URBAN FREIGHT DISTRIBUTION STUDY
E-COMMERCE TRENDS & IMPLICATIONS FOR URBAN PLANNING
Part I Report: E-Commerce Trends and Sustainability Impacts

METROPOLITAN
COUNCIL

Prepared by:

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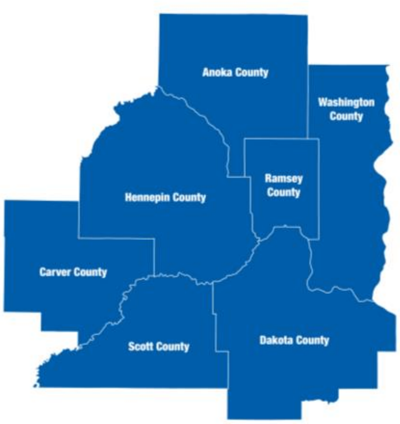
The Council's mission is to foster efficient and economic growth for

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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Table of Contents

Table of Figures

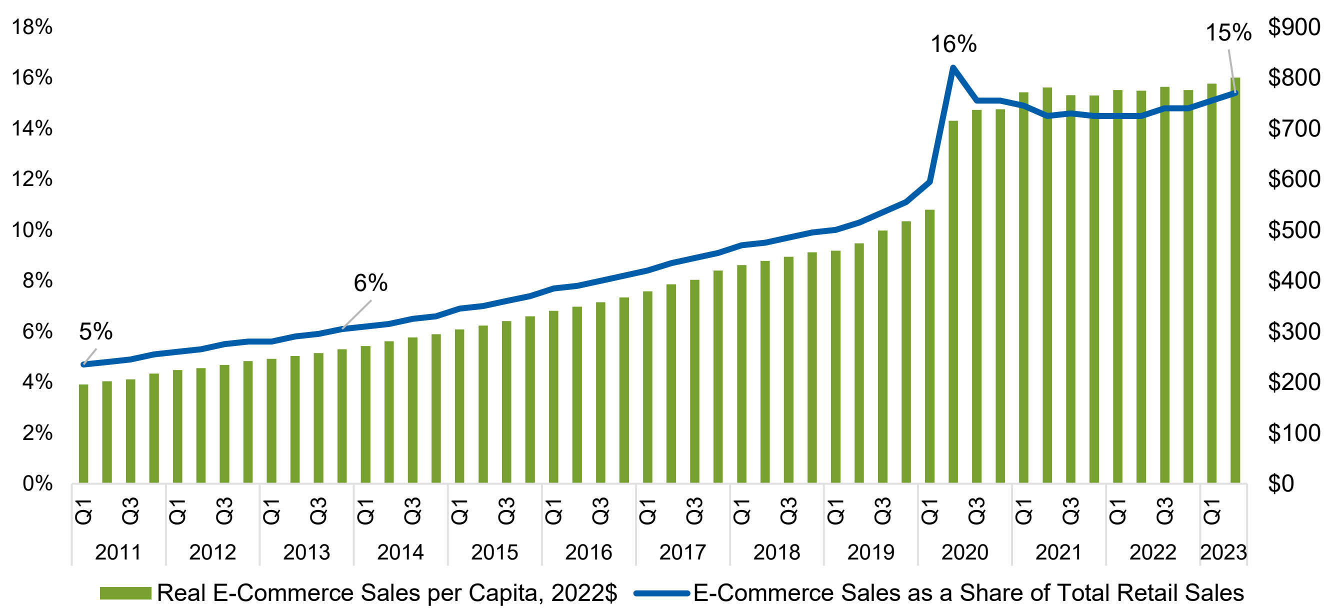
Executive Summary

This study examines the rise in online purchasing nationally and regionally, and its implications for Vehicle Miles Traveled (VMT) and greenhouse gas emission (GHG). It assesses the scale and efficiency of last-mile parcel deliveries relative to personal shopping trips. Findings are summarized below:

E-commerce has been on a long-term growth trajectory and – despite some pullback from the pandemic highs – is projected to grow into the future.

In real (inflation-adjusted) terms, national e-commerce sales have grown fourfold over twelve years, since 2011. The e-commerce penetration rate, defined as the ratio of e-commerce sales to total retail sales, stands at 15% in 2023 - three times higher than in 2011. Although this rate has stabilized since the pandemic, it is still ahead of the long-term pre-pandemic trajectory, and appears to be starting to grow again (see Figure ES-1). Extrapolating from pre-pandemic trends, the e-commerce penetration rate could grow to 35% by 2050, and some industry analysts are predicting even faster growth.

Figure ES-1: 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, Quarterly US population data, and price adjustment factors.

VMT is impacted by last-mile deliveries of e-commerce packages, but this amount is still small compared to the VMT that results from personal shopping trips.

Previous research has established that there is a degree of substitutability between online purchases and in-store shopping. Hence, when examining regional patterns, it is important to consider both the last-mile impacts of delivery vehicles bringing packages to customers' doorsteps as well as the personal shopping trips made by residents. This study examines the former through an analysis of data from NielsenIQ, which is based on actual purchasing and delivery activity by residents in the region and which identifies the parcel carriers used (i.e., FedEx, UPS, Amazon, and USPS). The study team then leverages a purpose-built route assignment model which is calibrated to factors (parcels per van, route lengths) from the literature and from onsite spontaneous interactions with carrier personnel. The study also examines personal shopping patterns using Met Council's Travel Behavior Inventory, a regional household travel survey database.

The net results are shown in Figure ES-2. Across the whole study area (which includes the seven-county region plus small areas of Sherburne and Wright Counties), there are estimated to be a total of 27.7 million vehicle miles traveled from last-mile parcel delivery operations, compared to an estimated 3.87 billion VMT from personal shopping trips. Similar proportions are observed for greenhouse gas (GHG) emissions. This suggests that even if e-commerce growth results in an increase in delivery VMT, this will be an order-of-magnitude smaller than the VMT associated with in-store shopping.

Figure ES-2: Base Year VMT and GHG emissions results

Measure	Base Year (2022)
Last-Mile Package Delivery VMT, annual million miles	27.7
Personal Shopping VMT, annual million miles	3,871.1
Total VMT, annual million miles	3,898.7
Last-Mile Package Delivery Emissions, annual million pounds CO2e	43.8
Personal Shopping Emissions, annual million pounds CO2e	3,190.1
Total Emissions, annual million pounds CO2e	3,233.8

Source: CPCS model results

E-commerce offers the opportunity to displace some personal shopping trips, which would be a net benefit for reducing total VMT and emissions.

