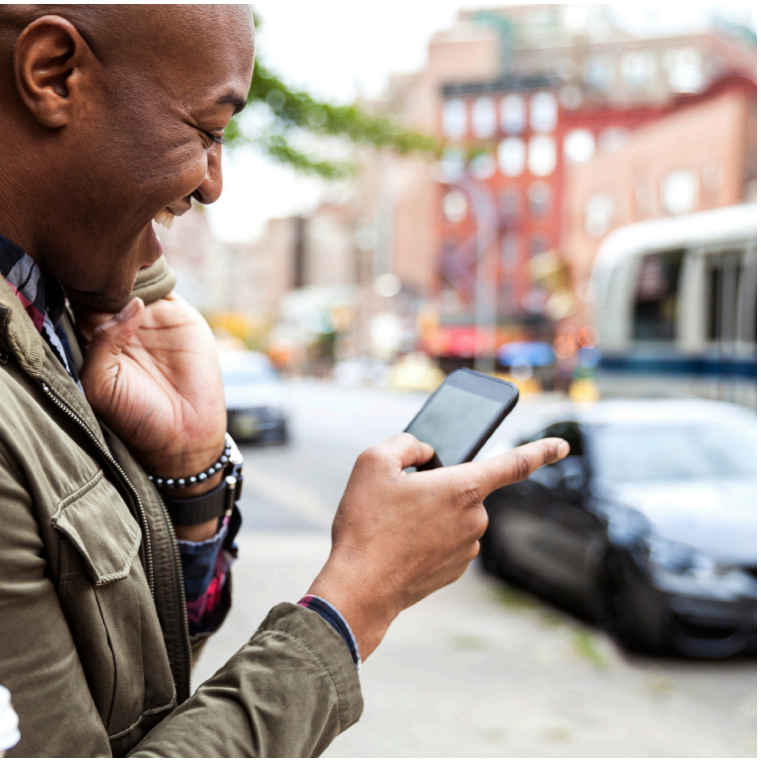

TECHNOLOGICAL DISRUPTION AND INNOVATION IN LAST-MILE DELIVERY

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STANFORD VALUE CHAIN INNOVATION INITIATIVE
IN COLLABORATION WITH UNITED STATES POSTAL SERVICE OFFICE OF INSPECTOR GENERAL

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Executive Summary

The e-commerce market continues to grow at a double-digit pace in the United States.[1] With this growth comes great opportunity for expansion in the market for product delivery. Recent technological innovations, new delivery firms, and new business models have unleashed major disruptions in how products are delivered to customers at the last mile. Whereas in the past customers ordering a product online could expect delivery by traditional players such as UPS, FedEx, or the U.S. Postal Service, today there are myriad options for who arranges for a product delivery and how it arrives in a customer's hands. Both traditional players and new entrants have opportunities to compete in this growing market.

Given customers' complex expectations for flexible, fast, and cheap or free delivery, intense market competition, and the variable profitability of last-mile delivery, it is unclear which technologies, firms, and business models will ultimately gain a successful foothold. This paper examines four innovations expected to influence last-mile delivery in the next five to seven years: advanced algorithms and analytics, drones, robots, and driverless vehicles. We also examine key market entrants leveraging these technologies and their emerging business models.

Last-mile delivery is generally arranged by one of three parties: a seller, an intermediary, or a buyer. Today, these parties can use traditional means of delivery or new algorithm- and analytics-driven applications (i.e., apps). Tomorrow, drones, robots, and driverless cars may become formidable new choices in various geographic settings and markets. New advanced algorithm- and analytics-based services catering to various customer needs will likely continue to emerge given low barriers to entry. Since the profitability of some of these models may be questionable, innovative firms that can reduce the cost structure through novel models may gain the ultimate advantage. Given that delivery services based on drones or driverless vehicles require heavy up-front investment, it is likely that large sellers or delivery providers will emerge as first movers in this space.

In the near term, the U.S. Postal Service (USPS) has an opportunity to leverage advanced algorithms such as dynamic routing to improve the efficiency of existing business models and develop new models. USPS may also consider drones for select purposes in the future, such as delivery to traditionally high-cost remote locations. Given that robots are likely to have niche applications in smaller communities in the early stages of deployment, they may not present a large opportunity for the U.S. Postal Service in the near term. As the cost of driverless vehicles becomes more competitive with traditional vehicles over time, the USPS may have an opportunity to consider incorporating driverless vehicles within its fleet, with the potential of saving labor and other costs.

In the longer term, there is potential for new technologies to improve the vast underutilization of private transport, which may lead to an entirely new transportation infrastructure and new commercial delivery models. For example, as driverless vehicles gain scale, one could envision more shared and/or public transportation. Crowdsourcing delivery companies could leverage private driverless vehicles or companies could deploy their own optimized driverless fleets for delivery. There may eventually come a time when drones, robots, driverless vehicles, and other technologies make it such that humans no longer conduct product delivery. In this scenario, delivery providers would need to rethink their business models and shift to offering services such as delivery orchestration and more. In the distant future, automated systems such as the Physical Internet, envisioned by a coalition of researchers, may develop that would deploy an open global logistics system and would continuously route and monitor products, leveraging the Internet of Things. While it is unclear who the winners and losers will be in future last-mile delivery, it is evident that many opportunities exist for firms to leverage new technologies in order to meet customers' fast-evolving needs.

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I. Introduction

The U.S. e-commerce market is projected to be nearly $500 billion in 2018.[2] With continued growth in e-commerce and heightened consumer expectations has come tremendous innovation in how last-mile delivery to customers takes place. Today, algorithm-driven delivery models and analytics enable urban customers to get products delivered faster, more flexibly, and sometimes less expensively than in the past. Options will continue to proliferate in the future, with innovative delivery vehicles such as drones, robots, and driverless vehicles reducing, or perhaps some day eliminating, the need for delivery personnel.

This paper examines the proliferation of new technologies and their implications for the future of domestic last-mile delivery. First, we survey the landscape of last-mile delivery, examine emerging delivery business models, and analyze four key technologies expected to disrupt product delivery in the next five to seven years: advanced algorithms and analytics, drones, robots, and driverless vehicles. Next, we discuss future applications of these technologies. Finally, we explore ways in which the U.S. Postal Service might incorporate these technologies and related strategies into its business going forward.

II. Landscape of Last-Mile Delivery

Stakeholder Challenges and Expectations

Last-mile delivery involves three main entities — customers, merchants, and delivery providers — each with their own set of expectations and challenges.

Customers have an increasingly complex set of expectations regarding the speed, flexibility, security, and cost of delivery. A 2016 survey by shipping platform company Temando[3] shows that most customers value same-day delivery options. Many customers would also like the flexibility to shop in store and have items shipped home or to have the ordered items shipped to a different location, such as an office, a self-service locker, or other pickup points. Many prefer that deliveries take place on weekends or after business hours when they are home to avoid exposure of the package to weather and potential theft.[4] This is one of the reasons that order tracking can be valuable. While customers value speedy delivery, a 2015 Deloitte survey shows that free shipping is even more important to them than fast shipping. And yet, shoppers expect free shipping to be fast and are not willing to pay much to expedite it.[5]

As for merchants, they face a range of concerns. Smaller retailers are mainly concerned with high shipping rates,[6] as they often lack the large network of distribution centers and the bargaining power that allows larger competitors to offer cheaper and faster delivery. Due to rate increases by UPS and FedEx and a shift to dimensional weight fees, along with concerns about delivery provider capacity, many e-retailers, large and small alike, have started looking for alternative solutions.[7] Meanwhile, a top priority for larger retailers is to meet varied customer expectations.[8] To achieve that, they often offer multiple shipping options. Still, many retailers don't offer same-day delivery or store pickup, which are valued by consumers.[9]

Delivery providers have their own challenges to profitably meet complex consumer and merchant expectations. Couriers are expected to provide flexible service based around technology that caters to these expectations,[10] while at the same time successfully manage peak times and costs.[11] They must also worry about poorly packaged goods, which cause problems for nearly 30 percent of delivery providers and can affect retailers, who bear the price of returns on faulty items.[12]

Emerging Technological Innovations

Forecasts for growth in product deliveries and evolving consumer expectations have stimulated increased competition and innovation in recent years. Key new innovations we examine in this paper include the following:

- Advanced algorithms and analytics: help delivery companies to optimize aspects of their operations, such as pricing, matching couriers to delivery tasks, routing, rating of deliverers, and more, and help them to better address consumers' expectations for speed, flexibility, and/or lower delivery costs.

