WORLD ECONOMIC FORUM

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The Future of the Last-Mile Ecosystem

Transition Roadmaps for Public- and Private-Sector Players

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Executive summary

There has never been a time of greater change for the "last mile". Consumers order more things online, expecting more control and faster deliveries. Disruptive technologies, such as droids and drones, are shaking up entire delivery chains. Emerging tech players such as Uber Freight and Postmates are changing the dynamics of the competitive landscape. However, these developments also have a downside: Inner cities are struggling with traffic congestion and air pollution due to the increasing number of delivery vehicles, their emissions and second-lane parking. Some cities predict that, if no interventions are made, inner-city traffic will be seriously disturbed in the next three years.

These developments are not surprising, but they are challenging because they are not linear. Rather, they are interwoven in complex ways that reinforce their speed and magnitude. This poses new questions to last-mile ecosystem players: Who is the competitor and who is the partner? Which disruptive technologies and delivery chain innovations should be prioritized over others? Which regulatory city interventions offer maximum impact? What will be the role of data and advanced analytics in the future?

This report presents an integrated perspective on the future of the last-mile delivery ecosystem, which was developed jointly by the World Economic Forum, McKinsey & Company, the World Business Council for Sustainable Development (WBCSD), Leaseplan and more than 20 public- and private-sector partners who contributed related data, expertise and case studies. The aim of our advanced analytics-based congestion simulation and quantitative modelling is to inform last-mile ecosystem players' strategy discussions through a solid fact base, to encourage public-private partnerships and to accelerate the development and implementation of effective interventions.

In the first chapter, we describe the context of urban last-mile delivery, focusing on the unparalleled rise of e-commerce and technological advancements. We then offer a base-case scenario that, without effective intervention, describes the impact of e-commerce on overall traffic volume, related congestion, emissions and additional qualitative factors of influence such as customer convenience and competitive dynamics. Next, the report puts forward an ambitious vision for the future of urban freight, describing and quantifying interventions for both private and public players along two city archetypes – a suburban, sprawling metropolitan area such as Los Angeles, and dense inner-core metropolitan areas such as London and Singapore. In closing, the report calls for immediate action, and recommends how cities and companies can implement effective transitions within the next one to three years.

Context:
Unparalleled growth in last-mile transport

In the past decade, e-commerce has risen significantly. From 2014 to 2019, e-commerce sales ratios nearly tripled globally.[1] This trend has been fuelled by a multitude of different factors: urbanization and the increasing purchasing power of the middle class, an increasing customer base worldwide, a widening range of products that can be purchased online and the emergence of new digital business models, as well as technological advancements in the delivery segments that allow for instant and time-definite delivery.

Base case:
Emerging challenges for the ecosystem

To satisfy customers' ever-rising desire to buy products online, without any intervention, the number of delivery vehicles in the top 100 cities globally will increase by 36% until 2030. Consequently, emissions from delivery traffic will increase by 32% and congestion will rise by over 21%, equalling an additional 11 minutes of commute time for each passenger every day. The challenge for the urban last mile is especially pronounced for the freight segment, as second-lane parking-induced congestion and emissions are higher than for the parcel segment when compared on a per-vehicle basis. While the public sector has started to pilot and run various initiatives on a city basis, systemic change and harmonized regulatory frameworks have not yet been fully implemented.

Last-mile interventions

To counteract this development, numerous interventions could be considered. This report assesses 24 supply chain and technology interventions in terms of increased traffic volume, CO_2 emissions, congestion, delivery cost, investment need and qualitative dimensions such as customer convenience and level of competitive disruption. Also, we want to start a discussion on how these interventions could best be combined, taking into consideration potential cannibalization or synergy effects.

Transition scenarios:
Recommendations to ecosystem players

Something needs to happen – so far, so clear. But where to begin? We present three different transition roadmaps and argue that an integrated ecosystem approach would optimize the last mile for both private and public players while minimizing customer disruption. This scenario includes electric vehicle (EV) regulation for inner-city areas, deliveries during night-time and before/after working hours, effective data-based connectivity solutions such as dynamic re-routing and load-pooling, as well as multi-brand parcel lockers and boxes. Such a scenario could reduce CO_2 emissions by 30%, congestion by 30% and delivery costs by 25% by 2030 when compared to a "do nothing" baseline. In addition, we also present a high-level timeline to indicate which interventions already have the potential to become effective in the next few years.

In terms of next steps, we encourage private and public players to team up and accelerate the roll-out of pilots on the suggested interventions. Also, we believe there is tremendous value in building discussion networks or consortiums for cities to exchange the most effective methodologies, discuss challenges and liaise with private-sector players. Besides, we believe that robust, harmonized regulations – e.g. for autonomous driving and inner-city e-mobility – would help automotive OEMs and logistics players to better allocate R&D investment and accelerate the adoption of sustainable supply-chain technologies. Lastly, the use of data and advanced analytics is a vital enabler for interventions such as effective load-pooling and real-time traffic control. Also, joint data standards and effective data sharing can bring tremendous benefits to all ecosystem players.

Context: Unparalleled growth in last-mile transport

In recent years, the face of urban commercial delivery has vastly changed. Parcel-delivery vehicles are double-parking and blocking lanes, e-grocers such as Walmart and Kroger, and food-delivery services such as DoorDash, Uber Eats and Postmates are increasing their online revenue by offering home deliveries in the downtown core via vans, bikes and scooters in increasingly shorter time windows. As a result, demand for last-mile delivery is soaring and is expected to grow by 78% globally by 2030. We see five main drivers of this development.

FIGURE 1:
There has never been a time of greater demand for last-mile transport

Urbanization

60%
people living in cities in 2030

20–35%
congestion increase since 2010

Customers

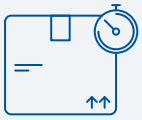
2.1bn
people expected to buy goods online by 2021

20%
online retail share by 2023

Products

10%
per annum e-grocery growth worldwide

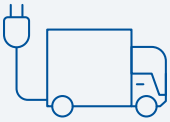
32%
of furniture sold online by 2023 in the US



Delivery

20%–40%
growth in same-day

10%
per annum growth in instant delivery



Technology

14–35%
xEV share of new car sales across regions by 2030

2024
year in which most OEMs will release L4/5 autonomous vehicles

78%
growth through 2030 in urban last-mile deliveries

Urbanization: Space as the scarcest resource

Cities are faced with increasing urbanization at a historically unprecedented rate. The global population is expected to reach 8.5 billion in 2030, of which 60% (equalling 5.1 billion people) will be living in cities. Increasing middle-class income and falling vehicle costs allow for individual mobility and will add millions of commuters per day to that figure. Unsurprisingly, mobility experts argue that the limiting factor for urban mobility will be land, not affordability, in the future.

As urban density increases, congestion increases exponentially. Some of the largest cities such as New York, Chicago and Los Angeles have seen congestion increases of 20–35% since 2010.[2] Also, cities are responsible for 70% of global emissions, to which delivery vehicles – both trucks and vans – add disproportionately high amounts compared to passenger cars.

Femke Halsema, Mayor of Amsterdam

"The city of Amsterdam is expected to have 1 million citizens in 2032, a growth of 20% compared to today. The number of jobs is expected to grow by 30% until 2040. The additional volume of traffic will lead to severe bottlenecks on the road and in public transport. Especially urban deliveries – mostly linked to the soaring e-commerce growth rates recently – cause structural problems to the city of Amsterdam. Currently, one in eight vehicles in the inner city is a truck or a van. Many old bridges and quays are not designed for the heavy loads and intensive use these days. Also, delivery vans cause gridlock, as these vehicles park on the street or in busy inner-city areas. Also, they present a safety risk to our many bike users and pedestrians. To combat this development and achieve our decarbonization targets, we have put a plan in place according to which the inner city will be free of fossil-fuelled trucks and vans by 2025, causing a 77% reduction in NO2, and a 42% reduction in CO_2 from all of the traffic in the city, including passenger cars."

E-commerce has a rapidly growing customer base

A new era of online presence has begun, and consumers are fully embracing online sales. Globally, 82% of all consumers have shopped online within a three-month period. A total of 2.1 billion people are expected to buy goods online by 2021. A large share of these sales will likely be made from mobile devices, considering the average consumer checks their phone 25 times per day (while the average US consumer does so 50 times a day).[3]

In fact, data shows that the growth of e-commerce is surpassing that of offline revenues: While the latter is expected to experience a 4% CAGR growth between 2019 and 2023, e-commerce will grow by 17% annually, representing about 20% of global retail share in 2023. This will fuel global parcel growth in business-to-consumer (B2C) and business-to-business (B2B), with the latter growing in proportion to the consumer segment. In terms of regional development, China is leading the pack with an online retail penetration of about 25% today and digital giants such as Alibaba and JD.com.

