of the new technocracy was predictive modeling enabled by detailed data about individual travel, which allowed the RA planners to begin

thinking long-term in real-time. At the large scale, routes could be adjusted day-to-day to address seasonal variations, long-term shifts in demand, or construction detours. At the very local scale, new scientific approaches to urban design based on activity data was used to advise municipalities and developers on ways to change the layout of areas around transit hubs to make them more appealing, and make the ever-higher density around transit hubs more liveable. Operational advances came from the tracking and optimization of assets, resulting in significant savings of fuel and preventive maintenance to avoid unplanned failures and disruptions.

As their knowledge expanded, RA planners and their academic and industry partners began to study travel phenomena transportation analysts had only previously dreamed of understanding. For instance, they could track how individuals' travel patterns changed over long periods of time. By identifying events that tended to trigger higher automobile use in the past (e.g. kids, new job, etc), they are altering development plans (more family housing as dual-income households shift preferences to transit hubs closer in) and even designing individual nudges that can help people stay on transit. Just as retailers learned how to mine purchase data to send baby product coupons to expecting mothers, the RA could send them para-transit incentives.

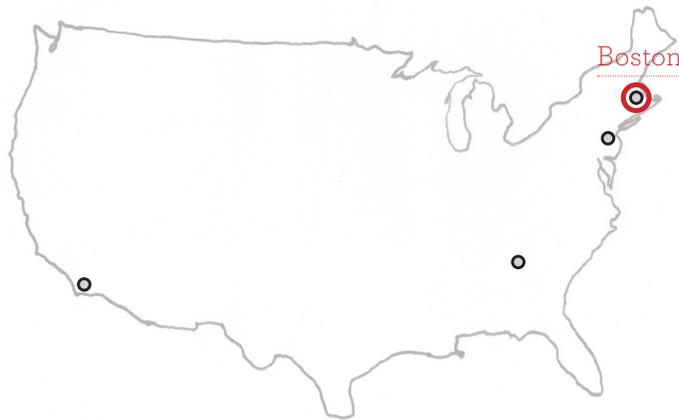
The final path to power was financial independence. Much as Robert Moses, New York City's mid-century planning czar, had gained his independence by financing planning with toll revenues, the RA developed a sustainable set of funding streams that allowed it to control the agenda. In 2016, changes in federal highway policy allowed states to toll roadways and use the proceeds for transit expansion. Since New Jerseyans were already the most heavily tolled people in the US, and the widespread adoption of e-tolling had broken the cognitive link between road use and out of pocket payment, the state began to massively expand the toll network. It created a huge backlash, but forced many people into transit - new riders who soon changed sides to support transit investment.

Technology and fiscal innovations often overlapped as well. As RA began to recognize the value of the growing amounts of mobility data it was producing, and the need for additional private sector data to improve its own planning and operations, it established a mobility data marketplace. This infrastructure allowed any party with real-time data on travel in the region to share it and dictate the terms of use including aggregation, anonymization, payment and re-use. It provided a mechanism for the transit operator to both buy and sell data, as well as publish open data for use by 3rd party developers and researchers.

By all measures, the new technocratic planning regime is holding on because it is working. Despite the objections of wealthy and influential suburban holdouts, the overall quality of life is being improved for a large swath of the population. Birthed into existence by crisis, the New Jersey's Regional Authority and its remarkable transportation solution has a bright future.

TRANSFORMATION

Boston, 2032: A Tale of Two Cities



TRANSFORMATION (n) • A future of disruptive emergence, “high tech,” with the end of some current patterns/values, and the development of new ones, rather than the return to older traditional ones. This is a transition to an innovation-based regime of new and even steeper GROWTH.

Boston, 2032: A Tale of Two Cities

In less than a generation, Boston had splintered into two new cities, living side-by-side but rarely touching - one of people and one of stuff, one existing by day, the other by night.

The daytime city, the city of people, was a place where mobility had changed profoundly. Yet Boston’s re-invention wasn’t driven by innovations in transportation, but by changes in consumption, digital media, and housing.

The first important shift stemmed from changing attitudes about ownership. By 2020, a generation of young people in their 20s and early 30s had come of age in what looked to be a perpetually weak economy. They had embraced a set of services that had been called the “sharing economy”, “peer economy” and “collaborative consumption” but by 2020 were simply called “alt-stuff”. With so much student debt, few young people actually owned anything. When pretty much any durable good could be summoned with a few swipes on a screen, there was no reason to.

The second shift had to do with new, immersive forms of digital media. This generation had also come of age in a world of cheap screens had blossomed ev-

erywhere, serviced by abundant streams of bandwidth and functionally unlimited computational horsepower. Almost as a kind of escapism from the desperate economic and political realities of the real world, they increasingly inhabited a network of ultra-high definition, completely immersive virtual realms projected through screens of every kind. Much like the stagnant Japanese economy in the 1990s, America had spawned its own generation of *otaku*, or home-bound geeks.