- Delivery drones and delivery robots: enable companies to provide extremely fast and flexible delivery service, with smaller environmental impact and potentially at a lower price; drones may also make it easier to deliver goods to remote locations.
- Driverless vehicles: potential benefits include lower operating costs for delivery companies, flexible delivery for consumers, and the ability to cost-efficiently reach remote locations.

Key Players

Today, last-mile delivery players include established delivery companies, merchants, and new technology firms. Traditional delivery companies include UPS, FedEx, DHL, and the U.S. Postal Service. Examples of technology companies include Google, Uber, Instacart, and TaskRabbit, several of which use crowdsourcing for deliveries. Amazon is the most prominent example of a retailer that can arrange its own delivery. Some companies serve niche markets such as restaurant food while others, such as Postmates, deliver a broader range of products. Both established firms and new entrants are developing, testing, or implementing various technologies including algorithm- and analytics-based apps, delivery drones, delivery robots, and driverless delivery vehicles.

Emerging Business Models

The emergence of technological innovations opens the door for new business models. Figure 1 contains a framework for last-mile delivery business models that either exist today or may be developed in the future, from the perspective of the party arranging for delivery.

Seller-arranged delivery: Traditionally, after processing a customer order, a seller would outsource delivery to a provider that uses its own fleet (UPS, USPS, FedEx, or local couriers). UPS and FedEx have long collaborated with the U.S. Postal Service in parcel delivery. In certain cases, the groups may split various legs of a delivery with the Postal Service, taking advantage of each party's strengths.[13] Some sellers are outsourcing to companies such as Uber and Deliv, which use crowdsourcing apps. Crowdsourced delivery is an answer to the growing customer expectations for faster, more personalized, and cost-efficient service, and can help companies contain rising labor costs. In the future, delivery providers may choose to enhance or replace their fleet with drones, robots, and/or self-driving vehicles, as shown in the framework.

A seller may choose to insource delivery instead, using its own network to ship orders. Amazon, the leader using this approach, started employing its own trailer fleet in December 2015 to complement deliveries by partners. It also started Amazon Flex, a crowdsourcing-based solution. The company is likewise testing various delivery drones. In the future, as innovations become more reliable and affordable, Amazon and other retailers may internally manage a larger portion of customer orders, either using their own delivery devices or through crowdsourcing apps, for greater control and lower cost.

Intermediary-arranged delivery: Rather than selling their own goods, intermediaries offer a website or app for customers to order goods from various merchants. Once the customer places an order, the intermediary shops for items at local stores and delivers them at a scheduled time, enabling more same-day service. Some intermediaries focus on categories such as groceries or restaurant food (e.g., Instacart, UberEATS). Others deliver a wide variety of products (e.g., Google Express). Companies may use employees or independent contractors to deliver each order, although there exists debate as to the best classification for such delivery people.[14] Algorithms for pricing, matching tasks with deliverers, and route optimization, as well as analytics for demand forecast and service rating, enable efficiency and better customer service.

Buyer-arranged pickup: To speed up delivery and eliminate shipping costs, consumers may prefer to pick up an online order at the store. Retailers such as Macy's and Target offer this option today, dependent on inventory availability. If/when drones and robots or driverless vehicles become adopted by individuals, consumers may be able to send their own drone/robot/driverless vehicle to pick up an order from the store.

Another option for the buyer is to use crowdsourcing firms (e.g., Roadie) that offer peer-to-peer delivery to identify a driver who will go to the store (or any other pickup location) to pick up the ordered items and deliver them to the customer.

Figure 1 - Business models for last-mile delivery

WHO ARRANGES DELIVERY	HOW *	USING WHAT		
		KEY ALGORITHMS & ANALYTICS	VEHICLES	DELIVERY PERSON
Seller	Seller collects orders, outsources delivery (e.g., UPS, USPS, UberRUSH, FedEx Express)	• Integrated inventory management • Product search & match • Task-courier matching • Determining delivery price • Courier selection • Dynamic routing • Communication with customers • Demand forecast • Rating system	• Cars/trucks/bikes • Drones • Robots • Self-driving cars	• Full-time/part-time employees • Crowds • No delivery person **
	Seller collects orders, insources delivery (e.g., Amazon)			
Intermediary	Intermediary collects and delivers orders (e.g., UberEATS, Postmates, Google Express)			
Buyer-Arranged Pickup	Buyer orders online and arranges pickup from store or other location (e.g., Roadie, self pickup)			• Buyer • Crowds • No delivery person **

* *Companies listed as examples are illustrative. Companies may fall under more than one category in practice.*

** *"No delivery person" indicates that a person is not involved in the delivery. Rather, an automated vehicle such as a drone, robot, or self-driving car is used.*

III. Technological Disruptions in Delivery

While many forces will influence which delivery models will become widely adopted, it is clear that the industry will continue to undergo major disruption in the coming years. In this section, we discuss how the main technological innovations of focus work; their potential advantages and limitations that may inhibit adoption; and their potential application in the market.

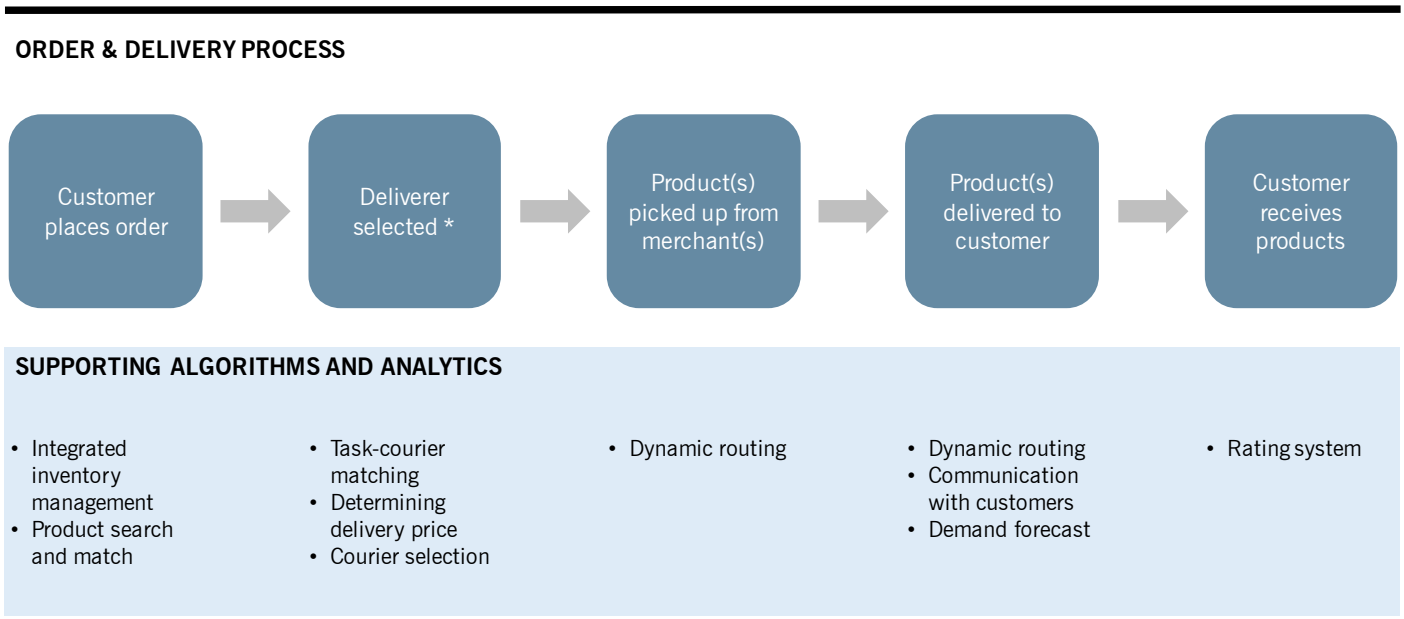
Advanced Algorithms and Analytics

Several software innovations have been improving last-mile delivery over the past few years and have opened the door for established delivery companies as well as new entrants to offer new or improved services that better address customer expectations. In particular, the main innovations that allow delivery companies to offer customized delivery (e.g., on-demand or same-day) include task-courier matching and dynamic routing algorithms. In the following pages we explore these and several other innovations and their impact on last-mile delivery.

