URBAN FREIGHT DISTRIBUTION STUDY
E-COMMERCE TRENDS & IMPLICATIONS FOR URBAN PLANNING
Final Report

METROPOLITAN COUNCIL

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The Council's mission is to foster efficient and economic growth for
a prosperous metropolitan region

The Metropolitan Council is the regional planning organization for the seven-county Twin Cities area. The Council operates the regional bus and rail system, collects and treats wastewater, coordinates regional water resources, plans and helps fund regional parks, and administers federal funds that provide housing opportunities for low- and moderate-income individuals and families. The 17-member Council board is appointed by and serves at the pleasure of the governor.

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Introduction

Over the last decade, e-commerce sales in the U.S. have seen a rapid rise, a trend significantly accelerated by the COVID-19 pandemic. This surge signals a fundamental shift in where and how consumers make their purchases. With industry analysts projecting even higher e-commerce retail penetration rates than seen historically, there emerges a critical need to examine the broader implications of this e-commerce boom. Specifically, it prompts an in-depth look at its effects on transportation, environmental sustainability, and the policies governing land use and curbside management.

The Metropolitan Council, the Metropolitan Planning Organization (MPO) for the Minneapolis-St. Paul area in Minnesota, has undertaken a comprehensive study to shed some light on these dynamics for the Twin Cities region. The report is structured into three main parts:

Part I explores the overarching trends and growth of e-commerce, starting with a nationwide analysis of sales increases and future projections. It narrows down to examine delivery logistics and consumer shopping patterns within the Twin Cities regions, assessing the transportation impacts and environmental footprint of online shopping in terms of Vehicle Miles Traveled (VMT) and Greenhouse Gas Emissions (GHG). The chapter progresses to extrapolate these impacts into future scenarios. The section concludes by offering strategies for the Metropolitan Council and local agencies to mitigate these impacts and suggests areas for further investigation.

Part II investigates the siting and land use trends for e-commerce warehouse and distribution centers, revealing the complex relationship between the sector's growth and evolving land use patterns. Through detailed research, expert interviews, and market analysis, this part provides insights into current and expected trends in e-commerce facility development and locational decisions. It also considers the variety of facility types and their roles in the supply chain, particularly focusing on the facilities serving last-mile deliveries. The chapter concludes with proposing land use strategies and planning actions, drawing from plans and policies of other regions and cities.

Part III assesses curbside management best practices and examines research on new or emerging technologies for last-mile delivery, especially in relation to reducing VMT and emissions of CO_2 and other greenhouse gases. It concludes with policy recommendations for curbside management and the adoption of new technologies, aimed at guiding the Metropolitan Council and its partner agencies.

Supplemented by a series of appendices offering detailed analyses, the study's findings will inform Met Council's 2050 Transportation Policy Plan. The individual report for each part can be found on the Met Council's website.

I. E-Commerce Trends and Sustainability Impacts

E-commerce sales in the U.S. have experienced a remarkable increase over the past decade. The COVID-19 pandemic spurred a further boost. This chapter delves into the trends and growth of e-commerce by first exploring the national rise in e-commerce sales and future projections. It then zeroes in on delivery logistics within the Twin Cities region and analyzes the shopping behaviors of its residents. Furthermore, it assesses the environmental impact of e-commerce, focusing on Vehicle Miles Traveled (VMT) and Greenhouse Gas Emissions (GHG). The chapter progresses to extrapolate these impacts into future scenarios. In its conclusion, the chapter outlines strategies aimed at reducing VMT and GHG for the Metropolitan Council and local government agencies. It also highlights areas ripe for further research. The report detailing this analysis is available on the Met Council's website.

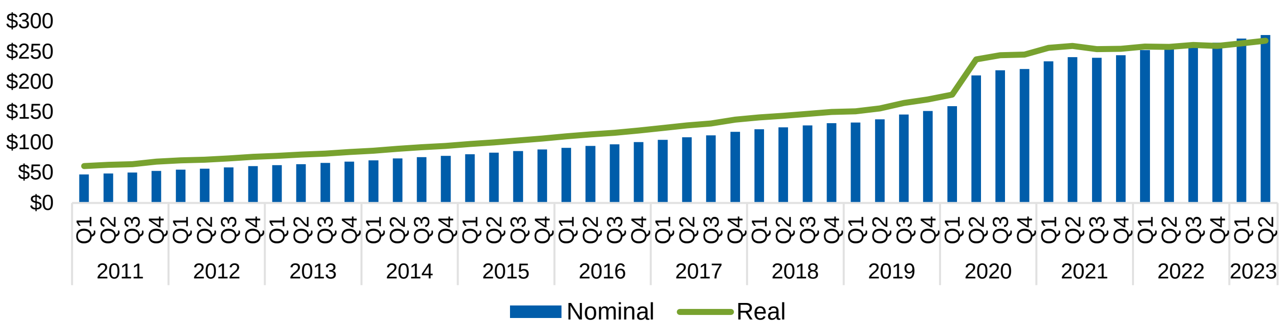
A. E-commerce and Shopping Growth Trends

1. Online shopping trends and projections

a. National e-commerce trends

In the past decade, e-commerce sales in the U.S. have shown a steady rise, as depicted in Figure 1. National e-commerce sales have risen from around $50 billion per quarter in 2011 to more than $250 billion per quarter in 2023. In real (i.e., inflation-adjusted) terms this works out to about a five-fold increase over twelve years. After a steady increase through the 2010s, e-commerce sales saw a major bump in early 2020 as a result of the COVID-19 pandemic. Since then, real e-commerce spending has flattened out somewhat.

Figure 1: U.S. quarterly e-commerce sales, nominal and real (2022$), billions



Source: CPCS analysis of US Census Bureau Quarterly Retail E-Commerce Sales data[1]

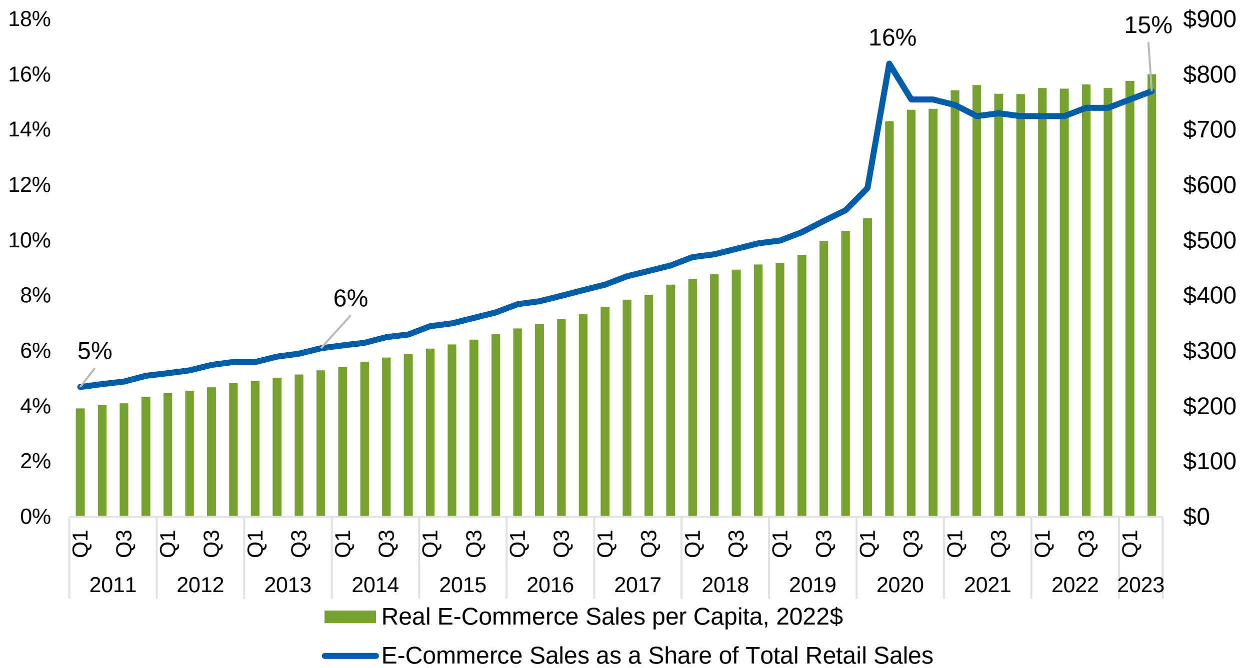
Two other metrics which can be used to assess national e-commerce trends are shown in Figure 2. The first metric, shown as bars, is real e-commerce sales per capita, which adjusts total e-commerce sales for both inflation and population growth. This measure reached $809 in the second quarter (Q2) of 2023, more than three times higher than a decade earlier in Q2 of 2013. This indicates that collectively, consumers have greatly increased their e-commerce purchases over the last decade.

The second metric is the e-commerce penetration rate, defined as the percentage share of total retail sales (shown as a line in the chart below). This measure has risen from about 6% a decade ago to 15% as of Q2 of 2023. Notably, the e-commerce share of total retail reached a high of 16% early in the COVID-19 pandemic, before dropping a bit. This likely reflects the fact that the effect of

[1] Quarterly Retail E-Commerce Sales, US Census Bureau, 2023. https://www.census.gov/retail/ecommerce.html. Accessed on October 31, 2023.

the public health concerns and government-mandated lockdowns was to divert some shopping away from bricks-and-mortar stores, which faced periods of closures, and towards online retailers.

Figure 2: U.S. quarterly real e-commerce sales per capita (2022$); and e-commerce sales as a percentage of total retail sales



Source: CPCS analysis of US Census Bureau Quarterly Retail E-Commerce Sales data,[2] Quarterly US population data,[3] and price adjustment factors.[4]

Another useful analytical approach is to look at the compound annual growth rate (CAGR) of e-commerce sales compared to traditional bricks-and-mortar (the latter can be assumed by subtracting e-commerce sales from total retail sales). These metrics are shown in Figure 3.

Prior to the pandemic, real per-capita e-commerce sales were increasing by 11.4% per annum, which increased to 19.0% over the pandemic years (taken as 2020-2021) and have since flatted out to a still-positive 2.6%.

In contrast, real per-capita bricks-and-mortar sales were positive at 0.5% per annum leading up to the pandemic and grew during the pandemic at an elevated 3.9% per annum. This pandemic spurt may have been driven by large purchases of durable goods supported by government stimulus.[5] However, since the end of 2021 bricks-and-mortar spending has been in decline, at -1.4%, as the stimulus programs ended, and consumer purchasing withdrew.

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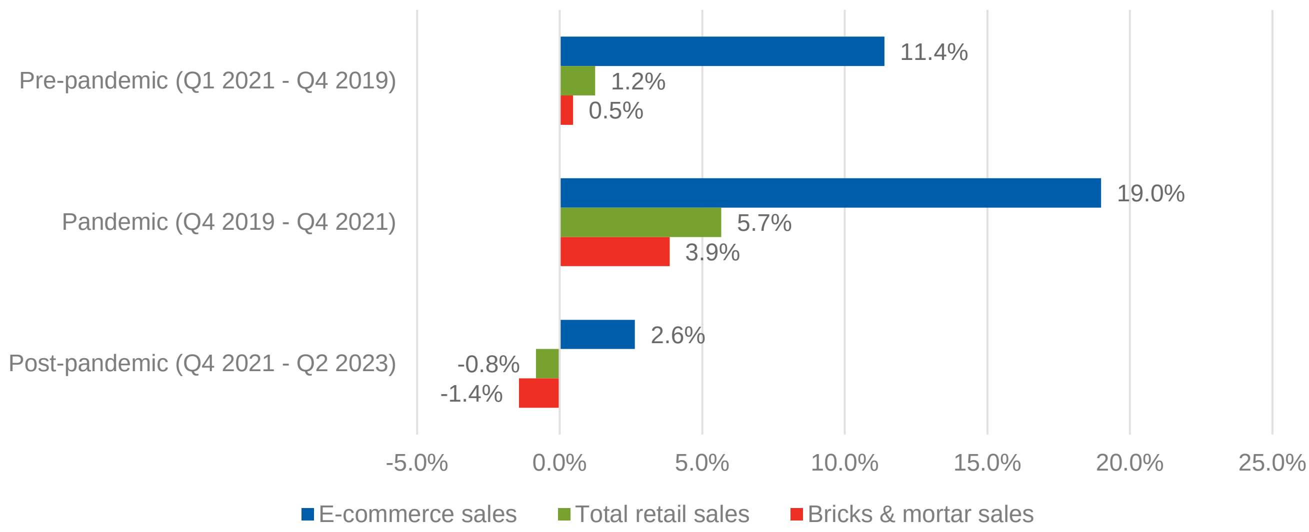
[2] Quarterly Retail E-Commerce Sales, US Census Bureau, 2023. https://www.census.gov/retail/ecommerce.html. Accessed on October 31, 2023.

[3] Quarterly US Population, Federal Reserve Economic Data, Federal Reserve Bank-St Louis, 2023. https://fred.stlouisfed.org/series/B230RC0Q173SBEA. Accessed on October 31, 2023.

[4] Gross Domestic Product: Implicit Price Deflator, Federal Reserve Economic Data, Federal Reserve Bank-St Louis, 2023. https://fred.stlouisfed.org/series/GDPDEF. Accessed on October 31, 2023.

[5] Tauber and Van Zandweghe, July 2021, Federal Reserve Bank of Cleveland, "Why Has Durable Goods Spending Been So Strong during the COVID-19 Pandemic?" https://www.clevelandfed.org/publications/economic-commentary/2021/ec-202116-durable-goods-spending-during-covid19-pandemic. Accessed on November 20, 2023.

Figure 3: Compound annual growth rate (CAGR), for national retail sales by time period (per capita, inflation-adjusted)



Source: CPCS analysis of US Census Bureau Quarterly Retail E-Commerce Sales data, Quarterly US population data and price adjustment factors.

Regional data on e-commerce trends are also available – albeit the regional data, available from the data provider Replica – are not straightforward to line up directly with the more comprehensive nationwide data from the US Census Bureau. This is further discussed in Appendix A.

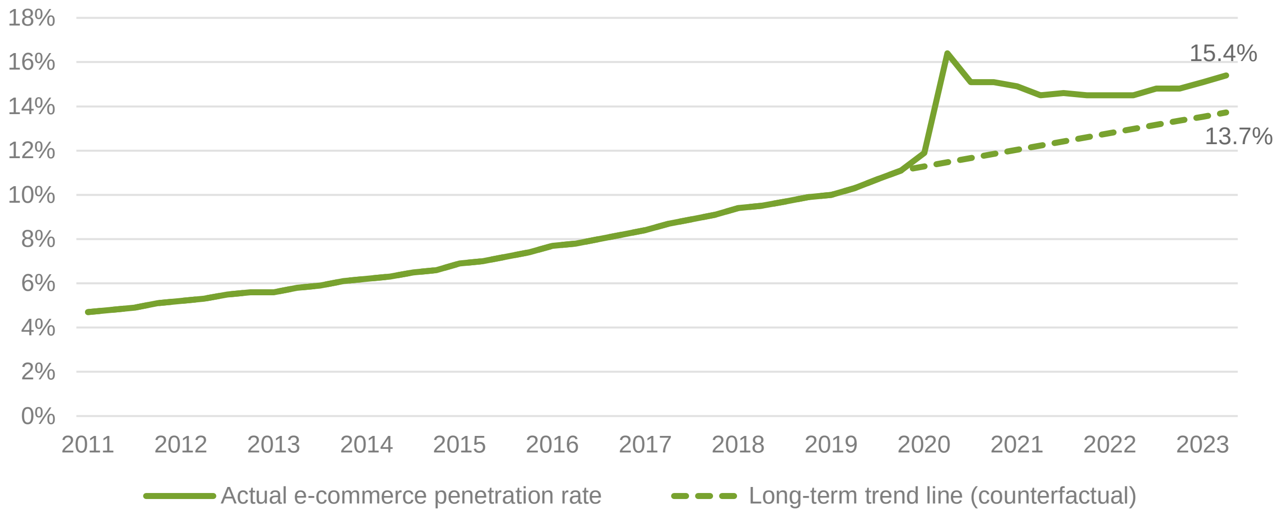
b. Online shopping projections

A relevant policy question has been whether the pandemic represented a temporary aberration from a long-term trend line, or alternatively a transformational change underlain by a fundamental shift in consumer habits. Based on the data available to date, the answer seems to be something in between.

Figure 4 compares the national e-commerce penetration rate for two cases – a) the actual Census sales data (solid line), and b) a hypothetical counterfactual scenario (dotted line). In the counterfactual scenario, the data since Q4 2019 is replaced by the pre-pandemic long-term trend line: specifically, it is assumed that the e-commerce penetration rate increases by 0.19 percent every quarter. The difference between these two lines is suggestive of the "pandemic bump" – in other words, the portion of the pandemic-era shift that appears to have been sustained.

As the chart shows, the pandemic appears to have added about 1.7 percentage points to the e-commerce penetration rate. Since 2022, the e-commerce penetration rate is again growing, suggesting that the pandemic bump may continue to be sustained into the future.

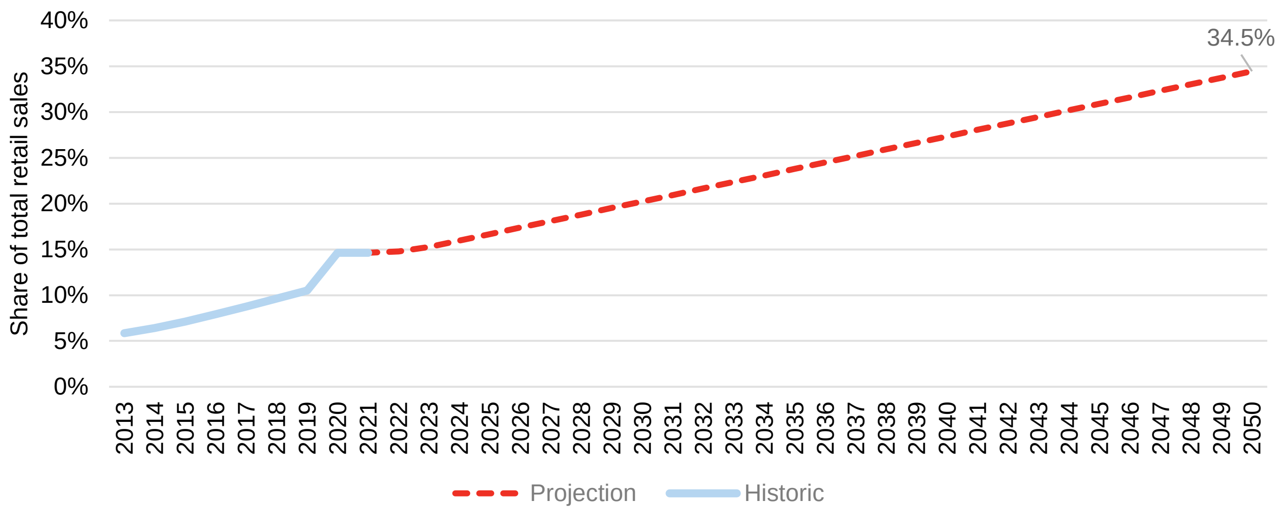
Figure 4: E-commerce penetration rate, compared to counterfactual long-term trend line from 2019



Source: CPCS analysis of US Census Bureau Quarterly Retail E-Commerce Sales data.

By extrapolating from the long-term trend line and applying a pandemic bump, one can forecast e-commerce penetration rates into the future. With these assumptions, the e-commerce penetration rate could reach 34.5% by 2050 (see Figure 5). This assumes that the pandemic will have a one-time sustained impact, albeit not an impact that changes the fundamental long-term trajectory of e-commerce's ascent.

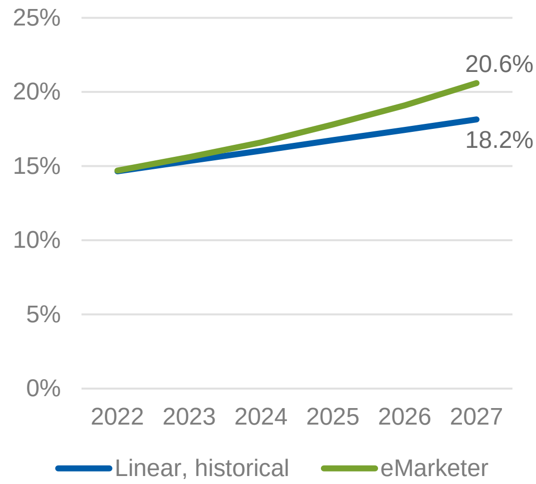
Figure 5: Projection of national e-commerce penetration rate, extrapolating from trends



Source: CPCS analysis, using historic e-commerce spending data from U.S. Census Bureau

Industry e-commerce forecasts generally do not predict e-commerce sales this far into the future, given the large number of unknowns that could alter the course. A notable industry source is eMarketer, which develops rolling five-year e-commerce forecasts for many countries, including the US. As shown in Figure 6, eMarketer predicts a non-linear growth rate, projecting 20.6% e-commerce penetration by 2027 (compared to 18.2%, if applying linear historical trend lines).

Figure 6: E-commerce forecasts for US, historical trends versus industry projection (eMarketer)



Source: CPCS analysis of trends (linear, historical); eMarketer 2023 orecast for the US[6]

In conclusion:

- The pace of transformation is rarely simple or linear, as the pandemic showed.
- Industry analysts expect that there could be considerable upside in e-commerce growth rates, above historical trends.
- Long-term forecasts are challenging because of the large number of unknowns that will inevitably emerge. Linear projections are often appropriate over multidecade periods, even if they may be overly optimistic or pessimistic in the short run.

2. E-commerce package deliveries

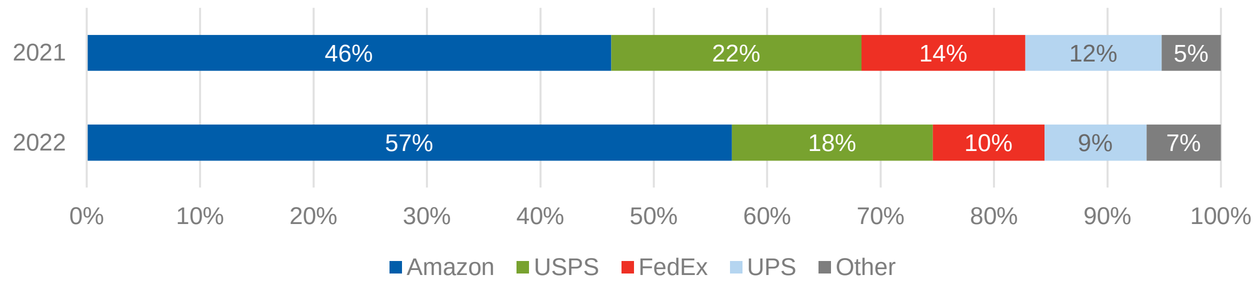
a. *Market shares of parcel carriers*

E-commerce retail products depend on courier services for delivery to consumers, either directly to their homes or to designated pickup points. In the Twin Cities region, a total of 80.4 million e-commerce packages were delivered in 2022 and Amazon is the dominant carrier for e-commerce retail package deliveries. In 2022, the company captured over half of the online package delivery market share, outpacing traditional carriers such as USPS, FedEx, UPS, and a small segment of other service providers (Figure 7).

The data underpinning these insights is sourced from NielsenIQ's zip code level e-commerce package and carrier share database (see inset box for description of this data source). This database is compiled from raw e-commerce email shipping receipts, further refined by aligning the demographic characteristics of email panelists with regional demographic trends. Consequently, NielsenIQ's findings present a distinct perspective on carrier market shares, especially when compared to other sources.

[6] Insider Intelligence, eMarketer, Aug 2023, "US retail ecommerce sales will see increasing growth through 2027" https://www.insiderintelligence.com/content/us-retail-ecommerce-sales-growth-2027. Accessed on November 20, 2023.

Figure 7: Carrier market share in the study area (by number of e-commerce packages)



Source: CPCS analysis of NielsenIQ data, 2023[7]

For instance, Pitney Bowes' national data on parcel carrier market share paints a different picture. According to their data, Amazon holds a 23% share nationally, while USPS, FedEx, and UPS have shares of 18%, 10%, and 9%, respectively.[8] The discrepancy most likely stems from the scope of NielsenIQ's data, which focuses exclusively on e-commerce packages. This contrasts with other datasets that include business-to-business (B2B) and nonretail parcel deliveries, sectors where non-Amazon carriers have a more substantial presence.

NielsenIQ's E-Commerce Shipping Insights Data

NielsenIQ (formerly Rakuten Intelligence) uses a US email receipt panel of close to 2.0 million panelists nationally to observe the purchases consumers make online at over 650 retailers.

Through passive tracking of e-receipts from consumer inboxes collected via Rakuten/Slice and Unroll.me, the data provides insights into the demographic characteristics of the consumers who made the purchases, the type of products that what were bought, when the products were bought and through which merchants, how much was paid, and how the orders were fulfilled.

NielsenIQ expands the sample panelists using a combination of demographic attributes including age, gender, ethnicity, and income for the top 50 major Metropolitan Statistical Areas in the US and the rest of the country divided into 9 divisions. The tracking numbers of those shipments are enriched by the shipping carrier APIs and further calibrated against the earnings reported by the major carriers by market segments.

b. *Trends in shipping practices*

E-commerce is a rapidly changing industry. Several important trends can be highlighted in carrier shipping practices:

Boosting velocity: Consumer demands for faster shipping are placing pressure on e-commerce supply chains to deliver quickly and reliably. Many e-commerce platforms and carriers are offering same-day or next-day delivery services. Amazon Prime's 2-day shipping has further shifted customer expectations, making speed a top priority. Target acquired Shipt to provide members with fast groceries delivery service in as soon as one hour.[9]

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[7] Other includes DHL, Costco Logistics, Eastern Connection, Home Direct, Hong Kong Post, Newgistics, Canada Post, China Post, Slice Generated, TNT, and unknown carriers.

[8] Pitney Bowes Parcel Shipping Index, 2023. https://www.pitneybowes.com/content/dam/pitneybowes/us/en/shipping-index/pb-2023-parcelshippingIndexInfographic-v5.pdf. Accessed on Nov 17, 2023.

9 Shipt, Target delivery at your fingertips. https://www.shipt.com/stores/target. Accessed on Nov 2, 2023.

Pursuing sustainability through improved efficiency: Carriers are continuing to seek opportunities which improve the efficiency of their operations, and thereby also help to reduce their carbon footprint. This includes overhauling the design of their delivery networks, making operational improvements such as in routing, and investing in fleet electrification. Notable examples are profiled in the text box below.

Improving flexibility: Carriers now increasingly allow customers to choose preferred delivery time slots, redirect packages to alternate locations, or even pick up from local collection points, providing greater convenience and reducing missed deliveries.

Leveraging the gig economy: Amazon's utilization of Flex drivers exemplifies a growing trend where carriers tap into the gig economy.[10] This system enlists individuals to deliver packages using their personal vehicles, offering flexible work schedules. This approach not only expands Amazon's delivery capacity but also adapts to fluctuating demand, especially during peak periods.

Mixing traditional and new models: Companies are looking to develop new distribution models which may leverage existing elements of the "traditional" bricks-and-mortar model. A notable example is Target's "stores as hubs" strategy, which involves using existing footprint within big-box stores to fulfill online orders.[11] At the other end, despite being known as an e-commerce company, Amazon has made strategic investments in bricks-and-mortar such as through its purchase of Whole Foods.

Appendix B profiles some major initiatives by industry, some of which have the potential to reduce VMT and GHG emissions – including network optimization, improved routing efficiency, and vehicle electrification.

3. In-person shopping trip patterns

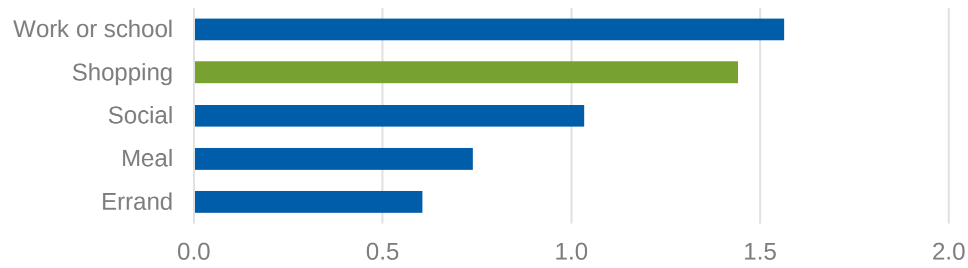
a. Significance of shopping trips

Examining in-person shopping trends can deepen insights into e-commerce, as there exists a degree of substitutability between in-person shopping and online purchasing. The best data on shopping trip activity in the region comes from the region's household survey – Met Council's Travel Behavior Inventory (TBI) Household Survey Program (see inset box for description of data source). Key findings are presented below, with additional information in Appendix A.

Shopping trips represent a significant source of trip-making in the region, as shown in Figure 8. Using the further disaggregation of trip purpose available from the TBI, trips to buy gasoline (about 190,000 per year) were hereafter removed from the shopping category, as e-commerce would not be considered a potential substitute. When gas trips are excluded, there are about 1.25 million shopping trips daily that originate in the study area.

[10] Amazon Flex. https://flex.amazon.com/. Accessed on Nov 8, 2023.
[11] Target, On Target: Inside our Stores-as-Hubs Strategy. Sep 21, 2023. https://corporate.target.com/news-features/article/2023/09/stores-as-hubs-strategy. Accessed on November 9, 2023.

Figure 8: Breakdown of daily personal trips within study area by trip purpose (millions, 2021)



Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area; trip purpose at destination

TBI Household Survey Program

TBI Household Survey is a travel survey of households in the greater Twin Cities region that has been conducted every 10 years since 1949. This survey supports transportation planning and forecast model development.[12]

In 2018, two significant changes occurred to the TBI household survey program: (1) the survey moved from a decennial survey to recur every other year and (2) the survey began using smartphone GPS applications as the primary means of data collection.

Since then, the Met Council randomly invites about 7,500 households every other year to the TBI household survey program. Households invited to participate include those in the seven-county metro area, as well as 3 Wisconsin counties.

The 2018-2019 TBI Household Survey was fielded from October 1, 2018, through September 30, 2019. The 2021-2022 survey was fielded from May 22, 2021, through February 5, 2022. Smartphone participants completed a 7-day travel diary. Online and call center participants completed a 1-day travel diary. The same questionnaire was used for smartphone, online, and call center participants. The survey was available in English, Spanish, Karen, Oromo, Somali, and Hmong.

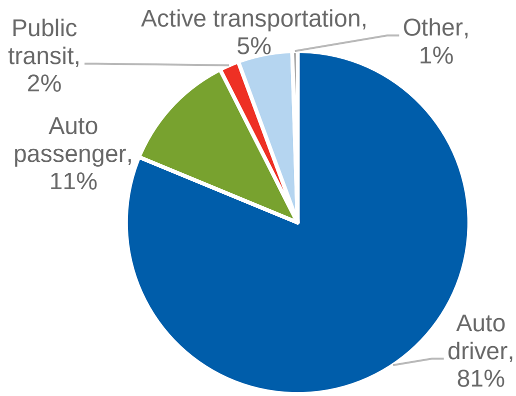
b. Mode share and trip length

Mode share and trip length are two important variables which influence the VMT of personal shopping trips.

The primary mode of transportation for shopping trips is the private vehicle (see Figure 9). 81% of shopping trips are made by an auto driver, thereby adding to regional VMT. 11% of trips are made by auto passenger (for example, if two people together make a shopping trip, the second person is counted as an auto passenger). Public transit has 2% of the mode share and active transportation (walk, bike) 5%.

[12] Minnesota Geospatial Commons. Travel Behavior Inventory (TBI) 2021. Household Interview Survey. https://gisdata.mn.gov/dataset/us-mn-state-metc-society-tbi-home-interview2021. Accessed on November 6, 2023.

Figure 9: Mode share for shopping trips (2021)



Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area; based on trip purpose of destination. Shopping excludes gas.

The average (one-way) trip distance is 4.9 miles, for shopping trips by auto driver. This means that the average shopping trip by private vehicle can be expected to add on the order of 10 miles (4.9 times two – including return leg) to regional VMT. Note that this accounts for the effects of trip chaining, as the metric was calculated for all shopping trips (not just home-based shopping trips).

It is also worth noting that trips longer than 10 miles (one-way) constitute only 10% of shopping trips, but contribute 50% of the total regional personal shopping VMT. This suggests that there is the potential for an outsized impact on VMT and emissions reductions if these trips could be shortened or substituted, such as through e-commerce.

c. Trends in shopping trips

In comparing the results of the TBI from 2019 to 2021, it is striking that while most types of trip-making declined over the two years – likely reflecting the effects of the pandemic – shopping trip activity did not change as much and in fact modestly increased.

Figure 10 compares the two years. Overall trips declined by 15%, with the biggest impact on work/school trips, which saw a 36% decline. However, shopping trips increased from 1.18 million to 1.25 million per day, an increase of approximately 6%.

Figure 10: Change in personal trip-making by trip purpose (2019 vs. 2021)

Trip Purpose	2019	2021	Change
Work or school	2,428,202	1,564,097	-36%
Shopping (excl. gas)	1,183,467	1,251,305	6%
Social/recreational	1,265,358	1,034,179	-18%
Meal	841,792	738,188	-12%
All trip purposes	**12,717,192**	**10,761,597**	**-15%**

Source: CPCS analysis of 2019 and 2021 TBI. Note: weighted trips; origin in study area; based on trip purpose of destination. Shopping excludes gas.

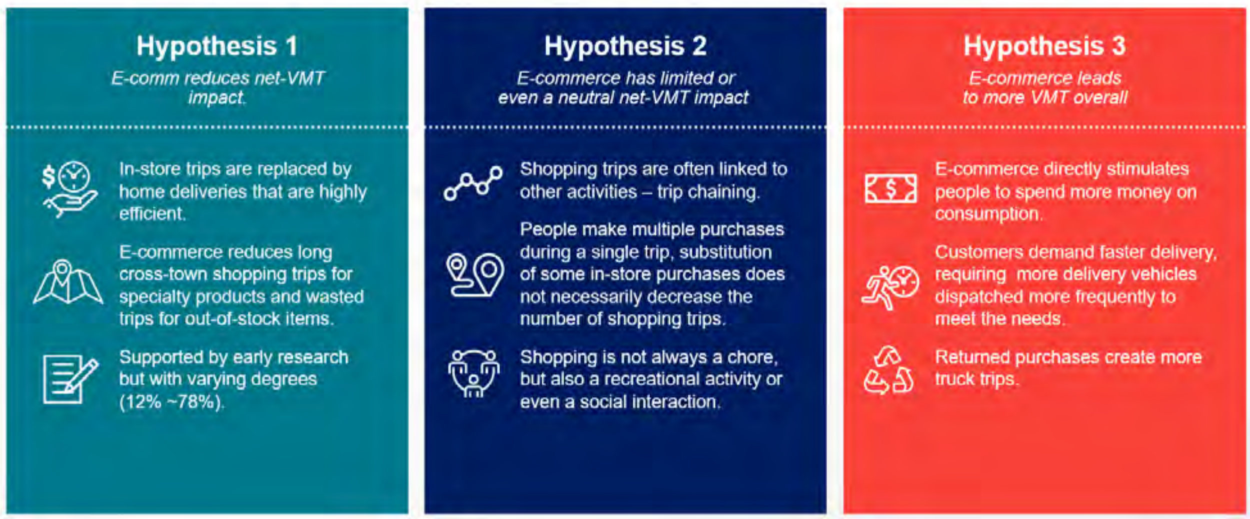
B. Vehicle Miles Traveled (VMT) and Greenhouse Gas (GHG) Impacts

This chapter describes the study team's structured approach for evaluating the VMT and GHG emission impacts stemming from e-commerce deliveries and in-person shopping activities. This approach primarily utilizes NielsenIQ's e-commerce package, shipping, and carrier share insight data, Met Council's TBI data, and EPA's MOVES4 model, in addition to literature and industry research on other model assumptions.

1. Key findings from literature review

Researchers have investigated the net effects of e-commerce package delivery and in-store shopping trips on transportation mobility and GHG emissions. Several studies have examined the complementary and substitution effects of online and in-store shopping, proposing hypotheses on the net VMT impacts resulting from these two phenomena, acknowledging the multitude of contributing factors (Figure 11).

Figure 11: VMT implications of e-commerce-related trips



Source: CPCS adaptation of Rotem-Mindali, O., & Weltevreden, J. W. (2013). Transport effects of e-commerce: what can be learned after years of research? Transportation, 40(5), 867-885.

a. VMT and GHG implications of e-commerce-related trips

In general, researchers have found that e-commerce does offer opportunities for overall reductions in VMT and associated negative social impacts.

- One study done for Chicago using a parcel delivery touring model in an agent-based platform finds that increasing rates of e-commerce have net benefits on the transportation system and energy use. As more households adopt e-commerce and e-commerce is used for a greater percentage of retail shopping occasions, substantial savings in VMT and fuel consumption result.[13]
- One study in Finland found a reduction of VMT by 54-93% and emission by 18-87%, when comparing the e-grocery versus private car trips through simulation.[14]
- Another study identified a reduction of VMT of nearly 20% when considering an e-commerce market penetration of 50%.[15]

[13] Stinson, M., Enam, A., Moore, A., & Auld, J. (2019, September). Citywide impacts of E-commerce: Does parcel delivery travel outweigh household shopping travel reductions?. In Proceedings of the 2nd ACM/EIGSCC Symposium on Smart Cities and Communities (pp. 1-7).
[14] Siikavirta, H., Punakivi, M., Kärkkäinen, M., & Linnanen, L. (2002). Effects of e-commerce on greenhouse gas emissions: a case study of grocery home delivery in Finland. *Journal of industrial ecology*, *6*(2), 83-97.
[15] Durand, B., & Gonzalez-Feliu, J. (2012). Urban logistics and e-grocery: have proximity delivery services a positive impact on shopping trips?. *Procedia-Social and Behavioral Sciences*, *39*, 510-520.

- One study used the American Time Use Survey and simulated delivery touring decisions for Dallas and San Francisco, finding that VMT decreases by around 7.2% when the population uses both shopping channels (in-person and online) and 87.6% if the online platform becomes the dominant choice. [16]

These studies suggest that with a sizeable market share, sustainable last-mile operations, and consumers substituting in-store shopping with online shopping, e-commerce can result in significant reductions in vehicle miles traveled and GHG emissions.

b. Counteractive effects of e-commerce strategies

However, the positive trends observed can be counteracted by e-commerce strategies such as offering free, same-day, or expedited deliveries. Such services necessitate shipping with lower consolidation levels, thereby increasing the frequency of shorter tours with smaller vehicles and reduced loads. [17] This often results in increased VMT and emissions. The negative environmental impact is demonstrated by the strong correlation between expedited delivery time windows and increased emissions.[18, 19]

c. Commodity and geographical variations in impacts

Additionally, the net impact of VMT and GHG emissions varies across different products and geographic contexts. For example, studies on home meal delivery find that shopping for meal ingredients typically has more negative effects on VMT, energy, and emissions than the meal delivery system.[20] Case studies from metropolitan areas like Los Angeles, New York City, Chicago, and Washington D.C., demonstrate that regional travel behavior can lead to disparate net-VMT and GHG impacts.[21] For example, in regions with higher public transportation use, the share of online shopping activity rises more; while in regions where passenger cars are more dominant, the contribution of in-store shopping to VMT is even more pronounced. This variation underscores the importance of contextual considerations in assessing the environmental footprint of e-commerce.

2. Data sources and methodology

Overview of data sources used

Figure 12 gives an overview of primary data sources used for VMT estimation in this study.

Figure 12: Overview of primary data sources used for VMT estimation

Analytical area	Data input	Source
E-commerce last-mile distribution	Number of packages delivered	Obtained from NielsenIQ dataset. The dataset includes information on the geographic

[16] Jaller, M., & Pahwa, A. (2020). Evaluating the environmental impacts of online shopping: A behavioral and transportation approach. *Transportation Research Part D: Transport and Environment*, *80*, 102223.
[17] Jaller, M., Otero-Palencia, C., & Yie-Pinedo, R. (2020, January). Inventory and fleet purchase decisions under a sustainable regulatory environment. In Supply Chain Forum: An International Journal (Vol. 21, No. 1, pp. 53-65). Taylor & Francis.
[18] Wygonik, E., & Goodchild, A. V. (2018). Urban form and last-mile goods movement: Factors affecting vehicle miles travelled and emissions. Transportation Research Part D: Transport and Environment, 61, 217-229.
[19] Jaller, M., & Pahwa, A. (2020). Evaluating the environmental impacts of online shopping: A behavioral and transportation approach. *Transportation Research Part D: Transport and Environment*, *80*, 102223.
[20] Heard, B. R., Bandekar, M., Vassar, B., & Miller, S. A. (2019). Comparison of life cycle environmental impacts from meal kits and grocery store meals. *Resources, Conservation and Recycling*, *147*, 189-200.
[21] Jaller, M., Xiao, R., Dennis, S., Rivera-Royero, D., & Pahwa, A. (2022). National Impacts of E-commerce Growth: Development of a Spatial Demand Based Tool.

Analytical area	Data input	Source
		distribution of receivers, and on the carrier shares at a disaggregated level.
E-commerce last-mile distribution	VMT impacts of package delivery	Modeled using a CPCS algorithm which assigns the packages from the NielsenIQ dataset to simulated truck routes, calibrated to industry literature.
E-commerce last-mile distribution	GHG emissions impacts	GHG emissions factors obtained from EPA's MOVES4 model for the study area.
Personal shopping trips	Number of shopping trips	Obtained from Met Council's TBI.
Personal shopping trips	VMT impacts of personal shopping trips	Factors for converting to VMT (auto mode share, trip lengths) obtained from Met Council's TBI.
Personal shopping trips	GHG emissions impacts	GHG emissions factors obtained from EPA's MOVES4 model for the study area.

Source: CPCS

a. VMT and GHG emissions impact assessment approach

The study team used a structured and innovative approach for evaluating the VMT and GHG emission impacts stemming from e-commerce last-mile deliveries and personal shopping activities. This approach integrates a comprehensive understanding of retail dynamics with an assessment of the logistics and consumer behaviors driving these impacts. Figure 13 illustrates the conceptual framework.

Further detail on the approach is available in Appendix C, which describes the technical methodology for VMT and GHG emissions modeling.

At a high level, the approach consisted of four steps:

Step 1: Analyzing retail activities and segments

The assessment begins by exploring the scale and segmentation of retail activities. This step is crucial as the extent of e-commerce penetration and regional consumption patterns directly influence both personal shopping trips and e-commerce package deliveries. The analysis incorporates metrics such as total per-capita retail sales and the e-commerce share of overall retail sales (penetration rate).

Step 2: Estimating package delivery VMT

Subsequently, the focus shifts to evaluating the VMT attributable to package delivery operations. This involves understanding the distribution of package delivery destinations and the operational areas and characteristics of major delivery service providers, including factors like vehicle capacity and delivery tour lengths.

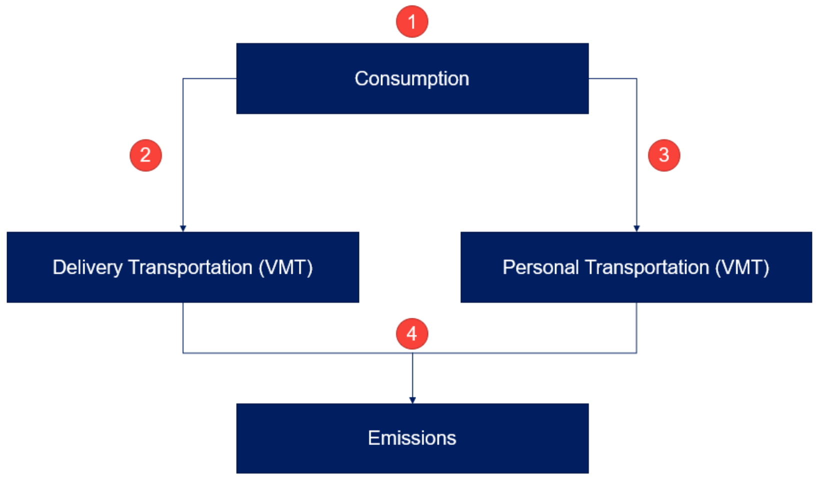
Step 3: Estimating personal shopping trip VMT

In parallel, the VMT for personal shopping trips is calculated. This estimation hinges on regional shopping behavior, informed by the TBI survey conducted by the Met Council. Key considerations include the frequency and length of shopping trips, which are fundamental in achieving an accurate VMT calculation for personal shopping.

Step 4: Emission impact estimation

Finally, the VMT from package delivery and personal shopping trips is converted into emission impacts. This is accomplished by applying specific emission factors to different types of vehicles, thereby quantifying the GHG emissions resulting from these activities.

Figure 13: E-Commerce VMT and emission impact assessment approach



Source: CPCS

Note that the study is focused on the last-mile impacts in particular. Therefore, first- and middle-mile impacts are not calculated as part of the scope of the study. Both e-commerce channels and "traditional" retail channels would have VMT and GHG emissions impacts, although to a large extent these may be outside of the Twin Cities region.

3. VMT and GHG emissions findings

a. Parcel delivery VMT by carrier

Figure 14 shows a summary of the modeled last-mile parcels delivered by major carriers and their associated VMT impacts. Note that the Amazon modeling in particular is sensitive to assumptions; for example, the extent of usage of Amazon Flex is unknown but assumed to be around 20% (Flex is an Uber-like model in which Amazon contracts private citizens to undertake delivery routes using their own vehicles). If the true usage of Flex is higher or lower, this would impact the aggregate VMT for the region.

A few key takeaways include:

- Amazon leads in total e-commerce package deliveries, carrying more than half (57%) of the total 80 million e-commerce packages delivered by all carriers. USPS follows, delivering around 20% of the total packages. FedEx and UPS each handle approximately 10%, with smaller or less traditional delivery services contributing the remaining 7%.
- Amazon's total annual VMT is significantly higher than other carriers, accounting for over 80% of the total last-mile e-commerce package delivery VMT. This is primarily driven by the VMT from Flex deliveries. UPS, FedEx, USPS, and other carriers account for 4%, 7%, 5%, and 4% of the total modeled VMT, respectively.
- Amazon Flex deliveries are assumed to have a higher VMT impact (VMT per package) of 1.5 miles, compared to van deliveries (0.24 miles). This difference highlights the

limitations of Flex delivery capacity and potential inefficiencies in routing, particularly for time-sensitive deliveries. Despite handling only 11% of the packages, Amazon Flex deliveries contribute 47% of Amazon's total modeled VMT, underscoring the disproportionate impact of these delivery methods on transportation efficiency.