Jun Fan, Head of JD Express, JD Logistics

"We determined early on that building our own logistics network from the ground up would enable us to deliver the best possible customer experience. Today, that network covers 99% of China's population, and enables us to deliver over 90% of orders same- or next-day. We are developing solutions and using advanced technologies such as artificial intelligence (AI) and big data in a wide range of application scenarios to improve efficiency and reduce last-mile delivery costs. We are also pioneering autonomous delivery robots and building smart delivery stations in several cities in China to further enhance last-mile delivery. As the only company able to control the entire logistics process from supply chain down to the last mile, we are taking things a step further by leveraging our consumer insights and data analysis capabilities to better understand demand and to direct product design through our consumer-to-manufacturer (C2M) initiative. Our goal is simple – to deliver trust."

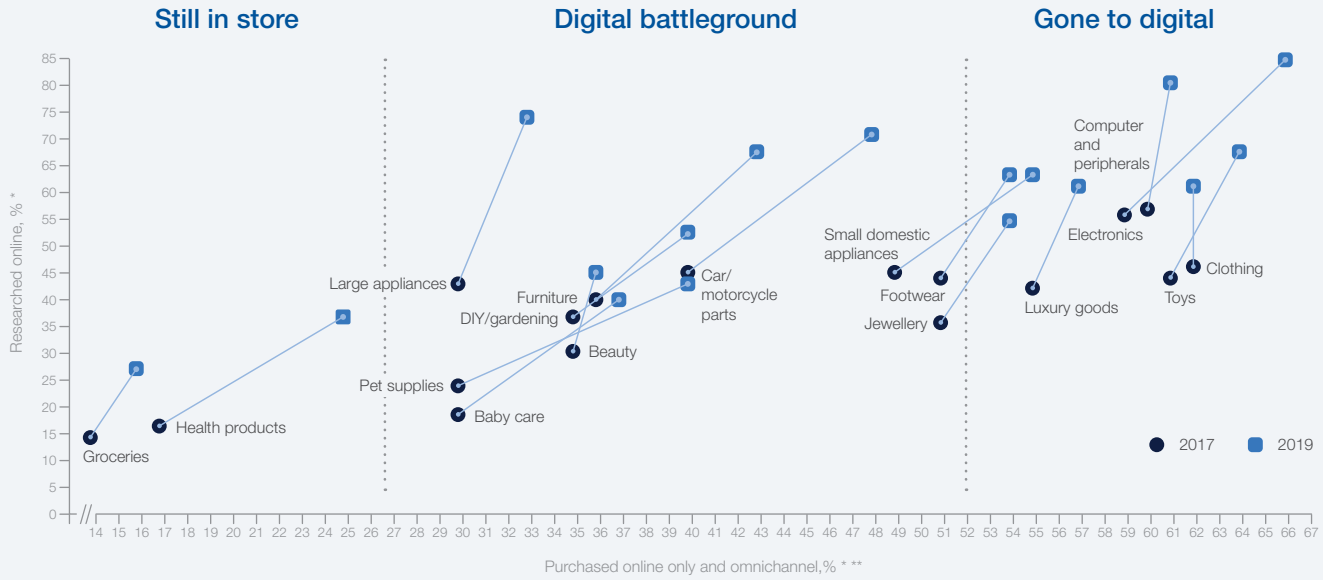
New categories move online and new business models emerge

The rise of incumbent online retailers, such as Amazon, Walmart and Alibaba, can be largely attributed to traditional online categories such as books, clothing and electronics. To illustrate this, Walmart's e-commerce sales grew by 43% in the first quarter of 2019, just ahead of its 40% year-over-year growth.[4]

In recent years, however, we have seen new categories scale online. Figure 2 shows that categories such as car parts, pet supplies, furniture, baby care and gardening are rapidly catching up and gaining momentum in online and multi-channel share in the United States.

Additionally, categories such as groceries and health products are still mostly bought in-store, but online penetration has drastically increased. Overall, we will continue to see more and more product categories enter and succeed in the digital battleground in the upcoming years, causing last-mile deliveries to increase in a similar fashion and contribute to the emergence of new business models such as Uber Freight, Instacart and Liefery.

FIGURE 2:
Ongoing digital and omnichannel shift across all categories[11]



* Base are online adults who are online at least once a week and over 18
** Combines online only and omnichannel (which use offline and online channels) buyers

NOTE: The 2017 and 2019 surveys are run in the respective years with minor changes to the methodology and number of survey participants

SOURCE: Forrester Consumer Technographics

Angela Hultberg, Head of Sustainable Mobility, Ingka Group (formerly IKEA Group)

"In challenging times for retail, Ingka group (formerly IKEA group) continues to grow. Online sales growth was close to 50% and is now surpassing 10% of total retail sales. With an increase in deliveries, we are sending more and more delivery vehicles into city centres, which has negative impacts on congestion, air pollution and noise pollution. Therefore, it is clear to us that we need to do things differently. We will transform our delivery services in all 30 markets to 100% electric or other zero-emission options by 2025. And we are well on the way. We reached 100% electric deliveries in Shanghai this year, and we have deployed EVs (electric vehicles) in 14 markets to date, with more coming soon. This transformation is about rethinking last-mile, finding new solutions that are not only more sustainable, but also more convenient for our customers. The number-one learning is that we need to act now. We cannot wait for perfect solutions; we need to take what is on the market today, deploy it and then work to make it better."

Faster delivery is the new normal

As regards delivery times, the need for speed is the third factor contributing to the overall increase in demand for last-mile deliveries. Deferred delivery – with a typical delivery time of one to three days – is, and will continue to be, the largest delivery segment. Same-day and instant delivery, however, are the fastest-growing segments in the last-mile environment, growing by 36% and 17% annually. In the US, they are expected to reach an aggregate retail online share of about 15% by 2025. While this growth will mostly occur in large cities, it disrupts the supply-chain models of incumbent delivery companies and supports the emergence of business models such as Uber Freight and DoorDash.

Clearly, Amazon is one of the players to look at when it comes to disrupting the delivery business. The firm has entered the market of third-party logistics carriers, and manages an empire of 390 warehouses and 20,000 delivery vans globally.[5] This allows the retailer to disclose plans setting one-day delivery as the new standard for all Prime customers. Globally, the service counts more than 102 million members. Currently, Amazon already delivers to 72% of all customers within 24 hours.[6] From a broader perspective, however, the majority of time-definite delivery models and related congestion and emission challenges will be linked to urban areas.

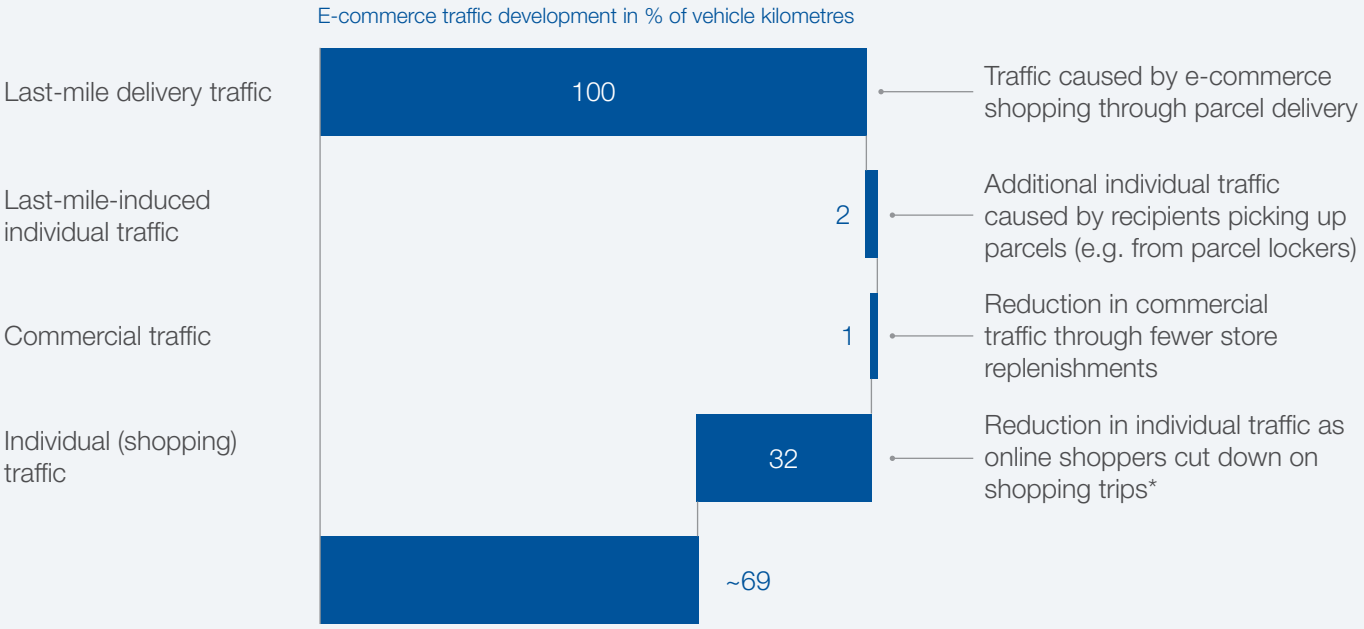
In particular, China is a fast-growing market in which same-day and instant delivery already make up more than 10% of overall parcel deliveries. This accounts for roughly 3 million daily, same-day items with approximately 400,000-500,000 instant deliveries. These numbers are more than double those of European deliveries, where same-day delivery accounts for only 5% of deliveries so far.

