THE TRANSIT METROPOLIS REVISITED

Robert CERVERO*

Abstract

In *The Transit Metropolis*, written in 1998, I identified two ways which transit services and urban development patterns have been integrated globally: by adapting cities to transit and by matching transit services to urbanization patterns. This chapter revisits the transit metropolis models in light of powerful and unfolding megatrends – aging societies, shifting demographics, changing employment structures as well as changing lifestyles (e.g., collaborative consumption), public policy agendas (e.g., decarbonizing cities) and technological advances like autonomous mobility. Collectively, such forces buttress arguments for adaptive cities that are resourceful and efficient as well as adaptive transit that offers a more diverse, often atomized set of mobility choices. It is argued that both models of sustainable mobility and urbanism can, and indeed should, co-exist in any metropolitan context. International case experiences are highlighted in this regard.

1. Introduction

The Transit Metropolis was written some two decades ago, at the close of the 20th century, as a framework for advancing sustainable urbanization and mobility (Cervero, 1998). This chapter revisits the transit metropolis models from a 21st century perspective, reflecting on shifting societal and lifestyle trends, changing public policy agendas, and emerging, potentially transformative technological advances. These forces, I argue, buttress arguments for both adaptive cities and adaptive transit – i.e., cities that are resourceful and efficient in their designs as well as adaptive forms of collective-ride transport that offer more diverse mobility choices. Both models of sustainable mobility and urbanism can, and indeed should, co-exist in most 21st century metropolitan contexts.

2. The Transit Metropolis: Core Principles

The central premise advanced in *The Transit Metropolis* – that cost-effective transit services rely on a 'glove-in-hand' fit between urban settlement patterns and transit service designs and technologies – still holds today, perhaps even

* University of California, Berkeley.

more so. More is required, however, than the integration and coordination of transit services and urban development. Notably, direction matters. Normative, holistic visions of urban futures should shape transit investments and policies, I argue, more than vice-versa. This reflects the derived nature of most travel – i.e., people hop on trains and buses to go places, and it is the designs, qualities, and make-up of these places and what takes place in them that people value most, more so than the physical act of getting there. As with any utility, transportation is largely a means, and with few exceptions, not an end unto itself. An apt analogy is the design of a house. In conceptualizing and planning a house, future homeowners dwell on what matters most to them – the layout, floorplan, bedroom sizes, architectural styles, kitchen designs, and so on. They don't start by laying out the utilities of a house – the plumbing, wiring, conduits, and pipes – and then design the house around them. Scaling up to a city, the same holds: successful linkages of transit and urbanism require a fairly cogent, widely shared vision of urban futures, most notably a well-defined long-range spatial plan, and public transport investments and services should serve as one of many tools for achieving the vision.

Transit metropolises that successfully linked transit and urban development, the book argues, did so in one of two ways. *Adaptive cities* alter their urban forms – often through higher densities and mixed land-use patterns – to promote sustainable patterns of growth, for environmental as well as social and economic reasons. Investing in what is inherently the most resourceful form of urban mobility – high-capacity, high-quality transit, such as metros – case experiences show, is critically important to shrinking a region's environmental footprint, economizing on public expenditures through the containment of sprawl, and promoting socially diverse urban landscapes that invite people from all walks of life to come into frequent face-to-face contact, to among other things build social capital. A contrasting model is *adaptive transit*: modifying traditional (e.g., fixed-route, fixed-schedule) transit services to better serve largely market-driven, low-density settlement patterns, and in so doing making it more time-competitive with transit's chief competitor, the private car. Through more flexible and demand-response service designs, adaptive transit reduces or marginalizes what for many are the scourge of public transit – the dreaded transfer and first/last-mile access – so as to mimic the door-to-door connectivity of private cars, though in a group riding context.

In today's vernacular, adaptive cities embrace and embody transit-oriented development, or TOD: compact, mixed-use, highly walkable development that is physically oriented, not just adjacent, to major transit stops. With neighborhood activities centered around stations, residents are drawn, almost instinctively, to transit when making out-of-neighborhood trips. The transit station and it surroundings are not just places to "pass through" to catch trains and buses. They are also "places to be" -- hang around with friends after work, shop at farmer's markets, enjoy an outdoor concert, or join in a public demonstration or celebration. As such, the transit station and the civic spaces and commercial development that surround it function as the hub of a community. At the metropolitan scale, networks of walkable communities are interlaced by high-quality, high-capacity transit. Within a 5 to 10 minute "ped-shed" of a TOD, green mobility dominates: most trips are by foot or bike. Longer, out-of-neighborhood trips are mostly by train or buses on dedicated running-ways. The necklace-of-pearls metaphor well represents the arrangement of TOD in Scandinavian transit metropolises like Stockholm and Copenhagen.

