Automation, Electrification, and Shared Mobility in Freight

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A research report from University of California Institute of Transportation Studies

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16. Abstract

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Abstract

Understanding the potential benefits and unintended consequences of automation and electrification revolutions in freight is challenging for academics, practitioners, and decision-makers. On one hand, these revolutions could help mitigate the disproportionate impacts of freight transportation on externalities and improve efficiency; on the other hand, they could generate additional issues such as right-of-way conflicts, crashes, and traffic incidents. To shed light on these issues, this report conducts an extensive review of the state-of-the-practice of such innovations for both long-haul and last-mile freight distribution. The study concentrates on the potential barriers, challenges, and opportunities of the different innovations, and discusses the market readiness of some of the technologies. Finally, the authors discuss planning considerations for the advent and widespread use of these innovations, and provide research and policy considerations.

Executive Summary

A desire to mitigate the disproportionate negative externalities due to transportation such as pollutant emissions, noise, and congestion has prompted a rethinking of transportations systems. Consequently, in the last several years, new systems have been tested; more efficient and less environmentally disruptive, these technologies are embraced in the so-called “Transportation Third Revolution (3Rev)”: *automation, electrification and shared mobility for both passengers and freight.* On the passenger side, the 3Rev has already shown significant benefits in operative cost, noise, and emission reductions. However, on the freight side, the revolution is still premature. This report focuses on the freight transportation side, and the status, potential, and challenges associate with these technologies in freight.

It is indisputable that electrification and automation technologies will change freight transportation, and will introduce new paradigms such as new services, regulations, and road rules/laws. These systems have different features; cargo capacities (size, weight), refueling needs, and even differences in infrastructure requirements (e.g., sidewalks, bicycle lanes, and near-ground air space). All of these changes are key challenges for the planners and decision-makers who will have to design new policies that guarantee the integrity and safety of all system users. Stringent policies could become hurdles for the penetration of these technologies, but policies that are too permissive could put the population at risk, at least until the technologies are demonstrated to be safe. This report provides an overview of different 3Rev technologies' penetration status, and explores the potential, challenges, and unintended consequences of their arrival in the urban system. Among the available technologies, in the short term and for the long-haul, full electric trucks are expected to be on the market in the current and following year or two. However, the fully autonomous versions for this segment still need to wait since, in the United States at least, there are no licenses for their operation. Some autonomous initiatives tested in controlled environments in Europe have given promissory results. Autonomous vehicles could potentially contribute to reducing crashes considering their multiple navigation devices that help to recognize threats on the road. The penetration of autonomous vehicles would promise a significant reduction of road fatalities.

For the last-mile segment, electric bikes stand as the most mature technology, with benefits that are more outstanding: zero-emissions, versatility, less congestion, less noise, and low cost. Similarly, electric vans are at a considerably mature level of development, with the associated advantage of having a higher cargo capacity than electric bikes, facilitating a 1:1 replacement with regular vans. Although this alternative does not contribute to reducing congestion, it does not generate tail emissions and produces low noise. On the other hand, in the long term in this segment, fully-autonomous devices promise benefits beyond reducing emissions, noise, and congestion. Autonomous mobile robots (AMRs) and unmanned aerial vehicles (UAV) also known as “drones“ show potential in replacing human labor while reducing the time, and increasing the efficiency and flexibility of deliveries. For years these devices have shown benefits in time and cost reductions in indoor scenarios, however, in dynamic outdoor environments (such as the urban system), the diversity of situations that may arise make their operation challenging. Recent leaps in automation technology have expanded the range and complexity of tasks that robots can perform. Several companies have tested prototypes for food and retail in last-mile deliveries such as DHL, Amazon, Kiwi, Yelp’s Eat24 and FedEx. One of the main challenges of these devices is how to operate them in the urban system without being disruptive of regular traffic and pedestrians. Some trials demonstrate that changes are required in the urban infrastructure and in regulations to help, for example, AMRs to cross intersections.

Although it is not yet clear which technologies will prevail, it is important that planners and other decision-makers understand the strengths and limitations of each to anticipate their benefits and unintended consequences within the freight transportation system. Furthermore, this understanding will allow the development of appropriate measures to either foster or deter their adoption. Considering the potential of these technologies, it is also necessary to make changes in the urban system to accommodate them better. The changes proposed here are those in the direction of adequate policies and infrastructure supported by further focused research.

1. Introduction and background

Everything that we consume, as well as the materials used in manufacturing or industrial processes are brought by the urban freight system (UFS). The UFS is very different from the long haul and other freight transportation segments. The long haul is simple; it moves large cargo quantities between two specific points using high-capacity vehicles, such as a load of wheat being transported by train to a mill, or containers on trucks from one city to the next. The UFS, on the other hand, makes the 'last-mile' deliveries of the supply chain (e.g., parcels to residents, products to commercial establishments), therefore, it deals with much more complex network environments. In the last mile, the customer could have specific delivery requirements, some vehicles could have restrictions in some areas, and road conditions are diverse. Even within the UFS, the business-to-business demand is significantly different from the business-to-consumer and consumer-to-consumer (usually in the form of parcels or mail) demand. A 2013 study found that grocery delivery trucks emitted between 20 and 75 percent less carbon dioxide per customer on average than passenger vehicles when grocery stores could choose the drop-off times and optimize routes (*1*). In this sense, e-commerce is beneficial for the environment compared to retail commerce, but only if the logistics operation can be optimized. Many factors are making the transfer of goods inefficient and expensive in the last mile: availability of parking/staging areas; access to the curbside; access to the building/store/house; readiness of the receiver (customer); the type and number of other logistics activities that have to be conducted during the transaction; the presence of information and systems; availability of fueling/charging stations; safety/security requirements; type of commodity/shipment size/weight; and delivery service/frequency, among others.

The inefficiencies mentioned above and the use of traditional internal combustion engines translate into freight transportation being a significant generator of disproportional negative externalities (*2*, *3*). These externalities involve social, environmental, and economic impacts, typically associated with traffic congestion, noise, greenhouse gases (GHG), safety, and even the stress generated by congestion. Transportation is recognized as one of the largest sources of GHG emissions in the world, and the largest in the United States (*4*). These pollutants in the air increase the burden to the environment and are responsible for lung disease impacts(*5*). The estimated urbanization rate further exacerbates the situation; the United Nations estimates an urbanization growth of 66% by 2050 (*6*), and the higher the number of people in cities, the higher the demand rate for goods that must be mobilized by the UFS.

Studies further warn that continuing our current behavior will increase emissions by approximately 30% compared to 1990 levels in the next thirty years, with expected significant consequences for the climate and the lives of U.S. citizens (*7*). According to the world's leading scientists, we must radically shift our carbon-based economy by 2030 (*8*). The world must reduce emissions by 45% by 2030 and reach net zero emissions by 2050 to stop warming at 1.5C. Otherwise, conditions will significantly worsen on earth for a significant part of the population. The Paris Agreement in 2015 (*8*), was the first worldwide collective accordance to avoid dangerous climate change, limiting future temperature increase to 1.5 to 2°C above pre-industrial levels.

Electrification, automation, and shared mobility, or the three revolutions (3Rs), stand as a promising alternative to improve the efficiency of urban freight operations, considering the benefits that these have had in the transport of passengers: reductions of costs, time, noise, and carbon emissions (*9*, *10*). However, in the freight field, major vehicle manufacturers have invested considerable resources in the development of heavy-duty trucks for the long haul. In terms of revolutionary change, the UFS has been overlooked; it constitutes the next frontier for the penetration and development of such technologies. Nevertheless, in recent years there has been a growth in the number of initiatives to incorporate automation and electrification in the last mile, some pursued at a considerable level of development, while others still require more research. Considering the number of initiatives in the trial stage, and those in progress, the arrival of 3Rev in freight seems imminent. However, despite its potential benefits, there are some challenges and barriers that these technologies must overcome before being widely disseminated. Accordingly, this study explores the challenges and opportunities for the introduction of the 3Rs in last-mile/last-feet delivery operations. Further, since the arrival of this revolution depends mainly on technological developments in transportation, this study provides an overview of the maturity status of different technologies, and explores the benefits and unintended consequences of their arrival on roads.

The rest of this document is organized as follows: Section 2 introduces the potential benefits of the 3Rs in freight. Section 3 discusses available and upcoming alternatives for electrification and automation for long-haul and last-mile operations, as well as sharing mobility alternatives for freight cargo. Section 4 illustrates road safety challenges and opportunities for the 3Rs technologies. Section 5 presents some drivers that will be needed to facilitate the arrival and use of 3Rev technologies in the urban system. Finally, Section 6 presents conclusions and insights.

2. Potential of the 3Rs in Freight Transportation

The 3Rs in freight transport are a promising alternative to mitigate transportation externalities. This section aims to illustrate the potential benefits of 3Rs and their related technologies.

2.1 Electrification

According to the Environmental Protection Agency (*4*), medium- and heavy-duty diesel trucks generate close to a quarter of the transportation carbon footprint and emit four times more nitrogen dioxide pollution and 22 times more particulates, on average, than cars that run on gasoline. Electrification, or replacing internal combustion engine vehicles with vehicles powered by electric engines, could contribute significantly to reducing both tail-pipe emissions and global CO_2 emissions when the electricity is generated without the use of fossil fuel energy.

Currently, manufacturers are selling all-electric (zero tailpipe emissions) vans, or are promising to market all-electric heavy-duty trucks in the next two years. Further, the development of more efficient batteries and electric engines has generated transformations in traditional modes, such as so-called cargo bicycles powered by electric engines, which allow the user to carry more weight with less effort. Cargo bikes eventually will have the advantage of mobilizing on the same infrastructure as regular bikes, and thus, contributing to the reduction of cargo vans and trucks on the roads.

Electrification has already shown significant benefits in passenger transportation, reducing noise, emissions and operational costs (*11*, *12*). Cities recognized for their high levels of air pollution such as Los Angeles (L.A.) bet on electrification as a means to reduce their emissions (*13*). Los Angeles has reduced its GHG emissions 25% below 1990 levels and its per capita greenhouse gas emissions are one-third of the national average. Currently, transportation is responsible for about 31% of GHG emissions in L.A., but a 50% reduction of the current levels is expected by 2025, and carbon neutrality is the goal by 2050, at least in public transportation. With these and other initiatives, L.A. could reduce GHG emissions in amounts equivalent to the annual emissions of New York, London, Tokyo and Hong Kong combined. Another example is the city of San Francisco, which plans to reduce below 30% its GHG emission levels compared to 1990 levels (*14*). San Francisco is also banking on electrification as a strategy to reach carbon neutrality by 2050. It has replaced the majority of its public transport with electric alternatives, and actively supported the use of electric cars through infrastructure investments.

On the freight side, although electric alternatives are available, the penetration level is much smaller. Academics and practitioners are still working on determining policies to effectively replace traditional vehicles with electric vehicles. For example, there is no 1:1 efficiency of replacing vans with electric bicycles. A real-life study case (*15*) indicated that one of the main issues is that cargo bikes can only cope with parcels and not pallets, consequently, they can only cover specific types of loads. For cargo bikes, the size and weight of parcels or mail should be small, and the travel distance must be short. These constraints suggest the need for a consolidation center, as well as the need for recharging networks. As a result, the conditions in which cargo bikes can help to achieve sustainable mobility are limited to what can be considered a niche market. Similarly a simulation case study (*16*) identified that the geographical scope of the implementation of cargo bikes is not the city level, but rather specific areas within the city; those with maximum linear distances close to 2 km. At that spatial level, the observed delivery patterns allowed deliveries to be made efficiently using cargo bicycles instead of vans at a replacement rate of 1: 1.

However, these results could not be generalized considering the different traffic conditions of all cities and the variety of available technologies. In each situation, the necessary conditions must be evaluated before taking action on vehicle replacements.

2.2 Automation

Automation encompasses several alternatives which rescind the need for human drivers: drone or unmanned aerial vehicles (UAVs), autonomous mobile robots (AMRs), and autonomous vans and trucks. Drone and AMRs are known for their versatility, enabling new possibilities such as delivering cargo to sites where traditional modes have restricted access, complementing the work of parcel workers, or performing autonomous long distances trips efficiently. The Swiss postal service delivers blood samples between hospitals efficiently using drones, avoiding the usual congestion of the downtown and producing zero tail-pipe emissions (*17*, *18*). Similarly, DHL has made tests to deliver medicines in remote places where weather conditions or the terrain restrict the use of regular vehicles (*19*, *20*). Peterbilts from Embark, autonomous class 8 heavy-duty trucks, can operate overnight moving cargo coast-to-coast in the U.S. The automation in such trucks enables improved efficiency in time at levels impossible for a human being who needs to make several stops during the trip. Also, thanks to the lack of a driver, the operation of these vehicles could be less costly. Further, one of the promising features under development in these vehicles is the possibility of reducing the risk of accidents thanks to the use of navigation sensors and other devices that can prevent crashes.

The results from different developers' tests suggest that overall, alternatives for automation have the potential to reduce operational costs, congestion, accidents, and emissions due to better efficiency in driving, particularly when the vehicles are electric. **Table 1** illustrates the results of the estimated impacts of automation in the streets of the U.S. without considering drones nor AMRs. These analyses consider three penetration levels: 10%, 50% and 90% for the percentage of autonomous vehicles in the whole vehicle mix (*21*). The benefits include a reduction in the number of crashes, with 211,000 fewer crashes per year (7.3 M crashes occurred in 2016), which could represent 1,100 saved lives, and a reduction in economic cost of $ 5.5 B, when autonomous vehicles share the market at a 10% level.

Because these vehicles can travel closer as they are system-linked for efficient braking, and for communicating to predict situations such as collisions, stops, and required lane changes, congestion can be reduced. A penetration of 50% could save about 1,680 million hours of travel time, which represents 224 M gallons of fuel saved. In addition, automation could affect parking space requirement and costs; with the assisted parking systems a reduction in parking space is expected when compared with human driver requirements. Another benefit is the possibility of connecting the vehicles with parking infrastructures to reduce the time spent finding parking. One of the unattended consequences considered in this study is the accessibility provided to disabled and older populations that could now have the possibility of independent travel.

Table 1. Estimates of annual economic benefits from Autonomous Vehicles in the U.S. Source, adapted from (*21*)

	Market Shares		
	10%	50%	90%
Crash Cost Savings from Aut. Veh			
Annual lives saved	1,100	9,600	21,700
Fewer crashes	0.211 M	1.88 M	4.22 M
Economic cost savings	$5.5 B	$ 48.8 B	$ 109.7 B
Congestion Benefits			
Travel time savings (hours)	756 M	1,680 M	2,772 M
Fuel savings (gallons)	102 M	224 M	724 M
Other Aut. Veh. impacts			
Parking savings	$ 3.2 M	$15.9 M	$ 28.7 M
VMT increase	2%	7.50%	9%
Some Assumtions			
Number of Aut. Veh. Operating in U.S.	12 M	45.1 M	65.1 M
Crash reduction rate per Aut. Veh.	0.5	0.75	0.9
Freeway congestion delay reduction	15%	35%	60%
Fuel savings	13%	18%	25%
VMT increase per Aut. Veh.	20%	15%	10%

2.3 Shared Mobility: Crowdshipping

As with passenger transportation, the possibility of sharing mobility exists in freight transportation. In passenger transportation, people can share trips when they have a similar destination. Shared mobility is part of the so-called Sharing Economy (SE), "a socio-economic ecosystem built around the sharing of human, physical and intellectual resources, which allows the production, distribution, trade and consumption of goods and services by different people and organizations" (*22*). There are two types of SE in transportation: passenger (e.g. shared mobility, ridesourcing) and freight (e.g. crowdshipping). Although there are several words to refer to the strategy of sharing cargo units--crowd logistics, crowdsourced delivery, cargo hitching or collaborative logistics (*23*)--this document uses the general term crowdshipping. Crowdshipping is a new business model for last-mile deliveries, where a professional freight (PF) delivery is supplemented or replaced by crowds of ordinary shippers. Shippers are involved with delivery tasks assigned to them, and get a small compensation fee in return to reimburse the additional costs. Widespread usage of smartphones and emergent mobility apps during recent years have increased the use of this strategy.

Crowdshipping can support sustainability by using excess available transportation capacity for freight deliveries without adding trips to the network. Successful implementation of crowdshipping benefits society by reducing the number of freight delivery trucks in urban/suburban areas, and benefits companies by reducing their delivery costs, while maintaining the same level of service. This design also creates an opportunity for social collaboration, offering a way for each individual to participate in the social change happening on the ground, and providing greater simplicity and convenience by adding a layer between service providers and end customers (*23*). All of these could lead to more environmental and economic system efficiency that could ultimately improve everyone's quality of life.

However, the realization of positive outcomes depends on the organization and performance of the strategy. Crowdshipping is challenging due to its novelty, and the lack of both operational uniformity and real-world systems that disseminate operational data. To implement an effective and efficient system, more understanding of the stakeholders involved and the environmental/economic/social impacts are needed.

The development of the 3Rs in freight and its potential success in mitigating transport externalities is determined by the characteristics of the new transportation technologies. The following section describes the strengths and challenges of these technologies.

2.4 The 3Rs' Technologies: Strengths and Limitations

This section summarizes the strengths and limitations observed for vehicles and the devices that are part of the 3Rs, both those available and in development for freight transportation. The electrification component concentrates on battery electric vehicles (BEVs). These vehicles use electricity stored in batteries that can be charged mainly by electric current. This category includes large, midsize, and small trucks, vans and bikes. Automation concentrates on prototypes in progress that promise to significantly reduce any dependence on human operational involvement. Among the available options are trucks, vans, drones, and robots.

One of the striking strengths of transportation electrification, in general, is the ability to reduce GHG emissions. This is true for electric vehicles at the local level, since at least for BEVs the tailpipe emissions are zero. This is definitely a benefit, because it carries the potential to improve the air quality of cities as electrification increases its penetration. However, where does the energy that charges the batteries of these vehicles come from? Are emissions a byproduct of this energy generation? Is transportation worth electrifying?

The batteries for electric vehicles are indeed charged with energy from the country's grid, and GHG production is a factor in the generation of such energy. To understand the environmental impact of market electrification in terms of energy consumption and GHG production, it is necessary to distinguish Well-to-Wheel and Tank-to-Wheel analyses. The first considers the emissions and energy consumption from the feedstock until the vehicles are started; the second only considers emissions and consumption during the operation of the vehicle. At a worldwide level, for a compact vehicle, tank-to-wheel emissions of traditional vehicles can represent 16.7% of the total emissions generated; well-to-wheel (119.7 gCO2eq / KW h) for gasoline, and 17.3% for diesel (96.1 gCO2eq / KW h). In the case of BEVs, tank-to-wheel emissions are zero, but for example for the United States market, BEVs generate an average of 67 gCO2eq/KWh (*24*). In this sense, if the country's mixed grid is mainly composed of coal and oil (fossil fuels) the expected GHG reductions can be insignificant. A recent study analyzed the differences in GHG emissions associated with BEVs in multiple countries according to their electricity generation mix from a Well-to-Wheel perspective, and compared these results with the GHG emissions of Internal Combustion Engine Vehicles (ICEVs)(*24*). The study chose four comparable and representative vehicle types of BEVs and ICEVs; subcompact, compact, full-size luxury, and SUV considering that these are the categories in which BEVs are most competitive. Also, from each representative type different car models were selected.

Table 2. Strengths and limitations of the automation and electrification initiatives. Source: (*25*)

Mode	Strengths	Limitations
Electric trucks and vans With comparable performance specifications to traditional vehicles for medium duty and demonstration heavy duty vehicles	Medium duty could substitute 1:1 Zero tail-pipe emissions Reduction of GHG emissions (dependent on energy source) Minimal regulatory barriers Public acceptability	Lack of recharging infrastructures High purchase cost Low fossil fuel prices No benefits for space and curb access Need a driver
Electric cargo bikes Motor assisted bikes or e-bikes help reduce effort and improve efficiency Currently used by some couriers	Relatively low purchase cost Able to better navigate congested streets Reduced parking space requirements Public acceptability	Need of a biker Low cargo capacity DMV classifications for motor or number of wheels
Autonomous trucks and vans Promise the possibility of rescinding of drivers lowering costs, improving safety and efficiency	Driverless Low operations costs Help to mitigate congestion Less parking spaced required Co-use of public transport infrastructures Time efficient Safer due to sensors and safety devices	Require load/unload automation technologies Higher security or theft risk Low public acceptability (labor) Difficult/uncertain regulations
Drones/unmanned aerial vehicles Drones or UAVs can serve difficult access areas. Some initiatives show time and cost efficiencies.	Driverless Have automatic loading/unloading devices Minimize travel distance Serve areas without road access Could operate 24/7	Moderate noise Collision risk, technical error/sabotage Risk of harm to humans or assets Lack of energy efficiency Local ecology impacts (e.g. birdlife) Uncertain near ground air regulations
Autonomous mobile/delivery robots AM/DRs can autonomously transport goods in open/close spaces Widely used in controlled environments: warehouses and distribution centers More tests in dynamic enviro	Driverless Opportunity for remote controlling Zero tail-pipe emissions Low noise emissions Reduced need for space on the sidewalks Could operate 24/7	Risk of collision, technical error or sabotage. Risk of harm to humans or assets Blocking curb space Uncertain curb regulations

The results reveal that the GHG emissions of BEVs that use electricity generated by fossil fuels were significantly higher than the emissions credited to BEVs that use electricity generated by nuclear or renewable sources. Furthermore, BEVs that use electricity generated with coal or oil may be associated with higher GHG emissions than internal combustion engines (ICEVs) at a global level. These findings confirm that it is necessary to consider the electricity generation mix to study the environmental impacts of BEVs versus ICEVs. The analysis shows that in general, the GHG emissions from BEVs in countries with a high fossil fuel ratio in their electricity generation mix were higher, and the difference between countries was considerable. In addition, the performance by type of vehicle was analyzed, and the results show that in the subcompact category, BEVs may or may not be associated with lower GHG emissions depending on the choice of the emission factors. On the other hand, for the other three categories, gasoline ICEVs had higher GHG emissions than BEVs regardless of the emission factors chosen. Another study demonstrates that the efficiency of motors (tank-to-wheel level), turbines (pump-to-wheel level), generator plants and other components for the conversion of energy generation have a significant impact on the BEVs' emissions and their desirability(*26*). In that study, the fuel considered was compressed natural gas to power electric plants to charge EVs. The results show that the most effective use of natural gas in transportation ultimately depends on the efficiency of the combustion prime mover, whether on the vehicle or in a stationary power plant. The difference in Well-to-Wheel energy use and emissions between CNGVs and EVs depends on the method of producing electricity from natural gas. In terms of petroleum energy reductions, all of the options that solely use natural gas offer nearly complete displacement of petroleum.