Figure 14: Model outputs – e-commerce last-mile delivery parcels and VMT by major carriers

	Amazon	UPS	FedEx	USPS	Other	Total
Total packages (associated with e-commerce)	45,687,000	7,224,000	7,912,000	14,212,000	5,271,000	80,308,000
of which by Flex	8,680,000					8,680,000
of which by Van	37,007,000	7,224,000	7,912,000	14,212,000	5,271,000	71,627,000
VMT impact (VMT per package)	0.51	0.15	0.24	0.10	0.23	0.36
Flex VMT impact	1.51					
Van VMT impact	0.24	0.15	0.24	0.10	0.23	0.36
Annual VMT (associated with e-commerce)	22,090,000	1,070,000	1,897,000	1,405,000	1,209,000	27,673,000
VMT by Flex	13,093,000					13,093,000
VMT by Van	8,996,000	1,070,000	1,897,000	1,405,000	1,209,000	14,579,000

Source: CPCS analysis and estimates

b. E-commerce parcel volumes by carrier

An additional point of validation is to compare the outputs of the model to the equivalent allocation obtained from assigning all of the packages delivered in the nation to the Twin Cities based on its share of the national population (see Figure 15). It is understood that the retail e-commerce packages of interest to this study are only a portion of the total packages delivered by parcel carriers.

Figure 15: Comparison of model output to equivalent allocated national shares

	Amazon	UPS	FedEx	USPS	Other	Total
Annual packages, from model	45,687,000	7,224,000	7,912,000	14,212,000	5,271,000	80,308,000
Annual packages, allocated from national totals*	45,381,000	48,794,000	38,352,000	63,653,000	4,618,000	200,800,000
Ratio of model to allocation (capture rate)	101%	15%	21%	22%	114%	40%

Source: CPCS analysis and estimates. *National totals: from Pitney Bowes for the whole of US, allocated on a proportional basis to the Twin Cities on the basis of share of the national population (Pitney Bowes Parcel Shipping Index, 2023. https://www.pitneybowes.com/content/dam/pitneybowes/us/en/shipping-index/pb-2023-parcelshippingIndexInfographic-v5.pdf. Accessed on Nov 17, 2023). Note that the allocation on a population-weighted basis is crude and may not reflect regional differences, hence a capture rate over 100% is acceptable. The approach is used as a general test of reasonableness.

The model's capture rate for Amazon comes to about 100%, which appears appropriate since it is expected that almost all of Amazon's package deliveries are related to retail e-commerce. In comparison, the capture rates for UPS, FedEx, and USPS are all on the order of 15-20%, which suggests that the majority of their package throughput is non-retail-e-commerce. In general, the similar range of these values across the three carriers can be considered reasonable.

c. In-person shopping VMT

In-person shopping trip VMT is estimated from the 2021 TBI results by multiplying total shopping trips (excluding to buy gas) by vehicle mode share and trip length. Figure 16 summarizes the annual modeled VMT for the region.

Figure 16: Base year personal shopping trip VMT estimation

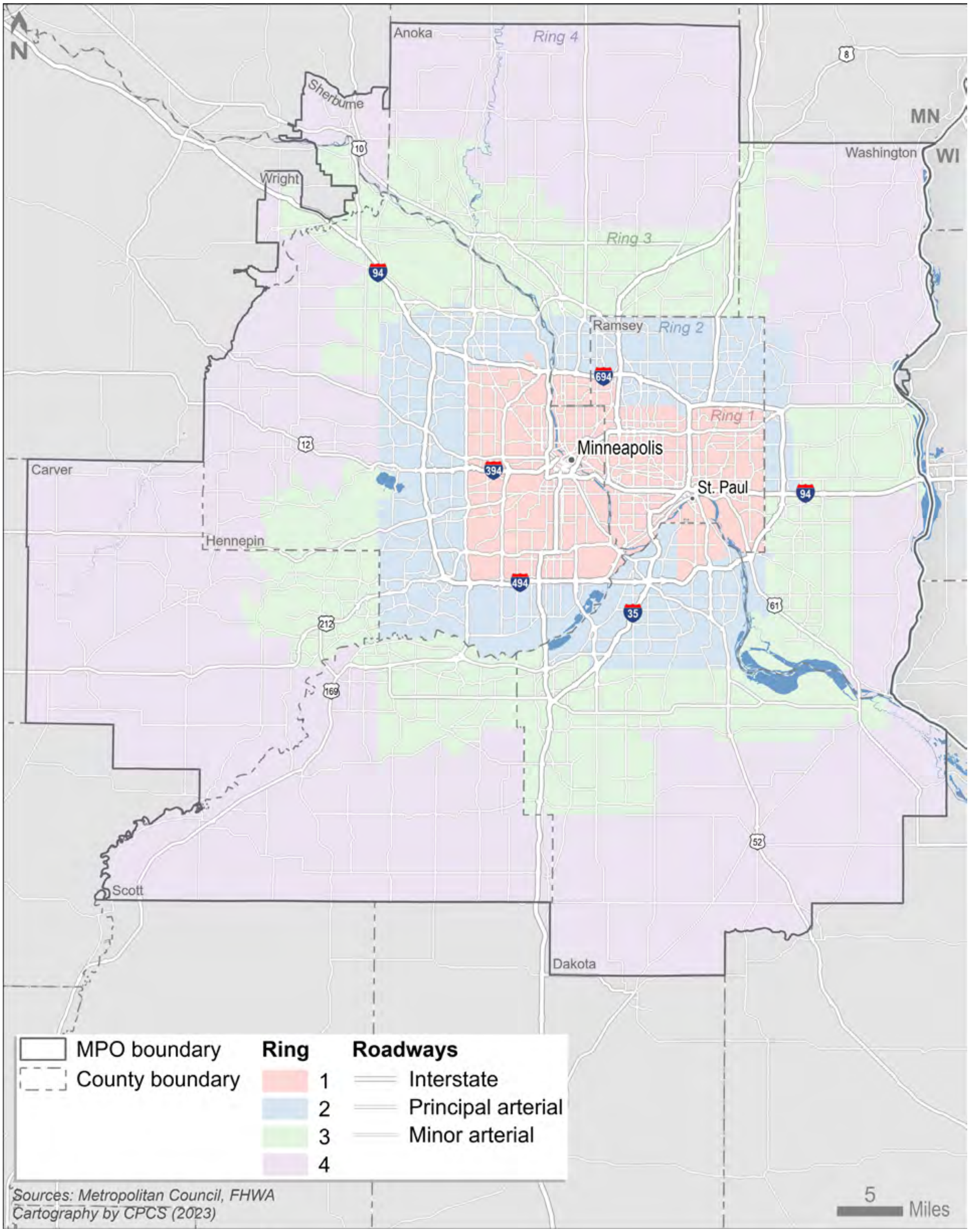
	Ring 1	Ring 2	Ring 3	Ring 4	Total
Shopping trips, annual	185,602,000	139,523,000	132,791,000	21,456,000	479,373,000
Auto driver mode share	77%	78%	89%	95%	81%
Shopping trip length, miles (round-trip)	8.4	9.6	11.0	16.2	9.8
Shopping VMT, annual	1,202,000,000	1,036,000,000	1,302,000,000	330,000,000	3,871,000,000

Source: CPCS analysis and estimates.

The rings introduce a geographic distinction defined for this analysis, as shown in Figure 17, and discussed in further detail in Appendix D:

- Ring 1: Urban land uses, within the ring highway network (494/694)
- Ring 2: Predominantly suburban, along the ring highways
- Ring 3: Predominantly suburban, outside the ring highway network
- Ring 4: Rural and agricultural (exurban) parts of the region

Figure 17: Ring structure used for modeling



Source: CPCS

d. *Base-year VMT and GHG emissions*

Figure 18 shows the VMT and GHG emissions results for the base year for the study area. The data shows a stark contrast between the VMT and emissions generated by e-commerce package last-mile deliveries versus personal shopping trips. Personal shopping trips accounted for the vast majority of both the VMT and emissions.

Figure 18: Base Year VMT and GHG emissions results

	Base Year (2022)
Last-Mile Package Delivery VMT, annual million miles	27.7
Personal Shopping VMT, annual million miles	3,871
Total VMT, annual million miles	3,899
Last-Mile Package Delivery Emissions, annual million pounds CO2e	43.8
Personal Shopping Emissions, annual million pounds CO2e	3,190
Total Emissions, annual million pounds CO2e	3,234

Source: CPCS model results

The data indicates that personal shopping trips are predominantly responsible for both VMT and emissions: they account for 99.3% of total VMT and 98.6% of total GHG emissions. In comparison, e-commerce last-mile deliveries contribute only 0.7% of the VMT and 1.4% of the GHG emissions. This significant difference underscores the impact of personal vehicle use for shopping, which contrasts with the potentially more efficient logistics of centralized last-mile package deliveries.

Note that the analysis of package delivery VMT is focused on the last-mile aspect, which directly involves delivering the product to the customer. The analysis does not account for the first- and middle-mile operations within the region, which may also contribute to VMT and emissions (similarly, the analysis excludes the first- and middle-mile operations of traditional retail supply chains).

C. VMT and GHG Emissions Projections and Scenarios Analysis

This section details the scenario analysis approach used to forecast multiple future settings, encompassing factors like increased urban densification, technological advancement, new shopping models and increased consumer awareness. The scenarios are intended to be illustrative, rather than depicting targets, goals, or (necessarily) achievable outcomes.

1. Key considerations for projections

There are a large number of factors that can affect vehicle miles traveled, as shown in Figure 19. A significant challenge is that some of these factors can be difficult to model and assess, let alone to project into the future. Generally, credible independent forecasts are only available for a small subset of factors, such as population growth and vehicle emissions. In some other cases, forecasts can be developed using growth trends that extrapolate from the past, or other types of analyst assumptions; while in other cases, projections would have to be based on very high-level, subjective judgments.

Figure 19: Factors that can affect vehicle miles traveled

Source: CPCS

Scenario analysis has advantages over traditional forecasting techniques, especially for complex systems that are rapidly evolving. Scenario analysis focuses on defining multiple visions of the future, each of which represents a meaningfully different set of conditions. The scenarios, while not intended to be comprehensive and reflective of every possible permutation, provide a good sense of how the key underlying change drivers may result in tangibly different outcomes.

2. Change drivers modeled in scenario analysis

The analysis is oriented around eight fundamental change drivers, each of which represents a key factor that can impact VMT and/or greenhouse gas (GHG) emissions. The change drivers may themselves be the product of a complex set of underlying interactions.

The key assumptions incorporated into the eight change factors are described below. Appendix D provides a detailed breakdown of scenario assumptions.

- **Demographics:** Changes in the demographic composition of the region will affect e-commerce: most obviously, a growing population will be expected to result in greater consumer demand. Other factors, such as household size and composition, age, income, and similar variables are also known to affect e-commerce demand. However, the nature of these relationships in the distant future is speculative (as an illustrative example, it seems unlikely that 75-year-olds in 2050 will have the same purchasing patterns as 75-year-olds today). Therefore, the study team did not model secondary demographic changes within the projections, and focused the analysis on population changes, including the geographic patterns of those changes (e.g., whether the growth happens in more urban, suburban or rural parts of the region).
- **E-commerce growth:** As consumers buy more products online, the number of parcels needing to be delivered is expected to increase. To exclude the effects of demographics (which are already covered above), this change driver assesses the level of e-commerce sales on a per-capita basis. That in turn is a function both of per-capita retail sales as well as the e-commerce penetration rate. Per-capita retail sales are a measure of consumer wealth and spending –as

the population tends to become wealthier over time, discretionary spending grows. E-commerce penetration is defined as the ratio of e-commerce sales to total retail sales – it is a measure of the extent to which consumers tend to buy goods online versus in-store.

- **Marginal delivery VMT:** This represents the marginal impact of an additional package on VMT by delivery vehicles. In principle, this change driver is a function of a multitude of factors, including the geographic distribution of package receivers (e.g., households) and the nature of the operations of delivery companies (number of competitors, locations of their delivery hubs, their network densities, their operating characteristics e.g. offering different levels of speed or priority, their routing decisions, etc.). Although it is impossible to predict how the delivery landscape will evolve in the distant future (e.g. the presence of new entrants, the opening of new distribution hubs, etc.), there are a few things that can be modeled with some confidence. The first is that the marginal delivery VMT impact will differ depending on whether delivering to urban, suburban or rural parts of the region; hence if the distribution of population changes there are likely to be VMT impacts. Secondly, in general, as e-commerce grows and more packages are delivered, it is likely that some network efficiencies will result, given that (probabilistically) receivers will be located closer to one another.
- **Marginal delivery GHG:** This represents the marginal impact that an additional vehicle mile traveled will have on greenhouse gas emissions, specifically for delivery vehicles. This change driver is essentially a function of the types of delivery vehicles used and the propulsion technologies of the delivery companies' fleets. As delivery companies electrify their fleets, the marginal delivery GHG impact will fall as a function of the rate of adoption of low- or zero-emission vehicles. The study team only took into account tailpipe emissions associated with delivery vehicles, and not second-order factors such as the embodied emissions impacts of the vehicles and their parts, nor the energy source for alternative propulsion technologies such as electricity (or hydrogen).
- **Bricks and mortar shopping growth:** This change driver runs parallel to Number 2 (E-Commerce Growth). Over time, as e-commerce penetration increases, it is likely that there will be some substitution away from bricks and mortar (in-store) shopping. In other words, shopping activity that may previously have taken place physically within a store will shift to taking place online, from the comfort of one's home. The detailed nature of the interaction between online and in-store shopping is very complex and difficult to forecast: there are many current and potential "omnichannel" models which may combine both physical and virtual components in various ways.[22] Nonetheless, in the base case it can be assumed that there is a certain amount of substitutability between online shopping and bricks and mortar shopping per capita. This analysis forecasts total retail sales growth per capita, and then assigns shares to e-commerce and bricks-and-mortar based on an assumption about the e-commerce penetration rate.
- **Marginal shopping VMT**: This represents the marginal impact of a shopping trip on vehicle miles traveled. In principle, this may be affected by the geographic distribution of the population, the geographic distribution of stores, and the relative availability of desired products or acceptable substitutes within the network of stores. Although there is no clear way to predict where stores will be located and what products they will stock, it can still be assumed that the marginal VMT of a shopping trip will continue to vary depending on whether the trip originates in urban, suburban or rural areas (including length of shopping trip and likelihood of using an automobile versus other modes of transportation)

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[22] As a few examples: Customers may visit a store to try a product, and then go home and do further research before buying the product online. Customers may visit a store for the experiential aspect, but make the transaction over their mobile phone. Customers may order goods online and go to the store to pick them up.

- **E-commerce-related personal travel:** For online sales, there will be a certain proportion of trips that still require personal travel. For example, under the “click and collect” model consumers will buy a product online and travel to pick it up (curbside or in-store).
- **Marginal shopping GHG:** The final change driver represents the marginal impact that an additional vehicle mile traveled will have on greenhouse gas emissions, specifically for passenger vehicles. This is conceptually similar to Number 4 (Marginal delivery GHG), except that it concerns trends in zero-emission vehicle adoption in the passenger vehicle market, rather than the delivery fleet market.

3. Scenarios analyzed

The analysis modeled a base-year scenario, a future-year Future Baseline Case, and four alternative future scenarios. This section describes the essential characteristics of the scenarios. More detailed assumptions are provided in Appendix D.

Base year: 2022

The base year represents the outputs of the VMT and GHG model and is selected as 2022, to correspond to the year for which the primary data sources (including Nielsen IQ) are available.

Future Baseline Case: 2050

The Future Baseline Case projects VMT and emissions to 2050, based on a continuation of present trends and conditions. Key assumptions in the Future Baseline Case are:

- The population of the region is assumed to continue to increase.
- Per-capita real retail sales are assumed to continue to increase at the rates observed nationally over the last decade. E-commerce penetration is assumed to grow linearly.
- Usage of zero-emission vehicles is expected to increase.

Scenario 1: The Urban Hub

With increased urbanization, population growth is concentrated in the core, enabling densification benefits including new networks of last-mile microhubs in the core. Key assumptions are:

- The overall population of the region is projected to grow as in the Future Baseline Case, but the growth is disproportionately assumed to be in the more central areas (Ring 1).
- Within the urban areas, there are assumed to be densification benefits including the potential for shorter trip distances and higher non-automobile mode shares.
- Furthermore, within the urban areas, it is assumed that a dense network of microhubs can operate such that many residents have a microhub within a mile of their home, making it attractive for a portion of these residents to order their deliveries to the microhubs instead of to their homes directly. The microhubs could function in a variety of ways in terms of their commercial and operating model, but most importantly could accommodate both couriers delivering packages to homes by bike or foot, or customers picking up packages themselves from the microhub.
- The other rings (Rings 2-4) would largely continue to operate as they currently do.

Scenario 2: The Techno-Freight Revolution

Increasing automation drives lower shipping costs, leading to an upsurge in e-commerce and rapid electrification of the delivery fleets. Key assumptions are:

- E-commerce penetration grows rapidly, leading to a large increase in packages for delivery across the region.

- Parcel carriers fully electrify their fleets, meaning zero tailpipe emissions from delivery vehicles.
- With increased e-commerce penetration, bricks-and-mortar shopping is assumed to decline, leading to fewer personal shopping trips across the region.

Scenario 3: The Omni Breakthrough

New shopping models combine increased online ordering with a continued need for personal travel. Key assumptions include:

- E-commerce penetration is assumed to grow faster than the baseline, albeit not to the level of Scenario 2.
- Although traditional “bricks-and-mortar” shopping declines somewhat, there is a continued need for personal shopping travel under the new model. This could be, for example, because an increasing number of e-commerce shoppers select the “click and collect” option, traveling to pick up their orders. Alternatively, it may be that consumers travel to stores for the experiential aspect, despite making the purchase online or via mobile app.

Scenario 4: The Eco-Conscious Consumer

Through a combination of measures, consumers shift their behavior in a desire for greater sustainability. Key assumptions are:

- Consumers are able to reduce the VMT impact of deliveries through a combination of more efficient ordering (e.g., consolidating purchases and/or deliveries to reduce excess vehicle travel) and reduction of wasteful orders (e.g., excess orders which generate wasteful returns).
- Consumers also reduce the VMT impact of their personal shipping trips through a combination of fewer trips (e.g., consolidating some shopping trips), shorter distances (e.g. shopping closer to home), and modal shift (greater use of non-automobile modes).
- Finally, it is assumed that residents shift in larger numbers to zero-emissions vehicles, thereby reducing the tailpipe emissions of personal shopping trips.

Figure 20 summarizes the key assumptions for the four scenarios.

Figure 20: Summary of key assumptions for the four scenarios

Factor	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Population growth and distribution	Same total, more urbanized	-	-	-
E-commerce sales growth (per capita)	-	High	Somewhat higher	-
Delivery vehicle VMT impact (VMT per package)	Somewhat lower in core due to microhubs	Lower due to network efficiencies	-	Somewhat lower due to less wasteful ordering

Factor	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Delivery vehicle GHG impact (GHG per mile)	-	Lower due to full carrier fleet electrification	-	Somewhat lower due to more Flex-type ZEVs
Shopping trip growth (per capita)	-	Lower due to e-commerce substitution	Mixed due to new shopping models	Somewhat lower due to some trip consolidation
Shopping trip VMT impact (VMT per trip)	Somewhat lower in core due to more options	-	-	Somewhat lower due to behavioral shift
Passenger vehicle GHG impact (GHG per mile)	-	-	-	Lower due to more ZEVs

Source: CPCS

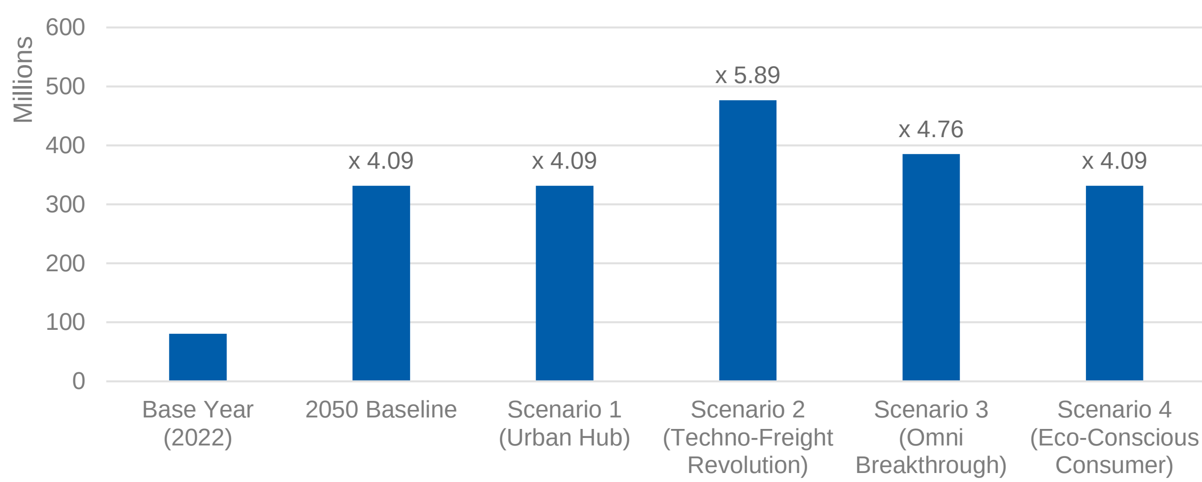
4. Findings and conclusions

a. E-commerce packages delivered

Figure 21 shows the number of e-commerce packages delivered in the region, modeled under the scenarios. In all cases, this value is projected to increase substantially from present levels. In the Future Baseline Case the total number of e-commerce packages increases by over four times, driven by a growing population, higher consumption, and in particular an increase in the use of e-commerce compared to traditional bricks-and-mortar shopping.

Scenario 2 entails a nearly six-fold increase in the number of e-commerce packages delivered. This is reflective of the e-commerce share of total retail sales increasing to 50% (i.e., half of all retail sales being online).

Figure 21: Number of e-commerce packages delivered in the region, under each scenario



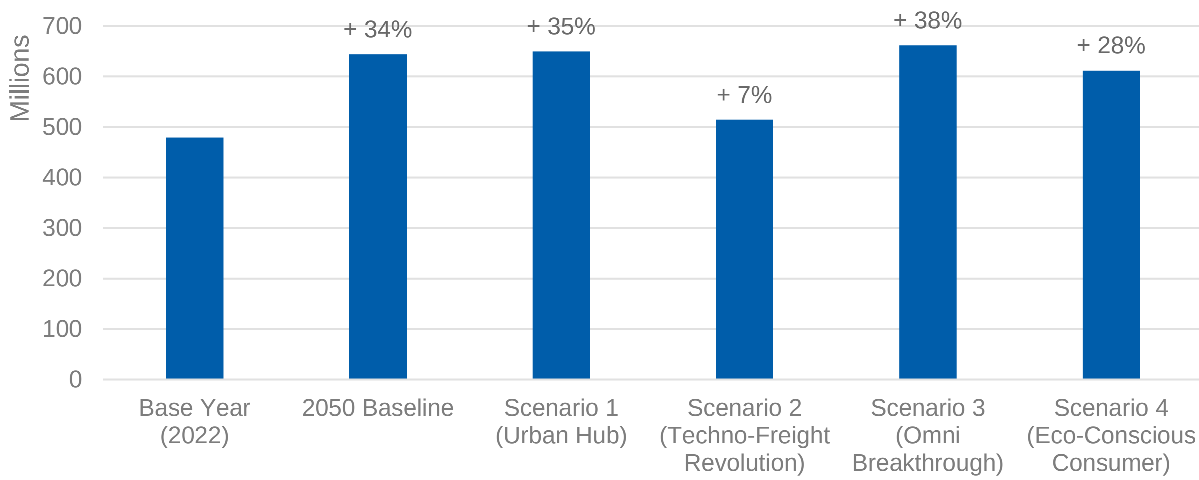
Source: CPCS analysis

b. Number of personal shopping trips

Figure 22 shows the number of personal shopping trips in the region, modeled under the scenarios. In the Future Baseline Case, this value is projected to increase by 34% to 2050, reflecting a growing population and increased retail sales due to greater wealth and consumer spending (offsetting the fact that some bricks-and-mortar shopping will shift online, removing some shopping trips).

Scenario 2 features the lowest increase in personal shopping travel, as it assumes a high shift to e-commerce. In this scenario personal shopping trips increase by 7%.

Figure 22: Number of personal shopping trips in the region, under each scenario

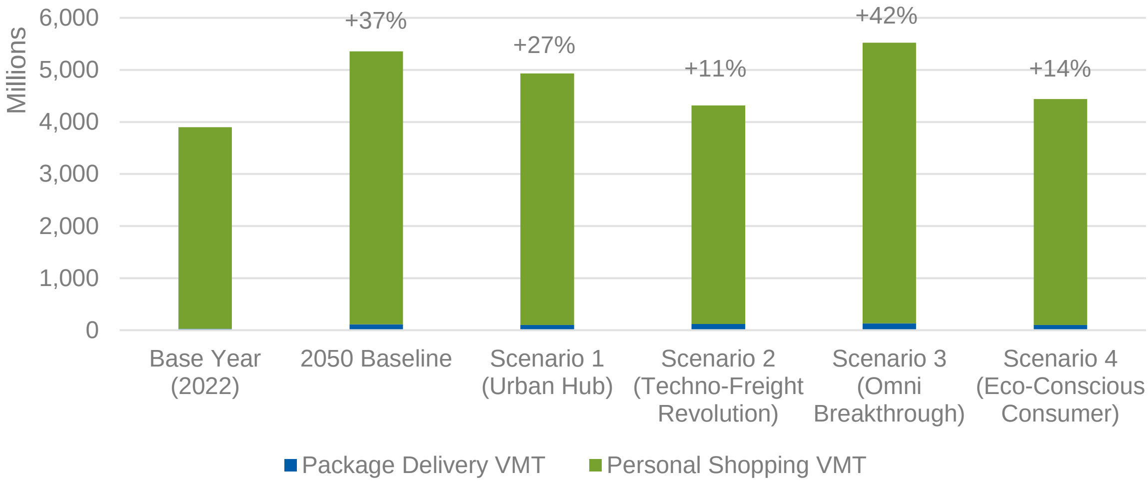


Source: CPCS analysis

c. Impacts on vehicle-miles traveled (VMT)

Figure 23 displays the total VMT for each scenario, as the sum of package delivery VMT and personal shopping VMT. All scenarios have a total VMT above the base year, but some involve a reduction relative to the 2050 Baseline case. The share of VMT from package delivery is expected to increase from less than 1 percent to above 2 percent in all future scenarios, with Scenario 2 expecting to see the highest share at 2.8 percent.

Figure 23: Total vehicle miles traveled in the region, under each scenario (miles, annual)



Source: CPCS analysis

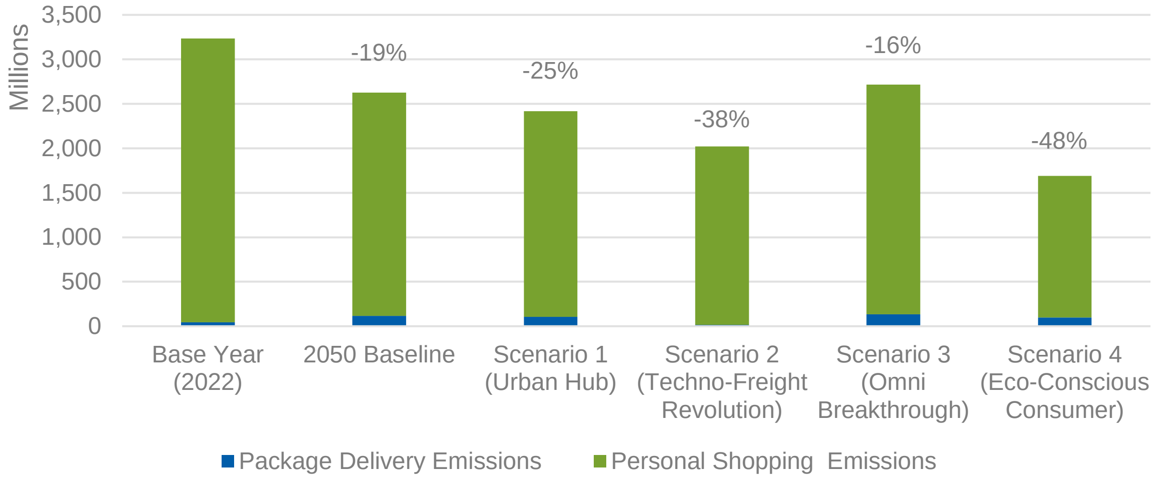
Summary of VMT impacts of the scenarios

- **Scenario 1** results in an increase of VMT of 27% over the Base Year, which is a reduction of 8% compared to the Future Baseline Case. The majority of the effect comes from the impact of urbanization on personal shopping VMT. This suggests that there can be VMT reductions from more compact growth patterns.
- **Scenario 2** results in an increase of VMT of 11% over the Base Year, which is a reduction of 19% compared to the Future Baseline Case. The big impact comes from the significant increase in online shopping, which can substitute for in-person shopping. This suggests that there are potentially significant VMT reductions from greater adoption of e-commerce.
- **Scenario 3** results in an increase of VMT of 42% over the Base Year, which is an increase of 3% compared to the Future Baseline Case. In this case, new shopping models drive essentially a net neutral impact. This suggests that an increase in online shopping may not necessarily reduce VMT, if they are also more likely to involve personal travel (such as the “click and collect” model).
- **Scenario 4** results in an increase of VMT of 14% over the Base Year, which is a reduction of 17% compared to the Future Baseline Case. The impact comes from a mix of behavioral changes among consumers, such as shorter shopping trips. This suggests that the decisions made by residents can also have significant potential for reducing regional VMT.

d. Impacts on greenhouse gas emissions (GHG)

Figure 24 displays the total GHG emissions for each scenario, as the sum of package delivery GHG and personal shopping GHG. All scenarios have a total GHG lower than the base year, due to fuel economy improvements and shifts to lower-emitting vehicles.

Figure 24: Total greenhouse gas emissions in the region, under each scenario (pounds, annual)



Source: CPCS analysis

Summary of GHG impacts of the scenarios

- **Scenario 1** results in a reduction of emissions of 25% compared to the 2022 Baseline Case. The change in GHG emissions is proportional to the change in VMT.
- **Scenario 2** results in a reduction of emissions of 38% compared to the 2022 Baseline Case. The emissions reduction is even larger than the VMT reduction, because of carrier fleet electrification and a reduction in the use of personal vehicles for delivering parcels.
- **Scenario 3** results in an emissions reduction of 16% compared to the 2022 Baseline Case. The change in GHG emissions is proportional to the change in VMT.
- **Scenario 4** results in a reduction of emissions of 48% compared to the 2022 Baseline Case. The emissions reduction is even larger than the VMT reduction, because of the increased adoption of ZEV among the passenger vehicle fleet.

e. Data and analysis limitations

Several limitations of the study and its methodology should be acknowledged:

- The analysis focuses specifically on the last-mile component of operations (i.e., the movement that results in the customer getting the product). The first- and middle-mile operations can also take place within the region, and also contribute to VMT and emissions. Finding ways to make these operations more efficient would also bring further regional benefits.
- The data focus on B2C e-commerce, in particular package deliveries and personal shopping. The analysis did not include B2B or other types of e-commerce / package delivery-oriented operations, nor did the dataset allow for evaluation of meal delivery. Once again, there may be further potential to find efficiencies with these other types of operations.
- The analysis includes assumptions about the use of gig economy drivers by Amazon, which are largely based on the team’s assumptions but could benefit from better data. Currently, Amazon employs Flex drivers, primarily for same-day deliveries during peak periods such as Cyber Monday and the holiday season. As carriers increasingly rely on

gig economy drivers for last-mile delivery, the impact on the transportation system could shift considerably.

- Any projections are challenged by the presence of significant unknowns and assumptions. For example, many relationships may not be linear. Within the evolution of e-commerce, customers may first order the types of products online where the benefit or convenience of doing so is highest The last items to shift to e-commerce may be those that are less convenient, more readily available locally, and/or where the in-store shopping experience is deemed valuable. Therefore, the substitutability of e-commerce for traditional shopping may vary depending on the stage of advancement / maturity of the market. Follow-up studies over time would serve to assess the extent to which the relationships of key variables are changing as e-commerce adoption increases.

D. Conclusions and Recommendations on VMT and GHG Impacts

1. Conclusions on strategies to reduce VMT and GHGs

Although e-commerce poses a significant challenge to traditional VMT and GHG reduction approaches, the findings of this study suggest that it also has a lot of promise in helping to reduce regional VMT to the extent that it substitutes for personal shopping trips. This is because the traditional shopping model puts a large (if potentially opaque) strain on the transportation system. If some non-essential shopping trips can be shifted to deliveries, scarce road space would be freed up for other types of trips, such as attending to errands and social outings, for which a physical trip is truly required. In fact, e-commerce has the potential to be a “win-win-win” by delivering benefits to consumers (convenience, choice), businesses (greater market reach, less need for real estate), and the environment (reduced VMT and emissions).

a. Strategies for last-mile delivery providers to reduce VMT and GHG impacts include

- Optimize delivery networks, including the locations of distribution hubs, to reduce VMT
- Optimize routing algorithms to reduce total distance of delivery routes, on an increasingly real-time basis
- Consolidate packages using van deliveries, rather than private automobiles (except where the latter are part of trips already being made)
- Promote consolidated pickup points in urban areas, where customers can retrieve packages by foot of bicycle
- Consider uptake of non-motorized delivery vehicles in urban areas, such as cargo bikes
- Progress towards full electrification of delivery vehicles
- Continue to advance technological capabilities to provide more options to customers and reduce incidences of failed deliveries
- Promote sustainable delivery options to customers, for example through consolidating multiple packages (e.g., providing the option to all customers to have their orders delivered on a preferred day of the week), and through more efficient packaging which enables greater efficiencies per delivery route

b. Strategies for retailers to reduce VMT and GHG impacts include

- Promote digitization of goods, where feasible (for example, music is now largely streamed, rather than requiring physical media)
- Right-size retail footprint to promote in-person shopping for the experiential benefit, while continuing to improve ease of online shopping; promote package delivery over click-and-collect in situations where the former is more VMT-efficient

- Partner with delivery companies to provide customers greater optionality as to the delivery company and delivery method
- Stock products in close proximity to the end user, to reduce the need for long-distance transportation (especially for standard products)
- Use algorithms to promote products that are locally manufactured or stocked
- Use technology, including augmented reality, to enable customers to better visualize and understand the products they are ordering online, to reduce the incidence of customer dissatisfaction and returns

c. Strategies for consumers to reduce VMT and GHG impacts

- Consider VMT impact in shopping decisions; shift more purchases towards e-commerce in situations where this would negate the need for a separate automobile trip
- Consider opportunities to shift some shopping trips to public transit, walking or cycling, where feasible; and to reduce trip distances by shopping locally
- Combine shopping trips with other trips ("trip chaining"), such as personal or work travel
- Take advantage of programs offered by retailers or delivery companies that promote sustainability and reduce VMT (for example, parcel pickup points, consolidated deliveries)
- Use electric vehicles instead of internal combustion engine vehicles to reduce GHG emissions
- Make efforts to reduce wasteful ordering, to diminish the need for returns

d. Strategies for government agencies to reduce VMT and GHG impacts

- Promote and facilitate electric vehicle uptake, including EV charging infrastructure
- Promote urban "microhubs" or consolidated pickup points, as well as cargo bikes, including through pilot projects
- Encourage industry to report on and track sustainability targets and strategies, including related to last-mile VMT and GHG emissions
- Facilitate a supporting infrastructure (including on the curbside) to efficiently accommodate last-mile delivery vehicles
- Facilitate a supportive land use that accommodates e-commerce innovation, while promoting measures that reduce VMT and GHGs
- Promote education and awareness on strategies to reduce VMT and GHG impact
- Consider opportunities to better measure, evaluate and track e-commerce impacts on travel demand

2. Recommendations for Met Council and state and local government agencies

The following specific recommendations are proposed based on the results from the quantitative assessment, literature review, and discussion with stakeholders:

Electrify last-mile deliveries: Electrifying last-mile deliveries represents a crucial strategy for significantly reducing greenhouse gas emissions in the transportation sector – both among delivery fleets and private vehicles.

Recommendation: Met Council and its transportation partner agencies should promote electrification through planning and investments in public charging infrastructure.

Enhance efficiencies where possible: The opportunity to locate “microhubs” or consolidated pickup points near the customer can significantly reduce VMT, especially if packages can be delivered to the customer by a non-automobile mode (e.g., foot couriers, cargo bikes) or picked up by the customer without going too far out of their way.

Recommendation: Cities and county transportation agencies in the region should consider leading or participating in pilot studies/projects that promote and facilitate parcel consolidation (for example, through provision of e-cargo-bikes / microhubs and delivery lockers at transit stations / mobility hubs). Partnering on pilot projects in concert with parcel carriers, for example, could test the benefits of these approaches in the Twin Cities.

Education and promotion: Although some of the inefficiencies of e-commerce are conspicuous (such as receiving multiple packages per day, in multiple deliveries), residents may not be as aware of the VMT impacts of their own shopping travel. As well, residents may not be informed on steps that parcel carriers can take, or are taking, to improve efficiency.

Recommendation: The region’s transportation, health, and environmental agencies should develop educational materials to inform the public and promote actions that residents and businesses can take to minimize VMT and greenhouse gas emissions.

Recommendation: Met Council and MnDOT should encourage major e-commerce parcel carriers to provide summary data related to delivery vehicle fleets and VMT and should develop aggregated data metrics to track progress in meeting regional and statewide goals.

Further study: The pandemic experience has shown how travel behavior can change rapidly and significantly. Met Council should continue to stay ahead of the curve on measuring and tracking the effects of e-commerce on regional freight travel and household shopping trips.

Recommendation: Met Council should explore how to incorporate e-commerce's influences on regional freight travel and household shopping trips during planned updates to the Council's freight and activity-based forecast models.

3. Opportunities for further study

There are many areas for possible further study, but listed below are a few study concepts for Met Council and Twin Cities area researchers, as well as for research in other regions and cities nationally.

- Investigating the impact of meal and grocery delivery on VMT. This research would aim to understand how meal and grocery delivery services affect transportation and traffic patterns. Data from food delivery companies, which document these movements, would be crucial for this research. Gaining access to such data could offer valuable insights for future policy-making, enhancing our understanding of the sector's influence on regional VMT.
- As this study research demonstrates, the largest portion of shopping-related VMT is driven by personal shopping trips. It would be valuable to do a research study to further investigate the patterns of trip chaining and understand to what extent different future scenarios of trip chaining could potentially reduce regional VMT. For example, making a trip (to a store, to pick up a parcel, etc.) on the way home from work could be argued to have a minimal marginal VMT impact, but this becomes less clear when multiple discretionary trips are bundled. The Council’s Travel Behavior Inventory offers a wealth of data which should allow for detailed analyses. Studying patterns of trip-making in closer detail would offer opportunities to identify additional strategies to reduce VMT (even if simply by increasing general awareness).
- Accurately quantifying the impact of private vehicles used for deliveries (e.g., Amazon Flex) is challenging due to the limited availability of data on the extent and characteristics of these deliveries. Any changes in carrier strategies regarding gig economy utilization (the use of

independent contractors or freelancers, often through digital platforms, for delivering goods and services) could have notable implications for delivery system efficiency and overall operational capacity in key freight corridors, and VMT. This would be a valuable area of further study.

- The link between sales and physical transportation needs is an interesting and underexplored one. Many of the findings in this study rely on the assumption that an increase in sales (due to growing population and discretionary income) will lead to an increase in physical travel, whether due to more e-commerce parcel deliveries or more personal shopping trips. However, this may underestimate the extent to which digitization (the conversion of physical to electronic goods) and product miniaturization (the technological evolution to smaller and more efficient products) may have a beneficial effect. Digitization through virtual goods and services can reduce the need to physically transport goods to the buyer, and smaller, higher-value products can take up less space, increasing the efficiency of deliveries.

II. Siting and Land Use Trends for E-Commerce Warehouse/Distribution Centers

This chapter delves into the siting and land use trends of e-commerce warehouse and distribution centers, uncovering the nuanced interplay between the industry's expansion and the evolving land use policies and strategies. Through a comprehensive investigation that includes reviewing publications, conducting interviews with industry experts, and surveying real estate brokers, this analysis sheds light on the current market activities and the anticipated trends within the e-commerce facility development and location decisions. Additionally, the chapter examines the diversity of e-commerce facility types and their functions within the supply chain, emphasizing the significance of the "last-mile" in fulfilling consumer demands swiftly and effectively. Finally, this chapter proposes potential land use strategies and actions to plan for the impact of e-commerce based on review of plans from other regions and municipalities. The report detailing this analysis is available on the Met Council's website.

A. E-Commerce Facility Types

1. Background and Context

The e-commerce industry is growing significantly, which has directly impacted land use and development patterns throughout North America and the Twin Cities region. E-commerce growth demands new development and varying facility types which have the potential to impact how state, regional and local agencies will plan for land use and transportation systems.

National, regional and local publications were researched to assess trends in e-commerce facility development and location decisions. The research was supplemented by extensive industry interviews with five industrial/retail developers and three regional real estate brokers. An online survey was sent to more than 20 active brokers within the Twin Cities region to solicit information about current market activities and known or anticipated demand within the e-commerce industry. Site visits were conducted at major e-commerce warehouse and distribution centers in the Twin Cities region, including multiple sites operated by Amazon, FedEx, UPS, US Postal Service, Whole Foods, and Target. A detailed tour of the Amazon Fulfillment Center in Shakopee was also attended.

2. Impact of customer expectations

The e-commerce industry is changing rapidly in response to evolving consumer demands which in turn is significantly impacting industry development and siting decisions. Increasingly, consumers expect to receive their deliveries on the same day, within two days – or depending on the purchase – within hours. Quick delivery expectations once reserved for Amazon are quickly becoming the industry standard and most competitors seek to match the “Amazon delivery experience.”

This shift in consumer expectations affects the supply chain and directly impacts how an operator defines its optimal facility locations. Simply put, operators need to find and site their e-commerce facility locations near their consumers if they want to successfully compete in the market. While the operator/developer location decision is driven by effectively and efficiently serving the last-mile on the supply chain, a corollary impact is the operator’s objective to reduce vehicle miles traveled (VMT) throughout the entire e-commerce supply chain. Efficiency in routing and shorter distances between facilities creates both transportation cost savings and customer satisfaction through faster deliveries. E-commerce companies, third-party delivery companies and retailers have spent the past decade researching and creating algorithms to find locations for their facilities that effectively balance transportation accessibility, land/development costs and proximity to concentrated population centers.

3. Facility type and function

The e-commerce industry is diverse and operators do not all function the same or utilize the same facility types to support their business. Finding common definitions across the industry is difficult because operations vary widely and facilities are often tailored specifically to the user/operator. Given the inconsistency in terms, the industry instead often refers to their facilities based on their function within the overall e-commerce supply chain. For purposes of this report, the focus of the analysis and discussion is related to location and siting decisions related to what the industry refers to as the “last-mile.” Last-mile is defined as the last stage in the supply chain where parcels or packages are delivered to or received by the consumer. Analysis and recommendations are primarily associated with last-mile facilities, whether they are standalone or co-located with another facility type in the supply chain. Figure 25 describes the facility types and functions that are presented throughout the report.

As shown in Figure 25, last-mile facilities may be standalone or co-located with a warehouse, distribution center, fulfillment center, and/or sortation center. The co-location of functions is also referred to as multi-functional facilities, because they support different parts of the supply chain. For additional information on e-commerce land use terminology, please refer to Appendix E.

Figure 25: E-commerce facility type and function

	E-commerce Facility Types that store or sort parcels for online customer purchase:	*E-commerce Facility Types that facilitate how and where customers receive their parcels:*	
	Single Function or Multi-functional Facility Types	**Last-mile Facility Type (Category 1)**	**Last-mile Facility Type (Category 2)**
Facility Type or Definitions used by Operators	Warehouse Distribution Center Sortation Center Bricks and Mortar Retail Store Fulfillment Center	Delivery Center Microwarehouse Micro-distribution Center Third Party Delivery Location Dark Stores	Microhub or Hub (example: Prime Now Hub) Automated Parcel Locker (APL) Retail Hub Online pick-up or Drive-up
Primary Functions	Facilities hold and/or store products for manufacturers or retailers. Activities may include order fulfillment and/or sortation depending on the operator.	Facilities receive the order from fulfillment or sortation and the parcels are delivered to the customer. The Facility Types in this category primarily deliver to the customer's home or workplace.	Facilities receive the order from fulfillment or sortation and the parcels are either delivered to the customer OR the customer picks up their parcels at a designated location. The Facility Types include both deliveries direct to the customer AND/OR customer pick-up.
Primary Activity Flow	Trucks In → Facility → Trucks Out	Trucks In → Facility → Trucks/Vans Out	Trucks In → Facility → Cars/Bikes/ Pedestrians Out Trucks In → Facility ← Cars/Bikes/ Pedestrians In
Co-location	May be standalone or co-located with a Last Mile Facility type depending on operator business model.	May be standalone or co-located within a multi-functional facility or campus depending on operator business model.	Primarily standalone but may be co-located with a small multi-functional facility type OR co-located with another compatible use (example APL in an apartment building or at a transit stop).

Source: SHC analysis

B. Trends in Last-Mile Facility Development and Location Decisions

1. Findings from across North America

a. Finding #1: Facility function within the supply chain impacts siting decisions.

E-commerce operators differ in their business lines, which impacts their logistics approach. For example, Amazon has a robust network of sortation centers which are often co-located with a delivery center, while Target uses their brick-and-mortar locations as mini-fulfillment centers with co-located delivery and pick-up services. Both are examples of last-mile delivery functions co-located with a warehouse/storage component.

i. Co-location of last-mile delivery facilities with multi-functional warehouse/distribution centers

- Access to major roadways is critical. Multi-functional facilities must be sited in proximity to major roadways and interstates to ensure trucks can easily access and navigate to the site. Accommodation of semi-truck traffic is important for any co-located facility with warehouse, distribution, fulfillment and/or sortation functions.
- Circulation and staging must also be considered. Large multi-functional facilities with co-location are a logistical semi-truck dance. Semi-truck movements require adequate area to maneuver, queue, load and unload. Meanwhile, last-mile delivery operations introduce vans and cars to a site which, if not properly planned, can cause unwelcome and inefficient co-mingling. Therefore, semi-truck parking/staging areas must be separated from other trucks, vans, and passenger vehicle types.
- Multi-functional e-commerce facilities employ more people than a traditional warehouse operation, especially if automation is minimal. This makes proximity to the labor force a critical selection criterion, though it is oftentimes secondary to truck route accessibility.
- Operators seek proximity to a region's urban core, and often find suburban locations most desirable. Locating multi-functional facilities near populated areas allows for co-location of last-mile operations with warehouse/distribution/fulfillment/sortation facilities because there is access to critical infrastructure, utilities, labor force and their customers. This trend has been magnified as more operators seek to find sites that balance their warehouse/storage needs (namely, very large land parcels) with adequate last-mile catchment areas (dense populations and households) to meet same-day and quick delivery time expectations.

ii. Standalone last-mile facility site selection

- Population density dictates the size, scale and type of facility that can be supported. Population density is a key driver in determining whether a standalone last-mile facility will be successful, and what type of facility is needed. Dense urban areas are more likely to be able to support a microhub designed for alternative delivery modes such as e-cargo bikes or walk-up pick-ups, while less populated suburban areas may be more likely to support drive-up pick-up from an Automated Parcel Locker. Local examples include:
    - Amazon's Delivery Center in Maple Grove is a last-mile facility that uses parcel delivery drivers in vans or personal vehicles exclusively.
    - Amazon's Automated Parcel Delivery pick-up and return centers (primarily located in Whole Foods and other similar grocery stores) are last-mile facilities that are accessed by personal vehicles, pedestrians, and bicyclists, and are oftentimes located in areas with higher household density or are co-located with high-traffic retail uses.
- Selection criteria for standalone last-mile facilities are most variable because operators look at density from the perspective of a variety of uses. Selection criteria are based on the areas intended to be served, which may be based on population density, households, employment or high-traffic volume retail users.
- Locations are chosen based on where customers are already going. For example, placing automated parcel lockers in grocery stores is strategic. Grocery stores provide a necessity (food) to consumers and, therefore, trip chaining on a parcel pick-up from a parcel locker removes the last-mile "delivery" trip to the customer's home. This potential efficiency gain through trip chaining can occur across most of the developed areas of the region.

b. Finding #2: Vertical warehousing is currently a niche development type in areas with significant land constraints but could become more common where automation technology becomes more accepted and integrated within e-commerce processes.