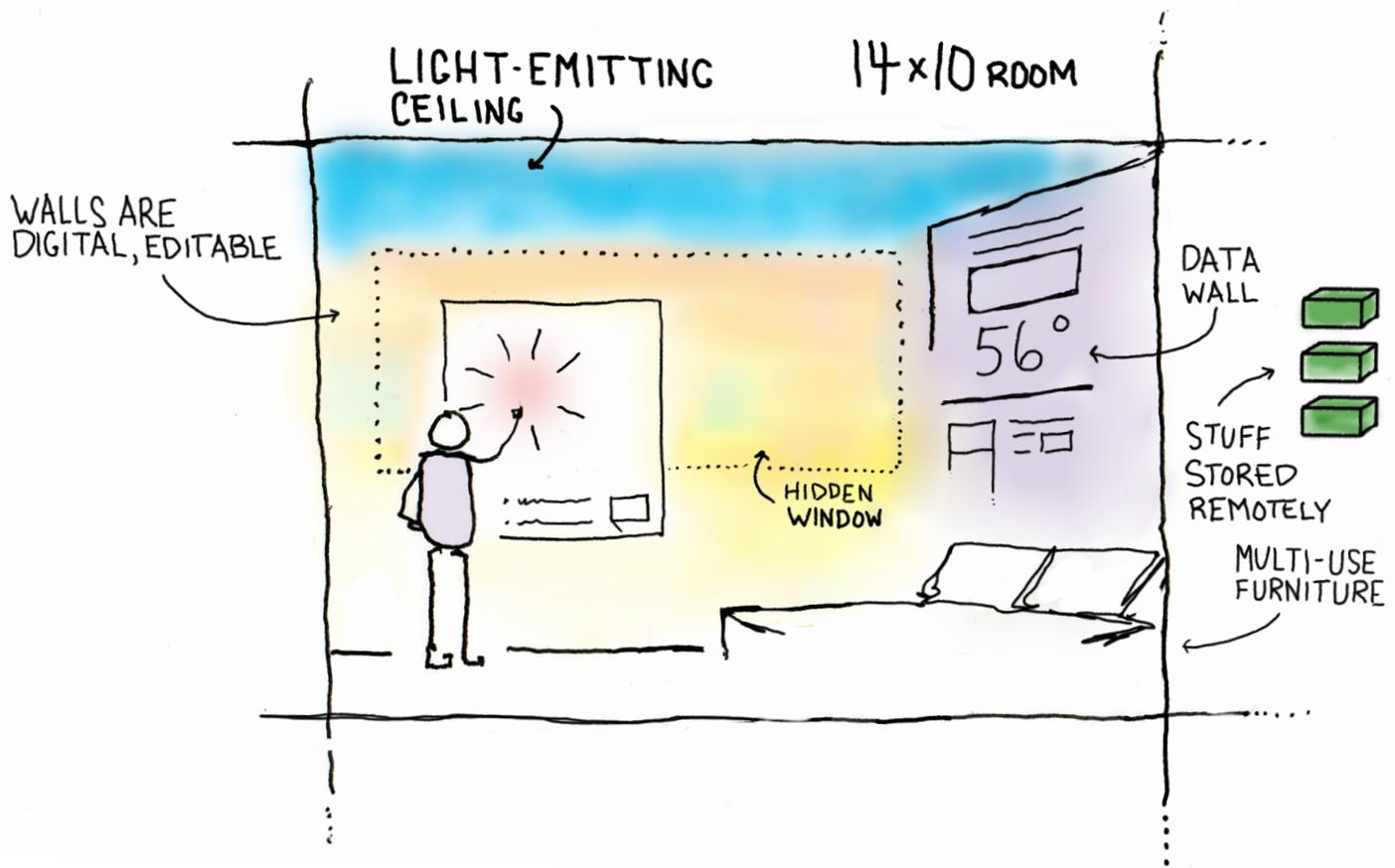
The third shift was the biggest surprise for city planners. As the economics and culture of alt-stuff came together with pervasive screens, it unleashed a flurry of innovation in housing design that caught everyone by surprise. In the late 2010s, many had held off moving out on their own, and new household formation ground to a halt. But between 2020 and 2023, they swept into central Boston in droves, snapping up a flood of new micro-apartments that design critics had simply dubbed “the Boston closet”.

An Electronic Cottage in the Sky

The appeal of the Boston closet was simple urban economics. By combining the amenities of alt-stuff with the immersive, personalized décor of pervasive screens, real estate developers had discovered a way to package dwelling space at a price point and in a style that was irresistible to young single people. In 1980 futurist Alvin Toffler had predicted the rise of the “electronic cottage” – often assumed to mean an exurban McMansion serviced by digital networks. But no one had ever imagined it would turn out to be a high-rise micro-apartment in the city. At anywhere from a mere 135 square feet to a relatively spacious 160 square feet, the Boston closet’s success was its ability to use large screens to create a feeling of connected spaciousness. The most basic Boston closet design featured a single wall covered by a single screen, but in high-end units all of the walls, ceilings and sometimes even the floor could be programmed to display anything the occupant wished – wallpaper and artwork, static scenery, data visualizations, etc. These screens were used as immersive experiences for entertainment, but also social media and communication, both personal and work-related. (And unsurprisingly, there were services that would pay a portion of your rent in return for advertising screen space in the tiny abodes.)