In general, the electrification, automation and sharing mobility revolution (3Rs) in freight is a promising alternative with the potential to mitigate disproportional transportation externalities, especially because it enables the possibility of changing our carbon-based consumption culture. Further, thanks to the versatility of such new technologies as drones and AMRs it may be possible to deliver small cargo efficiently in hard-to-access places. In addition, other technologies such as autonomous trucks will allow for improvements in the efficiency and cost savings for long-distance deliveries, thanks to the lack of need for human drivers. Crowdshipping—freight's version of mobility sharing--provides an opportunity to share cargo units between different users enabling a reduction in the number of trips. In general, these 3Rs could mitigate GHG production, noise, and congestion. **Table 2** illustrates other strengths and limitations for these technologies.

3. The leaders of the last-mile electrification and automation

In commercial terms, the interest in automation, shared mobility, and electrification (3Rs) have mostly focused on light-duty vehicles and passenger transportation, with technologies achieving a considerable maturity level in the last several years. This has not been the case for freight transportation. However, the number of entrepreneurs in 3Rs has grown recently, given the economic importance of these technologies, and their potential environmental impact. The declared interest of big companies such as Amazon, Walmart, FedEx, and DHL, among others, in electrifying and automating their cargo vehicle fleets has motivated manufacturers and technology developers to propose different alternatives to compete in a race to conquer the market.

There are alternatives in progress for both long-distance and last-mile distribution, with some being more market ready than others. The following sections discuss the characteristics and development status of the freight alternatives for electrification and automation that are expected to be available in the market in the coming years. Section 2.1 illustrates long-haul developments and Section 2.2 focuses on initiatives and alternatives for last-mile deliveries.

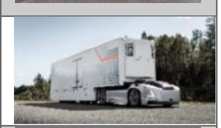
3.1 Long-haul Electrification and Automation Developments

The heavy electric truck industry has shown significant progress in recent years, with more efficient engines, higher load capacities and even establishing a market date for market release sooner than expected (between 2019 and 2021). This progress is due to the support received from governments such as the state of California, which encourages both developers to manufacture zero-emission vehicles and companies to use them. And the fact that many large companies have shown interest in acquiring these vehicles has also spurred progress. This has created a competitive environment for manufacturers anxious to put their vehicles on the streets. Some have decided to join forces to take control of the market quickly. The start-up Thor (now XOS Trucks) in a desire to reduce its developing time, has partnered with expert chassis company Navistar to manufacture trucks that use the Navistar chassis and the Thor electric motors. Another example is Daimler, which is working with Mitsubishi to mass produce the E-Fuso. Waymo is working with its sister company Google Logistics to boost the development of technologies to improve its trucks and design strategies to move cargo efficiently.

The arrival of all-electric and autonomous freight vehicles represents a challenge for countries, primarily because of the need to build recharging stations and to create economic incentives for companies to acquire these vehicles. Moreover, the transit of autonomous trucks is a challenge for lawmakers, who need to create new laws and policies warranting safety conditions for all road users while allowing manufacturers to keep developing new technologies. Undoubtedly there are many questions to be solved, given that the arrival of these technologies is imminent. APPENDIX A describes the developments in electric and fully automated vehicles for the long-haul, summarizing information gathered from commercial websites and advertisement materials.

Table 3 summarizes the developments for electrification and automation for the long-haul, indicating the status, place and most outstanding features of each development.

Table 3. Examples of long-haul innovations. Adapted from (*25*)

Developer	Development Status	Where	Features	Appearance
Tesla	- From prototype stage to sales - First units expected by the second half of 2020	USA	- Autopilot and other safety technologies - Quick acceleration fully loaded - Comparable capacity to class 8 diesel - Range between 300 and 500 miles	
Daimler and their electric truck divisions	- E-Fuso Vision One truck expected by 2021 - Freightliner Inspiration: self-driving all-electric truck in development - New Lvl 2 Cascadia truck	Europe, Japan, and USA	- E-Fuso (220-mile range, 11-ton cargo) - Cascadia improved navigation and safety devices; driver assistance, automatic lane centering, adaptive cruise control, and emergency braking, cameras, radar, ultrasonic sensors	
Waymo self-driving trucks	- Truck delivering to Google's data centers, Atlanta - Currently testing in California (2020) and Arizona and expect to expand soon to Texas and New Mexico in the near future.	Phoenix, USA	- Same sensors powering the company's self-driving minivans - Same self-driving software of passenger cars - Expected to be completely driverless	
Kodiak Robotics	- It has started making commercial deliveries with driver behind the wheel from Dallas to Houston.	Texas, USA	- Self-drive and other safety technologies - Focuses on "middle mile" highway routes Same capacity than class 8 diesel	
Embark Peterbilt	- Delivering coast-to-coast for Electrolux and Ryder - Sales being dependent on regulations	California, Florida, USA	- Safety technologies - Fully autonomous - Same capacity than class 8 diesel	
Thor (XOS) Trucks	- Available for demos - Production started in 2019 - Pre order available	California, USA	- Prototype (300-mile range) - Motor mounted between the frame rails Navistar International Corp.: chassis	
Volvo Electric Trucks	- Demonstrators in 2019 - Volvo FE Electric truck presented in 2018 - Sales started in 2019 in Europe for medium size, production and sales for the heavy duty expected in 2020.	Europe and USA	- All electric truck - Smart technologies: remote diagnostics, geofencing, and management platform	
Volvo Vera	- Development phase - Part of integrated solution - Cargo to port terminal in terminal in Gothenburg	Sweden	- Full autonomous, all-electric vehicle - Less emissions and low noise levels - Remotely controlled and monitored - Safety technologies	
BYD Electric Trucks	- All-electric automated side-loader garbage truck, Palo Alto, 2017 - Production in Ontario	USA and Canada	- All electric truck - 76-mile range - 2-3 hour full charge	

Cummins Kenworth T370	- Introduced in 2018 as hybrid electric solutions - Traveled over 6 million miles in a fleet setting in the U.S. and China	China, Europe and USA	- Configured with exporTable grid quality electric power to recharge other vehicles - The PowerDrive hybrid system for light, medium, and heavy-duty - Could pair with diesel or natural gas engines and battery pack outputs - 50-mile pure electric range - 300+ miles hybrid fuel economy	
Einride	- Demonstrated T-log operations - On testing during 2020	Sweden	- Autonomous, all-electric logging truck - 120-mile range. - Lvl. 4 autonomous driving - Detection sensors cameras, lidar and radars and intelligent routing software - Remotely controlled	

Note: All figures from manufacturer/developer's website

3.2 Last-mile Electrification and Automation Developments and Alternatives

Some of the last-mile alternatives in development promise to solve the common last-mile freight issues: high cost, high emissions, and delays, among others. In fact, some of these developments have a noticeable penetration rate in the market, e.g. since 2017, electric bikes have been widely used in the Netherlands and Germany to deliver cargo in urban downtowns.

All-electric vans are also widely used in the U.S. and Europe, even drones and AMRs are being used in some places. The start-up Kiwi, has been delivering food via four-wheel robots in Berkeley California since 2017, and the Ukrainian postal service has been delivering small packages with a drone in certain places in Ukraine since 2016.

Automation initiatives generate vast expectations for several reasons: 1) they are green-friendly; 2) they could work long hours; 3) on a large scale, they could reduce costs considerably; 4) their accuracy makes it difficult to make mistakes in deliveries; and 5) since some do not need to share the roads with cars and bikes a congestion reduction is expected (*25*, *27*).

The interest shown by global electronic commerce businesses such as Amazon, Alibaba or Ocado in using robots and drones has raised the expectations of users and developers. Developers are rushing to perfect their devices in real-world environments (high traffic, snowy, rains) after a long development period in controlled environments. However, developers have faced limitations imposed by some authorities who still perceive these technologies as unsafe. At least in the U.S., there are no licenses to operate these devices on a mass or commercial level; licenses are mostly limited to trial licenses. Even some companies located in California have decided to ally with companies in European countries where there seems to be more flexibility. APPENDIX B provides a description of some initiatives for electrification and automation in last-mile deliveries based on commercial and advertisement materials. Moreover, APPENDIX C-E summarize the key points of existing regulations from a sample of major metropolitan areas and states in the U.S.

Table 4 summarizes the initiatives of electrification and automation for the last mile, indicating mode, usability, development status, and place where they are operating, and a picture of each one.

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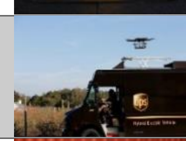
Table 4. Description of last-mile examples. Adapted from (*25*)

Company/ Developer	Mode	Usability	Development Status	Where	Appearance
DHL	Full electric vans	Parcel	Implementing from 2019 to 2050. On progress	USA, New Zealand	
	Electric bikes	Parcel and food	In use since 2017. Recently started a trial in New York in 2020	Utrecht, Netherlands and Frankfurt, Germany. Newy York, US.	
	Drone	Medicine and parcel deliveries in remote areas	Trial finished, expecting for commercial licenses	Bavarian community of Reit im Winkl	
Amazon	Full electric vans	Parcel	In transition, 50% in 2030	Worldwide	
	AMR	Parcel	In use in limited areas and under total supervision since 2019. It will start trial operation in Southern California	Washington, USA	
	Drone	Parcel	Trial developed in 2016. Operations were expected to begin in 2019; no materialized yet	USA, United Kingdom, Austria, France and Israel	
FedEx	Full electric vans	Parcel	In transition since 2019	California -USA	
	AMR	Parcel	Testing since 2019. No commercial operation yet.	California -USA	
Alibaba	AMR	Parcel / Food	Testing since 2018. Expected diffusion by 2020	China	
Swiss Post/ Matternet	Drone	Blood samples between hospitals	Testing since 2018 to 2019. To resume in 202 after incidents	Lugano; Berne; Zürich, Switzerland	
UPS/ Workhorse Group	Electric vans together with drone	Parcel in neighborhoods	Testing since 2017. Commercial operation still no materialized.	USA	
Domino's Pizza Enterp./ Flirtey	Drone	Pizza	Tested in 2016. No current operation. Company expecting commercial licenses to operate in U.S.	New Zealand	

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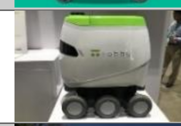
UkrPoshta/ Flytrex	Drone	Parcel	Demo trial developed in 2016	Ukraine	
Mercedes-Benz/ Matternet	Electric vans together with drone	Parcel	In development	Undefined	
Starship Technologies/Co-op	AMR	Groceries	In testing since 2018.	England	
Marble	AMR	Food, medicine, parcel	In use during 2017, the service was stopped by law regulations	San Francisco, USA	
Nuro	AMR	Food, parcel	Undefined	USA	
Robby Technologies	AMR	Groceries	Expected by 2020	California, USA	
TeleRetail	AMR	Groceries in rural areas	In use since 2018	Switzerland	
Dispatch	AMR	Parcel	Undefined	California, USA	
Unsupervised	AMR	Parcel	Undefined	Europa/USA	
Ford	Full automated electric van together with drone	Groceries and parcel	Expected release in 2021	Europe	
Kiwi	AMR	Food	Since 2018	California -USA	

3.3 Crowdshipping: State-of-the-Practice

This section describes the current operational environment for crowdshipping through a state-of-the practice review. Crowdshipping companies provide platforms to connect senders (who need to send packages) to couriers who are independent contractors and flexible with their work schedule. In almost all of the platforms, couriers are required to own a cell phone to install the app, be physically able to lift packages of a certain weight, and to pass a background check before registration. **Table 5** summarizes the crowdshipping initiatives, platform providers, indicating type of items delivered, mode, pricing/payment, and information related to how to schedule a service. APPENDIX G provides a general description of crowdshipping examples.

Table 5. Crowd-shipping platform providers

Platform	Delivery Item	Mode	Pricing/payment	Courier's schedule
Amazon Flex	Packages or food for Amazon Logistics, Prime Now, AmazonFresh, and Amazon Restaurants	Bike, sedan, van, truck	Average $18-25 per hour, including tips. Varies depending on region, time of day, number of packages, weather condition, and special events	Shift reservation with variable hours (1-6 hour per shift)
Uber Rush	Items no more than 30-50 pounds in size, restrictions[1] applies	Walk, bike, passenger car	Average $20-30 per hour. Based on base fare, per mile and minute delivery rates and service fees. Varies depending on location and distance.	No reservation required
Uber Eat	Food	Bike, passenger car	Average $8-12 per hour. Based on base fare, per mile and minute delivery rates, service and small order fees. Varies depending on location and time.	No reservation required
Deliv	Parcels from individuals and small business, Packages from retailers, Fesh and medical item (up to 50 pounds)	Car	Average $15-22 per hour with guaranteed minimum rate. Based on per hour and mile rates,	Hourly reservation
Shyp	Any, Packed/unpacked items including returned items Restrictions apply	Any	Average hourly of $17 as a courier and $14 as a packager. Varies depending on region.	n.d.
DHL My Ways	Any, Restrictions apply	Any	Flexible, minimum base fare and bided final price, 10% charge as transaction fee	No reservation required
Postmates	Any	Any	Couriers: base and min fare, per km rate and service fee, varies depending on location. Surge (Blitz) pricing applies Customers: vary depending on membership status and merchant	No reservation required

[1] Excluding animals, alcohols, fragile and dangerous items

Instacart	Grocery	Shopper: any Shopper and shipper: car	Couriers: average $11 per hour plus tips, busy pricing applies Customers: base fee, service fee and delivery fee, varies depending on membership status	Shopper: flexible Shipper: hourly reservation
Shipt	Grocery	Car	Couriers: $15-25 per hour plus tips Customers: membership fees plus service, picking, packing, and processing fees	Hourly reservation
Doordash	Food	Car, bike	Couriers: average $25 per hour with a guaranteed amount of $1. Customers: average $5 per order plus extra fees during rush hours.	No or hourly reservation
Walmart	Any item from store	Any	Store employees: average hourly $11 plus promotions In-store shoppers: discounted items	Store employees In-store shoppers:
Roadie	Any, restrictions apply	Car	Varies depending on the size/weight of the package, need to care and the delivery distance, minimum $8 per task and 20% service fee	No reservation required
Rappi	Any	Bike, motorcycle	Average $1 per delivery, 17% transaction fee	n.d.
Number	Any	Any	Biding	n.d.
Renren kuaidi	Any	Any	n.d.	n.d.

4. Challenges and Opportunities for the 3Rs in Freight

The arrival of 3R technologies brings significant challenges for decision-makers and policymakers because of the potential risks inherent to the operation of these vehicles, and because of the needs for these technologies to be accommodated in today's roads. The penetration level of each of these technologies is different, as is their technological maturity status. To safeguard all users of the U.S. transportation system, several regulatory policies have been developed limiting the operation of these vehicles. This section offers a view of infrastructure needs, legal and safety challenges, and potential risks of 3Rs technologies.

4.1 All-electric Vans, Medium and Heavy-duty Trucks.

In general, electrification alternatives are seen positively by both governments and the public due to their contributions to reducing GHG emissions. As illustrated, several large companies including Amazon, DHL and FedEx are committed to climate change remediation and plan to replace part of their regular van fleets with zero-emission van fleets. Today, electric vans have comparable cargo capacities and the same curb space and road requirements as regular vans, which facilitates a convenient 1:1 fleet renew. Also, in road safety terms, there are no significant challenges for these vehicles other than those related to regular vans. As a result, it is safe to assume that the number of these vehicles will increase in the coming years. However, for their wide market penetration, there are still barriers that need to be overcome: higher purchase costs, and the need for a wide network of charge stations and maintenances facilities.

One of the major challenges for all-electric trucks and vans either with automation levels or not is the need to ensure the opportune recharging of batteries for daily duties. It is important to note that the infrastructure for recharging batteries can be shared between light and freight vehicles. Even so, there is currently an insufficient number of stations in the U.S. just for light vehicles, even considering that 80% of their charging is done at home. The number of electric charging stations in the US is still small but growing, especially because the government incentivized building more stations, and manufacturers have made investments to expand their charging network to make feel costumers more confident about buying EVs. In September 2018 there were about 22,000 public charging stations in the US and Canada that are classified as level 2 (240 volts chargers) and DC fast charging. (CFast-charging stations supply a range of 60 to 80 miles per 20 minutes of charging, on average.) In contrast, there are seven times more gas stations: about 168,000. Volkswagen has been installing 2,800 electric vehicle charging stations in 17 of the largest cities in the US (*28*) since 2019, and invests $ 2billion in charging infrastructure across the country. However, most automakers rely heavily on burgeoning networks installed by governments, utility companies, and third-party companies. It is a cheaper option, but one with more uncertainty and less control. Luxury automakers (Mercedes-Benz, BMW, Jaguar, and Audi) have launched and plan to continue launching electric cars from 2019 (*28*), and virtually all major automakers are betting their future on electrification. This revolution has been supported by the rapid decrease in the price of batteries, a reduction of more than 70 percent between 2008 and 2014. Auto manufacturers have a choice: build their own charging networks or rely on third-party networks.

In terms of aggregate global growth, in the 100 most populated metropolitan areas in the US there is a projected need for 82,000 workplace charging stations, 103,000 Level 2 public stations, and 10,000 DC fast stations by 2025 (*29*). Compared to what was in operation at the end of 2017, these charging estimates for 2025 are 7 times, 3 times, and 3 times, respectively, the amount of stations needed of each type. Combining these three types of non-residential charging, the 195,000 charging points available today are 4.3 times more charging points than were available at the end of 2017. These estimates do not include domestic charging, rapid charging in the corridor between metropolitan areas, or other stations in rural areas, which were outside the scope of our analysis. The largest charging gaps are in markets where electric vehicle absorption will grow fastest, including in many cities in California, and in Boston, New York, Portland, Denver and Washington, D.C. In brief, much more charging infrastructure is needed to maintain the transition to electric vehicles. In the main US markets as of 2017, only approximately one quarter of the workplace and public chargers needed by 2025 are in place. The deployment of charging infrastructure will have to grow approximately 20% per year to meet the 2025 targets.

Specifically, in California, several programs have been announced that aim to deploy substantial charging infrastructure that could help reduce the charging gap from infrastructure for light-duty vehicles reported in a California study (*29*). The study includes the 10 largest metropolitan areas, which represent 86% of the state's population: Los Angeles, San Francisco, Riverside, San Diego, San Jose, Sacramento, Fresno, Bakersfield, Oxnard, and Stockton. The analysis indicates that about 84,000 charge points are required by 2025, with nearly 16,000 (15%) already placed at the end of 2017. The five announced statewide infrastructure construction projects, electrify America, and the three major electric power utilities, could cover approximately 27,000 workplace and public charge points across California. So, the final coverage is expected to be up to 40% of the charging gap. After these installations, 41,000 charging points would still need to be constructed; a substantial gap that is expected to be filled through public and private efforts.

As mentioned, the estimations presented are mainly based on light electric vehicles; charging demand for medium and heavy-duty electric trucks is not considered. So, the 4,1000 extra charging points mentioned is a lower bound for the market. However, trucks may only represent a small share of the traffic in urban areas, but still, they generate more than half of the overall emissions for specific contaminants (*2*) Nevertheless, the global all-electric truck market is expected to grow at a compound annual rate (CAGR) of approximately 65.0% over the next five years, reaching $ 12.4 billion in 2024, from $ 610 million in 2019 (*30*).

A study that aims to evaluate the use of zero-emission vehicles in last-mile deliveries distinguished (*31*) four general charging strategies: home/depot-charging; public charging, inductive charging, and battery replacement. Charging times are unique for the fleet characteristics in terms of their batteries, use of batteries over time (charge and discharge), and Electric Vehicle Supply Equipment (EVSE) infrastructure. The authors mention that considering some European pilots, depot-charging stands are the most viable option, however, considering the depot and yard, and the operations performed with and to the vehicles, one charger per vehicle is often required. Usually, this is performed overnight, while other logistics operations are conducted at the facilities. As a result, retrofits to the electric infrastructure at the facility and the grid may be needed; making functional chargers. The authors developed a sensitivity analysis and found out that even if charging infrastructure costs were 10 times higher, the total cost of ownership (TCO) impact would represent less than 20% of all the costs. Empirical data from different last-mile delivery fleets show operational differences among vocations; in particular, for beverage, linen, food, and parcel delivery vocations. For these vocations, routes within a 100-mile range represent more than 80% of their daily routes, the percentage is above 95% for parcel routes These are important findings because they show the opportunities for electrification in last-mile distribution since these range requirements are easily fulfilled by commercially available vehicles and charging technologies.