The contrasting model -- adaptive transit – has also been called 'development-oriented transit', or DOT. In places where minimally regulated land markets are left to run their course, producing spread-out cityscapes, a more adaptive form of transit is needed to compete with the private car. *The Transit Metropolis* highlighted cases like Adelaide with its track-guided bus ways (a precursor to Bus Rapid Transit, or BRT) and Karlsruhe, with its flexible tram-trains that morph between slow-moving tramways and fast-moving line-haul carriers, as examples. As discussed later, more contemporary forms of adaptive transit, or DOT, include micro-transit services like van-sharing Via in New York and Pickup in Austin, shared-ride taxi-like services such as UberPool and Lyft Line, and direct-line BRT services found in many Chinese cities.

The Transit Metropolis acknowledged a third form of city-transit relationships, called hybrids, with elements of both adaptive cities and adaptive transit. Here I conclude arguing that most transit metropolises are becoming hybrids – perhaps an inevitable "regression to the mean" (Stigler, 1997). This is all the more so in light of unfolding megatrends, lifestyle choices, and technological advances. It is to the topic of how such forces are redefining the 21st century version of the transit metropolis that I now turn.

3. Megatrends and Shifting Lifestyle Preferences

A number of powerful megatrends – aging societies and shrinking cities, increasingly diverse household types and structures, new patterns of employment -- are profoundly changing travel markets and forms of production (e.g., sharing versus ownership of cars). As a result, travel is becoming increasingly heterogeneous (over space and time) and more stochastic, less predictable in nature. In many ways, such trends work in favor of adaptive forms of transit while in other ways they are supportive of adaptive cities and TOD. Hybridization, wherein cities adapt their urban forms and embrace shared mobility options, I argue, is a natural evolution – a response to unfolding megatrends and technological advances.

Aging Societies

The fastest growing age group worldwide is individuals 60 years of age and older, who in 2015 comprised some 12 percent of global population, up from 8 percent in 1950 (UN Habitat, 2016). Growing at a rate of 3.3 percent annually, those 60 years and over will make up nearly a quarter of the world's population by 2050, except in the poorest continent, Africa. Societal aging is most pronounced in East Asian countries like Japan and Taiwan, where the shapes of population pyramids have dramatically flipped over the past half century, from bottom-heavy pyramids to top-heavy torsos. Graying societies in advanced economies are a product of declining birth rates (owing in part to changing roles of women), tight immigration policies, and medical advances and health-conscious living that have increased longevity.

Reverberations from societal aging include shrinking cities, all the more pronounced where globalization, deindustrialization and social forces (e.g., race and class segregation) have gutted the interiors of many industrial-era cities, particularly in America's rust belt and Europe. Certain aspects of aging societies favor less travel and transit-supportive growth – e.g., reduced household consumption, motorized travel, and commuting during later stages of lifecycle; residential down-sizing and empty-nesting to urban cores; a growing for appreciation for walking, cycling, and other forms of "active transport" as a means to stay physically fit. Other aspects of aging and accompanying trends could induce travel and car-oriented development – e.g., comparatively wealthy and thus relatively more active and mobile older households; aging-in-place in car-oriented suburbs; autonomous, self-driving vehicles that offer seniors door-to-door automobility. If autonomous vehicles are increasingly shared, they will effectively become a form of adaptive transit.

Public policies, like legislative mandates to de-carbonize cities, will influence the travel and urbanization impacts of aging societies. Shrinking cities could foretell a future of land reclamation, motorway de-construction, road dieting, and freeway-to-greenway conversions, as long as there is policy support to do so. With a rapidly aging population, South Korea has pioneered the conversion of motorways to greenways, especially in its national capital, Seoul. Increased land prices along Seoul's Cheongyecheong corridor, that was converted from motorway to a greenway, suggest that markets have placed a higher premium on livability and quality-of-place than on movement (Kang and Cervero, 2009).

Under the Walk-Friendly Seoul program, a number of Seoul's in-city neighborhoods, university districts, and even commercial roads have recently been converted into car-free zones. Seoul has also massively expanded BRT services while reclaiming land from cars and parking (Cervero and Kang, 2011). Thus elements of urban regeneration and BRT investments reveal an increasingly hybrid form of transit metropolis in Seoul's case.

Another example of reclaiming land and creating a more transit-oriented built form in light of shifting demographic trends comes from the suburbs of Seattle, Washington (Cervero et al., 2017). Thornton Place is a LEED-ND certified mixed-use development featuring senior housing and ground-floor retail, built atop a former surface parking lot of nearby shopping mall and adjacent to a major bus terminal-transfer facility. A light-rail transit station that connects the area to downtown Seattle will soon open. A formerly culverted creek alongside the Thornton Place project was day-lit, improving water quality, attracting water fowl, and encouraging many senior residents to take daily strolls. Housing units on Thornton Place's "Creekside", according to the project's web site, currently lease for 25 percent more than comparable units on the project's "Plaza-side" (i.e., facing the mall). With good nearby bus services and infill, mixed-use development, Thornton Place is a good example of TOD and DOT co-existing in a previously car-centric suburban setting.