Vertical warehousing currently represents a small percentage of the overall national and international industrial/warehouse development market due to the significant costs associated with construction and maintenance. However, as automation technology continues to evolve, going vertical may eventually become more economically viable. Currently, vertical warehouse development is cost-prohibitive in many markets, especially those with an abundance of available land (i.e., it will be cheaper to develop available greenfield sites with enough land to allow for one-story facilities than to construct a multi-story facility). Nevertheless, there are examples of e-commerce operators making significant investments in automation with vertical solutions that are paving the way for future innovations for this type of facility, such as Walmart Canada's vertical distribution center in Surrey, British Columbia and Prologis's Georgetown Crossing project in Seattle, Washington.

2. Twin Cities region/local findings

a. Finding #1: The Twin Cities region is a distribution hub for Minnesota and its adjacent Upper Midwest states.

The Twin Cities region is not likely to become a national/global e-commerce hub for parcel distribution based on its relatively remote location within the U.S. with respect to major ports and other densely populated metropolitan areas. Most of the Twin Cities' e-commerce activity will concentrate on serving the regional market, with some direct service into bordering states. Using Amazon as one example, Minnesota is a part of Amazon's "Great Lakes Region" on a national scale. The company's fulfillment center in Shakopee will serve the Twin Cities region by funnelling most shipments from the fulfillment center to local sortation and delivery centers. Amazon's objective is to co-locate their sortation and delivery centers in order to meet next-day and same-day delivery expectations most efficiently. A secondary but deliberate objective is to minimize the vehicle miles traveled of its delivery fleet.

b. Finding #2: Local developers, brokers and operators reinforced truck accessibility as a key site selection measure for co-located last-mile facilities

- Because of the increased demand for co-located last-mile facilities, locations must support the receiving of freight deliveries while considering how this will interact with last-mile delivery. Considerations noted during interviews included:
- Access to major thoroughfares, including interstate and other highways.
- Adequate site acreage to allow for flow of trucks through a site including adequate staging, storage and on-site queuing that does not conflict with last-mile delivery operations. Note that this is important both for larger facilities as well as for tight urban locations.
- Loading/docking areas that meet current industry standards and expectations. Retrofitting older warehouse/distribution center facilities can be challenging and cost-prohibitive, which is an impediment to adaptive reuse of the older facilities that are more common in urban areas.
- Separation of semi-truck (inbound) deliveries and last-mile (outbound) delivery trucks/vans is often tight in more densely developed areas, but as the industry moves toward co-location of multiple functions it will only become more critical.

c. *Finding #3: E-Commerce Facilities in the Twin Cities primarily function as bulk distribution warehouses.*

With average delivery route times of 40-50 minutes, warehouse/distribution and sortation centers have been positioned within the region to serve storage and distribution functions co-located with last-mile delivery operations within the same building and/or campus. Key observations regarding area-specific demand for e-commerce deliveries included:

- Locating in the “four corners” or “quadrants” of the region creates managable catchment areas that are well-positioned to serve the entire Twin Cities metro area. This has become a strategy for larger companies such as Amazon, UPS and FedEx. This means facility locations within proximity of the I-494/694 loop.

Several prominent companies have expressed interest in finding locations in the urban core, primarily along the I-35W corridor, but finding contiguous acreage to support a 100,000 – 200,000 square foot facility has been challenging. The desire to locate along this corridor was expressed in terms of access to areas with relatively higher household and population densities. As shown in

Figure 26, communities have guided industrial and commercial retail land uses along major freeways and transportation corridors. While the market and communities are aligned in where these uses should be located, the market indicated that there is steep competition for available land.

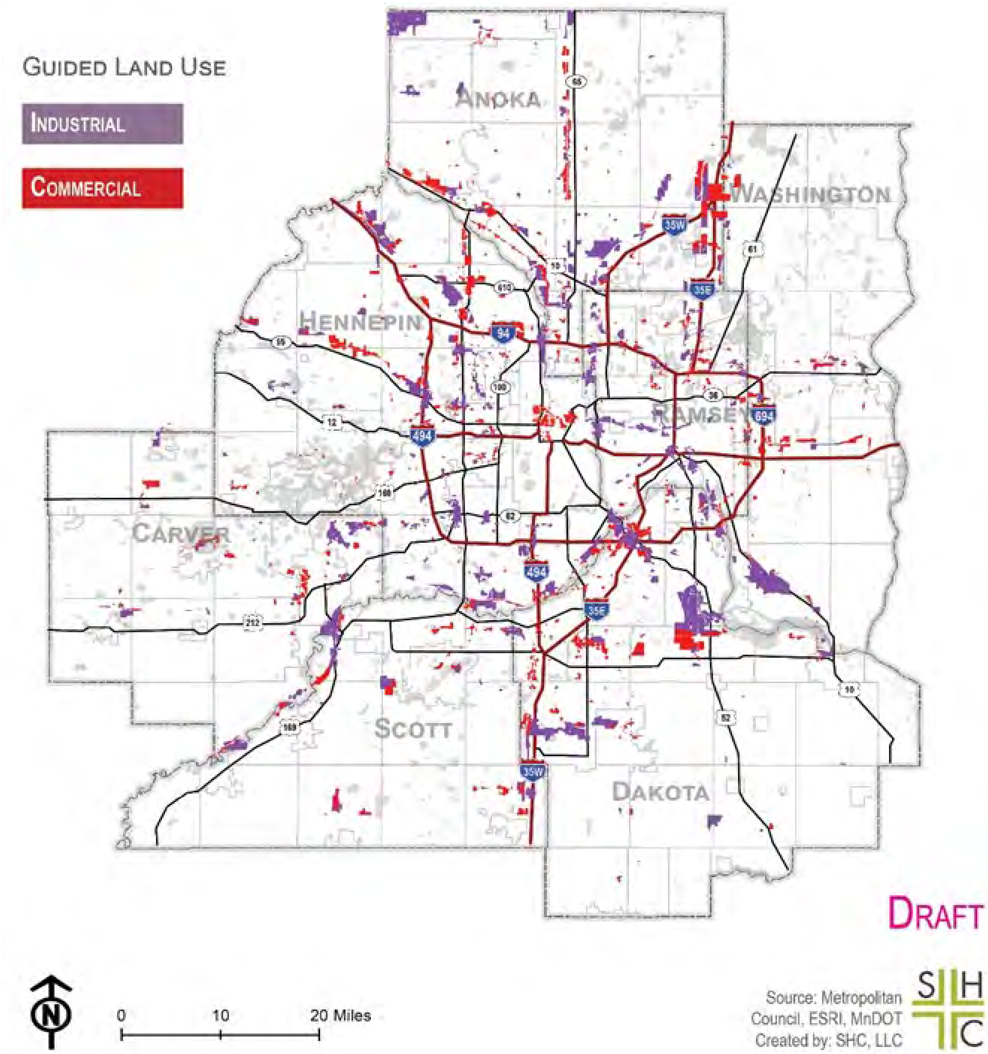
- Smaller facility types, less than 100,000 square feet, are active and in demand, and are sometimes referred to as a micro-warehouse, micro-distribution centers, or hubs when last-mile functions include both delivery and pick-up. Based on interviews, these facilities are becoming more popular as demand has grown for same-day and quick delivery. An example of a hub is Amazon's Prime Now Hub in Minneapolis. Facilities in this size range are more likely to serve a much smaller geographic area – such as urban neighborhoods in St. Paul, Minneapolis, or Urban Edge communities like Richfield or St. Louis Park – and are located specifically to meet last-mile same-day delivery demands.

d. Finding #4: New construction is preferred over adaptive reuse for e-commerce facilities.

In the Twin Cities region, industry experts indicated that the current trend is to build new structures, especially for e-commerce multi-functional facilities. This preference was based on several factors:

- Clear heights of 32-feet are desired and/or demanded and older buildings were typically built with 12 to 24-foot clear heights, which make them undesirable, especially for major users. Smaller scale and third-party operators may rent existing and/or older space if it is cheaper, but certain metrics are universal (such as that they must have adequate loading docks, minimum clear heights, and appropriate turning radii for trucks).
- Large contiguous parcels of flat land are available for much lower prices around the edges of the Twin Cities as compared to areas with land constraints and existing structures, such as the Central Business Districts/urban core. The larger acreages allow for the construction of multi-functional facilities that are driven by market demand. Larger parcels allow for on-site parking of semi-trailers and trucks, as well as adequate staging areas for queuing last-mile delivery trucks, vans and autos.
- Newly constructed facilities can more often be located adjacent to major freeways, making it faster for orders to be packaged and delivered, thus meeting same-day and 2-hour delivery times.
- Older buildings often have interior structural supports that are a hinderance for maneuvering and accessing goods via forklifts and other vehicles.

Figure 26: Guided land use in the Twin Cities region



Source: SHC analysis of data from Met Council

Appendix F summarized five major e-commerce siting and location planning themes.

3. Industrial development trends in the Twin Cities

Major e-commerce operators are focusing on expediting deliveries within the Twin Cities region to respond to the shift toward same-day and two-hour delivery expectations by consumers. This shift is one factor that is driving more localized siting of warehouse/distribution centers with co-located last-mile delivery functions and which is further supported by the region's industrial real estate activity.

a. Status of Twin Cities' industrial land market

Several large scale facilities, like those frequently built in national e-commerce hub cities, have been built in recent years in the Twin Cities, but industry experts have indicated that these facilities are not leasing up. In the short-term and medium-term horizons, they anticipate 100,000 to 200,000 square feet facilities will be built rather than the larger facilities (250,000 SF +) commonly developed in national e-commerce hub regions, given that the region has facilities in this range sitting vacant. While the Twin Cities may not become a national e-commerce hub region, there are some considerations that may impact whether exceptions to the rules may occur in some cases:

- The Twin Cities region is considered one of the nation's primary locations for manufacturing of medical devices and life sciences research. The industrial warehouses, distribution, and manufacturing facilities and activities related to the medical devices manufacturing industry have synergies with e-commerce that may impact which e-commerce operators choose to locate here.
- The robust manufacturing of medical devices and ancillary life science industries will drive competition in a tight market for developable and/or greenfield industrial land. This competition for space may continue to increase land prices.
- Third-party e-commerce delivery providers will more likely operate at the regional or national level because of their additional business lines. For example, the FedEx facility in Mahtomedi serves as a regional hub to upper-Midwest states, with a mix of local last-mile operations and out-of-state shipping. The Twin Cities region's strong manufacturing and medical supply industries are closely aligned with FedEx's alternate business lines (such as non-e-commerce shipping and delivery services that include business-to-business deliveries), making the region potentially a strong market for FedEx operations.

b. Opportunities for adaptive reuse of retail spaces

Large retailers are pursuing efforts to add distribution/warehouse capacity rather than resorting to mass closures of big box retail stores. As one example, Target is actively converting portions of their retail footprint into storage for distribution and pick-up. This adaptation is blurring the lines between industrial and retail square footage.

Target's traditional retail operations are supplemented by e-commerce operations that have been evolving for the past 15 years. How and in which locations Target focuses its e-commerce investments is in part related to where they have current real estate assets. Fortunately, their original site selection metrics used to choose store locations are also applicable to their e-commerce operations. Existing Target stores were in large part located in areas within proximity to an adequate number of households with favorable socio-economic demographics (meaning average or above average median household incomes).

While Target is the most visible or recognizable example in the region, many other retailers are following suit in an effort to compete in the e-commerce industry. Nearly all retailers have introduced a "pick-up" option and some offer delivery options that are provided by third-party delivery companies. This transition is impacting even small retail footprints that are increasingly dedicating more of their physical retail space for warehousing and/or storage.

For additional analysis on Twin Cities regional development patterns related to the e-commerce industry, please refer to Appendix G. Appendix I provides additional information on trends in retail closures and adaptive reuse.

C. Land Use Policies and Strategies Comparison

1. Introduction and analysis approach

The regulatory environment of a region or city impacts the siting of parcel distribution facilities and is becoming more complex and nuanced as the e-commerce industry continues to evolve. Since the e-commerce industry is changing quickly, cities and regions are forced to deal with operational and facility development-related requests that are not necessarily addressed within typical land use plans and zoning ordinances. This creates a regulatory environment that is reactionary rather than proactive, which is oftentimes difficult for both government agencies and private companies to navigate. Fortunately, there are some good examples of places that are conducting studies, pilot programs, and creatively using existing zoning and/or land use plans to help guide land use approvals of e-commerce facilities and uses. The facility types and functions are the primary considerations evaluated in emerging policies and regulatory examples, since how the facility functions within the overall supply chain has the most impact on land use and transportation planning.

The approach to this comparative analysis included a review of relevant literature, case studies and plans to learn how different regions and municipalities address and plan for e-commerce facilities within their communities. There are many examples of how new e-commerce industry trends are reflected in facility development and siting through planning and implementation processes. These case studies and pilot programs provide insight into how operators are utilizing existing policy to support their operations and what creative policy approaches may be required to ensure continuity in facility operations in the “highest and best” locations.

2. Comparative analysis findings

Due to the rapidly changing nature of the e-commerce industry, cities and other regulatory agencies often have a policy and regulatory environment that is out-of-date almost as soon as the policy is put into effect. It is difficult to find examples of land use policies and zoning regulations that are industry specific. Additionally, the level of planning and or sophistication in addressing and planning for e-commerce facilities is more established for large warehouse/distribution facilities than for multi-functional and co-located last-mile distribution facilities. Policies and strategies lag even further behind for standalone last-mile facilities such as small-scale, micro-distribution centers and last-mile microhubs. Given the differences that exist in the maturation levels of policies and to align with examples from other regions, the findings from this analysis are generally subdivided by facility function with cross-references as noted.

a. Multi-functional and co-located last-mile distribution facilities

i. Zoning challenges related to e-commerce facilities

Throughout the country most municipalities continue to designate e-commerce warehouse/ distribution/ sortation centers as Industrial land uses even if co-located with last-mile operations. Cities in metropolitan areas such as New York, Seattle, Phoenix, Austin, Dallas, Chicago and Indianapolis all provide industrially zoned areas suitable to meet the site selection criteria for large-scale, e-commerce facilities without establishing any special or unique zoning districts or land use policies. For these cities, major transportation corridors that accommodate freight movement are generally prioritized and zoned for industrial uses, and e-commerce multi-functional facilities are deemed compatible and consistent with this land use type. However, based on background research and review, there were few, if any, examples of established land use policies related specifically to e-commerce uses.

The functions and operations of multi-functional facilities are similar to warehouse or manufacturing operations that rely heavily on transportation and freight movements. However, one way that e-commerce facilities can differ from traditional warehouse uses is in having co-located last-mile operations with significant car and van traffic in what is typically a heavy truck volume area. This co-mingling of semi-trucks and cars/vans is generally viewed as inefficient and potentially unsafe. For this reason, there may be potential adjustments to land use policies that would better support these multi-functional facilities but to a large degree, industrial zoning codes and land use policies have been utilized and operators have successfully navigated permitting under these codes. A few communities and regions have acknowledged this conflict and determined that their codes are inadequate to address e-commerce uses and have begun to undertake planning initiatives (see box) to better guide e-commerce facility development.

Notable initiatives to address e-commerce zoning needs

PennFuture, a nonprofit in Pennsylvania, developed a model ordinance and guidebook titled "Living with Logistics: A Model Logistics Use Zoning Ordinance for Pennsylvania Municipalities."[23] The ordinance and report state that existing industrial and retail zoning designations do not adequately address e-commerce facilities, especially multi-functional and large warehouse/ distribution/ fulfillment/ sortation centers. The purpose of the model ordinance is to provide Pennsylvania municipalities with some direction on how to incorporate new policy into their ordinances that better addresses e-commerce facilities and operations.

The City of Long Beach, California initiated an E-Commerce & Delivery-Only Retail Zoning Code Update study in 2021 and the process is not complete.[24] The City's project website indicates that the purpose of the study is to adequate study, "recent technological advancements, the demand for e-commerce and delivery retail, or non0stroefront businesses such as ghost kitchens, distribution centers…" The City acknowledges that the current regulations and standards do not adequately address these new types of uses and that the code should be updated to more appropriately reflect the operations. While the ordinance is not complete, it could become a good example of how to incorporate some of these uses within codes, when adopted.

Cities will have opportunities to analyze how e-commerce multi-functional facilities may differ from other industrial developments; if there are significant differences, cities will begin to adjust land use policies to better align with e-commerce industry functions. Additional study would be advantageous, Land use policies will eventually need to catch up with the evolving demands of e-commerce to provide enough land suitable effectively manage the needs and impacts of the industry. Further research in these processes would be helpful to advance better practices in land use planning.

Appendix H details the challenges in site planning of re-commerce facilities.

ii. Convergence of industrial and retail land uses

The convergence of industrial and retail land uses is occurring throughout the nation and has accelerated during the pandemic while regulatory response is in its infancy. Most cities are responding to this new shift through creative/flexible land use applied on a case-by-case basis rather than wholesale land use policy changes. The most common tools employed include Planned Unit Developments, Planned Developments, and mixed-use zoning designations. These types of development are typically near transportation networks and population centers so that the last-mile is near the end consumer, while retail uses are benefitting the workers and surrounding residents.

iii. Creative facility types

Developers in land-constrained markets have explored projects that are not like traditional distribution centers. The creative facility solutions have been due to accelerated demand for distribution space to fulfill online purchases spurred by the pandemic. However, this trend has not reached areas with ample land available, especially areas connected by major freeways. The research is consistent with the interviews with industry experts who have stated the Twin Cities have land available at the edges, which makes peripheral development more economically viable than infill redevelopment.

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[23] Pennfuture.org/publication-living-with-logistics-a-model-logistics-use-zoning-ordinance-for-Pennsylvania-municipalities
[24] Longbeach.gov/lbds/planning/e-commerce-delivery-only-retail-zoning-code-amendment/

However, smaller-scale standalone last-mile facilities such as hubs or microhubs are already present in the Twin Cities region and the concept of dark stores or other adaptive reuse may be introduced faster than large-scale warehouse/distribution center conversions.

b. Last-mile standalone and multi-functional facilities / campuses

The last-mile is focused on the delivery or pickup of parcels to or from the end consumer. This operational function is sometimes located in single-function, standalone facilities, and other times is co-located within a multi-functional facility or campus.

Changing consumer demands for faster delivery have resulted in new and innovative ways to position goods in locations that are closer to the consumer, especially in urban locations. The examples documented below provide insight into emerging industry trends for last-mile facilities in higher-density, urban locations with specific attention on the standalone last-mile facility types such as microhubs or micro-distribution centers. Locally, some microhub facility types exist and are noted in this analysis to demonstrate how, operators may be thinking about the last mile in the Twin Cities' urban locations. Because smaller, standalone last-mile facilities are relatively new, examples from Europe are also included. The purpose of providing the European examples is not to suggest that this region will function the same or can support the same last-mile facility type, but rather to offer some useful design considerations that could be applied in the Twin Cities as these facilities become more common.

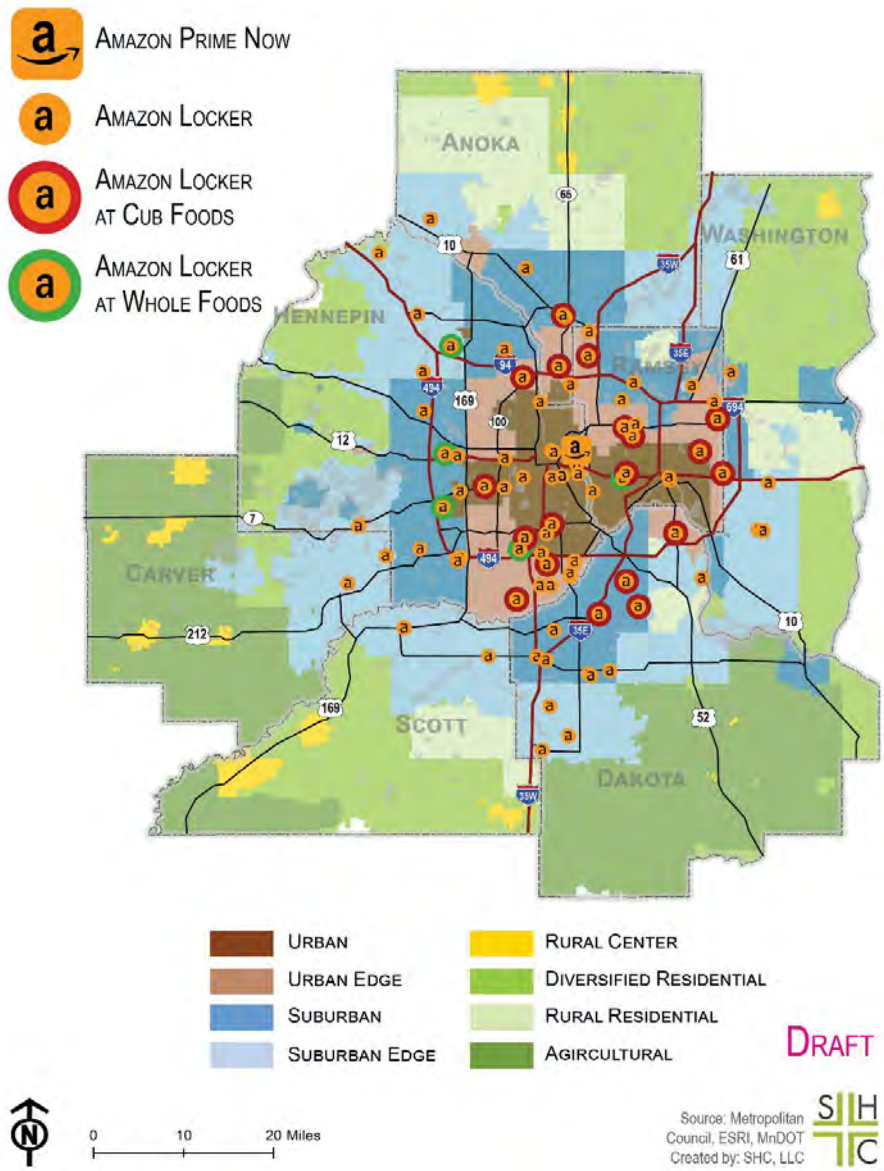
i. "Microhub" concepts in use in the Twin Cities

In the Twin Cities region last-mile facilities are largely dominated by multi-functional facilities that co-locate warehouse/distribution/fulfilment/sortation centers with last-mile delivery service to the end consumer. Major players in the local market include Amazon, Target, Walmart, and third-party delivery providers such as FedEx, UPS, and the US Postal Service. As the industry has evolved, these operators are changing their supply chain logistics and new last-mile facility types and delivery options are popping up. For example, Amazon has two last-mile "hub" concepts in the Twin Cities region. Examples of both concepts are predominantly located in the Twin Cities region's higher-density communities where the population and households can support the facilities. Figure 27 shows Amazon's Prime Now Hub located in Minneapolis with an Urban Community Designation, while the Amazon Automated Parcel Lockers can be found in Suburban/Suburban Edge communities, particularly in the west and south metro sub-areas. A description of Amazon's last-mile hubs identified on the map include:

- *Amazon Prime Now hub:* Located in Minneapolis, Amazon operates a 35,000 square foot facility which has been open for more than eight years. The hub is the only facility in the Twin Cities where customers can pick up their order. The facility is stocked with goods that the retailer has determined are the most commonly purchased and are generally available to consumers for pickup within 30-minutes to an hour. The location is centrally located; however, it is not on a major transit line or trail corridor, which makes it primarily an auto-centric facility.
- *Amazon Automated Parcel Lockers (APLs):* There are approximately 85 APL locations in the Twin Cities. The lockers are primarily located in high-traffic retail locations such as Whole Foods, Afrique in Minneapolis, Cub Foods, Speedway, a parking ramp, and in strip malls. The lockers are sited to leverage the existing pedestrian traffic, and in some cases are located near or on major transit lines.

In addition to Amazon, UPS, USPS and FedEx are all operating retail and satellite facilities that function as micro distribution hubs. One example is the UPS retail stores. Through our interviews, we understand that UPS's PO Box service has evolved from primarily serving small businesses to a mix of both small businesses and individuals that are seeking secure delivery locations. The UPS stores are functioning as both secure personal delivery locations, similar to automated parcel lockers, as well as package return drop-off stations. Our interview contact indicated that this has become such a large part of their business that they are running out space to store the packages, further demonstrating that this type of operation is functioning through microhubs within our region.

Figure 27: Amazon Prime Now and APL locations and Draft 2050 Community Designations



Source: SHC analysis of data from Met Council and Amazon

ii. Demand for innovative solutions

International and national e-commerce operators are seeking innovative solutions to solve the trending demand for last-mile quick deliveries. E-commerce companies and third-party companies recognize that the shift in consumer expectations for same-day or fast delivery means that operators must determine how to position goods in locations that are accessible for quick delivery or are easy for the consumer to pick-up. This has resulted in re-thinking how spaces are used, especially in densely populated and developed areas. While the operator is seeking locations that offer the fastest delivery times, municipalities and regulatory agencies are becoming increasingly aware of the external impact of such a location shift. From increased congestion to the re-use of traditional retail space for “warehousing” uses, regulatory agencies are faced with new challenges that are unique to the e-commerce industry and the consumers expectations that are driving the change.

3. Potential land use strategies and actions to consider

The following potential strategies and actions are suggested for consideration based on the research, themes and findings from this study and are organized by facility type group or planning issue. Readers can also refer to the Part II sub-report, developed as an input to this final report, on the study website.

a. Co-located and multi-functional distribution facilities (includes warehousing, fulfillment, and sortation centers)

- Encourage cities, especially those that are fully built out (i.e., Met Council community designations urban, urban edge, and suburban) to protect their inventory of industrial land in ways that support e-commerce uses.
- Encourage modernization of industrial land use policies and regulations to better accommodate e-commerce. Current land use definitions often do not adequately address, nor describe the facilities and their function within the supply chain.
- Encourage municipalities to guide land for co-located, multi-functional e-commerce facilities that are located near major roadways and public transit service. Operators sometimes overlook the value of locating in areas with multi-modal transportation options.
- Consider developing new land use policies that are tailored to address the variety and range of e-commerce related uses.
- Encourage communities to consider expanding their industrial and/or retail planned land uses in prime locations to support e-commerce facility development. Locations near higher-density population centers but within industrial or mixed-use zoned areas are most compatible for e-commerce facilities, followed by retail land uses.

b. Standalone last-mile distribution facilities

- Cities with larger populations and higher densities should consider opportunities for repurposing or reusing vacant / underutilized retail structures for standalone last-mile distribution facilities. For example, the conversion of a small retail space into a distribution microhub may encourage continued vitality and activity of an area through e-commerce delivery and pickup.
- Standalone last-mile facilities such as distribution microhubs should be located in the highest density and highest population areas and neighborhoods. As reference, microhubs or hubs in other markets typically serve a one-to-three-mile radius.
- Consider aligning distribution microhub locations as described in the Mobility Hub Planning and Implementation Guidebook. This Metro Transit planning effort[25] included extensive analysis to find locations with passenger transportation modal opportunities that could incorporate parcel distribution microhubs into mobility hub site planning.

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[25] See Metropolitan Council, Mobility Hub Planning and Implementation Guidebook: https://metrocouncil.org/Transportation/Performance/Emerging-Trends/Mobility-Hub-Planning-Guide.aspx

- Explore opportunities to incorporate last-mile facilities such as parcel distribution microhubs into people Mobility Hub planning efforts. Such co-locations could support the transition of some last-mile delivery vehicle trips to cleaner energy transportation modes such as pedestrian, transit, and traditional or e-cargo bicycle.

c. Convergence of traditional brick-and-mortar retail with industrial uses

Consider the introduction of new land use designation for Retail/Industrial Mixed Use as described herein. The convergence of retail and industrial uses as they relate to e-commerce is expected to evolve over the coming decades. As a result, the line between retail and industrial land use designations is likely to blur. Considerations could include:

- Develop new land use policies that address the variety and range of e-commerce related uses.
- Depending on land use context, consider appropriate mix and scale of traditional retail alongside e-commerce uses in revised land use designations.
- Advise cities on employment projections related to a potential new mix of uses within an area (e.g., if Walmart builds an automated fulfillment center attached to one of its store locations).
- Support the adaptive reuse of obsolete or underutilized retail uses for micro-warehouses or retail/e-commerce/mixed-use facilities. These converted facilities can function as last-mile distribution hubs in the supply chain and can help reduce VMT from these sites that are historically located in areas with high population densities.
- Promote microhubs in strategic locations with high population densities.
- Micro-warehouses and Retail/Industrial Mixed Use: Encourage cities with greater population and density to consider opportunities for repurposing and reusing retail structures where the demand for retail is weak.

III. Curbside Management and New Technologies for Last Mile Deliveries

This study element reviews curbside management best practices and provides a summary of research findings on new or emerging technologies for last mile deliveries, with a special focus on the impact on reducing VMT and overall emission of CO_2 and other greenhouse gases. This chapter concludes with policy considerations on curbside management and new technologies for Met Council and partner agencies.

A. Importance of Curbside Management

Curbside management to better accommodate goods deliveries among other curbside users of multiple transportation modes is an increasingly important topic across North American cities. Cities have been exploring and implementing new programs to better understand curb usage and to manage curb space in ways that address the rapidly growing demand for space from all modes. These initiatives are driven by several trends and factors, including:

Demand: Companies like Amazon, Uber Eats, and Grubhub have shaped consumer expectations for faster and more flexible delivery of products, meals, and other goods. Consequently, evolving consumer habits are fueling demand for innovative delivery models.

Supply: The availability of curbside space, particularly in dense urban centers, is limited. Depending on the location, this valuable resource may be in demand for various uses such as parking, driving lanes, bike lanes, public transit, freight unloading, pick-up/drop-off zones, expanded sidewalks, or lively public or private spaces like restaurant patios.

Technology: Technological innovations, both on the ground (e.g., new types of delivery vehicles) and virtually (e.g., mobile applications) are creating opportunities and challenges that have not traditionally been considered by urban and transportation planners.

Planning priorities: As planning priorities evolve, a greater focus is being placed on transit and cycling in many cities, diverging from the traditional emphasis on car travel. Concepts like "complete streets" prioritize increased safety and mobility for a diverse range of users, although the movement of goods can sometimes be overlooked.

B. Curbside Management Best Practices

Curbside management, including to better accommodate goods deliveries, is an increasingly important theme throughout North American cities. Cities have been exploring and implementing new programs to better understand the usage of the curb and to manage curb space in a time of growing demand from all modes. The following section describes Minneapolis' curbside management-related program. Appendix J details the review of other cities' curbside management practices.

1. Minneapolis curbside management practices

a. Background and context

Minneapolis is the largest city in Minnesota and is situated within Hennepin County, the most populous county in the Twin Cities metropolitan area. Minneapolis recently was the successful recipient of a US Department of Transportation (USDOT) grant under the SMART (Strengthening Mobility and Revolutionizing Transport) grants program, valued at $1.98M, for an open data approach to curbside management. This project was one of about 50 selected nationwide in 2022 and the only one in Minnesota.[26]

b. Priorities and objectives

Met Council requires cities, counties, and townships to undertake a comprehensive plan. The most recent plan for Minneapolis is called Minneapolis 2040.[27] As one of its plan policies, Minneapolis highlights the importance of "safe, efficient, and reliable movement of freight to a healthy local and regional economy". The Plan calls out the need to adapt to the changing needs of freight, e-commerce, and urban logistics as one of its Action Steps. In addition, Minneapolis 2040 calls for the adaptation of urban-centered freight innovation and technology, both for shipment into Minneapolis and last-mile distribution. The Plan also encourages "smaller delivery vehicles that are more compatible with an urban environment, centralized drop-off and pick-up zones, and other innovations that make freight delivery more convenient for the customer with less of an impact on the transportation network".

The Minneapolis Transportation Action Plan[28] (TAP) also highlights several strategies related to curbside management for freight deliveries:

- Utilize land-use tools to improve the efficiency of deliveries.
- Improve the safety and efficiency of freight movements and integrate freight into the Complete Streets framework.
- Implement dynamic freight loading zones into citywide curbside management efforts.
- Regulate new delivery technologies that use the public right of way.

Discussions with representatives of Minneapolis's Street Operations arm of the Public Works Department revealed that some of the city's challenges in implementing some of the action items laid out under these strategies, in part due to the tendency for curb access for commercial vehicles to be overlooked.

The City's Vision Zero and Street Design Guide have been primarily developed to prioritize modes of transportation other than freight, essentially reducing the availability of short-term stopping zones. This has resulted in issues such as illegal stopping and loading in bus or bike lanes, complicating the situation further. Moreover, the City's enforcement capability is limited by current technology, making it challenging to prevent such infractions on a larger scale. The City representative is hopeful, however, that a formal curb policy based off of the City's TAP and comprehensive plan will begin development later in 2023 to better address these challenges.

c. Initiatives and findings

Commercial loading zone program. The City of Minneapolis has established commercial vehicle loading zones which can be used by authorized commercial vehicles. Trucks must either be registered with the State or through a special program with the City (e.g. for certain personal vehicles also used for business). Registered vehicles can park for 30 minutes during the time the loading zone is in effect (Figure 28).

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[26] More information about grant recipients under the SMART program is available here, from USDOT: https://www.transportation.gov/sites/dot.gov/files/2023-03/FY22%20SMART%20Project%20List.pdf . Accessed June 2023.
[27] For more information on Minneapolis 2040 see: https://minneapolis2040.com/
[28] City of Minneapolis Transportation Action Plan Freight Strategies and Actions. December 4, 2020. https://go.minneapolismn.gov/application/files/3016/0753/2048/TAP_Final_FREIGHT.pdf. Accessed June 2023.

Figure 28: Minneapolis Commercial Loading Zone Sign

Source: City of Minneapolis. Loading and limited-time curb zones. 2023.

Outside of the signed times, any vehicles can use these spaces. In addition, the City has a unique provision whereby commercial vehicles can use any metered parking space for free for loading or unloading, before noon. Overall, there are few or no instances where commercial vehicles pay for curb space. In addition, Minneapolis has a network of alleys that are limited-use streets that provide property access and serve as primary locations for freight loading.

Audit of loading zones. The City has made substantial progress in mapping loading zones. Traditionally, loading zones had been established at the request of businesses, in some cases paid and in other cases for free. However, over time there was no single record of these spaces, outside of paid ones that were billed to businesses. The City moved to build up a geospatial database in house containing the full inventory street-by-street; the effort is ongoing. There are around 400 to 500 such zones in the city for commercial vehicles and other uses such as valet.

SMART grant for curbside management. The objectives of the project are: "Develop a collection of multifaceted, open-source application programming interfaces to communicate Minneapolis' policies and regulations, real-time changes to curb usage, and provide a historical view of curb usage, impacts, and efficiencies." [29] The project is focused on Nicollet Avenue in an area known as "Eat Street" due to the concentration of restaurants. There are four major components of the project: 1) stakeholder outreach to users of the corridor; 2) data collection to understand usage; 3) analysis of the data; and 4) developing an API to enable open access. The key metrics that will be assessed include the types of vehicles using the space, activities performed, dwell time, and peak demand times. It is hoped that this will provide insights that will also be applicable more widely in the City. The SMART grant is awaiting formal execution as of the time of writing.

d. Takeaways and lessons learned

Need for prioritization. Minneapolis's primary last-mile concern is the competing uses for curbside space and policy dilemmas related to prioritization. Currently, Minneapolis has street design guidelines that have considerations for freight and other curbside uses. However, there is presently no policy that specifically regulates curbside uses. As a result, prioritization is effectively done using high-level guidelines which can result in issues such as spaces for temporary stopping activities being excluded in street redesign projects. Consequently, commercial stopping and loading activity are increasingly taking place in non-authorized locations (e.g., including newly built bike lanes and dedicated bus lanes) thereby blocking traffic and increasing the likelihood of crashes. The City has limited ability to enforce such violations and these conflicts also impede the efficient delivery of

[29] Strengthening Mobility and Revolutionizing Transportation (SMART) Grants Program, Fiscal Year 2022 Planning and Prototyping Grants by State, 2023. https://www.transportation.gov/sites/dot.gov/files/2023-03/FY22%20SMART%20Project%20List.pdf. Accessed June 2023.

goods. The City is interested in best practices for prioritization of curbside uses and approaches to integrating freight needs.

Data collection mechanisms. The City is considering its options for data collection mechanisms. There are a variety of options such as cameras, sensors, location-tracking, or digital permits. One challenge is that in Minnesota, license plate recognition tools are permitted only for criminal enforcement matters; this limits the types of technology that can be used. The City is interested in understanding other cities' approaches to data and technology.

Other. The City is also interested in understanding other emerging technologies for last-mile deliveries. There was a planned cargo bike delivery pilot program, but this is not active now.

e. References and resources

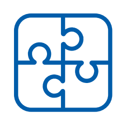
- Strengthening Mobility and Revolutionizing Transportation (SMART) Grants Program, and FY 22 awards
- Minneapolis 2019 Comprehensive Plan: Minneapolis 2040[30]

The Twin Cities can refer to the many ongoing curbside management programs and initiatives in other cities across the continent, for examples and best practice guidance. This study's review of curbside management practices focused on programs or policies that address commercial vehicles and urban freight issues in particular. The methodology applied consisted of identifying key criteria for the review, developing a long list of cities and programs, and selecting prioritizing cities for reviews. Three cities were selected for interviews with key planning staff, while an additional nine cities (covering 13 programs) were selected for further online research. The results of this analysis are presented in Appendix J.

2. Key findings from best practices review

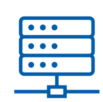
A review of the local agency curbside management policies and programs sheds light on important considerations for cities to consider when developing new policies or programs (Appendix J). These key findings underline the importance of a comprehensive and innovative approach and the need for local jurisdictions to continuously update their curbside management policies and strategies based on current data and evolving circumstances.

Holistic approach



Successful curbside management requires a holistic approach, considering various stakeholders and multiple planning tools. Bellevue's multi-strategy approach is a good example, where they mapped curb usage and tested monitoring technology solutions to inform the development of a new curb management plan. This detailed plan contains a Curb Practices Guide, a curb typology framework, and a curb pricing framework and identifies six pilot projects to test and refine the potential curb management practices.

Importance of data



Data are crucial in effective curbside management programs. Several cities, including Seattle, New York, and more recently Minneapolis, have created and continued maintaining updated curb allocation datasets, mapping different typologies for curb allocations and their respective regulations, often making this data layer available through open-data portals and public APIs. However, fewer cities have established programs to monitor curb use, therefore not only recording where certain curb zones are but also documenting how different curb zones are used. Bellevue ran a pilot program aimed at testing different video technologies for curb-use monitoring. Curb use data not only inform cities on curb demand but also enable several policies,

[30] City of Minneapolis. Welcome to Minneapolis 2040. The City's Comprehensive Plan. https://minneapolis2040.com/. Accessed June 2023.

such as pricing and enforcement. Oakland’s smart loading zone permit program relies on GPS data to bill vehicle owners based on their parking duration.

Collaboration and engagement

Businesses and residents are the final users of the public right-of-way. Therefore, establishing public-private partnerships and community involvement can foster innovation, facilitate the execution of pilot programs, and inform cities about the effectiveness of different curb management strategies. For instance, Santa Monica's Zero Emission Delivery Zone was a result of a partnership between LA Cleantech Incubator and the City. The program incentivized the use of clean and electric delivery vehicles and tested the efficacy of such an approach. Bellevue's strategy in drafting its new curb management plan also highlighted the importance of involving the local community and curb management experts in the decision-making process. During the development of regional and local transportation plans, from street/corridor level plans to city/county/MPO-level plans, incorporating the engagement with local businesses and freight delivery companies can also bring a localized understanding of the unique challenges businesses face.

Role and risks of technology

Technology plays a critical role in modern curbside management. From video-based curbside monitoring in Bellevue to in-ground sensors in Seattle, and automated license plate recognition devices in Washington DC, technology has been instrumental in monitoring and regulating curb use. While technological innovations can provide solutions, cities must also be mindful of the potential risks and challenges related to data sharing, privacy, and dependence on private operators.

Value of pilot programs and evaluations

Pilot programs can serve not only as practical testing grounds for new initiatives and technologies but also as a means to collaborate with private stakeholders in the curb management process. The findings can guide the expansion or modification of the program. In addition, when implementing new technologies or strategies, a rigorous evaluation process is crucial. Bellevue's curbside technology assessment pilot tested the accuracy and scalability of different technology solutions, which is a crucial step before widespread implementation.

Incentives and policy alignment

Incentives can play a key role in encouraging specific behaviors. Santa Monica's initiative of offering priority curb space to zero-emission vehicles illustrates the potential of such incentives. Furthermore, ensuring alignment between various policies and objectives is also crucial, as seen in Edmonton's initiative to revise parking policies to better align with curbside management goals.

Flexibility and adaptability

Cities have shown that flexibility and adaptability are keys to curbside management. Curbside management strategies that are more suitable in dense/urban settings may include:

- Demand-responsive pricing: In high-demand areas, dynamic pricing for curb space can help balance supply and demand, encouraging turnover and reducing cruising for parking. Prices can be adjusted based on the time of day, day of the week, or occupancy rates.
- Multi-modal loading zones: In dense urban environments with diverse transportation needs, flexible loading zones can accommodate different vehicle types – from delivery trucks to passenger vehicles to ride-hails.

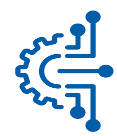
- Time-restricted loading/unloading: To manage peak demand, cities can implement time restrictions for loading/unloading. For example, they could prohibit or limit curbside loading during rush hour in congested areas.
- Delivery hubs: For densely populated urban areas, creating designated delivery hubs can consolidate delivery activity, reducing congestion and emissions from freight traffic.
- Curbside management strategies that are more suitable in less dense/suburban settings may include:
- Shared parking districts: Shared parking strategies can maximize the use of available parking resources in suburban areas. Underutilized parking spaces, such as those at offices, churches, or schools, can be shared with nearby businesses or residences.
- Flexible parking regulations: Due to less demand pressure, suburban areas can afford more flexibility in parking regulations, such as longer parking durations or lower fees.

C. Last-Mile Delivery Technology Review

There has been significant development in last-mile delivery technologies in recent years. This analysis provides a summary of research findings on these new or emerging technologies, with a special focus on the impact on reducing VMT and overall emission of CO2 and other greenhouse gases as well as the extent to which the benefits of these technologies vary in different urban settings (that is, urban centers versus suburban or exurban communities). The full review is included as Appendix K. Key findings from the review of last-mile delivery technologies and applications are detailed below.

1. Key findings

- **Some technologies are more mature than others**

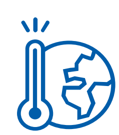


Technologies like electric delivery vehicles and cargo e-bikes are relatively mature with significant improvements in speed, battery life, and adoption rates over the past decade. More nascent technologies such as air-based drones, sidewalk delivery robots, and autonomous delivery vans are in the early stages of development, undergoing pilot testing or prototyping, and facing regulatory and infrastructural challenges. For example, staff who participated in Kiwibot's test operation in partnership with the Knight Autonomous Vehicle Initiative concluded that more piloting of sidewalk delivery robots is needed before they are further deployed on city streets. Also, they require a street permit in many municipalities.

- **Last-mile delivery technologies have implications for land and curb access**

Electric delivery vans, in addition to requiring traditional curb access, also necessitate charging infrastructure at least at their origin. Cargo e-bikes and e-scooters rely on well-developed bicycle and pedestrian infrastructure networks, as well as convenient access to the curb and potential package consolidation or pickup stations. The smaller carrying capacity of cargo e-bikes and e-scooters and their shorter operation distance would necessitate more frequent stations or consolidation facilities along urban delivery routes to restock or offload packages. Autonomous delivery vehicles also require curb access and designated loading zones to facilitate their operations effectively.

- **Alternative fuel vehicles may hold the highest promise for GHG emission reduction**



The key advantages of alternative fuel delivery vehicles, particularly hydrogen fueled vehicles, are their potential to yield the biggest reduction in GHG emissions. A comprehensive "well-to-wheels" assessment of global warming emissions reveals that current hydrogen-powered fuel cell electric vehicles, even when deriving their hydrogen from natural gas, achieve a reduction in emissions of over 30% in comparison to traditional gasoline vehicles. [31]In regions like California, where there are stringent requirements for renewable hydrogen, this reduction exceeds 50%. As technologies evolve, it's anticipated that future fuel cell electric vehicles will offer even greater environmental benefits.

- **Suitability for urban versus suburban settings**

Most technologies discussed are more suited to urban settings due to higher demand density and shorter delivery distances. These include e-carts, cargo e-bikes, e-scooters, and sidewalk delivery robots. Technologies like autonomous delivery vans and electric delivery vehicles, given their larger capacities and longer ranges, are well suited to serve suburban and rural communities in addition to serving more densely developed urban areas.

Air-based drones have the potential for both urban and suburban settings as well, depending on regulatory acceptance and infrastructure. In suburban settings, drones can be highly effective due to the larger distances between homes and businesses and the often more challenging terrain and less dense roadway networks. Suburban areas typically have less air traffic and fewer physical obstructions such as tall buildings, which make navigation easier for drones. By comparison, urban areas present unique challenges but also significant opportunities for drone deliveries. Higher development densities can pose navigational challenges and may increase the risk of accidents like collision with infrastructure or mechanical navigational errors. However, the high demand and frequency of deliveries in high-density urban areas, as well as the potential to bypass heavy traffic congestion, make air-based drones potentially a highly efficient mode for small parcel deliveries.

2. Lessons learned for piloting new last-mile delivery technologies

The Knight Autonomous Vehicle (AV) Initiative's pilot of sidewalk delivery robots in Pittsburgh, Miami-Dade County, Detroit, and San Jose[32] has provided valuable lessons that can be applied to other test operations of last-mile delivery technologies:

- **Engage community members before deploying the technology**

Community involvement and acceptance are crucial for the successful integration of new last-mile delivery technologies. Organizing events, information sharing and demonstration sessions. and public engagement initiatives can help familiarize community members with the technology, address their concerns, and build trust.