In summary, the need for recharging structures is even broader for California than has been estimated by available studies, even though most recharges are expected to be done at the depot at least for the last-mile deliveries, while medium size trucks may use public chargers. In the case of long-haul, vehicles are more likely to have to use charging stations arranged on the roads. However, estimating this required station gap is not an easy task because such estimates depend on factors such as vehicle sales projections, driver profiles, required charging energy by activity, the hour of charging demanded by activity, the number of charger points available by activity, accessibility to charging points, among other factors.

4.2 Electric Cargo Bikes

There is controversy about electric cargo bikes even in relation to their names: Is it an electric bike or a motor vehicle? If an electric bike is considered a motor vehicle due to its technical characteristics, then its great benefits in cost and versatility will be reduced.

The U.S. Consumer Product Safety Act states that electric bicycles and tricycles meeting the definition of "low-speed electric bicycles" will be considered consumer products. As such, the Consumer Product Safety Commission (CPSC) has the authority to establish guidelines and standards to assure that the public will be protected from unreasonable risks of injury or death associated with the use of electric bicycles. In conformance with legislation adopted by the U.S. Congress defining this category of electric-power bicycle (15 U.S.C. 2085(b)), CPSC rules stipulate that low-speed electric bicycles[2] (including two and three wheeled vehicles) are exempt from classification as motor vehicles providing they have: fully operable pedals; an electric motor of less than 750W (1 hp); and a top motor-powered speed of fewer than 20 miles per hour (32 km/h) when operated by a rider weighing 170 pounds. If an electric bike exceeds these standards then it will be regulated by the federal DOT and NHTSA as a motor vehicle, and will need to meet additional safety requirements and pay registration. The rules for electric bikes on public roads, sidewalks, and pathways are under state jurisdiction and can vary. The main differences between states include the need for a license for operation, the obligatory nature of a helmet, maximum speed, and maximum engine power, among others (see APPENDIX E for further information).

Under this federal law, the four-wheel bike Velove Armadillo, for instance, could not travel in U.S. bicycle lanes, losing its versatility. In addition to not meeting the criteria for the number of wheels, the weight and width of these bicycles could be considered a threat due to the potential damage generated in a collision with another bicycle or pedestrian. However, these bicycles have shown benefits in reducing the emissions, operating costs and time associated with deliveries in Germany and the Netherlands, where they have progressively gained acceptance[3] (*32*). This law limits developers to designing light and low-load bikes comparable to regular bikes. Despite these limitations, two-wheel electric bikes are being used as an economical and efficient alternative to navigate the congested streets of some cities in the U.S. Their market penetration grows every day; even cities where they were banned are now legalizing their use. In New York City, after a long controversy electric bikes were finally legalized in a legislative action this year.

2 Consumer Product Safety Act, Pub. L. 107–319, December 4, 2002; codified at 15 U.S.C. 2085(b): The CPSC regulations do not differentiate between commercially manufactured low speed electric bicycles and those converted from ordinary bicycles by their owners using an aftermarket electric motor and battery kit, nor do they regulate the construction of electric-power bicycles using owner-built or sourced components.

3 https://newsroom.hermesworld.com/international/pressematerial/hermes-e-cargobike-velove-armadillo/

Under the new state rules, electric bikes can operate in the street and bike lanes, but not on sidewalks. Officials legalized the use of pedal-assisted e-bikes, but $500 fines remain in place for the throttle-powered bikes (*33*).

4.3 AMRs

In the U.S., there are still no commercial licenses for the operation of AMRs. In fact, since AMRs are new to cities, there no regulations at a federal level, and only five states and some specific localities have granted licenses and only for testing purposes. For authorities and developers, vulnerable populations such as children, the elderly and people with disabilities are the main concern, and the reason why authorities want to impose constraints on the size, speed and areas of operation for AMRs. Overall, the transit speed is limited to under 10mph, and the total weight to between 50 and 90 lbs., with the exception of Concord, California, and Austin, Texas, which established limits of 500 and 300 lbs. respectively. In addition, states and localities demand different kinds of large coverage insurance (between 1 and 4 USD Million) such as liability insurances, body/personal injury insurance, and property damage insurance, and in some cases an extra insurance for the device operator (see APPENDIX D for further information). Moreover, some localities demand that devices should be supervised by operators within a certain distance; in San Francisco, the operator must be within 30ft. Despite the fact that the Bay Area is the epicenter of development for these technologies, the restrictions in San Francisco are the most severe in the country. In 2017, San Francisco approved a bill that limits AMRs to 3 mph, and operations are only allowed in a small industrial area. The bill was supported due to potential conflicts with elderly and disabled people on crowded sidewalks, privacy concerns related to AMRs' cameras, and labor displacement [4]. To comply with regulations and other possible contingencies, companies in active testing such as Amazon and FedEx operate their AMRs in close proximity to an employee and with extra remote supervision. Despite this, recently, a Kiwi AMR crashed with a car when a distracted driver did not notice that the little robot was crossing the street, and although the event did not result in human injuries it generated a traffic incident. Today, Kiwi operates its AMRS remotely 100% of the time, leaving aside the concept of full-automation and the opportunity of significantly reducing operative costs. Most of these devices have sensors that stop the AMR when an object approaches, and it cannot move again until an operator takes control of it. These limitations make the operation inefficient, but safer for humans.

AMRs' developer companies invest time and money to familiarize the public with their devices, so that their favorability is raised when it comes time to grant licenses. This seems to be working; a report from the Office of Inspector General (OIG) revealed that 50% of the people surveyed like the idea of an independent robot delivering a parcel, while 28% dislike the idea. When people were asked about their opinion of robots helping humans during parcel deliveries, 57% of the people asserted that they like the idea, while the 13% dislike the idea. Despite having a positive perception over delivery robots, when asked whether they preferred that a robot or a human deliver their parcel, the results showed that people were indifferent; only a small percentage showed a preference for robots. Also, over 80% of the respondents had the expectation that delivery robots will be in use within the next five years. While the perception of AMRs is positive, there is a minority of people who are against robots. One-quarter of respondents said they would always prefer that a human delivered their items, even if robots were faster and cheaper.

[4] A legislative aide at the Office of Supervisor Norman Yee, in discussion with the authors, November 16, 2017.

People perceive the prospect of robots doing parcel deliveries as an opportunity to improve service level, thanks to higher flexibility (deliveries at any time and any address), speed and security. The technology could also provide greater visibility about the deliveries by tracking robots through an app.

4.4 Drones

In the case of drones, the degree of penetration is higher than AMRs. However, even regulations in the U.S. limit drone flight to no more than two miles with full operator control. These measures try to avoid conflicts such as the intervention of areas of air traffic, or the potential loss of autonomy that would cause a drone to fall over people or objects. This flexibility is in part thanks to the constant suggestions and requests from companies like Amazon that find these limitations inconvenient. The FAA demanded that the use of certain drones be considered obsolete by Amazon because of their technical features. Although drones have caused some incidents where people were injured, there have been no drone-related fatalities(*34*). Nowadays, the FAA allows drones to transport up to 55 pounds including payload, to fly at or below 400 feet during daylight, and to fly at or under 100 mph (see APPENDIX C for further information).. There are still public concerns due to the encroachment on privacy, since these devices can load video cameras with online broadcast.

Technological developments should still be made to avoid potential operational incidents for drones. For example, some developers have tried to design self-destruct mechanisms for when a drone loses flight autonomy, or parachute launches for a soft landing when the thrusters do not work properly. This year the Swiss postal service had an incident in which a drone fell 50 ft. towards a group of children when the parachute did not open after a technical problem (*35*). This incident forced the Swiss postal service to suspend drone operations until April of next year. Drones falling, or risks to people or property are still issues that must be resolved at the technological level, and regulated by the authorities. Similarly, Amazon is developing a break-in strategy in case of an in-air emergency. The key part of this is that the parts will fall to "safe spots" such as trees or ponds in case of a mid-air malfunction. However, there are some underlying questions, such as: what type of situation could be considered an air-emergency? What kind of actions would be considered safe in these emergencies? For example, the drone self-destructing when a malfunction occurs in a crowded area could be a solution, but it could also be diverted to a tree if such an opportunity existed. There is a diversity of situations that must be studied and regulated by the authorities before cargo drones can be put in the air.

4.5 Autonomous Vans and Trucks

Fully autonomous vans and trucks have the lowest level of penetration between the discussed technologies, and they are facing the greatest administrative and perceptual hurdles. Although some initiatives such as the heavy-duty trucks developed by Waymo and Kodiak have shown high safety levels and reliability during long-haul testing (See Section 2.), current regulations still do not allow them to operate driverless; in testing situations, developers must maintain a driver to take action when necessary. Policymakers are still concerned about the potential risk of these huge trucks operating without an actual thinker at the wheel making decisions. However, research shows that autonomous vehicles have the potential to dramatically reduce crashes (*21*). **Table 6** illustrates the magnitude of automobile crashes in the United States, and indicates sources of driver error that could disappear as vehicles become increasingly automated. Driver error is found to be the primary reason for over 94% of all crashes. Even when the primary reason behind a crash is attributed to vehicle failure, roadway or the environment, additional human factors such as distraction, or speeding, are often found to have contributed to the crash.

Table 6: 2016 U.S. crash motor vehicles and selected human and environmental factor involvement.

Total crashes per year in US.	7.3 Million
Economic cost of U.S crashes	$ 242 Billion
Primary factors in crashes	
% Human errors. (Object recognition, decision, performance, sleep, etc.)	94%
% Vehicle or components failure. (Tires, brakes, steering, suspension, etc.)	2%
% Environment. (Slick roads, glare, visibility, road design, signals, etc.)	2%
% Unknown	2%
Total fatal and injurious crashes per year in U.S	3.2 Million (44%)
Total fatalities in crashes involving medium or heavy trucks	4,317
Fatal crashes per year in U.S.	34,439
Main involving causes in fatal crashes	
% Alcohol-Impaired driving	28%
% Speeding	27%*
% Distracted driver	10%
% Drowsy driver	2%

Source: (*36–38*). * The value was prorating considering that in 2016 occurred 37,461 fatalities associated with speeding and occurred 34,439 crashes, then 1.08 fatalities per fatal crash or a ratio of 0.2699.

Since autonomous vehicles would alleviate human error, there is the potential for a 40% fatal crash-rate reduction, assuming that malfunctions are minimal and everything else remains constant such as the levels of long-distance, night-time, and poor-weather driving. These potential reductions in the number of crashes would also have a direct economic impact. Currently, vehicle crashes have an estimated economic cost of $242 billion, and it is expected that the number of crashes and the overall cost would decrease with bigger market penetration.

Although many situations could easily be resolved by current vehicle navigation/safety devices--following a route with or without traffic, stopping at an intersection, recognizing / braking before other approaching vehicles--there are still many more challenging situations that would remain. (*39*). For example, recognizing humans and other objects in the roadway is both critical and more difficult for autonomous vehicles than for humans. Humans and objects can be small or large, they can adopt different positions, they can be, riding a board or a bike or be partially obscured (*40*, *41*). Other crucial challenges for sensors and navigations systems are poor weather, fog and snow, and road surfaces that are reflective from rain and ice.

In addition, computer vision has much greater difficulty identifying material composition than humans do. Depending on the composition of the object blocking the road, the vehicle should, or should not, take evasive action in an unavoidable crash. (*21*). However, judging by the current developments in both cargo and passenger vehicles it seems that these challenges will be overcome (see Section 2). Researchers assert that motor-vehicle fatality rates per person-mile traveled could reach or be close to those seen in aviation and rail, which is about 1% of current rates (*42*).

A study in California found that, between 2014 and 2018, humans were responsible for most of of the accidents that occurred on the roads involving autonomous test vehicles. The study found that when the self-driving cars were in autonomous mode and driving on their own, 88 incidents occurred while moving (*43*). In 81 of those cases, the accidents were caused by humans. In addition, of 62 incidents reported when the car was in autonomous mode, only one was primarily caused by the technology. When a person was taking the control, 6 of 26 incidents were caused by the technology. Liability for these incidents is a major concern and could be a substantial impediment to implementation. For product liability, when a crash occurs in SAE Level 4 and 5 vehicles, if the driver has handed the control to the vehicle, then the driver has no responsibility for the driving; liability rest with the manufacturer. For SAE level 3, when the vehicle is responsible for driving but monitoring by a driver, the liability situation is unclear. Further, if the vehicle is in control and causing harm, under U.S. laws, if the driver was not speeding or drunk, he/she will not be blamed as a criminal, but in Europe, he/she would be charged with negligence. There are liability situations that still have to be clarified, which is expected to happen over the years of development of autonomous vehicle technologies.

Currently, in the U.S., the federal government regulates the equipment and performance of autonomous vehicles, while the states regulate their use and licenses. In 2018, the NHTSA released the "Automated Vehicles 3.0" (*44*) which is the third iteration of the federal government's voluntary guidelines on the development and safe deployment of automated vehicle technology for industry and the states. This new document favors the true full autonomy of vehicles at least for non-heavy cars. However, as mentioned, the states can still regulate their use. Recently, some states have enacted bills to allow full autonomy (see APPENDIX F. for further details). Arizona and Nevada (including trucks aligned in the platooning technology in Nevada) have allowed testing without a safety driver since 2015 and 2017 respectively, while in California only Waymo has a license granted by the DMV to test full-autonomous non-heavy duty vehicles without a safety driver inside the vehicle (*45*). However, recently, the DMV in California announced a proposal to allow testing of light-duty (Class 1 and Class 2) autonomous trucks on public roads for deliveries (*46*). So, if developers want to do fully autonomous tests they could go to Arizona or Nevada now, but given these legislative advances, developers are close to having the necessary legal support to test true autonomy elsewhere, at least in California. It seems that the greatest challenge lies in technology limitations that still must be overcome for safety.

One of the characteristics of autonomous vehicles is their potential to link with the traffic control infrastructure. This possibility would improve safety for both pedestrians and the vehicles themselves, but it is also an alternative to improve traffic efficiency. The term connected and automated vehicles (CAVs) is used to embrace several technologies implemented to improve travel. These technologies can work at the vehicle level, at the transportation system level, or both. These technologies enable many types of connectivity and automation possibilities, e.g. vehicles could be connected without being automated, and possibly others could be automated without being connected. Automated vehicles could rely on information from their sensors and safety devices (camera, radar, etc.) to recognize the external environment, and human-operated vehicles could have connectivity applications (telematics, GPS, etc.). Furthermore, automated and connected systems can be combined with Intelligent Transport Systems (ITS). ITS, a much broader concept that involves a variety of advanced applications that go beyond vehicle systems, embrace automated and connected vehicle systems.

While the full rollout of CAVs may be premature, planners and economic developers have not yet fully anticipated or planned for it. In 2015, a national study found that only 6 percent of planning documents consider the possible effects of automated driving (National League of Cities 2015). In addition, a 2015 study of the 25 largest metropolitan areas in the US found that, despite planners' awareness of CAV technology, there is no region that considers CAVs in their current regional transportation plans (Guerra 2015).

Based on some comprehensive available studies (*47–49*), the following considerations and implications of CAV deployment should be taken into account by planners.

- **Prepare to change the legal framework:** Existing road rules are largely based on the assumption that drivers are human beings. Consequently, transit entities will have to start considering, and regulating, non-human drivers. The traffic structures and communication protocols that will serve to support traffic control must also be regulated and standardized within the framework of highway laws. For example, vehicles must comply with the communication norms and standards of the cities where they roll, otherwise, they would not be able to attend to the indications of the vital traffic control structures.
- **Anticipate parking needs reductions:** The potential for more efficient parking and reduced demand for parking space as CAV technology is implemented means that local governments must plan for changing the prices, and the amount of parking. This is particularly important for municipalities that rely heavily on this revenue to support public services. Local governments may also need to design new places and specifications for self-driving cars.
- **Move forward to determining communications standards and service providers:** Transportation agencies will need to manage the communication infrastructure required by the connected portion of CAV technology. This implies identifying how agencies will ensure that CAVs have timely, accurate information about the state, including abnormalities and issues such as detours, and other road hazards, and monitoring the evolution of intersection design and signalization infrastructure. Agencies must also consider high standards in the communication and sharing of data systems to avoid cyber-attacks and other malicious alterations. In this sense, agencies must handle the safe management of the databases.
- **Requirements for the current infrastructure:** Some automated vehicle technologies rely on pavement markings and traffic signals to help vehicles stay in their lane navigating roadways and following the road laws. A lack of reliable infrastructure may be a cost deterrent for the development of this technology. Although some vehicle manufacturers are moving away from a reliance on pavement markings and traffic signals, the direction in which this technology goes will have an impact on agencies' maintenance costs. Transportation agencies and planners should track how vehicle developers and manufacturers are handling CAV lane-keeping technology.
- **Developing new infrastructure:** To take advantage of the vehicle-to-infrastructure (V2I) technologies authorities at the federal and local levels must work with the automotive industry

and research community to develop, test, and deploy the necessary infrastructure to support these applications. Since these applications and supporting hardware constantly change, governments must closely follow which technologies automakers and suppliers are using and plan to use in the future. In this way, they can plan for the deployment of resources to update and install the required infrastructure. Similarly, locative decisions need to be taken for placing devices and systems for controlling the infrastructure. Along these lines, strategies must be designed, such as dedicated lanes for autonomous vehicles. For this purpose, demand, trip generation, and other studies must be carried out to determine the wide and length of the lanes.

4.6 Role of Electrification and Automation in Logistics and Industry 4.0

The development of robotics and software industries has boosted the logistic transformation in a revolution known as Industry 4.0, or fourth industrial revolution. Industry 4.0 describes a trend towards data exchange, automation and process including the Internet of Things (IoT), cyber-physical systems, artificial intelligence, cognitive computing, and cloud computing.

Today, warehouse operations (receiving, sorting, picking, packing, etc.) are increasingly sophisticated and automated, enabling high-efficiency and cost reductions. For example, the USPS asserted in a report to have saved 281.000 USD in annual salaries due to the use of AMRs (similar to those used in transportation) for repetitive activities in its sorting centers (*50*). Automation is increasingly gaining acceptance and affordability, as large companies globally find opportunities to reduce their operating costs and processing times. Kroger and Ocado supermarkets have increased the amount of automatic operations in their futuristic warehouses. Similarly, the ecommerce leaders Alibaba, Amazon and Walmart invest in both warehouse automation and alternative vehicles for last-mile deliveries. However, Ocado apparently has a higher level of development at the technological level. In their facilities in Andover, England, the company has thousands of AMRs that carry out the pick-in, and some pack-in activities with high efficiency. As the company asserts, a regular online order of 50 items could take a long time for humans to pack, however, with the Ocado's network of interconnected robots an order of this size would take seconds (*51*).

For better global exploitation (i.e., along the supply chain) of the reductions in cost and time gained in warehouse operations it is necessary to ease the bottlenecks generated in the last-mile. Accelerated warehouse operations are not useful if the other components of the supply chain, especially transportation, are not aligned with the process throughput. For example, if the orders in an Amazon warehouse are processed faster, but then they pile up at the loading dock waiting for transportation to take them away, the efficiency gained in the indoor operations is quickly lost, and the final customer would perceive service delays. Consequently, without more widespread efficiencies, much of the investment in automation might not make sense. This is where a deep penetration of the 3Rs could help the industrial revolution and logistics transformation boost logistics efficiencies and therefore generate more productivity and competitiveness for companies.

Automation in transportation has favored the emergence of new businesses that have taken advantage of the versatility and practicability of autonomous vehicles to design new logistics strategies. The start-up Stop & Shop expected to deliver grocery items with unmanned in the Boston area. Customers could order fresh products through an app, and then a vehicle arrives with them. Through RFID technology and computer vision technology the vehicles records which items are selected and quickly sends the buyer a receipt. The company uses electric full-automated electric vehicles that are remotely controlled from a

Robomart facility; Robomart is a robot developer partner based in San Francisco. The vehicles will be restocked periodically to ensure quality. Mark McGowan, Stop & Shop president, said that “This is one way in which we’re leveraging new technology to make shopping easier for our customers — by essentially bringing the store to them,” and also recognizing that many of their customers want the opportunity to make their own choices when it comes to fresh produce, and they feel proud to be the first retailer to engage with Robomart to address customers’ needs with their cutting-edge solution (*52*).

The founder's vision is to solve the necessity of going to local greengrocer and milkman in a more efficient way. For the client the service is much more practical since it avoids having to move. The driverless technology can recreate that level of convenience and accessibility. The company expects to change the way people buy their groceries globally.

In short, the arrival of electrification and automation has allowed rethinking the way in which logistics operations are carried out, especially indoor operations, forcing transportation to march at the faster pace of competition. If the 3Rs reach high penetration and development, we also would be close to having a revolution in logistics with productivity levels never before seen.

5. Fostering the 3Rs in Freight

The arrival of the 3Rs promises benefits for society and the environment, although there may be some unintended consequences from their implementation. In particular, the 3Rs promise to help mitigate the effects of climate change, so their expedited arrival is desirable. The next sections discuss potential key drivers to foster the 3Rs.

5.1 Research

There are still several questions about the potential of 3Rs technologies at different levels of penetration. As (*21*) results show, a wide penetration--from 10% to 90% of cars converted--of autonomous vehicles could have a significant impact; doubling the potential number of lives saved from fewer accidents; quadrupling the reduction of annual VMT on average, and reducing the economic cost of crashes by twenty times. Also, there are several work-related benefits of electric bikes (*53*, *54*).