Delivery technologies transform the last mile

Technology is a significant enabler for ever-shortening delivery times, allowing for more efficient supply-chain processes and the launch of alternative delivery methods such as drones and droids. For instance, many automotive OEMs have been working on concepts that actively support

FIGURE 3:

Impact of e-commerce on commercial and private traffic volume



* Estimate based on 14% online share, 17 brick and mortar shopping trips per year (excl. grocery), 26 online orders per capita per year, 4 items bought per shopping trip, eCommerce sales growth of 50%

SOURCE: Euromonitor, BIEK, MID, World Bank, McKinsey & Company

the work of parcel drivers with the aid of camera-based object tracking and machine-learning software, automated vehicle loading systems and advanced analytics-based driver apps. This is in addition to regular drivetrain efforts, for which we see OEMs working in parallel on more efficient conventional drivetrains as well as battery-powered and fuel cell-powered electric vehicles. However, it is not only the delivery to the end customer that will be revolutionized. The handling of parcels in retailer or logistic company distribution centres will be enhanced by autonomous, self-learning applications. Tech giants Alibaba and JD.com are investing heavily in automating the supply chain, with Alibaba alone investing an estimated $15 billion in logistics automation and driverless technology over the next five years, navigating new frontiers of supply-chain efficiency and use of data.[7]

Clemens Beckmann, Head of Smart Cities and Last Mile Solutions, Deutsche Post DHL Group

"The ever-increasing growth of e-commerce is imposing two major challenges for dense cities: pollution and traffic congestion caused by the rising number of delivery vehicles if the status quo remains. The consistent electrification of vehicles is one way to address the pollution issue. Deutsche Post DHL Group has developed the 'StreetScooter', an electrified van, with more than 10,000 vehicles already in service. It is also available to third parties. Traffic congestion in inner cities is mainly caused by challenging parking conditions for B2C 'to-door deliveries'. The introduction of consolidated pick-up and drop-off points is an appropriate solution to tackle the congestion problem. The drop-off points, either manned parcel stations/shops or unmanned parcel-locker concepts, could further develop into carrier-agnostic service structures very close to customers' home addresses. These parcel stations could even be transformed into mobile and autonomously operating parcel-delivery robots – big enough to carry several parcels and small enough to pass through doors. Managing all of these challenges for last-mile delivery, and responding to ever-increasing consumer expectations, can prove to be challenging for logistics service providers. Addressing this situation, DHL has created 'Greenplan', a new algorithmic solution that calculates the most efficient routes based on available space and time constraints, e.g. traffic flows or delivery windows. 'Greenplan' is available to logistics service providers."

E-commerce has an impact on both people and goods transport

Without any doubt, there is a certain degree of interdependence between the transportation of goods and people. Depending on the source, different realities seem to coexist. It could be argued that e-commerce allows for consolidation effects as individual trips to inner-city shopping areas are replaced 1:1. However, others claim that there is additional traffic due to the increased occurrence of delivery vehicles for goods as well as individual traffic vehicles used by people picking up parcels at stores or used by those who continue to make shopping trips to the inner-city area. A high-level calculation, as seen in Figure 3, shows that ~30% of e-commerce-related delivery traffic could be offset by a reduction in individual shopping traffic.

Base case: Emerging challenges for the ecosystem

To assess the benefits and challenges for the ecosystem of last-mile goods transportation appropriately, it is necessary to distinguish between different delivery networks, segments and vehicles. Generally speaking, there is parcel delivery and there is freight delivery. While the former is concerned with delivering parcels and small packages, the latter relates to items above 32 kg such as furniture and full store replenishments. Additionally, parcel and freight delivery can be further segmented in terms of time allowed from order to delivery. The parcel segment can be divided into deferred, time-definite, same-day and instant delivery. For freight delivery, recipient and purpose of transportation are the most frequently used forms of segmentation. One distinguishes between B2B store delivery, B2B carrier and B2C carrier. It is important to understand that the seven different delivery segments depicted in Figure 4 are typically linked to very different and distinct networks.

The growth in e-commerce offers tremendous economic benefits for the private sector. On a macro level, this growth will profoundly affect cities across several dimensions if no action is taken by either public- or private-sector players. The main question is: What happens if nothing happens? What will be the outcome if no effective interventions to manage the last mile are implemented?

Congestion, emissions and delivery cost: Key challenges if no effective intervention takes place

Using traffic simulation and quantitative modelling, we assessed the impact of growing B2B and B2C urban deliveries across several dimensions. This was done using two city archetypes – a suburban/urban sprawling metropolitan area, and a dense, inner-core metropolitan area.

To derive meaningful insights, we used real-time traffic and infrastructure data from cities such as Los Angeles, Chicago, Singapore, Amsterdam, Paris and London, and translated them into the two above-mentioned archetypes. We also generated distinct insights for the parcel and freight segment, as each of these typically follows its own logistics approach and uses distinct delivery networks. Lastly, we defined two different adoption scenarios: A 2030 “mandated adoption” scenario and a 2030 “customer choice” scenario, in addition to the “unguided adoption” scenario with no intervention. The former assumes that there will be a large push from the regulators, e.g. in the form of EV target shares and inner-city traffic regulation. The latter also includes a certain degree of regulation, but is primarily based on voluntary change in customer behaviour and demand patterns. For instance, we assume a 100% EV penetration rate in 2030 in the mandated adoption scenario, but only a 40% penetration rate in the customer choice scenario, assuming that logistics players will gradually transform their fleets even without heavy regulation. Likewise, heavily regulating the doorstep could promote a parcel locker penetration rate of up to 95%, but the intervention will likely not exceed a 30% penetration rate without heavy regulation.

The output factors to measure the impact of any scenario are clustered in line with the three Ps – namely, people, planet and profit. In addition to quantitative modelling results, qualitative factors such as customer convenience and changes in the competitor landscape are considered.

In an “unguided adoption” scenario, cities will mainly be affected along three main dimensions (Figure 6). First, the number of delivery vehicles on the road will increase by 36% between 2019 and 2030 (top 100 cities globally). Second, these vehicles will emit an additional 6 million tonnes of CO_2, putting additional pressure on cities’ and automotive OEMs’ decarbonization targets. Third, cities will be burdened with even more congestion. Our research has shown that the average commute time could increase by 21% (purely last-mile delivery induced), equalling an additional 11 minutes of commute time for each passenger every day by 2030. This modelling outcome is very much aligned with what we have seen in real life in recent years, with an increase of commute times of between 20% and 35% since 2010 in cities such as Los Angeles, Chicago, Beijing and New York City.

Without any doubt, there is an urgent need for action and effective interventions must be put in place, especially for freight delivery, as it currently accounts for ~85% of delivery mileage and is therefore mainly responsible for emissions and congestion driven by commercial vehicles.