The Millennials and the Shifting Economy

Millennials, the eponym for those in their late-teens to mid-30s, born between the early 1980s and the close of the 20th century, are radically transforming the demographic and cultural landscapes of modern societies. The traditional nuclear households they are not. Many are marrying and starting families later, opting out of having children altogether (i.e., dual-income, no-kids, or DINKS, households), or remaining single. They are thus associated with dramatically shrinking household sizes, in the case of U.S. from a mean of 3.14 in 1970 to 2.53 in 2018 (Statista, 2018). As notable are differences in core values and lifestyle preferences compared to prior generations. Unlike their parents and baby-boomers, where ownership of two major and costly assets – houses and automobiles – tended to be life-long goals, Millennials have other aspirations. Litman (2015, p. 25) writes: "much of the money, time, and excitement that previous generations directed at cars, Millennials direct at electronic devices (mobile phones, computers, sound systems)". Rather than 30-year mortgages and high-interest car loans, Millennials are more inclined to direct their incomes to travel, eating out, going to concerts, and other "life experiences". One survey of U.S. millennials revealed that 30 percent are willing to give up owning a car even if it means paying more to travel around (Dutzik et al., 2014). Declining shares of Americans aged 18 to 35 without driver's license compared to the past further underscore dramatic lifestyle shifts that underway (Sivak and Shoettle, 2012; 2016). Millennials are fueling the meteoric rise in shared and rating economies, which in the housing sector is no better represented than Airbnb and in the transport sector reflected by the omnipresence of ride-hail services like Uber and Lyft in trend-setting western cities like San Francisco and London and Didi throughout urban China.

Millennials are also profoundly reshaping the geomorphology of cities, not only in terms of residencies but also workplaces, retailing, and entertainment activities. Many are drawn to accessible, walkable, connected places, increasingly in traditional urban cores (Juday, 2015; Cervero et al., 2017). Mixed-use environments that support a live-work-shop-learn-play lifestyle are particularly popular, as is good public-transit access. Portland, Oregon's substantial investment in tramways and light-rail transit, along with the transformation and gentrification of former warehouse districts (like the Pearl District) into chic, bohemian-like, mixed-use neighborhoods, is credited with having attracted five-times the rate of in-migration of college-educated individuals 25 to 34 years of age than the U.S. as a whole during the 1990s (Impresa, Inc., 2007). In Portland and elsewhere, urban amenities, ACE (arts-culture-entertainment) investments, and 'third places' (like coffeehouses and outdoor eateries) that allow Millennials to hang out, socialize, and network are central to economic development strategies aimed at regenerating once stagnant urban districts, creating jobs, and attracting private investors (Cervero et al., 2017).

Where educated Millennials go, so do employers and retailers. Since the Great Recession of 2009-2011, America's fastest job growth has been in urban areas, reversing the past few decades of job suburbanization (Broberg, 2016). In the state of Washington's Puget Sound region, tech firms like Amazon, Expedia, and Microsoft have moved offices from suburban campuses and car-oriented edge cities to transit-friendly downtown Seattle and nearby districts. Rising commercial real-estate prices and rents are perhaps the best barometer of the premium employers are placing on being in highly walkable, mixed-use, transit-served in-city areas.

Since 2000, many of the cities chronicled in *The Transit Metropolis* as adaptive cities have witnessed urban regeneration on a grand scale. Two Scandinavian cities – Stockholm and Copenhagen – originally took on the persona of transit metropolises by building TODs on Greenfields, interlinked by high-quality rail services and interspersed by open green spaces – i.e., the necklace-of-pearls metaphor. Stockholm has since shifted to a focus on strategic infill and brownfield redevelopment, based on the city's 1999 master plan of "building the city inward not outward" and in keeping with its drive to be carbon-free by 2050. Markets have responded: from 1960 to 1980, the city of Stockholm's population fell by 20 percent; between 1980 and 2010, it grew by 31 percent (Sclar and Lönnroth, 2014). Stockholm's most notable example of urban regeneration is Hammarby Sjöstad, an energy self-sufficient, zero-waste eco-community on a former industrial site, served by a new inner-ring tramway. Through a combination of green urbanism, green architecture, and sustainable transportation initiatives like tramways, car-sharing, and bike-sharing, Hammarby Sjöstad is a "Green TOD", credited with reducing carbon emissions and energy consumption by a third relative to suburban projects with similar income profiles (Cervero and Sullivan, 2011a). Land that would otherwise be given over to asphalt parking is instead used for community gardens, playgrounds, and open space. Besides environmental benefits like reduced heat island effects and water pollution, the creation of a car-restrained, walking-friendly, mixed-use in-city neighborhood has drawn a diverse demographic: Millennials as well as empty-nesters and families with kids (Cervero and Sullivan, 2011b). Similar transformations – notably the reclamation of land from car parking to public squares and roadways to bikelanes – have occurred in Copenhagen, as chronicled by architect-planner Jan Gehl (2010) and discussed later in this chapter.