In the case of AMRs, there are no known estimates of their potential benefits in terms of time, costs and emission reductions under different uses and penetration levels. In terms of drones, they show great potential for delivering cargo to hard-to-access places, but little is known about their potential in supporting last-mile deliveries. Another big question is the replacement rate between traditional modes and these new technologies. It is no use putting electric vehicles on the streets if there is not enough infrastructure to recharge them. A recent study (*55*) emphasized that an important aspect to evaluating the replacement of regular vehicles with electrics is the relationship between investments in infrastructure to recharge batteries and CO_2 reduced emissions. Given the limited load capacity of the batteries of these vehicles enough recharging stations need to be developed to complete considerably extensive routes. For example, the authors consider cities with more than 100,000 inhabitants as a good reference because in these areas the CO_2 reductions would be the most significant. It is also not advisable to replace vans with electric bikes if more congestion would be generated and the cost and time might not be efficient. There is still uncertainty about how to make the most of these technologies, which could be resolved with research.

The importance of research lies in the fact that it provides information to decision makers for all of the actions to be taken, as well as estimating budgets of possible investments to support the diffusion of these technologies. In addition, it allows the public to have a clearer and more objective idea of the potential benefits and drawbacks of supporting / acquiring these technologies.

5.2 Policy and regulation alignment

Some policies have affected the development of 3R technologies, and could even be considered among the main barriers to their implementation worldwide (*27*). Developers call for more aligned and objective regulations that do not undermine the development of technologies. Some companies have decided to move their operations to other countries where regulations are more flexible. Marble suspended outdoor tests with its AMRs in San Francisco due to imposed local regulations (*56*), which demand complete supervision by a worker, very low speed (3 mph), limited testing areas, and expensive insurances (see APPENDIX C). Amazon tests its Amazon-Air drone in sparsely populated multiple international locations[5] . Amazon has been lobbying the FAA for more flexible regulations. The FAA requires the pilot to have full

5 https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011

visibility of the drone at all times and imposes other regulations (see APPENDIX C). The company's current plans are limited by these regulations and it recently requested a petition[6]. Amazon would like to eventually have a lower operator to drone ratio "subject to FAA approval based on flights and simulations that demonstrate required levels of safety." (*57*). The petition asserts delivery drones will fly autonomously, but there will be one operator for each drone in the sky at any time. The company also requested to be excused from complying with some aviation regulations associated with planes, such as requirements that pilots fly above certain heights, carry extra fuel, and fly with documentation including maintenance logs aboard the aircraft.

For technologies such as AMRs and drones, it is important to perform tests in real environments because this can improve their security systems and identify new challenges. Extra security measures can also undermine the economic benefits of these technologies. The "chaperones" that must accompany the AMRs, or the safety drivers of the electric vehicles raise the operating costs considerably, since they are operationally unnecessary. It is expected that these measures will be withdrawn over time, especially due to the low number of incidents presented so far by these technologies.

Another regulatory concern involves privacy. Since the majority of automated technologies are controlled by cybernetic means and equipped with cameras and microphones, some people do not feel comfortable when they are operating close to houses or crowded areas, causing debate over privacy rights. Another concern is the potential risk of cyber-attacks, since an eventual hack into these devices could represent a real threat. There is a technical consensus that designers and authorities must find to balance between the minimum requirements that cybersecurity protocols must-have; demands that are too high could delay and even completely restrict the implementation of these initiatives.

Developers and authorities must work jointly to better identify the potential risks of the technologies and establish balanced measures that do not affect their technological progress. In this sense, policies could boost progress instead of undermining it; more objective and flexible regulations could also motivate the arrival of new initiatives and investors.

5.3 Governmental Support

Governments could either undermine or support 3Rs' arrival with their programs and regulations. The authors have identified three primary mechanisms that could support this revolution: motivating/enforcing programs and regulations to mitigate transportation externalities, improving infrastructure, aligning laws and regulations with technologies features.

Programs and regulations can be designed to persuade manufacturers and consumers to develop and acquire green-friendly vehicles. BEVs have generated expectations in governments as a solution capable of reducing GHG emissions and alleviating problems such as global warming. The state of California, to contend with transportation externalities through its environmental agencies, has developed several guidelines, plans, and regulations including: fuel taxes to discourage combustion engine vehicles; purchase voucher incentives for cleaner vehicles; stringent fuel efficiency standard; vehicle manufacturer mandates; control and measurement systems; and other measures. In 2016 California released a multi-

[6] Petition for Exemption; Summary of Petition Received; Amazon Prime Air, FAA on 08/08/2019. Available at https://www.federalregister.gov/documents/2019/08/08/2019-17010/petition-for-exemption-summary-of-petition-received-amazon-prime-air

agency effort called Sustainable Freight Action Plan (CSFAP) based on three main objectives, to: improve freight environmental efficiency (the relationship between emissions and economic output); foster the use of zero and near-zero emission vehicles; and improve economic competitiveness. The plan includes primary actions to improve efficiency based on the use of cleaner vehicles and technologies. Also, the California Air Resources Board (CARB), to support the CSFAP and to align with other regulations, initiated discussions and work on the Advanced Clean Truck (ACT) Program. ACT's goal is "…to achieve NOx and GHG emission reductions through advanced clean technology, and to increase the penetration of the first wave of zero-emission heavy-duty technology." As part of ACT, CARB is considering requiring companies and fleets to acquire zero and near-zero emission vehicles. Moreover, Senate Bill 44 "Medium-duty and Heavy-duty Vehicles: Comprehensive Strategy," and Assembly Bill 1411 "Integrated Action Plan for Sustainable Freight" introduce targets for vehicle emission reductions and the deployment of 200,000 zero-emission vehicles and equipment by 2030.

In countries with high dependence on coal in their electricity generation mix, BEVs may be associated with increased GHG emissions compared to conventional ICEVs. GHG emission reductions may vary depending on the combination of electricity generation in each country, the type of vehicle (SUV, sub-compact compact, Luxury) and fuel type of competing ICEVs. The ICEV automotive industry has undertaken strategies to improve the efficiency of these vehicles and make them more competitive against BEVs; There has been a trend to downsize and improve exhaust gas reduction technologies. The continued market penetration of BEVs, coupled with enthusiastic government policies to improve the electricity generation mix, will significantly enhance the beneficial environmental effects of BEVs (mainly zero tailpipe emissions). Governments need to focus more on vehicle categories where the GHG reduction effect of BEV would be greatest. The results of studies in this area suggest that GHG emissions for a particular distance traveled are the highest for gasoline-based ICEVs (*24*), which always had higher emissions than diesel-based ICEVs in the analysis, and for most cases had higher GHG emissions than the BEVs. Therefore, countries whose goal is to reduce GHG emissions from their transport sector may consider discouraging the purchase of gasoline-fueled vehicles and encouraging the other types of vehicles analyzed in this study. Currently, the United States aims to reduce its dependence on coal and increase the proportion of energy sources with low or no GHG emissions with its Clean Energy Plan (*58*).

The second mechanism that could help support the 3Rs revolution is expanding and improving the road infrastructure, which is not only a necessity but also a motivator for consumers to acquire electric vehicles. The lack of infrastructure is one of the main barriers to the dissemination of the 3Rs (*27*). Without charging infrastructure many companies fear that their last-mile delivery vehicles will run out of ccharge in the middle of operations, or that they should return to the operations center more frequently than regular vehicles do (i.e., increasing operative cost and time). In this sense, a greater number of recharge infrastructure would generate confidence for buyers.

The third support mechanism that governments would put in place are objective and flexible policies that attract developers and facilitate progress. As a strategy to attract and enhance these technologies, the authorities must work hand in hand with the developers. Several companies have decided to move operation centers or have established partnerships with governments that offer greater flexibility and resources. Matternet, a company originally from the Bay Area in California, partnered with the Swiss Post to jointly develop delivery systems using drones able to reach hard-to-access areas in Switzerland, where regulations are more flexible. Similarly, Kodiak Robotics, also based in California, is delivering cargo in Texas due to their progressive and flexible laws

5.4 Summary and Discussion

Three key requirements have been identified to accommodate the 3Rev' technologies to the urban freight system: favorable policies and infrastructure, and further research. While stringent policies could block the development of promising technologies, policies that are too flexible could put road users at risk. To close this gap research plays an important role, in helping to evaluate more accurately the potential benefits and unintended consequences of these technologies, thus supporting policymakers to design more appropriate policies and infrastructure requirements.

As expected, it depends on the type of technology. For instance, (*59*) indicates, after analyzing several AMRS trials, that there are situations that should be considered before releasing AMRs to operate commercially. AMRs have not yet proven to be 100% autonomous; there are day-to-day situations that must be solved by human intelligence. AMRs take advantage of their sensors and urban traffic control signals to navigate cities. Following traffic rules and emulating human behaviors such as adopting a walking speed allow AMRs to handle the urban system to some extent; however, the diversity of situations of the urban system is still a major challenge for developers. For example, some AMR versions need human support to determine when to safely cross a crowded intersection in the absence of pedestrian traffic lights.

Although AMRs are currently operated under continuous human supervision, they could still represent a disruptive element for pedestrians and vehicular traffic. This is because at least the tested AMRs do not have enough versatility and agility yet to do fast evasive maneuvers. Any unknown or potentially unsafe situation will trigger a stop until the device or supervisor considers it safe to continue. Furthermore, due to technology limitations, AMRs experience delays in signal reception. For example, when the controller/supervisor (a human being remotely supervising) sends a stop order the AMR will keep moving for a while until the signal is fully processed. This delay or reaction time is larger for AMRs than for humans, since it accounts for the device reaction time plus the supervisor's reaction time, increasing the chances of crashes with pedestrians or blocking intersections.

As a first countermeasure to avoid crashes, developers program AMRs to keep a safe distance (i.e., following distance) between them and pedestrians. As a second countermeasure, supervisors, proximity sensors, and other tools are ready to stop the devices when required. So, the greater the pedestrian and traffic flow, the greater the chances of facing unknown situations, sudden stops, and road disruptions. During an intersection crossing, continuous stops and starts contribute to the fact that in some cases, an AMR will remain in the intersection even after the traffic light for cars has changed to green, increasing the chances for traffic disruptions and crashes. This could be a major issue at rush hours when traffic density is higher. In (*59*), the authors illustrate that in 43% of the cases over 1.000 trials, tested AMRs were not able to cross a regular intersection. In 10 percent of the cases, AMRs fully crossed the intersection within 5 to 11 seconds after the light changed to allow vehicles to cross, creating congestion for the vehicle traffic.

In some cases, AMRs will inevitably have to cross intersections; however, some intersections do not have help devices such as pedestrian traffic lights and timers. In addition, some traffic light timers require manual activation, which so far is impossible for AMRs. Overall, considering the current technology capabilities and urban infrastructure, it is necessary to determine under what conditions AMRs can operate safely for the device itself, pedestrians and drivers. These conditions include an evaluation of the pedestrian flow, topography, intersection geometry, and potential conflict zones. The latter refers, for example, to intersections in which AMRs may have difficulty crossing in time, or those that due to their geometry could increase the probability of collision. Although AMRs are not ready to operate autonomously in all urban environments, their gradual insertion into the urban system is key to boosting their development. Start-ups like Kiwi have shown that direct interaction with the real environment allows for more rapid technological growth. Soon this start-up expects to launch its fourth version of AMR, after learning and testing for the last 3 years running on the UC Berkeley campus. The small company has learned how to overcome more complex situations through software, hardware, and logistics improvements, including how to operate in the rain, physical changes in the design to improve the versatility and agility of the robot, and to improve delivery time efficiency.

Improvements in the urban infrastructure could help to accommodate these technologies, such as traffic lights and AMRs, to activate timers with a special time that allows the complete crossing of intersections. Another possibility is to activate cyclical timers, as is still done in some places. There could also be a specific section of sidewalks or intersections dedicated to AMRs, minimizing delays and improving AMR flow. In any case, all of these possibilities require further research.

Similarly, (*27*) identified that to accommodate electric and autonomous vehicles for either the long haul or last mile, the expansion of charging structures throughout the urban system is required. As noted in Section 2. Electric vehicles are one of the most developed technologies in the three revolutions (i.e., 3Rs: automation, electrification, and shared mobility)and its arrival, as well as its benefits for the environment, are imminent. Charging structures are necessary, not only to incentivize consumers, but also to support an imminent expansion.

Table 7 summarizes some research directions, required policies and infrastructure requirements to accommodate 3Rev technologies in freight to the urban system. It should be noted that to cover the specific requirements of each technology would require a more thorough and technical study into their technological components, beyond the scope of this paper.

As suggested in **Table 7**, to determine the replenishment rate between regular vehicles and some of the new technologies is important because, for example, indiscriminately increasing the number of electric bicycles instead of vans would only increase congestion. Furthermore, replacing regular trucks with electric trucks is not efficient if their operation would take place in a region with a restricted or inadequate charging network. Moreover, depending on the type of cargo, weather, and traffic conditions, the demand for electric charges will be higher or lower, which will affect the replenishment rate between regular vehicles and electric ones. Also, research is necessary to determine where it is safer, and efficient in terms of the traffic, to operate these new technologies, either the current roads: freeways/highways, bike lanes, sidewalk, or maybe it would be more efficient to consider dedicated new lines or sections to accommodate these technologies. As discussed, for example, it may be logical for AMRs to have dedicated sections in crosswalks to efficiently cross intersections. Furthermore, the specific technical features and capabilities of these technologies may represent risks for other road users;. these situations should be characterized, and protocols must be created to cover when devices are out of control.

One of the aspects to consider with these new technologies is the latent risk they represent if used for criminal acts, so policies must require companies to keep robust cyber protocols. Likewise, it is possible that these devices would sometimes lose autonomy, get out line, or simply decompose. Considering their size and the location where they operate, this could present major complications for traffic or even a risk to people. In this regard, regulations to recover off-line devices and actions to avoid congestion should be considered.

Table 7. Suggested further research, policies, and infrastructures changes to accommodate 3Rev freight technologies.

Mode	Research	Policy	Infrastructure
Electric trucks and vans	• Determine the replenishment rate between regular and electric vehicles depending on the operation conditions	• Incentives to acquires electric vehicles	• Charging facilities
Electric cargo bikes	• Determine the impacts of operating them in the bike lane, vehicle line, or sidewalk for different penetrations levels. • Determine the replenishment rate between them and vans.	• Where (geographic location) and what range of hours AMRs may freely operate.	• Charging facilities
Autonomous trucks and vans	• Determine capabilities and characterize potential risky situations under operation	• Cyber security protocols • Protocols for recovering off line vehicles • Accident liability according to the automation level	• Charging facilities • Dedicated lines in highways/urban networks
Drone	• Strategies to warrant safety when Drone get offline/ does not respond • Determine safe operation protocols routes	• Cyber security protocols • Protocols for recovering damaged/off line Drone • Where and what hours AMRs may freely operate	• Charging facilities • Upload/download cargo structures
AMRs	• Determine models/strategies for following safe distances • Determine strategies to efficiently and safely cross intersections • Evaluate potential traffic disruptions caused by AMRs • Determine capabilities of AMRs to operate in different urban environments	• Where and what hours AMRs may freely operate • Cyber security protocols • Protocols for recovering damaged/off line AMRs • Protocols for AMRs blocking intersections • Minimum required physical identification, sensors, navigation support devices • Monitoring	• Differential or longer times for crossing intersections. • Smart connectivity between traffic lights and AMRs • Dedicated lines for AMRs (Alternative)

However, the policy with the greatest impact would aim to determine where, and at what times, these new technologies, especially autonomous vehicles, AMRs and drones can begin to operate without presenting a risk to other road users. This policy is seen as a support to increase the penetration of the

3Rev while requiring a balance between the real capacities, potential risks and the impacts that these technologies can generate.

6. Conclusions and Final insights

The challenge of mitigating the disproportionate negative externalities due to transportation such as pollutant emissions, noise, safety issues, and congestion has motivated the development of alternative vehicles; green-friendly, versatile and efficient in the framework of what is known today as the third revolution -*electrification, automation, and shared mobility* (3Rs). This study provides an overview of different 3Rs' technologies and their penetration status, and explores the potential benefits and unintended consequences of their arrival.

In the transportation passenger side, the 3Rs have had a positive reception from the public and governments. In fact, several cities worldwide such as Los Angeles, San Francisco, Tokyo, Paris, and others are betting on electrification as a way to shift the globe's path towards climate change by replacing their public transportation powered by internal combustion engines with zero-emissions alternatives. In passenger transportation, the 3Rs have also shown benefits in operative cost and noise reductions. Electrification is increasingly being encouraged through government incentives and multiple policy and regulation efforts to capitalize of its benefits. The global reduction of GHGs depends to a large extent on the electricity mix grid of countries; despite the fact that electric vehicles generate zero or almost zero tailpipe emissions the global benefit may not be as significant if the power supply is mostly based on electricity generated from fossil fuels. In this sense, governments play a fundamental role.

On the freight transportation side, the penetration level of the 3Rs is not as widespread or analyzed; the revolution has just begun. Nevertheless, in the last few years, the number of initiatives and technology developments has grown; currently, there are some light electric vehicles already available for last-mile deliveries. Two- and three wheel-electric cargo bikes stand as the most mature technology with outstanding benefits: zero- emissions, versatility, contributions to congestion reduction, low noise, and low cost. Electric vans are also in a considerable mature level with the advantage of having a higher cargo capacity than electric cargo bikes. Although electric vans do not contribute to congestion reductions, they do not generate tail-pipe emissions and help to reduce noise. In the long term, fully-autonomous devices promise significant benefits. Autonomous mobile (or delivery) robots (AMRs) and unmanned aerial vehicles (UAV) also known as "drones" use sensors and navigation technologies to move around their environment with minimal human intervention. They show the potential to replace humans labor while reducing time, increasing efficiency, increasing flexibility, and enabling new services such as overnight deliveries, real-time tracking, urgent deliveries, and deliveries in hard-to-access places. Several companies are testing these devices for food and retail deliveries, like DHL, Amazon, Kiwi, Yelp's Eat24 or FedEx, however, at the moment most autonomous delivery applications are still too economically and technologically immature to be scalable.

For the long-haul, developers of all-electric heavy-duty trucks and autonomous trucks will bring to market their alternatives to market soon. All-electric trucks such as Peterbilt's XoS truck (zero-emission versions) or the E-Fuso Vision One are expected to be in the market between the end of 2019 and 2020. In the autonomous arena, alternatives are expected to be available between the end of 2020 and 2022, such as the Level 2 Freightliner or the full-autonomous Enride. The great benefit of these vehicles is the production of zero and almost zero GHG tail-pipe emissions, and potentially better safety because of the advantages of the supportive navigation sensors.

Crowdshipping is the equivalent to shared mobility in the passenger transportation side. This alternative supports sustainability based on using excess available transportation by reducing the number of deliveries and trucks in urban/suburban areas, and helps companies by reducing their delivery costs while maintaining comparable levels of service. There are several companies successfully using these systems, such as Doordash, Amazon, Walmart, Deliv, and others.

Since transportation is a connector of the stages of the supply chain, the 3Rs in freight could enhance the way in which logistics are done today in the context of the fourth industrial revolution or Industry 4.0. Thanks to the automation and software development, this industrial revolution has allowed reaching manufacturing/services levels of productivity and efficiency never before seen. However, to better exploit the reductions in time and cost obtained in indoor automated operations, it is necessary to reduce the inefficiencies of transport in the long-haul and last-mile. It makes no sense for factories and distribution centers to process at highly efficient rates if transportation is unable to line up at the same rate.

High costs, lack of recharging infrastructures, and governmental regulations are still the biggest barriers for the diffusion of the 3Rs. The arrival of the 3Rs is a challenge for transportation planners and policymakers who will have to design new policies that guarantee the integrity and security of all users. This is because traditional modes will be replaced, changing cargo sizes, efficiencies, and even the used routes; now the sidewalk, bicycle lanes, and the air space could be commercial routes. The interaction of these devices with other road users could generate potential conflicts, especially with vulnerable populations such as children and the disabled. For example, an AMR could block someone in a wheelchair from crossing a street, or it might not be seen by a truck driver and crash. It is still not clear how autonomous devices should share the sidewalk, nor what kind of regulations and policies should regulate them without stopping the progress or the development of their technologies. Currently, there are no commercial licenses for AMRs or drone operations; licenses are limited for testing purposes with total supervision.

Considering the benefits that the arrival of these technologies could have, it is necessary to make changes in the urban system to accommodate them. These changes are in the direction of new policies and regulations, as well as changes in infrastructure, all supported by further research. The philosophy behind these changes must be to allow the operation of these technologies in places and times such that they do not represent a risk for other devices/vehicles or for people. To ensure this, it is necessary to determine the exact possible risks, capacities and characteristics of the place where these technologies will operate, For example, policies that require cybersecurity protocols for companies that operate autonomous vehicles, will allow drones and AMRs to operate freely with low risk for cyber-attacks and invasions of privacy. In terms of infrastructure, lanes dedicated to autonomous vehicles should be considered, at least until the technology demonstrates greater robustness, as well as traffic signals such as intelligent traffic lights that can serve AMRs as well as people.

In the U.S. autonomous cars, vans and trucks have begun to achieve greater acceptance, especially because of the success they have had in terms of safety. There are states where their operation is allowed without a driver, and other states are expected to design policies to allow their circulation. It seems that the most important challenge to the further development and acceptance of these technologies are solutions to hard visibility situation situations, and evasion solutions when a crash is imminent. Electric bikes are a formidable alternative for passenger mobility, but in freight transportation, their expansion is still limited by federal and state regulations limiting their benefits. However, they are being widely used as an economic and time saving alternative for deliveries in cities with high congestion.