How They Work

Several critical algorithms and analytics have enabled last-mile delivery to become more efficient and effective.

Figure 2 - Algorithms and analytics that support last-mile delivery



** Deliverer selection may take place after product pickup in some cases.*

Integrated Inventory Management

Merchants typically hold inventories in numerous locations, including distribution centers and brick-and-mortar stores. In the past, most merchants managed inventories for online orders separately from store inventories. But they can fulfill online orders faster, and potentially at lower cost, if they use platforms that provide integrated inventory management, making inventory in all locations available to all customers. With such a platform in place, merchants can provide customers with more accurate information regarding product availability and expected delivery time. They can also fulfill an order from a location closest to

the customer, thus reducing delivery time. They can likewise offer customers the option to shop online and pick up at a close-by store, thus potentially bypassing delivery providers altogether.

Furthermore, interfaces with inventory management systems of other business partners, such as manufacturers or distributors, may allow merchants to have customer orders directly fulfilled from the manufacturer or the distributor's warehouse.

Product Search and Match

Product search and match is relevant for intermediary companies, which shop for products on behalf of customers in addition to delivering the purchased items. Customers use the intermediary's website or app to select the items they want to purchase. Advanced analytics can help present search results in a way that increases the likelihood of customers selecting items that will generate the highest profit for the intermediary company.

Task-Courier Matching

Task-courier matching identifies the best person to carry out a delivery task. Once a delivery task is created, the task is matched to a courier based on pickup and drop-off locations, requested delivery time, availability of the delivery person, and price. One way to match tasks to delivery people is through a centralized assignment mechanism using a high-quality matching algorithm. The second option is to allow customers to search for couriers and couriers to search for tasks, which requires an effective search algorithm.

Determining Delivery Price

Some delivery companies allow shipping prices to change from order to order, to more accurately reflect delivery costs and risk level and to balance demand and supply. The two pricing mechanisms most commonly used are auctions and centralized pricing mechanisms. The auction algorithm allows customers to post a price for a job or to request bids and then pick an offer. The centralized pricing mechanism is simpler for users, as the deliverer's wage per hour or mile is fixed. Customers and delivery people may also view a per-mile price as more fair compared with a fixed price.

> "Quality is very difficult with thousands of independent contractors. The way we solve that is having shoppers provide feedback."
>
> - APOORVA MEHTA, CEO, Instacart[15]

Courier Selection

Once the items are packed and the price is fixed, the courier role begins. Merchants often have several courier options including traditional firms and new entrants. Advanced software solutions may help merchants select the best courier for each order, based on price, speed, and the availability of services such as order tracking.

Dynamic Routing

Delivery routes may either be static and dynamic. Once a static route has been determined, it does not change until it is completed. On the other hand, changes in delivery requirements and traffic information may be used to modify a dynamic route in real time. While dynamic routing allows delivery companies to better respond to evolving requirements and constraints, it requires a timely and accurate feedback system and advanced optimization algorithms.

Several solution providers offer tools to improve routes based on delivery requirements, driver availability, and available capacity. Some also allow companies to dynamically modify the delivery route based on real-time new order information and other relevant updates. And state-of-the-art software allows companies to determine the best route with added constraints regarding expected delivery time windows.

Dynamic routing also enables greater flexibility and helps delivery providers better respond to customers' requests, such as a change in the scheduled delivery time. By informing drivers in real time regarding changes in the route, and by using innovations such as geofences to inform customers of a delivery, the delivery process becomes much more efficient and

flexible. Customers value knowing when to be home to accept a delivery, and drivers know when they can skip a delivery location if the customer will not be there to accept it (for example, in cases where a customer signature is required).

Communication with Customers

Several tools exist today that enable merchants and delivery providers to update customers on their order status, which they value. For instance, merchants can alert customers when their order has been shipped, and delivery providers can provide information regarding expected delivery date and time and whether a customer signature is required. They can also email/text customers a confirmation of delivery. Alternatively, they can notify customers when a package is available for pickup at a pickup location.

At the same time, various delivery companies also allow customers to communicate with them directly so that they can customize the delivery based on their constraints and preferences. For example, FedEx allows customers to select a preferred delivery date and time, to request a change to the delivery location, to hold the package at a FedEx location, to sign for their delivery in advance, to provide specific delivery instructions, and to request a vacation hold. The U.S. Postal Service offers similar services, including the ability to redirect shipments or ask to hold a package for pickup at the post office.

Data-Driven Demand Forecast

Just as retailers often use advanced analytics to forecast demand and determine optimal inventory levels at each storage location, delivery providers can use advanced analytics to forecast demand for delivery services. They can use past data, combined with other market information, to better predict expected future order volume and plan their operations (e.g., required number of drivers, delivery scheduling, and vehicle management) accordingly. Delivery companies may also share order predictions with their retail partners to help them better prepare for fluctuating demand.

Rating System

Since drivers/deliverers are often the face of the delivery company, it is important for delivery companies to ensure that their drivers provide high-quality service. One way to do this is through a rating system, which can be based on such factors as response rate and speed, as well as on customer rating. Customers are encouraged to provide feedback regarding their overall experience as well as issues such as lateness or damaged/missing items. The rating system motivates deliverers to provide better service and builds trust between customers and delivery firms. For peer-to-peer deliveries, the rating system is also helpful for customers to choose a deliverer in the task-matching process.

Application of Advanced Algorithms and Analytics for Last-Mile Delivery

The algorithms and analytics discussed in this section are being applied by traditional firms as well as new entrants. New entrants can access the last-mile delivery market quickly using these tools, often with relatively low upfront investment and low operating costs. This is especially true for companies that rely on crowdsourcing or subcontracted drivers, thus avoiding the need to operate their own fleet of delivery vehicles and to employ full-time drivers.

Advanced algorithms and analytics also make it easier for new entrants to offer on-demand or same-day delivery service, as well as the option to shop for goods on behalf of customers. For example, product search-and-match tools help providers improve efficiency, while task-courier matching and routing optimization make it easier to provide on-demand or same-day delivery service.

These algorithms also open the door for new processes that bypass traditional delivery companies altogether, including,

1. **Buyer pickup:** With advanced forecasting analytics, and greater visibility to in-store inventories, retailers can more easily offer customers the option to order items online and pick them up from a nearby store. Often this option will allow both retailer and customer to save on shipping costs, and customers receive orders faster. This is also a convenient option for customers who prefer their orders not to be shipped to their home.
2. **Crowdsourced delivery:** Peer-to-peer (P2P) and business-to-consumer (B2C) companies using crowdsourcing provide individuals a more flexible and possibly cheaper alternative to traditional delivery providers such as the U.S. Postal

Service, UPS, or FedEx. For example, the P2P Roadie app builds a shipping network to connect people who have a package to send with drivers already heading in that direction. The B2C UberRUSH app crowdsources drivers for merchants. Since deliveries take place by ordinary people rather than professional deliverers and don't require a company to own its fleet, the cost of entry to the market is very low. Companies mainly rely on task-courier matching and pricing algorithms to coordinate shipments. It is unclear how economically sustainable some of these models are — although the recent crowdsourced carpooling service UberPool is showing signs of economic success, indicating that more breakthroughs in reducing costs of crowdsourced models may be on their way.[16]

3. **Seller-arranged delivery:** Once the delivery process becomes easier to manage, retailers may choose to manage deliveries internally, rather than rely on external delivery companies, as a way to save costs and increase customer loyalty. One example is Amazon, which is employing its own trailer fleet and also using crowdsourcing technology to identify drivers to deliver its standard packages.

Optimization algorithms may also make it easier for merchants to select the best shipping method for each order based on multiple criteria (e.g., cost, speed) to better meet customer expectations. This may make it more challenging for traditional delivery companies to win merchants' business.