Structural shifts in employment, on the heels of globalization, modernization, and automation, have also profoundly changed urban landscapes and how workers move about them, particularly among Millennials and even younger generations (i.e., Zillenials, or Gen-Z's, reared in the era of iPhones and streaming services). Yesteryear's model of life-long employment and rising through the ranks of vertically integrated firms is being replaced by contingent employment, or in today's parlance, the "gig economy", marked by horizontal networks of independent contractors, consultants, free agents, freelancers, part-timers, and outsourcing. The dramatic growth in co-work spaces is one feature of the modern work environment. So is fluidity -- whether in the form of rapid job turnover, the proliferation of start-ups and mergers, LinkedIn networking for short-term assignments, or monthly changes in workplace locations. Job fluidity coupled with trends like shrinking household sizes foretell a future of less regularized, more atomized patterns of travel, especially for employment-related trips. This works in favor of adaptive forms of transit -- less standardized, market-responsive ones that adapt to shifting travel demand over space, by time-of-day, and even in terms of customer preferences (e.g., apps for ride requests and automatic payments targeted at convenience-minded, time-conscious Millennials). Micro-transit options, like private commuter minibuses (e.g., Pickup in Austin and Chariot in San Francisco), dynamic vanpools (e.g., Via in New York), dynamic carpools (e.g., Carma, Scoop, Waze Carpool), and ride-share, taxi-like services (e.g., UberPool Express and Lyft Line), are best positioned to meet such market preferences.

Locational and lifestyle preferences of Millennials in combination with structural shifts in employment further underscore the likelihood of 21st century transit metropolises taking on a hybrid form – i.e., elements of adaptive cities with great walking environments as well as adaptive transit, marked by flexible, demand-responsive forms of collective-ride mobility. Technological advances are likely to exert similar influences, the topic to which I now turn.

4. Transformative Technologies and Urban Futures

In the urban transport sector, progress towards sustainable futures is constrained in good part by path-dependence that locks out major breakthroughs, paradigm shifts, and changing practices. A succession of deeply rooted forces – ascendancy of automobiles as the dominant form of mobility, the prominence of automobile-manufacturing and services in modern economies, the entrenched practice of carving subdivision tracts throughout suburbia for low-cost housing development (enabled by the automobile and government-funded motorways built to accommodate it), etc. – form powerful barriers to significant change in how cities are designed and how we move about them.

Transportation scholars argue that paradigm shifts in how we move about cities are unleashed through disruptive forces (Garrison, 2000). In the urban realm, this might include climate change, what many argue will elevate the importance of resiliency in the design of communities, now and in the future. It also includes transformative technologies, like app-empowered industries that offer fundamentally new forms of urban mobility (e.g., Uber and Lyft) and, of course, the great unknown on the horizon, fully autonomous driver-less vehicles. Such disruptive technologies, I argue, further move us in the direction of transit metropolises with elements of both adaptive cities and adaptive transit.

Smart Mobility and Autonomous Vehicles

Advances in information-communications technologies (ICT) are moving utopian visions of cities dotted with sensors and monitored by satellites that control the movement of vehicles and virtually eliminate collisions closer and closer to reality. Autonomous technologies -- like automated braking, self-parking, lane-departure warnings, and adaptive-speed cruise control – are already found in most high-end cars today. Ford Motor Company recently set a target of all of its model 2021 vehicles achieving level-four autonomy, with full driver controls but able to operate in full-auto mode on certain kinds of roads under certain weather conditions. Places like Santander, Spain are fully committed to a smart-cities future, having implanted more than 12,000 sensors in buildings and light-posts to continuously monitor traffic conditions, parking spaces, and air pollution. There, big data are processed and used to schedule pick-ups from trash bins that need to be emptied, navigate motorists to the closest available parking spots, and adjust traffic signals, second-by-second, to facilitate green-wave traffic flows.

The likely consequences of ICT, connected vehicles, and driverless cars on travel demand, congestion levels, and ultimately urban form has sparked considerable debates in recent times (Jeekel, 2015). While there is little doubt such technologies will make travel safer, opinions are mixed in most other areas. On the one hand, driverless cars can be expected to increase vehicle miles traveled (VMT) by lowering generalized costs of travel and parking, thus inducing trips. This could happen by enabling cars to travel faster and closer together, effectively increasing road capacities; reducing non-recurrent incidences (which is said to account for as much as 60 percent of traffic congestion) from fewer road collisions; providing automobility to many who are currently unable to drives, including seniors, youngsters, and disabled people; and enabling car users to do other things (like text on their smart phones) and be less stressed when moving about the city, effectively reducing their perceptions of travel-time impedances when in the car. On the other hand, VMT could decline as a result of technology-enabled smart pricing (e.g., real-time congestion tolls) and shared-use of autonomous vehicles, particularly among Millennials as they move through mid-stages of lifecycle, their peak-consumption years. Both factors would promote compact development, shortening trips and thus lowering VMT.

In the U.S., travel forecasts suggest that VMT-inducing effects will likely outweigh VMT-reducing ones, leading to net increases in travel. Travel-demand modeling of the impacts of driverless cars in San Francisco, Seattle, Atlanta, and Philadelphia predicted 5 percent to 20 percent increases in regional VMT (versus the counter-factual of no driverless cars) (Guerra, 2016). If such forecasts materialize, the transit metropolis model, whether of the adaptive cities or adaptive transit form, will lose relevance. Cities will become increasingly car-centric versus transit-oriented. This prognosis could change, however, if the travel-inducing effects of ICT are moderated or even reversed by using technologies to promote smarter transit and green mobility as well as to 'set the prices right' (i.e., smarter pricing). Perhaps more important will be sharing (versus ownership) of autonomous cars and filling vacant seats via real-time carpooling. Recent forecasts of expected growth in autonomous cars to 2035 in seven regions of the U.S. estimated that the average VMT increases of 31 percent could be halved if 50 percent of self-driving cars were shared (Milam and Riggs, 2018).