In addition, vehicle automation could affect parking space requirement and costs, since they have assisted parking systems and need less space when compared with human driver requirements. Another benefit is the possibility of connecting vehicles with parking infrastructures to reduce the time spent finding parking spots. One of the unintended consequences considered in the study is greater accessibility for disabled and older populations which now could have the possibility of independent travel.

Overall, the review of the existing technologies shows promises for system improvements, and highlights some of the barriers and challenges. The study mainly relied on the limited academic literature, and commercial information from vendors. It is extremely important that more testing is conducted to evaluate the technical feasibility of the 3Rs, their operations in real-world environments, and private and public behaviors. During the development of the study, and the research before that, company and technology deployment targets have switched or where no met. It is still unclear when some of the discussed technologies will be market ready. The challenges span from technological, financial, and regulatory). Moreover, some of these technologies have focused on replacing existing technologies (e.g., BEVs for ICEVs), and others hint at potential structural changes in the distribution of cargo (e.g., the use of crowdshipping). The 3Rs are an exciting opportunity to reshape the way we transport goods (and people), and how the cities will look in the future.

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Data Management Plan

Products of Research

This research was based on a comprehensive literature review of the state of art and practice about automation, electrification, and shared mobility in freight. The documents are listed in the reference list. No other data were used for the descriptive analyses.

Data Format and Content

The research did not include any quantitative or qualitative data.

Data Access and Sharing

For the literature listed in the reference section, reader will follow the copyrights for each document. The team had access to academic (journal articles) through the subscriptions available at the University of California, Davis Library. Other documents were publicly available at the websites of the companies and service providers described in the report.

Reuse and Redistribution

There is no data available or used for this project. Readers planning on using the findings or synthesis results from the work, must appropriately cite the report and the authors.

Appendix A. Long-haul Automation & Electrification Developments

The section summarizes information gathered from commercial websites and advertisement material.

Tesla Semi

The Tesla Semi is advertised (though no detailed technical information is available) as the safest and most comfortable truck ever built for long hauls. Its four independent motors provide maximum power and acceleration and require the lowest energy cost. The vehicle data sheet indicates a quick acceleration—from 0-60 mph in 20 seconds--fully loaded[7], and instant traction control with four independent motors. The Semi has an autopilot to help avoid collisions and a centered driver position, which provides maximum visibility and control, while a low center of gravity offers rollover protection. However, the vehicle requires a driver on alert to take action at any time. Tesla ensures that the energy costs are half those of diesel, and fewer systems to maintain, the Tesla Semi provides $200,000+ in fuel savings and a two-year payback period. The company has passed from prototype stage to sales; the first units are expected to be delivered in the second half of 2020 (*60*). Tesla stated in its Q4 2019 and Full Year Update Letter that is under production of "limited volumes" of the Semi in 2020. Tesla initially aimed for a release date of late 2019. However, the company announced in its Q3 2019 earnings report that it will begin low-volume production in 2020.

Daimler and their electric truck divisions

Daimler currently has full-electric trucks in the market and, it is growing their rivalry with Tesla in the automated-truck market. Daimler agglomerates a group of companies in the automotive industry; Mercedes-Benz, Mitsubishi-Fuso, Freightliner, Maybach, Western Star, etc., and in few of their brands offers electric vehicles. For example, Daimler in their Mitsubishi-Fuso division supplied a fleet of eight local zero-emission FUSO eCanter trucks to well-known New York-based not-for-profits: Wildlife Conservation Society, New York Botanical Garden, Habitat for Humanity New York City, and Big Reuse Brooklyn[8]. As they assert on their web page, the FUSO eCanter is the first all-electric truck in series production and from now on the eCanters will be driving through the American metropolis both noise- and emission-free. The next big customer is the logistics company UPS, which would like to make its fleet more environmentally friendly with the eCanter. In addition, this year more vehicles that are electric will be delivered to customers in the U.S., Europe and Japan. Mitsubishi Fuso Truck and Bus Corporation (MFTBC), part of Daimler Trucks, is planning to deliver 500 units of this generation to customers within the next two years, and large-scale production is intended to start in 2019.

Moreover, Daimler in the same division unveiled an all-electric class 8 truck called ''E-Fuso'' in October 2017, underscoring its rivalry with Tesla, which revealed its all-electric Semi prototype weeks later. The E-Fuso Vision One prototype has a 220-mile range with an 11-ton cargo, and it is geared toward shorter, intra-city trips. Daimler's all-electric heavy-duty truck is anticipated to see production and sales in Europe,

7 https://www.tesla.com/semi
8 https://www.daimler.com

Japan, and the US by 2021. Furthermore, the company has collaborated with Hermes logistics, which is going to upgrade its delivery-fleet with 1,500 electric vans from Mercedes-Benz by 2020.

In the automated-trucks market, Daimler announced since 2015, that the company has been working on its own self-driving big rig and showed off a working prototype called the Freightliner Inspiration Truck. More recently, the company released the new Freightliner Cascadia, which is not much more advanced than the prototype was in 2015. In fact, the technology is still limited. Daimler says it is the first Class 8 commercial truck with Level 2 autonomy; still a driver is in control but is supported heavily by the truck's technology in certain situations. According to these features, the new Cascadia is comparable with many current cars, and has the same basic driver assistance technology including automatic lane centering, adaptive cruise control, and emergency braking. The new Cascadia has a forward-facing camera, a forward-facing radar, and a second radar sensor on the right side of the truck. That package pales in comparison to the dozens of cameras, ultrasonic sensors, and radars you'd find powering Autopilot, let alone the Tesla Semi, which is supposed to have a beefed-up version of this same sensor suite.

Waymo Self-Driving Trucks

Waymo is known for its driverless passenger vehicles; however, the company is expanding to autonomous trucks for freight deliveries. The Waymo trucks will soon begin delivering freight for Google's data centers in Atlanta (*61*). Although initially, the trucks will need a driver to operate on public roads in the testing phase, the trucks are expected to be completely driverless. Waymo's trucks use the same suite of custom-built sensors that power the company's self-driving minivans. They also use the same self-driving software that has enabled Waymo's passenger cars to go fully driverless in Arizona. The company is currently testing the trucks in California and Arizona, and they expect to expand soon to Texas and New Mexico. The company indicates on their webpage that they are also extending the Waymo Driver to help with local deliveries around town. In fact, they already launched a few pilot programs in the Phoenix area. They stated: "No matter what you're transporting or where it's headed, Waymo Via will have you covered." Waymo is teaming up with their sister company Google's logistics team to develop a technology and integrate it into the operations of shippers and carriers, with their network of factories, distribution centers, ports, and terminals. The operations will begin in Atlanta but are expected to be expanded to other logistic hubs in the US.

Kodiak Robotics

This start-up firm developed a self-driving truck, which has started making commercial deliveries for a costumer in Dallas-Texas since 2019 with a driver behind the wheel to take action when required. Through the launch of these operations, the company is making tangible the arrival of 3Rs in freight. Kodiak Robotics is sponsored by investors including Battery Ventures, CRV, LightSpeed Ventures, and Tusk Ventures. Kodiak defines itself as a "true freight carrier," with its self-driving trucks operating on "middle mile" highway routes (*62*). The company focuses on making highways safer while reducing the operational cost of trucking and travel time.

After closed testing on public roads in California, Kodiak chose to make Texas its home base for future testing and operations. The company asserted in its blog post in august in 2019 that it chose Texas because of its great people, freight-rich economy, reasonable regulatory structure, and robust infrastructure. In addition, Kodiak has manifested its willingness to collaborate with academia and public agencies "to ensure safe deployment of new technology," according to a statement from Christopher Poe, assistant agency director and connected automated transportation strategy lead at the Texas A&M Transportation Institute (TTI).

Embark Peterbilts

The Peterbilts from Embark are operating the longest automated freight route in the world. Together with their partners Electrolux and Ryder, Embark is putting their technology to work moving freight. Early in 2019, the company completed the first coast-to-coast haul test run by a self-driving truck, traveling from suburban Los Angeles to Jacksonville, Florida[9]. Embark's autonomous Peterbilts are also generating revenue hauling loads daily between Ontario and Phoenix for their partner's shippers. Following the law, the Peterbilts currently use a driver, however it is expected that in the near future it will not be necessary to use humans in driving. The ambition of the founders of the company is to conquer the entire I-10 route, so they claim to be moving quickly.

Thor Electric Trucks

The start-up Thor Electric Trucks (now XOS) is growing fast thanks to multiple agreements developed between truck manufacturers. Thor is using a specialized axle embedded with electric motors as the powertrain for a line of electric semi-tractors. The company believes that its base design can be combined with other manufacturer designs to create a wide range of vehicles for multiple applications, allowing it to sell the integrated system massively. Thor unveiled a prototype of the truck last December and plans to produce them in 2019[10]. That version was powered by a large electric motor mounted between the frame rails of a Navistar International Corp chassis, but they plan to produce their own chassis. A deal that Thor has with Wiggins Lift Co. is one example. Thor initially will provide battery technology for Wiggins' forklifts. An integrated electric powertrain may follow. Thor will gain valuable experience producing large equipment used in construction and warehousing that it can build on. They think that is an opportunity to validate a battery system with an e-axle purpose-built for heavier applications. Unlike Tesla, which is doing its own integration of its semi-truck, Thor has relied on partnerships, some of which it has not yet announced. Companies leading truck electrification are doing likewise. Axle makers, for example, are buying electric motors instead of making them. Dana Inc. in June acquired a 55 percent interest in Hydro-Quebec subsidiary TM4, becoming Dana's source for electric motors, power inverters and control systems. Furthermore, Thor will begin testing two electric medium-duty delivery trucks with UPS in greater Los Angeles in January. Those trucks are capable of 100 miles of electric range before needing a 60-minute recharge.

Volvo Electric Trucks

Through a partnership between the Volvo Group, California's South Coast Air Quality Management District (SCAQMD), and industry leaders in transportation and electrical charging infrastructure, Volvo Trucks plans to introduce electric truck demonstrators in 2020. The demonstration units will be based on the technology currently being used in the Volvo FE Electric, which Volvo Trucks presented in May and will begin selling in Europe in 2019 and in North America in 2020 (*63*).

9 https://embarktrucks.com/
10 https://www.thortrucks.com/

This initiative is called ''LIGHTS'' and is an example of a public-private partnerships that electrification of truck transport will allow, as a strategy to improve air quality, reduce traffic noise, and reduce congestion during peak hours – because operations can be carried out quietly and without tail-pipe exhaust emissions early in the morning or late at night. Volvo plans to use a variety of smart technologies including remote diagnostics, geofencing, and the company's web-based service management platform – to monitor all truck performance aspects of the project and maximize vehicle uptime.

BYD Electric Trucks

In November 2017, the company announced plans to expand its electric truck effort in North America by opening an electric truck plant in Ontario, Canada, after the successful delivery of the first all-electric automated side-loader garbage truck to the city of Palo Alto in late 2017 (*64*). The vehicle has a range of 76 miles per full charge and a charge time of two to three hours. BYD is a China-based electric vehicle company; BYD already maintains an electric bus manufacturing plant in Lancaster, California. The decision to have a plant in Canada was made due to numerous factors, including: the lower costs associated with building the vehicles in Canada rather than shipping them from China, lower barriers to entry for Chinese products in Canada compared to the US provincial tax incentives.

Cummins Kenworth T370

In 2018 Cummins introduced its PowerDrive suite of plug-in hybrid electric solutions on a functional Kenworth T370 utility truck at the IAA Commercial Vehicles Show in Hannover, Germany (*65*). PowerDrive replaces the conventional transmission and switches in real time between two hybrid and pure electric modes, optimizing the powertrain for the best fuel economy in any situation. The hybrid utility truck featured a recovery crane that could operate off either engine power take-off or electric power. The vehicle is also configured with exportable grid quality electric power to recharge other vehicles. The PowerDrive hybrid system is designed for light, medium, and heavy-duty applications, and it can be paired with various sizes of diesel or natural gas engines and battery pack outputs. So far, vehicles using the system have travelled over 6 million miles in a fleet setting in the U.S. and China. Work is underway to introduce it to the European market soon. The flexible hybrid architecture shifts between pure electric with a 50-mile range and hybrid for jobs requiring more than 300 miles of range. The Kenworth T370 with PowerDrive 6000 is paired with a Cummins B6.7 engine. This class 6 truck powered by PowerDrive can realize reduced emissions of up to 80%, according to Cummins, and can also reduce fuel costs.

Einride

Self-funded Swedish company Einride announced the production of T-log, an autonomous, all-electric logging truck that is designed to navigate hilly, winding forest roads (*66*). Einride continues testing during 2020. Einride claims that the T-log's 300kWh battery can last up to 120 miles on a charge. The T-log, which shares much of its guts with Einride's autonomous T-pod truck, is capable of level 4 autonomous driving, meaning it can operate with limited human input and oversight in specific conditions and locations. It is powered by Nvidia's Drive platform and uses a sophisticated combination of sensors including cameras, lidars, and radars and intelligent routing software to adjust its route to avoid congestion. This allows it to improve delivery times, battery life, and energy consumption. That said, the T-log is not strictly autonomous; like the T-pod, it takes a hybrid driverless approach. In especially tricky driving scenarios, it can be remotely controlled with Phantom Auto's teleoperation technology up to "hundreds of miles" away, via a low-latency cellular connection.

Other Technologies

Within the developments for the long-haul, there are two alternatives that could efficiently transport cargo. Both cases are expected to take advantage of economies of scale as a strategy to reduce costs. These are illustrated below.

Hyperloop consists of two massive tubes extending from San Francisco to Los Angeles (see FIGURE A1 for illustration). The pods carrying passengers or cargo would travel through the tubes at speeds topping out over 700 mph[11]. Magnetic accelerators that will be planted along the length of the tube propel the vehicle. The tubes would house a low-pressure environment, surrounding the pod with a cushion of air that permits the pod to move safely at such high speeds. The Hyperloop aims to make a cost-effective, high-speed transportation system for use at moderate distances. The Hyperloop tubes would have solar panels installed on the roof, allowing for a clean and self-powering system. A one-way trip on the Hyperloop is projected to take about 35 minutes; for comparison, traveling the same distance by car takes roughly six hours (*67*).

Figure A1: Hyperloop. Source: *https://www.thedailybeast.com/elon-musk-hyperloop-dreams-slam-into-cold-hard-reality*

Although there is no exact date for its completion, at least in the United States, there is interest in other countries in Europe and the Middle East in developing a Hyperloop. Although the budget is still under debate (around six billion dollars), some analysts consider the project unviable. The laws and regulations that will allow the use of these transportation systems are still uncertain. However, in recent years, the state of Nevada has offered its support in the development of Hyperloop.

Platooning is a semi-autonomous driving strategy by which trucks use sensors and vehicle-to-vehicle communication to travel at high speeds in convoys in short proximity to one another (**Figure A2**). According to developers, this tactic potentially has several benefits. The truck at the head acts as the leader, with the vehicles behind reacting and adapting to changes in its movement; requiring little to no action from drivers. The trucks take advantage

Figure A2: Platooning appearance. Source: *https://www.scania.com/group/en/automated-platooning-step-by-step/*

11 https://hyperloop-one.com

of aerodynamics in the same way that racing cars build momentum by getting into a line and drafting around a racetrack. Drivers will always remain in control, so they can also decide to leave the platoon and drive independently. The air-friction reduction could reduce fuel consumption and emissions. Besides, this ''smart'' linking increases safety since the trucks in the line brake just in time according to traffic conditions and eventual threats. Furthermore, the high speed at which the convoy travels and the reduction of unnecessary stops would reduce travel time considerably.

Daimler indicated that it sees "no business case" for platooning (*68*). The company developed several platooning projects last year and concluded that the benefits were not as impressive as initially expected. It looks that the fuel savings from platooning, one of the top expected benefits of the driving tactic, are marginal. The company announced that it will focus on other, more advanced solutions, such as a Level 4 autonomous truck, much more advanced than its newest Level 2 Cascada truck. It seems that Daimler sees more profit in the race to put autonomous trucks on the market.

However, numerous other truck makers and developers remain committed to platooning as a time and fuel reduction strategy. Volvo Trucks, for instance, has showcased its platooning trucks several times over the last few years. Alphabet's Waymo, lastly, continues to operate platooning trucks in the Atlanta area. Peloton is still developing its proposal, and announced that it is working on designing a cloud through which trucks can upload and download communications to improve their performance, for example to adapt their speed according to the state’s laws and incoming conditions in the road (*69*).

Appendix B. Last-mile Automation & Electrification Developments

Velove electric bikes

Figure B1: Velove Armadillo. Source: https://newatlas.com/velove-armadillo-cargo-cycle/36995/

Velove is one of the largest developers of electric bicycles for cargo[12]. Their designs allow loading small containers that have maximum load, and, counting the chassis, they arrive weighing 350kg. With a width of only 86 cm and a limited height, they expect to easily drive on bike paths to quickly deliver cargo in city downtowns, without causing problems for other cyclists. The Armadillo last-mile delivery cargo bike (**Figure B1**) is offered as an alternative that is 2X more productive and with a significantly lower total cost of ownership compared to van-based delivery because they utilize bike infrastructure in harmony with other cyclists. Additionally, Velove has introduced a variant to the logistic system, micro containerization. Large containers or trailers transport smaller containers through the long-haul segment, then the small containers are loaded onto bicycles to complete the last mile. This system, which can be considered a mix between multi-modal and inter-modal transport, poses a new challenge for logistics since it could imply a higher level of planning. Currently Velove is working with DHL, Hermes and other smaller companies delivering cargo in Europe and USA. Currently Velove and DHL are rolling out its Cubicycle in New York City, participating in a pilot program to test the use of cargo bikes to alleviate traffic congestion as well as lessen air and noise pollution in the city's crowded streets. Deploying the Cubicycle in Manhattan fits in with DHL's ambitious environmental targets which include achieving net zero emissions from transport activities by 2050 and performing at least t70 percent of pick-ups and deliveries with green energy solutions such as electric vehicles and bikes by 2025.

Some of the underlying questions related to these vehicles are: considering the size and mass of these bicycles should they share the same routes as regular bicycles? Should the use of these bicycles be restricted in certain spaces in the cities? What hours should they operate? However, it looks like this technology will develop more quickly than expected.

Coaster Cycles

Coaster is another example of a company developing a wide range of cycles for both passenger and cargo applications. With manufacturing in Montana and an operations presence in California, the company has conducted a number of tests with major corporations in the U.S. The company produces electric-assisted bikes with power settings between 500-700w, and more than 750w for off-road uses. The company has implemented a number of pilot tests, and has commercial operations and working with major businesses. The research team is planning a pilot at the University of California Davis, once the school returns to full operations after the COVID-19 pandemic.

12 https://www.velove.se/

DHL

DHL has been actively working on different alternatives, not only green-friendly but also cost-efficient for the company. Between January and March in 2016 in the Bavarian community of Reit im Winkl, the DHL “Parcelcopter” performed a series of flights round trip from the valley to plateau at roughly 1,200 meters above sea level covering eight kilometers of flight. The drone’s cargo was typically sporting goods or urgently needed medicines, and it arrived at the Alm station within just eight minutes of take-off. The same trip by car can take more than 30 minutes during the winter. DHL plans to use this technology commercially soon. Recently in 2018, DHL Supply Chain, a logistics division of DHL, announced a plan to invest $300 million dollars in robots and sensor developments in order to partially automatize at least 60% of its warehouses in North America (*70*). The company expects to reduce workflow, as well as to mitigate the demand for seasonal positions using robots. In an interview published in Venture Beat in 2018 (*71*), DHL Supply Chain North America CEO Scott Sureddin indicated that the company is already working with companies like Locus Robotics developing robots able to collaborate with humans to fulfill orders in most DHL facilities. In addition, the DHL Supply Chain president of retail Jim Gehr said that DHL is in ongoing conversations with more than 25 robotics and developer leaders industries. Gehr said "DHL Supply Chain warehouse robots will work primarily with unit-picking operations and will be able to complete a range of tasks, from collaborative piece-picking to shuttling items across a factory to following human packers," also, Gehr mentioned that productivity of the picking operation has been improved over 100%, and they expect more.

DHL is not only working actively on warehouse automation, but also to automate and electrify the supply chain, including the last-mile operation. In an interview by the Robotics Business Review (*72*), Matthias Heutger, senior vice president of strategy, marketing, and innovation, and Denis Niezgoda, robotics accelerator lead at DHL, highlighted that warehouse automation is one of the interests of DHL; however, they are also actively working in the implementation of autonomous vehicles and drone deliveries. Heutger emphasized that "application outside controlled premises will remain niche for the time being," he continued, "in my view, drone deliveries will mainly be in remote areas. Medical deliveries to islands or mountains make sense, but drone deliveries in cities will require laws, acceptance, and, most importantly, economics."

In addition, DHL is involved with electrification. The company is rolling out a new fleet of electric delivery vans that will serve U.S. markets. DHL also launched a fleet of electric vehicles in Auckland, Christchurch, and Wellington, in line with Deutsche in New Zealand, and where they expect to reduce CO2 emissions by about 80%. This fleet has been partly funded by the Government’s Low Emission Vehicles Contestable Fund, which supports innovative projects that expand the use and possibilities of electric vehicles and other low emissions technology in the transport space (*73*). As part of a longer-term corporate commitment, DHL has set the goal of operating 70 % of first- and last-mile delivery services with clean transport modes worldwide by 2025, and reducing all emissions to zero by 2050. The company is replenishing its fleets with alternative fuel vehicle (AFV) fleets, which includes fully electric, hybrid-electric, compressed natural gas (CNG) and clean diesel. DHL is working together with the equipment manufacturer Workhorse Group, which expects to deliver a fleet of 63 NGEN-1000 electric delivery cargo vans capable of running up to 100 miles on a charge, with 1,008 cubic feet of cargo capacity. DHL will operate the first 30 cargo vans in the San Francisco Bay Area (*74*).