- **Start with low-stake deliveries**

Pilot programs should initially start with delivering low-stake delivery items to test the system effectively. Opt-in models, where the recipient isn't reliant on the promptness and success of essential service deliveries, represent a responsible approach to introducing these technologies in their current developmental phase.

- **Choose the right partners**

Collaborating with the appropriate technology providers and local businesses is essential for achieving success in pilot programs. Selecting partners who have expertise in the specific technology being tested and establishing strong partnerships with local businesses that can benefit from the last-mile delivery solution are critical factors for a well-rounded pilot program.

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[31] Union of Concerned Scientist. How Clean Are Hydrogen Fuel Cell Electric Vehicle? https://www.ucsusa.org/sites/default/files/attach/2014/10/How-Clean-Are-Hydrogen-Fuel-Cells-Fact-Sheet.pdf. 2014. Accessed September 2023.

[32] Amanda Howell, Becky Steckler, Nico Larco, Urbanism Next Center, Knight Foundation, Piloting Sidewalk Delivery Robots in Pittsburgh, Miami-Dade county, Detroit, and San Jose, 2022, https://global-uploads.webflow.com/5d9f83b8b237fa6c07d5d69d/6310e6536ecf171b2d44871b_Knight%20AV%20Initiative%20PDD%20Report%20Final_Aug%202022.pdf. Accessed June 2023.

- **Test in controlled environments before large-scale implementation**

If deploying testing pilots, cities benefit from starting from controlled built environment to allow the technology partners to resolve technical issues, like navigating challenging terrains, including wide intersections or poor sidewalk conditions. This also allows for monitoring, evaluation, and the ability to adapt the pilot program based on the insights gained.

D. Policy Considerations on Curbside Management and New Technologies

Regional policy considerations cover three themes: 1) preparing for the future, 2) promoting efficient curbside use, and 3) leveraging new technology. More information on some of the examples is available within the body of the full sub-report for Part III (insert link to Part III report).

These findings can inform the Met Council as it updates its foundational transportation and land use plans in line with its broader policy objectives. Because of how complex and context-specific curbside issues and solutions can be, it is the local governments that are typically at the front lines of planning and implementation. The policy suggestions are therefore intended to have a regional focus with broad applicability throughout the region, rather than tailored to specific government agencies or contexts.

1. Theme 1: Preparing for the growing demand for e-commerce deliveries

- **Promote the establishment of curbside use inventories**. A basic inventory includes a geocoded shapefile or digital repository of road segments that provides information on the nature of any locational rules or restrictions on curbside use such as signed or permitted areas.

  Example from Minneapolis: Loading zones in Minneapolis used to be established primarily upon requests by businesses, sometimes involving a fee, and in other instances being provided free of charge. The city has significantly advanced in systematically cataloging loading zones through the development of a comprehensive geospatial database that details the entirety of these zones on a street-by-street basis, an effort that is still ongoing.

- **Promote data collection and sharing on curb usage**. Local agencies in the region can leverage new technologies for the collection of data on curb usage and share any findings or strategies to begin building a local knowledge base.

  Example from Minneapolis: Minneapolis recently was the successful recipient of a US Department of Transportation (USDOT) grant under the SMART (Strengthening Mobility and Revolutionizing Transport) program for an open data approach to curbside management. The project will allow Minneapolis to develop a collection of multifaceted, open-source APIs to communicate the City's policies and regulations, document real-time changes to curb usage, and provide a historical view of curb usage, impacts, and efficiencies. This program could provide valuable insight for local communities that are interested in curbside management initiatives.

- **Facilitate industry engagement and coordination**. Harnessing industry perspectives in resolving curbside challenges can be valuable, as these stakeholders are on the front lines operationally and often bring a pragmatic perspective.

  Example from New York City: As part of the city's commercial loading zone expansion efforts, the City DOT's Freight Mobility Unit uses a public outreach and survey team to gauge the need among business owners for Commercial Vehicle Loading Zones (CVLZs) and traffic management. Regular surveys and an online feedback form allow couriers and business owners to request additional CVLZs, as well as changes to loading/unloading policies in their neighborhoods. New York City can use these responses to inform neighborhood or street-by-street prioritization for expanding commercial parking and mitigating public concerns.

- **Prepare organizationally by assigning freight leads**. Large cities or counties can designate individuals or teams to be responsible for important freight issues, such as curbside deliveries. Smaller agencies can ensure that freight planning is noted as an assigned area of responsibility.
- **Monitor key trends and developments over time**. This includes tracking national-level e-commerce trends, staying up to date on the results of studies and programs in other cities nationwide, following relevant developments across the region, and tracking changes at a local level. Coordinating and sharing these types of information can help to support adaptable and pragmatic policies.

2. Theme 2: Ensuring efficient use of curbside space

- **Promote smart prioritization of curbside space**. Good prioritization combines a grounding in policy priorities with solid information on supply, demand, and usage needs. Effective prioritization is also tailored to the local context, such as having different typologies (with different prioritization hierarchies) for different types of roads and neighborhoods.

Example from Seattle: Seattle developed a Curbside Prioritization Framework that is based on surrounding land use (residential, commercial and mixed-use, and industrial), for six major function categories, including access for commerce, access for people, mobility, activating vibrant social spaces, greening, and storage. Curb access for commercial purposes is ranked in the top-3 for all three land use types.

- **Properly prioritize truck loading and unloading spaces**. Allocating sufficient space for loading and unloading activities is particularly important in space-constrained areas where freight receivers do not have dedicated off-road space such as a driveway or loading dock. Good solutions can be quite pragmatic and location-specific, taking account of the particular shipping and receiving needs of businesses and the availability of unloading space both on the curbside and elsewhere in the vicinity (for example, alleyways, shared off-street areas).

Example from Seattle: Seattle has a dedicated curbside management team which supports the City’s planning processes and street redesigns, including with analysis and outreach. For transportation and roadway projects over $500,000, the City DOT employs a checklist to incorporate considerations for commercial curb access.

- **Ensure delivery needs are integrated into complete streets**. Wholistic designs that accommodate both delivery vehicles and cyclists/pedestrians are mutually beneficial, whereas suboptimal designs can exacerbate conflicts, such as unloading trucks blocking bike or bus lanes, or trucks circling the block to find parking (with more turning movements across bike lanes and crosswalks).

Example from New York: The Complete Streets Considerations for Freight and Emergency Vehicles Guidebook developed for the New York State Energy Research and Development Authority identifies design, regulatory, and operational strategies to address common challenges that freight operators face on compact, mixed-use streets.

- **Consider opportunities to monetize the curbside to promote efficient use**. Truck deliveries are usually efficient uses of the curbside, compared to private automobiles which may park for a longer duration and/or have more flexibility in where to park. Pricing can be done at a block-by-block level to target a certain level of utilization, such as 70% usage.

Example from Seattle: Seattle Department of Transportation collected data on curb use at selected curbside segments to train a mathematical model estimating curb occupancies from historical parking transactions, and partnered with the University of Washington Urban Freight Lab to study commercial vehicle parking behavior in the city. This information is used to inform pricing and determine how much curb space should be dedicated to commercial vehicles.

- **Encourage flexible and creative solutions for loading and unloading**. Flexible and creative solutions can include time-of-day allocation of uses, and new types of loading zones tailored to emerging uses (such as short-duration zones for pickup of food deliveries or parcels by customers or last-mile delivery companies).

Example from Philadelphia: Philadelphia implemented a six-month pilot that established 21 Smart Loading Zones in the city center. Delivery drivers download the Pebble Driver App that maps the available Smart Load Zones, allows for reservations, gives directions to the zone, and accepts a preferred payment method based on the length of visit.

3. Theme 3: Promoting new technologies to fulfill regional objectives

- **Facilitate private-sector trials and pilot projects**. Pilot projects and trials are an important first step to establishing technical, operational, and commercial viability. This can include both delivery technologies themselves, as well as data-gathering technologies such as sensors.

Example from Bellevue: With funds from a T4A grant in 2019, Bellevue conducted a pilot study to test the accuracy of video-based curbside monitoring technology solutions and identify a scalable system that could detect high-volume curb areas accurately for future enforcement and payment. Five technology vendors were selected, each deployed its technology and shared data with the City, and its performance was evaluated.

- **Pursue joint pilot programs with partners**. Pilot projects in coordination with public agencies, private stakeholders, and the academic community can be a valuable approach for testing new technologies and models, collecting data, and leveraging the diverse strengths of different partners.

Example from The Knight Autonomous Vehicle (AV) Initiative. The initiative is a multi-year collaborative effort between the Urbanism Next Center at the University of Oregon, Cityfi, the cities of Detroit, Pittsburgh, and San José, and Miami-Dade County (the “cohort”). The initiative recently tested sidewalk delivery robots in partnership with Kiwibot for food and goods delivery from local restaurants and stores to residents who chose to participate. This collective effort allowed participating municipalities to share findings from deployment in each unique setting and make shared requests of the private partner that might not have been possible individually.

Appendix A Regional E-Commerce and Personal Shopping Insights

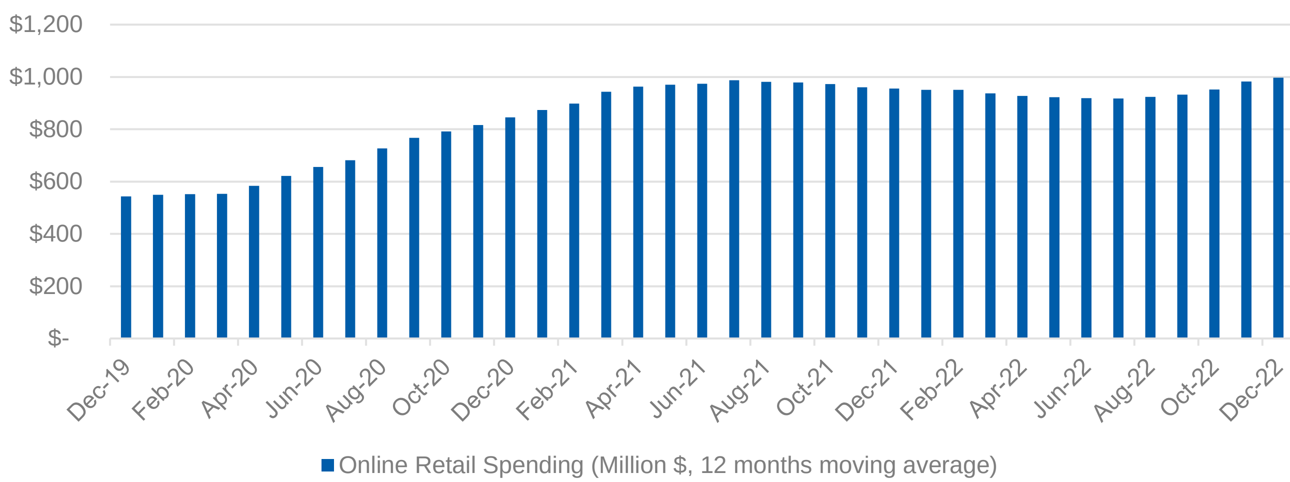
A. Regional E-Commerce Trends

1. Regional trends in e-commerce activity, from Replica

The US Census Bureau's e-commerce data are provided at a national level, but not a subregional level. Using other data sources, including online spending transaction data provided by Replica, it is possible to develop an understanding of finer patterns in the Twin Cities metropolitan area.

Based on online spending transaction data provided by Replica, in 2022, the seven-county Minneapolis-St. Paul region saw consumers spend approximately $11.97 billion on online retail (Figure 29). Online retail spending in the region experienced an 84% growth since 2019, outpacing the 79% growth observed in the State of Minnesota during the same timeframe.

Figure 29: Online retail spending trend, 2019-2022

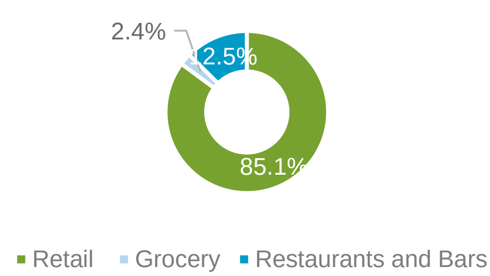


Source: CPCS analysis of Replica data, 2023

Figure 30 shows in 2022, around 85% of online spending in the region is general retail while grocery and restaurant/bars online spending account for 2.4% and 12.5%, respectively.

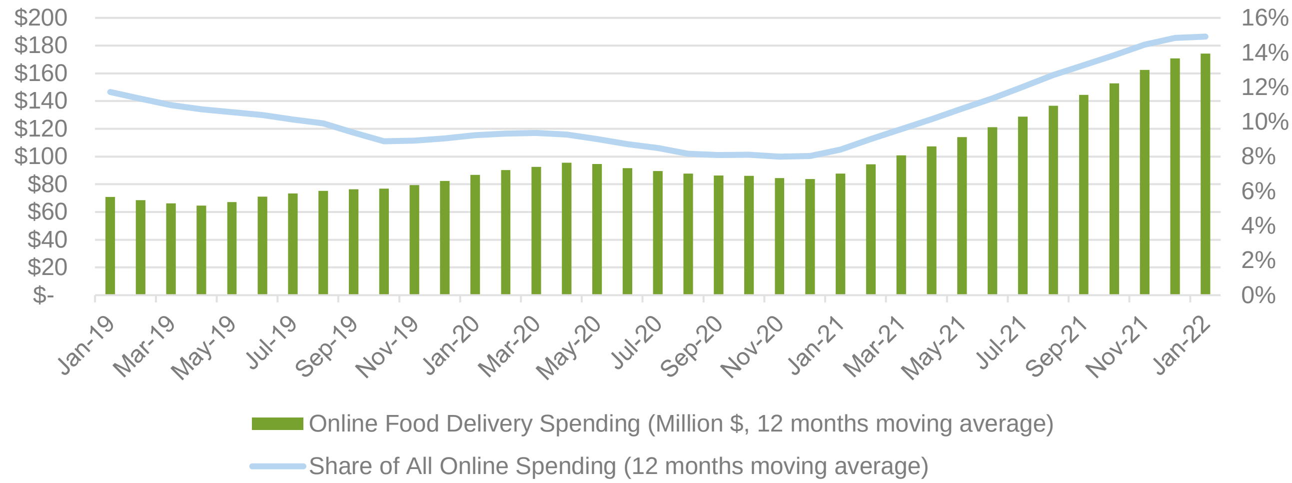
While only accounting for around 15% of all online spending, online grocery and restaurant delivery expenditures have also seen a notable rise during the same period. In 2022, consumers in the region spent more than 2.1 billion dollars on online food delivery, more than doubling the amount spent in 2019 (Figure 31).

Figure 30: Online spending share by category, 2022



Source: CPCS analysis of Replica data, 2023

Figure 31: Online food delivery spending trend, 2019-2022



Source: CPCS analysis of Replica data, 2023

Replica's Online Spending Data

Replica provides data about the built environment and how people interact with it. Among the datasets offered by Replica is the Trends dataset, which captures consumer spending information. This dataset encompasses data from all types of transactions made at points of sale, including those via credit cards, debit cards, and cash, across diverse venues like retail outlets, supermarkets, dining establishments, taxis, and bars.

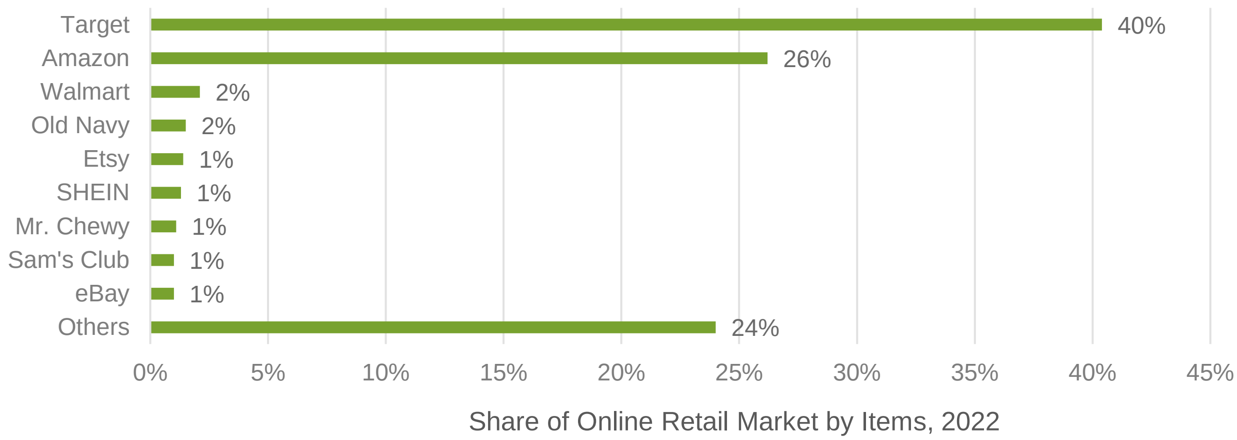
The platform delineates consumer expenditure both online and offline at the census tract level. It mainly covers three categories: dining and bars (accounting for online food delivery services like Door Dash or Uber Eats), grocery shopping, and general retail. The expenditure recorded is attributed to the location where the goods or services are delivered and where the sales tax is applicable. It's important to note that the data excludes certain household expenses, such as rent, car payments, and healthcare costs. Replica calibrates its consumer spending figures with the Census Bureau's Monthly Retail Trade Estimates.

2. E commerce retailer market shares, from NielsenIQ data

In the competitive landscape of e-commerce in the United States, leading retailers like Amazon, Walmart, Apple, eBay, and Target collectively command over half of the market share.[33] In the Twin Cities region, Amazon and Target emerge as the primary online retailers in terms of the volume of items ordered, followed by other key players such as Walmart, Old Navy, Etsy, and eBay (Figure 32). This ranking is derived from the latest NielsenIQ e-commerce shipping insights data.

[33] Market share of leading retail e-commerce companies in the United States as of June 2022, Statista, June 2022. https://www.statista.com/statistics/274255/market-share-of-the-leading-retailers-in-us-e-commerce/, accessed on November 2, 2023.

Figure 32: E-commerce retailer market shares in Twin Cities region (by number of items ordered online)



Source: CPCS analysis of Nielsen IQ data, 2023[34]

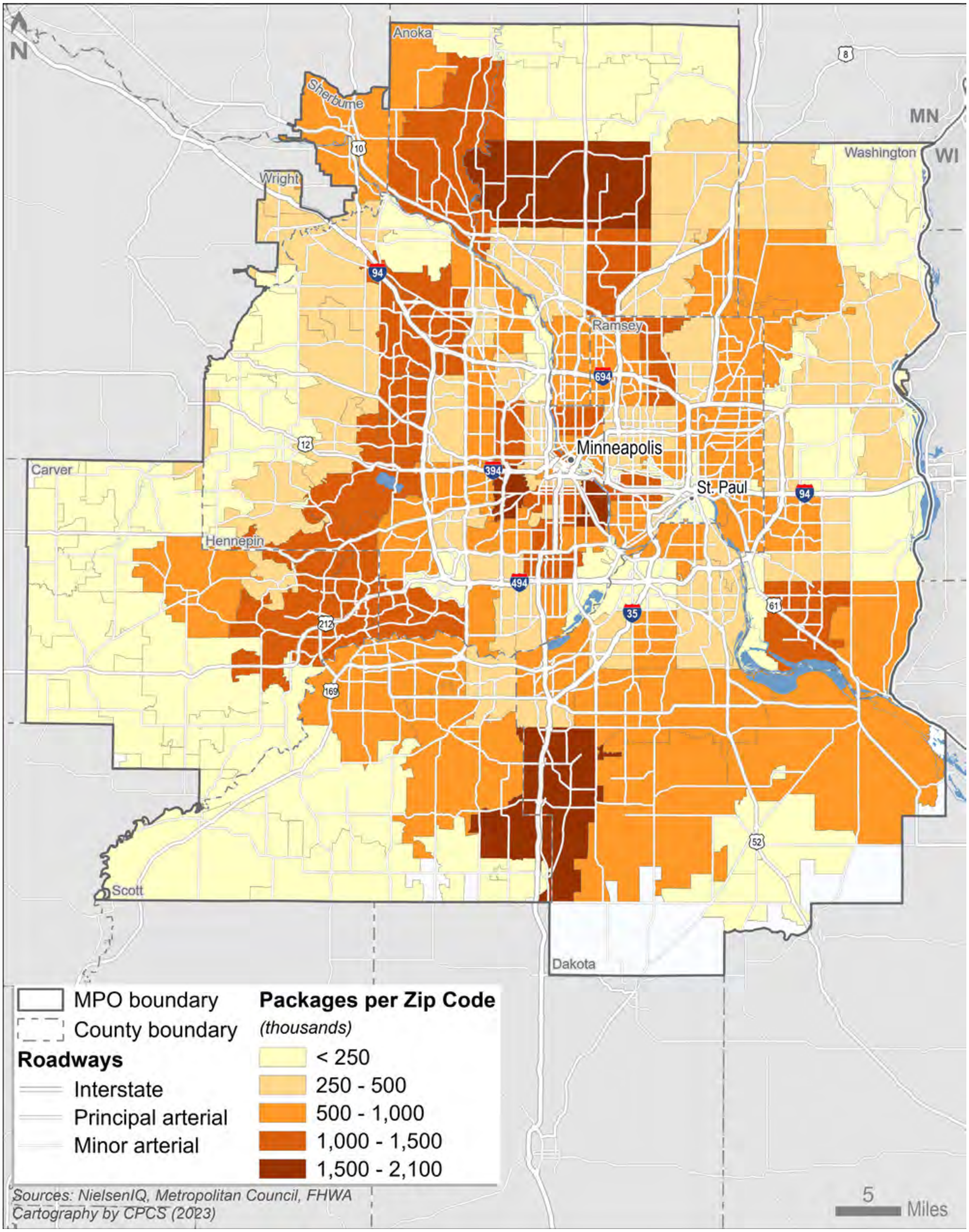
Given that Minneapolis is the home base for Target, it is not surprising to see Target leading in the quantity of online order fulfillments. Interestingly, a significant proportion of Target's online orders are categorized as "click-and-collect," where customers opt to pick up their purchases in-store. This trend highlights a hybrid shopping model that combines the convenience of online shopping with the immediacy of physical retail.

For items that are not part of the "click-and-collect" system but rather delivered directly to consumers, Amazon maintains a strong lead. The company accounts for over 51% of delivered items, with its packages typically containing an average of one item each.

Based on NielsenIQ data, Figure 33 shows the distribution of packages by zip code. Notably, the data do not appear to show a particular geographic bent, in terms of a more urban or suburban orientation.

[34] This is based on shipping records weighted by the buyers' demographic characteristics within the study area.

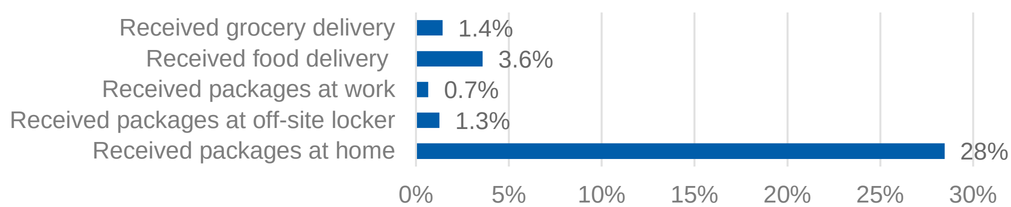
Figure 33: E-commerce packages received in the study area



3. Receipt of e-commerce packages, from Travel Behavior Inventory

Another perspective is offered by Met Council's TBI in the context of personal shopping trips. This survey of the population includes a question asking respondents about the frequency with which certain activities occur on a given day (see Figure 34). Of note, 28% of respondents reported receiving a package at home on the given survey day. Receiving packages at work or in an off-site locker was relatively less popular. Also, 1.4% of respondents reported receiving a grocery delivery and 3.6% reported receiving a food (e.g. meal) delivery on a given day.

Figure 34: Percentage of study area residents receiving deliveries



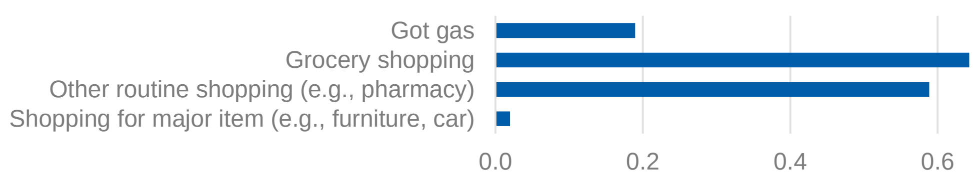
Source: CPCS analysis of 2021 TBI. Note: weighted, excludes survey responses where no selection indicated (Yes or No)

B. Regional shopping trends

1. In-person shopping trips, from Travel Behavior Inventory

The TBI includes trips to purchase gas within the shopping category, but these can be considered somewhat different in their nature. As e-commerce would not be considered a substitute, the analysis in this study excludes buying gasoline as a shopping trip.

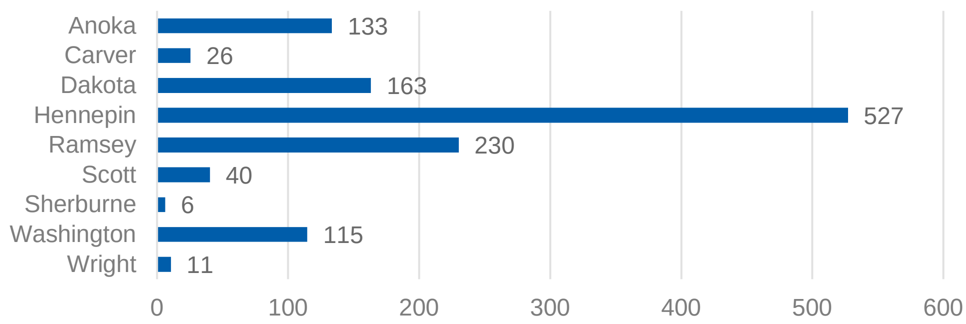
Figure 35: Breakdown of daily shopping trips within study area By trip purpose (millions, 2021)



Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area; trip purpose at destination

A geographic breakdown reveals that Hennepin County generates the most shopping trips of all counties, at about 527,000 per day (based on the origin of the shopping trip). This is followed by Ramsey, Dakota, and Anoka counties. Figure 36 shows the number of daily shopping trips originating in each county within the study area. Note that the analysis is based on trip origin, hence both household location and other factors (such as location of workplace or other frequented sites) can influence the trip origin.

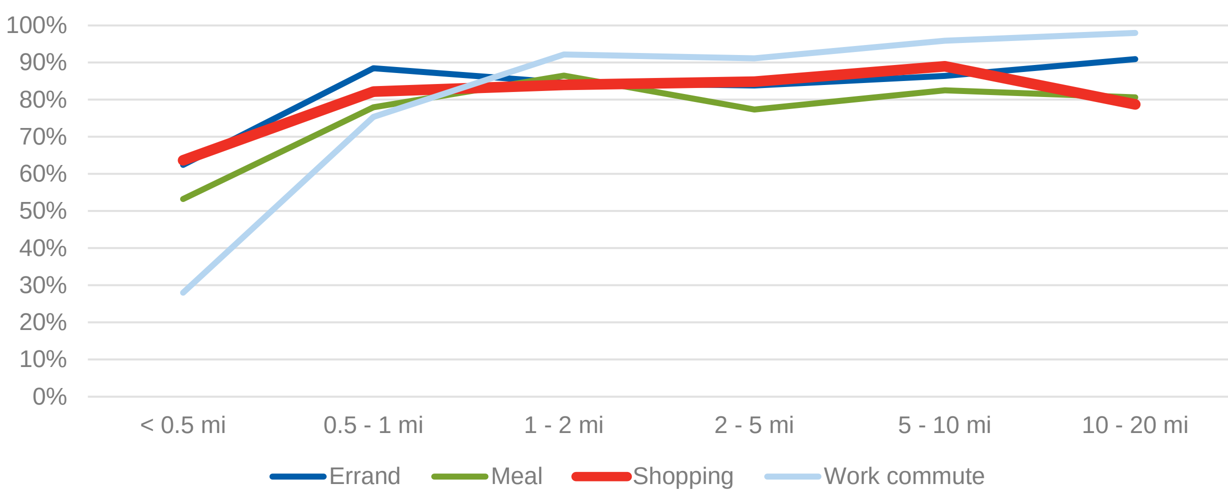
Figure 36: Daily shopping trips within study area, by origin county (thousands, 2021)



Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area. Shopping excludes gas. Only the portions of Sherburne and Wright counties that are within the study area (MPO area) are included. The other seven counties are within the study area in their entirety. Note that the analysis is based on trip origin (not necessarily the location where the trip maker lives).

In terms of mode share, the high dependence on personal automobiles for shopping trips is illustrated in Figure 37, which supplements the charts shown in the main body of the report. This figure shows the auto driver mode share (percentage of total trips that are made by the driver of a personal vehicle) for various common trip purposes, and across various distance "buckets." Notably, even for very short shopping trips, many of these trips tend to be made using a private car. This is not unexpected, as a car provides storage space that may be important for many shopping trips. Therefore, if some personal shopping activity can be diverted (such as through e-commerce), there may be the opportunity to reduce regional VMT.

Figure 37: Auto driver mode share, by trip distance and trip purpose (2021)



Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area; based on trip purpose of destination. Shopping excludes gas. Note that the chart shows "auto driver" mode share, which is associated with VMT. For longer-distance trips, most remaining trips are "auto passenger" (which do not add to VMT). For shorter trips, walking/cycling are also significant.

As relates to trip length, Figure 38 summarizes some relevant statistics for shopping trips in the study area. Notably, the longest shopping trips have a disproportionate impact on VMT. Specifically, trips over 10 miles in length (one-way) constitute only 10% of shopping trips, but comprise 50% of the regional VMT.

Figure 38: Selected trip statistics for shopping trips (2021)

Trip Distance Band	Share of all Shopping Trips	% of Shopping Trips by Auto Driver	Avg. Shopping Trip Distance (mi) (auto driver)	Distribution of Shopping Trips (auto driver)	Distribution of Shopping VMT (auto driver)
< 0.5 mi	16%	64%	0.3	13%	1%
0.5 – 1 mi	13%	82%	0.7	13%	2%
1 – 2 mi	18%	84%	1.4	19%	5%
2 – 5 mi	28%	85%	3.3	28%	19%
5 – 10 mi	14%	89%	7.1	16%	23%
10 – 20 mi	7%	79%	13.7	7%	20%
20+ mi	3%	91%	40.2	4%	30%
All distances	**100%**	**81%**	**4.9**	**100%**	**100%**

Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area; based on trip purpose of destination. Shopping excludes gas.

Appendix B Notable initiatives by Major Parcel Delivery Providers

A. FedEx

FedEx is undertaking a major reconfiguration of its network operations by combining FedEx Express and FedEx Ground, which presently function as separate operating divisions. The phased transition is expected to be complete by June 2024, according to press releases.[35] At present, FedEx Express delivers time-sensitive packages via its own employees, a service that is oriented around FedEx's air transportation network. In comparison, Ground delivers less urgent packages using a trucking-driven model which relies on independent contractors employing their own drivers. One of the implications of this change is likely to be a more rationalized, consolidated network of last-mile deliveries at the urban scale – including in the Twin Cities. This change has the potential to reduce vehicle miles traveled by reducing the presence of duplicate trips on the same day to the same neighborhoods from multiple distribution facilities.

FedEx is also pursuing electrification of its delivery fleet. The company has a target of carbon neutral operations by 2040. This includes the intention to purchase 50% new pickup and delivery vehicles by 2025, and 100% by 2030. By 2040 the entire parcel pickup and delivery fleet is intended to consist of electric vehicles.[36] FedEx has purchased and received its first electric delivery vehicles from BrightDrop, the technology startup from General Motors. [37]

B. UPS

UPS is using technologies like machine learning in an effort to increase its deliveries-per-stop ratio from 1.28 to 1.4. Increasing delivery density – meaning the number of deliveries made on a single route – has benefits both in terms of reducing costs through more efficient use of assets, and in eliminating unnecessary emissions through reduced vehicle miles traveled.[38]

UPS is also pursuing fleet electrification. The company is pursuing carbon neutrality by 2050, including fueling 40% of ground operations with alternative fuels by 2025.[39] UPS has a partnership with the electric vehicle startup Arrival to produce purpose-built delivery vans for UPS, co-developed by the two companies.[40]

C. USPS

The US Postal Service is implementing a significant makeover of its distribution and delivery network, which is currently seen as having non-essential empty miles for trucks and soaring air transportation

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[35] FedEx news release. FedEx announces planned consolidation of operating companies. https://investors.fedex.com/news-and-events/investor-news/investor-news-details/2023/FedEx-Announces-Planned-Consolidation-of-Operating-Companies/default.aspx. Accessed on November 9, 2023.

[36] FedEx news release, Charged up about electric vehicles.https://investors.fedex.com/news-and-events/investor-news/investor-news-details/2023/FedEx-Announces-Planned-Consolidation-of-Operating-Companies/default.aspx. Accessed on November 20, 2023.

[37] FedEx, FedEx Continues Advancing Fleet Electrification Goals with Latest 150 Electric Vehicle Delivery from BrightDrop. https://newsroom.fedex.com/newsroom/global/fedex-continues-advancing-fleet-electrification-goals-with-latest-150-electric-vehicle-delivery-from-brightdrop. June 21, 2022. Accessed on November 20, 2023.

[38] Max Garland, Supply Chain Dive, UPS pursues greater delivery density to reduce emissions, November 1, 2023. https://www.supplychaindive.com/news/ups-delivery-density-emissions-reduction-impact-summit/. Accessed on Nov 2, 2023.

[39] UPS news release. UPS's commitment to a greener planet. Oct 17, 2021.https://about.ups.com/us/en/our-stories/innovation-driven/forest-of-the-future.html. Accessed on Nov 2, 2023.

[40] UPS news release. UPS invests in Arrival, accelerates fleet electrification with a commitment to purchase up to 10,000 electric vehicles. JAN 29, 2020. https://about.ups.com/us/en/newsroom/press-releases/sustainable-services/ups-invests-in-arrival-accelerates-fleet-electrification-with-order-of-10-000-electric-delivery-vehicles.html. Accessed on Nov 2, 2023.

expenditures, as well as inefficient utilization of network facilities. The new network structure will involve 60 regional processing and distribution centers across the country, which will handle both mail and packages. These regional centers will serve as transfer hubs which then serve an overhauled network of local distribution centers from which last-mile delivery will take place.[41]

The USPS is also undertaking a green transition, having received funding from Congress to support its efforts to acquire at least 66,000 battery electric vehicles as part of its 106,000 vehicle acquisition plan for deliveries from 2023 to 2028.The Postal Service is seeking to phase out its aging delivery fleet with a combination of new-generation purpose-built vehicles and off-the-shelf vehicles, and is exploring the feasibility of achieving 100% electrification for the entire delivery vehicle fleet. The Postal Service anticipates that the combination of vehicle mix changes and network modernization efforts will lead to significant carbon reductions in its system.[42]

D. Amazon

Amazon has recently been overhauling its delivery network as well, moving to a regional model with eight more-or-less self-sufficient regions across the country. This means that customers shopping online are likelier to see products that are already stocked within their region of the country. The benefit of this model is faster delivery times for consumers, cost savings for Amazon, and an overall reduction in the total distance that items travel.[43]

Within the Twin Cities specifically, Amazon is opening a new delivery station in Centerville to complement its current delivery stations in Maple Grove and Eagan, and its facility in Brooklyn Park.[44] The new 140,000 SF facility in the Minnesota Technology Corridor will likely serve the northern and eastern part of the metropolitan area *(note: this facility has now opened, after the original date of analysis.)*

New delivery routing algorithms are anticipated to reduce millions of miles driven for Amazon, when deployed across the country. Its Customer Order and Network Density Optimizer (Condor) algorithm works by optimizing shipping options: during the time between when an order is made and when the fulfillment center begins processing the order, the software reevaluates multiple times to see if a more optimal route can be created.[45]

Amazon is electrifying its delivery fleet with electric vans from Rivian. Starting from 2022, and as of October 2023, it has rolled out more than 10,000 electric delivery vans across the US and is targeting 100,000 electric delivery vehicles on the road by 2030.[46]

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[41] Mike O'Brien. Multichannel Merchant. DeJoy details USPS network overhaul. May 25, 2023. https://multichannelmerchant.com/operations/dejoy-details-usps-network-overhaul/. Accessed on Nov 2, 2023.

[42] USPS news release, USPS Intends To Deploy Over 66,000 Electric Vehicles by 2028, Making One of the Largest Electric Vehicle Fleets in the Nation, December 20, 2022. https://about.usps.com/newsroom/national-releases/2022/1220-usps-intends-to-deploy-over-66000-electric-vehicles-by-2028.htm. Accessed on November 9, 2023.

[43] Alarice Rajagopal, Supermarket News, Amazon overhauling network to prioritize inventory near customers. May 16, 2023. https://www.supermarketnews.com/online-retail/amazon-overhauling-network-prioritize-inventory-near-customers. Accessed on November 9, 2023.

[44] MN Tech Corridor, New Amazon facility benefits from MN Tech Corridors' speed-to-market, Jul 28, 2022. https://www.mntechcorridor.com/news/p/item/44849/new-amazon-facility-benefits-from-mn-tech-corridors-speedtomarket. Accessed on November 9, 2023.

[45] Max Garland, Supply Chain Dive, Amazon rolls out delivery route algorithm to reduce miles driven, Aug 31, 2022, https://www.supplychaindive.com/news/amazon-deploys-new-delivery-route-algorithm-condor/630747/. Accessed on Nov 2, 2023.

[46] Amazon news release, Everything you need to know about Amazon's electric delivery vans from Rivian, Oct 17, 2023. https://www.aboutamazon.com/news/transportation/everything-you-need-to-know-about-amazons-electric-delivery-vans-from-rivian. Accessed on November 9, 2023.

Appendix C Technical methodology for VMT and GHG estimation

A. Further Information on Data Sources Used

1. E-Commerce package count and carrier share data

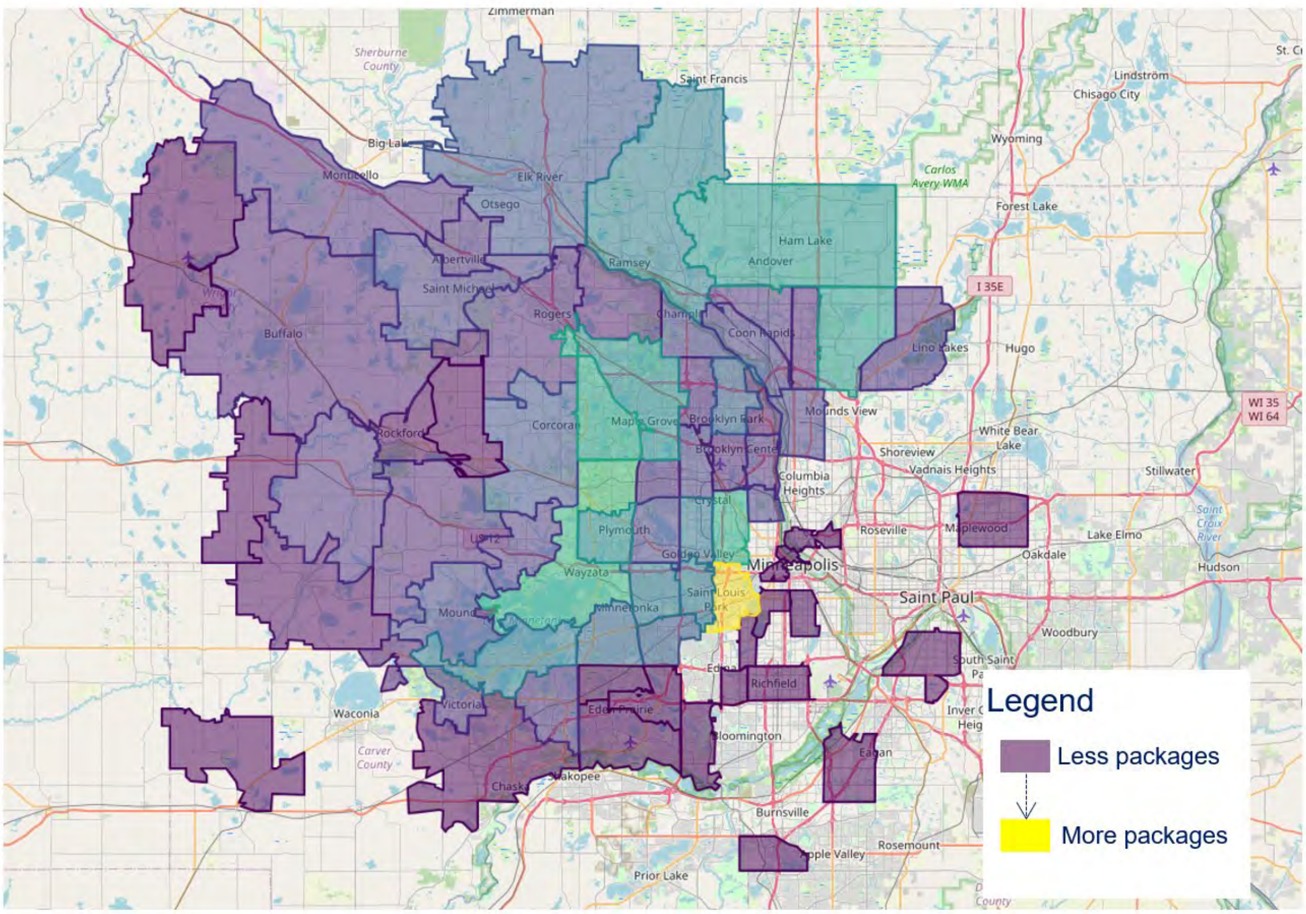
The NielsenIQ e-commerce package count data provides observed and projected total package counts and carrier share at the zip code level. The NielsenIQ package count and carrier share data was acquired for the Minneapolis-St. Paul Metropolitan Statistical area for 2019, 2021, and 2022.

2. E-Commerce delivery scan data

The delivery scan data from NielsenIQ provides detailed information on the route of a delivery for each package containing the items in each order from an online buyer. It provides the zip code where a package was scanned and identifies the carriers conducting the delivery.

Using the UPS facility at Maple Grove as an example, Figure 39 illustrates the package destinations served by that facility for the last-mile deliveries.

Figure 39: Package destinations at Zip Level from the UPS Maple Grove facility



Source: CPCS analysis of NielsenIQ data

Since this analysis is only concerned with the last-mile portion of the delivery journey, additional adjustments were made to filter for the last leg of the delivery. Additionally, NielsenIQ's delivery scan data is missing origin and destination information for some of the Amazon deliveries due to limitations in the raw scan data that was scraped. The project team made assumptions on the origins of those deliveries based on local knowledge on the Amazon facilities that function as delivery stations.

3. GHG emission rate and vehicle fuel types

The average vehicle CO2 emission rate per mile by vehicle and fuel type for the Twin Cities region is derived from the latest MOVES 4 model for the seven-county area. Figure 40 shows the CO2 emission rate and vehicle population share by vehicle and fuel type for 2022.

Figure 40: Vehicle CO2 emission rate and population share

Vehicle and Fuel Type	CO2 emission rate (g/mi)	Vehicle population share
Medium Trucks	**Medium Trucks**	**Medium Trucks**
Gasoline	1,084.66	31%
Diesel Fuel	992.59	68%
Compressed Natural Gas (CNG)	1,983.32	0%
Ethanol (E-85)	0	0%
Electricity	0	0%
Light Duty Vehicles (Cars and Light Trucks)	**Light Duty Vehicles (Cars and Light Trucks)**	**Light Duty Vehicles (Cars and Light Trucks)**
Gasoline	404.72	87%
Diesel Fuel	595.58	1%
Compressed Natural Gas (CNG)	0	0%
Ethanol (E-85)	419.27	4%
Electricity	0	8%

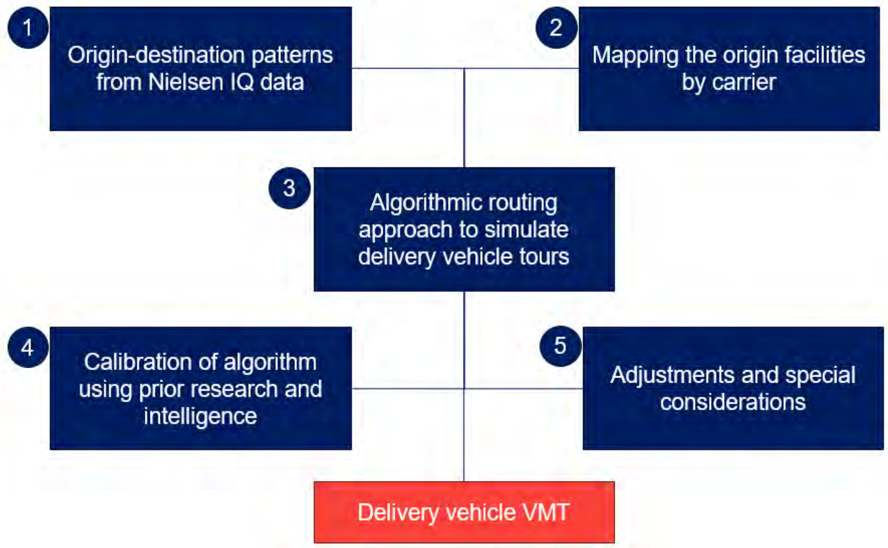
Source: CPCS analysis of MOVES4 model results

B. Further Information on Methodology and Assumptions

1. Package delivery VMT estimation approach

Figure 41 illustrates the steps taken to estimate delivery vehicle VMT by carrier facilities.

Figure 41: E-Commerce Package Delivery VMT Estimation Approach



Source: CPCS

Step 1: Developing origin-destination trip patterns

The NielsenIQ e-commerce package count data at the zip code level was used to develop the package delivery destinations in the region. The zip-code level destination distribution was further disaggregated down to the census block group level, using the population distribution as the guide, to allow for more granular simulation of delivery vehicle tours.

The NielsenIQ e-commerce package carrier share and delivery scan records were used to develop the package delivery origins in the region. The packages destined for last-mile delivery were assigned to each carrier facility based on the patterns reflected in the carrier share data and delivery scan records. To capture the variability in delivery demands, demand patterns were simulated probabilistically based on package counts over a 30-day period. This provided a dynamic framework reflecting the day-to-day changes in package delivery volumes.

Step 2: Mapping the origin facilities by carrier and assigning carrier shares

Figure 42 below shows the major last-mile delivery origin facilities by carrier. This list was developed based on desktop research, field observations, and stakeholder interviews. Once the facilities were identified, the shares of packages served by the major carriers were determined. This is mainly derived from the NielsenIQ carrier share by zip code database with adjustment to gaps in the data related to Amazon based on local knowledge. Figure 43 shows the facilities and the daily packages assigned within the model. (Note that these figures only capture the retail e-commerce packages obtained from the NielsenIQ data, and likely exclude other types of parcels handled in these facilities which are not directly in-scope for this study).