In the future baseline case (2050), total shopping and last-mile delivery VMT is estimated to increase by 37% and GHG emissions to decline by 19%, relative to 2022. VMT and emissions impact is context-dependent and tied to technological factors (e.g., vehicle types) and societal-behavioral factors (e.g., shopping and travel decisions by households). The study team evaluated four alternative scenarios which assume various changes in key inputs. The scenarios are:

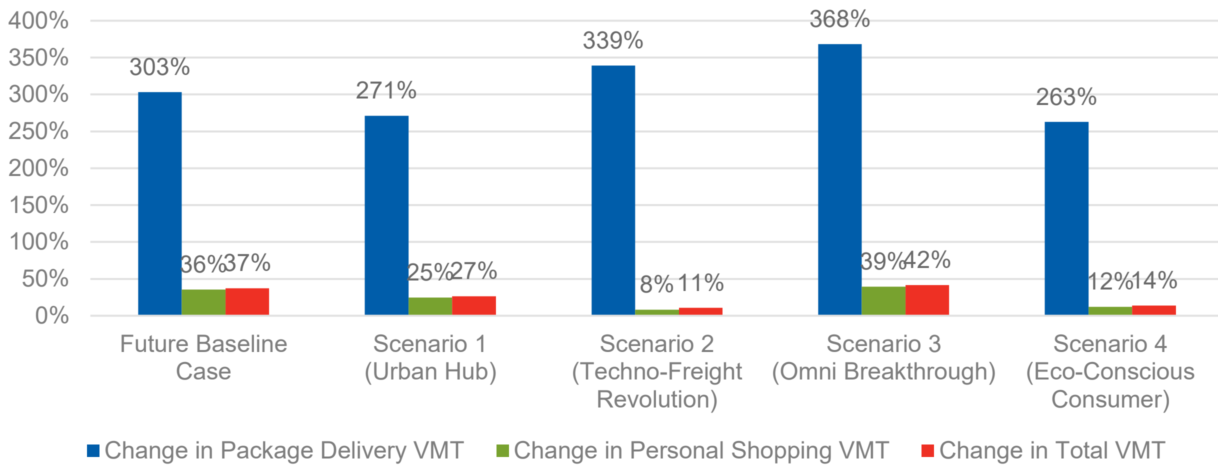
Figure ES-3: Scenarios evaluated

Scenario	Key assumptions
Base Year (2022)	Current baseline.
Future Baseline Case (2050)	“Status quo” for 2050. Assumes growing population, growing per-capita retail sales, growing e-commerce penetration, and increasing adoption of zero-emission vehicles.
Scenario 1: The Urban Hub	Population growth is more concentrated in the urban core, enabling densification benefits including new networks of last-mile microhubs within the urban core.
Scenario 2: The Techno-Freight Revolution	Increasing automation drives lower shipping costs, leading to an upsurge in e-commerce and rapid electrification of delivery fleets.
Scenario 3: The Omni Channel Breakthrough	New shopping models combine increased online ordering with a continued need for personal travel.
Scenario 4: The Eco-Conscious Consumer	Through a combination of measures, consumers shift their behavior in a desire for greater sustainability.

Source: CPCS

As shown in figure ES-4, delivery vehicle miles traveled are expected to rise substantially from present levels under all of the scenarios. Total VMT (accounting for delivery vehicles and personal shopping trips) are also expected to rise under all scenarios.

Figure ES-4: Change in total vehicle miles traveled in the region, for each scenario relative to Base Year



Source: CPCS analysis

Figure ES-5 shows that among the four scenarios, the greatest reduction in VMT is achieved in Scenario 2 (Techno-Freight Revolution), which results in a total VMT reduction of 17% compared to the Future Baseline Case. This reduction corresponds with a rapid upsurge in e-commerce (growing to 50% of all retail sales by 2050) which would enable greater substitution of traditional shopping trips and an expansion in zero and low-emission delivery fleets.

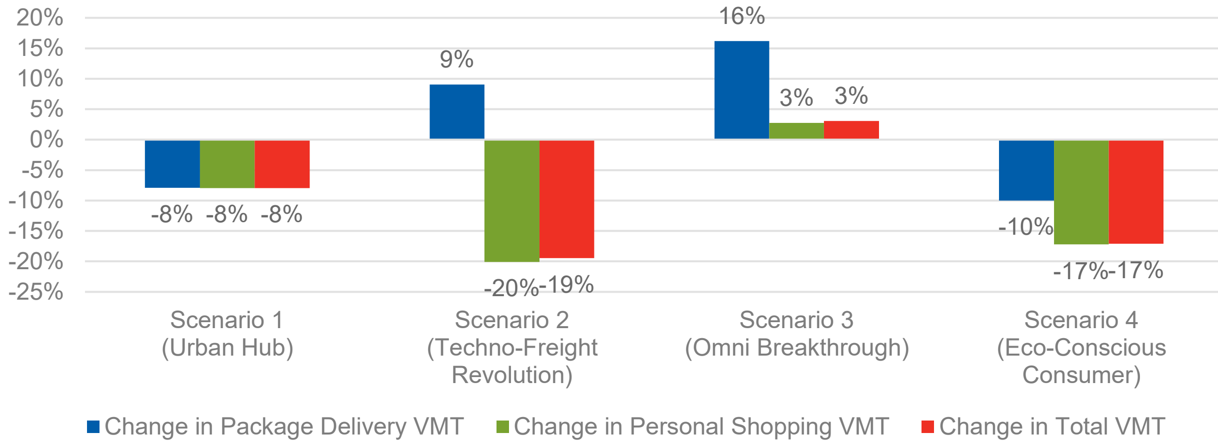
Scenario 4 (Eco-Conscious Consumer) also finds considerable opportunities for VMT reduction (17% in total VMT reduction compared to the Future Baseline Case) as a result of various changes in shopping behavior, such as shopping closer to home.

Scenario 1(Urban Hub), which results in a total VMT reduction of 8% compared to the Future Baseline Case, finds some benefits from opportunities enabled by more compact growth.

Scenario 3 (Omni Channel Breakthrough), which results in a VMT increase of 3% compared to the Future Baseline Case, offers somewhat of a cautionary finding – even if e-commerce grows significantly relative to overall retail, it may not achieve reductions in VMT if personal travel is not substituted. For instance, in the “click-and-collect” model, where consumers purchase online but travel to pick up their items, either curbside or in-store, personal travel still occurs, thereby not diminishing VMT.