Amazon

Encouraged by environmental activists and its employees, Amazon annunciated in 2019 aggressive sustainability measures and a plan to address climate change. The company has vowed to reduce dramatically fossil fuel dependence and move to 100 percent renewable energy. Although there is not a specific date for this goal, Amazon hopes to make 50 percent of all shipments to customers with net zero carbon (both their own fleet and third-party associated) in the next 11 years as part of an initiative it is calling Shipment Zero (*75*). Details on this long-term project were not yet available, but Amazon says it plans to share its company-wide carbon footprint "along with related goals and programs," later (*76*).

Amazon asserts that this initiative has been enabled because of improvements in areas like electric vehicles, aviation biofuels, reusable packaging, and renewable energy; the company says it "can now see a path to net zero carbon delivery of shipments to customers." Amazon did not give a timeline for achieving net zero carbon on all deliveries (*75*).

Although it is also unclear what kind of strategies the company will use, judging by its latest innovations in deliveries in the last mile, it seems that Amazon is betting on autonomous devices, such as robots, drones, and electric vans.

In 2019 Amazon released a new, fully-electric delivery system called Amazon Scout (*77*). The Amazon Scout was developed in a lab in Seattle, where Amazon performed several trials to ensure the devices can safely and efficiently navigate around pets, pedestrians and anything else in their path. This four-wheel robot rolls along sidewalks to deliver packages to customers in a neighborhood in Snohomish County, Washington. The customers order as they regularly would, and their Amazon packages will be delivered either by one of the trusted partner carriers or by Amazon Scout. Customers can shop on the Amazon App or amazon.com and enjoy the same delivery options including fast, FREE Same-Day, One-Day and Two-Day shipping for Prime members. The company states on its webpage that over the last few months, Amazon Scout has made thousands of deliveries outside of their headquarters in Washington state. All the while, the devices have safely and autonomously navigated the many obstacles you find in residential neighborhoods—trashcans, skateboards, lawn chairs, the occasional snow blower, and more. In the Pacific Northwest, Scout has experienced different weather conditions: rain shower, infrequent sun, and the biggest snowstorm of the decade. Now, Scout is moving to experience the traffic and weather conditions in Southern California, where the company expects to start operations soon. The company notes on its website: "We'll start with a small number of Amazon Scout devices, delivering Monday through Friday, during daylight hours. Customers in the Irvine area will order just as they normally would, and their Amazon packages will be delivered either by one of our trusted carrier partners or by Amazon Scout."

With the program Amazon Prime Air the company hopes to reduce the delivery time by 30 minutes[13]. This program consists of deliveries by autonomous drones as long as the warehouse and the client are up to 16km away and the package weight is up to 5 pounds. Amazon has Prime Air development centers in the United States, the United Kingdom, Austria, France and Israel. The main challenge is to meet and follow air regulations; this is why Amazon is oriented towards develop strong safety strategies for both people and the devices.

13 https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011

Amazon has been testing drones since 2015 in the U.S once the FAA granted permissions under a waiver to the then regulations, but the company was previously testing drones at the Canadian border. Current U.S. regulations require that drones fly no higher than 400 ft. (122 m), no faster than 100 mph (161 km/h), and remain within the pilot's line of sight. Amazon has stated that it intends to move towards operating above 200 ft (61 m) and beneath 500 ft (152 m). Amazon has stated it plans to fly drones weighing up to 55 lb (25 kg) within a 10 mi (16 km) radius of its warehouses, at speeds of up to 50 mph (80.5 km/h) with packages weighing up to 5 lb (2.26 kg) (*78*). Operations were expected to begin in select cities starting late 2019; however, as of April 2020, they have not.

FedEx

FedEx is making efforts to reduce its footprint, as are other big logistic companies. FedEx has been using all-electric vehicles as part of its pickup-and-delivery fleet since 2009. On its website (*79*), the company points out that "We believe that wider adoption of alternative-fuel, electric and hybrid electric vehicles will play a key role in reducing global emissions while diversifying and expanding renewable energy solutions." FedEx is purchasing 100 electric vans from Chanje Energy Inc. and leasing 900 from Ryder System, Inc. These vehicles will be used for commercial and residential pick-up and delivery services in the United States.

The vehicles are manufactured by FDG in Hangzhou, China, and purchased through Chanje Energy Inc., the company's subsidiary for global business. Ryder System, Inc. will provide support services for all of the vehicles. These EVs have enough energy to travel more than 150 miles with one fully charged battery while avoiding 20 tons of emissions per vehicle each year. The maximum cargo capacity is around 6,000 pounds. All of the EVs will be operated in California.

In addition, FedEx recently unveiled its autonomous delivery robot for last-mile operations through its website (*80*) in February as: "a cutting-edge delivery solution to meet the rapidly changing needs of consumers — the FedEx SameDay Bot — an autonomous delivery device designed to help retailers make same-day and last-mile deliveries to their customers." FedEx launched this bot with the expectation of delivering orders from nearby retail customers and delivering them directly to consumers' homes or businesses the same day. The company is currently collaborating with companies such as AutoZone, Lowe's, Pizza Hut, Target, Walgreens and Walmart to help assess retailers' autonomous delivery needs. On the FedEx website it asserted, "on average, more than 60 percent of merchants' customers live within three miles of a store location, demonstrating the opportunity for on-demand, hyper-local delivery."

Brie Carere, executive vice president and chief marketing and communications officer for FedEx said: "The bot represents a milestone in our ongoing mission to solve the complexities and expense of same-day, last-mile delivery for the growing e-commerce market in a manner that is safe and environmentally friendly." The bot was built on the basis of the iBot, an advanced, FDA-approved, mobility device for the disabled population with more than 10 million hours of reliable, real-world operation in order to make even more accessible to those who need it for their own mobility. The FedEx bot was designed to travel on sidewalks and along roadsides. Bot features include pedestrian-safe technology from the iBot, plus advanced technology such as LiDAR and multiple cameras, allowing the zero-emission, battery-powered bot to be aware of its surroundings. The company asserts, "These features are coupled with machine-learning algorithms to detect and avoid obstacles, plot a safe path, and allow the bot to follow road and safety rules." The company hopes to make the bot highly capable, allowing it to navigate unpaved surfaces, curbs, and even steps for an extraordinary door-to-door delivery experience.

FedEx plans to test the bot in select markets, including Memphis, Tenn., pending final city approvals. FedEx announced that the initial test would involve deliveries between selected FedEx Office locations. FedEx Office currently offers a SameDay City service that operates in 32 markets and 1,900 cities using branded FedEx vehicles and uniformed FedEx employees. The FedEx bot will complement the FedEx SameDay City service.

In summary, the market niche which FedEx is trying to explore are the stores that have high customer demand within a three-mile radius. Apparently, this distance allows for maintaining cost-effective operating conditions. The bet is on providing a service to save time and money to professionals who will never have to leave the job site for the critical tools and supplies they need. Said Don Frieson, Lowe's Executive Vice President, Supply Chain: "We look forward to exploring all the possibilities to enhance the service we provide our customers through this innovation." The bot also meets zero-emissions conditions, making the alternative environment-friendly.

Alibaba

Alibaba, which is considered the biggest e-commerce seller in the world, announced last year a couple of tech innovations that hint at a future with even more delivery conveniences (*81*). Alibaba unveiled an autonomous delivery robot that will help ship goods purchased online to customers, and a storage locker with facial recognition that promises to keep food warm. This robot was called G Plus, and it is still being tested in the company headquarters in Hangzhou, China. The G Plus is different from many available robots since it can carry multiple packages of different sizes (because of its larger size and capacity) with a long battery life. Like others, the robot has a built-in navigation system that relies on LIDAR to create a 3D map. The robot will reduce its speed to 6.2 miles per hour, to leave enough room for braking when detecting cars or people nearby. For safety reasons, its max speed is 9.3 miles per hour. Once the G Plus reaches the destination, there are to options to drop off the packages; automatically deposited by the device at a specific point or the customer can enter a PIN code provided by Alibaba to get the package. The commercial production is expected by 2020.

Apparently, as with other technologies, one of the biggest challenges for the diffusion of these devices is their operating cost and their efficiency. It seems that the strategy of Alibaba is the possibility of delivering multiple packages with a single device, so that G Plus has a larger size than regular robots, as well as a higher capacity and battery capacity.

Kiwi

Kiwi is a start-up that operates on the University of California, Berkeley campus. Kiwi has several designs of robots that deliver mainly food to the university students in the area. Now, three types of robots get the food out of a restaurant and into a semi-autonomous tricycle that carries four tinier Kiwi Bot robots, which can each carry five meals to deliver them the last 200 meters[14]. The client uses an app to open the KiwiBot when it arrives outside, and the average delivery takes 27 minutes with an average cost of $3.7 USD, according to the company. Kiwi is in negotiations to obtain licenses to operate at UC Davis, the

14 https://kiwicampus.com/

Sacramento area and Denver, Colorado. Kiwi have been actively improving the communications system and navigability of the robot, and is currently planning to launch version 3.2.

Workhorse Group

Workhorse Group, based in Cincinnati, makes electric parcel vans and pickup trucks, and has expanded into flying "last-mile" deliveries with its truck-launched "HorseFly" octocopter drone. The HorseFly drone can carry packages of up to 10 pounds, and has been tested in real-world conditions by UPS. It was expected to be put into commercial use in 2019 – 2020, but that still has not materialized. The drone sits atop a delivery van and is loaded and launched by the driver. It delivers to remote rural addresses and hard-to-reach locations while the van continues on to its next scheduled stop. The drone can operate in a radius of 2 miles around the van, according to the FAA rules, and is programmed to return to the van for reloading after making a delivery. The system reduces the time a driver must spend reaching remote locations, which can either cut fuel and other operating costs or increase the number of deliveries that can be made in a normal shift, slashing driver overtime.

Domino's Pizza Enterprises

Domino's Pizza Enterprises, an international franchiser of the Domino's Pizza brand, concluded in 2016 a successful test of a drone pizza delivery service in New Zealand. The company collaborated with drone delivery start-up Flirtey in an effort to reach rural customers and improve delivery times in congested rural environments. The company said that it does not make sense to have a two-ton machine delivering a two-kilogram order. Domino's use of drones is the next stage of the company's expansion into the artificial intelligence space, giving them the ability to learn and adopt new technologies in the business. Barring any regulatory hurdles, (New Zealand law currently allows unmanned aircraft for commercial operations), Domino's New Zealand expects to continue making drone pizza deliveries. If there are no setbacks, the company plans on expanding its service to other drone-friendly countries like Australia, Japan, The Netherlands, France, Belgium and Germany.

UkrPoshta

The denizens of at least one city in the Ukraine later this year will have the option of having packages delivered via drone (*82*). The country's postal service, UkrPoshta, has collaborated with Israeli drone maker Flytrex on the pilot program, enabling packages up to 6.6 pounds to be delivered over 14 miles away at speeds of 44 mph. An alliance with Flytrex is not surprising considering the tech firm's pioneering development of drone delivery technology. In fact, such partnerships with Israeli tech firms are likely to become commonplace around the world, with the country assuming a leadership role in drone development in much the same way it did for global desalination. As of today, over 40 start-ups in Israel are working to advance various sectors of the drone industry.

Mercedes-Benz

Mercedes-Benz announced a partnership with Silicon Valley drone start-up Matternet to develop an integrated van/drone delivery system in 2016. Dubbed the "Vision Van," this kind of last-mile delivery system would employ two drones capable of delivering packages up to five pounds within a radius of six miles. Matternet, which already has a drone delivery pilot service operating in Switzerland, has previous experience delivering medical supplies and specimens in countries like Haiti, Bhutan, the Dominican

Republic and Papua New Guinea. Both Matternet and Mercedes envision their concept delivery system working hand-in-hand with other services like Amazon Prime Air.

Starship Technologies

Starship is an Estonian start-up led by Skype co-founders Ahti Heinla and Janus Friis. This company created a self-driving robot designed to carry up to 40 lb of goods, such as groceries, product samples, drugstore items, fast food, and small packages. It has a range of up to 2 miles on an electric motor that consumes 50 Watts, moving at 4mph. According to the developer, the robot can reduce the cost 10 to 15 times less than the cost of current last-mile delivery alternatives. Also, the robot will arrive at its destination within five to 30 minutes of leaving the warehouse (*83*). The customer can track the robot's location in real time using a smartphone app and can use the same app to get access to the items he or she has been waiting for. These delivery bots are not completely autonomous. There are control towers, currently located in Estonia and Washington D.C., where the robot can call for help if needed. The humans can then take control of the robot, navigate around an obstacle or help it cross a street safely, and then let the robot take over again (*84*).

The robot is based in a modular warehouse or retail outlet for loading, unloading, and recharging before getting out on the streets. The robot uses preprogrammed maps, GPS, and the public sidewalk to make its way to the delivery address. The machine is equipped with obstacle- and collision-avoidance technologies that protect it from eventual crashes with pedestrians. The robot is also equipped with an alarm to alert authorities or call the attention of someone quickly. High-definition video, speakers, and microphones enable the robot or the human worker to communicate with any pedestrians if necessary. The company announced that they have two business models: first, they offer a delivery service, running and then taking the delivery fees; second, they work with partners in a variety of industries that pay a fee in a Robot-as-a-Service (RaaS) model. The company said the cost would always be less than the human option, around 1.99 USD per delivery. Starship Technologies celebrated 50,000 autonomous deliveries. The company says on its website: "The company's robots have travelled in over 100 cities around the world, operating commercially every day in local neighborhoods and university and corporate campuses across five different time zones. Today, Starship celebrates its one year anniversary of operation in Milton Keynes, having seen the number of houses served in the town grow by 450% in the last year."

In January 2020, Starship expanded operations to the University of Mississippi, and in February 2020, the company began operating on the campus of Bowling Green State University in a partnership with BGSU Dining Services. Starship also worked with campus Information Technology Services, to make limited use of campus networks. In March 2020, Starship became the first robot delivery service to operate in a UK town center with the rollout of its service in central Milton Keynes. The company also announced that NHS staff living and working in its UK service areas would be able to get free deliveries for a limited time period. Starship also announced the launch of its service in Washington DC's Broad Branch Market. The company charges a flat rate fee of $1.99 per delivery.

Marble

One of the new companies in the sidewalk robot arena is the start-up Marble, located in San Francisco[15]. Although still small, their investors are not; their parents include China's tech giant Tencent, as well the

15 https://www.marble.io/

self-driving start-up called Cruise Automation, property of General Motors. Marble has been working on developing fully autonomous delivery robots that can navigate the chaos of a city sidewalk, where pedestrians, pets, and peddlers of bicycles engage in a complex network. The Marble's robot size is comparable with an office copier, and they use cameras, LiDAR and high-resolution 3D city maps to navigate. Although the company first tested its delivery robots in collaboration with food delivery service Eat24, the robots have swappable cargo bays to transport various types of goods, from food to medicine.

Nuro

Nuro is another start-up in the robot industry, sponsored by Banyan Capital, a Chinese venture firm, and one of the top VC firms in Greylock Partners[16]. The company competes in the category of super-sized delivery robots in Silicon Valley. Their self-driving car is about the size of a golf cart and is equipped with LiDAR, cameras, and radar. Their founders are a couple of former Google self-driving car engineers. Forbes reported that Nuro is currently building a half-dozen electric vehicles to carry everything from groceries and food orders to flowers and packages. Although comparable with cars in size, the cost to build the hardware should be significantly less than a regular self-driving car.

Robby Technologies

Robby is also a new start-up in the Silicon Valley founded in 2016 by a couple of MIT experts in robotics and computer vision. The four-wheeled Robby robot looks like a grocery cart, but with more NASCAR-type advertising[17]. The new Robby 2 model has a range of more than 20 miles on a single charge. The delivery robot is reportedly at work in eight California cities.

TeleRetail

A Swiss start-up called TeleRetail was founded in 2013, and mainly sponsored by grants from the European Space Agency[18]. The company is developing a tri-wheeled delivery robot that uses computer vision, GPS and high-tech sensors to navigate autonomously. Their model called Pulse 1 is solar-powered and covers almost unlimited distances to deliver laundry or pick up groceries.

Dispatch

Dispatch is robot-developer start-up located in the Bay Area. Dispatch produced a delivery robot model called Carry, which has four independent compartments that allow multiple deliveries in a single trip with a total weight of about 100 pounds[19]. Carry uses sophisticated algorithms and computer vision to navigate its environment.

Unsupervised

Unsupervised presents a design different from the regular wheeled delivery robots[20]. Their AIDA is a four-legged machine able to climb obstacles on the sidewalk while carrying up to 30 pounds. The company was co-founded by a former data scientist at Lyft. The idea is for a network of Lyft-like drivers to drop several

16 https://nuro.ai/
17 https://robby.io/
18 https://teleretail.com/
19 https://www.dispatch.me/
20 https://unsupervised.com/

of the robots, at any given street corner, where they would start their path to delivering the freight. Although based in Silicon Valley, the early stage start-up will operate in Europe.

Savioke

Savioke does not operate on the sidewalks; this start-up located in the Silicon Valley uses robots to deliver coffee and other items in settings like hotels or manufacturing facilities[21]. The company was founded in 2013 and has several important investors such as Intel. Relay, the first design, delivers towels or your coffee for a $2 USD; it can report trash in the hallways and even tell jokes to the guests.

Ford

The vision of the future by Ford is apparently one where autonomous vans and drones deliver things to your doorstep (*85*). Ford's proposal is called "Autolivery," and is basically an all-automated van able to roll in the streets and launch drones to deliver cargo even in the top floors of a building. Ford believes the pressure to develop mobility solutions in urban areas will grow soon due to the rise in local deliveries from online sales. Ideas like Autolivery can potentially reduce gridlock, air pollution, and allow people to move about more easily. Ford plans to have its fleet on the road shuttling packages and people in 2021.

21 http://www.savioke.com/

Appendix C. Regulations on drones in the U.S.

The US Federal Aviation Authority (FAA) regulates the use of drone in the U.S. space air. The general commercial rules for flying a drone for work purpose are listed below:

- Must hold a remote pilot certificate issued by the FAA to fly commercially.
- Register the UAV with the FAA on the FAA Drone Zone website.
- The UAV must weigh less than 55 pounds, including payload, at takeoff.
- Fly in Class G airspace.
- Must keep the UAV within visual line-of-sight.
- Fly at or below 400 feet.
- Fly during daylight or civil twilight.
- Fly at or under 100 mph.
- Yield right of way to manned aircraft.
- Must not fly directly over people.
- Must not fly from a moving vehicle, unless in a sparsely populated area.

Appendix D. Regulations on AMRs in the U.S.

Since some of these regulations can be restrictive for many companies testing prototypes, each state has its own regulations. On the other hand, to date, no federal laws exist in the U.S. regarding the operation of delivery robots on public sidewalks. However, a number of states and local municipalities have created legislation conditionally permitting delivery robot operations. The table below summarizes key points of existing regulations from a sample of major metropolitan areas as well as states.

Table D1: AMRs regulation per state or municipality in the U.S.

Jurisdiction	Date released	Testing limitation	Speed Limit (mph.)	Weight Limit (Lbs.)	Special Requirements
San Francisco, CA	5/12/17	Yes	3	Unlimited	Comprehensive general insurance for automotive and worker. Human operator must be within 30 ft. No more 3 robots per permit holder
Concord, CA	3/10/17	Yes	10	500	This permit was issued for the Company Marble, a similar one was issued for Starship in July 2017.Required minimum property damage insurance, personal injury and bodily injury $4,000,000. Required minimum automobile liability $1,000,000.
Redwood City, CA	11/13/2016	Yes	10	80	Required minimum commercial general liability insurance $4,000,000. Required minimum bodily/personal injury insurance $ 2,000,000. Required minimum property damage liability insurance $1,000,000 per accident, plus an automobile and workers comprehensive insurance
Austin, TX	10/08/17	Yes	10	300	Required minimum general liability insurance $1,000,000.
Washington, DC	08/10/16	Yes	10	50	In event of technology failure, the owner must retrieve the robot within a period of 24 hours.
	Proposed/ Waiting for approval	No	10	90	Required minimum public liability and property damage insurance. $1,000 permit fee per applicant
Virginia State	2/24/2017	Yes	10	50	Other jurisdictions in the state can prohibit but not further regulate delivery robots
Ohio State	9/29/2017	Yes	10	90	Other jurisdictions in the state may enact additional regulations that apply to the operation of delivery robots. Required minimum general liability insurance $ 100,000
Wisconsin State	6/212017	Yes	10	80	Other jurisdictions in the state can prohibit but not further regulate delivery robots
Florida State	6/23/2017	Yes	10	80	Other jurisdictions in the state may enact additional regulations that apply to the operation of delivery robots. Required minimum commercial general liability insurance $ 100,000
Idaho	3/24/2017	Yes	10	80	Other jurisdiction in the state may adopt additional regulations for safer operation of delivery robots on sidewalks

Appendix E. Regulations on electric bikes in U.S.

According to the federal Consumer Product Safety Act a "low speed electric bicycle" is a two- or three-wheeled vehicle with fully operable pedals, a top speed when powered solely by the motor under 20 mph (32 km/h), and an electric motor that produces less than 750 W (1hp.). The Act authorizes the Consumer Product Safety Commission to protect people who ride low-speed electric vehicles by issuing necessary safety regulations. However, the regulation on public streets is subject to state vehicle codes. The variations per state in the U.S. are summarized below.