Ride-hailing and Shared-Ride Services

The past decade has witnessed an explosive growth in new-age forms of mobility, ones that fill the vast spectrum between expensive, exclusive-ride taxi services and highly standardized, fixed-route/fixed-schedule bus services. Using smart-phone technologies and riding the wave of increased collaborative consumption, a rich assortment of mobility providers today ply the streets of cities world-wide, from ride-hail services like Uber and Lyft to various forms of micro-transit, including private commuter minibuses, dynamic vanpools and carpools, and the really micro-carriers, electric scooters and e-bikes. New-age micro-mobility is hardly a developed-cities phenomenon: in Jakarta, a motorcycle-taxi service called GoJek that uses smart-apps for ride requests and payments has exploded onto the scene, as has BluJek, which offers motorcycle-taxi services for women, operated by women. For consumers, new-age mobility services have been mostly good news, enriching their travel options by providing heretofore unprecedented levels of, in economist-talk, 'service and price points'. My own research with Berkeley colleagues of ride-hail services in San Francisco found that what appeals to customers most is convenience and time-savings: among the chief reasons people took Uber and Lyft were ease of payment and ride requests using smart-phones plus short average wait times (compared to taxis) (Rayle et al., 2016). To no surprise, this was particularly so among Millennials.

The meteoric growth in private-sector app-based mobility seems unstoppable. In the four key markets of the U.S., Europe, China, and India, ride-hailing has rocketed from about 1 billion trips in 2013 to an estimated 14 billion in 2018 (Meyer et al., 2019). While some envisage services like Uber and Lyft becoming partners and complements of transit agencies, increasingly they appear to be competitors. One recent study found that 60 percent of ride-hail would have traveled by foot, bike, or transit had ride-hailing not be available (Clewlow and Mishra, 2017). Further evidence comes from plummeting transit ridership in cities like Los Angeles (down 20 percent in the past five years), attributed in part to competition from Uber and Lyft, despite the billions of dollars spent on new rail lines (Nelson, 2019).

While ride-hailing stands poised to weaken the role of transit in cities, to the degree that Uber and Lyft users begin sharing rides in return for a break in fares, it could transform "mass transit" as we know it, elevating the mobility role of dynamic ridesharing worldwide. As they continue to scale up and lower unit costs, shared ride-hailing has become the fastest growing market for companies like Uber and Lyft. In 2016, UberPool operated in more than 30 U.S. cities, claiming over half of all journeys in some (Hawkins, 2016) and has since steadily expanded across the country. In Los Angeles and San Francisco, shared ride-hail services (UberPool and Lyft Lines) are flourishing, sometimes functioning as station cars, a form of micro-mobility envisaged for California's urban rail systems two decades ago (Cervero, 1997): in 2014, 14 percent of UberPool trips in Los Angeles and 10 percent in San Francisco began and ended at rail-transit stations (Hawkins, 2016).

What could be truly transformative, catapulting shared ride-hail services into the big leagues of urban mobility and advancing the adaptive transit model more than anything, is the mapping of and organizing services around 'hot spots' – i.e., frequent passenger pick-up and drop-off points. In return for walking a few blocks to a hot spot, customers get a break in fares. Hot spots effectively convert the much more complicated ride-matching of many-to-many trips to a much more tractable pattern of matching few origins and few destinations. It is infinitesimally easier for on-board computers to work out a traveling salesman algorithm to pick up multiple passengers along a route if people load and disembark at hot spots rather than their individual street addresses. In 2018, Uber used heat maps to design such services in San Francisco, Boston, and six other U.S. cities. Called Uber Express Pool, customers share vehicles by typically walking a few blocks for a pick-up and to their final destination after drop-off in return for upwards of 70 percent break in fares compared to door-to-door ride-alone ride-hail service.

The marriage of self-driving cars and car-sharing, in the view of some, could be the real game-changer. Waymo, Google'a autonomous vehicle arm, envisages car-sharing subscription services as the company's 'end game', profiteering from 3-D Lidar mapping and storage of big data on roads, traffic, and passenger demands, at all times of day and days of year, to optimize the delivery of driverless car-sharing services to its subscribers (Jiang et al., 2015). Waymo along with Uber and other tech companies venturing into the shared mobility space see themselves one-day becoming the 'Spotify of shared mobility' – i.e., one-stop concierges, providing on-demand 'mobility as a service' (MaaS) to subscribers for any origin-destination combination across a range of price and comfort/convenience levels. With MaaS, travel simply becomes conveyance, not unlike an elevator, escalator, or airport people-mover co-shared by unrelated individuals. The reduced emotional attachment to vehicles, some speculate, will dramatically reduce private car ownership over time. Research by the International Transportation Forum (2015) estimates that 'Robo-Taxis' (i.e., driverless shared taxi services) could replace 90 percent of cars in large cities by 2030, eliminating on-street parking and reducing congestion. For medium-sized cities, Robo-Taxis could obviate the need for conventional public transit, providing 3-to-4 passenger "micro-transit" connectivity throughout a city. If they ever come to fruition, they would be the archetype of adaptive transit services.