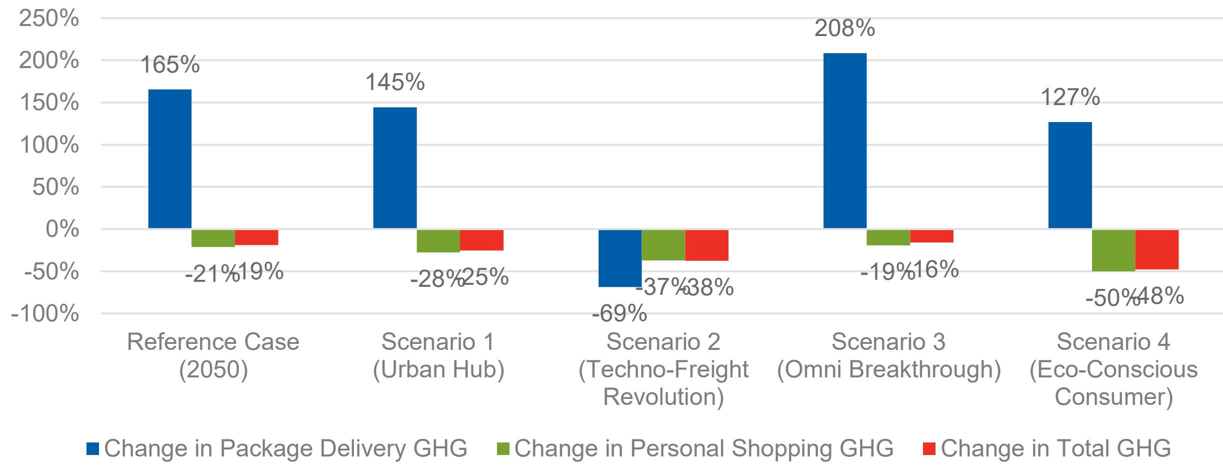
The results for GHG emissions are similar, but even more magnified for Scenarios 2 and 4, which assume faster adoption of zero-emission vehicles among delivery fleets and personal vehicles (respectively). This suggests that accelerating the electrification of delivery vehicles is more impactful than relying on the “click-and-collect” model.

Figure ES-5: Change in total vehicle miles traveled in the region, for each scenario relative to Future Baseline Case



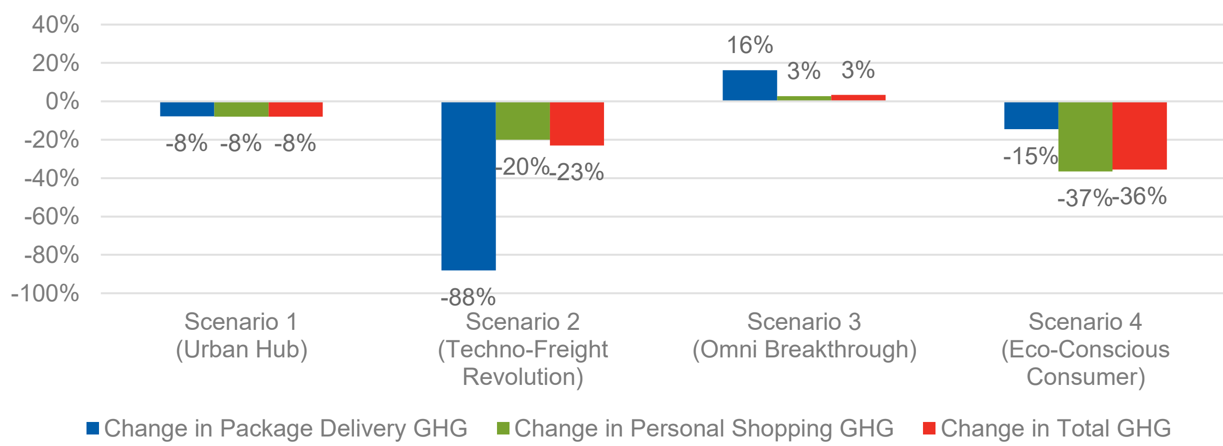
Source: CPCS analysis

Figure ES-6: Change in total GHG emissions in the region, for each scenario relative to Base Year



Source: CPCS analysis

Figure ES-7: Change in total GHG emissions in the region, for each scenario relative to Future Baseline Case



Source: CPCS analysis

E-commerce has the potential to be a “win-win-win” by delivering benefits to consumers (convenience, choice), businesses (greater market reach, lower real estate costs), and the environment (reduced VMT and emissions).

Met Council, municipalities, industry, and the public all have a role to play in helping to reduce vehicle miles traveled and associated greenhouse gas emissions.

The following study recommendations are proposed:

1) **Electrify last-mile deliveries:** This is a key opportunity for accelerated reduction in greenhouse gases, as fewer decision makers are involved, making it simpler for businesses to factor in the potential for ongoing cost savings in fueling and maintenance during their initial decision-making process.

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

2) **Enhance efficiencies where possible:** There may be opportunities to leverage urban microhubs and cargo bikes in certain parts of the region.

   Recommendation: Urban municipalities 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.

3) **Education and promotion:** Industry and the public also have a role in minimizing VMT and greenhouse gas emissions.

   Recommendation: Met Council and MnDOT should consider developing a strategy to encourage major e-commerce parcel carriers to provide summary data related to delivery vehicle VMT and to develop aggregated data metrics to track progress for the region/Metro District.

   Recommendation: Met Council should consider developing educational materials to inform the public and promote actions that residents and businesses can take to minimize VMT and greenhouse gas emissions.

4) **Further analysis:** This study identifies several potential research areas, including for Met Council to incorporate the effects of e-commerce on regional VMT and greenhouse gas emissions into its freight and travel demand models.

   Recommendation: Met Council should explore how to incorporate ecommerce's influences on regional freight travel and household shopping trips during planned updates to the Council's freight and Activity Based forecast models.

I. E-commerce growth trends

KEY TAKEAWAY

E-commerce sales in the U.S. have experienced a remarkable increase over the past decade. The COVID-19 pandemic spurred a further boost. Key metrics such as e-commerce sales per capita and the e-commerce penetration rate have risen substantially, indicating a profound shift in consumer purchasing behaviors. Industry analysts expect that there could be considerable upside in e-commerce growth rates, above historical trends.

In the Twin Cities region, major carriers, including Amazon, FedEx, UPS, and USPS, captured over 93% of the online package delivery market share. Notable trends in e-commerce last-mile package delivery practices include boosting delivery speed, pursuing sustainability, and leveraging the gig economy, as seen in Amazon's use of Flex drivers. These trends underscore the dynamic nature of e-commerce and its significant impact on traditional retail and shipping sectors.