FIGURE 4:
Seven different delivery networks for last-mile delivery

	Segment	Use cases		
Parcel size	**Deferred delivery** – arrives some day	Normal/express e-commerce shopping and returns	Small-scale B2B shipping	C2C shipping
	Time-definite delivery – arrival next/specific day/time	(Largely international) B2B reliability shipping	Express e-commerce shopping	
	Same-day delivery – arrival on same day	E-grocery shopping and returns	Same-day e-commerce shopping	
	Instant delivery – delivered right away (less than ~2 hours)	Urgent document and item delivery	Prepared food delivery	Instant e-commerce shopping
Larger than parcel size	**B2B store delivery**	Store delivery and replenishment		
	B2B FTL/LTL carrier	Remaining full-truckload (FTL)/less-than-truckload (LTL) carrier (items >32 kg)		
	B2C LTL/two-person handling carrier	B2C LTL/two-person handling (esp. furniture)		

* Store replenishment and freight delivery out of scope for now, estimate in later stag

FIGURE 5:
Key variables for modelling

Key variables

City archetype*	**(Sub-)urban sprawling metropolitan area** e.g. Los Angeles, Shenzen	vs.	**Dense, inner-core metropolitan area** e.g. Chicago, London, Singapore
Delivery types	**Parcel deliveries** incl. deferred, express, same day, instant	vs.	**Freight deliveries** incl. B2B LTL/FTL and B2C two-person handling
Adoption scenario	**Mandated ("aggressive"/ "push")** heavy incentivization or regulation	vs.	**Customer choice ("realistic"/ "pull")** adoption based on economics and end-user demand

Output factors

Planet	CO_2 emissions
People	Congestion
	Customer convenience**
	Worker safety
Profit	Unit cost
	Vehicle volume
	Business model disruption
	Investment need

* Archetypes based on real-life city data;
** Enhanced customer convenience through enhanced timing, quality of delivery and distance to travel

Urban freight has a disproportionately high impact

As already mentioned in the beginning of this chapter, goods delivery can be separated into parcel and freight. As can be seen in Figure 4, it is worth elaborating on the different delivery segments and their impact on the baseline. In both of our city archetypes, freight trucks present approximately two-thirds of urban delivery vehicles today; the remainder can be allocated to light commercial vehicles and passenger cars. While LCVs (7% CAGR) and passenger cars (7%–12% CAGR) will experience the strongest growth between today and 2030 – mostly driven by e-grocery and food delivery – the number of freight trucks is expected to increase by only 1–3% annually. However, these trucks will continue to make up the majority of last-mile related vehicles, adding disproportionately to congestion due to slower acceleration, slower average speed and higher vehicle backlog resulting from second-lane parking. Replacing some of this vehicle volume with bikes, electro-scooters, drones and droids can be impactful, but various pilots have shown that they bring about new challenges such as the regulation and enforcement of micro-mobility and air traffic.

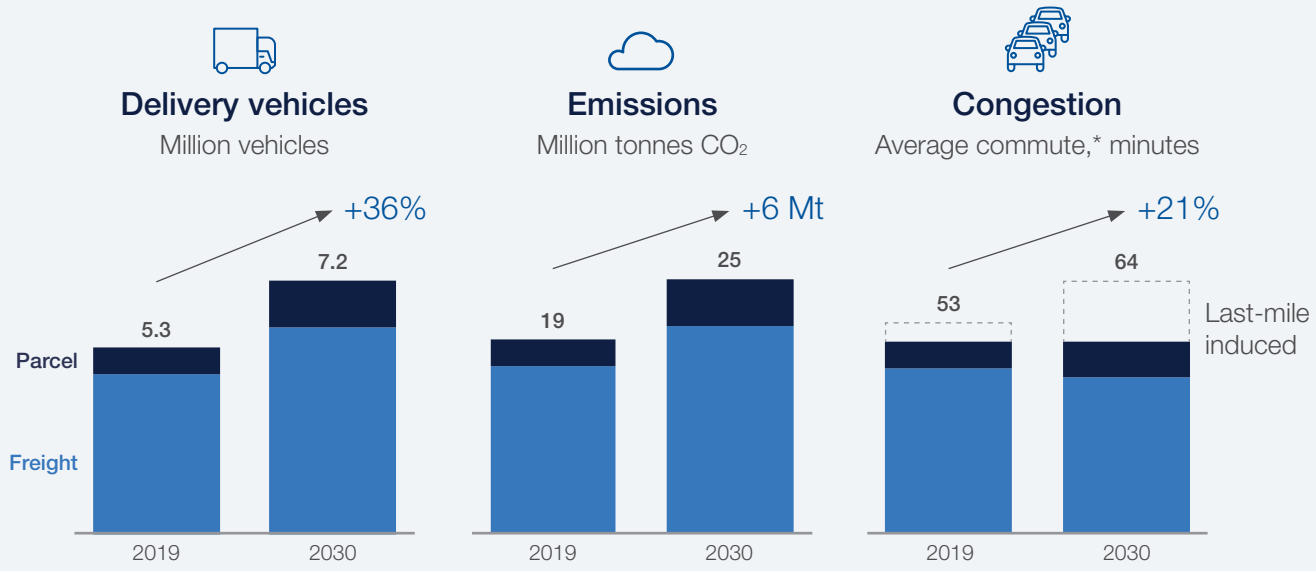
Nascent city activities and interventions

Across many different cities worldwide, first pilots and initiatives are already in place or are soon to be launched. For instance, in Amsterdam, the action plan called Actieplan Schone Lucht has been set up this year and shifts the conversation “from the inside to outside” and “from business to private”. Thereby, the ultimate objective is to offer emission-free traffic in the entire city centre by 2030, banning diesel and other combustion engines by 2025 for commercial purposes. One of those facilitators of this is the collection and usage of big data through a central storage system.

Singapore is also pushing innovative last-mile initiatives. Most recently, the city’s first drone estate, covering a 200-hectare business park, has been established to conduct trials and test a variety of potential use cases and urban environment complexities. It is also a fertile field for co-working and research as a vibrant community of start-ups, research institutes and technology providers pilot their latest urban innovations. Until 2023, autonomous vehicle will be piloted in three districts to cover home delivery.

When looking across most global capitals and major cities, many different initiatives can be identified. However, we argue that it takes a systematic change in which the entire last-mile ecosystem moves from the most effective individual examples to systemic change. In addition, a clear prioritization based on quantified impact assessment is needed to accelerate implementation – the initial fact base shall be provided by this report.

FIGURE 6:
2030 base case scenario



* Average commute for representative city

NOTE: Top 100 cities globally only.

Last-mile interventions

This report has chosen to look at technology and supply chain interventions that not only help to improve congestion, emissions and delivery costs, but also positively contribute to the three Ps – people, planet and profit. In this chapter we provide an overview of these interventions and quantify their impact.

Interventions grid: Overview of 24 prioritized interventions

Companies and cities have explored many solutions, which generally fall into six broad categories: vehicle change, secure delivery, customer movement, consolidation, last-leg change and delivery environment, thereby encompassing the full last-mile funnel. Figure 7 shows an overview of 24 prioritized interventions and their level of maturity. Clearly, this set of interventions is not comprehensive, but it is based on the focus topics that emerged during the many partner discussions and workshops in the context of this project. We want to emphasize that there is a lot of activity and media buzz regarding interventions beyond the 24 covered in this report. For instance, optimizing packaging and minimizing the amount of used plastics and air shipments could help to increase the use of cargo bikes and droids. Also, new innovative approaches such as the "Amazon Day"[8] and efforts around combined people-goods-taxis are worth further exploring. Likewise, we recognize that different regulatory interventions – such as congestion charging – are effective but beyond the scope of this report.

Last-mile simulation: Quantified impact of interventions

The main focus of this initiative has been to analyse how different interventions can reduce the negative impact of last-mile delivery. We have found that each of the prioritized interventions could have a tremendous impact on specific outcomes of the three dimensions of people, planet and profit. There is, however, no silver bullet with the potential to address all outcomes at once.

Some interventions are effective at addressing a single dimension. For instance, even in a conservative scenario ("customer choice"), battery electric vehicles and H2 electric vehicles can reduce CO_2 emissions by 16% and 24%, respectively. In a regulated scenario ("mandated implementation"), effective parking enforcement mechanisms could help prevent double parking, thereby reducing congestion by up to 29%.

FIGURE 7:

Overview of 24 prioritized last-mile interventions

- Can be in use at scale only after more than three years
- Can be in use at scale in the next one to three years
- In use today

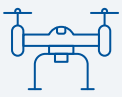
Vehicle change

EV

Efficient gasoline/ diesel ICE

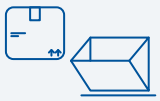
H2 FCEV

Autonomous with runner



Drones and truck

Secure delivery



Parcel box

Trunk delivery

Secure delivery systems

Customer movement

Parcel locker

Office delivery

Multi-brand parcel shop

Consolidation

UCC

Load-pooling

Last-leg change

Goods tram

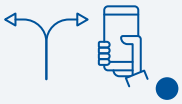
Micro-hub

Retrofitting of parking-based infrastructure

AGV locker (on street)

Droid (on pavement)

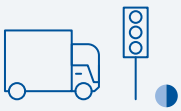
Delivery environment



Dynamic re-routing

Double-parking enforcement

Express lane use



Real-time traffic lights

Delivery parking zones

Night-time delivery

There are many potential interventions being explored to reduce the impact

Other interventions can produce better ecosystem outcomes across several dimensions. For instance, mobile parcel lockers, i.e. convenient, mobile multilayer post boxes, could reduce delivery costs by 2% to 12% and, at the same time, ease congestion by 5% to 18%, depending on the scenario.