Yet a future of robo-taxis and shared, smart urban mobility could very well also work in favor of TOD, infill development, and walkable communities, principally by reducing numbers of cars and parking spaces. Ride-hailing services by themselves, whether shared or not, are strongly associated with low car ownership: a 2015 survey found the average car ownership of Uber and Lyft riders to be 1.05 vehicles per household versus a 1.50 average for all households in cities served by Uber and Lyft (Shared-Use Mobility Center, 2016). This reflects in good part the sharing preferences of Millennials: the San Francisco study of ride-hail services, for instance, found three-quarters of Uber and Lyft riders to be between 15 and 35 years of age, compared to 44 percent of frequent taxi users and 30 percent of citywide residents (Rayle et al., 2016).

The 20th century model of individual car ownership and single-occupant travel is unsustainable. The typical car sits idle 23 hours per day. When it is used, three out of four seats are often empty. For many trips, cars are vastly overpowered and oversized: relying on a two-ton steel cage to shuttle a 150-pound person around a neighborhood is unforgivingly wasteful in an era of increasingly turbulent weather patterns and steadily rising sea levels, fueled by anthropogenic carbon emissions. Shrinking the car's urban footprint by de-populating vehicles would densify cities and thus shorten travel distances, making it easier and cheaper to share driverless cars, kicking off a virtuous cycle if you will.

Smart Pricing and Technologies

Besides smart micro-transit, smarter pricing will also be critically important in moderating the potential trip- and sprawl-inducing effects of autonomous vehicles and smart-car technologies. Smart pricing is needed when cars are both stationary and moving. Dynamic parking pricing has been introduced in San Francisco, under the SF Park pilot program. Donald Shoup (2005) maintains that to prevent excessive cruising for open parking spaces, no more than 70 percent to 80 percent of curbside spaces should be occupied. Too many unoccupied curbside spaces are also wasteful, namely of valuable urban land. Under the SF park program, some 6000 sensors have been installed in curbside spaces, both to inform motorists of closest available parking spots and to allow prices to be adjusted to achieve 70 to 80 percent occupancy targets. Block faces with fewer occupied spaces see hourly parking costs drop, to as low as 25 cents. Streets that are consistently full cost more to park, as much as $6 per hour. Over the pilot program's first two years, the number of miles driven and amount of exhaust spewed during parking searches dropped 30 percent (SFMTA, 2014). The average time spent hunting for parking, moreover, fell by 43 percent, or by 5 minutes (Millard-Ball et al., 2014). Smart parking charges contribute to the transit metropolis model as an "auto-equalizer", helping to 'set the prices right' and in so doing drawing more travelers to transit and a transit-oriented lifestyle.

Singapore was highlighted in the 1998 book as a model transit metropolis, buttressed by TDM (travel demand management). The most prominent TDM measure introduced was electronic road pricing (ERP), relying on gantries and on-board transponders to pass on charges to motorists for traveling into cordoned zones during peak periods. Singapore pioneered congestion charging, soon followed by London and Stockholm. Cordon pricing, however, is a fairly crude and often inequitable way to pass on congestion charges, not necessarily reflecting the marginal contributions of individual motorists to traffic tie-ups. Taking advantage of smart technology, Singapore is in the midst of introducing the next generation of ERP, using the Global Navigation Satellite System (GNSS) to dynamically adjust prices according to actual congestion levels. Under ERP 2.0, prices will be based on the actual length of congested roads used by motorists. Motorists will be charged according to when, where, and how far they travel. Such VMT-based congestion charges will move Singapore closer than any other city to what transport economists have long maintained is necessary to substantially reduce traffic congestion and emissions – marginal social-cost pricing. It will also reinforce the city-state's unwavering commitment to island-wide transit-supportive development.

Yet Singapore also shows signs of moving in the direction of a hybrid transit metropolis through the introduction of new, innovative forms of surface transit. An example is the pilot-testing of autonomous station cars, aimed at providing first-mile/last-mile connectivity to MRT rapid-transit stations. At two MRT suburban stations, Singapore built automated and elevated people-movers, similar to those found at many airports, to connect to surrounding housing developments that are beyond a 5-to-10-minute walk. Jerry Schneider calls the use of people-movers, or personal rapid transit (PRT), to connect housing to nearby rail stations an 'Extended TOD'. In her study of human-scale mobility, Roxanne Warren referred to the interface of PRTs and metros in clustered suburban development as an 'Urban Oasis' (Warren, 1997). People-movers, however, are very expensive to build and maintain. More economical is to run 'pod-cars' on surface streets, using automated technologies. Singapore's Land Transportation Authority recently partnered with several private companies to pilot-test autonomous electric station cars and self-driving shuttles that operate on local streets, connecting several business parks to two MRT stations along three routes. Safety drivers currently occupy the pre-programmed smart autonomous shuttles however as the program matures and kinks are worked out, Singapore's station cars are to become fully autonomous. Smart pricing and smart shuttles are but part of Singapore's big push towards a 'car-lite' society, aimed at zero automobile growth and eventually 'mobility as a service' substituting for individually owned cars (Hean, 2019).