Figure 42: E-Commerce last-mile distribution facilities by major carriers

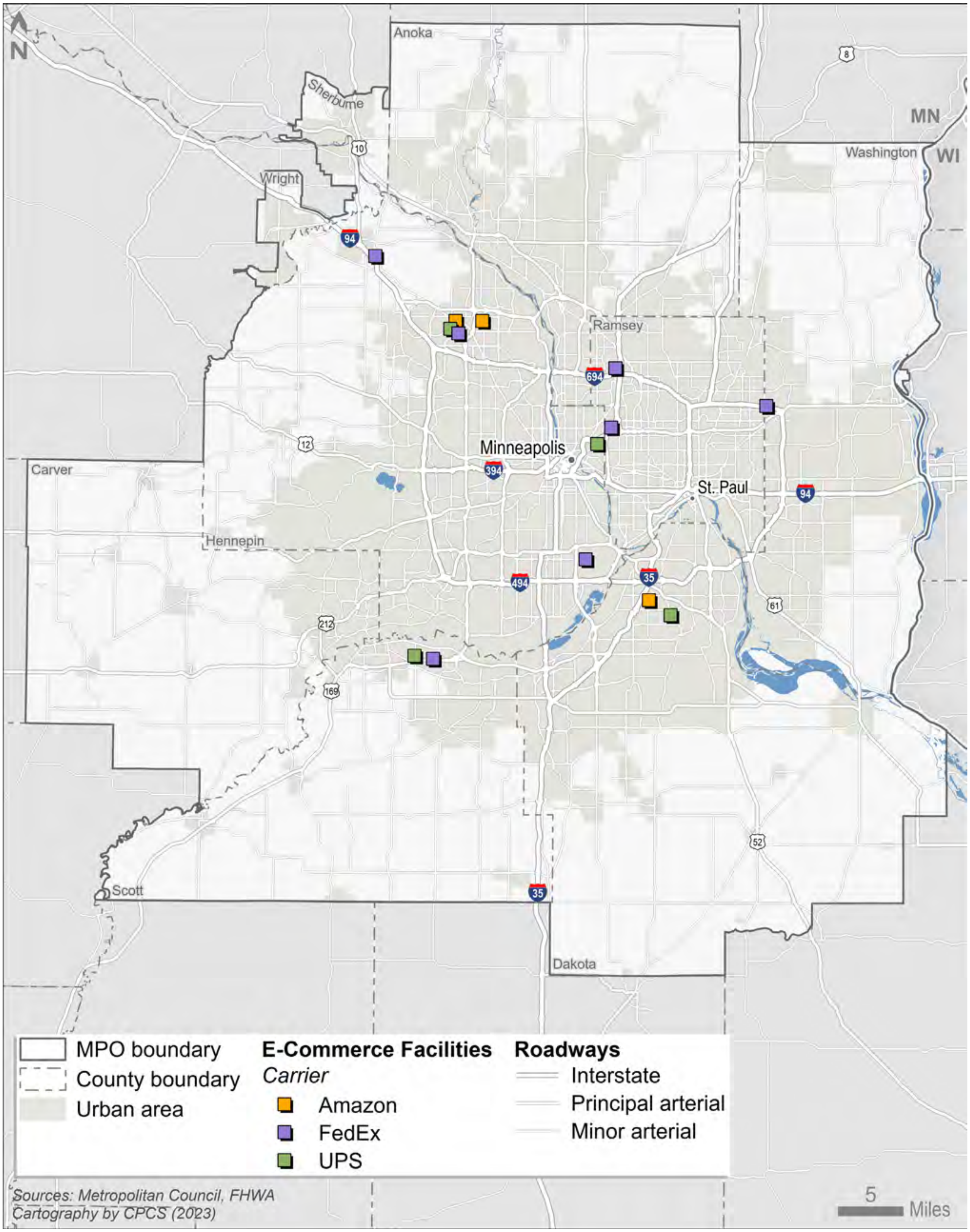


Figure 43: Major carrier last-mile delivery facilities and yearly package estimates

Carrier	Address	City	Zip	Yearly packages
Amazon	3130 Lexington Ave S	Eagan, MN	55121	21,345,000
Amazon	10750 89th Ave N	Maple Grove, MN	55369	21,345,000
Amazon	7500 Setzler Pkwy	Minneapolis, MN	55445	12,525,000
UPS	8601 Valley Forge Ln N	Maple Grove, MN	55369	2,424,000
UPS	555 Opperman Dr	Eagan, MN	55123	1,514,000
UPS	3312 Broadway St NE	Minneapolis, MN	55413	2,200,000
UPS	901 Canterbury Rd #500	Shakopee, MN	55379	866,000
FedEx	19705 Rogers Dr	Rogers, MN	55374	3,728,000
FedEx	5800 12th Ave E	Shakopee, MN	55379	1,733,000
FedEx	7 Long Lake Rd	Mahtomedi, MN	55115	1,835,000
FedEx	8450 Revere Ln N	Osseo, MN	55369	143,000
FedEx	2323 Terminal Rd	Roseville, MN	55113	417,000
FedEx	50 14th St NW	St Paul, MN	55112	242,000
FedEx	2825 Cargo Rd	Minneapolis, MN	55450	121,000

Source: CPCS analysis of NielsenIQ data, 2022. Note: onluy includes e-commerce packages as available from the NielsenIQ dataset. Excludes other types of packages (e.g. B2B, nonretail packages).

Step 3: Simulating delivery vehicle tours

A "traveling salesman" algorithm was applied next, tailored to the centroids of the census block groups, to determine the shortest and most efficient route for the delivery vehicles between the delivery facilities and destination block group pairs. An adjustment was made to account for the expected travel within each block group to account for the additional distance.

The Traveling Salesman Algorithm

The Traveling Salesman Algorithm is a mathematical method used to solve a well-known logistical problem: finding the most efficient route that visits a set of locations once and returns to the starting point. This challenge is fundamental to route planning and optimization in various sectors, including logistics, transportation, and manufacturing.

OR-Tools is a comprehensive toolkit designed by Google to tackle complex optimization problems, including vehicle routing. One of the problems that OR-Tools is particularly adept at solving is the Vehicle Routing Problem, which is a generalized form of the Traveling Salesman Problem. This tool is used by the project team to simulate carriers' delivery tours.

By defining the scope and scale of the delivery tours, including fleet's size, the base of the deports from which they operation (the delivery facilities), and the geographic spread of the delivery points (derived from the carriers' market share from NielsenIQ data), the algorithm identifies the best set of routes for the combination of the origin-destination pairs.

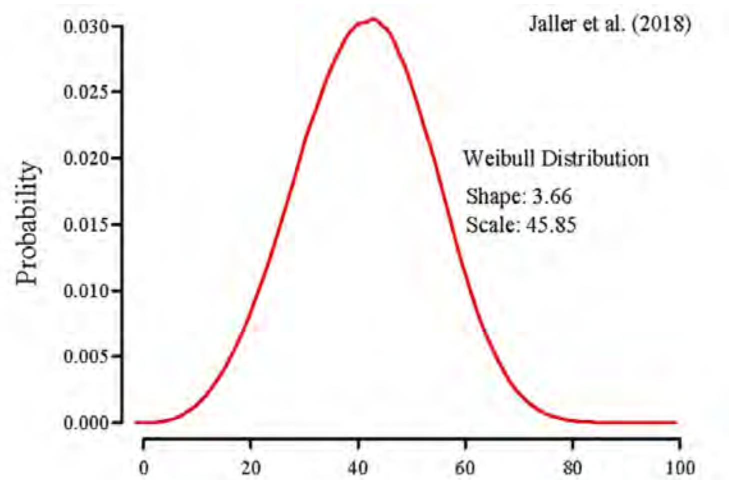
Step 4: Calibration of algorithm using prior research and intelligence

The key assumptions used during this simulation include the number of packages per delivery vehicle and delivery tour length distribution. Therefore, the study team calibrated the delivery vehicle tour algorithm for these two variables using academic research and field interviews.

- Number of packages per delivery vehicle: Information obtained from field interviews and desk research suggests a typical value of approximately 250 packages per delivery van.

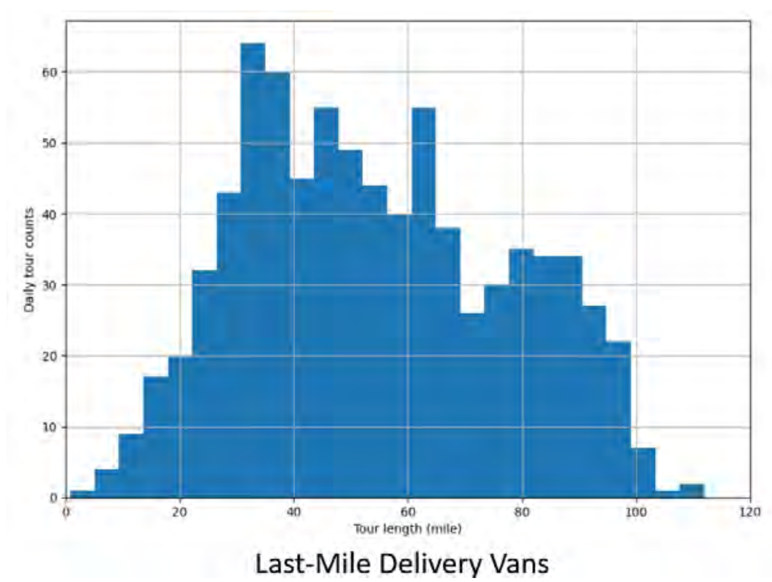
- Delivery route length: The study team's research indicates that the typical length of a delivery route, or tour, centers around 45 miles (Figure 44). This finding aligns with patterns observed during field interviews with staff at carrier distribution facilities. The team's model-generated data on delivery van tour lengths supports this observation, showing most tours ranging between 35 to 65 miles (Figure 45). This range not only corroborates the patterns noted in existing literature but also reflects the unique aspects of the distribution facilities' catchment areas. These unique characteristics are influenced by factors such as the density of the facilities and the roadway network of the study area.

Figure 44: Delivery tour length distribution from literature



Source: Jaller, Miguel, Leticia Pineda, and Hanjiro Ambrose. "Evaluating the use of zero-emission vehicles in last mile deliveries." ITS Reports 2017, no. 33 (2018).

Figure 45: Modeled delivery tour length distribution – vans



Source: CPCS

Step 5: Adjustments and special considerations

USPS

The above-mentioned simulation was applied to analyze delivery trips for Amazon, FedEx, and UPS, with an exception made for USPS. The reason for this divergence stems from the unique operational structure of USPS as indicated by NielsenIQ delivery scan data. USPS's distribution model is highly decentralized due to the extensive network of postal offices that serve as starting points for the final leg of delivery tours. Moreover, their delivery vehicles often transport a mix of e-commerce and traditional mail items, making their routing decision different from other carriers.

USPS delivery VMT was estimated by taking the average distance of a typical USPS delivery route, approximately 24 miles,[47] and multiplying this number by the estimated count of such routes in the Twin Cities region. To arrive at this regional route estimate, the proportion of the total U.S. population represented by the Twin Cities area was used to approximate its share of national USPS delivery routes – resulting in an estimated 2,102 routes in the study area.[48] Considering USPS vehicles carry both packages and regular mail, it was necessary to allocate the VMT among packages and non-packages (e.g., mail). The allocation was done by assigning a proportion equivalent to USPS's revenues from parcel shipping as a share of its total revenues[49] (about 40%).[50] This resulted in an estimated 6.3 million annual miles attributable to packages. Finally, an adjustment was applied to account for non-e-commerce packages, by comparing the total USPS packages in the NielsenIQ dataset to USPS's equivalent share of total packages obtained from Pitney Bowes and allocated to the region based on population (this assumes about 22% of USPS packages are associated with retail e-commerce).

FedEx and UPS van capacity

It is also noted that FedEx and UPS vans likely deliver a mix of e-commerce and non-e-commerce retail packages along the same routes. Consequently, as a modeling assumption, the effective capacity of the vans was reduced by 50% to account for the fact that a large proportion of deliveries of these carriers are likely to be non-e-commerce packages such as documents, business supplies, and other expedited products (of which a portion will be carried on the same vans as supply retail e-commerce customers). It is acknowledged that there is limited publicly available data to precisely determine these allocations, hence the simplified assumption. (Note that after this assumption was applied, the resulting VMT tour distance profiles compare well to results from the literature).

Amazon operations and Flex share and capacity

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[47] Eric Katz, Government Executive, USPS Could Serve Nearly All Its Mail Routes in Electric Vehicles, a Watchdog Says, March 2022. https://www.govexec.com/management/2022/03/usps-could-serve-nearly-all-its-mail-routes-electric-vehicles-watchdog-says/363435/. Accessed on November 8, 2023.

[48] USPS, Postal Facts, 2022. https://facts.usps.com/total-delivery-routes/#:~:text=The%20Postal%20Service%20has%20233%2C585%20delivery%20routes%20across%20the%20United%20States. Accessed on November 8, 2023.

[49] Note: The allocation requires an estimation of how much of the Postal Service's VMT is driven by mail versus packages. This is a debatable and somewhat subjective question which could invite both practical and theoretical argumentation. The most straightforward approach is to apply allocations based on the significance to USPS of its various segments. Both from a financial and operational perspective, revenues were deemed to be the most suitable metric. As an alternative, the other readily available metric is number of units; this measure was deemed inferior because a single piece of mail is significantly smaller and less revenue-generating for USPS compared to a parcel.

[50] USPS, National News, U.S. Postal Service Reports Fiscal Year 2022, November 10, 2022. Results https://about.usps.com/newsroom/national-releases/2022/1110-usps-reports-fiscal-year-2022-results.htm. Accessed on November 8, 2023.

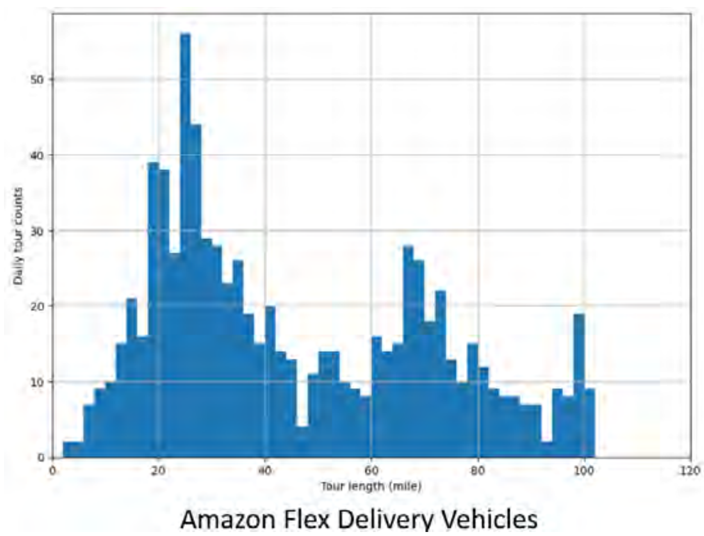
The model also accounted for the role of Amazon Flex[51] drivers in the delivery network. In the simulation, it was assumed that each Amazon Flex driver, using their personal vehicle, can deliver up to 50 packages per trip. This differs from the use of commercial delivery vans or trucks.

First, the study team assumed that deliveries from Amazon's two major delivery stations – Eagan and Maple Grove, serve an approximately equal volume of e-commerce packages. Second, the study team assigned 10% of the packages at random to its Brooklyn Park facility, which is understood to focus on same-day deliveries including Prime. [52]

Given the limited detail in NielsenIQ data regarding Amazon deliveries, and the lack of detailed public data, the study team assigned about 10% of deliveries originating from Maple Grove and Eagan to Flex, as an annual average (understanding that this ratio may be highest during peak periods such as prior to the holidays). Finally, it was assumed that the packages from Brooklyn Park are also delivered by Flex – for a total of approximately 20% of Amazon packages assigned to Flex.

This approach provides a cautious yet informed estimate of the contribution of Amazon Flex drivers to the overall delivery system. Figure 46 shows the delivery tour length distribution modeled for Amazon Flex.

Figure 46: Modeled Delivery Tour Length Distribution – Amazon Flex



Source: CPCS

Note on returns: Returns can be facilitated in a number of ways, with differing impacts on VMT. The study team did not identify good quality data sources that could be used to track the VMT impact of returns. It is also noteworthy that the 2022 report by the National Retail Federation "Consumer Returns in the Retail Industry"[53] stated a similar rate of returns from online sales as from in-store sales – suggesting that in aggregate online sales may not be contributing disproportionately to returns.

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[51] Under the Amazon Flex model, independent contractors (similar to Uber/Flex drivers) can sign up to deliver blocks of packages from Amazon's distribution facilities, using their own private vehicles.
[52] Amazon launches new service out of Brooklyn Park warehouse, CCS Media, September 27, 2021. https://ccxmedia.org/news/amazon-launches-new-service-out-of-brooklyn-park-warehouse/. Accessed on Nov 20, 2023.
[53] See https://cdn.nrf.com/sites/default/files/2022-12/AR3021-Customer%20Returns%20in%20the%20Retail%20Industry_2022_Final.pdf

Although it is not modeled in this study, it is reasonable to conclude that reducing the rate of returns would be supportive of VMT reduction.

Appendix D Projections and Scenarios Analysis

A. Further Information on Data Sources Used

The table below provides a more detailed breakdown of the data inputs and assumptions used for the VMT and GHG emissions projections and scenarios.

Figure 47: Data sources used for scenario analysis

Change Driver	Data Input	Source
Demographics	Population growth (aggregate)	The total population growth for the region is provided by Met Council from its models for demographic scenarios as part of the Transportation Policy Plan development. The population growth scenarios include a high and compact growth scenario, a high and dispersed growth scenario, a low and compact growth scenario, and a low and dispersed growth scenario. For baseline growth projection for population, the Business As Usual scenario results set from Met Council's Scenarios Explorations Project (2022-23) was used for the spatial distribution of population while the Regional Level 2050 forecasts result was used for total population growth.
Demographics	Population distribution	The relative distribution of the population across the region is derived from the population distribution projections at the block group level provided by Met Council.
E-commerce growth	Per-capita retail sales and growth	The per-capita retail sales are derived using the quarterly US total retail sales data and population data from the Census Bureau. Total national retail sales are adjusted for inflation and divided by the population to develop per-capita real retail sales.
E-commerce growth	E-commerce penetration growth rate	The e-commerce penetration rate is derived from the quarterly US e-commerce sales data from the Census Bureau.
Marginal delivery VMT	Marginal VMT per additional package delivered	This estimation on the marginal VMT increase per additional package delivered is derived from the package delivery VMT estimation model described in earlier section of this report. A simpler version of this model was used for a sample facility (UPS Maple Grove) to estimate how the marginal VMT may differ by geography within the study area.
Marginal delivery GHG	Marginal GHG emission per delivery vehicle VMT	This estimation on the marginal GHG emission increase per additional package delivered is estimated emission derived from EPA's latest MOVES model.
Bricks and mortar shopping growth	In-person shopping trip and growth	The growth in bricks-and-mortar retail sales is backed out from the quarterly US total retail sales data, by subtracting e-commerce sales from total retail sales.
Marginal shopping VMT	Marginal VMT per additional shopping trip	The marginal VMT per additional shopping trip is derived from shopping trip length distribution and automobile mode share, accounting for regional variation (e.g., urban, suburban, and rural), reflected in the regional TBI analysis.
Marginal shopping GHG	Marginal GHG emission per passenger vehicle VMT	This estimation of the marginal GHG emission increase per additional passenger vehicle VMT is estimated from emission factors derived from EPA's latest MOVES model.

Source: CPCS

B. Further Information on Methodology and Assumptions

1. Geographic disaggregation

For the scenario analysis, a four-ring model was applied within the region, as shown in Figure 48. This custom-defined geographical structure is intended to capture contextual differences between urban, suburban and rural parts of the region – which, as described above, can impact VMT. The structure accounts for both transportation and land use considerations:

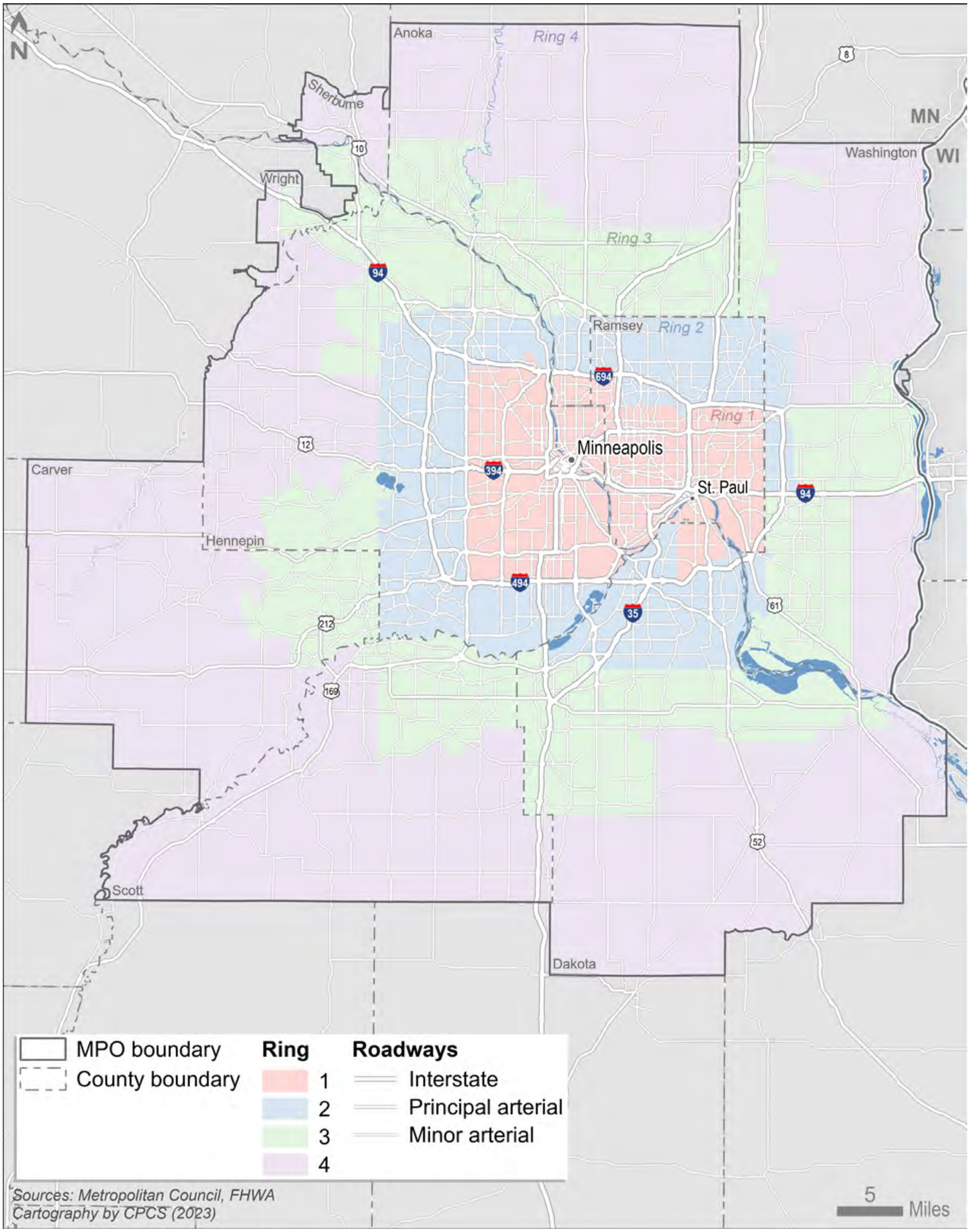
- From a transportation perspective, more central areas tend to have a denser road network and be closer to multiple transportation corridors such as highways; whereas in more rural areas the road network is less dense and may require more circuitous travel.
- From a land use perspective, more central areas tend to have higher population density, meaning that the distance between successive delivery stops is smaller; whereas in more rural areas population density is lower and the distance between successive delivery stops is higher.

The four rings are informed by the region's updated Community Designation maps as well as the general shape of the transportation network, notably the ring highways.

- Ring 1 consists of urban land uses, within the ring highway network (494/694)
- Ring 2 consists of areas generally along the ring highways, where the land use is predominantly suburban
- Ring 3 consists of areas generally outside the ring highway network, but where the land use is predominantly suburban
- Ring 4 consists of rural and agricultural areas of the region

Note: the four-ring structure is used for modeling purposes for this study, and does not imply any legislative, planning or other purpose.

Figure 48: Ring structure used for modeling



Source: CPCS

2. Detailed assumptions for the scenarios

a. Base year inputs

Figure 49 displays key model inputs for the base year.

Figure 49: Key model inputs for base year (2022)

Ring	Population (mil.)	Packages delivered, annual (mil.)	Delivery vehicle VMT, annual (mil.)	Shopping trips, annual (mil.)
Ring 1	1.22	30.75	9.62	185.6
Ring 2	0.79	18.97	6.17	139.5
Ring 3	0.89	19.58	6.37	132.8
Ring 4	0.27	11.58	5.51	21.5
Total	3.16	80.88	27.67	479.4

Source: CPCS analysis

b. Population growth

Figure 50 shows the assumptions for population growth for the scenarios (cumulative to 2050). The Future Baseline Case population forecast is based on the 2050 TPP information, as available at the time of writing. The Future Baseline Case assumes that the population grows to 3.8 million in 2050, an increase of about 21% over 2022. The population growth is distributed geographically according to proportions calculated from Met Council's Scenarios Explorations Project (2022-23). This was deemed sufficiently representative, noting that the full disaggregated 2050 projections were not available at time of writing.

Scenario 1 (Urban Hub): The overall population projection for the region is the same as in the Future Baseline Case, but the distribution is weighted using Met Council's "compact growth" demographic scenarios as part of the TPP. This assigns a higher proportion of the population increase to the more central areas, and a lower proportion to more exurban parts of the region. The total population growth for the whole region works out to the same level for Scenario 1 as for the Future Baseline Case.

Scenarios 2-4: Same as the Future Baseline Case.

Figure 50: Assumptions for scenario model (2050) – Population growth rate (cumulative to 2050)

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	18%	29%	18%	18%	18%
Ring 2	24%	22%	24%	24%	24%
Ring 3	30%	23%	30%	30%	30%
Ring 4	48%	34%	48%	48%	48%

Source: CPCS analysis

c. E-commerce sales growth

Figure 51 shows the assumptions for the growth in real per-capita e-commerce sales (cumulative to 2050). The Future Baseline Case incorporates two assumptions. First, it is assumed that real per-capita retail sales grow at 1.2% p.a., equal to the national pre-covid growth rate from 2011-19, as calculated from the US Census Bureau's data. Second, it is assumed that the e-commerce penetration rate grows as a linear function, adding 0.7 percentage points every year, also equal to the pre-covid trend from the same source. Under the Future Baseline Case the e-commerce penetration rate would grow to 34% in 2050 – more than double the current level.

The rate of e-commerce sales growth is assumed to be equal to the rate of growth in the volume of packages.

The scenarios all assume that real per-capita retail sales grow at the same rate, but the assumptions about the e-commerce penetration rate vary.

Scenario 1 and 4: same as the Future Baseline Case.

Scenario 2: The e-commerce penetration rate grows as a linear function, adding 1.25 percentage points every year. This is in line with some industry forecasts;[54] under this scenario the e-commerce penetration rate would grow to 50% in 2050.

Scenario 3: The e-commerce penetration rate grows as a linear function, adding 0.91 percentage points every year.(30% higher than the Future Baseline Case). Under this scenario the e-commerce penetration rate would grow to 40% in 2050.

Figure 51: Assumptions for scenario model (2050) – Real per-capita e-commerce sales growth rate (cumulative to 2050)

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	236%	236%	383%	290%	236%
Ring 2	236%	236%	383%	290%	236%
Ring 3	236%	236%	383%	290%	236%
Ring 4	236%	236%	383%	290%	236%

Source: CPCS analysis

d. Delivery vehicle VMT impact

Figure 52 shows the assumptions for the delivery vehicle VMT impact, defined as the average miles per package for delivery vehicles. Note that this only accounts for the last-mile VMT, i.e., from delivery routes. In the Future Baseline Case, the regional VMT impact is calibrated to the base-year value. It is acknowledged that it is unknown how the geographic locations of distribution facilities will change over time. In principle, there may be network efficiencies from a large increase in e-commerce packages which would lower the marginal VMT, but this would be speculative without understanding how parcel carriers may change their network designs in the face of such a large increase in demand.

The VMT impact is assumed to vary by ring, as calculated by the study team from running its trip assignment model for a sample facility (UPS Maple Grove), deemed to be representative of the general areas in which distribution centers are located in the study area. This analysis determined that the VMT impact is similar in urban and suburban areas, likely due to the offsetting impacts of (one the one hand) greater network density in the core, and (on the other hand) shorter line haul distance for routes in the suburbs. However, exurban areas were found to have a proportionally higher VMT impact because of the low network density and longer line haul. The regional distributions from that sample are then weighted to average out to the regional total VMT impact, as

[54] See for example CBRE Research Q2, 2022, Figure 14 from CBRE, “US Real Estate Market Outlook 2023” https://www.cbre.com/insights/books/us-real-estate-market-outlook-2023/industrial

calculated from an assessment of all distribution facilities and calibrated against findings from the literature.

Scenario 1: Within Ring 1, a series of assumptions were made to simulate the presence of urban microhubs. First, it is assumed that one-third of packages are delivered to microhubs, and two-thirds are delivered directly to receivers in the normal way. Among the ones delivered to the microhubs, half are assumed to be delivered by bicycle or by foot from the microhub, and the other half are assumed to be picked up by the customer. Among customer pickups, 33% are assumed to pick up their packages by car, and 67% by other modes.[55] Finally, among drivers picking up their packages, 3/4 are assumed to pick it up on the way home from some other function (thereby not adding to VMT), with the other one-quarter making a unique trip. Furthermore, it is assumed that the microhubs are supplied by vans which operate out of a centrally located distribution center, with a total route length of 18 miles supplying 250 packages (linehaul plus possibly supplying a few microhubs per route). These assumptions result in a total VMT impact of 0.11 miles per package for the microhub model.

Scenario 2: It is assumed that the proportion of packages delivered via Amazon Flex-type vehicles decreases by half. This decreases the VMT impact per package because van deliveries are considerably more VMT-efficient.

Scenario 3: Same as Future Baseline Case.

Scenario 4: The VMT impact per package is assumed to decrease by 10%. This reflects an assumption about the potential for behavioral shifts by consumers, which could arise due to various factors, such as opting to better consolidate deliveries (e.g., through programs like Amazon Day Delivery, which allows participants to have all their packages delivered on a single day of the week) and efforts to cut waste (including through new tools, such as augmented reality) to make fewer wasteful orders that end up in returns. Effectively, this assumes that although the total shopping activity (sales) are the same as in the Future Baseline Case, the resulting impact on VMT can be reduced. For context, the National Retail Federation estimates that returns constitute 16.5% of online sales.[56]

Figure 52: Assumptions for scenario model (2050) – Miles per package, for delivery vehicles

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	0.30	0.24	0.23	0.30	0.27
Ring 2	0.32	0.32	0.24	0.32	0.29
Ring 3	0.32	0.32	0.24	0.32	0.29
Ring 4	0.46	0.46	0.35	0.46	0.42

Source: CPCS analysis

e. Delivery vehicle GHG emissions impact

Figure 53 shows the assumptions for the greenhouse gas emissions impact, defined as pounds of CO2-equivalent emissions per vehicle-mile traveled. The MOVES model projects that in 2050 the share of single-unit short-haul trucks for the seven-county region will be: 25.4% gasoline, 58.3%

[55] For reference, according to the 2022 TBI, for shopping trips of a distance under 1 mile which originate within St. Paul or Minneapolis, the auto driver mode share is 45%.

[56] National Retail Federation, “2022 Consumer Returns in the Retail Industry” https://cdn.nrf.com/sites/default/files/2023-01/Customer%20Returns%20in%20the%20Retail%20Industry_2022_Final_1.pdf

diesel, 0.4% CNG, and 15.9% electric. These are multiplied by the forecasted emissions rates for each type of technology for 2050. Subsequently, an adjustment is made to incorporate passenger vehicles that are used for delivery purposes: as described in the previous chapter, it is assumed that 47% of delivery VMT is by passenger vehicles (although the share of packages delivered through this channel is much lower, the Flex-type routes are assumed to be much less efficient in terms of VMT per package). Note that passenger vehicle forecasts are provided below under *Passenger vehicle GHG emissions impact.*

Scenarios 1 and 3: Same as Future Baseline Case.

Scenario 2: The parcel carriers are assumed to fully electrify their fleets, in line with their publicized targets. In addition, it is assumed that the usage of passenger vehicles for deliveries declines by half (from 11% of packages to 5% - thereby from 47% of delivery VMT to 24%).

Scenario 4: There are no changes to the fleets of parcel carriers, but there is a carryover impact via greater electrification for passenger vehicles (see *Passenger vehicle GHG emissions impact).*

Figure 53: Assumptions for scenario model (2050) – GHG emissions per VMT, for delivery vehicles (pounds per mile)

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	1.04	1.04	0.11	1.04	0.99
Ring 2	1.04	1.04	0.11	1.04	0.99
Ring 3	1.04	1.04	0.11	1.04	0.99
Ring 4	1.04	1.04	0.11	1.04	0.99

Source: CPCS analysis

f. Growth in personal shopping trips

Figure 54 shows the assumptions for growth in per-capita shopping trips (cumulative to 2050), for trips associated with traditional shopping activity, e.g., shopping at bricks-and-mortar stores. The Future Baseline Case is directly tied to the assumptions described under *E-commerce sales growth.* Essentially, it is assumed that total retail sales are subdivided into e-commerce sales and bricks-and-mortar sales. As the former increases (due to higher e-commerce penetration), the latter decrease in proportion. However, the Future Baseline Case still assumes positive growth in bricks-and-mortar sales, because the overall increase in real per-capita sales (e.g., due to growing wealth and disposable income) outweighs the shift of some sales to e-commerce.

Scenario 1: Same as the Future Baseline Case.

Scenarios 2 and 3: The impacts follow mathematically from the greater e-commerce penetration assumed for these scenarios, as described above in *E-commerce sales growth.*

Scenario 4: Per-capita shopping trips are assumed to decline by 5% from the Future Baseline Case, as a function of consumers finding ways to economize on their shopping activity in an effort to reduce inefficient/wasteful travel.

Figure 54: Assumptions for scenario model (2050) – Per-capita traditional shopping trip growth rate (cumulative to 2050)

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	8%	8%	-16%	-1%	3%
Ring 2	8%	8%	-16%	-1%	3%
Ring 3	8%	8%	-16%	-1%	3%
Ring 4	8%	8%	-16%	-1%	3%

Source: CPCS analysis

In addition, Figure 55 shows the assumptions for growth in per-capita shopping trips (cumulative to 2050), for “non-traditional” trips not associated with traditional bricks-and-mortar shopping (for example, personal travel as made under a click-and-collect model for curbside or in-store pickup).

To first determine the base-year split between traditional and additional shopping trips, we took the total shopping trips from Met Council’s household survey (TBI) and assigned 1.2% of those trips as “non-traditional.” That number is derived by multiplying the national e-commerce penetration rate for 2022, 14.5%, by an estimate of click-and-collect sales as a share of retail e-commerce sales (estimated as 8.6%, according to industry sources.[57])

The Future Baseline Case assumes that the 8.6% value will be retained over time, as industry forecasts[58] project this ratio to be fairly stable. However, as the e-commerce penetration rate grows, the total volume of non-traditional shopping trips will grow in lockstep. Hence the Future Baseline Case matches the *E-commerce sales growth* forecast.

Scenario 1: Same as the Future Baseline Case.

Scenario 2: This value derives directly from the assumption described under *E-commerce sales growth.*

Scenario 3: The ratio described above is assumed to increase from 8.6% to 25% - a factor of three. This implies that a much larger share of e-commerce purchases are matched by physical travel on the part of the buyer. This could be due to various causes, such as increased use of click-and-collect, or other kinds of travel such as for the experiential benefits of shopping (without necessarily buying products in-store). In addition, under this scenario the e-commerce penetration rate is assumed to be higher than in the Future Baseline Case, as described in *E-commerce sales growth.*

Scenario 4: Per-capita shopping trips are assumed to decline by 5% due to more eco-conscious decision-making on the part of consumers (just as assumed for traditional shopping trips).

Figure 55: Assumptions for scenario model (2050) – Per-capita non-traditional shopping trip growth rate (cumulative to 2050)

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	236%	236%	383%	1070%	219%
Ring 2	236%	236%	383%	1070%	219%
Ring 3	236%	236%	383%	1070%	219%
Ring 4	236%	236%	383%	1070%	219%

Source: CPCS analysis

g. Shopping trip VMT impact

This is subdivided into two factors: personal shopping trip mode share, and personal shopping trip distance.

Figure 56 shows the auto driver mode share for personal shopping trips, based on the TBI. The study team assigned the overall mode shares to the rings on the basis of the geographic origins of

[57] Insider Intelligence, eMarketer, Oct 2023, “US Click-and-Collect Forecast 2023” https://www.insiderintelligence.com/content/us-click-and-collect-forecast-2023
[58] Ibid

shopping trips. This reflects that the auto driver mode share is highest in the exurbs and lowest in the core. The Future Baseline Case assumes that base-year mode shares will be retained in 2050.

Scenario 1: The non-auto-driver share for Ring 1 is assumed to increase by a factor of 1.2, assuming that within a more urbanized core there are greater opportunities for alternative travel modes. The other rings are unchanged.

Scenarios 2 and 3: Same as Future Baseline Case.

Scenario 4: The non-auto-driver mode share for all rings is assumed to increase by a factor of 1.15, reflecting that some residents shift to alternative modes in order to reduce the impact of their shopping trips.

Figure 56: Assumptions for scenario model (2050) – Percentage of personal shopping trips by auto driver

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	77%	72%	77%	77%	73%
Ring 2	78%	78%	78%	78%	74%
Ring 3	89%	89%	89%	89%	88%
Ring 4	95%	95%	95%	95%	94%

Source: CPCS analysis

Figure 57 shows the round-trip distance of the average shopping trip, based on the TBI. The focus specifically is on the distances of trips by auto drivers, as other modes are assumed not to contribute to VMT. The study team has computed these metrics by ring based on the geographic origins of shopping trips. The Future Baseline Case assumes that base-year mode trip lengths will be retained in 2050.

Scenario 1: The average trip length for Ring 1 is assumed to decrease by 20%, under the assumption that within a more urbanized core destinations may be closer together and some shopping trips shorter. The other rings are unchanged.

Scenarios 2 and 3: Same as Future Baseline Case.

Scenario 4: The average trip distance for all rings is assumed to decrease by 10%, reflecting that some residents shift their behavior to prioritize shopping closer to home.

Figure 57: Assumptions for scenario model (2050) – Round-trip distance of shopping trips, by auto driver (miles per trip)

Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	8.4	6.8	8.4	8.4	7.6
Ring 2	9.6	9.6	9.6	9.6	8.6
Ring 3	11.0	11.0	11.0	11.0	9.9
Ring 4	16.2	16.2	16.2	16.2	14.6

Source: CPCS analysis

h. Passenger vehicle GHG emissions impact

Figure 58 shows the assumptions for the greenhouse gas emissions impact, defined as pounds of CO2-equivalent emissions per vehicle-mile traveled. Using the MOVES model projections for 2050, one can assume that the share of light duty vehicles for the seven-county region will be: 61.7% gasoline, 0.8% diesel, 2.7% ethanol, and 34.8% electric. This is based on an assumption of an even split of passenger cars and light-duty trucks. These are multiplied by the forecasted emissions rates for each type of technology for 2050.

Scenarios 1, 2 and 3: Same as Future Baseline Case.

Scenario 4: Zero-emissions vehicles are assumed to represent 50% of all personal vehicles, compared to 35% in the Future Baseline Case (or 8% in 2022).

Figure 58: Assumptions for scenario model (2050) – GHG emissions per VMT, for passenger vehicles (pounds per mile)

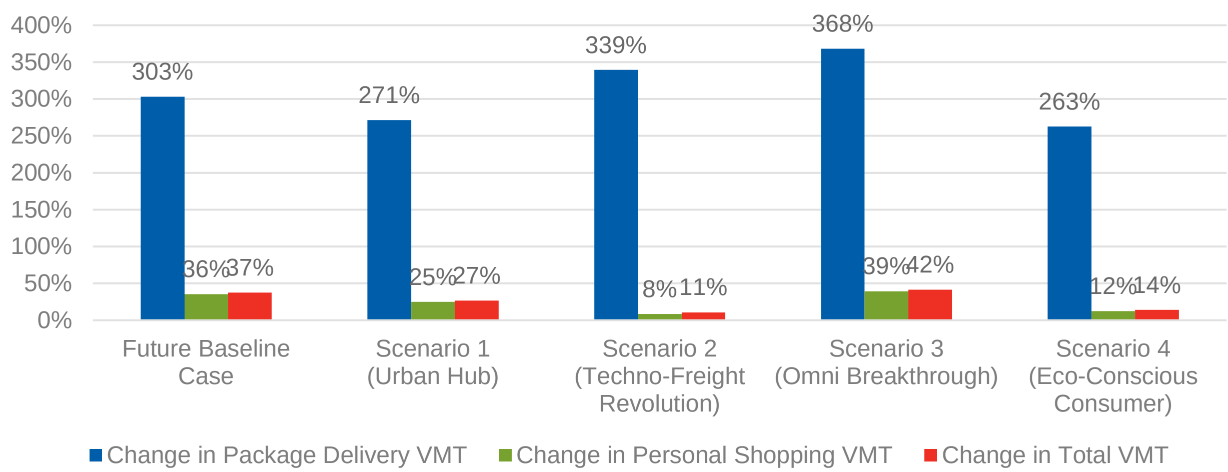
Ring	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 1	0.48	0.48	0.48	0.48	0.37
Ring 2	0.48	0.48	0.48	0.48	0.37
Ring 3	0.48	0.48	0.48	0.48	0.37
Ring 4	0.48	0.48	0.48	0.48	0.37

Source: CPCS analysis

C. Scenario Results

Figure 59 illustrates the change in total VMT for each scenario relative to the Base Year. The delivery vehicle VMT rises substantially under all of the scenarios.

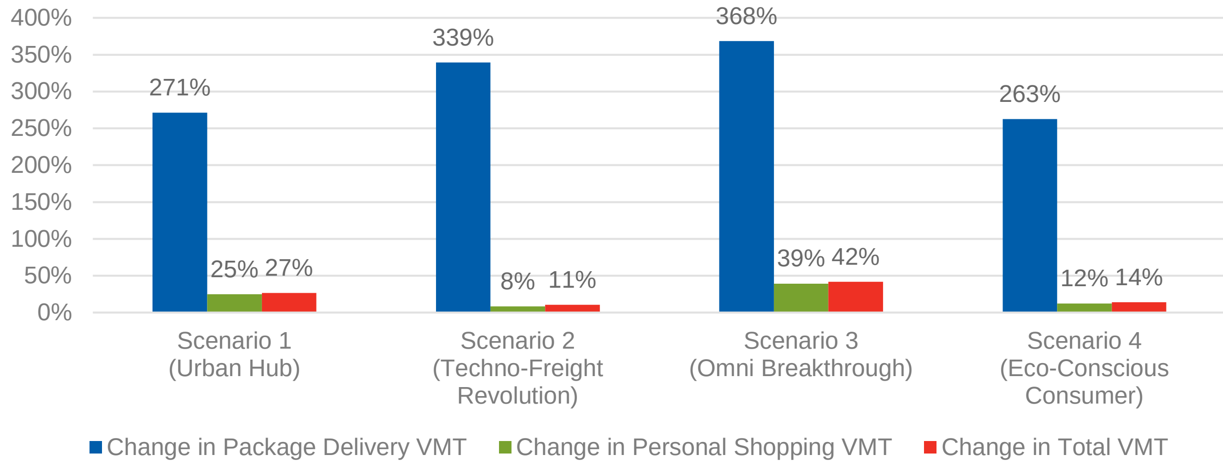
Figure 59: Change in total vehicle miles traveled in the region, for each scenario relative to Base Year



Source: CPCS analysis

Figure 60 illustrates the change in total VMT for each scenario relative to the Future Baseline Case. Because shopping trips contribute the overwhelming majority of VMT, the total VMT is largely driven by the change in shopping VMT.

Figure 60: Change in total vehicle miles traveled in the region, for each scenario relative to Future Baseline Case



Source: CPCS analysis

Figure 61 provides a summary of the change in VMT for each scenario, when compared to both the Future Baseline Case and the base year.

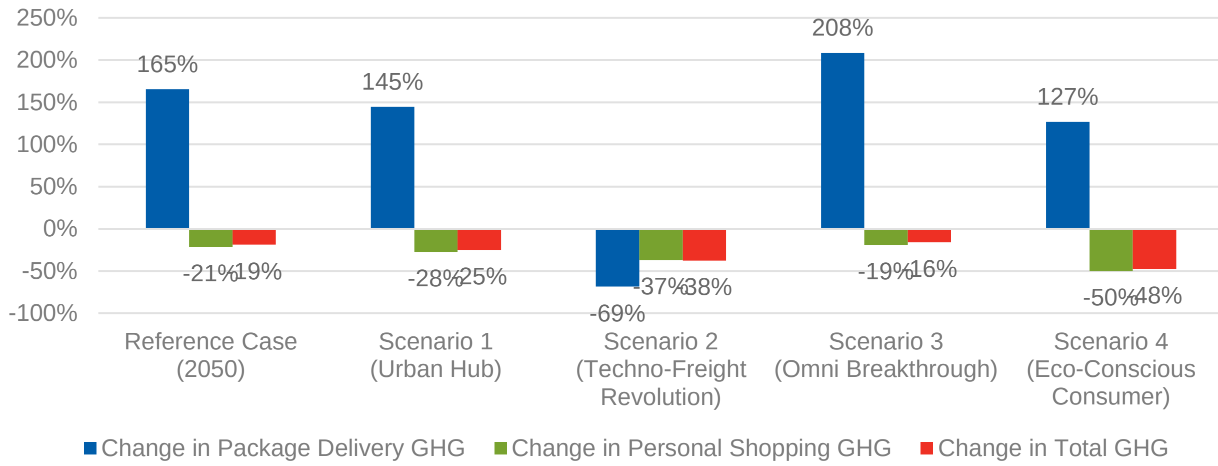
Figure 61: Summary of change in VMT for each scenario

Measure	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Break-through	Scenario 4: Eco-Conscious Consumer
Change in package delivery VMT, versus Future Baseline Case	-	-8%	+9%	+16%	-10%
Change in personal shopping VMT, versus Future Baseline Case	-	-8%	-20%	+3%	-17%
Change in total VMT, versus Future Baseline Case	**-**	**-8%**	**-19%**	**+3%**	**-17%**
Change in package delivery VMT, versus base year	+303%	+271%	+339%	+368%	+263%
Change in personal shopping VMT, versus base year	+36%	+25%	+8%	+39%	+12%
Change in total VMT, versus base year	**+37%**	**+27%**	**+11%**	**+42%**	**+14%**

Source: CPCS analysis

Figure 62 illustrates the change in total GHG emissions for each scenario relative to the Base Year. The greenhouse gas emissions associated with delivery vehicles rise in most of the scenario, except for Scenario 2 (as a result of delivery vehicle fleet electrification). The overall emissions decline in each scenario, compared to the Base Year.