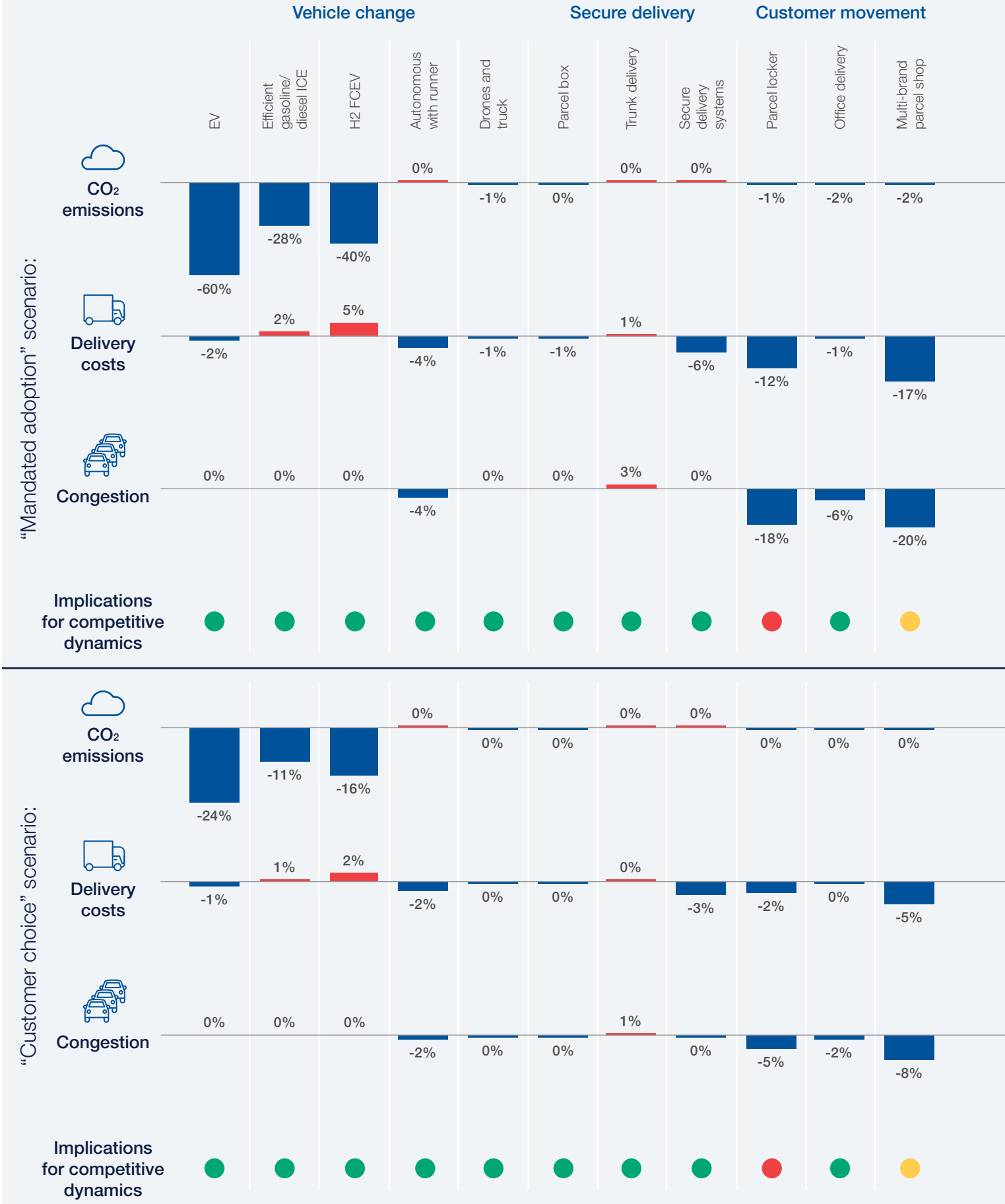
Likewise, while multi-brand parcel shops would considerably improve customer convenience and reduce congestion and emissions to an equal degree, they would require logistics players to cooperate on retail space and build merged supply chains. The first pilot opened in Hamburg in 2018,[9] allowing customers to pick up parcels from DPD, GLS, Hermes and UPS. Another intervention with outcomes on several dimensions is night-time delivery. In our ambitious scenario, a 15% reduction in congestion is possible when CO_2 levels drop by 4% and delivery costs fall by 28%. These reductions can be achieved through larger vehicles, which will move with higher average speed during night-time.

Finally, several interventions have notable negative impacts that must be considered along with the positive ones. For instance, urban consolidation centres can bring costs down by 3%, emissions by 2% and congestion by 5% (mandated adoption scenario). However, they can also have unintended consequences in other areas – in this case, they can massively disrupt established delivery networks and lead to structural changes in delivery players' entire supply chain.

We hope the quantification of interventions in Figure 8 will inform all types of ecosystem players' strategy and technology discussions. The true challenge of the last mile, however, is to understand how these interventions can be combined in the most effective way to create collaborations between individual interventions and produce a balanced, positive outcome for both private- and public-sector players.

FIGURE 8:

Interventions grid with overview of impact on emissions, delivery cost, congestion and implications on competitive dynamics