While algorithms and analytics enable new entrants, they also present opportunities for traditional delivery companies to enhance their service offerings. For example, they can use more sophisticated routing algorithms to better meet customer requests for specific delivery times, to inform customers of the expected delivery time, to schedule a specific pickup time from a merchant, or to make the best use of the deliverer's available capacity. Alert systems can be used to notify customers of their order status, expected arrival time, and delivery time. Other innovations can also make it easier for deliverers to offer customers special services, such as change of delivery location or time, or the ability to submit specific delivery instructions.

UberRUSH

Merchants can offer same-day delivery to local customers using UberRUSH, an app that connects couriers with merchants that need to make a delivery. Typically, customers order a product from a merchant, and UberRUSH handles the delivery in the background. Currently limited to Chicago, San Francisco, and New York, UberRUSH can deliver via couriers using bicycles, cars, or traveling on foot. Each delivery currently costs merchants $5 to $7, with the driver receiving 75 to 80 percent of that fee, and UberRUSH keeping the balance. Merchants can decide whether they want to cover the cost of delivery or add it to the customer's bill.

Merchants see several advantages with UberRUSH: (1) there is a reduced amount of time customers wait to receive orders; (2) they pay only for the orders that ship (i.e., no overhead costs); (3) they can deliver at lower rates than if they managed the delivery; and (4) they can enable customers to track the location of their orders in real time. If Uber can balance supply, demand, and efficiency at massive scale, then the service could expand the market for affordable same-day delivery, posing a real threat to delivery giants such as UPS, FedEx, and the U.S. Postal Service.

Finally, forecasting models can help delivery companies better predict future demand, especially during peak demand periods, and plan accordingly.

Many customers value the reliability of traditional delivery providers such as UPS, USPS, and FedEx and have more trust in them, particularly when shipping valuable or time-sensitive items. This may be especially true when compared with new entrants to the market that rely on crowdsourcing for identifying drivers for each delivery order. By using advanced algorithms to provide better (faster/cheaper/more flexible) service, traditional delivery companies should be able to recapture some of the market share lost to the new entrants.

Moreover, many new entrants to the market are still in early stages, and it is still not clear whether their business models are sustainable in the long run. Several on-demand companies seem to be struggling to maintain their growth momentum and reach profitability, and investors are also more cautious. For instance, recently Instacart had to raise its delivery fees — and then cut the fees it pays to its couriers[17] — in an effort to raise revenue and contain costs. The company also laid off 12 recruiters in December 2015 due to an expected slowdown in hiring in 2016.[18] Food delivery startup DoorDash had to significantly lower its proposed valuation to investors in its recent fundraising discussions, illustrating how some

delivery startups are losing some of their allure.[19] And in March 2016, SpoonRocket announced that it is shutting down its on-demand pre-made meal delivery service after failing to raise the necessary capital to continue operations.[20] With rising delivery fees, customers are also less excited about some on-demand delivery services, as they find out that these services are not necessarily inexpensive and may have minimum shipping requirements. Adding to that, the people who act as couriers for some of these companies have taken to the internet to complain about their lack of consistent hours and the low workload, which lead to lower-than-expected hourly income. These recent developments bring to light that while algorithm- and analytics-driven models have key advantages, they also face significant limitations that may influence their long-term sustainability.

Drones

The use of unmanned drones for commercial package delivery offers several advantages. One key advantage is speed: since drones are not constrained by road infrastructure and congestion, they can deliver packages faster than a car/truck from a close-by storage location. Furthermore, drones can traverse difficult terrain (e.g., mountains, jungle) with relative ease and, in many cases, take a much shorter route. Similarly, drones can easily fly over water or rural areas with poor infrastructure to deliver a package. Delivery drones should also have a reduced environmental impact, as they will result in fewer delivery trucks traveling on roads and polluting the atmosphere.

> “One day seeing Amazon drones will be as common as seeing a mail truck.”
>
> - JEFF BEZOS, CEO, Amazon[21]

Given the potential benefits, it is not surprising that many delivery providers are testing drone delivery. One example is DHL, which launched a drone delivery service in September 2014 to get urgently needed goods such as life-saving medicines to Juist, an island in Germany's North Sea where more traditional delivery options such as ferries or trains aren't always available. Amazon has developed nearly a dozen aircraft as part of its Prime Air drone project and plans to develop a family of delivery drones to suit different environments. Google is testing drones that could deliver small packages in less than 30 minutes and has announced it will launch its drone delivery service in 2017. Table 1 provides a timeline of the evolving drone delivery landscape.

Table 1 – Evolution of delivery drones

TIME FRAME	MILESTONE
2005 – present	**Experimental delivery drones**. Companies such as Amazon, Google, UPS, DHL, and others have tested drone delivery for years, some since 2005.
2014 – present	**Commercial delivery drone pilots**. DHL launched its first commercial drone delivery for the German island of Juist in 2014. Matternet has been running drone deliveries in Switzerland, Haiti, and the Dominican Republic. Flirtey ran the first legal drone delivery for bottled water, food, and a first-aid kit in the United States on July 17, 2015. Amazon received FAA approval for research and development for drone delivery in 2015.
2018	**Widely permitted commercial delivery drones**. The FAA estimates that as many as 7,500 commercial drones may obtain drone permits from the FAA by 2018, provided that necessary regulations are in place.

How They Work

Two main types of electric drones are being tested for delivery: multirotor drones (quadcopter/ hexacopter/octocopter) and hybrid drones. The multirotor drone is the most popular type given its maneuverability, and it runs on batteries. Depending

on the model, electric multirotor drones have an average maximum carrying capacity of 2 to 5 pounds, a maximum flying distance of 10 to 30 miles, top speed of 10 to 40 miles per hour, and a maximum flying altitude of 100 to 400 feet. These drones land for each delivery.[22,23,24]

Hybrid drones, equipped with propellers and wings, can take off and/or land like a copter and can glide like a plane. This design increases the drone's range. Some hybrid drones are designed to lower deliveries on a line, while others are designed to land. Google scrapped its initial design of a hybrid drone because it was too difficult to control.[25] In 2015, Amazon unveiled a new hybrid delivery drone, which uses eight rotors to take off vertically, then switches on an extra rotor to fly through the air horizontally at up to 60 mph, and finally lands vertically to a given location.[26]

Most drones developed by Google, Amazon, and DHL only use batteries now. However, a startup named Top Flight Technologies has designed a hybrid gas-electric aircraft that uses both batteries and gasoline, significantly improving its performance. Specifically, this drone has a maximum carrying capacity of 20 pounds, a maximum flying distance of 100 miles, top speed of 40 miles per hour, and a maximum flying altitude much higher than 500 feet (the current FAA limit).[27]

Several technologies are improving the safety of unmanned commercial drones by providing better visibility to surroundings. One example is the automatic dependent surveillance-broadcast (or ADS-B) technology, which determines an aircraft's own position in space via satellites and periodically broadcasts its position and direction. While ADS-B is already in use for manned commercial aviation, new innovations are making ADS-B units sufficiently small and inexpensive so that they can be placed on unmanned drones as well.[28] Another innovation is a sense-and-avoid situational awareness technology, which allows the drone to scan its surroundings so it can identify and avoid obstacles in the air and while taking off and landing.

Advantages and Limitations of Drones

As mentioned, key advantages of commercial delivery drones include speed, the ability to reach difficult terrain or remote locations and fly over obstacles on the ground, and their reduced environmental impact. This is evident in many of the current areas of application being explored, which include emergency deliveries of medication and other urgently needed items and deliveries to remote locations. In addition to DHL's delivery service to the island of Juist, Matternet has been running drone deliveries of medical supplies and specimens in collaboration with Swiss WorldCargo and Swiss Post. Google used delivery drones in 2014 to deliver supplies to farmers in the Australian outback.[29] In 2016 Chinese retailer JD.com, looking for ways to reach consumers in the country's vast rural interior, started testing drone deliveries to the remote countryside.[30] In this context, drones can provide a cost advantage because low-volume remote locations usually represent an expensive component of standard delivery networks, and they may also require a non-standard infrastructure tailored to regional specifics.[31] Consumers have reported wanting many types of products in 30 minutes or less, including gifts, electronics, and food.[32] In line with this need, Amazon plans to use drones for a wide set of products with its future Amazon Prime Air service.