Their size and modularity made Boston closets an ideal tool for re-developing the existing city – large numbers could be pre-constructed and assembled within almost any existing building envelope. Parking structures were a particular favorite candidate for retrofit, and thousands of units came online in a matter of months during the summer of 2020. An instant hit, demand soared and developers rushed to acquire more aging buildings for rehabilitation as well as sites for new construction. The city of people was becoming one of living alone – single-person households were well on their way to taking over.

The ephemeral approach to ownership in the alt-stuff market carried over into the new housing as well. With its large transient student population, Boston



had always been a place where people moved around a lot. By 2022, thousands of Boston closets in central Boston were on AirBnB. Considering that you could “skin” your apartment using the big digital screens anyways, it made relocating residences effortless. It became common practice for young singles to move around the city, spending a few weeks here or there, as school and work obligations shifted (since these were now mostly structured as short-term or freelance commitments anyways), or as friendships and romantic affairs waxed and waned.

The great irony of the Boston closet, however, was its severely limited closet space. While alt-stuff had dramatically cut back the number of possessions most people used to store at home (almost no one owned a vacuum cleaner, for instance), they still needed some personal storage for clothing and sundries. And so, borrowing one the cloud’s key innovations, real estate developers partnered with a host of remote storage providers that had popped up in recent years. Part self-storage, part valet package delivery, these service allowed occupants of Boston Closets to store up to a dozen small bins remotely, and request delivery through an app. A variety of service levels were available – the cheapest plan provided overnight delivery from an off-site warehouse far outside the city. The most expensive plans drew on a limited amount of on-site storage, usually in building

The New Urban
Neighborhood: Mediated
Micro-Apartments
and Vibrant Streets

basements. As bins are checked in, they are photographed and 3-D scanned, allowing owners to view contents remotely. And as these systems were built out, alt-stuff services started using it as well as a logistics network to reposition shared goods from user to user.

To outsiders, the whole arrangement was unsettling, a kind of bourgeois evolution of the Occupy movement. The city seemed to be operating as a giant encampment with the consumer economy replaced by a giant lending library. Yet while much of America looked on in derision, (“It really has become the People’s Republic of Massachusetts”, Rush Limbaugh said on the air), young Bostonians were living better and more sustainably than anyone anywhere else in the nation.

The Delight of the Tele-Serviced City

If the idea of a generation of young people spending much of their life inside a digitally-mediated and robotically-serviced bubble struck outsiders as deeply alienating, what balanced it out was that when they stepped outside, these pioneers entered a vibrant, bustling streetscape that would have made Jane Jacobs proud.

As planners had long hoped, the boom in micro-apartments set in motion a virtuous cycle, increasing population density to levels where it could support a broad range of retail and local services. And Bostonians were ready to spend – while they might have been living more austere lives in private at home, but they have more than made up for it in public consumption. They eat out more, and consume a greater variety and volume of local services. As street cafes and public markets blossomed, a growing number of neighborhoods became delightful places to walk. But strolling wasn’t just for recreation, it became a major mode of travel. Because the housing market was so flexible, people were able to live much closer to work and school, replacing car and transit trips with walks and bike rides.

Meanwhile, walking itself got a major upgrade. Dozens of wayfinding apps designed for pedestrians now provide route planning based on almost any criteria imaginable – the “most liked” route based on Facebook Places, or the most beautiful architecture based on crowdsourced ratings. Walkability also became the subject of intense quantitative research. Neuroscientific techniques were used to measure cognitive response and perception to different kinds of walking environments. At a larger scale, the same tracking technologies retailers used to map shoppers’ movements in malls were re-purposed to study how people move through neighborhoods. Using these new techniques, streets, plazas, and side-walks are constantly being reviewed and evaluated, re-designed and re-arranged for maximum performance along various performance criteria – throughput, “stickiness”, happiness, etc.

With the need for automobiles greatly reduced, the city began reclaiming a growing number of streets for pedestrian and alternative uses, as part of a plan

phase out automobiles throughout much of central Boston by 2034 (following the example set by the German city of Hamburg in 2014). A wave of placemaking took hold, as local businesses, community groups, and public space advocates deployed a wide array of tactical interventions to reclaim street space previously devoted to moving and parking cars. Outside the city, these efforts were copied by many surrounding suburbs, which copied Boston's auto ban in their historic village centers.

As automobiles disappeared, alternative modes of transportation expanded to serve and interconnect these walkable hubs.