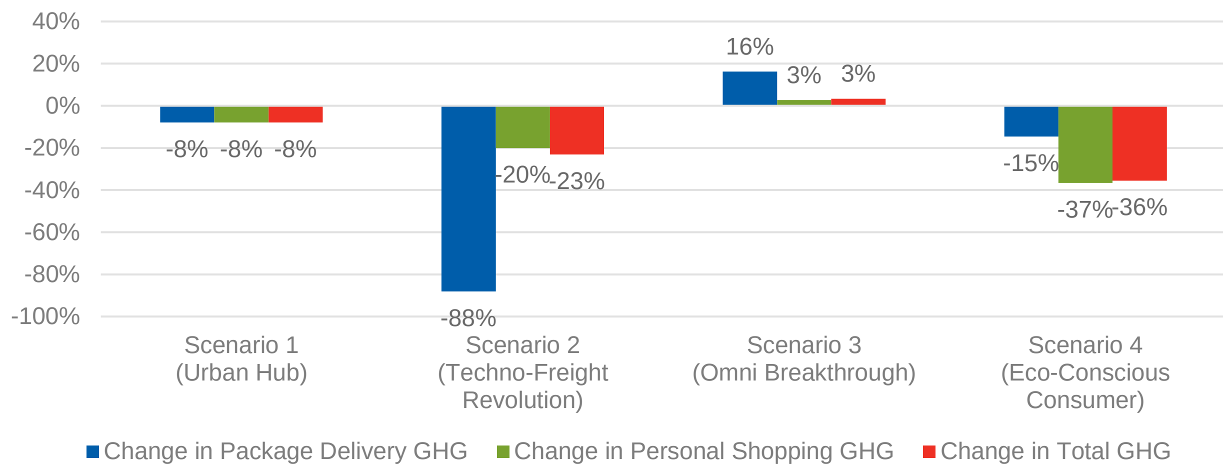
Figure 62: Change in total GHG emissions in the region, for each scenario relative to Base Year



Source: CPCS analysis

Figure 63 illustrates the change in total GHG emissions for each scenario relative to the Future Baseline Case. Because shopping trips contribute the overwhelming majority of VMT, the total GHG emissions are largely driven by the change in shopping GHG emissions.

Figure 63: Change in total GHG emissions in the region, for each scenario relative to Future Baseline Case



Source: CPCS analysis

Figure 64provides a summary of the change in GHG emissions for each scenario, when compared to both the Future Baseline Case and the base year.

Figure 64: Summary of change in GHG emissions for each scenario

Measure	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Break-through	Scenario 4: Eco-Conscious Consumer

Change in package delivery GHG, versus Future Baseline Case	-	-8%	-88%	16%	-15%
Change in personal shopping GHG, versus Future Baseline Case	-	-8%	-20%	3%	-37%
Change in total GHG, versus Future Baseline Case	**-**	**-8%**	**-23%**	**3%**	**-36%**
Change in package delivery GHG, versus base year	165%	145%	-69%	208%	127%
Change in personal shopping GHG, versus base year	-21%	-28%	-37%	-19%	-50%
Change in total GHG, versus base year	-19%	-25%	-38%	-16%	-48%

Source: CPCS analysis

a. Largest impact drivers

Figure 65 profiles the impacts of each of the change factors individually. While there may be variability in how plausible it would be for these “partial” changes to materialize independently of other changes, this analysis is of help in identifying the mechanisms that have the largest potential benefits for reducing VMT and GHG emissions.

Figure 65: Summary of impacts of individual change factors assessed

Scenario	Individual change factor	Delivery VMT	Delivery GHG	Total VMT	Total GHG
1	Due to more urbanized population growth distribution	-0.6%	-0.6%	-0.1%	-0.1%
1	Due to lower delivery vehicle VMT impact (-21%) in Ring 1 as a result of parcel microhubs	-7%	-7%	-0.1%	-0.3%
1	Due to lower auto mode share for personal shopping trips (72% from 77%) in Ring 1 from urbanization effects	-	-	-1.8%	-1.8%
1	Due to shorter trip length of personal shopping trips (-20%) in Ring 1 from urbanization effects	-	-	-6%	-6%
2	Due to higher e-commerce sales growth (+60%)	+44%	+44%	+2.8%	+3.8%
2	Due to lower delivery vehicle VMT impact from reducing reliance on Flex-type vehicles by 50%	-24%	-24%	-0.5%	-1.1%
2	Due to full electrification of parcel carrier delivery fleets (vans, but not Flex-type vehicles)	-	-78%	-	-3.5%
2	Due to reduction of personal shopping trips (down 16% from base year, versus up 8% in Future Baseline Case)	-	-	-22%	-21%
3	Due to higher e-commerce sales growth (+23%) and higher non-traditional shopping trips (+350%)	+16%	+16%	+11%	+11%
3	Due to reduction of personal shopping trips (down 1% from base year, versus up 8% in Future Baseline Case)	-	-	-8%	-8%
4	Due to lower delivery vehicle VMT impact (-10%) resulting from more efficient ordering practices	-10%	-10%	-0.2%	-0.4%
4	Due to reduction of personal shopping trips (-5%) from more behavioral shift	-	-	-5%	-5%
4	Due to reduction of auto mode share for personal shopping trips (-15%) from behavioral shift	-	-	-3.1%	-3.0%
4	Due to shorter trip length of personal shopping trips (-10%) from behavioral shift	-	-	-10%	-10%
4	Due to increased adoption of ZEVs for passenger vehicles (50% ZEVs, from 35%)	-	-5%	-	-23%

Source: CPCS analysis. Note: all comparisons are to the 2050 Future Baseline Case, unless otherwise specified

As the table shows, the greatest regional VMT and GHG reductions are obtained from:

- A reduction in personal shopping trips. These are a large contributor to both vehicle miles traveled and emissions. To the extent that these trips can be substituted, including through greater use of e-commerce, this would have the largest impact of all measures.
- Adoption of ZEVs among the passenger vehicle fleet. To the extent that ZEVs can be substituted for gasoline or diesel-powered vehicles, this would have a significant benefit for GHG emissions reduction (though no impact on VMT).
- Shorter trip lengths for personal shopping trips. This suggests that finding substitutes for the longest trips, in particular (including through e-commerce), or finding ways to increase “trip chaining” can be beneficial for reducing regional VMT and GHG impacts.

In addition, there are several measures that would have a big impact on delivery impacts in particular:

- Electrifying carrier delivery fleets would have a massive benefit for reducing delivery vehicle GHGs (although no impact on VMT)
- Reducing the use of personal vehicles (Flex-type vehicles) for parcel delivery would have a significant positive impact on reducing both VMT and GHGs associated with delivery operations.
- In addition, more efficient / less wasteful ordering practices and use of parcel microhubs would offer further opportunities to reduce delivery VMT and emissions.

Appendix E E-Commerce Land Use Terminology

E-Commerce: Buying, selling, and ordering of goods and services using the internet. For purpose of this Part of the Study the scope is limited to primarily consumer goods.

E-Commerce National Hub: Significantly sized facilities positioned to serve the country/across states (generally more than 1M SF).

E-Commerce Regional Hub: facilities positioned to primarily serve a Metropolitan Area.

E-Commerce stages[59]:

First-mile. When consumer goods arrive in a region, their first stage of transportation is known as the "first-mile." Traditionally, goods arriving by sea, rail, truck or air are transported to warehouses, then to retail stores for purchase.

Middle-mile. This stage of the transport system entails the movement of goods from a warehouse/distribution center to a fulfillment center or retail store. This leg of the journey moves the product closer to the end destination, without delivering it to the customer. The definition of the middle-mile is expanding with the rise of e-commerce and expectations of rapid home delivery. This has evolved in recent years to be more urbanized, with new route options from warehouses to microhub fulfillment (dark stores) or distribution centers, as well as from one store to another to fulfill "click-and-collect" orders.

Last-mile. The last-mile is delivery to the end consumer. When ordered online, delivery is typically completed by corporate operators or gig-delivery workers via courier vans, e-cargo bikes or other means. The last-mile stage may be:

a) co-located with another function within the supply chain, or

b) co-located with another use such as a multi-family building, grocery store, or

c) a standalone delivery center or facility.

E-Commerce Models: Overall the distinction between retail and industrial (warehouse/distribution/at times manufacturing) is blending.

Bricks-and-mortar retailer sells items on-line. For example Target, Walmart, Home Depot, and Nordstrom sell products online and ship to customer or make available for pick up. Orders may be fulfilled in stores or directly from an e-commerce warehouse or sortation center. Stores and distribution centers have been strategically placed near households and key markets. (*By relying on Walmart's expansive network of last-mile delivery drivers, Home Depot can continue to expand its ship-from-store capability and push to reach its goal of next-day delivery to 90 percent of the US population[60].)*

On-line E-commerce, may have strategic retail experience locations: Historically Amazon was a fully on-line E-commerce company, but with the purchase of Whole Foods, partnership with Kohl's for returns, experiments with Amazon Fresh and Amazon Go[61] (opening and closing in recent years), sponsoring non-profit community events (Somali Week[62]), is looking for more direct consumer connections. Another example is the on-line store, Warby Parker, is opening stores in busy locations such as airports and urban neighborhoods.

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59 NAIOP, How E-Commerce Affects Urban Industrial Lands and Transportation Systems, Eric Aderneck and Russell Whitehead, Winter 2022/2023 Issue

60 The Home Depot teams up with Walmart to expand same-day and next-day delivery," The Home Depot, October 6, 2021.

61 OmniTalk, https://omnitalk.blog/2023/06/23/amazon-go-closures-continue/

62 Amazon Sponsor, https://www.somaliweek.org/

E-commerce logistics and support: Companies that support the e-commerce process on behalf of companies and consumers – services range from on-line transactions, market research, payments, inventory management, etc. Companies such as eBay, Etsy, Meta, Shopify provide a platform and generally do not supply their own inventory. Third-party companies have warehousing and transportation space to meet the needs of smaller retailers and manufacturers.

E-commerce shipping and receiving: FedEx, UPS, and other third-party delivery companies move goods resulting in the need for distribution space to sort, load and the temporarily store goods on behalf of companies and consumers. Movement of parcels through these facilities is quick and long-term storage of goods is not provided at these facilities.

Brand Direct Sales: A company provides items to retail stores and direct to consumer via e-commerce. Example of Nike shoes – major distribution center in Memphis sends to customers directly and also sends inventory to brick-and-mortar locations. The location is based upon distribution center costs and efficient nationwide transportation access. Smaller companies may have offices near a warehouse that sends out products, example of Quality Bike Products, a local Minnesota bike parts distribution center that ships parts directly to the consumer and also to other bike shops nationwide.

Clear/Clear Height. Height of the building's interior space.

Retail/Industrial Mixed-use. Convergence, or line blurring, between traditional retail and industrial uses.

Multi-channel business. A multichannel retailing business I the process of using multiple channels for selling similar products across different platforms. The platforms may be online and offline, brick and mortar store, online store, mobile store, etc.

Multi-functional E-Commerce Facilities or Campus. A building or collection of buildings that includes more than one component of the supply chain. This report focuses on the co-location of last-mile functions with warehouse/distribution/fulfillment/sortation centers.

Multi-User. A facility that holds goods and products of different companies (e.g. a 100,000 SF facility leases 50,000 SF to two users).

Last-mile Facility Types. The following definitions and/or descriptions of the last-mile facility types are based on general trends within the industry. There are two categories of last-mile facility types 1) parcels are delivered from the facility to the consumer's home or business; or 2) parcels may be delivered from the facility to the consumer OR the consumer may pick-up their parcels from the facility.

Figure 66: Last-mile facility types

Last-mile facilities that deliver (no customer pick-up)	**Description**
Delivery Center	Large warehouse facility that prepares parcels for delivery to consumers. Facilities are often co-located with sortation or fulfillment centers.
Micro-warehouse	Small warehouse facilities that may be located in non-traditional buildings and/or in non-industrial areas that enable fast, seamless deliveries that are primarily last-mile deliveries. The smaller footprint and location may lead to greater diversity in delivery mode choice to the end consumer, including cargo bikes, personal vehicles, EV vans, etc.
Micro-distribution Center	Smaller footprint warehouse facilities that include co-location of storage and/or sortation with last-mile delivery.

Last-mile facilities that deliver (no customer pick-up)	**Description**
	The smaller footprint and location may lead to greater diversity in delivery mode choice to the end consumer, including cargo bikes, personal vehicles, EV vans, etc.
Third-Party Delivery Location	These locations include FedEx, UPS, and other shipping/delivery companies. These facilities do not store products in a warehouse, it is a pass through to delivery.
Dark Stores	Warehouse or storage functions located in a vacant or underutilized retail store or location. These facilities generally do not permit pick-up from the consumer, but delivery mode may be more diverse because of their location in traditional retail and urban locations.

Last-mile facilities that deliver OR customer pick-up	**Description**
Microhub or Hub	A micro-consolidation logistics facility set near a final delivery point. Functions as a logistics space that links warehouse centers to final delivery points. If properly located, they can allow for a variety of delivery modes including walk-up, e-cargo bike, and cars/vans for last-mile deliveries.
Automated Parcel Locker (APL)	
Retail hub	
Online pick-up or drive-up	

Source: SHC Analysis

Warehouse/Distribution/Fulfillment/Sortation Center Sizes and Facility Types.
The following categories are based upon what is happening in our region; there is not a universal national standard. In National E-Commerce Hubs, like Dallas, a Medium Facility may be 1 Million SF. In Minnesota (including the Twin Cities Metropolitan Area) the standards are approximately:

- **Small Facility.** Typically less than 100,000 SF. This designation includes last-mile facilities such as microwarehouses or microhubs.
- **Medium Facility.** Warehouse/Distribution Center: 100,000 SF to 200,000 SF
“In general, new industrial buildings in the Twin Cities market tend to fall in the ranges of 120,000 to 200,000 square feet and 28-to 32-foot clear.” According to industry experts as the “sweet spot” as it correlates to the Twin Cities position in the national and global supply chain.
- **Large Facility/Campus**. Major Warehouse/Distribution Center: 200,000 SF +
In the Twin Cities we have a handful of 1M SF facilities, but industry experts do not anticipate many additional facilities of this size.

Regardless of size, industry experts and research reference the following types of distribution and warehousing:

- **Bulk Distribution Warehouse.** A building that is primarily used for storage of goods that will be delivered to the end consumer, whether it is an individual household or business. Very little to no office, clear height of 32’ -40’, many loading docs and often speed bays where fork lifts can easily maneuver (Most new construction in the Twin Cities region is bulk distribution).
- **Office Showroom**. A warehouse building with 30% office, clear heights of 14’-18’, higher end finishes to provide a nice image for the tenant.

- **Office Warehouse**. A building with less than 30% office, clear heights of 18’-24’, more doc loading than an office showroom, modest to no interior finishes, typically no air conditioning.
- **Sortation Center**. A building with the function of preparing/assembling goods for distribution.
- **Fulfillment Center**. A building where inventory is held and where product is picked once an order is made.
- **Distribution Center**. A building where packages are consolidated for final distribution to homes and businesses.
- **Manufacturing/light industrial storage**. A building that holds manufacturing materials or finished products for a manufacturing/light industrial user. The Twin Cities has robust manufacturing and life science industries that order, store and produce products to export.

Appendix F E-Commerce Siting and Location Planning Themes

As the e-commerce industry evolves it will be important for the Twin Cities region to be flexible, responsive, and proactive to remain competitive. The research demonstrates that e-commerce operators are becoming more sophisticated and new technologies are constantly emerging. This evolution in the industry will make it increasingly difficult for local municipalities and regulatory agencies to keep up, since policy changes and adoption take time. While many aspects of the e-commerce industry are rapidly evolving and making it difficult to know where it is headed, others are more apparent, especially as they relate to location and development decisions. The e-commerce siting and location themes are what we call “high risers,” meaning they are concepts or considerations that rise to the top in terms of their significance and their consistency in direction moving forward.

These “high riser” themes include considerations for potential policy, action or strategic statements for regional and/or local land use and transportation plans. The suggestions are grouped under five “high riser” themes:

THEME 1: Siting of e-commerce facility types (warehouse, distribution, fulfillment, sortation center and last-mile) is based on population density, land costs, available labor and transportation access modes.

- Municipalities should account for e-commerce facilities within their land use plans using their Community Designation as support for e-commerce facility function within the supply chain. Community Designations provide future density expectations that can be used to help identify the type of e-commerce facility that may be supported and/or demanded within an area.
- Met Council population, household and employment projections could be used by communities to forecast where gaps in the supply chain may emerge. Promoting co-location of warehouse/distribution/fulfillment/sortation centers and last-mile facilities in proximity to high growth areas will reduce time and miles between e-commerce facilities and delivery destinations.
- The Twin Cities region should consider pilot microhubs in areas with high population and household density that are planned to grow over the planning period.
- Microhubs should be co-located in modal transportation hubs where mode choice is available or planned.

THEME 2: Plan for the convergence of industrial and retail land uses as retailers continue to co-locate their warehouse/distribution/mini-fulfillment centers with their brick-and-mortar locations.

- Municipalities should plan for the convergence of industrial and retail land uses into a single development or parcel area. This convergence could be reflected in a new land use designation within their Comprehensive Plans.
- Estimated ratios of the mix of industrial (warehouse) uses and retail uses should be established for mixed Retail/Industrial Land Use designations. For example, some areas in a community may be better suited for dominant light industrial (warehouse) e-commerce use with a small retail footprint, while others may be more suitable for a larger retail footprint with limited light industrial (warehouse) uses.

- Plan for a mix of transportation needs when siting and/or planning land use designations for a specific area. The convergence of these uses will create demand for semi-truck, box trucks, vans, delivery vehicles and personal vehicles all contained in a single site.

THEME 3: Innovations in transportation such as the electrification of vehicles will impact land use and development decisions and may provide the greatest opportunities to reduce greenhouse gases in the industry.

- Municipalities should plan for supporting a network of charging stations on major roadways, especially where critical connections exist for e-commerce users.
- Consideration should be given to how charging station locations will support a more robust inventory of electric vehicles. From semi-trucks and box trucks to vans and personal vehicles, the electrification of vehicles will only be supported if the infrastructure is available.
- Consideration of where vehicle staging and/or queuing areas should be incorporated into land use and transportation plans. These areas could be equipped with charging infrastructure to assist with more efficient flow of traffic.
- Evaluate the use of multi-modal hubs (e.g. e-bikes and scooters) co-located with delivery microhubs to create a more efficient system in areas that have adequate density to support the use.
- Municipalities should keep up to date on the demands and needs of e-commerce utilities, including increased power requirements related to charging vehicles on site.

  One example is a strategic partnership between Amazon and Rivian where more than 5,000 electric vehicle (EV) vans are in operation for Amazon’s parcel delivery. The EV vans are not in the Twin Cities region yet, but Amazon plans to continue expansion of its EV van fleet in the coming years. Other examples include Volvo, Tesla, and other large scale truck manufacturers announcing new electric vehicle models.

Figure: An electric truck charging station

E-commerce companies are moving towards electric vehicles and truck companies are introducing new electric truck models. Electric vehicle infrastructure will be necessary to reduce emissions and keep goods moving in and out of our region.

THEME 4: As e-commerce grows, truck and vehicle storage, parking, and queuing space demands will continue to increase, impacting land use and development decisions.

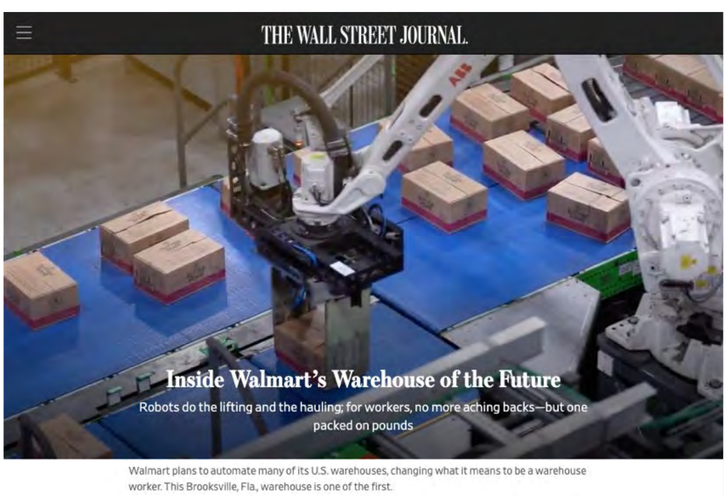
- E-commerce demands multi-modal facilities and municipalities should plan for increased demands for parking of all vehicle types from semi-trucks to electric cargo bikes.
- Lack of available parking options may lead to increased vehicle miles traveled (VMT) for all modes. (for example, lack of truck parking for deliveries leads to semi-trucks excessively idling and circling for a parking space; likewise, facilities that have insufficient parking for delivery vans may require off-site parking solutions creating an extra trip.)
- Site planning for short-term parking, loading/unloading, queuing and vehicle storage should correspond to the facility types within the supply chain.

  For example, the City of Eagan has indicated that the Amazon sortation and delivery center has inadequate parking for delivery vans which must be stored off-site as a result.

THEME 5: Facility automation is likely to eventually impact e-commerce facility siting and land use decisions.

- Communities in suburban or rural areas should consider that e-commerce facility automation may allow for siting in more remote locations that lack a significant labor force. This may provide opportunities for better e-commerce services in more exurban/rural areas of the Twin Cities region.
- Automation will support more innovation within facilities and may provide opportunities for adaptive reuse. Municipalities may consider where obsolete and underutilized parcels exist to support adaptive reuse and redevelopment.

Figure: One of Walmart's first automatic warehouses in Brooksville



Wall Street Journal, July 2023 Article, features one of Walmart's first automatic warehouses in Brooksville, Florida. Video of the automation process available at https://www.wsj.com/articles/inside-walmarts-warehouse-of-the-future-6f17d17

- Be aware that automation may lead e-commerce operators to think about operations on a regional scale leading to different site selection metrics and/or criteria.

For example, a Walmart vertical warehouse in Canada provides 66-feet of vertical racking that is made possible because of internal automation. In addition to automation to access goods on high shelves, automation within warehouses is tackling the scanning, sorting and packing of parcels with less human labor.

Appendix G Twin Cities Region Development Patterns Relative to E-Commerce Facilities

There is a strong correlation between population density, socio-economic characteristics, and facility type, function and location that is demonstrated by existing e-commerce development patterns. The supporting maps in this section were developed to demonstrate the relationships between regional land use and development patterns and e-commerce facility function and types.

A. Density and capacity of land impacts facility function and type.

Using the Metropolitan Council's Draft 2050 Community Designations is a way to organize and categorize the types of facilities that are found in our region. The following table provides a summary of e-commerce facility types and where the types of facilities most common to the draft 2050 Community Designations.

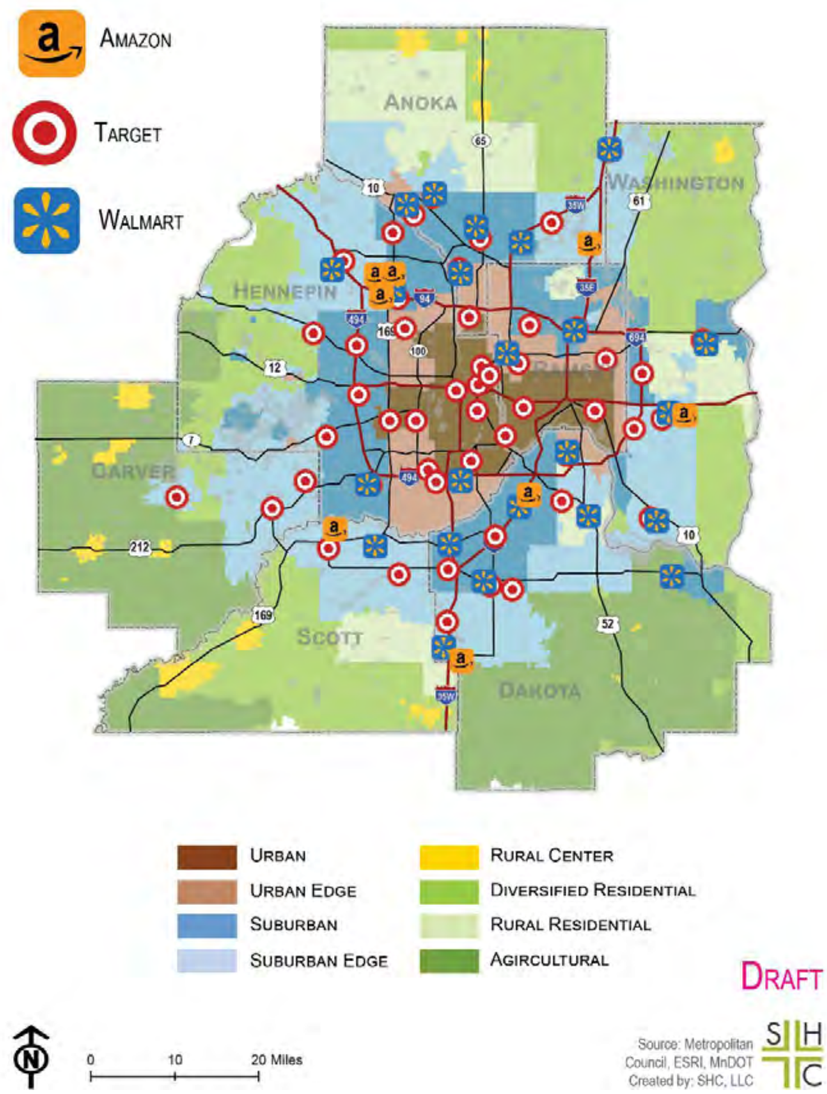
Figure 67: Correlation of Existing E-Commerce Facility Types with Draft 2050 Community Designations

	Community Designation	Existing E-Commerce Facility Types	Average Facility Sizes	Examples
Urban Service Area	Urban	Microhubs, microwarehouses, retail hubs, online pick-up, retail bricks-and-mortar, automated parcel lockers	100 SF to less than 50,000 SF[a]	Automated Parcel Lockers at Whole Foods Prime Now Hub (Minneapolis) Target Pickup from retail locations
Urban Service Area	Urban Edge	Microhubs, delivery centers, sortation centers, last-mile facilities, automated parcel lockers	100,000 SF +/-	Target Sortation Facility (on edge of urban/urban edge)
Urban Service Area	Suburban	Sortation Centers, last-mile delivery centers, retail hubs, online pick-up, retail brick-and-mortar, third-party e-commerce delivery (UPS/FedEx), Automated Parcel Lockers (APLs)[b]	100,000 SF – 300,000 SF	Amazon Sortation and Delivery Center FedEx regional hub Home Depot Automated Parcel Locker pickup
Urban Service Area	Suburban Edge	Fulfillment center, sortation center, last-mile delivery center	200,000 -300,000 SF	Amazon Fulfillment Center Amazon Sortation and Delivery Center
Rural Service Area	Rural Center	Retail brick-and-mortar (Target/Walmart)	less than 50,000 SF[a]	Pick-up locations from existing retailers
Rural Service Area	Rural Residential	Retail brick-and-mortar (Target/Walmart)	less than 50,000 SF[a]	Pick-up locations from existing retailers
Rural Service Area	Diversified Rural	None		
Rural Service Area	Agricultural	None		

Source: SHC analysis.
a Retail/Industrial use, warehouse is not more than 50,000 SF of facility footprint.
b Automated Parcel Lockers (APLs) for individual retailers are not categorized as a microhub under the definition since it is generally stocked by the retail operator with existing inventory.

Geographically, this relationship is shown in Figure 68. The map demonstrates that last-mile facilities co-located with larger facilities such as warehouse/fulfillment/distribution/sortation centers are predominantly located in communities with suburban household densities (Amazon) and are less likely to be located in communities with urban densities. This directly correlates with the interview feedback that most co-located facilities require larger contiguous acreages with strong access to both the regional and local road network to support efficient and fast last-mile delivery. Further, interviewees indicated that high land costs including high tax rates contribute to the lack of operator interest in locating such facilities in more urban locations.

Figure 68: Facility Types in the Region and Draft 2050 Community Designations



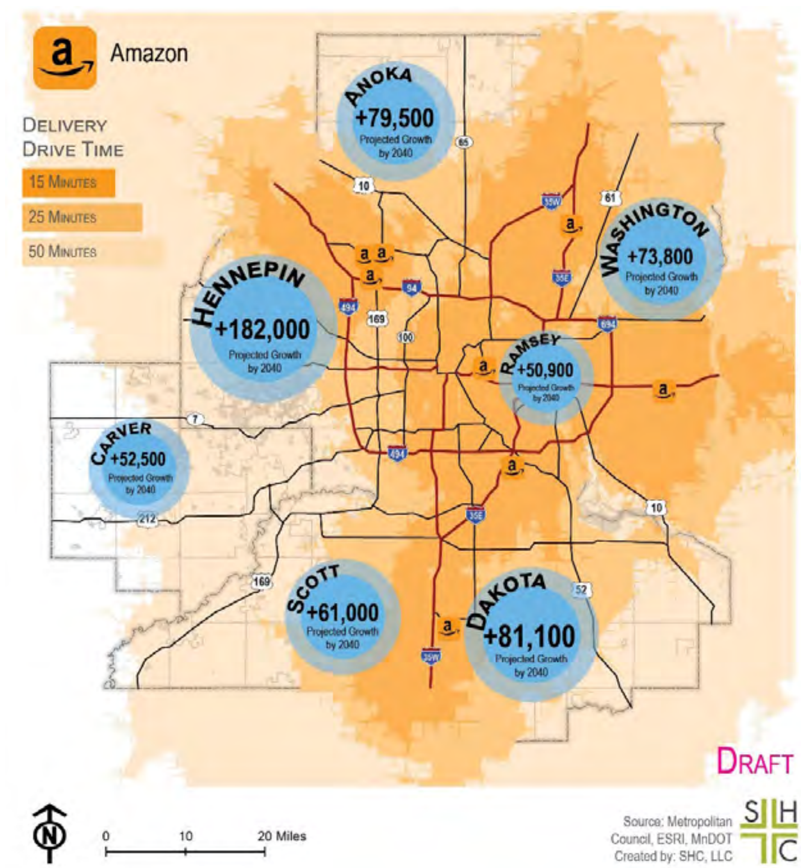
Source: SHC analysis.

Industry experts agreed that as the region grows, development patterns will impact what types and scales of facilities will be needed. For example, some parts of a community may increase in density creating a more compact and walkable area which might necessitate the need for a microhub (i.e., a parcel pick-up/drop off station) near a pocket of multi-family units.

- For example, Figure 69 demonstrates that the southwest quadrant of the Twin Cities region has some of the highest anticipated growth rates, but may not have adequate last-mile facilities in place to meet customer demands. Operators identified a 40-50 minute catchment area in their facility location decisions, but operators recognize that this might not be adequate as customer demand for same-day and fast/quick delivery time increases. For example, if a 25-minute catchment area is used, Amazon's existing last-mile facilities may not adequately cover this part of the metropolitan area. This may indicate a future gap in the last-mile facility catchment area of some operators such as Amazon.

- Creating opportunities for more standalone last-mile facility types such as microhubs or Automated Parcel Locker locations in the region is most likely in areas designated as either Urban or Urban Edge given the current and projected density within these community designations. The closest existing example of this type of facility is the Amazon Prime Now location in Minneapolis that includes both last-mile delivery operations and pick-up opportunities.

Figure 69: Regional Growth Rates and Amazon Delivery Catchment Areas



Source: SHC analysis.

B. Co-located e-commerce facilities that perform multiple functions are most prevalent in Suburban and Suburban Edge Communities.

As described in the National and Regional Trends section, the facility type within the supply chain is less about the size of the facility and more about its function. Increasingly, operators are moving towards co-location of their last-mile operations to increase efficiency and minimize trips between facilities. These facilities are described as multi-functional within the supply chain. An example of this co-located facility type is Amazon's Sortation and Delivery Centers.

- Multi-functional can have a variety of meanings but for this report it generally means that the parcel delivery to consumers (last-mile) is co-located with at least one of the other functions in the facility or campus such as:
    - Receiving goods through freight shipment. This is primarily truck and semi-trailer deliveries of bulk products and goods.
    - Dispatching goods through semi-truck, small truck, van, and cars.
    - Sortation of goods.
    - Storage (warehouse) of goods prior to delivery.
- Current multi-functional facilities are predominantly Amazon, while e-commerce shipping multi-functional facilities are predominantly UPS and FedEx.
- The multi-functional warehouse distribution and sortation facilities are predominantly located in communities that have the Metropolitan Council's draft 2050 Community Designation "Suburban." This aligns with several key metrics identified by the operators including: population densities of these communities, distinct separation of land use patterns, proximity to the I-494/694 loop and access (though somewhat limited) to public transit to connect facilities with the labor force.
    - One exception is the new Target Sortation facility that is located within Minneapolis in the Mid-City Industrial Area, which has access to I-35W and State Highway 280. Competition for large tracts of land is significant, and only small pockets of industrial land are typically available. According to industry experts, it is nearly impossible to find land of suitable size in the Urban and Urban Edge communities, and therefore it easier and more cost effective to find land in Suburban and Suburban Edge communities.

Figure: Target Sortation Facility in Minneapolis, MN

    - Using time as the metric to establish an operators' last-mile catchment area versus using a mileage metric has the potential to impact how many facilities the region needs today and into the future. For example, if one part of the region expands significantly (increase in density or households.) then the delivery catchment area, or delivery-shed area, may contract and additional facilities may be needed. As opposed to using:
- Sophisticated logistics software is used to create parcel delivery routes, since labor and transportation costs (including VMT) are significant.

- Data on time spent driving delivery vehicles aligns with interview statements and research that customers are demanding next-day, same day, and two-hour delivery windows. There are no indications that this expectation will change.
- Given the Twin Cities' population distribution, Amazon, Target, and Walmart have existing facilities that are well positioned for delivering online orders within the next-day, same-day, or 2-hour window. New locations will likely be correlated with high growth areas and/or areas with projected increases in household density.
- Operators indicated that currently a 40-50 minute delivery catchment area is optimum for last-mile facility locations in the Twin Cities. In the Twin Cities region this allows products to move significant distances (miles) as compared to more densely populated metropolitan areas with high ratings for traffic congestion (Chicago, New York, Miami, Los Angeles, San Francisco, Houston, Atlanta, Austin, and Seattle). If congestion were to increase drastically in the Twin City area, this might have a significant impact on the number, type, scale and location of last-mile facilities needed in the future to meet customer expectations.
    - Example 1: If congestion increases significantly in our urban neighborhoods there may be growing demand for more standalone last-mile facilities such as microhubs.
    - Example 2: If congestion increases in the southwest metro area due to increased development of new households, a new Amazon sortation/delivery center may be needed to meet last-mile delivery expectations.

Appendix H Challenges in Site Planning for E-Commerce Facilities

Through this study's interview process, several developers indicated that cities and regulatory agencies have introduced policies into land use plans and zoning ordinances that are adversely impacting the development potential for multi-functional e-commerce facilities in prime locations. This was particularly noted with respect to larger multi-functional and co-located facilities within urban and/or suburban areas. The developers indicated that these policies are impacting development nationwide, but their comments were primarily about the Twin Cities region. Some of the specific land use policy and zoning issues mentioned are highlighted below.

- Some cities require minimum Floor Area Ratios (FAR) that reduce the space available for truck/semi-trailer parking and staging. Policies that require large FARs often make sites undesirable because there simply is not enough space for the exterior operational needs. Municipalities often establish these policies with good intentions hoping to increase their tax base through higher assessed values for larger structures or to reduce truck traffic and conflicts with other users. Further study of the impact to e-commerce is likely needed to better understand the true impact to the industry; however, there is a perception, at least, that FAR is especially impacting development sites for co-located multi-functional facilities.
- E-commerce warehouse and distribution centers are primarily used for warehousing, storage, and sortation functions. Cities have enacted minimum dedicated office area requirements within industrial zoning that are not correlated to how e-commerce uses function and operate within the space. This increases costs, and results in spaces that are not used consistent with policy. The purpose of office area minimums aims to increase the number of employees per square foot in a facility, but may not achieve the desired goal as facility offices often sit empty. Currently, the e-commerce industry employs more people per square foot than traditional warehouse facilities, but they do not demand office space. This creates a mismatch between the policy and the e-commerce operational function.
- Developers indicated that there is a shortage of industrial land uses and space, especially in desirable submarket areas. This shortage is exacerbated by the fact that cities are categorizing e-commerce similarly to all other industrial uses, but e-commerce users require more space. As indicated by the National Association for Industrial and Office Parks (NAIOP), e-commerce industrial space requires as much as three times more industrial space than other modes of distribution in the absence of advanced technologies. This is because the warehouses used in e-commerce fulfillment must provide retailers, as well as third party logistics companies with whom they work, with sufficient space to pick, pack, ship and process returns for a larger assortment of goods than are typically held on the shelves of retail stores.[63]
- Automation will make warehouse/distribution centers more viable in areas further out from the urban core and many municipal land use plans do not account for this transition. As automation becomes more prevalent, the number of jobs in distribution/warehouse facilities is anticipated to continue to decrease and it may become less important to be located near population centers. Likewise, automation may make tighter urban sites viable by allowing for vertical warehousing/distribution space. Current policies do not align with this reality and future plans will need to consider how land uses may be impacted by the potential shift to automation.
- E-commerce developers indicated that there is a "style" of building that is expected by the industry, and that several municipalities have introduced policies that require certain building material

[63] NAIOP, How E-Commerce Affects Urban Industrial Lands and Transportation Systems, Eric Aderneck and Russell Whitehead, Winter 2022/2023 Issue

standards that do not align with the industry's expectation or facility function. The policies are oftentimes targeted at larger multi-functional facilities, but also impact last-mile, co-located facilities such as micro-distribution centers and micro-warehouses. These performance standards tend to be more robust in areas of greater population density that have more compact development, which further compounds the price problem of developing facilities closer to urban and compact suburban centers.

Appendix I Trends in Retail Closures and Adaptive Reuse

A. Introduction

Traditional bricks-and-mortar retail stores have been impacted by shifts in consumer behavior, especially the shift to online purchases that has been happening since the early 2000s. This impact, along with other changes in consumer demographics, behaviors and choices, led to what was referred to as the "Retail Apocalypse" of 2017. As stated in The Atlantic, "several trends – including the rise of e-commerce, the over-supply of malls, and the surprising effects of a restaurant renaissance – have conspired to change the face of American shopping.[64]" Store closures, bankruptcy and restructuring of the retail industry has been happening for years, well before the pandemic hit. But the pandemic had a seismic shift in pushing many consumers to online purchases to purchase goods, even those who had never or rarely purchased goods online before. Post pandemic, more people are going back to retail stores for in-person shopping, but many have converted and now complete more of their purchases online than ever before. This trend is only expected to grow and continue, and its effect on the retail industry is apparent today as retailers shift their perspectives and increasingly seek ways to compete in the e-commerce industry.

While retail bricks-and-mortar stores have recovered in some areas, there remain several vacant storefronts that are not quickly being replaced. Examples of how some of these shuttered facilities have been reused and redeveloped are provided in this section. Other retailers have decided to compete and have entered the e-commerce market sector converting their operations to not only meet in-person retail demands but to compete with online sales. The following analysis and research looks at both of these scenarios and considers how such changes in the industry might present themselves in the Twin Cities region in the coming years.

B. Research and Analysis

According to Business Insider, as of July 2023 nearly 2,400 retail stores are closing in 2023[65]. This number is far from the staggering numbers of closures during the "retail apocalypse" (over 12,000 stores closed in 2017) but still represents significant changes and shifts in the industry. Since the height of the pandemic, retailers have struggled to bring consumers back to traditional bricks-and-mortar locations and malls and that impact can be seen throughout the country. E-commerce is playing a significant role in the restructuring and reorganization as many retailers reduce their real estate footprints, and if not filing for bankruptcy, are looking for ways to compete online. The closures of the past few years have left vacant malls, strip malls and other big box locations that oftentimes are in prime locations near high population centers with numerous households.

1. Retail conversions remain challenging, but do happen if the site characteristics are desirable.

Nationally, functionally obsolete big-box retail spaces and shuttered shopping centers are becoming more attractive for conversion and reuse as last-mile distribution facilities. The building size, site acreage, and relatively underdeveloped land area make them prime redevelopment opportunities for e-commerce warehousing and distribution centers that are looking for locations within proximity to high density population centers and households. One property type, shopping malls, have been hit especially hard from all the retail store closers. As reference, *"In the 1980s, there were about 2,500 shopping malls in the U.S. Today, only about 700 remain, and many industry analysts believe that hundreds more are likely to close within the next decade."[66]* Shopping

[64] What in the world is causing the retail meltdown of 2017," Derek Thompson, the Atlantic, April 10, 2017.
[65] Nearly 2,400 stores are closing across the US in 2023. Here's the full list. Dominick Reuter, Business Insider, Updated July 20, 2023.
[66] 2023 APA Trend Report

malls are almost all located in high-population suburban or urban locations, and they may be prime for e-commerce conversion over the next several years. A couple of examples are provided:

- *Middle Georgia Industrial Park*. The Westgate Shopping Center was constructed in 1961 and was redeveloped in the mid-1990s into a retail power center which is an outdoor shopping mall including a few big box stores with small retailers and restaurants. After less than 20 years the mall was struggling and was largely vacant. The property was well positioned to be converted to a warehouse and distribution center because it was large enough with over 400,000 square feet, had 18-24 foot ceiling heights[67], has proximity to Interstates, and there was a surplus of land available for truck parking.

  Figure: Middle Georgia Industrial Park after Conversion from Shopping Center

- *Rustic Hills North Shopping Center, Colorado Springs, CO.* The Rustic Hills North Shopping Center is more than 220,000 square feet and is undergoing a conversion from a retail *shopping* center to an industrial facility. The property was originally constructed as a grocer-anchored center and was successful for more than 30 years. Once the grocer left the center, other tenants followed and it became largely vacant. The conversion to industrial uses is possible because the spaces are conducive to smaller industrial and manufacturing users that will accept 15-foot and 16-foot ceilings. The property is located on a heavily travelled thoroughfare in a growing area where industrial land and properties are in short supply.

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[67] Note that while the industry prefers clear heights in excess of 30-feet, most referenced that in optimum locations a minimum is 20-feet given the current standards.

Figure: Rendering of Retail Conversion to Loading Docks

a. *Lessons Learned from Retail Conversions through Adaptive Reuse.*

Conversions of retail shopping centers and big box retail stores to e-commerce facilities are often met with neighborhood and municipal opposition. As stated within the National Association for Industrial and Office Parks report, “People often oppose the development of distribution centers near their neighborhoods because they think it is all about 53-foot trailers coming in and out all day. They need to be [shown] what different types of distribution look like. A facility 30 miles out of town is going to operate differently than a last-mile facility. Last-mile distribution facilities may also be the best option for a property when it no longer makes sense for any type of retail.[68]” The report further details that highest-and-best use analysis must be completed to truly determine whether conversion of a retail location to industrial use is truly viable because conversion is expensive and not a straight path towards success. Additionally, conversions oftentimes require façade improvements in addition to internal improvements to make buildings look like distribution facilities, rather than their former life as a retail building.

b. *Other Notable Trends in Adaptive Reuse*

While some adaptive reuse is occurring within the marketplace, it has been slow to catch on in the Twin Cities region because land is available at the edges making greenfield development more economically viable. However, even with the availability of land around the edges, developers indicated that there is interest in locating facilities closer to the core by some operators and are seeking spaces that are 50,000 to 100,000 square feet. Many shuttered big-box retail locations are in this size range, and if vacant long enough, may become economically viable as a distribution center or dark store. As mentioned previously, the national emergence of dark stores has begun and cities are challenged to figure out how they fit within retail zoning. While this trend may not be dominating the Twin Cities region today, it is something to consider as the e-commerce industry continues to grow.

Locally, Amazon announced plans to open six (6) Amazon Fresh retail locations between 2020 and 2022 in the Twin Cities. In early 2023 they pulled out after the stores were constructed. Now the building shells are sitting vacant. Not a true retail closure, since they never opened, but it is worth noting that this occurred over the past few years in our market. The stores are built in suburban locations with proximity to the I-494/694 loop, and fairly high suburban densities. From

68 New Places and New Spaces for E-commerce Distribution: Three Strategies for Bringing Industrial and Retail Real Estate Closer Together. Dustin Read, PhD/JD, NAIOP June 2022.

a site selection perspective, the locations seem ideal to bring the concept to our market. But for unknown reasons, they decided not to open and now each approximately 40,000 SF store are sitting on fully developed sites - vacant. It is unknown how these buildings and sites will eventually be used, but it is clear that Amazon does not plan to open an Amazon Fresh location in the Twin Cities region in the near future.

2. Retail and e-commerce distribution space is converging, creating the new land use/development type "Industrial/Retail Mixed Use."

The shift to e-commerce and online shopping has significantly changed how existing bricks-and-mortar retailers are doing business. To compete in the e-commerce market space, retailers are investing significant money into creating online platforms that offer same-day pickup and delivery of their goods. This co-mingling of retail and industrial uses is a deliberate progression by retailers to compete with Amazon which dominates the e-commerce sector. Retailers have existing land and real estate assets that are in optimal locations to capitalize on nearby households and populations with desirable metrics such as adequate density, median household income, and disposable income#.

The integration of the retail and industrial uses into one property or structure can result in significant site and land use impacts including access, parking, loading/unloading docks, or structural changes. Retailers are adding more fulfillment and storage spaces to their existing footprints and are reducing their retail footprints in some cases. An example of this shift in retail format is Target, a traditional bricks-and-mortar retailer, who announced in late 2022 that it was unrolling a new store format for new locations that includes, "*reimagined store design and larger store footprint that better supports our same day services…"* and the new format will "offer customers more merchandise options, including an expanded grocery area, and provide five times the amount of backroom fulfillment space.[69]"

"*The rise of e-commerce is poised to dramatically alter the urban landscape in many communities, by such means as shrinking the footprint of brick-and-mortar retail, expanding warehousing, increasing delivery vehicle traffic, and increasing the commercial use of the curbside and sidewalks."*

- CTS The Future of E-commerce

Target is not the only retailer to jump on this trend, with many bricks-and-mortar retailers announcing some store closures while others use existing retail space as quasi-fulfillment space for their goods. As more retailers adopt this operational format there will likely be impacts to how the spaces function and feel within a community or neighborhood. For example, some retail bricks and mortar stores are increasing their storage/fulfillment space to more than 50% of their footprints. This changes how the spaces are used, and what types of trips are generated from a facility. But according to industry experts, the shift is necessary for any retailer that wants to remain competitive, because online sales are consuming more of the market share every year.

The following national and local examples of how retail and industrial space are converging into one mixed-use category are provided:

[69] Target's idea of a large store is changing again. Nicole Norfleet, Star Tribune, November 10, 2022.