While drones certainly offer several advantages compared with more traditional delivery methods, many limitations still lie ahead for drones to scale. Drones currently have small shipping capacity. Global-positioning-system (GPS) data can be inaccurate, affecting package drop-offs. With current technology, drones could drop off packages at the wrong house or over a swimming pool.[33] Delivery drones may be considered as trespassers when they fly over the airspace above a person's private property.[34] Finally, drones can lead to injuries to people who are subject to having drones flown over them. Given the risks, insurance costs for drone systems may

Amazon Drones

Amazon has been operating a pilot drone delivery program since 2014. The company has asked the FAA for an exemption from rules prohibiting the use of drones for commercial purposes, and plans to deploy drones to deliver packages to customers within 30 minutes of placing an order in the near future. The range of drone delivery will be 15 miles. The hybrid drones that Amazon released in 2015 weigh about 55 pounds each and can deliver parcels that weigh up to 5 pounds.

Amazon has developed nearly a dozen aircraft as part of its Prime Air project and plans to develop a family of delivery drones to suit different environments. The company uses both octocopter and hybrid delivery drones, which it tests inside its research and development lab in Seattle. These are highly automated drones with sense-and-avoid technology. Research firm ARK Invest estimates the size of the market for Amazon to be $400 million per year. The biggest challenge the company may face going forward is regulations governing the scale of deployment. Other competitors with serious intentions to deploy drones include Matternet, Flirtey, Boeing, DHL, and Google.

> **[Drone] technology is not going to be the long pole. The long pole is going to be regulatory.**
>
> - JEFF BEZOS, CEO, Amazon[39]

further increase operating costs. To ensure safety, current FAA rules forbid drones from flying over people and require an on-the-ground observer to monitor the safety of the drone at all times when the drone is in operation. Commercial use of drones is permitted only if a business obtains a Section 333 exemption from the FAA, granted exclusively on a case-by-case basis.[35] Customer acceptance is another issue to consider, although a 2016 Temando survey found that 51 percent of customers are willing to accept a drone delivery in the future.[36]

The expectation is that as drone technology evolves and the associated risks are resolved, regulations will become less strict. It is expected that beyond visual line-of-sight technology will be permitted by new commercial drone regulations that the FAA is working to finalize by 2017.[37] In the meantime, the uncertainties regarding regulations also impact the cost estimates of drone delivery operations. For example, a 2015 report by ARK Invest suggests that Prime Air, Amazon's drone delivery service, could cost the company only 88 cents per delivery,[38] which is likely cheaper than current shipping costs paid by the company to external delivery providers. Yet a different set of assumptions, described in a June 2014 Robot Economics article, resulted in an estimated cost of a single drone delivery to be between $9.75 and $17.44.[40] One of the key differences between these two estimates is that the ARK Invest report assumes that each operator will be able to simultaneously monitor 10 to 12 drones, while the second article assumes that a 1:1 ratio between drones and operators must be maintained.

Other costs considered in these analyses include costs for the fulfillment center, insurance, drone purchasing and maintenance, batteries, and data streaming and storage. The drones themselves are relatively inexpensive. For example, Amazon's octocopter is estimated by ARK Invest to cost $1,000 to $3,000.

Application of Drones for Last-Mile Delivery

Once the technological limitations are resolved, regulatory restrictions are relaxed, and public concerns around safety and privacy are addressed and minimized, drones could have a significant impact on the landscape of last-mile delivery. Traditional delivery companies, new entrants to the market, as well as merchants themselves could use drones to offer same-day delivery services, thus satisfying customers' desire for speedy delivery in an environmentally friendly way. Similarly, intermediary companies could save costs by having their workforce focus on shopping for customers while using drones for the actual delivery, at least for those orders within the drone's capacity limitations. If the cost to own and operate a highly functional drone becomes sufficiently low so that individual people could own drones for personal product transport, customers could potentially send their drone to the store to fetch their orders. Even though the use of drones will be limited to a certain delivery distance and package size, the market potential is high; for example, it is estimated that around 20 percent of Amazon's e-commerce orders meet these criteria.[41] Furthermore, retailer Walmart has locations within 5 miles of 70 percent of the U.S. population, creating real opportunities for drone delivery.[42]

Drones can also provide a convenient solution for delivering urgently needed items to remote or hard-to-reach locations. Drones already have been used to deliver small aid packages after the Haitian earthquake in 2012, and Doctors Without Borders used them to transport dummy TB test samples from a remote village to the large coastal city of Kerema in Papua New Guinea.[43]

Delivery Robots

Another innovation set to disrupt the status quo in delivery services is robots. Like delivery drones, delivery robots are unmanned devices remotely monitored by an operator. But unlike drones, robots are designed to travel on pedestrian and bike lanes at low speeds of about 4 miles per hour.

Leading companies currently exploring delivery robots include SideWalk (partnering with DHL), Starship (created by the founding engineers of Skype), and Dispatch (formed by MIT and University of Pennsylvania experts). Robots require recharge every few hours. The Starship robot can carry a load of 20-25 pounds,[44] and Dispatch's "Carry" robot can carry loads of up to 100 pounds.[45] Deliveries can be made within 5 to 30 minutes from a local hub or retail outlet.[46] The robots could be used for delivering small packages, groceries, laundry, pizza, and more. SideWalk has already conducted pilot projects with DHL in Lithuania, and the District of Columbia is discussing plans to allow Starship to pilot robots for local deliveries sometime in 2017.[47] Table 2 provides a timeline of the evolution of delivery robots.

Table 2 – Evolution of delivery robots

TIME FRAME	MILESTONE
2013 – present	**Prototypes.** Startups including SideWalk, Starship, and Dispatch have designed and tested robots for last-mile delivery since 2013.
2015 – present	**Pilot deliveries.** SideWalk delivery robot has already been tested by a DHL unit in Lithuania since 2015. Dispatch has tested the delivery robot "Carry" in China and plans to roll out in select university campuses in California in 2016. Starship robots will be tested on the U.K.'s streets in 2016 as well.
2017	**Commercial roll out.** Starship plans to roll out commercial delivery robots in 2017. DHL and Sidewalk also plan to expand to Germany and Denmark in the following years.

How They Work

Delivery robots are typically targeted for relatively affluent and uncrowded suburban areas, gated communities, assisted-living facilities, and campuses. In these settings, they would be able to travel on sidewalks or bike lanes, programmed to travel amongst pedestrians, bicyclists, and cars.[48] Robots would travel a short distance from a local hub or retail outlet to a receiver, within 5 to 30 minutes.[49] Customers would be able to schedule the delivery using an "Uber-like" app and may also use a real-time mobile app to track the robot's location and unlock the goods upon arrival.[50] The robot would return to the distribution hub after each delivery, or it could potentially carry multiple deliveries, each located in a separate locked compartment.

Robots use GPS, sensors, and cameras for navigation, stopping for an obstacle or pedestrian in its path. Some models can travel up and down curbs and small stairs. While a human operator would track a delivery robot, it would drive autonomously 99 percent of the time in a carefully mapped local area.[51] Robots typically have microphones for two-way communication. If a thief posed a threat, the human operator at a control center could scare the thief away via a speaker and call the police.

Advantages and Limitations of Delivery Robots

Similar to drones, delivery robots can address customers' desire for speedy delivery and for the flexibility of choosing a convenient delivery time. Another shared benefit is their reduced environmental impact, since robots are carbon-emission free. Robots provide additional benefits compared with drones. Robots' higher shipping capacity means they can be used for larger orders or to deliver to several customers in close proximity. Secure compartments, unlocked with the recipient's access code, ensure that people get only products that belong to them. Due to their relatively small size, low speed, and the fact that they travel on the ground, their chances of causing significant harm to their surroundings are low. Privacy concerns, which may be associated with drones flying over private properties, are also not an issue with delivery robots.