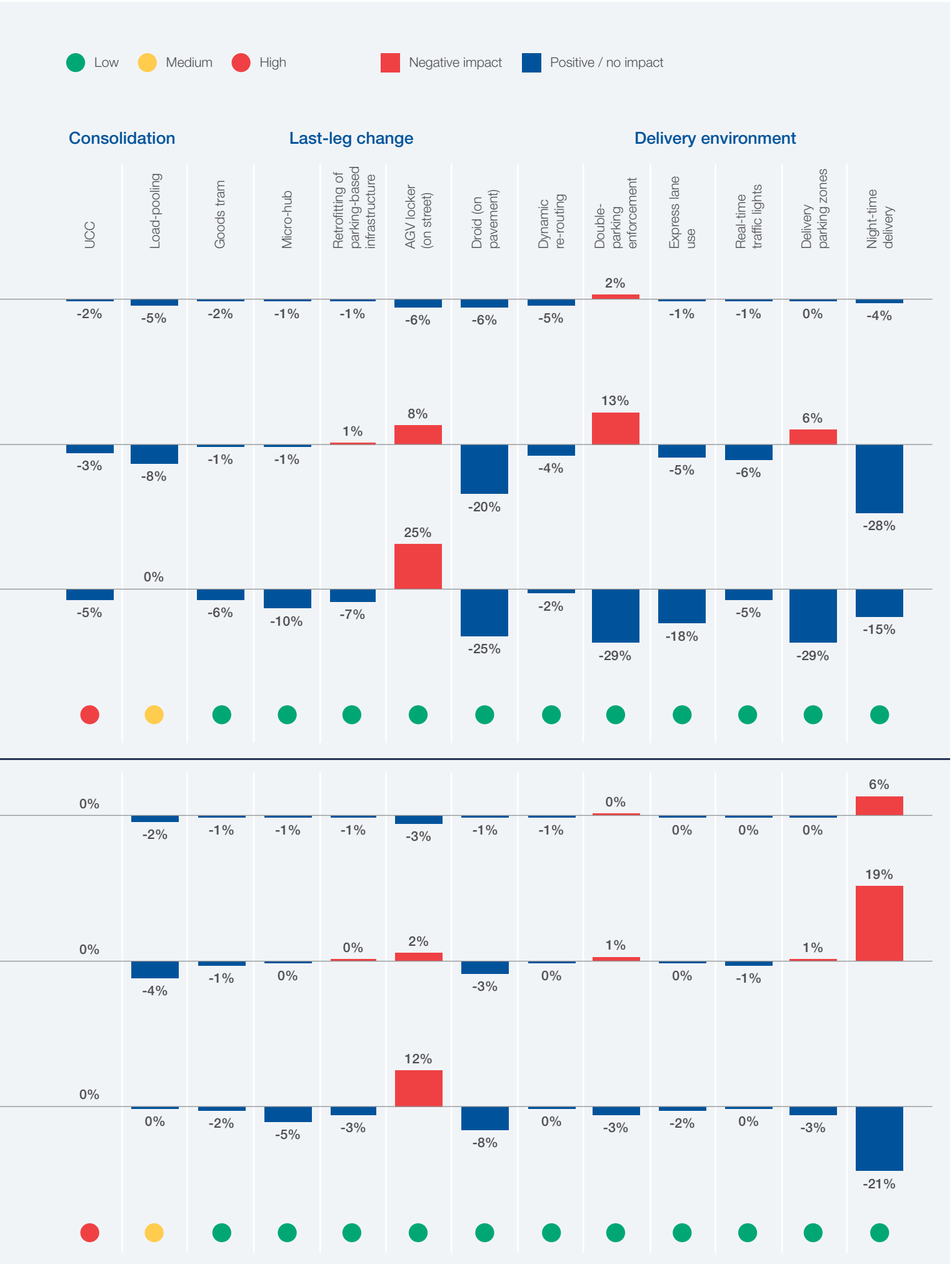
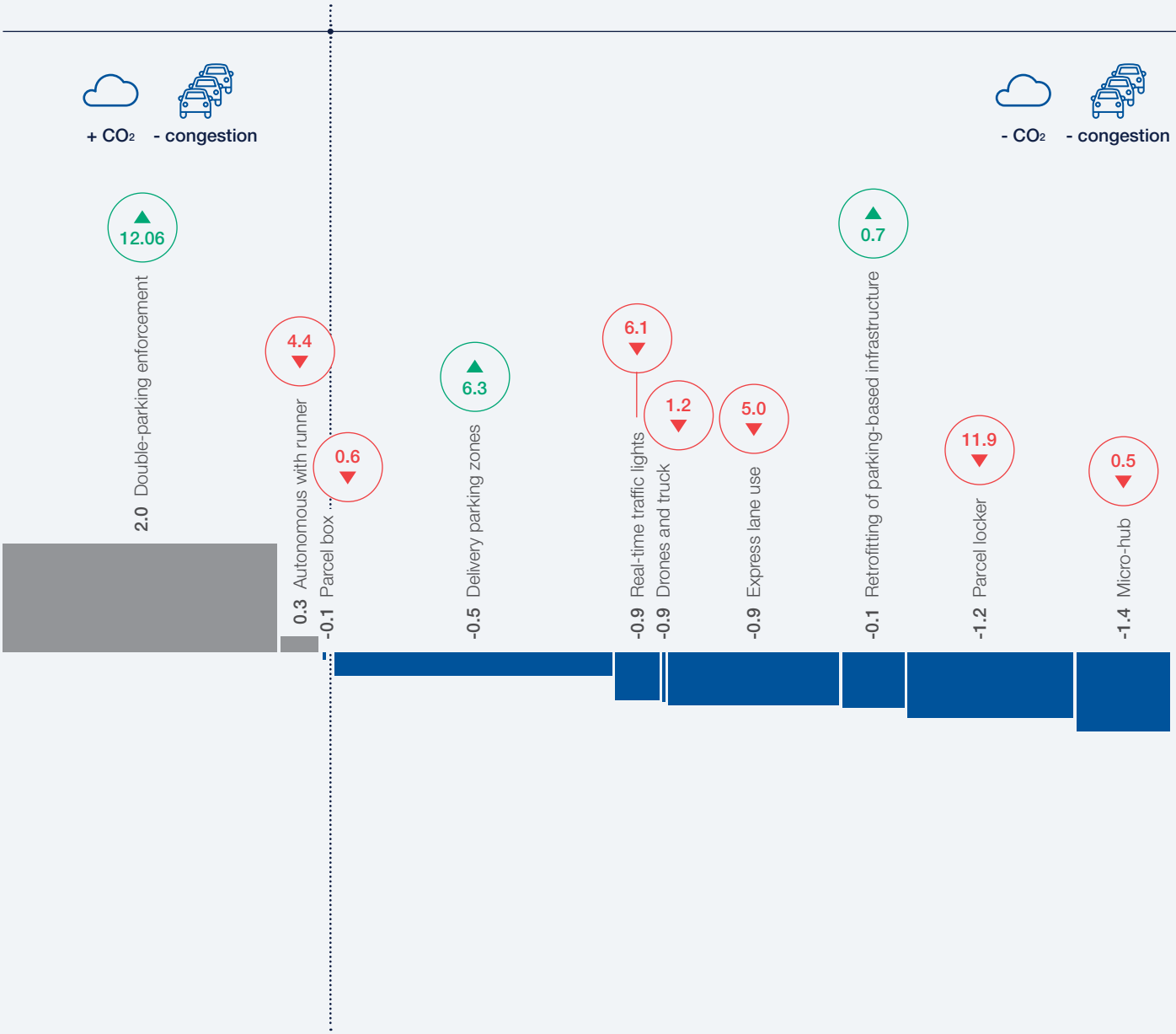

Low
Medium
High
Negative impact
Positive / no impact
Consolidation
Last-leg change
Delivery environment
UCC
Load-pooling
Goods tram
Micro-hub
Retrofitting of parking-based infrastructure
AGV locker (on street)
Droid (on pavement)
Dynamic re-routing
Double-parking enforcement
Express lane use
Real-time traffic lights
Delivery parking zones
Night-time delivery
-2%
-5%
-2%
-1%
-1%
-6%
-6%
-5%
2%
-1%
-1%
0%
-4%
-3%
-8%
-1%
-1%
1%
8%
-20%
-4%
13%
-5%
-6%
6%
-28%
0%
-5%
-6%
-10%
-7%
25%
-25%
-2%
-29%
-18%
-5%
-29%
-15%
0%
-2%
-1%
-1%
-1%
-3%
-1%
-1%
0%
0%
0%
6%
0%
-4%
-1%
0%
0%
2%
-3%
0%
1%
0%
-1%
1%
19%
0%
0%
-2%
-5%
-3%
12%
-8%
0%
-3%
-2%
0%
-3%
-21%

FIGURE 9

CO_2 and congestion curves for the last mile

"Mandated adoption" scenario:



Description

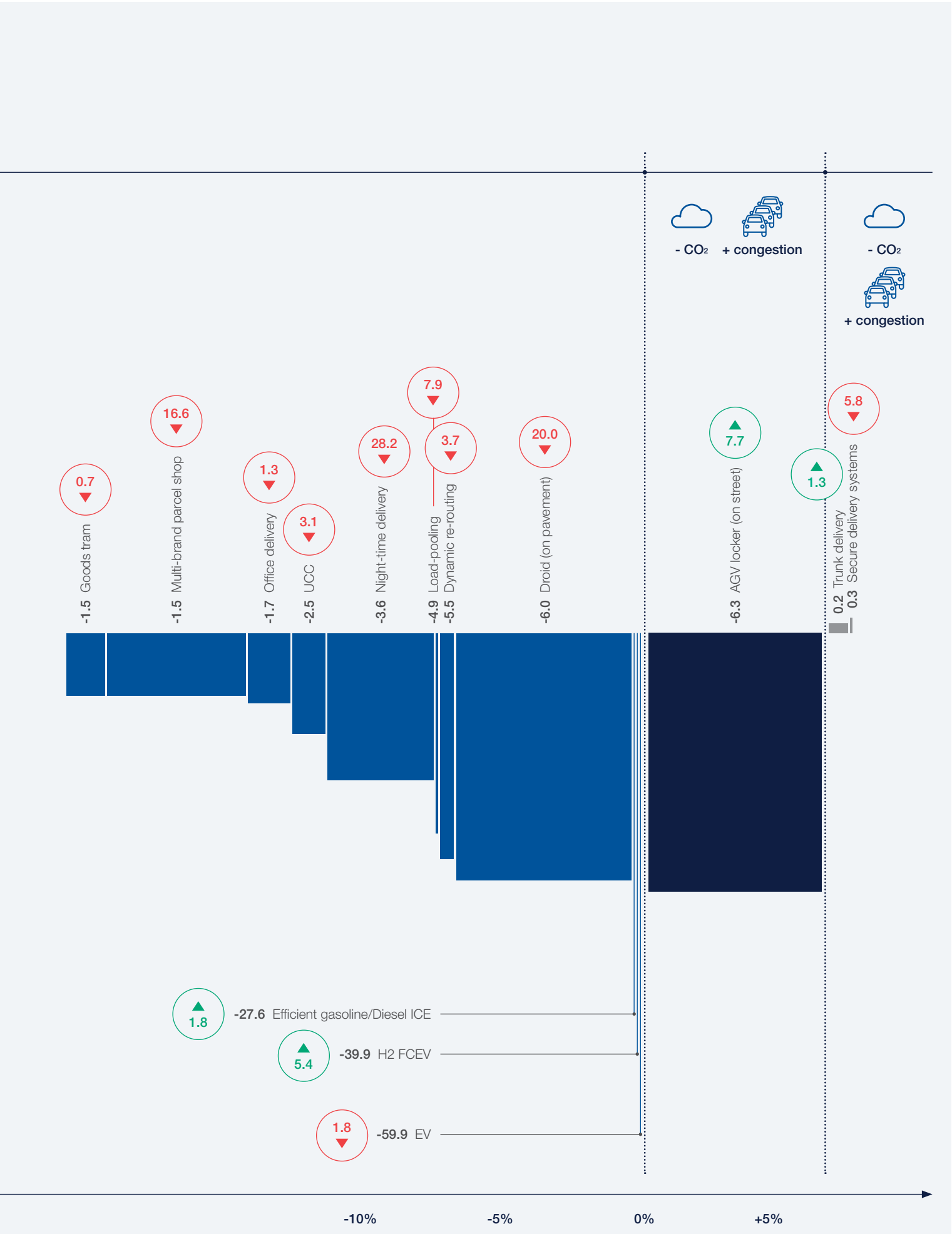
Y-axis: Impact on **CO_2 emissions**, in %