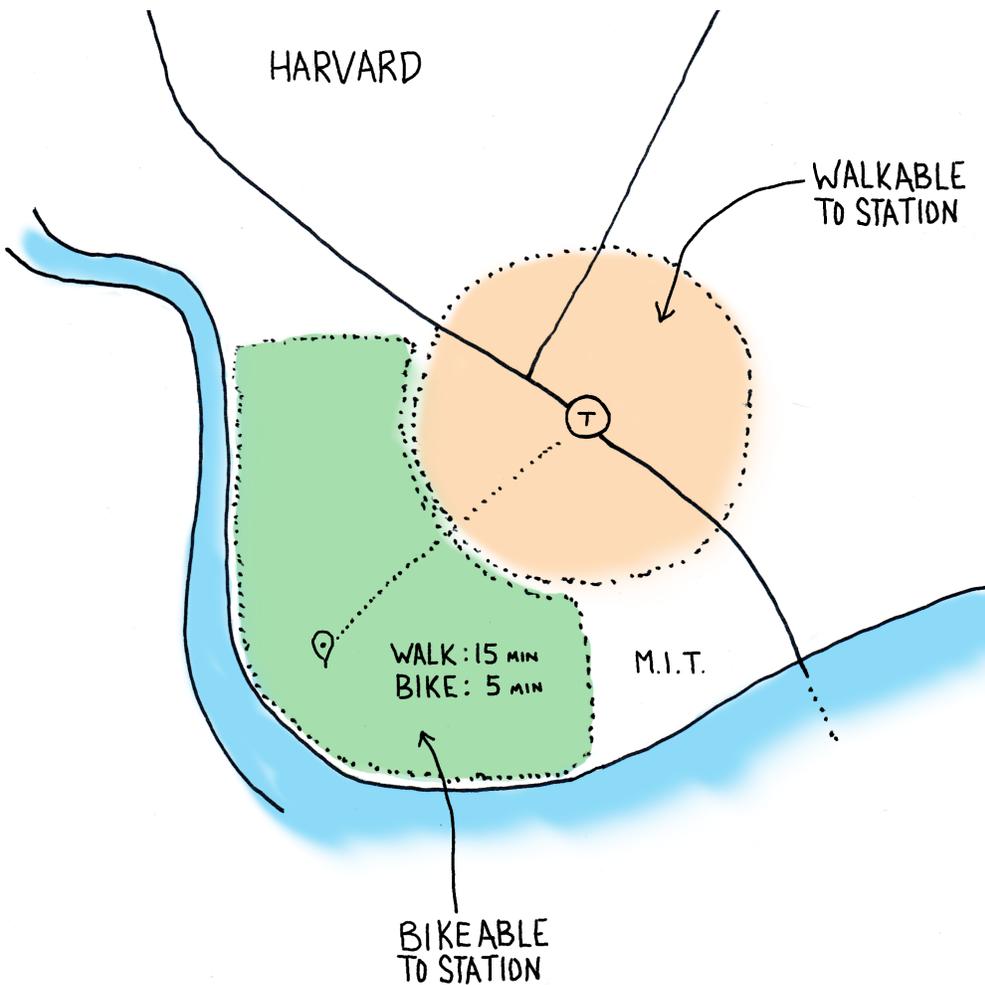
Major investments were undertaken in bicycling infrastructure, including new protected bike lanes, parking facilities and repair shops. As electric bikes became more widespread, solar-powered rapid charging stations were deployed as well. In 2022, when an MIT spinoff introduced the first autonomous, gyroscopically stabilized electric bicycle, it was used to implement a bike share network in neighboring Cambridge that could rebalance itself and even deliver a bike to your door on request.

While the personal transportation revolution started with electric bikes, it soon expanded to many kinds of personal electric-powered vehicles. Some, like the Lit Motors C-1 motorcycle were capable of high-speed operation but in no-car zones, an automatic geofenced governor keeps them under 20 mph to avoid fatal encounters with pedestrians. Others, like the OneWheel self-stabilizing skateboard, spawned whole new urban subcultures. But what they share is programmability - manufacturers have figured out clever schemes to sell "upgrades" over the stock, out of box performance, for instance different riding modes, tricks, or autonomous capabilities.

As small electric vehicle networks proliferated, they catalyzed a kind of high-density urban sprawl around transit stations. Because the radius that can be reached in 5 minutes by e-bicycle from a transit station is 3-4 times greater compared to walking, the area practically serviced by that transit station is 10 to 15 times larger. With e-bikes growing from less than 10 percent of non walking journeys in 2020 to more than 50 percent, the impact was substantial. The new transit-feeder scheme allowed extensive upzoning throughout the city, creating enormous private value and public revenue through various tax increment financing schemes.

The success of e-bikes in feeding riders from upzoned districts posed a considerable challenge to the already over-burdened T subway system. But by retrofitting trains for autonomous operation, transportation engineers were able to operate with greatly reduced headways, increasing throughput substantially. Real-time data about next vehicle arrivals, travel times and most importantly - crowding - are distributed widely and used to help even out peak demand. This

As small electric vehicle networks proliferated, they catalyzed a kind of high-density urban sprawl around transit stations.



Expanding the Impact of Transit Services Through E-Bike Feeder Systems

open data is fed to the public through thousands of apps, as well as public displays. The T's service condition information is like a stock ticker, a ubiquitous piece of everyday life in Boston.

By 2032, the private automobile remains, if only in a niche role for inter-city travel. And self-driving autonomous taxis are being allowed to return to the center of the city, after a long hiatus driven by lingering safety concerns. As it turned out, designing a car that can drive itself in urban traffic was a lot harder than making a bike that could, because the stakes were so high. A light bike travelling at 8 mph could cause minor injuries, but a car at the same speed could still kill. But with less need for taxis due to the rise of alternatives - and the triple-whammy of e-hailing, autonomous operation, and

ride sharing - fleet has shrunk to a mere fifth of its previous size, from 1,825 in 2013 to just 400 in 2030. As they trundle along, carefully picking their way through bike and pedestrian traffic at low speeds, they go almost unnoticed.