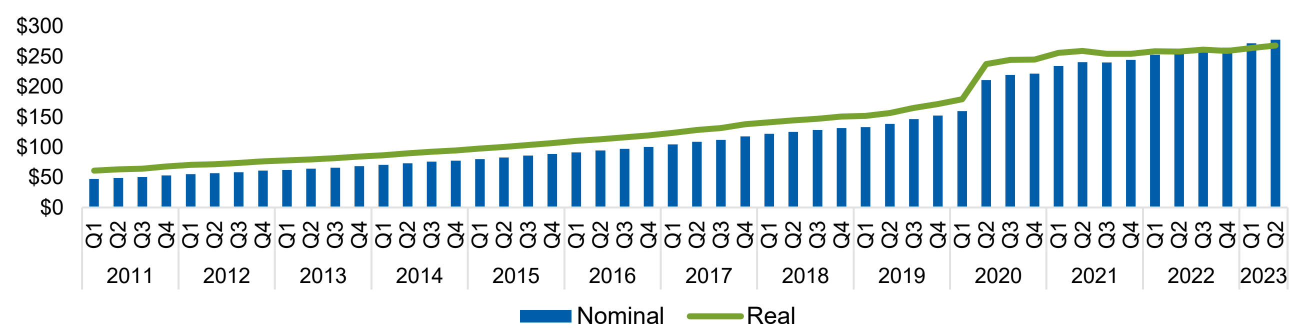
In-person shopping trends, as per Met Council's TBI Household Survey, reveal that approximately 1.44 million shopping trips occur daily in the Twin Cities region, with private vehicles being the primary mode of transportation. Notably, even amidst the pandemic, there was a slight increase in shopping trips. These findings highlight the continued importance of physical retail in consumers' lives, despite the surge in e-commerce, and underscore the need for considering in-person shopping trips while discussing e-commerce's impacts to total Vehicle Miles Traveled (VMT) and associated greenhouse gas (GHG) emissions.

A. Online shopping trends

1. National 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 four-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



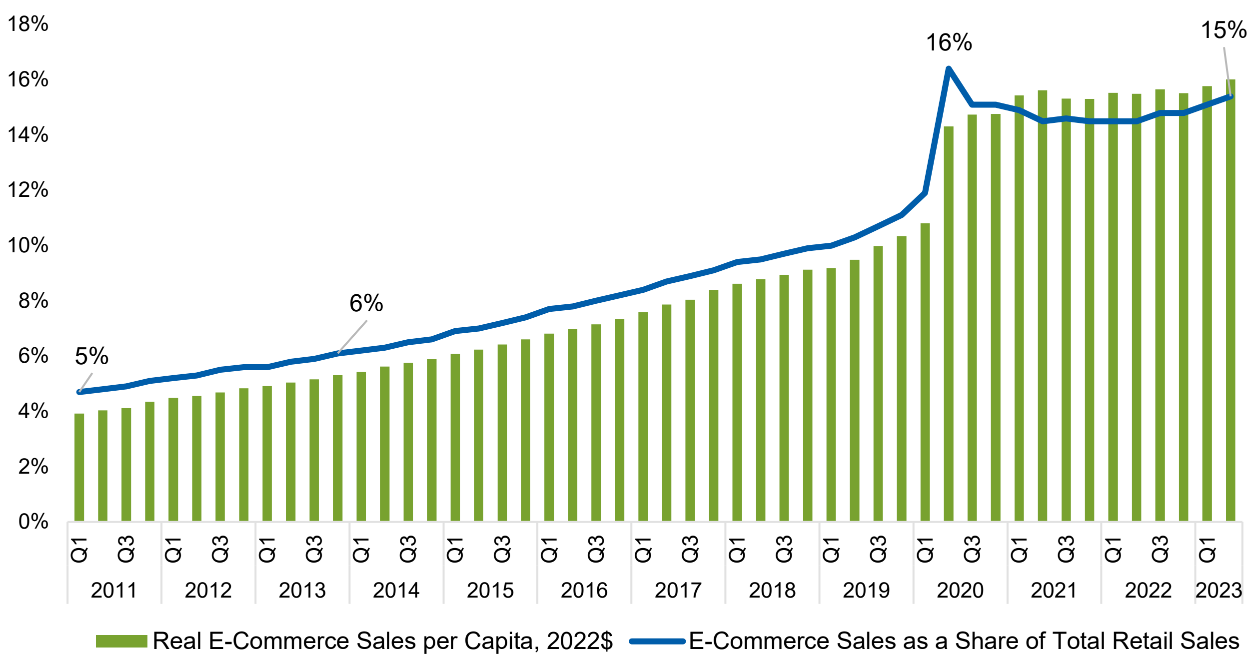
Source: CPCS analysis of US Census Bureau Quarterly Retail E-Commerce Sales data[1]

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

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 consumers have greatly increased their e-commerce purchases over the last decade.

The second metric is the e-commerce penetration rate, defined as the ratio of e-commerce sales to 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 penetration rate reached a high of 16% early in the COVID-19 pandemic, before dropping a bit. This likely reflects the fact that the effect of 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.

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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.

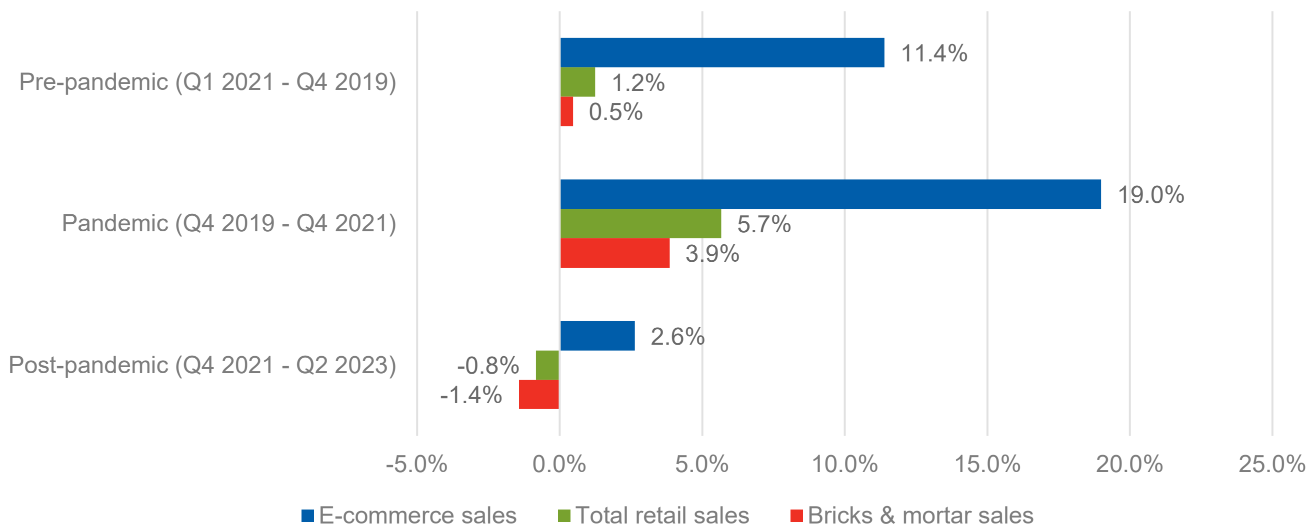
[3] Quarterly US Population, Federal Reserve Economic Data, Federal Reserve Bank-St Louis, 2023. https://fred.stlouisfed.org/series/B230RC0Q173SBEA. Accessed on October 31, 2023.