X-axis: Impact on **congestion**, in %

Unit cost: Increase in %; Decrease in %

Cannibalization and synergy effects not accounted for

Average value of two city archetypes


- CO2
+ congestion
- CO2
+ congestion
0.7
-1.5 Goods tram
16.6
-1.5 Multi-brand parcel shop
1.3
-1.7 Office delivery
3.1
-2.5 UCC
28.2
-3.6 Night-time delivery
7.9
3.7
-4.9 Load-pooling
-5.5 Dynamic re-routing
20.0
-6.0 Droid (on pavement)
7.7
-6.3 AGV locker (on street)
1.3
5.8
0.2 Trunk delivery
0.3 Secure delivery systems
1.8
-27.6 Efficient gasoline/Diesel ICE
5.4
-39.9 H2 FCEV
1.8
-59.9 EV
-10%
-5%
0%
+5%

Transition scenarios: Recommendations to ecosystem players

Having reinvented the CO_2 abatement cost curve and tailored it to the last mile, we now need to develop interventions for cities and businesses and estimate their respective costs. This chapter describes three distinct scenarios that could be relevant for private- and public-sector players. Also, we end with concrete recommendations for how an ecosystem change can be accelerated, namely with the aid of effective public/private-sector collaboration and joint investment, the set-up of city platforms for the most effective exchange methods, the development of a robust, harmonized regulatory framework as well as the effective use of data- and analytics-related activities.

Figure 9 shows the impact of interventions on emissions, congestion and delivery costs for the scenarios “mandated adoption” and “customer choice”, respectively.

The transition scenarios with different target functions

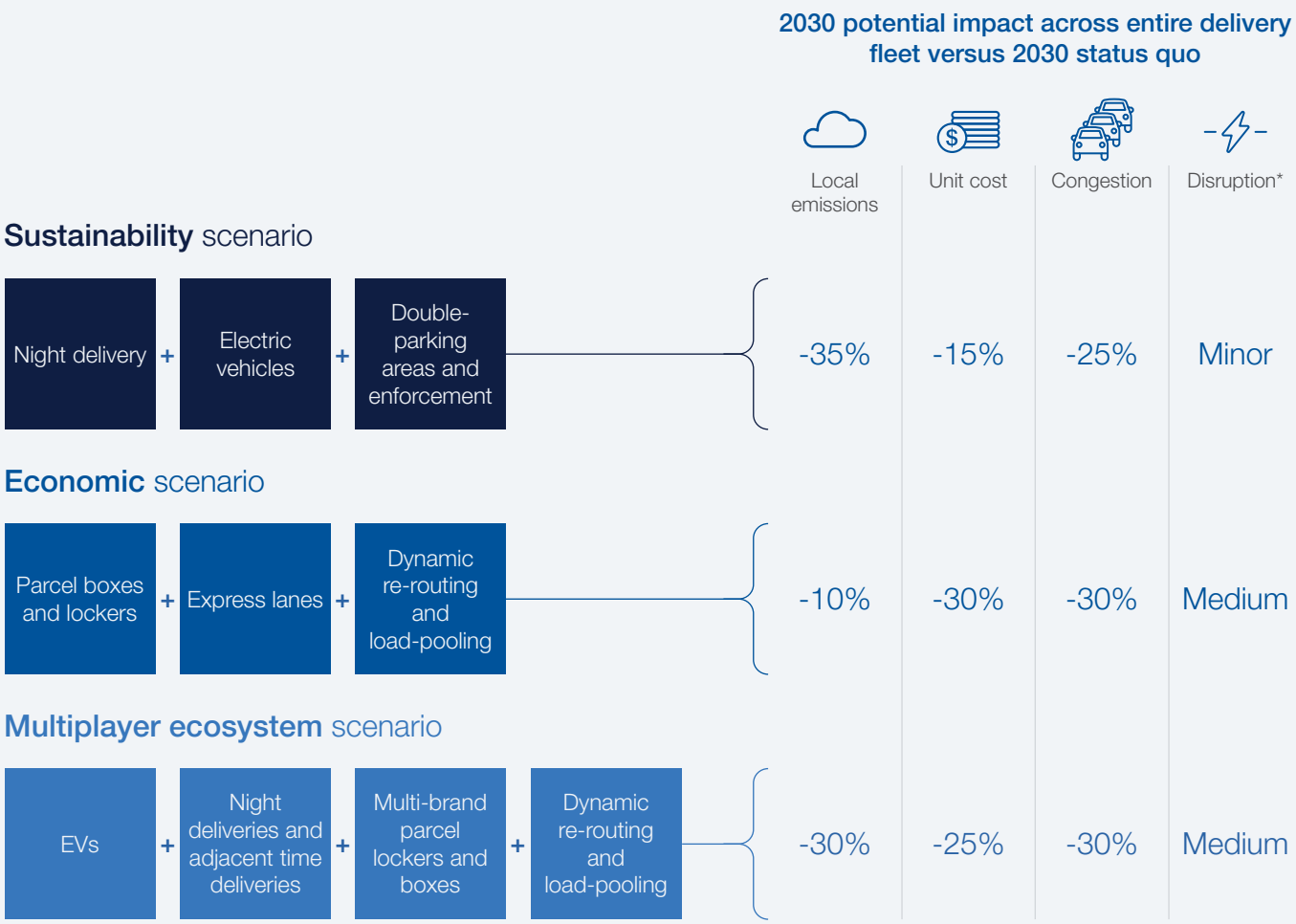
At first glance, it’s a given that private and public players might have different objectives that would require different interventions. For example, reducing emissions and traffic congestion are bound to be top priorities for cities and municipalities, whereas interventions that decrease delivery costs and minimize disruptions in current business models are more appealing to logistics players. The optimum transition roadmap scenario aligns business priorities with ecological and social priorities, and urges quick action on all stakeholders.

Our first scenario is based on the premise that cities’ priorities centre on sustainability-related topics such as achieving decarbonization targets, freeing inner-city traffic zones from congestion and increasing overall street safety and quality of life for citizens. This scenario could include EVs, night deliveries and deliveries at marginal times, explicit parking areas for delivery vehicles, as well as stronger enforcement mechanisms regarding second-lane parking. One could argue that the disruption for automotive OEMs and logistics players is bearable, as the technology is market-ready and the private sector will manage to bring down battery costs in the short or mid-term. This intervention could produce great interactions with night deliveries, as noise emissions of EVs are minimal. Overall, such a scenario could reduce CO_2 emissions by 35%, unit costs by 15% and congestion by 25%, assuming that there will be some degree of cannibalization between the interventions and that the impact of these interventions will not be purely additive.

Our second scenario addresses the economic perspective of logistics players. Essentially, logistics players are keen to reduce delivery costs while, at the same time, promoting sustainable deliveries and avoiding excessive delivery-chain disruptions that are usually accompanied with interventions such as urban consolidation centres (UCCs).

From a logistics point of view, express lanes would be desirable to reduce delivery times and thus costs. Also,

FIGURE 10:
Transition scenarios



* Disruption referring to a) disruption of customer behaviour/processes, and b) disruption of competitive dynamics and business models

parcel boxes and lockers are desirable because they are less disruptive than UCCs. In other words, a consolidation of the very last mile is more desirable than a consolidation of the second-to-last mile for logistics players, as the level of disruption would be manageable.

This intervention could include a multi-brand approach, in which consumers can pick up and return parcels from different players such as UPS and DHL. While multi-brand solutions come with the need to collaborate with competitors and to give up certain privileges, they might still be less costly than waiting for last-mile start-ups to disrupt the last mile and launch convenient, local delivery solutions. Additionally, advanced analytics and Internet of Things (IoT)-based solutions such as load-pooling and dynamic re-routing could contribute to an overall scenario that reduces emission by 10%, unit cost by 30%, and congestion by 30%.

The ecosystem perspective, our third scenario, has the potential to benefit private and public players equally. However, to do so, everyone – companies, regulators, drivers and citizens – must contribute to the ecosystem and change their behaviour to some degree. Increased EV penetration will become effective through both regulation and automotive OEMs working to bring down battery costs and enabling positive total cost of usage (TCU). Likewise, night deliveries will most likely take place through regulation, but also on a voluntary basis as it helps logistics players to bring down costs significantly. Multi-brand parcel lockers and boxes could be implemented in cooperation with cities that invest in future-ready infrastructure. Connectivity solutions should continue to be the priority for logistics players as well as IoT/big data players that help to optimize delivery routes, irrespective of traffic regulations or type of drivetrains.