- As noted above, Target is not only releasing a new store format but they are retrofitting retail stores to include larger 'warehouse' storage areas that are used for pick-up and third-party delivery as their e-commerce business line has expanded. Well before the pandemic Target committed to growing its e-commerce presence when it purchased Shipt for home delivery in 2017 for $550 million. In early 2023, Target pledged to invest another $100 million in its next-day delivery operations. The investment will include the development of new sortation centers as well as more robust storage areas within existing locations. Target's pursuit of this market began well before the COVID 19 pandemic, in 2014 Target's supply chain and merchandising chief stated:

  "By leveraging the store network as fulfillment centers, we can offer faster standard shipping, typically one or two days and provide access to store-only items not previously available from Target.com."[70]

  The evolution of Target, and other retailers, will continue but it is evident that the convergence of these uses is accelerating.

  "Stores like Walmart and Target increasingly use those stores to fulfill online orders…Target stores fulfilled more than 75% of its online orders in the retailers fiscal first quarter of 2021."[71]

  Figure: Target drive-up, pick-up example.

- Walmart is investing heavily in its e-commerce operations, including pilot in-store fulfillment centers. Given its large real estate portfolio, utilizing existing store campuses as fulfillment centers is a way to expand its e-commerce business line. In May of 2023, Walmart opened its second *"Market Fulfillment Center (MFC), an in-store warehouse designed to increase the number of digital orders the retailer can complete each day. It's part of Walmart's ongoing strategic shift toward automation and the use of the existing stores as fulfillment centers."*[72] It is undisclosed how many of the MFCs Walmart intends to construct, but

[70] How Target laid the groundwork for its delivery growth, Heather Lalley, WinSightGroceryBusiness.com
[71]Target Corp.'s ecommerce sales increased 50% in its fiscal first quarter, but stores remained a large part of its digital growth. DigitalCommerce360.com

[72] Walmart opens its 2nd in-store fulfillment center, Heather Lalley, WinSightGroceryBusiness.com

several are in the pipeline. Walmart describes the MFC as a “compact, modular warehouse built within, or added to, a store.”

“Retailers are using their existing assets to build operations that better serve the omnichannel customer. Major players such as Target, Walmart, and Best Buy are using their less productive and excess store space as a competitive advantage to fulfill e-commerce orders from stores. Using stores as fulfillment centers allows retailers to ship from locations closer to customers, which in turn drives down delivery times and cost.”

- McKinnsey

- Whole Foods functions as a retailer/grocery store, as well as a ‘micro’ hub of Amazon activities. This includes Automated Parcel Lockers (APLs), return drop off, etc. Amazon provides third-party home delivery directly from the retail locations.

Appendix J Review of Curbside Management Best Practices in Key Cities

Key Steps in Approach

1. Selected key criteria for the review

2. Developed a long list of cities and programs

3. In addition to the City of Minneapolis, selected two cities for an in-depth review (including one-hour interviews with city staff)

4. Developed summaries for an additional nine cities, covering 13 programs

A. Key Criteria for Program Identification

Figure 70 shows the key criteria used for identifying a list of curbside management programs and policies. These key criteria were selected in collaboration with the Met Council staff to highlight elements that are most relevant for regional planning and policy-making purposes.

Though there are other factors that cities need to consider when planning for and implementing curbside management programs for goods delivery, only the factors depicted in Figure 70 were the focus of this review exercise. Some of these other factors include program costs (such as hardware/software costs, ongoing operation costs, and staff hours), funding sources, utilization of third-party partners/vendors, and the logistical details of implementation (such as training required for staff or timeline for deployment).

Figure 70: Criteria for Curbside Management Policies/Programs Review

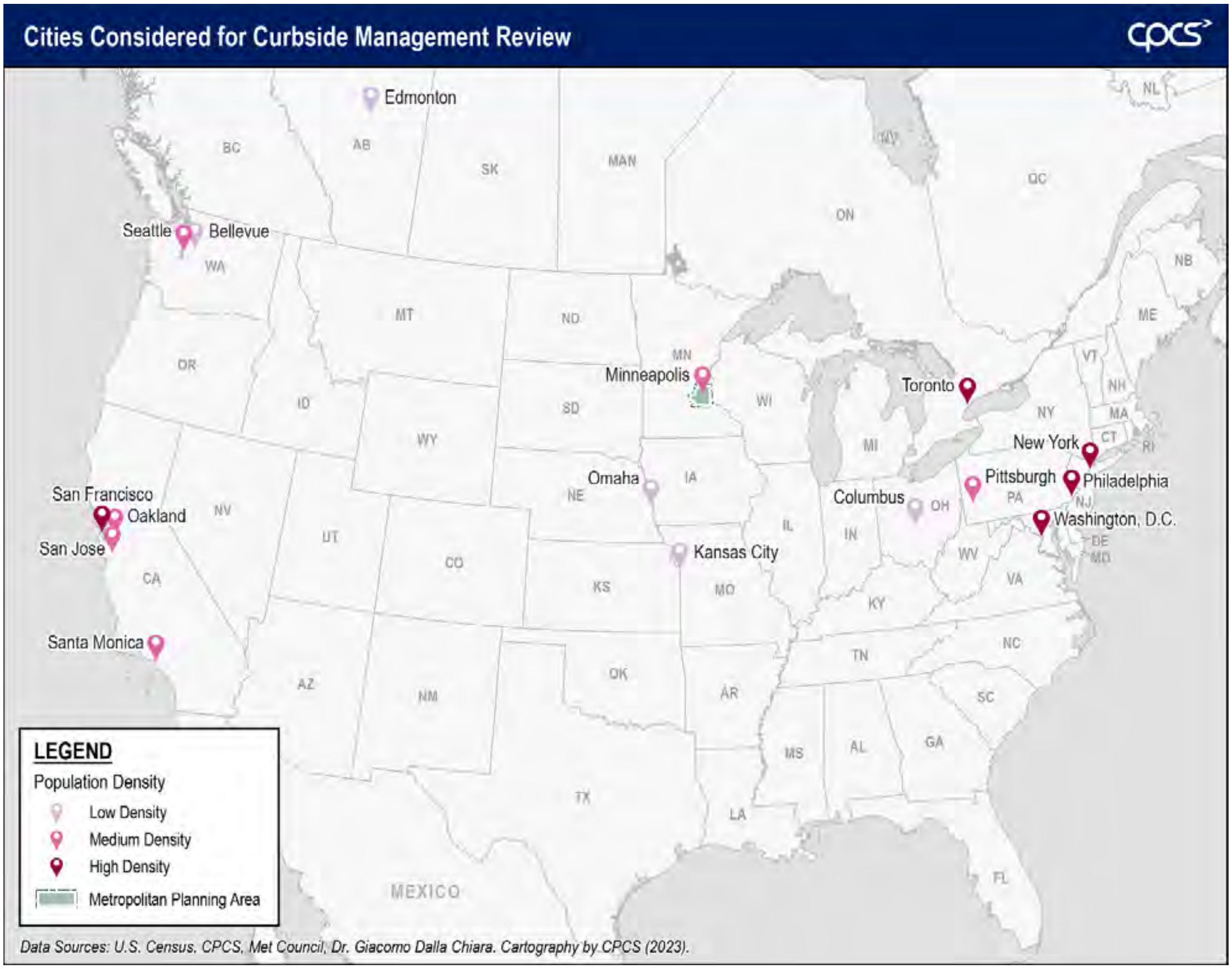
Criterion	Description	Examples
Objectives	What are the objectives or evaluation criteria?	• Improving productivity and efficiency of goods delivery • Reducing VMT and/or emissions • Enhancing safety • Enhancing user satisfaction • Demonstrating feasibility
Program approach	What was the program approach?	• Regulatory/policy: Programs that are implemented through regulatory and enforcement measures or through incorporation with metro planning documents • Pricing/permits: Initiatives using pricing or a permitting system • Technology: Programs driven by the development or incorporation of new technologies, including cameras, license plate readers, curb sensors, and mobile apps
Stage of adoption	How mature is the program or type of project?	• Pilot program/trial/study • Implementation/expansion • Established program • Post-implementation review
Setting	Where is the program implemented?	• Urban arterials; dense urban core • Suburban neighborhoods • Mixed-use districts • Commercial districts

Source: CPCS and Dr. Giacomo Dalla Chiara

B. The Long List of Cities and Programs

A desk review was conducted of existing curbside management programs for goods deliveries across North American cities. In general, metropolitan areas were considered that were a) contextually similar to the Twin Cities, and/or b) notable as best-practice leaders or for certain specific programs that may have relevance to the Twin Cities. Figure 71 shows a map of the cities identified in this review.

Figure 71: Cities Considered for Curbside Management Review



Source: CPCS and Dr. Giacomo Dalla Chiara, 2023

Figure 72 lists the cities by total population, land area, and population density, alongside the Cities of Minneapolis and St. Paul, and the Met Council MPO region. The selected cities span a range of population densities and exhibit varying degrees of sophistication in their curbside management practices. This selection includes high-density cities like New York City (NY) known for their innovative solutions in addressing urban goods delivery challenges at the curbside. Insights from these cities can provide valuable lessons for dense urban areas within the Twin Cities region, particularly in accommodating curbside goods delivery.

Additionally, cities with medium population densities that have implemented curbside management programs for goods delivery, such as Seattle (WA) and Pittsburgh (PA), are included. These cities, bearing similarities to Minneapolis and St. Paul—two of the largest cities in the MPO region—provide pertinent insights into potential initiatives or programs that could be immediately relevant for the Twin Cities in the near term.

Furthermore, cities with lower population densities, like Kansas City (MO), or those serving as suburban communities to larger cities, such as Bellevue (WA), were chosen to inform suburban or exurban communities within the MPO region about relevant best practices.

Figure 72: Population, Land Area, and Population Density of Cities Considered*

Rank	City/Region (State)	Total Population	Area (sq. mi)	Population Density	Population Density Type
1	New York City (NY)	8,804,190	300	29,302	High density
2	San Francisco (CA)	873,891	47	18,629	High density
3	Philadelphia (PA)	1,603,845	134	11,937	High density
4	Toronto (ON, CAN)	2,794,356	243	11,484	High density
5	Washington, DC	689,545	61	11,281	High density
6	Santa Monica (CA)	93,076	16	11,067	High density
7	Seattle (WA)	737,015	84	8,775	Medium density
8	**Minneapolis (MN)**	**429,954**	**54**	**7,962**	Medium density
9	Oakland (CA)	440,646	56	7,879	Medium density
10	San Jose (CA)	1,013,240	180	5,812	Medium density
	St. Paul (MN)	**311,527**	**56**	**5,717**	Medium density
11	Pittsburgh (PA)	302,970	58	5,461	Medium density
12	Bellevue (WA)	151,854	33	4,538	Low density
13	Columbus (OH)	905,748	220	4,110	Low density
14	Omaha (NE)	486,051	127	3,824	Low density
15	Edmonton (AB, CAN)	1,010,899	296	3,420	Low density
	Met Council MPO Area	**3,153,879**	**2,974**	**2,594**	Low density
16	Kansas City (MO)	508,090	319	1,460	Low density

*The Cities of Minneapolis and St. Paul and the MPO area are highlighted in colored cells. The City of St. Paul and the MPO area are not numbered in the Rank column as they do not have an official commercial vehicle-focused curbside management policy/program.

Source: CPCS and Dr. Giacomo Dalla Chiara analysis of 2020 Census Demographic Data[73], 2023

C. Cities and Programs for Detailed Review

This long list of cities and their distinctive strategies served as a foundation for the MPO staff to identify suitable cities for a detailed review through desktop research and consultation with city staff. Besides the City of Minneapolis, Seattle and New York City were chosen for a thorough examination. To better comprehend the lessons learned, one-hour interviews were conducted with city staff. An additional nine cities, encompassing 13 programs, were chosen for a more focused but less intensive review.

Figure 73 itemizes the programs in each and indicates the corresponding sections where these programs are discussed in further detail. This collection of cities and programs represents a diverse spectrum of curbside management programs for goods delivery, covering a range of objectives, program methodologies, settings, and stages of adoption.

[73] 2020 Census Demographic Data Map Viewer, https://mtgis-portal.geo.census.gov/arcgis/apps/MapSeries/index.html?appid=2566121a73de463995ed2b2fd7ff6eb7. Accessed June 2023

Figure 73: List of Programs Reviewed

City	Programs	Section
Seattle (WA)	• Commercial Vehicle Load Zone (CVLZ) Program • SMART Grant • Mapping and Data Collection • Collaboration with UW Urban Freight Lab	C.2
New York (NY)	• Neighborhood Loading zones (NLZ) program • Off-peak hour delivery program • Commercial cargo bicycle pilot program • Loading Zone expansion • Microhub pilot	C.1
Philadelphia (PA)	• Loading Zones Reservation Partnership	C.3.a
Washington (DC)	• Strategic Delivery and PUDO Zone Data Collection • Delivery Microhub Feasibility Study	C.3.b
Oakland (CA)	• Smart Loading Zones Program	C.3.c
Santa Monica (CA)	• Zero Emission Delivery Zone Pilot	C.3.d
San Jose (CA)	• Neighborhood Delivery Hub Initiative	C.3.e
Pittsburgh (PA)	• Oakland Neighborhood Commercial Plan	C.3.f
Bellevue (WA)	• Curbside Management Plan and Video-Based • Curbside Management Technology Testing	C.3.g
Edmonton (AB, CAN)	• Curbside Management Plan and CVLZ Designation	C.3.h
Kansas City (MO)	• Midtown Complete Streets Plan • Crossroads District Parking Study • Overland Park, KS Parking Plan	C.3.i

Source: CPCS and Dr. Dr. Giacomo Dalla Chiara, 2023

Results of other cities' curbside management practices as related to goods deliveries reviewed are detailed in the following section.

1. New York City

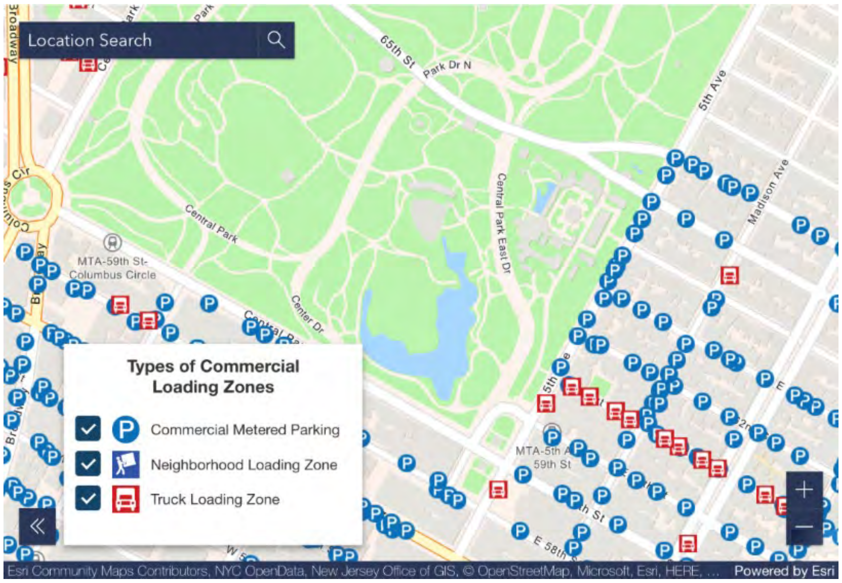
a. Background and context

Since 2007, the New York City DOT (NYCDOT) has had a dedicated Freight Mobility Unit responsible for advancing programs to mitigate the externalities produced by commercial vehicles on communities and the infrastructure while guaranteeing a functional and efficient urban logistics system supporting the City's economy.

Over the last decade, the Freight Mobility Unit has implemented numerous curb management programs that developed and expanded the existing network of curb load zones, supported low- and zero-emission freight vehicles adoption, and reduced truck vehicle miles traveled.

NYC is characterized by very high densities of population and commercial establishments. NYC had to manage commercial traffic from an early stage to avoid continuous road blockages caused by delivery activities. In NYC, there are 7,853 signs designating commercial loading zones. Of these signs, 2,055 are used to identify Commercial Metered Parking locations, 361 are used to identify Neighborhood Loading Zone locations, and 5,437 are used to identify Truck Loading Only locations. Figure shows a snapshot of the map tool motorists can use to locate the three different types of loading zones.

Figure: New York Commercial Loading Zone Map Tool



Source: NYCDOT,2023[74]

b. Priorities and objectives

The NYCDOT staff from the Freight Mobility Unit reported the following curbside objectives:

- Reduce traffic congestion and improve mobility
- Enhance safety
- Enhance the efficient movement of goods in the city
- Promote the adoption of low and zero-emission vehicles

c. Initiatives and findings

Neighborhood Loading Zones (NLZ) program. NYCDOT expanded the pool of commercial loading zones via the NLZ program, which added 361 loading zones in front of residential buildings to facilitate the increase in demand for residential deliveries due to e-commerce. The program's objective is to reduce the amount of double-parking taking place in residential areas. Typically, neighborhood loading zones are 40 feet long and are signaled by the sign in Figure.

[74] NYCDOT, Motorist & Parking Loading Zones. https://www.nyc.gov/html/dot/html/motorist/loading-zones.shtml. Accessed June 2023.

Figure: Sign Designating Neighborhood Loading Zone

Source: NYCDOT, 2023[75]

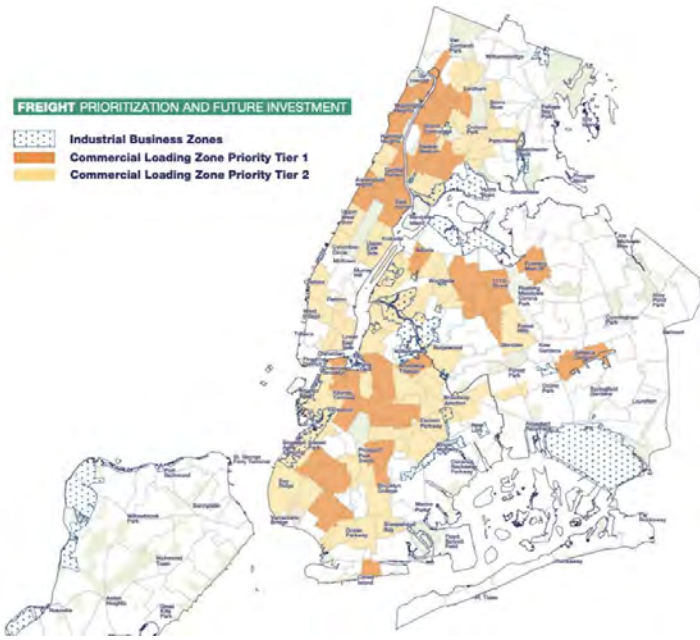
Loading zone expansion. Passed in 2021, the Loading Zone Expansion Law requires NYCDOT to create a methodology for loading zone allocation. The law mandates the installation of at least five loading zones annually in every neighborhood, and at least 500 zones annually across the City between 2023 and 2026. As part of the ordinance, the NYCDOT had to develop a methodology to identify blocks that require loading zones. NYCDOT used datasets (e.g., land use, population density, existing loading zones, bus stops, and bike lanes) as well as public engagement to identify three tiers of priority locations to create new loading zones (see Figure). NYCDOT reported that some residents do not always welcome new loading zones, especially in areas that are lacking parking spaces.

Off-peak hour delivery program. Between 2009 and 2010, NYCDOT piloted and deployed an off-peak hour delivery program. The program incentivized off-peak commercial deliveries (between 7 pm and 6 am) to reduce curb demand and traffic during daytime hours. A total of 25 businesses and 8 carriers participated in the pilot. NYCDOT reported an increase in delivery speed (130% higher) and a decrease in parking dwell times.

Commercial cargo bicycle pilot program. The Commercial Cargo Bicycle Pilot Program, launched in December 2019, encourages the use of cargo bikes for commercial purposes in the City. Commercial cargo bicycles enrolled in the pilot can load and unload wherever commercial vehicles can and at designated cargo bike corrals. Cargo Bike Corrals are cargo bike loading areas marked by bike racks, flexible bollards, and markings in the curbside lane (Figure).

[75] NYCDOT, "DOT is working to combat double parking by developing Neighborhood Loading Zones, a demonstration project to dedicate curb space", NYCDOT Twitter, October 2019. https://twitter.com/NYC_DOT/status/1164554031634817026. Accessed June 2023

Figure: Loading Zone Expansion Prioritization Map



Source: NYCDOT, 2023[76]

Figure: NYC Curbside Cargo Bike Corrals

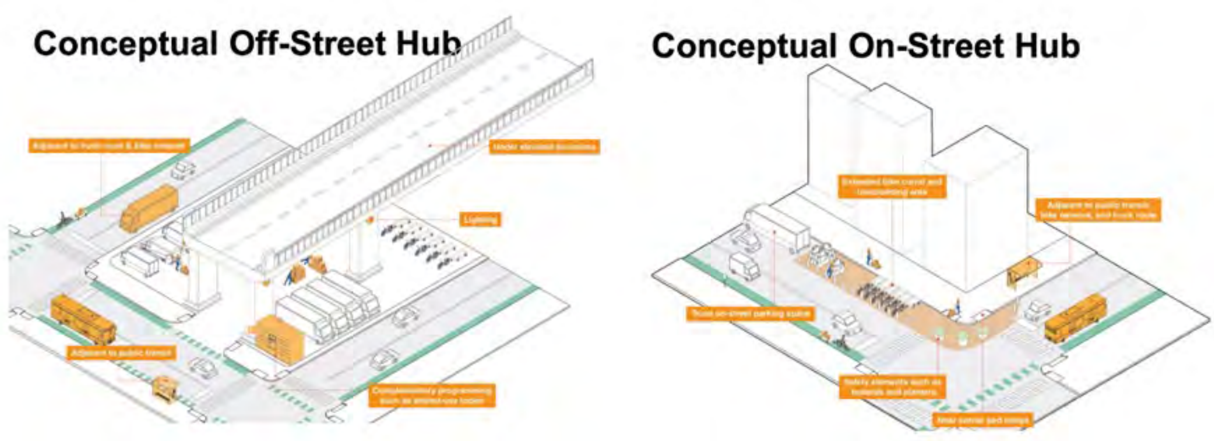
Source: NYCDOT, 2021[77]

Microhub pilot. In the summer of 2023, NYCDOT will start the first phase of a microhub pilot. Microhubs are defined as spaces located near delivery customers, where goods are loaded from large freight vehicles to smaller, low-emission, or human-powered vehicles for the final leg of the delivery process. The first phase aims at establishing twenty microhub sites throughout NYC, establishing operating agreements and contract mechanisms with the microhub operators. Figure

[76] NYCDOT, Loading Zone Expansion Progress Report, April 2023. https://www.nyc.gov/html/dot/downloads/pdf/loading-zone-expansion-progress-report.pdf. Accessed June 2023.
[77] NYCDOT, Commercial Cargo Bicycle Pilot, May 2021. https://www.nyc.gov/html/dot/downloads/pdf/commercial-cargo-bicycle-pilot-evaluation-report.pdf. Accessed June 2023.

shows two conceptual types of microhubs: an on-street hub that has curb space (similar to the cargo bike corrals) and unloading spaces in off-street locations.

Figure: NYCDOT Conceptual Off-Street and On-Street Microhub Rendering



Source: NYCDOT, 2023[78]

d. *Takeaways and lessons learned*

Monitoring and engaging public opinion. With its significant expansion of curbside management policies and commercial parking space, NYCDOT has closely monitored the public's reception to the changes in parking availability. NYCDOT has employed a survey team and online feedback form to regularly measure the efficacy of DOT strategies in addition to data analysis. It is important to educate the public as well as DOT staff that providing loading zones does not mean reducing paid parking space and revenues, but instead, it improves the livelihood of neighborhoods, reduces congestion, and supports the local economy. Mitigating public pushback while also gauging demand and concerns through public surveys can guide the loading zone prioritization process and improve the speed of implementation.

Data-driven approach. NYCDOT's approach to determining locations of loading zones, cargo bike corrals, and microhubs is heavily data driven and uses quantitative and qualitative performance measures after implementation. Proactive data-driven planning for loading zone allocation is preferred over responding to ad-hoc requests from the public, as demand can be assessed quicker and with greater detail. This approach is particularly crucial for unmetered spaces for which transaction data are not available to monitor utilization.

Regulatory enforcement. Neighborhoods and city entities are often responsible for implementing DOT guidelines and ensuring compliance with NYCDOT's goals and timelines. Political will supporting the loading zone expansions by mandating them was essential to support the freight programs. Under a mandate, NYCDOT can enforce compliance with curbside use designation and ensure that unsafe or illegal parking is reduced.

e. *References and resources*

- Loading zone expansion report[79]

[78]NYCDOT, Microhubs Pilot, April 2023. https://www.nyc.gov/html/dot/downloads/pdf/microhubs-pilot-report.pdf. Accessed June 2023.
[79] NYCDOT, Loading Zone Expansion Progress Report, April 2023. https://www.nyc.gov/html/dot/downloads/pdf/loading-zone-expansion-progress-report.pdf. Accessed June 2023.

- Commercial cargo bike pilot report[80]
- Microhub pilot plan[81]

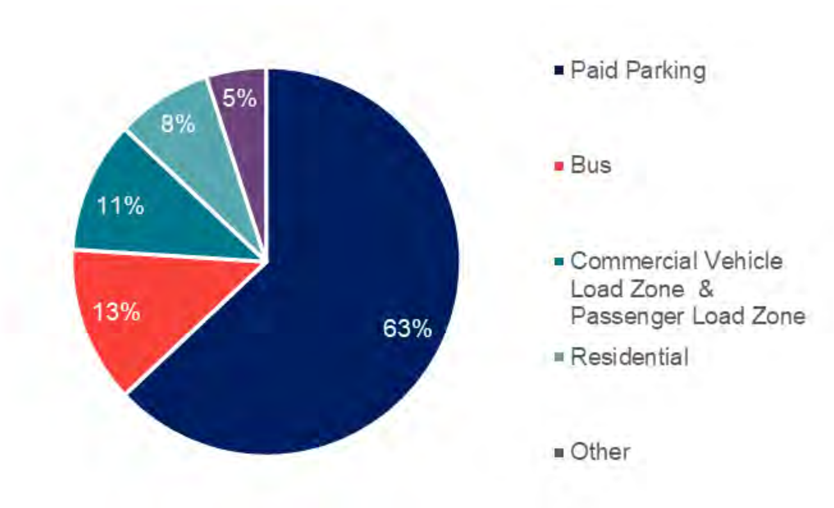
2. Seattle

a. Background and context

Seattle is the largest city in the Pacific Northwest with a population of over 3 million (urban area). It is one of the fastest-growing cities in the US.[82]

Over the past 15 years, the curb management team of the Seattle Department of Transportation (SDOT) has taken a pro-active data-driven approach to map, monitor, and monetize curb space. There are approximately 53 miles of curb space allocated to on-street parking in downtown Seattle which represents roughly 63% of total curb space. about 11 percent of the allocated curb space in the downtown area is reserved for commercial vehicle and passenger load zones (Figure).

Figure: Curbside allocation in the Seattle Downtown Core



Source: Seattle Department of Transportation, 2020[83]

The following types of curb space are allocated to commercial vehicles (Figure):

- Truck-only load zones: spaces restricted to vehicles licensed as trucks.
- Commercial vehicle load zones (CVLZ): spaces for commercial service delivery vehicles.
- Passenger load zones (PLZ): space reserved for 3-minute pick-up and drop-off, where drivers are required to stay in their vehicles.
- 5-minute priority pick-up zones: space reserved for 5-minute loading and unloading (can include designated Food Pick-Up spaces).

[80] NYCDOT, Commercial Cargo Bicycle Pilot, May 2021. https://www.nyc.gov/html/dot/downloads/pdf/commercial-cargo-bicycle-pilot-evaluation-report.pdf. Accessed June 2023.
[81] NYCDOT, Microhubs Pilot, April 2023. https://www.nyc.gov/html/dot/downloads/pdf/microhubs-pilot-report.pdf. Accessed June 2023.
[82] U.S. Census Bureau. 2010-2018 American Community Survey 5-year Estimates. https://data.census.gov/table?q=Population+Total&tid=ACSDT1Y2021.B01003. Accessed June 2023.
[83] Seattle Department of Transportation, Curbside Management Team 2019 Annual Report, May 2020. https://www.seattle.gov/Documents/Departments/SDOT/ParkingProgram/CurbsideManagementTeam_2019AnnualReport.pdf. Accessed June 2023.

Figure: Typologies of Commercial Curb Parking Signs in Seattle

Source: Seattle Department of Transportation, 2016[84]

b. Priorities and objectives

In 2023, SDOT released the Curbside Management Climate Plan[85], aligning the curbside management programs and strategies with the City's climate goal to reduce 58 percent of greenhouse gas (GHG) emissions by 2030. SDOT also identified the need to manage curb access for commerce as one of the top three functions for all types of land use (residential, commercial and mixed-use, and industrial), therefore pro-actively allocating commercial vehicle load zones across the city.

c. Initiatives and findings

Commercial vehicle loading zone (CVLZ) program. The CVLZ program was established in 1989 to provide designated space for service delivery vehicles. A CVLZ permit or payment at nearby pay stations or by phone payment is required to park at CVLZs, and vehicles can park for up to 30 minutes. Parking permits cost $250, is valid for a year from the time of purchase and are issued to persons or entities having a valid City of Seattle business license.[86]

SMART grant. In 2023 SDOT was awarded a USDOT grant under the SMART program, valued at $1,975,000. The grant will be used to modernize the CVLZ permit program to pilot test a "digital permit" based on a vehicle-to-curb communication system. The new permit will provide visibility for SDOT on the use of the CVLZ spaces, enabling future operational functions such as seamless pay-per-use, data collection and monitoring, and zero-emission zone enforcement, among others.[87]

Mapping and data collection. SDOT has maintained a detailed GIS data layer recording curb allocation, parking signs, and other parking-related data, and made it available to the public through an open data portal and APIs. The SDOT has also recurrently collected data on curb use at selected blockfaces[88] to train a mathematical model estimating curb occupancies from historical parking transactions and used the obtained information to adjust parking prices seasonally.

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[84] Seattle Department of Transportation, Can I Park Here?, November 2016 https://www.seattle.gov/documents/Departments/SDOT/ParkingProgram/CanIParkHere_Brochure_English_20161101.pdf, accessed May 2023.
[85] Seattle Department of Transportation, Curbside Management Climate Plan, 2023 https://www.seattle.gov/documents/Departments/SDOT/ParkingProgram/Curbside%20Climate/Curbside_Climate_Plan_Report.pdf. Accessed May 2023.
[86] Seattle Department of Transportation, Annual Truck Permits – Commercial Vehicle Load Zone Conditions of Uses. https://www.seattle.gov/transportation/permits-and-services/permits/atp-commercial-vehicle-load-zone. Accessed May 2023.
[87] Ethan Bancroft, We Applied for a $2 Million Federal Grant for Data-Driven Curb Space Management, SDOT Blog, November 2022. https://sdotblog.seattle.gov/2022/11/22/federal-smart-grant-freight-curb-management/. Accessed May 2023.
[88] SDOT defines a blockface to be the length of city infrastructure abutting a roadway, bounded between two roadway intersections.

Collaboration with the Urban Freight Lab. The SDOT has collaborated with the Urban Freight Lab (UFL) on several research projects aimed at studying curbside usage by commercial vehicles and at pilot testing new technology. The UFL within the Civil and Environmental Engineering Department of the University of Washington, is a public-private partnership bringing together public sector and private companies to delve deeper into urban logistics challenges. In 2020 the UFL and SDOT collaborated on a US Department of Energy-funded project to test the first curb availability information system for delivery drivers. Curb proximity sensors were deployed in a 10-block study area. The sensors detected the presence of vehicles and reported in real-time the information to delivery drivers in the area.[89]

d. Takeaways and lessons learned

The City has been pro-active in prioritizing curb access for commerce and in developing programs for commercial vehicles. The three key features of this approach are:

- Collaboration with the private sector and the local communities, through public engagement and collaboration with the Urban Freight Lab;
- Applying a data-driven approach, starting with mapping and making publicly accessible their curb allocation, signage, and parking regulations, followed by more data collection on curb uses and development of data-driven strategies; and
- Pilot testing new technologies, including curb proximity sensors and cargo bikes.

SDOT Curbside Management Team staff highlighted the need to incorporate and prioritize curbside access for commercial vehicles during planning and street redesigns. To this end, SDOT created a checklist for projects over $500,000 to incorporate considerations for commercial curb access. When curb usage is affected, SDOT Curbside Management Team staff assists the project team with stakeholder outreach to discuss critical building access and other loading needs.

Figure shows the Curbside Prioritization Framework the City uses that is based on surrounding land use. Curb access for commercial purposes is ranked in the top-3 for all three land use types.

Figure: Seattle Curbside Prioritization Framework

	Residential	Commercial & Mixed Use	Industrial
1	Support for Modal Plan Priorities	Support for Modal Plan Priorities	Support for Modal Plan Priorities
2	Access for People	Access for Commerce	Access for Commerce
3	Access for Commerce	Access for People	Access for People
4	Greening	Activation	Storage
5	Storage	Greening	Activation
6	Activation	Storage	Greening

Source: City of Seattle, 2023[90]

[89] Dalla Chiara, G., Krutein, K.F., Ranjbari, A. et al. Providing curb availability information to delivery drivers reduces cruising for parking. Sci Rep 12, 19355 (2022). https://doi.org/10.1038/s41598-022-23987-z. Accessed June 2023.
[90] City of Seattle, Flex Zone/Curb Use Priorities in Seattle. https://www.seattle.gov/transportation/projects-and-programs/programs/parking-program/parking-regulations/flex-zone/curb-use-priorities-in-seattle. Accessed June 2023.

Some of the items on the checklist include:

- "Are there critical building access needs that don't seem to be met by existing regulations? (Y/N) (e.g., This could be via seeing trucks using the center left turn lane, which is not legal, and an indication of insufficient curb loading area) If yes, please describe areas/locations."
- "Describe recommendations for curb lanes that maintain or mitigate critical access needs."

Other challenges the City is facing include defining and coding a delivery vehicle. With an increasing number of carriers employing delivery service partners who use not only trucks but also personal vehicles for deliveries, this challenge has been magnified.

References and resources:

- Curbside Management 2023 Climate Plan[91]
- Commercial Vehicle Load Zone conditions of use[92]
- SMART grant application announcement[93]
- Department of Energy funded a project on curb availability information system[94] and published paper[95]
- Curbside GIS layer and other data[96]

3. Other Cities

a. Philadelphia, Pennsylvania

i. Background and context

As the most populous city in Pennsylvania and a major city center in the mid-Atlantic, Philadelphia's metro area is dealing with several traffic-related issues exacerbated by the pandemic. In the last few years, Philadelphia's transit ridership has decreased, while the number of traffic deaths and hours of delay have increased.[97] Philadelphia's increasing population is looking for ways to reduce commuting drivers and provide efficient routes that reduce the need for unsafe and illegal parking.

ii. Priorities and objectives

Philadelphia's first and foremost concern is the reduction of traffic-related deaths. Encouraging public transportation ridership and reducing unauthorized curb usage are two of multiple means to achieve the city's "vision zero."

In addition to making driving in Philadelphia safer for all drivers and pedestrians, the city's press release announcing the partnership emphasized the need to improve delivery vehicle parking by

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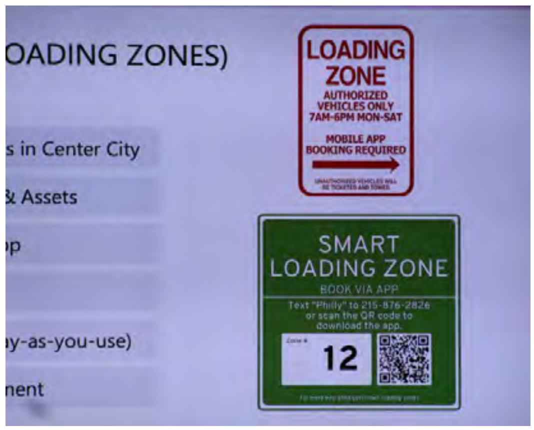
[91] Seattle Department of Transportation, Curbside Management 2023 Climate Plan, March 2023. https://www.seattle.gov/documents/Departments/SDOT/ParkingProgram/Curbside%20Climate/Curbside_Climate_Plan_Report.pdf, accessed June 2023.
[92] Seattle Department of Transportation, Annual Truck Permits – Commercial Vehicle Load Zone Conditions of Use, N.D.. https://www.seattle.gov/transportation/permits-and-services/permits/atp-commercial-vehicle-load-zone. Accessed May 2023.
[93] Ethan Bancroft, We Applied for a $2 Million Federal Grant for Data-Driven Curb Space Management, SDOT Blog, November 2022. https://sdotblog.seattle.gov/2022/11/22/federal-smart-grant-freight-curb-management/. Accessed May 2023.
[94] University of Washington Urban Freight Lab, Urban Freight Lab Uses AI to Show, Forecast Available Parking, November 2021. https://www.youtube.com/watch?v=f0wl411pDwM. Accessed June 2023.
[95] Dalla Chiara, G., Krutein, K.F., Ranjbari, A. et al. Providing curb availability information to delivery drivers reduces cruising for parking. Sci Rep 12, 19355 (2022). https://doi.org/10.1038/s41598-022-23987-z. Accessed June 2023.
[96] Seattle Department of Transportation, Maps and Data, N.D.. https://www.seattle.gov/transportation/projects-and-programs/programs/parking-program/maps-and-data. Accessed June 2023.
[97] City of Philadelphia, 2022 Safety and Congestion Omnibus Action Plan, 2022. https://www.phila.gov/media/20220624114025/2022-OmnibusPlan__Updated.pdf. Accessed June 2023.

allowing them to easily locate and reserve available curb space. This could potentially reduce driving time while improving safety.

iii. Initiatives and findings

Loading Zones Reservation: Philadelphia implemented a six-month pilot that established 21 Smart Loading Zones in the city center. Delivery drivers download the Pebble Driver App that maps the available Smart Load Zones. Drivers were able to reserve a Smart Load Zone within 15 minutes of arrival, get directions to the zone, and pay via a preferred payment method for the length of time stopped in the zone. The city would also penalize any driver that was not using the spaces for loading/unloading purposes or failed to reserve for the $3 fee.

Figure: Signs at a Smart Loading Zone in Philadelphia



Source: Cory Sharber. 2023.[98]

iv. Takeaways and lessons learned

Philadelphia recently concluded the 6-month study and has yet to release any related findings. However, the stated goals for the project were to provide a safer and more efficient means for loading and unloading and reduce the amount of unsafe and illegal parking throughout the city. In addition to creating a public-private partnership with the Pebble app, the pilot study tested a pay-as-you-use price model for load zones. The pilot also outfitted areas in the Center City District with specific signage and numbering to designate smart loading zones for the future.

v. Resources and references

- City Pilot Project Press Release and Program Summary[99]

b. Washington, DC

i. Background and context

Washington, DC has a population of 5.3 million people and is home to 13% of jobs in the mid-Atlantic region. As a result, DC accommodates thousands of commuters each day by commuter rail, cars, and public transport in addition to traffic generated by local commerce and residents. With

[98] Cory Sharber. Philadelphia to launch 'Smart Loading Zones' pilot program. WHYY. October 2022. https://whyy.org/articles/smart-loading-zones-pilot-program/. Accessed June 2023.
[99] Kelsey Hubbell, City Announces New SmartCityPHL Pilot Project Focused on Loading Zones in Center City, Philadelphia Office of Innovation and Technology, October 2022. https://www.phila.gov/2022-10-03-city-announces-new-smartcityphl-pilot-project-focused-on-loading-zones-in-center-city/. Accessed June 2023.

$26 million in funds awarded under the FAST Act in 2016, DC has implemented a series of programs aimed at improving freight traffic flows within city limits.

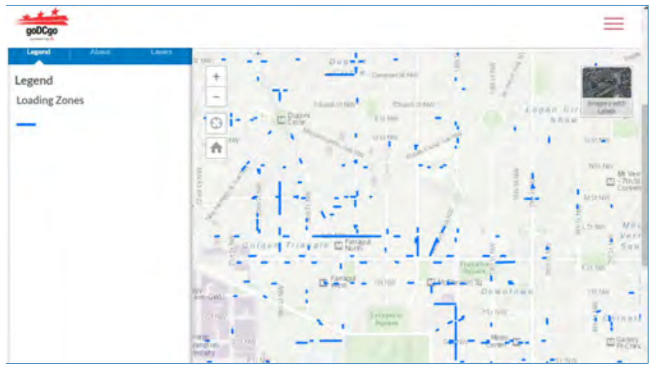
ii. Priorities and objectives

With 600 commercial loading zones across the city, DC has explored methods over the last seven years to monitor and improve their availability through better enforcement. Strategies identified in the district's freight investment plan have suggested gathering data to draw time-sensitive curb pricing strategies, increasing penalties for illegal parking, and encouraging switches to smaller delivery vehicles.

iii. Initiatives and findings

MoveDC Strategic Delivery and PUDO Zones: Drawing on transportation network company (TNC) activity data from Shared Streets, the nonprofit Open Transport Partnership's geographic data-referencing project, DC DOT created dedicated commercial vehicle pick-up/drop-off (PUDO) zones equipped with in-ground sensors and license plate recognition devices. Those zones are then priced to incentivize shorter stays.

Figure: DC's Interactive Truck and Bus Map Display Commercial Loading Zones



Source: Washington DC Department of Transportation, 2023 [100]

Delivery Microhub Feasibility Study

DC DOT is researching eco-friendly delivery mechanisms that reduce the reliance on vehicles powered by internal combustion engines for last-mile deliveries. The objective of this project is to gain a more comprehensive understanding of how delivery micro hubs can facilitate the use of bicycles, e-cargo bicycles, and/or pedestrian methods for final-stage deliveries within the District of Columbia. This endeavor will involve detailed case studies concerning the utilization of delivery microhubs, pinpointing essential micro hub requirements, and identifying the traits of delivery zones and District neighborhoods that conform to these requirements. The findings of this feasibility study are set to be released in the summer of 2023.

iv. Takeaways and lessons learned

Implemented in 2018, MoveDC has accomplished most of the strategies listed in the freight plan addendum. After examining the current demand-based parking policy, DC DOT was able to designate use types for curbside segments and develop an implementation plan for new policies. Data on commercial zone utilization informed dynamic pricing and the re-allocation of curb space from paid parking for private vehicles to commercial loading/unloading. Since the strategy's implementation in 2017, the District has established 30 PUDO locations and 47 individual zones. Seven more locations are pending installation in the next two years.

[100] Washington DC Department of Transportation. DC Truck and Bus Map. 2023. https://godcgo.com/dc-truck-and-bus-map/. Accessed June 2023.

v. **Resources and references**

- District of Columbia Freight Plan Addendum[101]
- MoveDC Snapshot[102]
- Curbside Management Programs[103]
- DC Truck and Bus Map[104]

c. Oakland, California

i. Background and context

Oakland is the largest city and the county seat of Alameda County, California. It has a population of 441,000 people and a density of 7,900 people/squared mile. The City of Oakland DOT dedicates portions of the curb to passenger and material loading and unloading between 7 am and 6 pm. Any vehicle with a registered commercial license plate can park for at most 30 minutes.

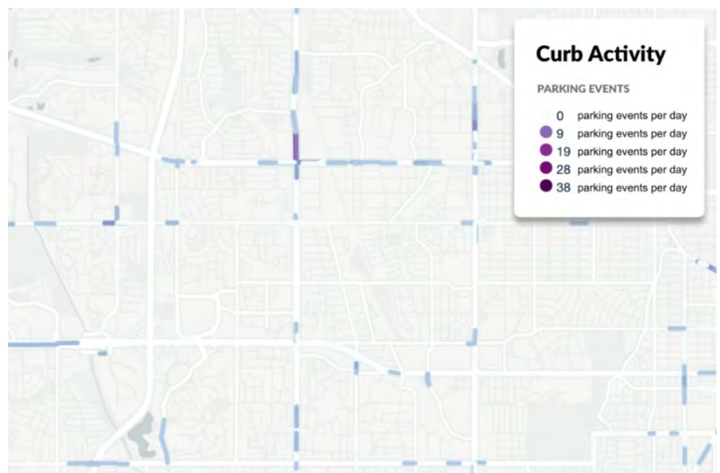
ii. Priorities and objectives

The Oakland DOT aims at automating the payment of parking meter fees for commercial vehicles parking at the yellow curb loading zones. The program's objectives are (1) to reduce vehicles misusing commercial vehicle load zones by introducing parking meters while (2) improving delivery vehicle access to safe parking, and providing a seamless payment method.

iii. Initiatives and findings

Smart Loading Zone Permit Program: The city of Oakland started a collaboration in 2023 with Populus, a curb-technology provider, to launch a smart loading zone permit program. The permit costs $3. Registered vehicles must agree to share their GPS data with Populus every month. The data is used to identify parking stops and bill the vehicle owner directly according to their stop dwell time on a per-minute basis.

Figure: Populus Occupancy Data Interface



Source: Populus, 2023[105]

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[101] District Department of Transportation, DDOT Freight Plan Addendum and 2014 Freight Plan, October 2017. https://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/District%20Freight%20Plan%20Addendum.pdf. Accessed June 2023.

[102] District Department of Transportation, moveDC Snapshot, January 2021. https://movedc.dc.gov/apps/abe15342d9a348d4bc781d15b12eabfe/explore. Accessed June 2023.

[103] District Department of Transportation, moveDC Curbside Management, January 2021. https://movedc-dcgis.hub.arcgis.com/pages/curbside-management. Accessed June 2023.

[104] Washington DC Department of Transportation. DC Truck and Bus Map. 2023. https://godcgo.com/dc-truck-and-bus-map/. Accessed June 2023.

[105] Populus, Curb Manager, https://www.populus.ai/products/curb-manager. Accessed June 2023

iv. Takeaways and lessons learned

The program has just started in early 2023, and no performance metrics are available at the time of this report. The stated objectives are to allow for a per-minute payment system without the need for operators to use cash or credit cards at parking meters, as well as to avoid the deployment of infrastructure that could be hard and costly to maintain and operate (e.g., parking meters and curb sensors for payment and vehicle detection). The main risks of this program include (1) dependence on a private operator; (2) legal issues related to the detection of parking stops and payment; (3) unwillingness of delivery operators to share GPS data; and (4) unavailability of resources for collecting and sharing GPS data.

v. Resources and references

- Oakland DOT portal to apply for a loading zone permit[106]
- Populus announcement[107]

d. Santa Monica, California

i. Background and context

Santa Monica, CA is a city in Los Angeles County, situated along Santa Monica Bay on California's South Coast. Its downtown is home to 15,850 residents and two commercial districts—downtown Santa Monica and Mian Street—which employ more than 28,000 workers. The area receives millions of annual visitors and tourists annually.

ii. Priorities and objectives

In 2018, the Los Angeles Cleantech Incubator (LACI) launched the Transportation Electrification Partnership (TEP). This public-private collaboration aims to chart a course for the reduction of greenhouse gas emissions and air pollution. The collaboration aims to have 60% of medium-duty and 40% of heavy-duty trucks to be zero emissions by 2028, among other goals.