[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.

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.

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.

2. Online shopping projections

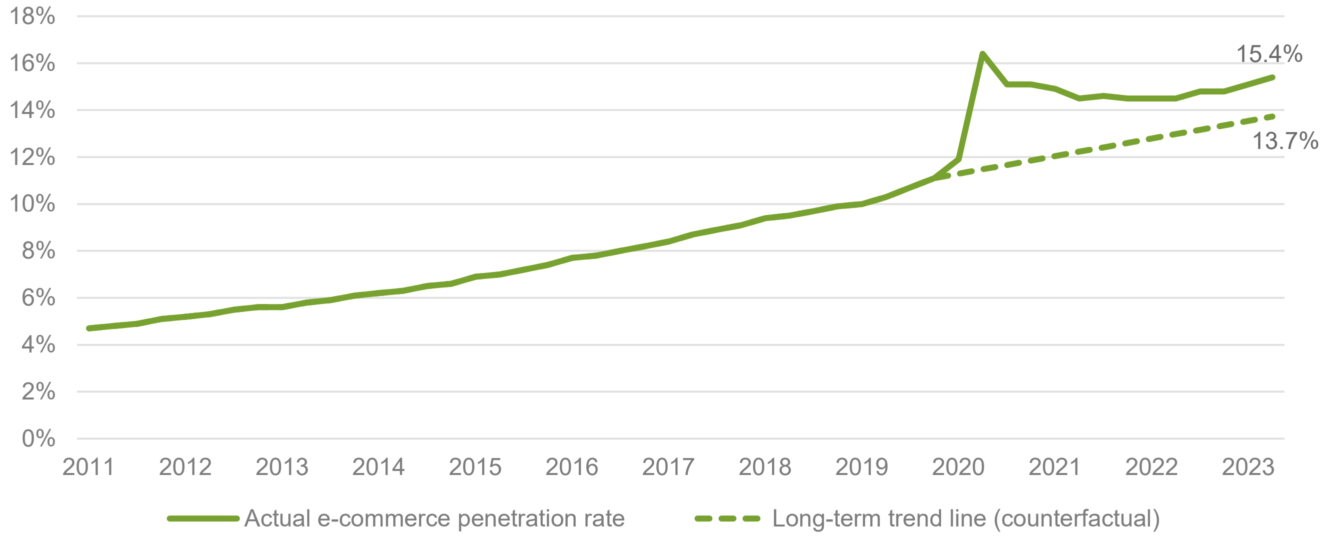
A relevant policy question has been whether the pandemic represented a temporary aberration from a long-term trend line, or alternatively a transformational change underlain by a fundamental shift in consumer habits. Based on the data available to date, the answer seems to be something in between.

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.

[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.

As the chart shows, the pandemic appears to have added about 1.7 percent 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.

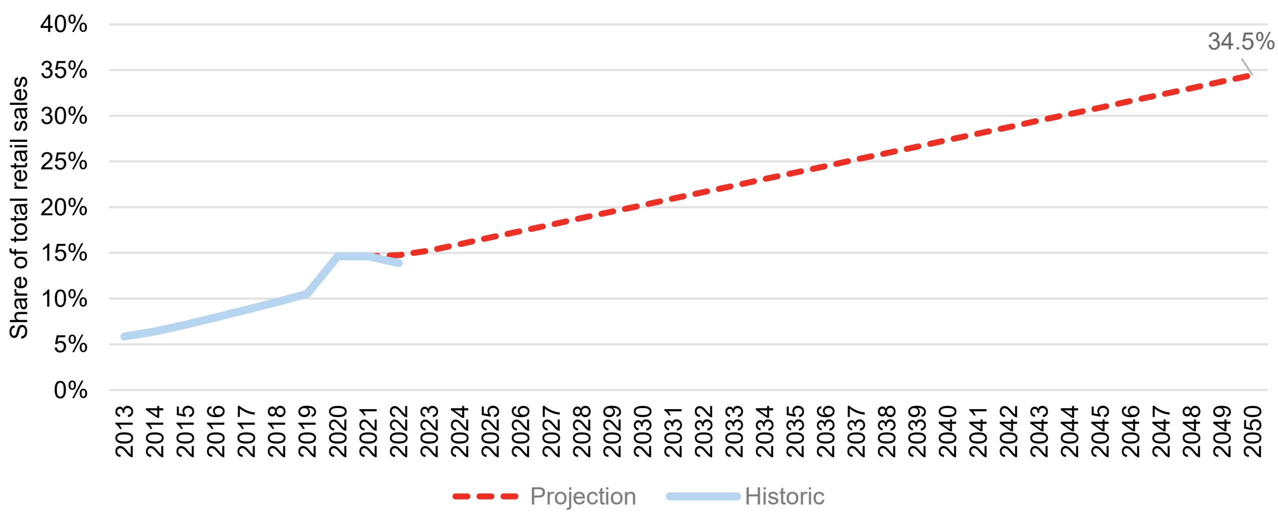
Figure 4: E-commerce penetration rate, compared to counterfactual long-term trend line from 2019



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.

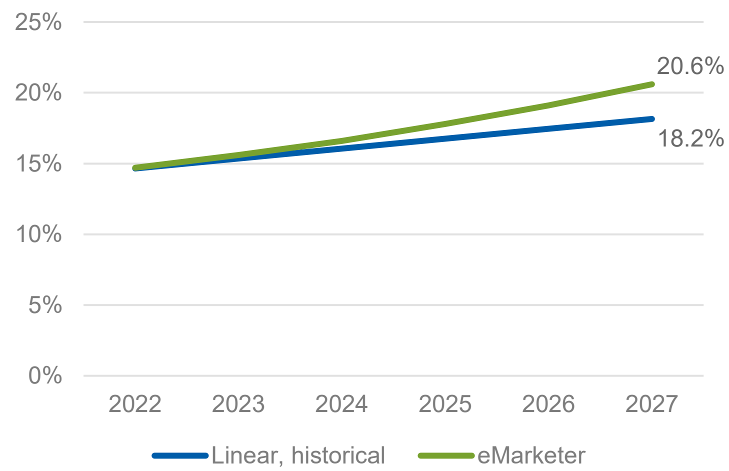
Figure 5: Projection of national e-commerce penetration rate, extrapolating from trends



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.