We do recognize that systemic change will require considerable investment. For instance, fully implementing our proposed “ecosystem scenario” would require investment of ~11.5 billion euros ($12.7 billion) in the ecosystem by 2030 for a city archetype with ~2 million inhabitants. These investments include a fleet transition to EV-only, additional labour costs for night-time deliveries, the costs of installing and maintaining parcel lockers and boxes as well as multi-brand parcel shops, and development and licensing costs for vehicle-to-anything (V2X) connectivity solutions.

Timeline for implementation

With no intervention, e-commerce and correlated last-mile traffic will immediately pose severe challenges to cities in the next one to three years. Opportunities to effectively manage urban traffic, boost the liveability of cities and the health of the private sector, however, are abundant. Figure 11 depicts a high-level timeline, assessing the technological mass-market readiness in the upcoming years and the effort needed in terms of infrastructure change. As shown, most private players will need to take a parallel approach to product development and investment allocation, piloting and scaling interventions such as parcel lockers and effective B2B delivery systems, while at the same time continuing to invest in breakthrough technologies such as autonomous driving and robotics. The good news, however, is that short-term interventions which can already be implemented today and in the next three years do exist – and can create positive effects for the ecosystem in the upcoming years.

Public- and private-sector collaboration for accelerated impact

The essence of our report is that the last-mile challenge is so big and unique in nature that it requires closer collaboration of all ecosystem partners to produce beneficial results for every stakeholder, but also distributing the burden on to multiple shoulders that might come with certain effective solutions.

In terms of the next steps towards implementation, we want to encourage firms and cities to accelerate pragmatic intervention pilots, especially in mid-sized cities that do not have the innovation and traffic management budget of forward-thinking metropolises such as New York and London. This could include projects based on multi-brand parcel lockers and night-time deliveries. Also, we believe new financing models beyond conventional public procurement will become relevant.

Set-up of city platforms

In addition, we see a strong need for city platforms or forums in which public-sector players of all sizes can exchange the most effective methodologies, report back from successful last-mile pilots, interact with businesses and discuss which evolutionary interventions can be implemented now and which revolutionary measures must be prepared to accelerate implementation in the upcoming decade. While examples of these platforms are abundant for large cities – such as the C40 Cities Climate Leadership Group, which presents one-twelfth of the world's

FIGURE 11:
Timeline for implementation of interventions

population – we argue that such forums are missing for medium-sized cities and large cities with a less systematic approach to, and budget for, traffic management. Congestion and decarbonization challenges have also become a major pain point for cities beyond the usual suspects such as Los Angeles, London and New York, and medium-sized cities have the ability to pilot last-mile interventions rather pragmatically, without bureaucratic processes or the risk of media scrutiny, but with the unique asset of many ambitious and personally engaged mayors and city planners who want to improve traffic beyond repairing potholes.

Robust, harmonized regulatory environment

We argue that today's heterogenous regulatory landscape – or, in some cases, the absence of any legal boundary conditions – makes it extremely difficult for the private sector to plan for the next three to five years, let alone for the next ten years, during which major technology trends such as autonomous driving, droids and hydrogen will reach a certain maturity stage. To illustrate, in the US, 29 states have passed certain laws for autonomous vehicles, and there is a clear risk of proliferation of different, occasionally conflicting regulations. While in California, the law requires that pilot data related to vehicle and robot testing is shared with the state government, other states such as Texas and Arizona have a less explicit regulatory framework that, in the end, creates compliance challenges, reduces street safety and prevents technology players from developing scalable, standardized offerings. Another example would be inconsistent regulation of drone usage in the US. While state statutes restrict use by law enforcement over critical infrastructure, private property and other forms of operations, such as large public events, most local restrictions only prohibit flying over private property without the owner's consent. Also, the required permission to fly a drone is enforced only in some states, such as Massachusetts and North Carolina.[10]

Therefore, we believe that a robust, consistent and globally binding regulatory landscape for vital technologies such as autonomous driving, emissions and multi-brand delivery solutions would be tremendously beneficial for improving predictability, strategic investment planning and, ultimately, road safety.

Sophie Punte, Executive Director, Smart Freight Centre

Why are good data and common methodologies important to improve last-mile delivery in cities?
"These will allow us to identify where policy and action will have the most impact as well as track and report progress. Luckily, there is a global methodology for calculating and reporting GHG emissions from freight, called the GLEC Framework, which is consistent with the GHG Protocol that many cities and companies already use."

Many cities and companies are pinning their hopes on electric and alternative fuel vehicles, but is that sufficient?
"Cities and companies that deliver urban freight services need to pull everything out of the closet to reduce congestion and emissions in the face of growing demand. Low or zero-emissions vehicles are key but won't address the congestion problem in, for example, New York, with more than 1.5 million deliveries per day."

What role can "city platforms" and discussion forums play in enabling faster implementation of measures?
"Cities are in a unique position because they don't compete with each other and therefore can only benefit from collaboration. Cities can act as 'laboratories' and, through city platforms, can accelerate learning and innovation. Companies can help transfer solutions from one city to another as we have seen with, for example, parcel lockers and cargo bikes."

What role do public-private partnerships play in reinventing the last mile?
"Ideally cities and companies develop plans that fit like a hand and glove. This means that city policies are complemented by concrete company actions. For example, the switch to electric vehicles is made faster if a city introduces low-emission zones and invests in parking places with charging infrastructure. If they also use common indicators, they can communicate successes together."

Effective use of data and analytics

Lastly, we want to stress the inevitable importance of data usage and sharing for developing and implementing effective interventions. Generally speaking, the availability of data is not the main challenge. Both cities and private players collect abundant data; however, analytics capabilities to derive achievable insights, and build a solid baseline against which to measure the impact of interventions, as well as cross-sector collaboration, are often missing. We see a need for action along two dimensions. First, private-sector players – especially automotive OEMs, logistics players and infrastructure providers – need to embrace the shift from hardware to an increasing number of software solutions and accelerate their efforts in the analytics sphere, enabling the use of real-time routing and tour-planning solutions, smart load-pooling, flexible pricing offerings etc. This can be done by building up their own capabilities or – as in most cases – will occur through an increased level of partnership and merger-and-acquisitions activities.

Second, cities need to embrace their role as vital and central players in urban mobility. Gone are the days when cities could focus on fixing potholes and building yet another bypass. We encourage cities to develop data-sharing models. One important example here is the work the WBCSD does on defining data-sharing principles and standards. Also, through systematic, data-driven traffic management and control, cities can combine different data such as traffic flow, emissions and intersection data with dynamic, real-time traffic interventions and regulations. Players such as Siemens, Kapsch and Swarco, which specialize in traffic-management software and platforms, as well as emerging tech players such as Remix, which offers real-time simulation and analytics, are supporting cities to make this transition. However, it is important to mention that it is not only about large exchange-to-exchange (E2E) platforms and revolutionary interventions; small connectivity solutions and data-sharing agreements are as valuable.

In sum, there is tremendous pressure for all ecosystem players to act, but there is also promising impact potential to be unleashed in the next one to three years.

The “last mile” is a complex, interwoven topic as it involves many different ecosystem stakeholders. We have always had trends affecting the last mile, but not at this speed, not in parallel and not at this global scale. Getting it right is not easy – but getting it wrong is what we are doing at the moment if we continue to innovate and change at the current speed. We recognize that there is no silver bullet or breakthrough intervention, but we encourage ecosystem players of all kinds – from both the private and public spheres – to tackle the problem, one intervention and last-mile pilot at a time.

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PNO rental
Renault-Nissan-Mitsubishi
Siemens Logistics
Singapore Economic Development Board
Smart Freight Center
Transport Decarbonisation Alliance
Uber Freight
Unilever
UPS
Walmart
Zalando

Acronyms

B2B	Business-to-business
B2C	Business-to-consumer
CAGR	Compound annual growth rate
CO_2	Carbon dioxide
EV	Battery electric vehicle
H2 FCEV	Fuel cell electric vehicle
ICE	Internal combustion engine
IoT	Internet of Things
kg	Kilogram
L4/5	Level 4 and level 5 autonomous driving
LCV	Light commercial vehicle
NO_x	Nitrogen oxides and dioxides
OEM	Original equipment manufacturer
R&D	Research & development
TCU	Total cost of usage
UCC	Urban consolidation centre
V2X	Vehicle-to-anything (e.g. vehicle-to-infrastructure, vehicle-to-vehicle, vehicle-to-driver)
WBCSD	World Business Council for Sustainable Development
xEV	Electric vehicle (can include both battery electric and fuel cell electric vehicles)

Endnotes

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