The transformation of mobility has had unexpectedly positive economic benefits for the city. A massive stockpile of land has been repurposed not only for housing and commercial development but also parks, urban farms and gardens and other recreation facilities. The economy is pumping on all cylinders, thriving on a densely networked assemblage of human talent and flexible architecture. And an unexpected "cognitive surplus" has been unlocked through reduction in average commutes, freeing up time for more productive activity. Marchetti's constant, a term used by transportation scholars to describe the surprising historical continuity of human tolerance for commuting (about an hour each day), seemed to be breaking down for the first time.

The City That Plans Itself

The way that the city gets made has changed dramatically as well, leveraging the same digital capabilities that have had such a profound impact on housing and transportation. Boston's transformation wasn't planned, but planning has responded by re-inventing itself to become massively participatory, yet also ruthlessly scientific and technocratic. In a way, urban planners have become facilitators who help the public interact with phenomenally complex yet effective artificial intelligences that help design, plan and manage the city.

First, social media and ubiquitous computing allowed planning to become a massively participatory and collaborative effort. Long-standing skepticism from the early days of the World Wide Web about the possibilities of engaging large number of people in planning processes began to fade as a number of grassroots experiments began to show promise. For instance, amidst the NIMBY uproar surrounding the 2025 up-zoning of larger areas around transit stations, walkability and transit advocates deployed a series of immersive simulations that allowed people to experience first-hand the impacts on livability, sustainability and the economy. Using the same kinds of geodemographic profiling long employed by mobile advertisers, they pushed alerts not just to residents of the surrounding area, but also frequent visitors, who were recognized as key stakeholders in this city of increasingly itinerant tenants. As the city's physical transformation accelerated, the sight of small groups gathered in the street intensely debating proposed projects with their handheld future-city viewfinders became commonplace. As new tools for debating the what-ifs of planning worked to break open planning processes and foster a greater sense of shared governance, the science of cities also advanced rapidly.

The built environment was an area of intense study as researchers developed new techniques for quantifying good urban design. Building on earlier versions of the Place Pulse tool, in 2017 a group at the MIT Media Lab conducted a bold experiment to evaluate walkability for the entire city of Cambridge. Employing crowdsourced workers to tag Google Street View photos of thousands of city blocks, the team trained a set of machine learning algorithms to recognize elements in the built environment that either facilitated or interfered with pedestrian use. The software was then able to quickly replicate the analysis citywide, generating a list of tens of thousands of detailed small-scale changes to improve walkability that could be implemented by citizens.

The convergence of these two shifts conspired to empower block-level and neighborhood-level planning, as small groups came together through crowdfunding tools to carry out the tactical interventions suggested by the MIT study. But the algorithm's recommendations were merely a starting point, and as the high return on these targeted interventions became clear, citizen groups began to

As new tools for debating the what-ifs of planning worked to break open planning processes and foster a greater sense of shared governance, the science of cities also advanced rapidly.

design their own tweaks, add-ons and upgrades to the plans. The same software could then be used to evaluate the impact of citizen-generated ideas. The result was an incredibly rapid, iterative transformation of the public realm through a coordinated array of small-scale, citizen-driven efforts.

This was the first step in a broader transformation of how the city was planned and managed by making it more self-aware. The MIT software showed how automating the survey of the city's shortcomings could power a far more fluid and adaptive planning process that engaged a broad web of stakeholders in both design and implementation of the plan.

Self-awareness could be seen throughout the transportation system as well. In partnership with mobile phone companies, transit agencies are able to make precise travel forecasts that can be used to balance supply of transit with demand. Your subway knows when to expect you, even before you leave your home. And at your destination, the same predictive information allows taxis, bike share systems, and restaurants to anticipate your arrival.

With much of their traditional work becoming automated by software and crowdsourced by the public, transportation planners are thinking much more holistically than in the past. It is no longer enough to focus merely on efficiency and safety. They are now addressing questions of resilience, happiness and health and the role transportation can play in advancing these goals. To achieve these aims, they are exploiting a rapidly expanding analytical capacity gained through partnerships with universities. For instance, one project sought to leverage the city's fluid housing market to develop personalized recommendations to encourage people to relocate in ways that would reduce their need to travel. ("You seem to be wasting a lot of time going to x, there is a y closer, or you could move and save z").

For a while, it seemed that Boston was on the right track. The city's population was rapidly de-mobilizing, helped along by density, walkability and easy access to more energy-efficient alternative forms of transportation. Planning was changing in profound and positive ways, although there were concerns about the level of individual tracking that underlay the whole scheme.

For a while, Boston seemed to be moving towards a very different future than anyone had expected. It was denser, less auto-dependent and more economically successful than at any time since World War II. Government's role in planning and running the city was shrinking, since it more or less ran itself.

But just as the city seemed to be reaching a stable new equilibrium, a second city began to emerge within the first, at a frightening machine-driven pace.