E-Commerce

Another technology-driven, potentially transformative trend that could reshape 21st century transit metropolises is e-commerce. On-line shopping is growing exponentially. In 2014, over $1 trillion in retail goods were purchased on-line, 6 percent of retail sales worldwide, up from a fraction of a percent a decade earlier (Berg, 2016). By the end of 2018, one out of ten retail sales in the U.S. occurred over the internet (U.S. Department of Commerce, 2019). The nature of urban goods movement is radically changing as a result: from truckloads of merchandise hauled to brick-and-mortar stores to parcels and packages carried to purchasers' front doors. With Millennials leading the way in on-line purchases and increasingly concentrated in urban centers, new urban logistics challenges have surfaced – notably, more and more delivery trucks encroaching on in-city residential neighborhoods and compact urban districts. Big e-commerce players, like Amazon, have opened freight warehouse-consolidation-distribution centers on the peripheries and in the exurbs of numerous U.S. cities. To save on costs, parcel deliveries are often consolidated and traveling-salesman algorithms are used to reduce the amount of freight VMT logged on central-city streets. Still, new, somewhat unprecedented problems are cropping up, such as increased noise, fumes, and traffic disruption in residential neighborhoods and worsening pavement damage from steady flows of FedEx, UPS, and other package-delivery couriers. The arrival of more and more delivery trucks has prompted some to insist that staging areas, curb-side spaces, and even passageways be provided for these carriers in keeping with 'complete streets' principles. Parcel trucks are legitimate users of street-space and just as with cyclists and pedestrians, it is argued, need to be accommodated. Some even call for wider roads and thicker pavements to accommodate rising numbers of parcel delivery trucks. To do so, however, would favor mobility over place, the antithesis of the transit-metropolis model. More consistent with the place-making focus of transit-oriented communities would be the siting of drop-off/pick-up bins near neighborhood bus stops or the conversion of vacant stores in outdated local shopping plazas and even decommissioned public schools to parcel-pick-up areas (Haake, et al., 2016). This could reduce truck traffic or at least deflect it from neighborhood centers. A number of Germany cities have installed package delivery/drop-off boxes, some refrigerated, on neighborhood peripheries for the very purpose of minimizing in-neighborhood truck traffic.

Pandemics and The City

The lingering effects of COVID-19 on cities and public transport in particular remains a huge uncertainty. In the near term, public transit systems are introducing cleansing and physical distancing measures to lower the risks of transmissible diseases. Chinese cities like Shenzhen and Shanghai have used QR codes for contract tracing. In China, access to public spaces is controlled through QR codes. When boarding a train or bus, passengers must scan their PR code. If a user is found to have COVID, other passengers can be quickly tracked down and, if necessary, quarantined. As a result, ridership has largely recovered from pre-COVID levels, from a 90 percent decline in January of this year when cities were under lock down to only a 10 percent drop in early Fall of 2020.

The longer term implication of pandemics on public transport and cities remains unclear. Some forebode a future of increased low-density living and (accordingly) car travel. Increased VKT from switching from transit to cars could be off-set by more people working at home during the work week, eliminating commute trips. Some predict the emergence of "transit villages" – less dense housing with limited neighborhood retail and a less welcoming environment for outside visitors. The adage that "mass transit" needs "mass" holds as much for today as ever thus a de-coupling of transit and densification of cities suggests a smaller mobility role for shared mobility in coming decades. New micro-forms of transit that allow social distancing – e.g., autonomous micro-shuttles or some form of PRT hired by family members or friends for group travel – could lie on the horizon.

5. 21st Century Transit Metropolises as Hybrids

A number of powerful megatrends and technological forces, touched on in this chapter, are profoundly changing household structures, lifestyle choices, travel patterns as well as the physical make-up of cities and regions worldwide. Collectively, they are reshaping the 21st century version of the transit metropolis. The dichotomy of transit metropolises as adaptive cities and adaptive transit, while apropos in the 20th century, is far less so in the 21st. Most of today's transit metropolis are hybrids, featuring not only well-designed TOD but also an assortment of flexible, near-door-to-door forms of mass transportation. As a result, the modern transit metropolis is adapting in ways that produce a rich assortment of mobility options – e.g., high-capacity transit, micro-transit, movement by foot and bike, ownership versus shared consumption of cars and bikes – and built forms that serve changing lifestyle preferences among city-dwellers.