Table E1: Electric bikes regulation per state in the U.S.

State	Identity	Type	Max speed (mph)	Max power	Helmet	Min age	Driver's License
Alabama	Motor-driven cycle	Motorcycle	None	150 cc	Motorcycle helmet required	14	Yes, M class [68]
Alaska	Motor-driven cycle	Motorcycle	None	50 cc		14	Yes, M class
Arizona	Motorized electric bicycle or tricycle	Bicycle	20	48 cc	No	None	No
Arkansas	Motorized bicycle	Bicycle	None	50 cc	Yes	10[citation needed]	Yes
California	Motorized Bicycle	Bicycle	20	750 W[69]	Class dependent	Class dependent	No
Colorado	Electrical assisted bicycle	Bicycle	20	750 W	No	None	No
Connecticut	Bicycle with helper motor		30	2.0 bhp (1.5 kW) and <50 cc	yes	15	yes
Delaware	Bicycle	Bicycle	20	<750 watts	Under 16		
District of Columbia	Motorized bicycle		20		No	16	No
Florida	Electric-assist bicycle	Bicycle	20	None	No	16	No
Georgia	Electric bicycle	Bicycle	20	1,000 W	Under 16		no
Hawaii	Moped		30	2 hp	No	15	Yes
Idaho	Motorized Electric Bicycle	Bicycle	30	< 2 brake hp	No	16	Yes, class D & liability Ins.
Illinois	Low-speed bicycle	Bicycle (625 ILCS 5/11-1516)	20	None	No	16	No
Indiana	motorized bicycle		25		yes if under 18	15	ID card
Iowa	Electric Bicycle	Bicycle	20, unless pedaling	<750 watts	No	None	No
Kansas	Electric with Pedal	Bicycle	Not street legal without registration, cannot register without VIN,	1000 Watts	yes, under 18		No

			cannot ride on sidewalk				
Kentucky	Motorized bicycle	Moped	30	2.0 brake hp or 50 cc	yes, under 18	16	yes
Louisiana	motorized bicycle		25	1.5 brake hp or 50 cc	yes	15	yes
Maine	Electric Bicycle [70]	Electric Bicycle	20 Class I & II, 28 Class III	750 Watts	yes, under 16	Minimum 16, for Class II & III	no
Maryland	Electric bicycle		20	500 watts	yes		no
Massachusetts	Motorized bicycle		25	50 cc, cannot go more than 30 mph	Yes	16	Yes
Michigan	Electric bicycle, generally not allowed on Mackinac Island		20 Class I & II, 28 Class III	750 Watts	yes for class III	14	No
Minnesota	Electric-Assisted Bicycle		20	1000w	No	15	No
Mississippi	Bicycle with a motor attached	Bicycle	None	None	No	None	No
Missouri		motor vehicle	30	750W or 50cc			yes
Montana	Bicycle	Bicycle	30	2.0 bhp and <=50cc or 500W	Yes, under 18(?), and under 16 in some cities		No, mopeds and bicycles do not require driver's license
		Definition 61-8-102(2)(b)(ii)					
Nebraska	Moped [71]	Motorized Bicycle with Pedals [71]	30 [71]	50cc or 2 bhp, whichever is less [71]	Yes [72]		Yes [73]
Nevada	Electric Bicycle (NRS 482.0287)	Bicycle	20 (motor only on the flat with 170LB rider, undefined if pedal assist is allowed to go faster)	750W (it is undefined as to whether this is input or output power, but in the USA, motors are rated on output power at the shaft)	No	none (use caution here because of "reckless endangerment" laws)	no (not a "motor vehicle")

New Hampshire	Low-Speed Electric Bicycle	Bicycle	20	750 watts	Required Under 16	14	no
New Jersey	motorized bicycle	moped	25	50 cc 1.5 brake hp	motorcycle helmet	15	yes
New Mexico		moped	30	50cc			yes
New York	Illegal, except "non-throttle controlled" 20mph e-bikes in NYC,NY as of July 2018						
North Carolina	Electric Assisted Bicycle[74]	Bicycle[74]	20[74]	750 W[74]	Under 16		No
North Dakota	motorized bicycle	motorcycle	2 brake hp	30	yes, under 18	14	yes
Ohio	Motorized bicycle	Bicycle	20	1 bhp (750 W) or 50cc		18 for class III	No
Oklahoma	Electric-Assisted Bicycle	Bicycle	30	1000 W	Under 19	16	Unclear. Class A, B, C, or D
Oregon	Electric assisted bicycle	Bicycle	20	1000 W	Under 16	16	No
Pennsylvania	Pedalcycle with electric assist	Bicycle	20	750 W	No	16	No
Rhode Island	electric bicycle		25 (30 for motorized bicycle)	2bhp (4.9bhp for motorized bicycle)		16	no (yes, for motorized bicycle)
South Carolina	moped					yes, under 14	yes
South Dakota		moped			yes, under 18		
Tennessee		750 W	20mph, 28mph for Class III		Yes, under 16 and all ages on Class III	14 for Class III	No
Texas	Electric bicycle	Bicycle	20(without pedaling)	None	No	None	No
Utah	Electric bicycle	Bicycle	20	750Watt	No	8 (accompanied by parent/guardian), 14 (unaccompanied)	No
Vermont	Motor-assisted bicycle	Motor-assisted bicycle	20 on the flat	1000W or 1.3hp	No	16	No
Virginia		moped	35mph	50cc		16	yes
Washington	electric-assisted bicycle	electric-assisted bicycle[75]	28[76]	750W[76]	No	16, for class III[76]	No

West Virginia	motorized bicycle	moped	30mph (25mph if 2018 WV-SB563 passes)	50cc 2hp (35cc or 1000W if 2018 WV-SB563 passes)	Yes,under age 16 on bicycles. Yes, all ages on mopeds. Motorcycle helmets on mopeds.	16 for moped	Yes (No, if 2018 WV-SB563 passes)
Wisconsin	electric motor bicycle	motor bike	20 mph (150lb rider on flat)	750 W			Yes
Wyoming		moped (Senate File 81 takes effect July 1, 2019 to redesignate into 3-class system of bicycles)	50cc (SF-81 changing to 750W)	30mph (SF-81 changing to 20mph & 28mph for class III)			Yes (SF-81 changing to No)

Source: https://en.wikipedia.org/wiki/Electric_bicycle_laws#cite_note-65

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Appendix F. Regulations on autonomous vehicles in the U.S.

In the U.S., the federal government regulates the equipment and performance of autonomous vehicles (*44*) while states are in charge of regulating the use and licenses. Below are a summary of the bills of the state with current legislation about the operation of autonomous vehicles.

Table F1: Autonomous vehicles regulations per state in the U.S.

STATE	BILL NUMBER	RELEVANT PROVISION
Alabama	SB 125(2018)	Defines a truck platoon as "A group of individual commercial trucks traveling in a unified manner at electronically coordinated speeds at following distances that are closer than would be reasonable and prudent without the electronic coordination." The bill also exempts the trailing trucks in a truck platoon from the state's following too closely provisions if the truck platoon is engaged in electronic brake coordination and any other requirement imposed by the Department of Transportation by rule.
Alabama	SJR 81(2016)	Established the Joint Legislative Committee to study self-driving vehicles.
Arkansas	HB 1754(2017)	Regulates the testing of vehicles with autonomous technology, relates to vehicles equipped with driver-assistive truck platooning systems.
California	SB 1298(2012)	Requires the Department of the California Highway Patrol to adopt safety standards and performance requirements to ensure the safe operation and testing of autonomous vehicles, as defined, on the public roads in this state. Permits autonomous vehicles to be operated or tested on the public roads in this state pending the adoption of safety standards and performance requirements that would be adopted under this bill.
California	AB 1592 (2016)	Authorizes the Contra Costa Transportation Authority to conduct a pilot project for the testing of autonomous vehicles that are not equipped with a steering wheel, a brake pedal, an accelerator, or an operator inside the vehicle, if the testing is conducted only at specified locations and the autonomous vehicle operates at specified speeds.
California	AB 669(2017)	Extends the sunset date of the law allowing the testing of vehicle platooning with less than 100 feet between each vehicle from January 2018 to January 2020. Prohibits someone from participating in the testing unless drivers hold a valid driver's license for the class of vehicle.
California	AB 1444(2017)	Authorizes the Livermore Amador Valley Transit Authority to conduct a shared autonomous vehicle demonstration project for the testing of autonomous vehicles that do not have a driver seat in the driver's seat and are not equipped with a steering wheel, a brake pedal, or an accelerator.
California	SB 145(2017)	Repeals a requirement that the Department of Motor Vehicles notifies the Legislature of receipt of an application seeking approval to operate an autonomous vehicle capable of operating without the presence of a driver inside the vehicle on public roads. Repeals the requirement that the approval of such an application is not effective any sooner than a specified number of days after the date of the application.
California	SB 1 (2017)	This bill encourages the California Department of Transportation and cities and counties to, when possible, cost-effective and feasible, use funds under the Road Maintenance and Rehabilitation Program to use advanced technologies and communications systems in transportation infrastructure that recognize and accommodate advanced automotive technologies that may include, but are not necessarily limited to, charging or fueling opportunities for zero-emission vehicles, and provision of infrastructure-to-vehicle communications for transitional or fully autonomous vehicle system
California	AB 87(2018)	Authorizes law enforcement or a public employee who is engaged in directing traffic or enforcing parking laws and regulations, to remove a vehicle that uses autonomous technology without a valid permit that is required to operate the vehicle on public roads. The bill authorizes the release of the vehicle after the registered owner of, or person in control of, the autonomous vehicle furnishes the storing law enforcement agency with proof of current registration and a valid driver's license. Also either a valid permit that is required to operate the autonomous vehicle using autonomous technology on public roads or a declaration or sworn statement to the Department of Motor Vehicles that states that the autonomous vehicle will not be operated using autonomous technology, as specified.
California	AB 1184	Authorizes the City of San Francisco to, if approved by voters, levy a tax on trips taken in autonomous vehicles that originate within the City and County of San Francisco provided by a transportation network company, i.e. TNC. Such taxes may be up to 3.25 percent of the fare for each trip. The bill includes some limiting and optional conditions to such fees, including: (1) discounted fee shall be charged to any shared trip (i.e. greater than one passenger) not to exceed 1.5 percent of the total fare. The city may charge a lower rate for trips taken in zero-emission vehicles; revenues collected from such a fee would be required to fund transportation operations or infrastructure and the authority is sunset in 2045.

Colorado	SB 213(2017)	Defines automated driving system, dynamic driving task and human operator. Allows a person to use an automated driving system to drive or control a function of a motor vehicle if the system is capable of complying with every state and federal law that applies to the function that the system is operating. Requires approval for vehicle testing if the vehicle cannot comply with every relevant state and federal law. Requires the department of transportation to submit a report on the testing of automated driving systems.
Connecticut	SB 260(2017)	Defines terms including “fully autonomous vehicle,” “automated driving system,” and “operator.” Requires the development of a pilot program for up to four municipalities for the testing of fully autonomous vehicles on public roads in those municipalities. Specifies the requirements for testing, including having an operator seated in the driver’s seat and providing proof of insurance of at least $5 million. Establishes a task force to study fully autonomous vehicles. The study must include an evaluation of NHTSA’s standards regarding state responsibility for regulating AVs, an evaluation of laws, legislation and regulations in other states, recommendations on how Connecticut should legislate and regulate AVs, and an evaluation of the pilot program.
Florida	HB 1207(2012)	Defines “autonomous vehicle” and “autonomous technology.” Declares legislative intent to encourage the safe development, testing and operation of motor vehicles with autonomous technology on public roads of the state and finds that the state does not prohibit or specifically regulate the testing or operation of autonomous technology in motor vehicles on public roads. Authorizes a person who possesses a valid driver's license to operate an autonomous vehicle, specifying that the person who causes the vehicle’s autonomous technology to engage is the operator. Authorizes the operation of autonomous vehicles by certain persons for testing purposes under certain conditions and requires an instrument of insurance, surety bond or self-insurance prior to the testing of a vehicle. Directs the Department of Highway Safety and Motor Vehicles to prepare a report recommending additional legislative or regulatory action that may be required for the safe testing and operation of vehicles equipped with autonomous technology, to be submitted no later than Feb. 12, 2014.
Florida	HB 599(2012)	The relevant portions of this bill are identical to the substitute version of HB 1207.
Florida	HB 7027(2016)	Permits operation of autonomous vehicles on public roads by individuals with a valid driver license. This bill eliminates the requirement that the vehicle operation is being done for testing purposes and removes a number of provisions related to vehicle operation for testing purposes. Eliminates the requirement that a driver is present in the vehicle. Requires autonomous vehicles meet applicable federal safety standards and regulations.
Florida	HB 7061(2016)	Defines autonomous technology and driver-assistive truck platooning technology. Requires a study on the use and safe operation of driver-assistive truck platooning technology and allows for a pilot project upon conclusion of the study.
Georgia	HB 472(2017)	Specifies that the law prohibiting following too closely does not apply to the non-leading vehicle in a coordinated platoon. Defines coordinated platoon as a group of motor vehicles traveling in the same lane utilizing vehicle-to-vehicle communication technology to coordinate automatically the movement of the vehicles.
Georgia	SB 219(2017)	Defines automated driving system, dynamic driving task, fully autonomous vehicle, minimal risk condition and operational design domain. Exempts a person operating an automated motor vehicle with the automated driving system engaged from the requirement to hold a driver's license. Specifies conditions that must be met for a vehicle to operate without a human driver present in the vehicle, including insurance and registration requirements.
Illinois	HB 791(2017)	Preempts local authorities from enacting or enforcing ordinances that prohibit the use of vehicles equipped with Automated Driving Systems. Defines “automated driving system-equipped vehicle.”
Indiana	HB 1290 (2018)	Defines “Vehicle platoon" to mean a group of motor vehicles that are traveling in a unified manner under electronic coordination at speeds and following distances that are faster and closer than would be reasonable and prudent without electronic coordination. The bill clarifies vehicle platooning is exempt from the following too close provisions of three hundred feet. The bill also lays out an approval system for vehicle platooning in the state, including requiring the person or organization to file a plan for general vehicle platoon operations with the transportation commissioner.
Kentucky	SB 116(2018)	This bill allows a motor carrier to operate a platoon on Kentucky’s highways if the motor carrier provides notification to the Department of Vehicle Regulation and the Kentucky State Police, including a plan for general platoon operations. The Department of Vehicle Regulation then has thirty days from the date of receipt to review the notification plan submitted and approve or reject the plan. If the department rejects a submitted plan, it must inform the motor carrier of the reason for the rejection and provide guidance on how to resubmit the notification and plan to meet the standards. Only commercial motor vehicles shall be eligible to operate in a platoon. An appropriately endorsed driver who holds a valid commercial driver's license shall be present behind the wheel of each commercial motor vehicle in a platoon. A commercial motor vehicle involved in a platoon shall not draw another motor vehicle in the platoon. Each commercial motor vehicle involved in a platoon shall display a marking warning other motorists and law enforcement that the vehicle may be part of a

		platoon. The department shall promulgate administrative regulations to set forth procedures for platooning, including required elements of a platooning plan.
Louisiana	HB 1143(2016)	Defines "autonomous technology" for purposes of the Highway Regulatory Act.
Louisiana	HB 308 (2018)	Defines "Platoon" or "platooning" to mean a group of individual motor vehicles, including any truck, truck-tractor, trailer, semitrailer, or any combination of these vehicles, utilizing vehicle-to-vehicle communication technology to travel in a unified manner at close following distances. A platoon may be operated if the platoon operator submits an operational plan. The plan must be approved by the Department of Public Safety and Corrections, office of state police, and the Department of Transportation and Development and the same agencies may promulgate rules to implement these provisions. The provisions of this bill do not apply to the operation of a non-lead motor vehicle in a platoon. The operation of a platoon is not authorized on a two-lane highway.
Maine	HP 1204(2018)	This bill created the Commission on Autonomous Vehicles to coordinate efforts among state agencies and knowledgeable stakeholders to inform the development of a process to allow an autonomous vehicle tester to demonstrate and deploy for testing purposes an automated driving system on a public way. The commission will consist of at least 11 members. The commission shall: (1) Develop a recommendation for a process to evaluate and authorize an autonomous vehicle tester to demonstrate and deploy for testing purposes an automated driving system on a public way. (B) Review existing state laws and, if necessary, recommend legislation for the purposes of governing autonomous vehicle testers and the testing, demonstration, deployment and operation of automated driving systems on public ways. (C) Monitor state compliance with federal regulations as they relate to autonomous vehicles. (D) Consult with public sector and private sector experts on autonomous vehicle technologies, as appropriate; and (E) Invite the participation of knowledgeable stakeholders to provide written and oral comments on the commission's assigned duties.
Michigan	SB 995 (2016)	Allows for autonomous vehicles under certain conditions. Allows operation without a person in the autonomous vehicle. Specifies that the requirement that commercial vehicles maintain a minimum following distance of 500 feet does not apply to vehicles in a platoon.
Michigan	SB 996 (2016)	Allows for autonomous vehicles under certain conditions. Allows operation without a person in the autonomous vehicle.
Michigan	SB 997 (2016)	Defines automated driving system. Allows for the creation of mobility research centers where automated technology can be tested. Provides immunity for automated technology manufacturers when modifications are made without the manufacturer's consent.
Michigan	SB 998 (2016)	Exempts mechanics and repair shops from liability on fixing automated vehicles.
Michigan	SB 169(2013)	Defines "automated technology," "automated vehicle," "automated mode," expressly permits testing of automated vehicles by certain parties under certain conditions, defines operator, addresses liability of the original manufacturer of a vehicle on which a third party has installed an automated system, directs state DOT with Secretary of State to submit report by Feb. 1, 2016.
Michigan	SB 663(2013)	Limits liability of vehicle manufacturer or up fitter for damages in a product liability suit resulting from modifications made by a third party to an automated vehicle or automated vehicle technology under certain circumstances; relates to automated mode conversions.
Mississippi	HB 1343(2018)	This bill defines “Platoon” to mean a group of individual motor vehicles traveling in a unified manner at electronically coordinated speeds at following distances that are closer than would be reasonable and prudent without such coordination. The bill also creates an exemption from the state’s following too closely traffic law for the operator of a nonleaded vehicle in a platoon, if the platoon is operating on a limited access divided highway with more than one lane in each direction and the platoon consists of no more than two motor vehicles.
Nevada	AB 511(2011)	Authorizes operation of autonomous vehicles and a driver’s license endorsement for operators of autonomous vehicles. Defines “autonomous vehicle” and directs state Department of Motor Vehicles (DMV) to adopt rules for license endorsement and for operation, including insurance, safety standards and testing.
Nevada	SB 140(2011)	Prohibits the use of cell phones or other handheld wireless communications devices while driving in certain circumstances, and makes it a crime to text or read data on a cellular phone while driving. Permits use of such devices for persons in a legally operating autonomous vehicle. These persons are deemed not to be operating a motor vehicle for the purposes of this law.
Nevada	SB 313(2013)	Relates to autonomous vehicles. Requires an autonomous vehicle that is being tested on a highway to meet certain conditions relating to a human operator. Requires proof of insurance. Prohibits an autonomous vehicle from being registered in the state, or tested or operated on a highway within the state, unless it meets certain conditions. Provides that the manufacturer of a vehicle that has been converted to be an autonomous vehicle by a third party is immune from liability for certain injuries.
Nevada	AB 69(2017)	Defines terms including “driver-assistive platooning technology,” “fully autonomous vehicle” and “automated driving system.” Allows the use of driver-assistive platooning technology on highways in the state. Preempts local regulation. Requires the reporting of any crashes to the department of

		motor vehicles within 10 days if the crash results in personal injury or property damage greater than $750. Allows a fine of up to $2,500 to be imposed for violations of laws and regulations relating to autonomous vehicles. Permits the operation of fully autonomous vehicles in the state without a human operator in the vehicle. Specifies that the original manufacturer is not liable for damages if an unauthorized third party has modified a vehicle. Allows the DMV to adopt certain regulations relating to autonomous vehicles. Defines "driver," for purposes of an autonomous vehicle, to be the person who causes the automated driving system to engage. Specifies that the following distance requirement does not apply to a vehicle using platooning technology. Imposes an excise tax on the connection of a passenger to a fully autonomous vehicle for providing transportation services. Specifies requirements for autonomous vehicle network companies, including a permitting requirement, prohibitions on discrimination, and addressing accessibility. Permits the use of autonomous vehicles by motor carriers and taxi companies if certain requirements are met.
Nebraska	LB 989(2018)	This bill defines automated driving system and other relevant terms. The bill states that a driverless-capable vehicle may operate on public roads in the state without a conventional human driver physically present in the vehicle, as long as the vehicle meets specific conditions. (1) The vehicle is capable of achieving a minimal risk condition if a malfunction of the automated driving system occurs that renders the system unable to perform the entire dynamic driving task within its intended operational design domain, if any. (2) While in driverless operation, the vehicle is capable of operating in compliance with the applicable traffic and motor vehicle safety laws and regulations of this state that govern the performance of the dynamic driving task, including, but not limited to, safely negotiating railroad crossings, unless an exemption has been granted by the department of motor vehicles (DMV). The DMV shall consult with the railroad companies operating in the state when considering an exemption that affects vehicle operations at railroad crossings.
New York	SB 2005(2017)	Allows the commissioner of motor vehicles to approve autonomous vehicle tests and demonstrations. Requires supervision from the state police for testing. Specifies requirements for operation, including insurance of five million dollars. Defines autonomous vehicle technology and dynamic driving task. Requires a report on testing and demonstration.
New York	AB 9508(2018)	This bill amends SB 2005 of 2017 (see above) to add additional language regarding autonomous vehicle demonstrations and tests. Such tests and demonstrations shall only take place under the direct supervision of the New York state police and in a form and manner prescribed by the superintendent of the New York state police. Additionally, a law enforcement interaction plan shall be included as part of the demonstration and test application that includes information for law enforcement and first responders regarding how to interact with such a vehicle in emergency and traffic enforcement situations.
North Carolina	HB 469(2017)	Establishes regulations for the operation of fully autonomous motor vehicles on public highways of this state. Defines terms. Specifies that a driver's license is not required for an AV operator. Requires an adult be in the vehicle if a person under 12 is in the vehicle. Preempts local regulation. Establishes the Fully Autonomous Vehicle Committee.
North Carolina	HB 716(2017)	Modifies the follow-too-closely law to allow platooning.
North Dakota	HB 1065(2015)	Provides for a study of autonomous vehicles. Includes research into the degree that automated motor vehicles could reduce traffic fatalities and crashes by reducing or eliminating driver error and the degree that automated motor vehicles could reduce congestion and improve fuel economy.
North Dakota	HB 1202(2017)	Requires the department of transportation to study the use of vehicles equipped with automated driving systems on the highways in this state and the data or information stored or gathered by the use of those vehicles. Also requires that the study include a review of current laws dealing with licensing, registration, insurance, data ownership and use, and inspection and how they should apply to vehicles equipped with automated driving systems.
Oregon	HB 4059(2018)	This bill exempts a person operating a vehicle that is part of a connected automated braking system from the traffic offense of following too closely. "Connected automated braking system" is defined as "a system that uses vehicle-to-vehicle communication to electronically coordinate the braking of a lead vehicle with the braking of one or more following vehicles."