The Shadow City of Stuff

Boston's unique blend of new land uses and new mobility technologies was the secret behind its highly livable and economically-productive neighborhoods. But it was also the seed of a new transportation crisis. For as prosperity began to

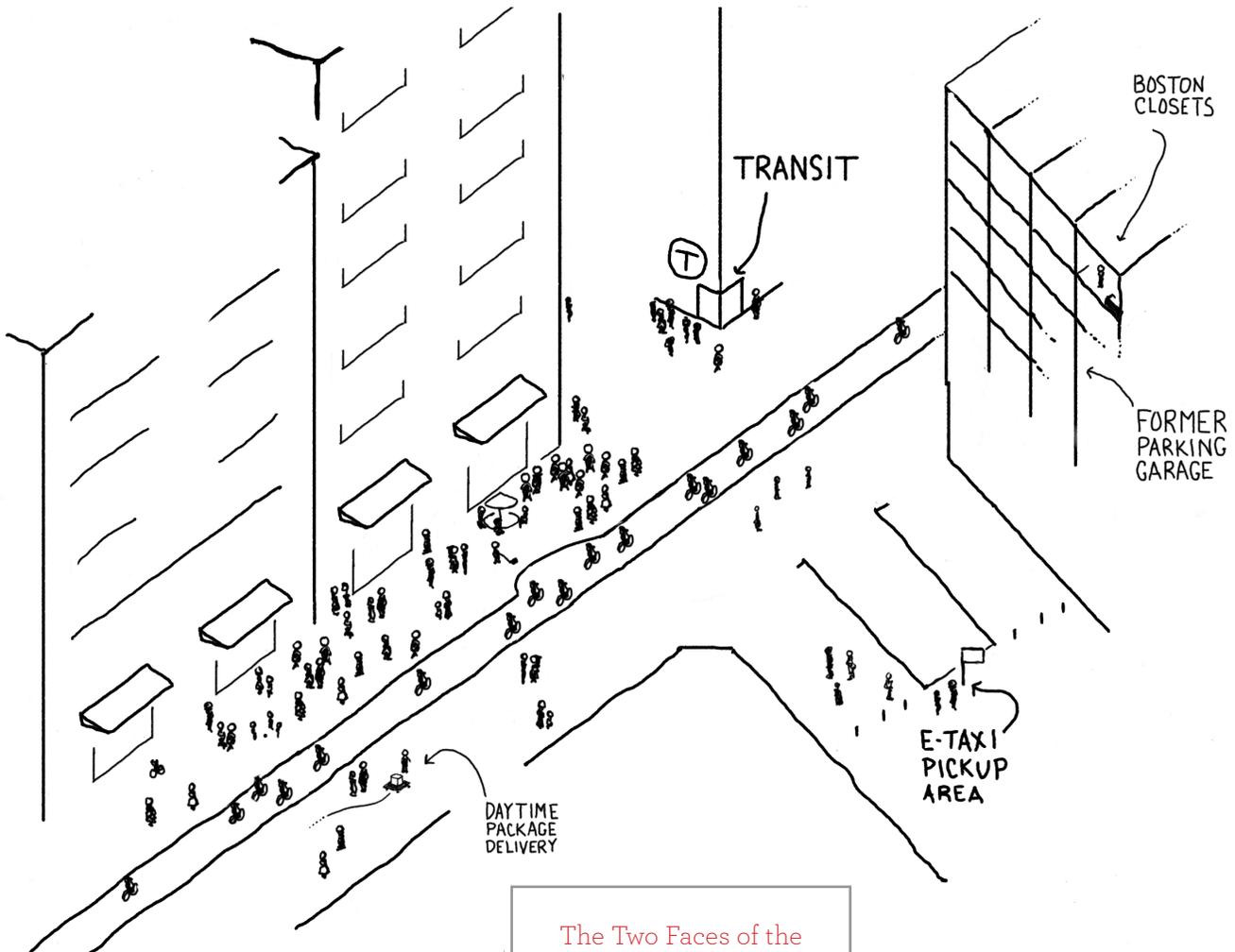
replace austerity for many young people, the sharing economy began to give way to increasing desire for personal possessions. A weird tension began to emerge between collaborative and conspicuous consumption.

For a while, the remote storage scheme that made the dense, walkable neighborhoods of Boston closet buildings work was able to keep up with the increasing amount of stuff and frequency of access that Bostonians wanted. But as the hothouse of creativity and innovation that the new urban form had created began to throw off more and more wealth, the system began to break down, as retrieval requests backed up and delivery costs soared. At the same time, traditional shipping companies like UPS and FedEx struggled to keep up with the volume of e-commerce shipments driven by this newly affluent, hyper-connected youth market. By 2026, the average Boston closet occupant was receiving ten to twelve deliveries each day from food vendors, e-commerce merchants, alt-stuff services, and remote storage lockers, an eight-fold expansion of urban freight delivery. Streets were clogged all day with delivery vehicles, which had filled up the remaining street space devoted to vehicles like water.