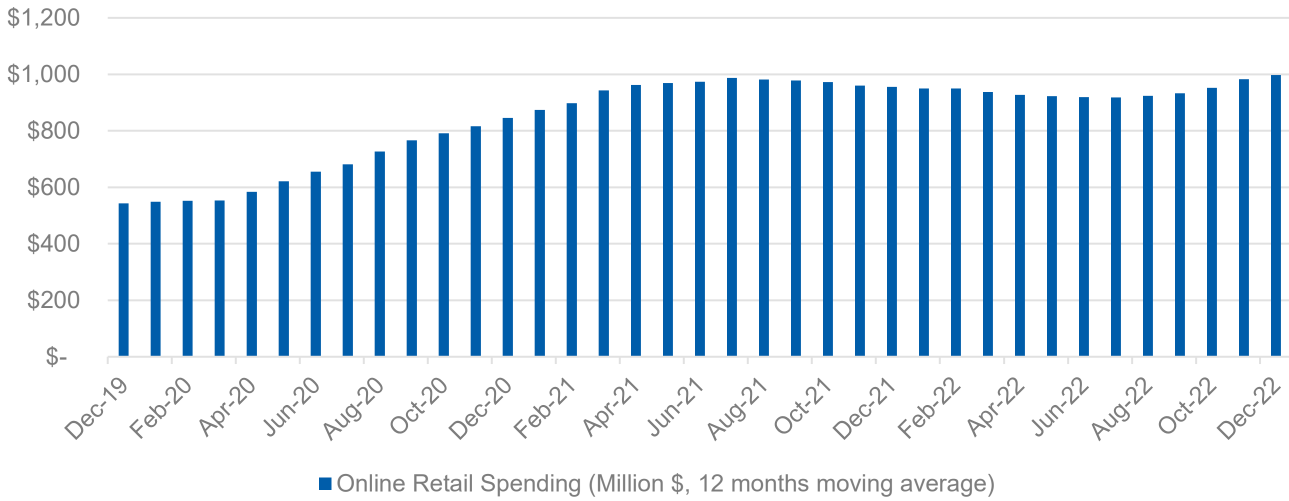
3. Regional trends

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 7). 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.

[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: Online retail spending trend, 2019-2022



Source: CPCS analysis of Replica data, 2023

Replica's Online Spending Data

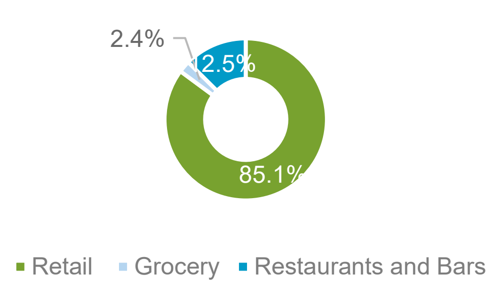
Replica provides data about the built environment and how people interact with it. Among the datasets offered by Replica is the Trends dataset, which captures consumer spending information. This dataset encompasses data from all types of transactions made at points of sale, including those via credit 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.

Figure 8 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.

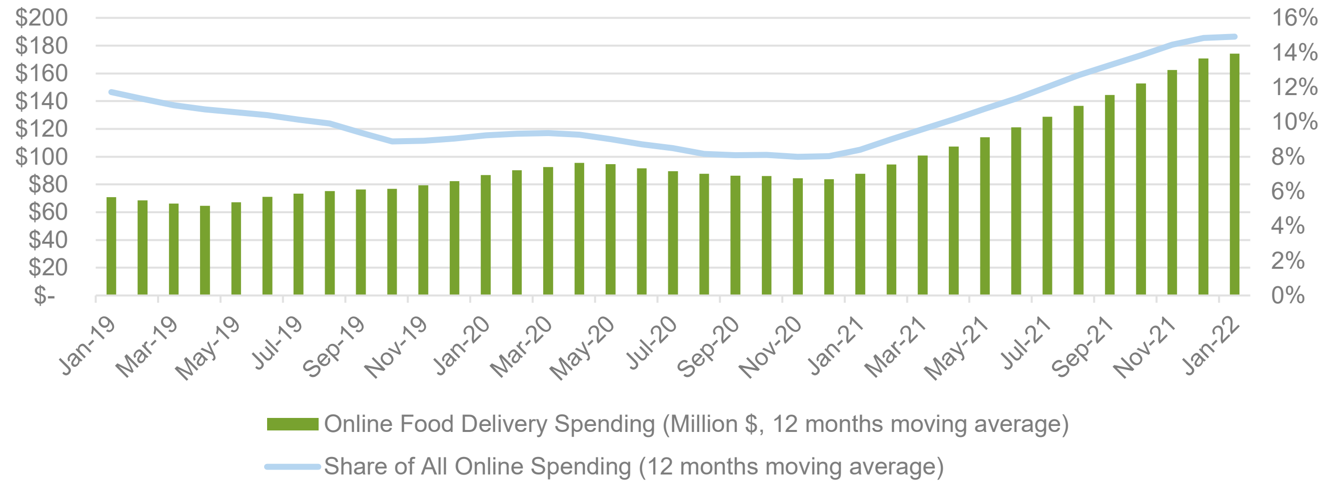
While only accounting for around 15% of all online spending, online grocery and restaurant delivery expenditures have also seen a notable rise during the same period. In 2022, consumers in the region spent more than 2.1 billion dollars on online food delivery, more than doubling the amount spent in 2019 (Figure 9).

Figure 8: Online spending share by category, 2022



Source: CPCS analysis of Replica data, 2023

Figure 9: Online food delivery spending trend, 2019-2022



Source: CPCS analysis of Replica data, 2023

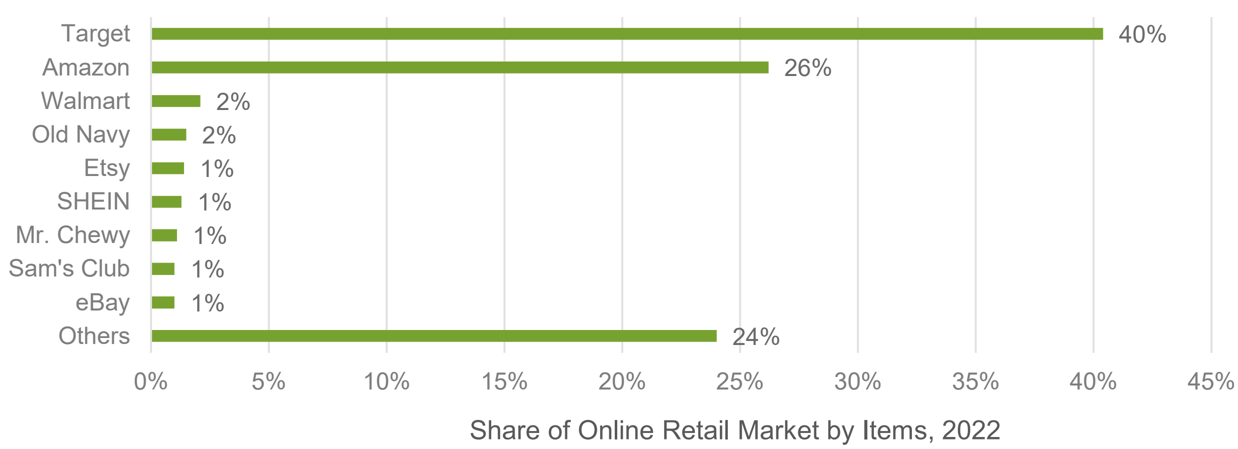
B. E-commerce retail and parcel shipping trends

1. E commerce retailer and carrier market share

E-commerce retail items

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.[7] 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 10). This ranking is derived from the latest NielsenIQ e-commerce shipping insights data.