Copenhagen, like Singapore, was prominently featured in *The Transit Metropolis* as an adaptive city, compact and mixed-use in form, with housing and commercial development physically concentrated around radial metro-rail lines. Like Stockholm, Copenhagen's early-generation TODs focused on suburban corridors, however over the past few decades, the city has emphasized urban re-generation, partly through land reclamation that has shrunk the amount of land given over to using and parking private automobiles. In 1962, all of Copenhagen's 18 public squares were parking lots; today, all are car-free, populated by pedestrians and cyclists (Gehl and Svarre, 2013). Copenhagen has also invested massively in bicycle infrastructure, on the heels of policies that require every square meter of additional road capacity to be matched by at least as much added bicycle lane and cycle-path capacity. Copenhagen is today's Europe's most bicycle-friendly capital city, with more than a third of residents getting to work by bicycle and comparable shares of access trips to suburban rail stops being by bicycle (Pucher and Buehler, 2008; Martens, 2004). In this sense, Copenhagen's rail-served corridors function as Extended TODs, featuring compact, pedestrian-friendly development but also high-quality bicycle and zero-emission bus connectivity to outlying areas. The reach of bicycle infrastructure is soon to extend well beyond rail corridors. Currently, 26 Cycle Super Highways, spanning 300 km in length, are being built in Greater Copenhagen, providing long-distance, grade-separated bicycle mobility throughout the region. Copenhagen is also using smart technologies to expedite bicycle flows: smart-phone apps exist that allow cyclists to pace themselves so that they catch 'green waves' through signalized intersections, in addition to providing route navigation assistance and GPS tracking of bike-sharing opportunities. It is this widening array of green mobility choices that makes regions like Copenhagen more of a hybrid than a transit-oriented metropolis.

Guangzhou, China has also taken on the persona of a hybrid transit metropolis. Guangzhou boasts Asia's most cost-effective BRT service, handling more than three times the peak passenger flows of any BRT system outside of Latin America (Suzuki et al., 2013). This partly due to a careful matching of BRT services to the 'lay of the land'. Rather than operating a trunk-feeder system that requires BRT riders to transfer, Guangzhou opted for a 'direct-line' service that mimics the many-to-many travel patterns found in many Chinese cities that are dense, yet spread-out (Yang et al., 2012). In Guangzhou, most BRT bus routes operate as both mainline carriers and feeder connectors, converging on a 23 km center-city busway (Figure 2). Having buses that operate at high speeds along busways morph into neighborhood feeders ensures a high degree of regional connectivity, reducing and for some riders eliminating transfers altogether. For this reason, Guangzhou bus-based services have been called “adaptive BRT” (Suzuki et al., 2013). Yet most of the stations along Guangzhou’s BRT spine are TODs: mixed-use development concentrated within a five-minute walk of stops. Guangzhou’s BRT spine features seamless pedestrian connectivity to surrounding development, courtesy of gently sloped footbridges and same-level integration with the second floors of adjoining commercial buildings. Owing to the combination of high-quality BRT services and pedestrian connections to stations, high-rise commercial development is gravitating to Guangzhou’s BRT spine, increasing real estate prices by 30 percent relative to non-TOD projects during the first two years of BRT operations (Cervero and Dai, 2014).

Some of the emerging technologies reviewed in this chapter, such as autonomous and connected vehicles, are controversial for the very reason that they could end up inducing motorized travel and, as a result, sprawl. Public policies become critically important in moderating and possibly reversing some of the unintended consequences of such technologies. Notably, public policies should nudge technological advances in the direction of smarter transit, green mobility, and, as in Singapore, marginal social-cost pricing of car use. The public sector also needs to break down barriers to the emergence of efficient and market-responsive forms of micro-transit, like dynamic ride-sharing. Key in this regard is relaxing taxicab regulations that restrict market entry, service delivery options, and innovative pricing, and eliminating the outdated and market-distorting system of regulating supply through taxi medallions (Gilbert and Samuels, 1982; Cervero, 1985; Transportation Research Board, 2015). Public policy can also play a critically important role in promoting inclusive transit metropolises. An example is Central Saint Giles, a mixed-use TOD in central London, near the Tottenham Court Road underground station. In the *TOD Standard*, the Institute for Transportation and Development Policy (2014) rated Central Saint Giles as the ‘best’ TOD worldwide, earning a ‘TOD score’ of 99 out of a possible 100. Besides being compact, varied in land uses, and highly walkable, Central Saint Giles also earned high marks for being inclusive. To promote affordable in-city living and create opportunities for middle-income workers to reside at Central Saint Giles, the city of London granted the project’s developers two additional commercial floors in return for nearly half of the project’s 109 dwelling units being priced below market rates.

Fortunately, public policies that promote sustainable mobility (e.g., GPS-informed VMT charges and dynamic ridesharing) also tend to promote sustainable urbanism, including TOD. A 2006 pilot-test of VMT charges in Portland, Oregon, for example, found a larger decline in VMT among those living in dense, mixed-use neighborhoods than those living elsewhere (Guo et al., 2011). This suggests strong interactions and positive synergies between policies that advance adaptive cities, including TOD, micro-transit, and smart pricing. Consistent with the visions set in *The Transit Metro*polises, public policies that help create great walkable communities along transit corridors, promote short-distance travel via slower modes, and that embrace smart, clean technologies as well as smart pricing offer promising pathways to sustainable urban futures.

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