Figure: Santa Monica Zero-Emission Delivery Zone Map Rendering

Source: City of Santa Monica, 2021[108]

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[106] Oakland DOT Parking and Mobility Division, Apply for a Commercial Vehicle Loading Zone Permit, N.D.. https://www.oaklandca.gov/services/apply-for-a-commercial-vehicle-loading-zone-permit. Accessed June 2023.
[107] Populus, Oakland, California Approves New Smart Loading Zones to Better Manage Their Curbs, January 2023. https://www.populus.ai/latest-news/oakland-california-approves-new-smart-loading-zones. Accessed June 2023.
[108] City of Santa Monica, LACI Launches First-In-Nation Zero Emissions Delivery Zone With City of Santa Monica and Partners including Nissan, IKEA, February 2021. https://www.santamonica.gov/press/2021/02/25/laci-launches-first-in-nation-zero-emissions-delivery-zone-with-city-of-santa-monica-and-partners-including-nissan-ikea. Accessed June 2023

iii. Initiatives and finding

Zero Emission Delivery Zone

The LA Cleantech Incubator (LACI) partnered with the City of Santa Monica to pilot test a zero-emission delivery zone in a one-square-mile area in the commercial downtown core. The pilot was voluntary, ran through December 2022, and incentivized the use of clean and electric delivery vehicles by reaching out to the private sector and offering priority curb space through zero-emission curb loading zones.

The parking spaces are marked by signage and are monitored by video cameras that track how the spaces are being used. Any zero-emission vehicle is eligible to park and load-unload for at most 10 minutes. A similar curbside strategy has been deployed in the City of Los Angeles.

iv. Takeaways and lessons learned

The ZE delivery zone initiative, although voluntary, enabled a private-public collaboration to test and implement zero-emission modes of urban goods transportation, accelerating the development of charging infrastructure, analyzing the availability and efficacy of different zero-emission vehicles, and assessing the grid capacity. The curbside played a key role in incentivizing and prioritizing the use of zero-emissions delivery vehicles.

v. Resources and references

- Los Angeles Cleantech Incubator (LACI) transportation electrification partnership[109]
- 2021 curbside management ordinance allowing for the creation of five zero-emission commercial loading zones[110]
- Transport Decarbonization Alliance report on Zero Emissions delivery zones[111]

e. San Jose, California

i. Background and context

San Jose is the largest city in the Bay Area and all of Northern California. Given its proximity to other major urban centers, only a fifth of San Jose's workforce stays within the city each day. As a result, San Jose has traditionally struggled to provide enough public transit and major roadways to accommodate drivers during peak commuting hours. Lately, however, the city's remote work culture has left San Jose with an abundance of parking infrastructure that is going unused on weekdays. Post-pandemic working conditions and a resurgence in commercial activity have required San Jose to adjust its traffic and parking management strategies and accommodate varying levels of demand.

ii. Priorities and objectives

In addition to creating a complete streets initiative, San Jose's curbside and traffic management goals have focused on reducing the physical and environmental footprint of transportation networks. San Jose's primary strategy, therefore, centers on the creation of mobility hubs and the reduction of mandatory parking minimums.

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[109] Los Angeles Cleantech Incubator, Transportation Electrification Partnership, May 2018. https://laincubator.org/transportation/. Accessed June 2023.
[110] City of Los Angeles, Ordinance 187117, 2021. https://clkrep.lacity.org/onlinedocs/2021/21-0147_ord_187117_08-07-21.pdf. Accessed June 2023.
[111] Transport Decarbonization Alliance, Zero-Emission Zones in the City: Don't Wait to Start with Freight!, March 2023. https://tda-mobility.org/wp-content/uploads/2023/05/Zero-Emission-Zones-in-the-City-Dont-Wait-to-Start-with-Freight.pdf. Accessed June 2023.

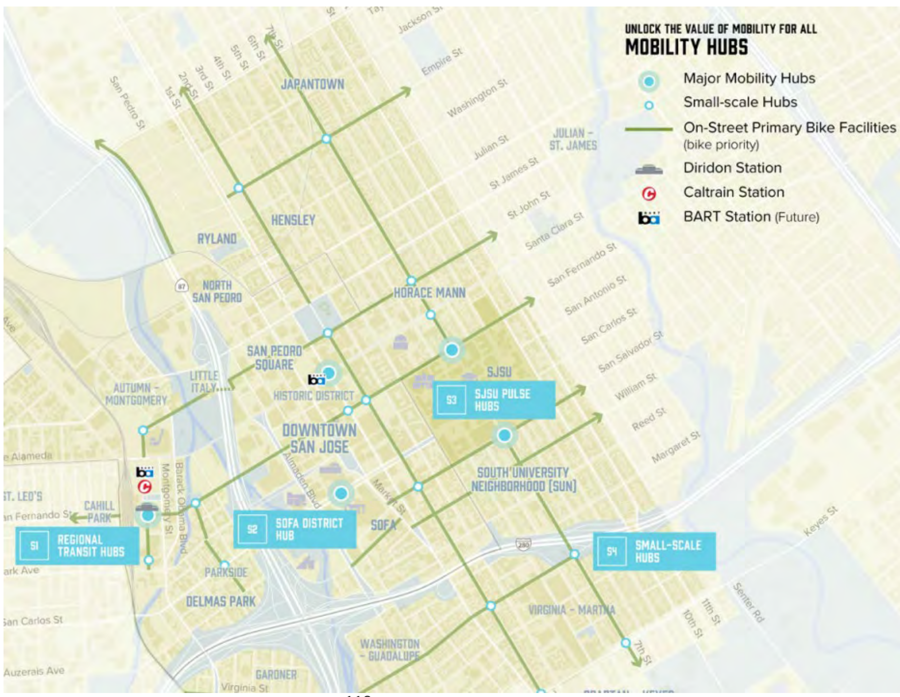
By creating centers for easy access to multiple transportation modes and reducing the amount of low-priced parking, the city hopes to increase the value of shared transportation methods and improve access to the city and the region’s most congested areas.

iii. Initiatives and findings

Neighborhood Delivery Hubs

San Jose uses active curbside management and parking strategies to constantly modify parking availability and pricing based on demand. The city modeled its curbside management plan after Seattle’s and suggested two neighborhood delivery hubs that take advantage of underused surface lots along common freight routes. Four multimodal transportation hubs have been identified in the Curbside Management Plan, to be established by 2027, two of which explicitly provide commercial parking. These lots aim to direct and consolidate freight trips to off-street locations where dwell time would have minimal impact on other transportation modes. These would be used as a point of transition from larger delivery vehicles to micro freight (porters or cargo bikes) to reduce vehicle miles traveled and emissions.

Figure: San Jose Mobility Hub Map



Source: San Jose Downtown Association, 2022[112]

iv. Takeaways and lessons learned

The city has found that improving availability while shifting away from free and discounted parking improves utilization and decreases the amount of illegal/unsafe parking. Shared facilities are critical to San Jose’s curbside management plan. To create these hubs, the city encourages private parking to be shared among adjacent buildings, public lots to allow for multiple uses, and private developers to allow commercial parking during times of lower demand.

[112] San Jose Downtown Association, Downtown Transportation Plan, October 2022. https://www.sanjoseca.gov/home/showpublisheddocument/90619/638040474240370000. Accessed June 2023

v. Resources and references

- San Jose Downtown Transportation Plan[113]

f. Pittsburgh, Pennsylvania

i. Background and context

With a population of roughly 2.35 million people, Pittsburgh is the most populous city in western Pennsylvania. Its unique geography has long caused issues for traffic flow in and around the city, making it the 7th most congested city in the U.S. based on hours of delay per driver.[114]

In 2016, Pittsburgh received a $10.8 million USDOT grant to implement advanced transportation and congestion management technologies (ATCMTD). Pittsburgh has used the funds over the last six years to invest in traffic detection and pollution sensors along “smart spine” corridors that connect residential areas with primary commercial centers and amenities.

ii. Priorities and objectives

After receiving its Congestion Management Technology grant, the city of Pittsburgh prioritized its most congested neighborhoods in the city center, including Oakland and downtown. These areas are connected to several residential to commercial-corridors that have high levels of public transit and pedestrian traffic, presenting issues for safety and right of way. The Oakland neighborhood specifically is home to a university campus, hospitals, museums, and retail establishments.

Pittsburgh aims to make its commercial centers more accessible, incentivizing non-auto transportation and creating designated off-street parking areas that preserve the public right-of-way but have alternative uses during peak hours.

iii. Initiatives and findings

Oakland Neighborhood Commercial Plan: The neighborhood of Oakland developed a curbside management plan after conducting a land use survey related to parking use and locations. The plan includes eliminating some metered parking and replacing them with rideshare and small delivery vehicle Pick up / Drop Off (PUDO) zones. It also plans to implement time restrictions to encourage off-peak (5 am-8 am) delivery times. During peak hours, delivery vehicles are directed to park a block down from buildings with high parking demand in other designated commercial spots. Delivery vehicles are restricted from parking outside of designated PUDO zones. The number of zones created and their pricing will be determined by street-by-street demand context.

iv. Takeaways and lessons learned

The Oakland Plan was completed in mid-2022 and has yet to implement or present findings on most of its strategies. However, Pittsburgh has modeled its policies after plans in Seattle and Gilbert, Arizona, that have identified a higher demand for commercial parking on congested city-center streets than the demand for private vehicle parking The Oakland neighborhood has emphasized the need to increase the flexibility of their curb space to accommodate the parking demand of a university campus and commercial area at the same time. Therefore, Oakland plans to use a multi-pronged and street-by-street approach to adjust parking prices, time limits, and the number of spaces.

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[113] City of San Jose, Downtown Transportation Plan: Unlock the Value of Mobility for All, November 2022. https://www.sanjoseca.gov/home/showpublisheddocument/90615/638040466452470000. Accessed June 2023.
[114] CBS Pittsburgh, New Study Says Pittsburgh Traffic Ranks Among Worst in Nation, February 2019. https://www.cbsnews.com/pittsburgh/news/new-study-says-pittsburgh-traffic-ranks-among-worst-in-nation/. Accessed June 2023.

v. Resources and references

- The Oakland Plan, City of Pittsburgh[115]
- Pittsburgh Advanced Transportation and Congestion Management Technologies (ATCMTD) Grant Announcement[116]

g. Bellevue, Washington

i. Background and context

Bellevue is a city in the eastside region of King County, Washington, located across Lake Washington from Seattle. The city has been recently going through a rapid transformation. Bellevue's population grew by 10% between 2017 and 2022; many technology companies are opening offices in its downtown core; its public transit network is about to expand with the opening of new light rail stations connecting the city with the Seattle light rail network. The downtown core includes a total of 104,487 linear feet of curb supply, of which 60% is dedicated to travel lane only (no parking allowed), 7.4% to time-limited parking, and 3% for general loading/unloading (including commercial vehicles loading/unloading, bus and other vehicles passenger pick-up and drop-off).

ii. Priorities and objectives

The City of Bellevue set itself to innovate its curbside management practices to accommodate future changes in curb demand, transitioning from the use of the curb for single-vehicle occupancy to increasing access for transit, office shuttles, delivery services, and active transportation.

iii. Initiatives and findings

Curbside inventory program: In 2019, the City began creating a curbside inventory of the downtown core, recording curb allocation and regulations in digital format. The inventory was completed in June 2020.

Curbside Technology Assessment Pilot: In 2019, the City received a Transportation for America (T4A) grant to conduct a curb pilot program. The goal of the pilot was to test the accuracy of video-based curbside monitoring technology solutions and identify a scalable system that could detect high-volume curb areas accurately for future enforcement and payment. Five technology vendors were selected, each deployed its technology and shared data with the City, and its performance was evaluated.

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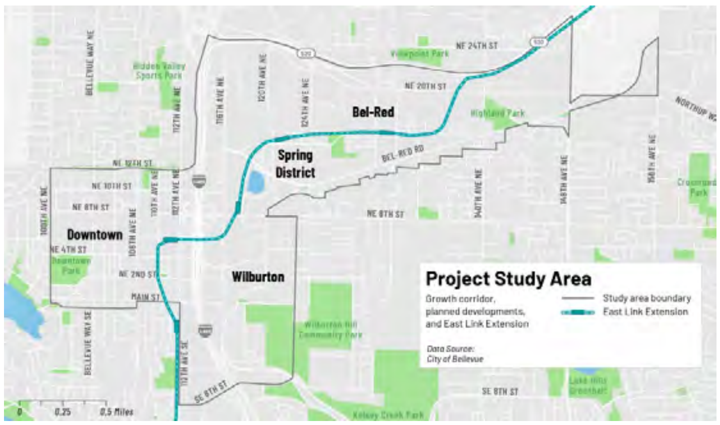
[115] The City of Pittsburgh, The Oakland Plan: Mobility, March 2022. https://engage.pittsburghpa.gov/oakland/oakland-mobility. Accessed June 2023.

[116] Nancy Singer, USDOT Announces $10.8 Million Grant for SmartPGH in Pittsburgh, US Department of Transportation, October 2016. https://highways.dot.gov/newsroom/usdot-announces-108-million-grant-smartpgh-pittsburgh. Accessed June 2023.

New Curb Management Plan: The drafting of the new curb management plan started with several initiatives to engage not only local community groups but also curb management experts through a series of public meetings. The plan created a framework defining four main curb functions: movement, access, place, and storage. Then, it identified 28 different curb practices recommendations, with 10 having higher priorities, including collecting and analyzing curb activity data, updating paid parking, on-street dining, and curbside vendor programs, and adding more resources for curbside enforcement.

Figure: Curbside Management Plan Study Area



Source: City of Bellevue, 2023[117]

iv. Takeaways and lessons learned

The City of Bellevue took a multi-strategy holistic approach to modernize its curb planning and practices. Over the past few years, the City initiated and completed several programs to map its curb, study its uses by testing video monitoring technology solutions, and created a new curb management plan to prioritize future pilots and strategies.

v. Resources and references

- The City of Bellevue New Curb Management Plan[118]
- Curbside Technology Performance Assessment Report[119]

h. Edmonton, Alberta, Canada

i. Background and context

Edmonton has a population of 1.1 million and is among the least dense cities examined in this review. The city's population has increased significantly in the last 10 years, challenging the city to identify the right amount of parking without exceeding what is necessary. In contrast with other major cities, Edmonton has no discernable relationship between land use/neighborhood context and the number of parking spaces provided and utilized. In 2020, the city eliminated parking

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[117] City of Bellevue, Curb Management Plan, 2023. https://bellevuewa.gov/sites/default/files/media/pdf_document/2023/Bellevue%20Curb%20Management%20Plan%20-%20TC%20Recommendation.pdf. Accessed June 2023

[118] City of Bellevue, Curb Management Plan, April 2023. https://bellevuewa.gov/sites/default/files/media/pdf_document/2023/Bellevue_CMP.pdf. Accessed June 2023.

[119] City of Bellevue, Curbside Technology Performance Assessment Report, February 2022. https://bellevuewa.gov/sites/default/files/media/pdf_document/2022/curbside-management-pilot-assessment-report-020722_2.pdf. Accessed June 2023.

minimums established in 1970 and developed a curbside management strategy in tandem with the city's comprehensive plan.

ii. Priorities and objectives

Outdated parking minimum policies and an increasingly sprawled city have made the management of excess parking a priority for the city of Edmonton. The city's curbside management plan emphasizes the need to increase efficiency and reduce the footprint of public parking facilities, reducing and repurposing existing parking infrastructure. With the recent elimination of parking minimums, the city is working to reallocate on-street spaces to other modes of urban mobility, opening up commercial parking availability based on demand by street block, and minimizing spillover or excess where parking maximums do not exist.

iii. Initiatives and findings

Curbside Management Plan and Designated CVLZs: Edmonton has a comprehensive plan with a curbside management strategy component outlining immediate, 2-year, and 5-year goals for opening curb space to zero and low-emission vehicles, bicycles, and commercial vehicles. The city has thus far implemented a wide network of commercial loading zones in congested areas.

iv. Takeaways and lessons learned

The city's curbside management strategy was approved in August 2022. The document has detailed strategies concerning dynamic pricing, reallocation of spaces, and policy changes for higher-density neighborhoods. This document provides the city with a guide for parking reform under the recent elimination of parking minimums and increased flexibility for parking repurposing or elimination. The majority of programs and strategies listed in the document have yet to be implemented, though the CVLZ strategy has created 13 new zones for permitted vehicles and revealed that increased monthly rates and shorter time limits increase vehicle turnover in congested areas.

v. Resources and references

- Edmonton Curbside Management Strategy[120]
- Edmonton Open Option Parking Policy[121]

i. Kansas City, Missouri

i. Background and context

The Kansas City metropolitan area has a population of 2.3 million people and is the least dense city referenced in this review. Kansas City faces curbside management issues in a variety of areas, including outside their most dense districts. In addition to historical parking shortages in historical areas and the metro center, the city is experiencing rapid densification of suburban areas that have slowed the flow of traffic through suburban downtowns.

ii. Priorities and objectives

In Kansas City's 2020 Curbside Management Plan, the city emphasized three principles to guide any curbside management strategies: (a) re-organizing the relocation of spaces while maintaining supply, (b) narrowing spaces where possible, and (c) increasing flexibility in who can use each

[120] City of Edmonton, Curbside Management Strategy, 2022. https://www.edmonton.ca/sites/default/files/public-files/Curbside-Management-Strategy.pdf?cb=1679936835. Accessed June 2023.
[121] City of Edmonton, Parking Rules for New Homes and Businesses, June 2020. https://www.edmonton.ca/city_government/urban_planning_and_design/comprehensive-parking-review?utm_source=virtualaddress&utm_campaign=makingspace. Accessed June 2023.

space at different times of the day. The city's surplus of free parking in some areas has also made metered parking and PUDO zone conversion a priority for the city. As the city's public transport network is sparse and there is a surplus of non-commercial parking, Kansas City has less concern for accommodating personal and public vehicles in on-street spaces and can free a significant amount of space for freight traffic.

iii. Initiatives and findings

Overland Park, KS Parking Plan: The Kansas City suburb is looking to manage its downtown parking and rush hour traffic by offering financial incentives to private parking lot/garage owners to make their properties public during peak hours. In sharing private parking lots and garages, Overland Park hopes to increase parking supply while still minimizing the land and development necessary to accommodate the high parking demand.

Wayfinding methods and signage will be added to ensure that any garage or lot spaces that often go unused are filled on a regular basis. By increasing usage of off-street parking facilities near the downtown strip, Overland Park hopes to facilitate a "park once and walk" environment that encourages pedestrian traffic over searching for parking on the downtown strip. The plan also includes PUDO zones in and around the city's downtown strip, minimizing long-term parking along active roadways and increasing curbside parking supply on less congested streets in the downtown area. Tiered timing in public curb spaces near these PUDO zones would also create different time regulations based on customer versus employee parking patterns and avoid priced parking on the downtown strip.

Crossroads District Parking Study: The City's art district faces challenges with non-commercial loading/unloading for art galleries and high pedestrian traffic. The study suggested consolidating the existing private loading areas or lots into shared parking, extending the parking supply for commercial vehicles.

Midtown Complete Streets Plan: Kansas City is focusing on its widest and busiest streets in midtown as part of its curbside management plan and complete street efforts. The plan highlights the importance of trying creative solutions to integrate curb access for freight in complete streets. problematic, other strategies exist to address freight delivery issues.

iv. Takeaways and lessons learned

After the implementation of the 2020 Curbside Management Plan, both Kansas City, Missouri, and surrounding suburbs have found that varying parking standards by neighborhood are essential to provide an ideal supply range and maximize flexibility for private parking providers. In Overland Park, the utilization of shared commercial and public spaces is at nearly 100% during peak hours and has reduced the distance from parking to delivery destinations to a ¼ mile or less. Though the Midtown and Crossroads district studies identified fewer action items, both codified better roadway access for multi-modal uses and pedestrians, while not disrupting existing commercial parking access. The studies also allowed for an increase in 15-minute, non-commercial loading zones that allow for increased turnover in central Kansas City and maintain 3-hour loading/unloading times for commercial vehicles.

v. Resources and references

- Kansas City Area Curbside Management Plan[122]

[122] Mid-America Regional Council, Kansas City Area Curbside Management Resource and Guide, November 2020. https://www.marc.org/sites/default/files/2022-06/curbside-management-resource-guide.pdf. Accessed June 2023.

- Overland Park Parking Standards Update[123]
- Overland Park Downtown Parking Plan[124]

[123] City of Overland Park, Overland Park Parking Standards Update & Community Parking Strategy, September 2021. https://www2.opkansas.org/files/dw/api/Docs/11527. Accessed June 2023.
[124] City of Overland Park, Downtown Parking Plan, January 2014. https://www2.opkansas.org/City-Government/Agendas-and-Minutes/Committee-of-the-Whole/Agendas/2014/2014-05-05/INF-1.pdf. Accessed May 2023

Appendix K Review of New Last-Mile Delivery Technologies

A. Introduction

There has been significant development in last-mile delivery technologies in recent years. This chapter provides a summary of research findings on these new or emerging technologies, with a special focus on the impact on reducing VMT and overall emission of CO_2 and other greenhouse gases as well as the extent to which the benefits of these technologies vary in different urban settings (e.g., urban centers versus suburban or exurban communities). Figure 74 provides an overview of the last-mile delivery technologies reviewed.

Figure 74: Overview of Last-Mile Delivery Technologies Reviewed

Category	Description	Examples
Micro freight	A general term referring to "micro-mobility for freight". Small, low-emission, and space-efficient mode of transporting goods, including vehicles and non-vehicles (e.g., bikes)	• E-walkers • Cargo e-bikes • E-scooters
Driverless vehicles	Last-mile delivery technologies that use driverless vehicles	• Unmanned aerial vehicles: air-based drones • Unmanned road vehicles: autonomous vehicles, sidewalk delivery robots
Alternative fuel vehicles	Vehicles that use alternative fuel for last-mile delivery purposes	• Electric vehicles (EV) • Hydrogen fuel cell electric vehicles

Source: CPCS and Dr. Giacomo Dalla Chiara, 2023

As listed in Figure 75, an introduction to the key features of each technology is given, followed by a discussion on technological maturity, potential impacts on VMT and GHG emission reduction, and key concerns for wide adoption. A few adoption examples and resources are also provided for technology for additional information.

Figure 75: Last-Mile Delivery Technologies Elements Reviewed

Element	Description
Key features	Key features of the delivery technology, including operational efficiency and geographic suitability
Technology maturity and prerequisites	Technology maturity as of today and prerequisites for adoption including infrastructure and regulatory changes needed.
Potential Impacts and key concerns	Potential impacts to VMT reduction, safety, etc., and key concerns from existing adoptions
Adoption examples and resources	Links to adoption examples and additional resources

Source: CPCS and Dr. Giacomo Dalla Chiara, 2023

B. Review of Delivery Technologies

1. Micro freight

a. E-Carts

i. Key features

E-carts (also called e-walkers) refer to technology supporting on-foot-porters (delivery workers performing last-mile delivery routes entirely on foot) in urban areas with high-drop densities. This technology often takes the form of a four-wheeled electric-assist delivery cart/trolley that assists a delivery porter in walking and carrying goods. The maximum payload is typically around 440 lb. with the container at 110 lb.

Figure: A UPS E-Walker

Source: Fernhay, 2023[125]

ii. Technology maturity and prerequisites

While the technology for e-carts is not new and several companies are producing e-carts, their adoption is still in its early stage. In particular, delivery carriers are still learning from pilot projects and how to include e-carts within their existing operations.

iii. Potential impacts and key concerns

- **Agile last-mile delivery solution:** E-carts empower porters to transport larger loads over extended distances and through narrow spaces. Some e-carts can go through a standard-sized door.
- **Minimum driver requirements:** Unlike traditional delivery vehicles, they do not need specialized drivers (e.g., do not require a driver's license).
- **Pedestrian friendly:** Unlike sidewalk robots or other land-based drones (see Figure for more detail), pedestrians can easily see over and maneuver around e-carts in busy city streets.
- **Zero emissions:** By mitigating the necessity for parking, e-carts contribute to the reduction of associated externalities such as emissions and congestion.
- **Infrastructure requirement:** Their effective deployment requires strategic infrastructure, including a depot near delivery customers—often in the form of a logistical microhub. Furthermore, their operation heavily relies on the availability of well-developed pedestrian infrastructure, comprising elements such as expansive sidewalks, ramps, and elevators

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[125] E-Walker Sustainable Last Mile Delivery Access in Pedestrian Shared Spaces. FH Fernhay. https://fernhay.com/ewalker/, accessed June 2023

iv. Adoption examples and resources

Several companies are producing and piloting e-carts:

- UPS piloting e-walkers in Europe[126]
- Brightdrop is a branch of GM producing electric vans and e-carts[127]
- FedEx uses electric vehicles to deploy e-carts and couriers in small neighborhood routes[128]

b. Cargo E-Bikes

i. Key features

Cargo e-bikes are two, three- or four-wheel cycles with a cargo compartment and/or with an attached cargo trailer, often partially propelled via electricity, used to perform deliveries in urban areas. Cargo e-bikes with larger compartments can carry up to 400 lbs of cargo. The UPS cargo bike pilot in Seattle revealed that cargo e-bikes on average deliver 20 to 24 percent of the number of packages delivered by a truck during a single tour but have a lower failed delivery rate and quicker delivery routes.

Figure: Cargo E-Bike Delivery Pilot Test in Seattle

Source: Washington State Transportation Center, 2020[129]

ii. Technology maturity and prerequisites

Cargo e-bikes have been around for more than 50 years though fleet adoption has grown significantly in the last ten years. Cargo e-bikes have also increased exponentially in battery range and capacity. Dedicated lanes in dense geographies could help with safety and navigation concerns. They could also be accompanied by urban fulfillment/consolidation centers to facilitate the deliveries.

iii. Potential impacts and key concerns

- **Efficient and sustainable:** Cargo e-bikes are flexible in the use of the urban infrastructure in urban areas, such as travel lanes, sidewalks (although it is not desirable due to safety concerns), and bike lanes. This makes them more resilient to road traffic congestion and lack of available parking.
- **Widely tested:** While not all delivery trips can be converted into cargo e-bikes, they have been used in many markets and contexts, from parcel delivery to grocery, food trucks, and landscape maintenance.

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[126]Walther Ploos van Amstel. UPS and Dublin innovate to reinvent sustainable last mile deliveries. City Logistics. July 16, 2020. http://www.citylogistics.info/business/ups-and-dublin-innovate-to-reinvent-sustainable-last-mile-deliveries/. Accessed June 2023.
[127] BrightDrop Trace Move. https://www.gobrightdrop.com/products/brightdrop-trace-move. Accessed June 2023.
[128] Frank Holland, FedEx is testing electric carts for last-mile delivery in big U.S. and Canadian cities, CNBC, March 2022, https://www.cnbc.com/2022/03/25/fedex-tests-electric-carts-for-last-mile-delivery-in-us-and-canadian-cities.html. Accessed June 2023
[129] Washington State Transportation Center. Cargo E-Bike Delivery Pilot Test in Seattle. September 2020. http://depts.washington.edu/trac/research-news/freight/cargo-e-bike-delivery-pilot-test-in-seattle/. Accessed June 2023

- **Infrastructure requirement:** Compared to delivery vans, the spatial range that they can cover is limited. Consequently, they need to access goods storage closer to where the deliveries are taking place.
- **Driver requirement:** Since they are also relatively new, many carriers that start using cargo bikes are facing labor issues, as drivers are more exposed to the weather and require more physical activity to operate them.

iv. Adoption examples and resources

Cities in North America have seen a rise in the use of cargo e-bikes.

- New York City started an e-cargo bike pilot program after Whole Foods started delivering all their groceries in Manhattan using cargo e-bikes[130].
- B-line[131] operation in Portland (OR)
- Cornucopia Logistics[132] operation in NYC
- UPS ran several cargo bike pilots across the United States and in Europe (see for instance the UPS cargo bike pilot in Seattle[133])
- Denver residents can save up to $500 on the sale of an e-cargo bike[134]
- The Colorado Energy Office’s eCargo Bike Commercial Delivery Pilot Program encourages disbursing eCargo bikes to low-income individuals that participate in the gig economy, where eCargo bikes are used to make deliveries through a delivery app service (e.g. Door Dash, Postmates, Instacart, etc) . The Minnesota State Legislature recently passed an e-bike purchase credit of up to $1,500.

c. E-scooters

i. Key features

E-scooters are electric scooters sometimes with small, attached compartments for one or two deliveries. The cargo platform out front typically loads up to 50 lb. The average distance of delivery is estimated to be 0.8 miles, mainly serving dense urban areas for food deliveries.

[130] Winnie Hu, Park It, Trucks: Here Come New York’s Cargo Bike, New York Times, December 2019. https://www.nytimes.com/2019/12/04/nyregion/nyc-cargo-bikes-delivery.html. Accessed June 2023.
[131] B-Line Urban Delivery, Last-mile logistics, distribution and warehousing reimagined, N.D.. https://b-linepdx.com/. Accessed June 2023.
[132] Cornucopia Logistics, Our Company, N.D.. https://www.cornucopialogistics.com/. Accessed June 2023.
[133] University of Washington Urban Freight Lab, Cargo E-Bike Delivery Pilot Test in Seattle, 2020. https://depts.washington.edu/sctlctr/research/publications/cargo-e-bike-delivery-pilot-test-seattle. Accessed June 2023.
[134] City of Denver. Electric Bikes (E-Bikes). https://denver.prelive.opencities.com/Government/Agencies-Departments-Offices/Agencies-Departments-Offices-Directory/Climate-Action-Sustainability-Resiliency/Sustainable-Transportation/Electric-Bikes-E-Bikes-Rebates#:~:text=Standard%20Rebate%3A%20As%20a%20Denver,of%20an%20e%2Dcargo%20bike. Accessed June 2023.

Figure: A Cargo E-Scooter

Source: ebiketips, 2022[135]

ii. Technology maturity and prerequisites

E-scooters have existed for over 30 years, though speed and battery life have improved significantly in the last 20 years. As a result, adoption for delivery purposes is growing more common in recent years. As with cargo bikes, dedicated lanes would improve efficiency and safety as would the incorporation of more urban fulfillment or consolidation centers.

iii. Potential Impacts and key concerns

- Safety concerns: In the absence of dedicated lanes, e-scooters can pose safety concerns for both the scooter operators and vehicle drivers. Delivery drivers have found that a scooter with a range of less than 40 mile-per-hour is not an ideal choice for the type of short and quick deliveries needed.
- Reliance on labor**:** On the economic front, e-scooters present notable reductions in fuel and operational costs, although labor remains a significant expense.
- Restricted capacity**:** A limiting factor for this delivery method is the restricted capacity, allowing only a few deliveries per route, which in turn increases the frequency of returns to the fulfillment center. This creates additional logistics considerations and can potentially offset some of the economic and environmental benefits.

Adoption examples and resources

Though couriers have long used e-scooters without a cargo compartment for delivery, e-scooters with an attached compartment are new and emerging:

- Beyond Cargo One is targeting operations in New York City[136]
- University of Minnesota Facilities Management Department uses e-scooters with trailers during event setups

[135] Alex Bowden, Cargo e-scooter for delivery workers launched by New York micromobility subscription service, ebiketips, Sep 2022. https://ebiketips.road.cc/content/news/cargo-e-scooter-for-delivery-workers-launched-by-new-york-micromobility-subscription. Accessed June 2023.
[136] Alex Bowden, Cargo e-scooter for delivery workers launched by New York micromobility subscription service, ebiketips, Sep 2022. https://ebiketips.road.cc/content/news/cargo-e-scooter-for-delivery-workers-launched-by-new-york-micromobility-subscription. Accessed June 2023.

2. Driverless Vehicles

a. Air-based Drones

i. Key features

Air-based Drones are small, automated aerial vehicles that can avoid on-land obstacles to make short-distance (often singular) deliveries of smaller goods, regularly returning to the distribution hub (Figure). With a potential payload of up to 33 lbs., air-based drones can reach remote or difficult-to-access areas, bypassing traffic congestion and offering a significant advantage in urgent delivery situations, such as healthcare supplies.[137-138]

ii. Technology maturity and prerequisites

This technology has been used commercially since 2013 while permits application have tripled since 2016. According to the FAA, all drones that weigh more than 0.55 lbs. (250 g) and less than 55 lbs. (25 kg) must be registered[139]. However, there are currently no standardized safety protocols, privacy regulations, or official guidelines for drone operation in urban areas and near-restricted zones in the US.

Figure: An Air-Based Cargo Drone

Source: Unmanned Airspace, 2019[140]

iii. Potential Impacts and key concerns

- Potential for reducing VMT: Drone technology for last-mile delivery has matured significantly. It does not interfere with on-road delivery traffic and can reduce vehicle trips needed for smaller goods and save fuel and labor costs.
- Challenges for widespread adoption: Key constraints include safety, noise pollution, privacy, and the environmental impact of producing and disposing of drone batteries. There are also concerns over dropping parcels or crashing in residential areas. Furthermore, ensuring secure delivery to inaccessible locations like apartments or locked mailboxes is another challenge that needs to be addressed.

iv. Adoption examples and resources

- Amazon has started to deliver orders by drones in California and Texas[141]

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[137] Eskandaripour, Hossein, and Enkhsaikhan Boldsaikhan. "Last-Mile Drone Delivery: Past, Present, and Future." Drones 7, no. 2 (2023): 77.
[138] Miguel Figliozzi. Modeling the Sustainability of Small Unmanned Aerial Vehicles Technologies. Freight Mobility Research Institute College of Engineering & Computer Science, Florida Atlantic University. December 2018.
[139] What are the drone laws in the USA? Drones under 250 grams. April 2, 2022. https://www.dronesunder250g.com/drones-under-250-grams/what-are-the-drone-laws-in-the-usa/.Accessed June 2023.
[140] Drone delivery operations underway in 27 countries. Unmanned Airspace. April 7, 2019. https://www.unmannedairspace.info/latest-news-and-information/drone-delivery-operations-underway-in-26-countries/. Accessed June 2023.
[141] Sheena Vasani. Amazon's started to deliver orders by drones in California and Texas. The Verge. December 2022. https://www.theverge.com/2022/12/28/23529705/amazon-drone-delivery-prime-air-california-texas. Accessed June 2023

- Meituan flies drones between skyscrapers to kiosks around the City of Shen Zhen, China[142]
- Drone delivery operations are underway in 27 countries[143]

b. Sidewalk Delivery Robots

i. Key features

Also known as autonomous delivery robots (ADRs) or personal delivery devices (PDDs), sidewalk delivery robots are small, automated vehicles that can use sidewalks and roadways to make short-distance deliveries of smaller goods, regularly returning to the distribution hub. The storage capacity is around 1.5 cubic feet, or about two paper grocery bags, and can drive at a speed of approximately 3-6 miles/hr on sidewalks. [144]

Figure: A Sidewalk Delivery Robot

Source: Tech Crunch, 2023[145]

ii. Technology maturity and prerequisites

These land-based drones have been used since 2014. Almost all have HD cameras, GPS, and object avoidance through ultrasound or lidar.

Infrastructure/condition requirements for robot operation include continuous, smoothly paved, and unobstructed sidewalks with sufficient width and pedestrian crossings that have sufficient time phased for crossing the intersection and do not require pushing a crosswalk button, among others.[146] This makes college campuses or commercial shopping and dining centers the ideal locations for operation.

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[142] Zeyi Yang. Food delivery by drone is just part of daily life in Shenzhen. MIT Technology Review. May 23, 2023. https://www.technologyreview.com/2023/05/23/1073500/drone-food-delivery-shenzhen-meituan/. Accessed June 2023.
[143] Drone delivery operations underway in 27 countries. Unmanned Airspace. April 7, 2019. https://www.unmannedairspace.info/latest-news-and-information/drone-delivery-operations-underway-in-26-countries/. Accessed June 2023.
[144] Pani, Agnivesh, Sabya Mishra, Mihalis Golias, and Miguel Figliozzi. "Evaluating public acceptance of autonomous delivery robots during COVID-19 pandemic." Transportation research part D: transport and environment 89 (2020): 102600.
[145] Rebecca Bellan. Uber and Cartken are bringing sidewalk delivery robots to Virginia. Tech Crunch. April 20, 2023. https://techcrunch.com/2023/04/20/uber-and-cartken-are-bringing-sidewalk-delivery-robots-to-virginia/#:~:text=Uber%20did%20not%20specify%20what%20the%20delivery%20radius,identify%20objects%20and%20help%20them%20reach%20their%20destination. Accessed June 2023.
[146] Amanda Howell, Becky Steckler, Nico Larco, Urbanism Next Center, Knight Foundation, Piloting Sidewalk Delivery Robots in Pittsburgh, Miami-Dade county, Detroit, and San Jose, 2022, https://global-uploads.webflow.com/5d9f83b8b237fa6c07d5d69d/6310e6536ecf171b2d44871b_Knight%20AV%20Initiative%20PDD%20Report%20Final_Aug%202022.pdf. Accessed June 2023.

iii. Potential Impacts and key concerns

- Potential for reducing VMT and emission: Can replace trucks or personal vehicles to deliver short-distanced goods such as meals, and can reduce fuel, labor, and operating costs as a result.
- Safety and accessibility concerns: Sidewalk delivery robots can pose a tripping hazard for pedestrians with low mobility and or vision, as well as seniors and children.
- Not yet ready for widespread use: The limited storage capacity and delivery range of 1-1.5 miles for sidewalk robots limit the potential customer base.
- Privacy and vandalism/theft concerns: Sidewalk delivery robots can also be struck by vehicles on the road or be vandalized or stolen.

iv. Adoption examples and resources

- Kiwibot's sidewalk delivery robots test operation in Santa Monica[147], Pittsburgh, Miami-Dade County, Detroit, and San Jose in partnership with the Knight Autonomous Vehicle (AV) Initiative[148]
- Uber and Cartken are bringing sidewalk delivery robots to Virginia[149]
- Los Angeles looks to regulate the delivery of drones and devices through permit requirements[150]

c. Autonomous Delivery Vans

i. Key features

Autonomous delivery vans are larger autonomous vehicles capable of transporting multiple deliveries in one trip. These vans can operate autonomously on public roads, navigating traffic and obeying road rules. They are equipped with sensors, lidar, and computer systems for navigation and may have a human safety driver for backup. They are bigger in cargo capacity (up to 500 pounds) when compared with sidewalk delivery robots and are built for on-road delivery.

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147 Ben Bergman. Delivery Robots Come to Santa Monica. Dot.LA. March 2021. https://dot.la/delivery-robot-2651302336.html. Accessed June 2023.

148 Amanda Howell, Becky Steckler, Nico Larco, Urbanism Next Center, Knight Foundation, Piloting Sidewalk Delivery Robots in Pittsburgh, Miami-Dade county, Detroit, and San Jose, 2022, https://global-uploads.webflow.com/5d9f83b8b237fa6c07d5d69d/6310e6536ecf171b2d44871b_Knight%20AV%20Initiative%20PDD%20Report%20Final_Aug%202022.pdf. Accessed June 2023.

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Figure: An Autonomous Delivery Van

Source: Insider, 2019[151]

ii. Technology maturity and prerequisites

Driverless vehicles are the least commonly used among the technologies listed as most are still in the prototyping and safety testing phase. Larger company fleets have been used since 2019. For use outside of the pilot phase, a legal and liability framework must exist that accounts for potential damage to infrastructure or danger to pedestrians. While not required for implementation, dedicated corridors or lanes along major freight routes could reduce the congestion and safety concerns faced by these vehicles.

iii. Potential Impacts and key concerns

- Pedestrian and infrastructure security and safety concerns: The technology has generated concerns over sidewalk, pedestrian, and road infrastructure safety due to computer programming errors, unauthorized use, and unpredicted obstacles. However, driverless vehicles could also improve safety by reducing crashes due to driver error and slower human reaction times.
- Reduced fuel and operation costs: While the reduction in VMT is not easily predicted, optimized routing and reduced driver navigational errors could potentially reduce costs for fuel and failed deliveries. Driverless vehicles also eliminate labor costs apart from vehicle maintenance.

iv. Adoption examples and resources

- Domino's Pizza partners with Nuro to operate driverless vehicles in select cities[152]
- Walmart's partner with Udelv for online grocery delivery[153]

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[151] Dennis Green. Walmart is launching its 3rd online grocery test with a self-driving car in just 6 months. Insider. Jan 8, 2019. https://www.businessinsider.com/walmart-launching-autonomous-car-pilot-with-udelv-2019-1 Accessed June 2023.
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3. Alternative Fuel Vehicles

a. Electric Delivery Vehicles

i. Key features

Electric delivery vehicles run partially or entirely on a battery and produce no tailpipe emissions. All-electric vehicles can typically go between 110 and over 300 miles on a single charge. [154]The length of charge for electric vehicles varies depending on the type of charger used. With a Level 2 charger, typically available in residential homes with a 7kW to 19kW power output, charging an electric truck can take 5 to 10 hours, while a rapid charger can charge 80% in around 45 minutes. [155]

ii. Technology maturity and prerequisites

Although electric vehicle (EV) models have been mass-produced since 2000, there has been a notable surge in EV adoption by companies. Key e-commerce parcel carriers are moving swiftly to electrify their fleet. For example, by 2025, 50% of FedEx Express committed to have global parcel pickup and delivery vehicle purchases be electric, rising to 100% of all purchases by 2030.[156] US Postal Service also committed to only buying electric delivery vehicles After 2026.[157] Similarly, UPS[158] and Amazon[159] also committed to have more electric delivery vehicles on the road. Expanding the available charging infrastructure along critical freight routes and providing priority parking or reduced parking costs for EVs could further increase fleet adoption.

Figure: A FedEx Electric Delivery Van

Source: NPR,2021[160]

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iii. Potential Impacts and key concerns

- Potential for reducing air pollution: Electric vans emit no tailpipe pollutants, positioning them as prime solutions for enhancing air quality, particularly in dense urban areas.
- Lower running and maintenance cost: The operational cost of electric vans is notably less than their diesel counterparts due to the lower per-mile expense of electricity. With fewer mechanical components and reduced brake wear, maintenance expenditures for electric vehicles are also curtailed.
- Range anxiety and necessary infrastructure: The concern of 'range anxiety'—the fear among EV drivers of the battery depleting before reaching a destination or charging station—remains prevalent for many. As battery technology progresses and offers extended ranges, those traveling longer distances may face less downtime. It's worth noting that the Bipartisan Infrastructure Law provides the largest-ever federal investment in EV charging infrastructure to accelerate the transition to electric delivery vehicles.

iv. EV adoption examples and resources

- UPS operates a fleet of 13,000 alternative fuel and electric vehicles across North America[161]
- FedEx advanced fleet electrification in 2022 with 150 electric delivery vehicles from BrightDrop[162]
- Amazon expanded electric vehicle delivery to over 100 cities in 2021[163]
- US Postal Service committed to only buying electric delivery vehicles After 2026[164]

b. Hydrogen Fuel Cell Electric Vehicles

i. Key features

Hydrogen fuel cell electric vehicles use fuel cells to convert hydrogen into electricity to power an electric motor. Fuel cells are three times more efficient than internal combustion engines[165] and have a high potential to reduce GHGs when compared to other alternative fuel vehicles. Hydrogen-powered vehicles only emit water vapor and hot air. Compared to other electric vehicles, fuel cell EVs generally have a longer range at an average of 300 miles per charge and take less time to refuel (in 3 to 5 minutes).[166]

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[161] UPS, Electrifying our Future, May 2022, https://about.ups.com/us/en/social-impact/environment/sustainable-services/electric-vehicles---about-ups.html. Accessed June 2023.
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[165] Vehicle Technologies Office, Hydrogen's Role in Transportation, US Department of Energy, February 2022. https://www.energy.gov/eere/vehicles/articles/hydrogens-role-transportation. Accessed September 2023.
[166] California Air Resource Board. Drive Clean. https://driveclean.ca.gov/hydrogen-fueling. Accessed September 2023.

Figure: A Daimler GenH2 hydrogen-powered truck

Source: New York Times, 2023[167]

ii. Technology maturity and prerequisites

Though only 50 US fuel stations provide hydrogen today, plans by carriers and automotive companies to expand the selection of hydrogen-powered vehicles are likely to be accompanied by an increase in availability and affordability of clean hydrogen.[168] At the current hydrogen fuel cell production rate, the Department of Energy anticipates the cost of clean hydrogen to reach $1/kilogram (kg) in the next decade. Like EVs, the advancement in distance on a single charge depends on the size of the cell and is highly variable. The availability of charging infrastructure and battery construction materials is crucial to the eventual widespread adoption of this technology.

iii. Potential impacts and key concerns

- Reduction in noise and air pollution: Vehicles powered by hydrogen fuel cells are eco-friendly as they emit just heat and vapor. Additionally, the inherent efficiency of fuel cells means fewer moving parts in the vehicle, leading to reduced vibrations and a quieter ride than combustion-engine vehicles.
- Allows for longer distance travel with less refueling: Hydrogen fuel cell–powered vehicles travel longer distances using less energy. While a kilogram of hydrogen offers energy equivalence to a gallon of gasoline, fuel-cell electric vehicles can journey about 60 miles on just 1 kg of hydrogen. In contrast, traditional vehicles average a mere 25 miles per gallon of gasoline.[169]
- Challenges in Infrastructure and Production Costs: The journey to mainstream adoption of hydrogen-fueled vehicles faces two main challenges: high production costs and insufficient refueling infrastructure. Currently, over 12,000 hydrogen fuel cell–powered vehicles are being used in the US.[170] Yet, the growing interest from several automotive manufacturers and trucking fleets in hydrogen fuel cell technology holds promise. As production costs diminish and economies of scale become a reality, the prevalence of hydrogen-powered commercial vehicles is projected to surge.

[167] Jack Ewing, New York Times, World's Largest Long-Haul Truckmaker Sees Hydrogen-Fueled Future, July 2021. https://www.nytimes.com/2021/05/23/business/hydrogen-trucks-semis.html. Accessed September 2023.
[168] Vehicle Technologies Office, Hydrogen's Role in Transportation, US Department of Energy, February 2022. https://www.energy.gov/eere/vehicles/articles/hydrogens-role-transportation. Accessed September 2023.
[169] Vehicle Technologies Office, Hydrogen's Role in Transportation, US Department of Energy, February 2022. https://www.energy.gov/eere/vehicles/articles/hydrogens-role-transportation. Accessed September 2023.
[170] Vehicle Technologies Office, Hydrogen's Role in Transportation, US Department of Energy, February 2022. https://www.energy.gov/eere/vehicles/articles/hydrogens-role-transportation. Accessed September 2023.

iv. Adoption examples and resources

- US Postal Service’s trucking carrier, AJR Trucking, plans to incorporate 50 new hydrogen fuel cell trucks in their California fleet and expand to other states in 2024[171]
- Hydrogen-powered Daimler truck passes 1,000 km on a single fill.[172]
- The world’s largest long-haul truck manufacturer, Daimler, starts testing for hydrogen-powered 18-wheelers and plan to convert entirely to hydrogen in the next 15 years.[173]

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