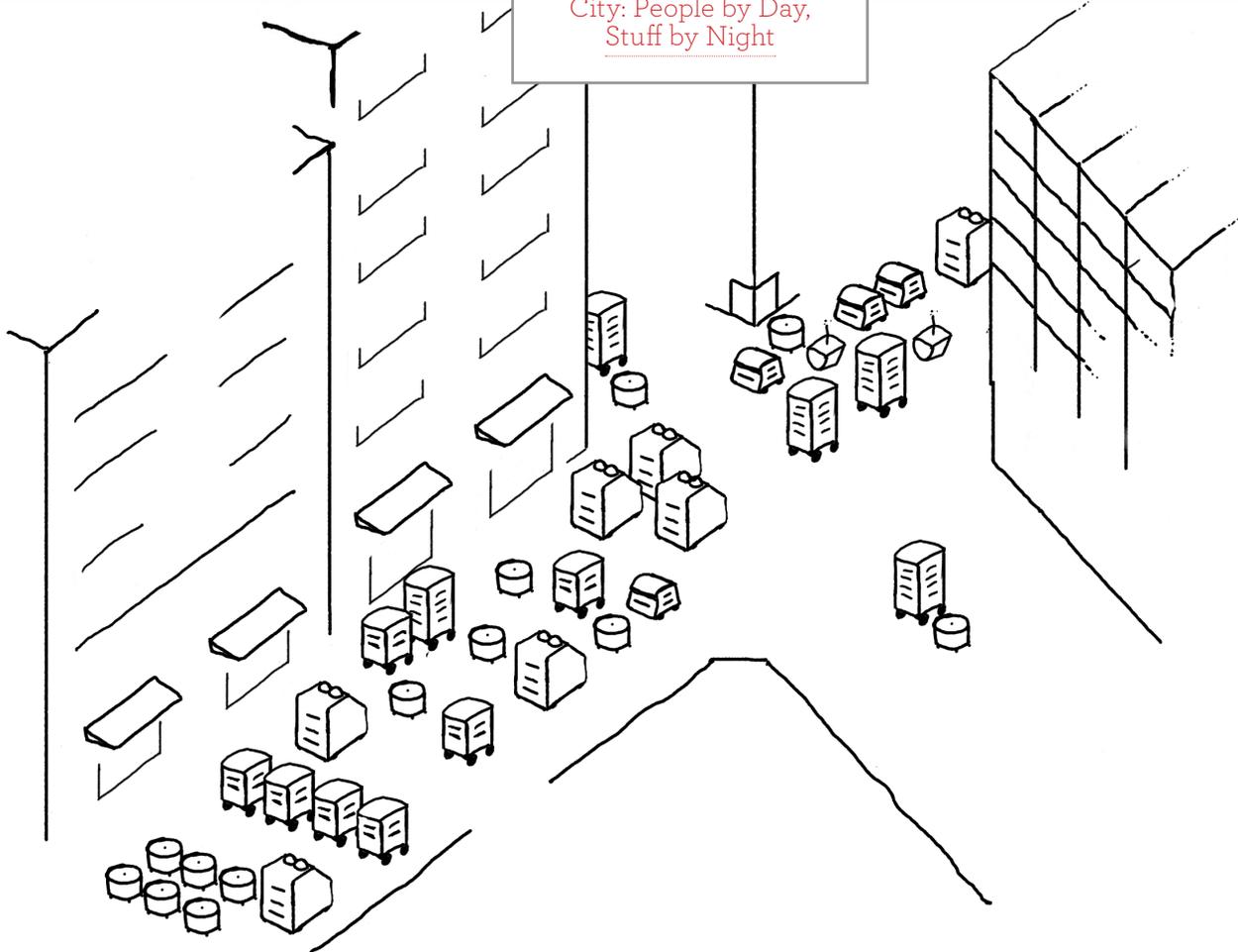
Boston needed a new scheme for managing urban freight deliveries, and the only viable option that would preserve all the gains of neighborhood de-mobilization was to run it at night. The city of stuff would be pushed into the shadows.

In 2028, the city released a tender for franchises to operate an automated freight delivery system that would operate only at night, when the sleepy city's streets were mostly free of pedestrians and bicyclists. Two proposals stood out from the crowd, and signaled the scale of industrial competition the country could expect in the business of moving stuff. The first came from Amazon, for which an expansion into urban logistics was a no-brainer. The company's Kiva subsidiary, based in the nearby suburb of North Reading, had revolutionized the way goods were moved around in warehouses, using robotic couriers. By 2028, Kiva was ready to deploy its technology at a citywide scale. The second proposal was from Google, which leveraged local know-how as well. Its subsidiary Boston Dynamics, had grown rapidly in the 2020s after shifting from its early focus on ruggedized military logistics robots to cheap civilian cargo haulers, mass produced at its plant in Providence, Rhode Island. For these new entrants to the logistics sector, Boston was a perfect testbed for the same reason the Boston Closet had taken off - its huge student population - which had swollen to some 500,000 students in the region's nearly 100 colleges and universities.

To encourage choice and competition (and to hedge its bets on unproven technology), the city accepted both proposals. From 2 am to 5 am each night, the two companies fleets swarmed onto the streets to move the city's goods around. Kiva's machines were incredibly banal in appearance - like small skateboards scooting around with crates on top. Google's were far more frightful - the silhouettes of its ambulating robotic pack animals were the backdrop for many a scary bedtime story. Each had its advantages - the Kiva drones were faster, more reliable, and



The Two Faces of the City: People by Day, Stuff by Night



could be loaded and unloaded more quickly; but Google's mule-bots could trudge through even the most severe blizzard without the slightest impedance.