Figure 10: E-commerce retailer market shares in Twin Cities region (by number of items ordered online)



Source: CPCS analysis of Nielsen IQ data, 2023[8]

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[7] 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.

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

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.

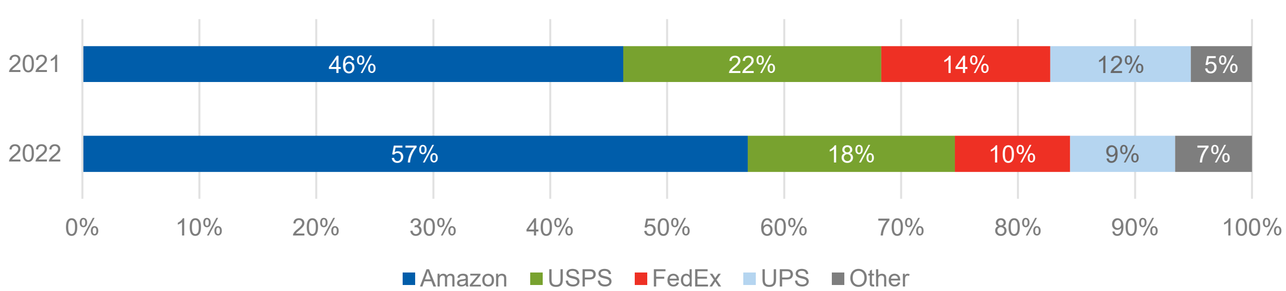
Given that Minneapolis is the home base for Target, it is not surprising to see Target leading in the quantity of online order fulfillments. Interestingly, a significant proportion of Target's online orders are categorized as "click-and-collect," where customers opt to pick up their purchases in-store. 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.

E-commerce retail package deliveries

In the Twin Cities region, 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 11).

Figure 11: Carrier market share in the study area (by number of e-commerce packages)



Source: CPCS analysis of NielsenIQ data, 2023[9]

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

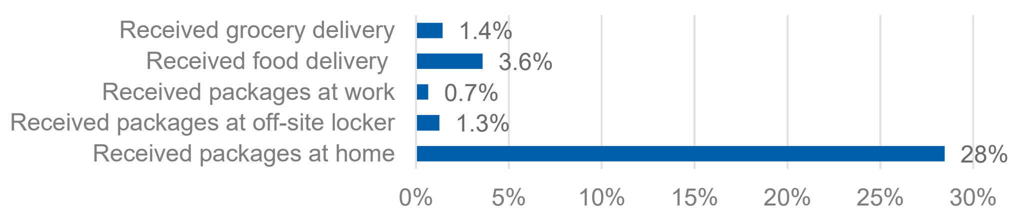
The data underpinning these insights is sourced from NielsenIQ's zip code level e-commerce package and carrier share database. This database is compiled from raw e-commerce email shipping receipts, further refined by aligning the demographic characteristics of email panelists with regional demographic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

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.[10] The discrepancy largely 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.

The NielsenIQ data estimated a total of 80.4 million e-commerce packages were delivered to the Twin Cities region in 2022. Figure 13 shows the distribution of packages by zip code.

Another perspective is offered by Met Council's TBI which is further described in Section C of this chapter 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 12). 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.

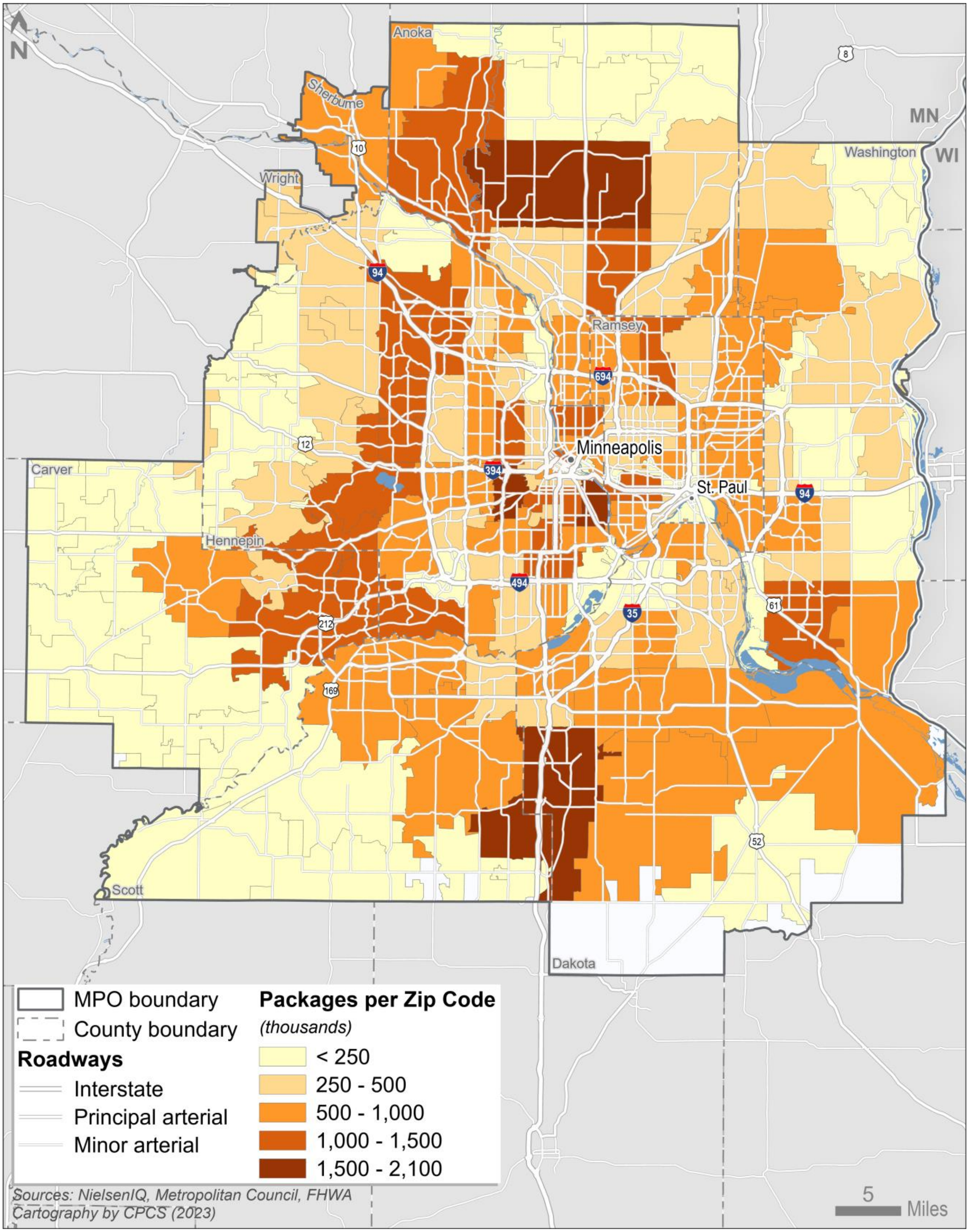
Figure 12: Percentage of study area residents receiving deliveries