Robots may also have regulatory advantages compared with drones, since they are designed to take on pedestrian lanes and travel at low speeds.[52] Furthermore, many of the regulatory hurdles delivery robots will face will already have been paved over by autonomous cars.[53]

Another key advantage of delivery robots is their relatively low cost. Since delivery robots are earthbound, the technology required to monitor and operate them can be less sophisticated than drones, thus reducing costs. A Starship robot currently costs less than $2,000. Starship CEO Ahti Heinla claims that their robots would cost less than a dollar for each delivery when deployed.[54] The cost structure of delivery robots is similar to delivery drones, including infrastructure cost (for delivery hubs), the costs of the robots themselves, and operating cost (mainly labor costs for the operators, plus data streaming and storage, maintenance, recharging, and insurance costs).

At the same time, delivery robots have a shorter range when compared with drones. Roadblocks such as ramps, steps, and curbs may be problems for some.[55] And since robots are designed to share the sidewalk with pedestrians, there may be limitations as to their numbers. They may also not be able to operate in crowded areas. Starship tested its service over 62 miles of sidewalk and past approximately 5,000 pedestrians. Eighty to ninety percent of passersby showed "no reaction to the robot whatsoever," while 10 to 20 percent "expressed a positive reaction,"[56] indicating that they may be well accepted. With respect to challenges, theft is a concern. However, thieves would be at risk of exposure to high-resolution cameras and a GPS system that would need to be disabled.[57]

> "Our vision revolves around three zeroes — zero cost, zero waiting time, and zero environmental impact. We want to do to local deliveries what Skype did to telecommunications."
>
> - AHTI HEINLA, CEO, Starship Technologies[58]

Application of Robots for Last-Mile Delivery

Since delivery robots are intended for less dense areas, their applicability may be limited. Dispatch's strategy, for example, is initially centered on university campuses in California, with hopes to scale into other private locales.[59] Starship also acknowledged that its system is intended for uncrowded areas.[60]

In settings where delivery robots are applicable, they can potentially be quite successful. For example, on university campuses students often don't have their own vehicles and rely on bicycles and public transportation. This can make grocery shopping a challenge. Students are also more likely to have tight budgets, so robot delivery, which is expected to be relatively cheap, will likely be more attractive than delivery services such as Instacart. The technology would pose similar benefits for seniors in assisted-living housing.

In both contexts, delivery could be arranged by a grocery store and carried out by the store's own fleet of robots, or the store could outsource to a robot delivery company. Another option is for intermediary companies to offer shopping with delivery via robot.

Robots could also be used by retail stores or restaurants to deliver goods ordered online to nearby customers. Alternatively, customers could be the ones to initiate the delivery process, either through a third party that offers robot delivery services or by themselves, if in the future individuals owned robots for personal use. Since the range of delivery robots is relatively small for the foreseeable future, their use for direct delivery will be more limited than drones.

Robot Delivery - SideWalk

Current leaders exploring delivery robots include SideWalk, Starship, and Dispatch. SideWalk began testing in Lithuania in 2015, with plans to expand to Germany and Denmark soon. SideWalk provides instant (±15 min) first-mile, last-mile city delivery. Robots require recharge once every 7 hours (travel time). They can carry a load of up to 45 pounds, and can travel up to 6 miles. The SideWalk robot can drive mostly on its own, with integrated navigation and obstacle avoidance software, but it's also overseen by human operators in the office to ensure safety at all times. SideWalk has tested deliveries for e-food delivery platforms, restaurants, cafés, and flowers shops. The estimated cost of delivery by a SideWalk robot is 2.99 Euro (about $3.40 USD).[61] Delivery robots are designed to share the sidewalk with pedestrians, which may limit their numbers. They also may not be able to operate in crowded areas given the risk of collisions.

In terms of cost, the lack of a driver helps to reduce operating costs. However, profitability of services would depend on many factors and would need to be assessed on a case-by-case basis.

Driverless / Autonomous Cars

Increasingly, autonomous cars, or vehicles capable of sensing their environment and navigating without any human input, are being visualized as a key transportation mode of the future. Most major automakers, as well as technology companies including Google, Apple, and Uber, are working on autonomous driving technologies of varying degrees. Google is testing a fully autonomous prototype that replaces the driver completely. Automakers, meanwhile, are moving toward full autonomy in stages, gradually adding more capabilities to their vehicles. Several manufacturers, including Volvo, Tesla, General Motors, Nissan, and Renault, have recently introduced advanced levels of autonomous functionality in their vehicles or plan to do so in the near future. Others, including Mercedes-Benz, Audi, BMW, Daimler, and Honda, have already unveiled prototypes of self-driving cars or are testing highly as well as fully autonomous vehicles. Ford CEO Mark Fields promised to produce an autonomous driving car for the masses that can't afford the prices of luxury vehicles. Meanwhile, Toyota has a different approach, aiming to make the car a partner — not to replace the driver completely. Many suppliers, including Delphi Automotive, Bosch, Continental, Mobileye, Valeo, Velodyne, and Nvidia, are researching and developing autonomous vehicle technology as well.[62]

All these activities are a clear indication that driverless vehicles are coming our way, even though it may take several more years before this technology is widely available. While most of the current discussion surrounds the use of driverless vehicles for public or private transportation, this technology is likely to also have an impact on the last-mile delivery market. Predictions vary on when fully autonomous vehicles will be available for purchase. Table 3 provides a tentative timeline, incorporating several sources. Even as the technology evolves, it may still take several more years for regulatory approval.

Table 3 – Evolution of driverless cars

TIME FRAME	MILESTONE
2015 – 2016	Vehicles with varying levels of self-driving capability (mostly on highways) start to become available to consumers.
2018 – 2020	Fully autonomous vehicles that can operate in any condition and on any road will be available [relatively optimistic predictions].[63]
2025	More cautious predictions regarding the time when fully autonomous vehicles will become publicly available.[64]

How They Work

Self-driving cars use multiple technological innovations to figure out where they are, what's around them, and what they should do to safely reach their destination. More specifically, light detection and ranging (LIDAR) devices, as well as cameras, radars, and sensors, provide a 360-degree view of the surrounding environment and help the vehicle "see" other vehicles, pedestrians, and other objects around it, as well as road signs and traffic lights. Access to precise geo-location information and to very detailed maps helps the vehicle know where it is, where it should go, and what to expect along the way. A software system uses all the information gathered to identify all objects around the vehicle, predict what these objects will do next, and choose a safe speed and trajectory for the vehicle. In addition, the software can interpret common road behavior and signs. Although some of these technologies are already commercially available, critical pieces of hardware such as LIDARs will need further development, and their price will have to scale down before they can be used commercially.[65]

One interesting emerging technology that will likely be revolutionary in the future of autonomous cars, and is already in development, is the concept of vehicle-to-vehicle (V2V) communication systems. This technology is expected to provide a

way for vehicles located in close proximity to share information about their location, speed, and direction, as a way to help electronic safety systems work more smoothly, and eventually minimize crashes.[66] The National Highway Traffic Safety Administration (NHTSA) has been conducting research on V2V communications for over a decade.[67]

Advantages and Limitations of Driverless Vehicles

Some of the general benefits of self-driving vehicles include significant reduction in car accidents and the resulting thousands of annual fatalities,[70] more productive and less stressful commute time, and reduction in insurance, fuel, and maintenance costs. Shared self-driving cars are also expected to reduce the total number of vehicles on the roads, resulting in smaller environmental impact.[71]

When used for delivery, driverless vehicles could provide very fast delivery service if well-scheduled. Such vehicles can also operate for longer hours, thus providing greater flexibility in delivery times and increasing operational efficiency. Available technology requires a recipient to be present at the time of delivery, to unlock and retrieve the delivered items. Secured compartments will guarantee that customers will receive only the items that belong to them.

While dense urban areas are a natural place to use driverless vehicles for parcel delivery, they can also be useful for last-mile delivery to remote areas. Since driverless vehicles are not limited by such constraints as driver fatigue, it would be easier for them to drive longer distances to deliver (and pick up) items to/from more remote locations.

There are, however, significant challenges to creating a driverless car that can drive anywhere. Very detailed maps covering the entire country must be created and maintained, and algorithms must be developed to support a wide range of weather conditions.