During early trials, the city's residents were strongly discouraged from being on the streets during those hours. As the first pilot phase began in 2030, both companies' vehicles were restricted to walking speed and deliberately designed to stop at any hint of an obstacle other than each other. The companies took two very different approaches to teaching the machines how to recognize and avoid everything else. Amazon trained its algorithms using its Mechanical Turk platform - if a bot saw something it didn't understand, it would simply stop, take a picture, and have it identified by a human. Over time, the system got smarter and smarter, making very few requests to humans. Google's system was much smarter from the get-go, with sophisticated sensing and machine vision systems built-in, but it cost more and took longer to perfect.

Those early safety concerns were soon proven overblown. While there were a few low-speed collisions with autonomous taxis, no human injuries were attributed to the cautious robots. City officials phased in higher speed limits, reaching 50 mph by 2032. And since neither system required visible light to function, they began shutting off city's street lighting in the absence of people. Boston had become two different cities, one inhabited by people, the other by robots, rarely coming into contact. To a night owl out strolling at a time that had come to be known as "the hurry-scurry", the only sign that something had changed was the occasional blur of metal hurtling through a cone of lamplight and echoes of the whirring and patter of robotic wheels and feet.

In fact, robotic delivery vehicles do inhabit the daytime city of people, but there are far fewer of them and they are far more conventional in how they move about. The most urgent deliveries - mostly food - are serviced by a small fleet of about 5000 autonomous vehicles of various sizes spread throughout the city and surrounding region. Using a large-scale predictive model of travel patterns as well as real-time data on individuals' movements, they try to avoid concentrations of pedestrians and cyclists by taking urban highways and back streets.

The next big innovation in Boston's logistics business will involve figuring out what needs to be delivered before it get ordered. As Amazon and Google got into the city-running business, they brought their big data and machine-learning prowess with them, and began tackling the challenge of predictive logistics. For instance, Amazon's "anticipatory delivery" service ships items before you even think about them - say, that sweater you browsed on L.L. Bean, and if you don't want it, you just swipe and it goes away.

Epilogue: Liftoff, 2045

Over the next decade, it became clear that while Boston had made enormous gains in reducing carbon emissions from passenger travel, these were being clawed back by the enormous amount of energy involved in moving stuff around.

Much like WalMart's data-driven logistics enabled American's mass consumption of Chinese-manufactured goods in the 1990s by dramatically cutting costs, despite all the sharing and mass transit Boston's electricity use is growing rapidly. But while the city was clearly on the wrong path to sustainability, it was far more resilient to the impacts of climate change to which it was contributing so prodigiously.

The threat of sea level rise to the city was well understood. Both New York and Boston had seen the writing on the wall after Hurricane Sandy inundated the Big Apple in 2012. And as ice sheet melting in Antarctica accelerated through the 2030s, sea level rise projections steadily worsened. By 2045, the city was facing mid-century sea level rise estimates of about 12-15 inches and 25-30 inches by 2075, which would inundate 30 percent of the city's land area. For now, only a handful of waterfront areas were permanently flooded, but storms and high tides conspired to put large swaths of the city's streets underwater on a regular basis. And the nightly robotic logistics operation was frequently suspended, severely disrupting the city's fly-by-wire distribution systems.

But what could be done? New York's solution had been to build a wall to try to keep the sea out, which was mostly working for now. But in Boston, where large-scale interventions had fallen out of favor under the new AI-assisted, neighborhood-driven decentralized planning regime, it was hard to mobilize support for such a grand scheme.

There was one solution, the subject of speculation since Amazon first floated the idea in 2014, that was so simple yet at the same time so daunting, that many wondered whether it could be done - take the entire logistics fleet to the sky.

Amazon's vision had spurred an entire generation of researchers and students at MIT to explore the potential of unmanned aerial vehicles (or "drones") for logistics. At first they experimented with designs for use in remote rural areas in Africa that lacked infrastructure. These drones delivered medicine and other high value goods. Later, they developed drones for search and rescue operations, and some students took to operating their own personal "guardian angel" drones that would follow them everywhere. All the time, they were pushing the limits of engineering, building them smaller and smarter. The potential for these flying robotic swarms to move goods became all too clear in 2039, when a group of students staged a repeat of famous 1994 prank, in which an MIT police car was torn apart and re-assembled atop a university building's dome. Only this time, the car was air-lifted by a fleet of 30,000 insect-sized flying robots.

Tinkering turned into mass-production as several university spin-offs developed methods for the robots to build copies of themselves. By 2045, substantial volumes of nightly freight delivery were being done by air, and the surface vehicle fleet was phased out, replaced by airborne swarm of small drones, the character of the city began to change. The streets were even more friendly than before, and late at night, like crickets in summer, the buzz of a millions of drone bots lifting off into the sky could be heard through open windows.

WORKSHEET: YOUR SCENARIO



The four scenarios in this report represent a wide range of plausible futures. However, a nearly infinite number of possible futures can play out at the intersection of transportation systems, the built environment, and digital technology. In the spaces provided below, we encourage you to develop your own forecast.

Consider the following as you outline your scenario



SCENARIO TITLE:

Where does the scenario take place? What are the key developments and events?

What are the public priorities and market opportunities around transportation and land use?

What technology and policy responses are being implemented to address these priorities?

Who is implementing them?

What unintended consequences result, and what conflicts are left unresolved?