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Oregon	HB 4063(2018)	This bill establishes a Task Force on Autonomous Vehicles and clarifies that the state Department of Transportation is the lead agency responsible for coordination of autonomous vehicle programs and policies. The Task Force will consist of 31 members, including two members from the Senate and two members from the House, with each chamber represented by one member of each party. Members of the legislature appointed to the task force are nonvoting members and may act in an advisory capacity only. The task force shall develop recommendations for legislation to be introduced during the next odd-numbered year regular session of the Legislative Assembly regarding the deployment of autonomous vehicles on highways. The proposed legislation shall be consistent with federal law and guidelines and shall address the following issues: (A) Licensing and registration; (B) Law enforcement and accident reporting; (C) Cybersecurity; and (D) Insurance and liability. The task force may study and consider the potential long-term effects of autonomous vehicle deployment to be addressed in future legislation, including the following: (a) Land use; (b) Road and infrastructure design; (c) Public transit; (d) Workforce changes; or (e) State responsibilities relating to cybersecurity and privacy. The task force must submit a report with recommendations for legislation to the appropriate interim committee of the legislature related to transportation no later than September 15, 2018.
Pennsylvania	SB 1267(2016)	Allows the use of allocated funds, up to $40,000,000, for intelligent transportation system applications, such as autonomous and connected vehicle-related technology, in addition to other specified uses.
Pennsylvania	HB 1958 (2018)	This bill defines a “Platoon” as a group of motor vehicles, buses, military vehicles or motor carrier vehicles operated by a human traveling in a unified manner at electronically coordinated speeds at following distances that are closer than would be reasonable and prudent without such coordination. Clarifies this does not include a school bus or school vehicle. Defines a “Highly automated work zone vehicle” as a motor vehicle equipped either with an automated driving system or connected by wireless communication or other technology to another vehicle allowing for coordinated or controlled movement, used in an active work zone as implemented by PennDOT or the PA Turnpike Commission. Lastly, the bill establishes the Highly Automated Vehicle Advisory Committee within PennDOT, which must report annually on their activities and post on PennDOT's website.
South Carolina	HB 3289(2017)	Specifies that minimum following distance laws for vehicles traveling along a highway does not apply to the operator of any non-leading vehicle traveling in a platoon.
Tennessee	SB 598(2015)	Relates to motor vehicles. Prohibits local governments from banning the use of motor vehicles equipped with autonomous technology.
Tennessee	SB 2333(2016)	Allows a motor vehicle to be operated, or to be equipped with, an integrated electronic display visible to the operator while the motor vehicle's autonomous technology is engaged.
Tennessee	SB 1561(2016)	Redefines "autonomous technology" for purposes of preemption. Defines "driving mode" and "dynamic driving task."
Tennessee	SB 676(2017)	Permits the operation of a platoon on streets and highways in the state after the person provides notification to the department of transportation and the department of safety.
Tennessee	SB 151(2017)	Creates the “Automated Vehicles Act.” Defines a number of terms. Modifies laws related to unattended motor vehicles, child passenger restraint systems, seat belts, and crash reporting in order to address ADS-operated vehicles. Specifies that ADS-operated vehicles are exempt from licensing requirements. Permits ADS-operated vehicles on streets and highways in the state without a driver in the vehicle if it meets certain conditions. Preempts local regulation of ADS-operated vehicles. Specifies that the ADS shall be considered a driver for liability purposes when it is fully engaged and operated properly. Makes it a class A misdemeanor to operate a motor vehicle on public roads in the states without a human driver in the driver’s seat without meeting the requirements of this Act. Specifies that this Act only apply to vehicles in high or full automation mode.
Texas	HB 1791(2017)	Allows the use of a connected braking system in order to maintain the appropriate distance between vehicles. Specifies that "connected braking system" mean a system by which the braking of one vehicle is electronically coordinated with the braking system of following a vehicle.
Texas	SB 2205(2017)	Defines a number of terms, including “automated driving system,” “automated motor vehicle,” “entire dynamic driving task” and “human operator.” Preempts local regulation of automated motor vehicles and automated driving systems. Specifies that the owner of an automated driving system is the operator of the vehicle when the system is engaged and the system is considered licensed to operate the vehicle. Allows an automated motor vehicle to operate in the state regardless of whether a human operator is present in the vehicle, as long as certain requirements are met.
Utah	HB 373(2015)	Authorizes the Department of Transportation to conduct a connected vehicle technology-testing program.
Utah	HB 280(2016)	Requires a study related to autonomous vehicles, including evaluating NHTSA and AAMVA standards and best practices, evaluating appropriate safety features and regulatory strategies and developing recommendations.

Utah	SB 56(2018)	This bill amended HB 373 of 2015 (see above) to define a "connected platooning system" to mean a system that uses vehicle-to-vehicle communication to electronically coordinate the speed and braking of a lead vehicle with the speed and braking of one or more following vehicles.
Virginia	HB 454(2016)	Allows the viewing of a visual display while a vehicle is being operated autonomously.
Vermont	HB 494(2017)	Requires the department of transportation to convene a meeting of stakeholders with expertise on a range of topics related to automated vehicles. The secretary of transportation must report to the House and Senate committees on transportation regarding the meetings and any recommendations related to automated vehicles, including proposed legislation.
Washington	HB 2970 (2018)	The Washington State Transportation Commission must convene an executive and legislative work group to develop policy recommendations to address the operation of autonomous vehicles on public roadways in the state.
Washington, D.C.	DC B 19-0931 (2012)	Defines "autonomous vehicle" as "a vehicle capable of navigating District roadways and interpreting traffic-control devices without a driver actively operating any of the vehicle's control systems." Requires a human driver "prepared to take control of the autonomous vehicle at any moment." Restricts conversion to recent vehicles, and addresses the liability of the original manufacturer of a converted vehicle.
Washington, D.C.	DC B22-0901 (2018)	By July 1, 2019, the District Department of Transportation, in consultation, as needed, with the Office of the Chief Financial Officer or other District agencies or organizations such as DC Surface Transit, shall make publicly available a study that evaluates and makes recommendations regarding the effects of autonomous vehicles on the District. (1) The effect on the District's economy, including economic development and employment. (2) The impact on the District government's revenue, including motor vehicle excise taxes, motor vehicle registration fees, motor vehicle fuel taxes, residential parking permit fees, parking meter revenue, fines and fees relating to moving infractions or parking, standing, stopping, and pedestrian infractions, and commercial parking taxes. (3) The impact on the District's infrastructure, traffic control systems, road use, congestion, curbside management, and public space. (4) The impact on the District's environment and public health. (5) The impact on public safety in the District, including the safety of other road users such as pedestrians and bicyclists. (6) The impact on the District's disability community. (7) The impact on the various transportation modes in the District, including mass transit, shared-use vehicles, and public and private vehicles-for-hire. (8) The need for and use of autonomous vehicle data, including data from autonomous vehicle manufacturers and public and private vehicle-for-hire companies.
Wisconsin	SB 695(2018)	This bill defines a "platoon" as a group of individual motor vehicles traveling in a unified manner at electronically coordinated speeds. This bill creates an exception for platoons to the traffic law requiring the operator of a motor truck with a gross weight of more than 10,000 pounds to maintain a distance of not less than 500 feet behind the vehicle immediately preceding.

Appendix G. Crowdshipping Initiatives

Amazon Flex

Amazon initiated this service in Seattle in September 2015 to handle Prime Now's one- and two-hour deliveries (*86*). The service is currently available in more than 50 cities across the U.S. Crowdshippers choose their time shift and get paid per shift with an hourly average of $18-25 depending on the region, time of day and number of deliveries. Payments tend to change due to weather conditions or special events. Crowds must have at least a mid-sized sedan or truck and van. Some locations are eligible to deliver by bike with a basket. Through Amazon Flex, drivers will be responsible for delivering packages or food through several services, including Amazon.com packages, Prime Now, AmazonFresh, and Amazon Restaurants (*87*).

Uber Rush

This on-demand same-day delivery service started in NY in 2014 to deliver items of no more than 30 pounds in size. It was initialized with a fleet of bike couriers, and then included personal vehicle drivers as well. Later in 2015, the service was extended to SF and Chicago. The services and prices change depending on location and distance. In Uber Rush, customers are charged between $5 to $7 for the first mile and an additional fee of $2 to $4 per extra mile, depending on the delivery region. Couriers receive 75% to 80% of the total fee, making $20-30 per hour on average. Early in 2017, Uber shifted its food delivery to another new on-demand service named Uber Eat (described next). Afterward, it never expanded beyond those three cities and ultimately, shut down in June 2018. There were several reasons behind this shut down, most importantly high opportunity costs for the driver.

Uber uses the same pool of labor for its various services, while all these services have different strategic and economic values. Uber ride is the most economically promising, and is the core focus of the company. In Uber Eat, partnered restaurants pay Uber 30% of the order value because it is marketing their food. However, Uber Rush was only a delivery service without any opportunity for the company to make side money out of it. Thus, when a driver/biker was committed to an Uber Rush delivery, they can no longer serve a higher value task in the passenger or food market at the same time, which is considered a very high opportunity cost. Another critical factor is the stochastic nature of parcel deliveries, which makes the supply allocation difficult. The popularity of passenger services makes tremendous data available to the company to predict future demand. For Uber Eat, demand prediction is more straightforward, as it will be during lunch and dinner time for the most part. However, delivery requests are highly random, which makes supply matching almost impossible. This uncertainty in demand discourages drivers/couriers from signing up, which causes for the company a supply shortage, which limits its ability to provide fast shipping and attract enough demand to be profitable.

Uber Eat

Uber Eat is a food delivery service founded in 2014 where demand is matched with food. Customers can select different food items from the menu, place their orders, make their payment and track the food preparation and delivery process online. There are two types of delivery, depending on the operation area: 1) curbside delivery, where drivers hand over the order without getting out of the car; and 2) walk-in drop-off delivery, where the driver has to get out of the car and walk into the customer's location to hand over the order. Uber Eat started the service with a flat fee of $3.99-4.99 per order; it then set a pricing tool that calculates the fee according to the delivery distance and number of available couriers. It also includes 15-25% of order subtotal as service fee and small order fee for orders less than $10. Couriers are paid similarly to Uber Ride service, with base fare as well as per minute and mile rates. Uber Eat drivers can expect to earn between $8 to $12 per hour after factoring in vehicle expenses. Tips might also add to the final payments.

Deliv

This service was founded in Menlo Park, California, in 2012, fostering same-day delivery for retailers (e.g., Macy's, and Best Buy) as well as small businesses (or individuals) in 35 locations across the U.S.. Deliv also developed two other services, Deliv Fresh and Deliv RX, for fresh food and medical item deliveries, respectively. Payment is based on both an hourly rate, typically $13–18, and a mileage rate of at least $0.50/mile. Deliv drivers can expect to make $15–22 per hour in total, with a guaranteed minimum payment. Deliv has a significant number of working crowds (potential delivery personnel) that fit the platform well for fast and high volume of deliveries.

Shyp

This was founded in San Francisco, California, in 2013, to ease the shipment process for individuals and businesses. Using the Shyp app, individuals send a photo of the item they want to ship and set a pickup location. Shyp agents pick the item up (packed/unpacked) and pack it (if needed) and ship it to UPS/FedEx for a $5 flat fee. Shyp also provides Shyp Return service to return customers' online purchases to e-retailers like Amazon or Target. It also integrated with eBay to ship things quickly and efficiently. In response to the wide range of package sizes people send, the company introduced fees that could vary based on the item size, which diminished the service attractiveness for some of its customers. Depending on location, a Shyp courier and packager could earn an average hourly rate of $17 and $14, respectively. The company was among the first on-demand start-ups to turn its contractors into employees; however, the start-up faced difficulties with profitability and ceased operations in March 2018.

DHL MyWays

In 2013, DHL launched a platform to facilitate LMD in Stockholm using a mobile app that connects individuals requesting a delivery with those who are willing to deliver a parcel on their daily itinerary for a small fee. Deliverers are independent in their mode choice of delivery. The pricing is flexible, where the platform recommends a base price for a task, but users can increase it to find their preferred match courier. Platform charges 10% of the final price as its maintenance fee. Stockholm residents embraced the flexibility of deliveries and feel that it benefits the environment as well as making small income for students. The pilot ended at the end of 2013 (*88*).

Postmates

Postmates was Launched in SF in 2011 as a pioneer for America's on-demand fast delivery service operating in 3,500 cities across 50 states. It has the largest on-demand delivery fleet, estimated to be more than 150,000 dedicated couriers. It can deliver almost anything; however, food-delivery represents a significant portion of its business. Couriers' income is comprised of base and per km fares with a guaranteed minimum payment variable depending on the delivery region. Postmates also implements surge (blitz) pricing for its rush-hour deliveries. Customers are charged depending on their membership status (e.g. unlimited members do not pay Blitz pricing or delivery fees on orders over $15) and merchant type (e.g. $0.99–$3.99 for Partner Merchants and $5.99–$9.99 for all other merchants). The platform charges a variable percentage-based service fee as its maintenance cost. The service is reported to be popular among millennials, who represent about 75% of its customers. Recently, Postmates announced launching a new feature called "Party," which lets customers shared the delivery service with others who are ordering at the same time within their neighborhood to get free delivery (*89*). Another innovation revealed recently is the development of a small automated robot that runs on electricity with walking speeds appropriate for small, short distance delivery tasks in San Francisco (*90*).

Instacart

Instacart was founded in SF in 2012, operating as a sometimes-same-day grocery delivery service. Customers purchase items through a web application from various local retailers, and a personal shopper delivers the order within one or two hours. Since 2017, the service has also operated in Toronto and Vancouver, Canada. Delivery fees consist of a default base fee of $3.99 per order of $35 or more plus a 5% service fee. There are various membership subscriptions for customers depending on whether they pay portion of the total price (e.g. Instacart express members enjoy free delivery on orders of $35 or more with annual $99 membership fee). There is a limit of $10 minimum purchase. Couriers can be either in-store shoppers or shipper. In the former case, there is no vehicle required but in the latter, they must have access to a vehicle. It is estimated that couriers earn between $7 to $20 per hour, with an average of $11 per hour. During periods of high order demand, Instacart charges customers an extra "Busy Pricing" service fee, which increases drivers' income in return. However, no hourly guaranteed price is applied (*91*).

Shipt

This is another platform similar to Instacart for grocery deliveries founded in Alabama in 2014. Later in 2017, Target announced it would acquire Shipt to improve its same-day shipping capabilities. However, the company continued to form delivery partnerships with retailers in addition to Target. A unique feature of this service is that customers can contact the shopper via text to make adjustments and get live updates from the store aisles. There are different monthly and annual membership subscription types available for customers to select. Delivery is free for members with orders over $35, and $7 for smaller orders, plus a service fee. Shipt prices may vary slightly from in-store prices to cover the costs of picking, packing, and processing. It is estimated that drivers earn $15 to $25 per hour. According to drivers' experiences, one way to compensate for fuel costs is to get discounts by scanning personal fuel cards while shopping for others. The company requires the shopper to have a car and pass a background check.

Doordash

Doordash Is an on-demand restaurant delivery platform that was initially developed in San Francisco in 2013 by Stanford university students. Using the Doordash app, users place an order for food from their favorite restaurants, and a delivery person brings it to them. There are a variety of restaurants (national, chain, and local) available through Doordash. There is no specific restriction on the delivery mode. However, Doordash offers a generous commercial auto insurance policy for drivers. DoorDash has other benefits for its occasional couriers as well. It protects them from rude or threatening customers through its employment policy. As incentives, DoorDash drivers are provided two free meals and drinks during the flexible working hours, and a periodic bonus in the form of DoorDash gift cards. Drivers can earn up to $25 with a guaranteed amount of $1. The average fee per order is about $5 to $8, depending on the distance traveled, time of day and the company's relationship with the restaurant where the order has been placed, plus extra fees during rush hours (*92*). The platform takes about 20% of the order as a service fee. Tips can be added to the rates if they are in cash, otherwise, it is not clear which portion of income is from tips and which portion is from DoorDash (*93*).

Walmart

Walmart is a multinational retail corporation that operates a chain of hypermarkets, department, and grocery stores. The company has been testing various plans to foster its online ordered package delivery service and reduce its LMD cost. Early in 2017, Walmart started a test in New Jersey, in which its employees volunteer-delivered groceries to customers on their way home after regular working hours. An app was built to allow them to set preferences, such as the number of packages they can deliver, their size and weight as well as their available schedule. The package assignment was based on minimizing the driver's collective detour distance from their final destination. The shifts continued until 9:00 PM and started at $11 per hour. Initially, employees enjoyed earning more cash on their way home, free/discounted electronic items offered by Walmart and unexpectedly finding new, quicker routes home. However, the pilot ended within a few months, as it could not attract enough employees to participate. The main concern among employees was over liability and security issues, as well as long waiting times and unattended packages (*94*).

In another test in 2013, Walmart asked in-store customers to deliver online ordered packages. Customers could get a discount on their purchases, and this might motivate them to shop more, benefiting the store in return. However, similar to the previous test, there were barriers to the plan, such as reliability, security, and liability (*95*). Similar to the Amazon locker idea, Walmart started testing lockers for its online customers in 2013. It worked as such that if a customer made a purchase online, he or she would have two weeks to pick it up from a locker at a nearby store via an access code provided with the purchase (*95*). With the goal of seamless shopping experiences, Walmart has collaborated with several other different crowdsource delivery services too. It started a partnership with Postmates in June 2018 to provide same-day deliveries of groceries to customers in Charlotte, NC for a $9.93 fee and a $30 minimum order. Ford recently announced an intention to team up with these two to test its automated robot deliveries in Miami, Florida. In late July 2018, the company announced a partnership with Waymo — formerly Google's self-driving car project — to test an online grocery service in which driverless vehicles pick up customers at their homes and take them to the store to collect their orders. In September 2018, Walmart collaborated with Sparke Delivery to foster its same-day delivery of online grocery orders. Toward this end, drivers use a platform to sign up for delivery time shifts that work with their schedule, and get information on order details and navigation. Partnerships with U.S. Deliv, Doordash, and TNC (i.e., Uber and Lyft) are also among Walmart's practices to foster its LMD (*96*).

Roadie

Roadie is a delivery platform founded in Atlanta in 2014 to match drivers (on their daily commute or cross-country trips) with individuals or retailers (such as Macys, Home Depot and Delta) for regional and last-mile deliveries. Currently it has 90,000 drivers on the platform that can expect to earn anywhere from $12 to $650 per job, depending on the size/weight of the package, need for care (e.g., pet) and the delivery distance. Roadie makes money by taking on average 20% out of each transaction.

Rappi

This is a popular platform for crowdsourcing deliveries in Latin America, which was founded in 2015 by a restaurant-delivery business in Colombia's capital, Bogota. It now includes a large crowd of bikers who deliver everything from grocery orders to health care items. The company expanded into Peru, Argentina, Chile, and Uruguay and was active in 35 cities as of the end of 2018. The delivery fee per order is slightly more than $1 including tips. There is a minimum payment of 50 cents, and the platform charges 17% as a transaction fee per order. The company keeps growing and attracting significant fundraisers.

Nimber

A matching platform for deliveries in the UK and Norway, where crowds utilize their capacity to deliver senders' items. The Nimber platform allows senders to post their pick-up and delivery locations and dates/times, as well as other information about the item(s) that must be shipped. Deliverers then bid over the offer, and the sender accepts the best bid.

Renren Kuaidi

This China-based crowdsourced delivery service funded in 2011 allows anyone who meets the eligibility requirements to sign up to be a courier for local store delivery tasks. Couriers can choose to deliver packages by bike, scooter, car, bus, or even on foot. Currently, it is active in six Chinese cities, including Beijing and Shanghai.