Government regulations are another significant hurdle. For example, in December 2015 the California Department of Motor Vehicles (DMV) released draft rules requiring a licensed driver to be in the vehicle at all times in order to monitor the safe operation of the vehicle and take over immediate control in the event of an autonomous technology failure or other emergency.[72] New rules will likely be released only after further tests of driverless vehicles on public roads that can prove an autonomous car is safe.[73]

Another challenge is the very high cost of driverless vehicles — although these costs keep going down. While an article published in January 2014 estimated the cost to build Google's driverless car to be more than $300,000,[74] estimates made later that year put the cost of the technology added to the car at between $70,000 and $100,000.[75] IHS Automotive forecasted in a 2014 study that the price for the self-driving technology will add between $7,000 and $10,000 to a car's sticker price in 2025, a figure that will drop to around $3,000 by 2035.[76] The main factors that will impact the rate of price reductions are innovations meant to consolidate and simplify the hardware — and higher volumes.

> **"The data is not yet there to support a fully autonomous vehicle. ... The point at which it becomes statistically clear that an autonomous car is safer, I think, regulators will be comfortable with allowing it."**
>
> - ELON MUSK, CEO, Tesla[68]

Driverless Car Delivery – Google

The idea of driverless cars being used for autonomous delivery is appealing. In February 2016, Google obtained a patent for an autonomous delivery vehicle. The vehicle will have multiple compartments, each to be unlocked by the customer with a unique code. Compartments could also be equipped with credit card slots or chip readers for payment. Once the customer retrieved the items, the vehicle would drive to its next destination or back to its origin point to load additional items for delivery. Alternatively, vehicles could deliver packages to a pickup station where consumers could retrieve them.

Since the vehicles could pick up packages and deliver them, there exists an opportunity to use them as couriers. For example, a sender could order a pickup, place the package in one of the compartments, prepay, and send the retrieval PIN to the recipient. Google notes that "the two largest commercial delivery services in the U.S. operate over 100,000 last-mile vehicles — each requiring a human operator." The company expects autonomous delivery vehicles to increase the efficiency of those last-mile operations as shipping demand increases.[69]

Liability insurance rules will also need to evolve and take into consideration such aspects of driverless vehicle operations as the reduction in the number of crashes, the severity of the crashes that do occur, as well as who is responsible for any fatalities or damages associated with such crashes.[77] Once driverless vehicles become more popular, supporting infrastructure may also need to be developed.

Application of Driverless Vehicles for Last-Mile Delivery

Many of the technical challenges associated with driverless vehicles are easier to address when the car is expected to operate in a limited geographic area, which is why one of the first emerging business applications of driverless vehicles is as taxis or buses for local transportation.[78] Some cities are considering the use of buses and trains without drivers, which may allow them to expand transit routes and capacity more cost effectively due to the expected significant savings in labor costs.[79] And Uber is currently building its own driverless car technology,[80] and expects this technology to allow the company to lower the price of Uber rides.[81]

Last-mile delivery is another natural application for driverless vehicles, as this industry shares many of the characteristics of taxis and shuttle buses, including long hours of driving and operation in a limited geographic area. Trials run by U.K. government-funded research units will test how successfully driverless vehicles can be used to deliver parcels and other goods in London.[82] In the United States, Google obtained a patent in February 2016 for an autonomous delivery truck, which could potentially deliver anything from the obvious packages purchased online to advertising circulars and even pizza.

Another potential application of driverless vehicles is as support vehicles for letter and parcel delivery, as suggested by a 2014 DHL study titled "Self-driving vehicles in logistics." This application could tackle the inefficiency associated with long-distance walking whenever parking is not available close to the recipient's mailbox or front door, which is especially relevant in dense urban areas. Under this model suggested by the study, the delivery person will walk to each delivery location (assuming they are close by) with the delivery vehicle following autonomously, so that the delivery person could retrieve the parcels for each location when reaching the destination. When the support vehicle is nearly empty, a second one (loaded with more parcels and letters) would arrive autonomously. According to the study, the biggest advantage of this application is its potential to increase the productivity of each delivery person, making the job easier and at the same time more attractive.[83]

> **"Eventually, Google's driverless vehicles will compete with not just Uber and taxis but also FedEx, Amazon, Seamless, transit operators, and the very notion of individual car ownership."**
>
> - BRYANT WALKER SMITH, University of South Carolina[84]

IV. Summary Table of Technological Disruptions

Each of the technologies examined comes with advantages and limitations. Below we summarize the key distinguishing factors that will influence the extent to which these technologies will disrupt future last-mile delivery.

Table 4 – Summary table of technological disruptions in last-mile delivery

	ADVANTAGES	LIMITATIONS	STAGE OF DEVELOPMENT
Algorithms and Analytics	• Fast / cheap / flexible delivery • Low capital cost; low barriers to entry • Open the door for new delivery models	• Some companies have yet to demonstrate a viable business case • Trust issues with crowdsourcing	Large-scale adoption
Delivery Drones	• Fast / flexible delivery • Environmentally friendly • Can reach remote / hard-to-reach locations more cheaply • Can bypass crowded / poor roads	• Strict regulatory restrictions • Safety and privacy issues • Capacity limitations • Delivery distance limitations • Remaining technological challenges	Pilots
Delivery Robots	• Fast / cheap / flexible delivery • Environmentally friendly • Fewer safety and privacy issues compared with drones • Higher capacity compared with drones	• Delivery distance and speed limitations • Cannot operate in crowded areas • Theft issues • Limited ability to overcome obstacles in their way	Pilots
Driverless / Autonomous Cars	• Fast / flexible delivery • Low operating cost • Environmentally friendly • Cost-efficient to reach remote locations	• Strict regulatory restrictions • High cost of driverless vehicles • Many technological challenges still exist	Experimental

V. Future Directions

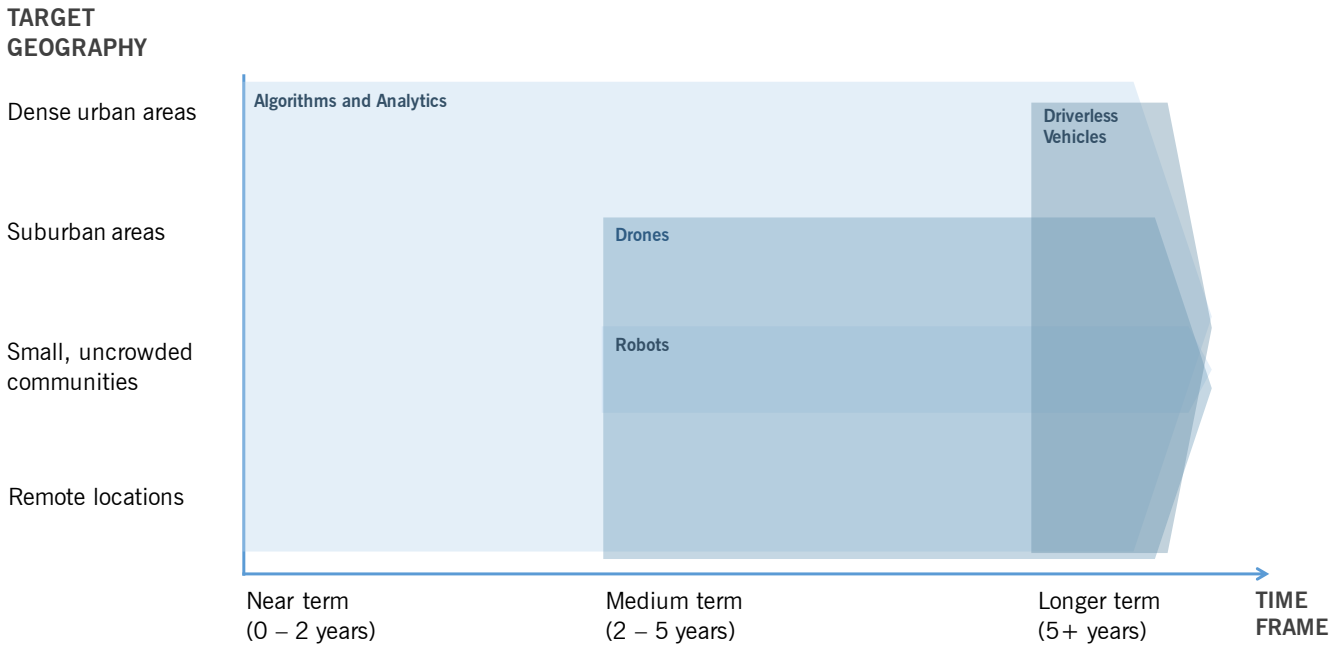
Technological disruptions are helping to improve existing business models, as in the example of the UPS advanced routing system Orion, and they are also creating new delivery models, as in the examples of UberRUSH, Postmates, and Instacart. In the near term, there are several areas in which technology will enable new entrants to emerge. We expect the main area to be algorithm- and analytics-driven technologies, given the low barriers to entry. However, the economic viability of algorithm- and analytics-driven models is not always clear, given the general public's unwillingness to pay a significant premium for fast and convenient delivery. New private transportation models such as UberPool are bringing costs down for consumers.[85] It is possible that similar new commercial parcel delivery models will also emerge in the near term that take advantage of crowdsourced carpooling strategies and other strategies aimed at improving the efficiency, flexibility, speed, and affordability of delivery. Such models may have challenges with brand reputation if lost/damaged parcels become an issue. Employment issues with crowdsourcing, such as those currently faced by Uber, may also limit scalability of certain models.

Another area where technology will likely gain adoption for last-mile delivery within the next five years is drones. Given that large retailers such as Amazon and Walmart see a high potential for drone delivery, this market will likely grow once new regulations are issued and as the economics continue to improve. Seller-driven delivery models will likely emerge whereby sellers insource delivery using drones. This will likely be seen primarily with large retailers in the near term, as in the case of Walmart and Amazon's planned Prime Air service. Another feasible model may be adoption of drones by delivery providers such as FedEx, UPS, the U.S. Postal Service, and by new drone delivery companies. Intermediary-driven delivery models could also emerge using drones, in which a buyer visits a website and orders products that the intermediary then uses a drone to pick up from a seller. Drone technology, however, may have challenges such as citizen complaints regarding crowded and noisy skies, pedestrian accidents, and regulatory roadblocks with directing drone flights.

Robots may remain a niche application in the near term given regulatory constraints, their limited geographic range, and risks of pedestrian accidents in dense areas, thefts, and more. Still, given the state of the technology and the relatively lower risks associated with it, we expect to begin to see commercial rollouts in the next couple of years. Over time, as the technology advances and public acceptance increases, delivery robots will likely become more popular. However, in the near term, they will likely remain a niche application, limited to low-density and relatively small communities. Therefore it is not clear whether this technology will have relevance for the U.S. Postal Service in the next 5 to 7 years.

Driverless cars still face many technological challenges as well as issues with regulatory constraints, customer trust, affordability, and more. It will therefore be several more years before this technology is widely deployed. In the longer term beyond 5 to 7 years, driverless cars will likely gain more traction, and adoption rates will grow for both private and commercial purposes. As the price of driverless cars continues to drop and become more affordable for personal ownership, commercial models may emerge using crowdsourced delivery via private driverless cars, and delivery companies may start deploying their own fleets of driverless vehicles.[86] Figure 3 below provides a general estimate for when and where delivery technologies may gain adoption — for illustration purposes only.

Figure 3 - Delivery technologies: main geographies and projected timeline for adoption



Entirely new models are also being envisioned, which may ultimately transform private transportation and commercial delivery. With the potential expansion of drones, robots, and driverless cars, it is possible to envision a time when humans are not required to physically deliver products. Vehicle optimization will also likely improve. For example, the startup Next envisions driverless modular vehicles that can optimize personal transport and commercial logistics.[87] It is also possible to envision a time when vehicles are standardized and modular, creating a more efficient logistics network. For example, research is taking place to design what is being called a "Physical Internet," defined as "an open global logistic system founded on physical, digital, and operational interconnectivity, enabled through encapsulation of goods, standard interfaces and protocols." The vision of the Physical Internet is to move, store, produce, supply, and use physical objects throughout the world in a manner that is economically, environmentally, and socially efficient and sustainable.[88] If the transport of physical goods is ultimately automated, delivery providers may need to adapt to providing services rather than conducting the delivery itself. While this remains a possibility in the distant future, delivery models will continue to make incremental evolution over time.

Technology disruptions present an opportunity and a challenge for traditional delivery providers such as the U.S. Postal Service. Opportunities may arise for how products are delivered (e.g., faster, more flexible, more convenient deliveries), where they are delivered (e.g., urban vs. suburban vs. rural areas), and what products are delivered (e.g., food, medicines, grocery items). Challenges will be the continual emergence of new technologies, entrants, and business models, some of which will succeed in offering an economically sustainable alternative to traditional delivery business models.

Some of the key strengths of the U.S. Postal Service pertaining to last-mile delivery are local offices and a fleet of vehicles that regularly reach U.S. households, large workforce, brand recognition, and customer trust.[89] Based on these strengths, the USPS can consider some of the technology-based business models presented on page 22. Some of these options are more in line with near-term possibilities and others are more for long-term consideration. Each option depends on meeting customer needs and having a viable business case.

Table 5 – Options for the USPS in last-mile delivery

BUSINESS MODEL	TECHNOLOGY / STRATEGY	APPLICATION	ADVANTAGE FOR CUSTOMER
Seller-arranged delivery: outsourced to USPS	Dynamic routing	Same-day delivery On-demand delivery	Speed Convenience
	Customer communication	Provide customers with more real-time information on delivery order	Predictability
	Rating system	Customers can view ratings for the type of USPS service they select	Build trust
	Drones	Remote locations, lightweight packages, urgent packages	Speed, may be lower cost than traditional delivery to remote locations
	Driverless cars	Remote locations, markets where it is costly to deliver	May be lower cost than traditional delivery to remote locations
	Robots	Delivery in gated communities or closed campuses – use trucks for transport to community gate; use robots within community	Convenient delivery time (customer can choose off hours) May be lower cost than delivery by a person
	Lease space	Sellers without warehouses close to the customer can use local USPS space	Speed, lower costs
	USPS drivers/trucks deliver for a crowdsourcing company		
Intermediary-arranged delivery	USPS could design a marketplace using pricing, search/match, inventory algorithms, and deliver products	May appeal to rural customers that trust USPS brand	Convenience
Buyer pickup	USPS could offer space to retailers to store packages for buyers to pick up	For sellers that don't have local retail presence	Convenience for buyers who do not wish to receive packages at home, and want low cost

VI. Conclusion

Given the rapid evolution of last-mile delivery in the last five years, the next five to ten years will see massive disruptions, with new business models certain to emerge. Traditional delivery providers such as the U.S. Postal Service and new entrants will face challenges with increased competition and threats to profits.

However, opportunities exist to leverage analytics, algorithms, and drones in the near future to protect and potentially expand markets. In the medium to long term, robots and driverless cars will also likely gain adoption although, as with any technology, how they will be deployed will likely evolve over time. Factors affecting the adoption of the new technologies and business models examined in this paper include business profitability; environmental considerations that may accelerate the use of technologies that help save carbon emissions; customer safety and trust concerns regarding new technologies; labor issues with crowdsourcing and other models; and regulations governing drones, robots, and driverless cars.

The delivery industry will continue to face many disruptive dynamics going forward. Delivery providers, retailers, and other value-chain actors will need to explore competitive and cooperative strategies to leverage their digital, physical, and human capital for future business growth.

Authors and Acknowledgments

Hau L. Lee, Principal Investigator
Thoma Professor of Operations, Information and Technology
Faculty Co-Director, Value Chain Innovation Initiative
Stanford Graduate School of Business

Yiwen Chen
Master's Candidate
Department of Management Sciences and Engineering
Stanford School of Engineering

Barchi Gillai, PhD
Principal, Gillai Consulting

Sonali Rammohan
Staff Director, Value Chain Innovation Initiative
Stanford Graduate School of Business

Please contact Sonali Rammohan at ***sonalir@stanford.edu*** *with inquiries.*

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