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

[10] 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.

Figure 13: E-commerce packages received in the study area



2. 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.[11]

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.[12] 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.[13] 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.

Notable initiatives by the major parcel delivery companies, which will affect VMT and GHG

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.[14] 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

11 Shipt, Target delivery at your fingertips. https://www.shipt.com/stores/target. Accessed on Nov 2, 2023.
12 Amazon Flex. https://flex.amazon.com/. Accessed on Nov 8, 2023.
13 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.
14 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.

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.[15] FedEx has purchased and received its first electric delivery vehicles from BrightDrop, the technology startup from General Motors. [16]

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.[17]

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.[18] UPS has a partnership with the electric vehicle startup Arrival to produce purpose-built delivery vans for UPS, co-developed by the two companies.[19]

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 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.[20]

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

[15] 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.
[16] 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.
[17] 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.
[18] 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.
[19] 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.
[20] 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.

Postal Service anticipates that the combination of vehicle mix changes and network modernization efforts will lead to significant carbon reductions in its system.[21]

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.[22]

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.[23] The new 140,000 SF facility in the Minnesota Technology Corridor will likely serve the northern and eastern part of the metropolitan area.

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.[24]

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.[25]

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[21] 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.

[22]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.

[23] 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.

[24] 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.

[25] 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.

C. In-person shopping trip patterns

Shopping trends are relevant to an understanding of e-commerce, because there is accepted to be some level of substitutability between in-person shopping and online ordering. The best data on shopping trip activity in the region comes from the region's household survey.

This section summarizes in-person shopping trends observed from Met Council's Travel Behavior Inventory (TBI) Household Survey Program from 2019 and 2021.

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.[26]

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.

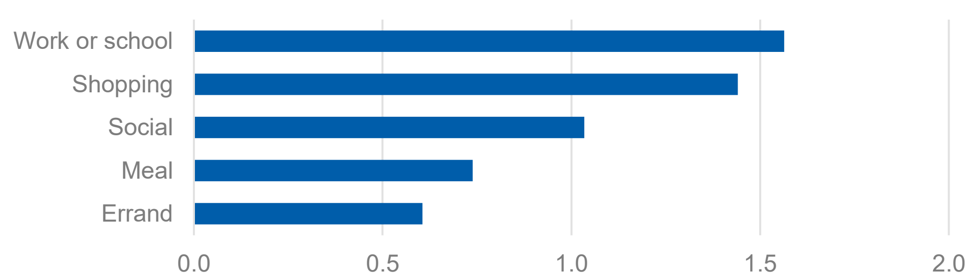
Since then, the Met Council randomly invites about 7,500 households every other year to the TBI household survey program. Households invited to participate include those in the seven-county metro area, as well as 3 Wisconsin counties.

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.

1. Total shopping trips

On a daily basis, about 12.3 million trips are made within the study area, according to the TBI. Figure 14 highlights the breakdown in trip purpose (note: the purpose is the "destination" purpose, i.e., the activity that is performed at the destination. For ease of reference, the chart omits purposes like "home" which can be considered the return leg). Of particular importance, the TBI shows that there are about 1.44 million shopping trips made daily – nearly as many as work/school trips.

Figure 14: Breakdown of daily personal trips within study area by trip purpose (millions, 2021)

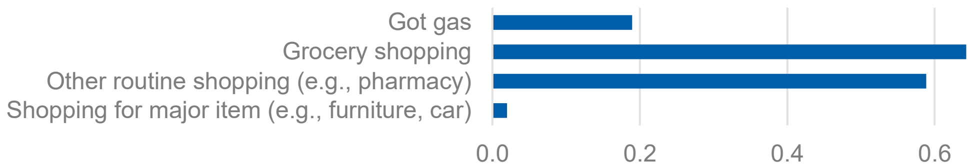


Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area; trip purpose at destination

[26] 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.

The TBI allows for a further disaggregation of shopping trips into four sub-categories, as shown in Figure 15. Each day there are about 645,000 grocery shopping trips and about 590,000 other routine shopping trips, as well as 20,000 major item trips. These can all be considered shopping in the traditional sense. There are also about 190,000 trips to buy gas, which the TBI includes within the shopping category, but which can be considered somewhat different in its nature. As e-commerce would not be considered a substitute, the remainder of the analysis in this study excludes buying gasoline as a shopping trip. When gas trips are excluded, there are about 1.25 million shopping trips daily that originate in the study area.

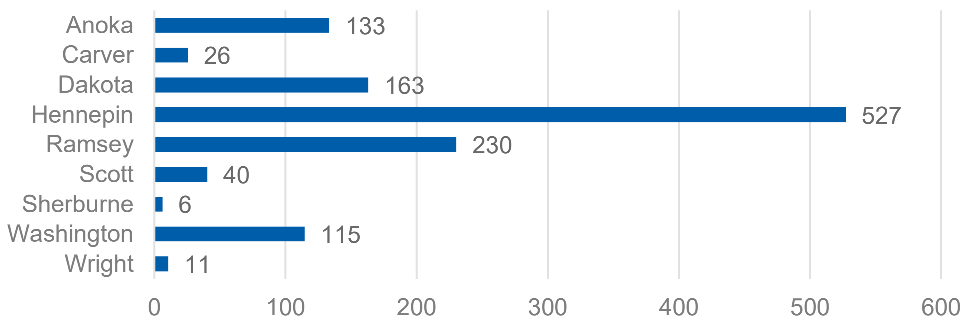
Figure 15: Breakdown of daily shopping trips within study area by detailed trip purpose (millions, 2021)



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

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 16 shows the number of daily shopping trips originating in each county within the study area.

Figure 16: Daily shopping trips within study area, by origin county (thousands, 2021)

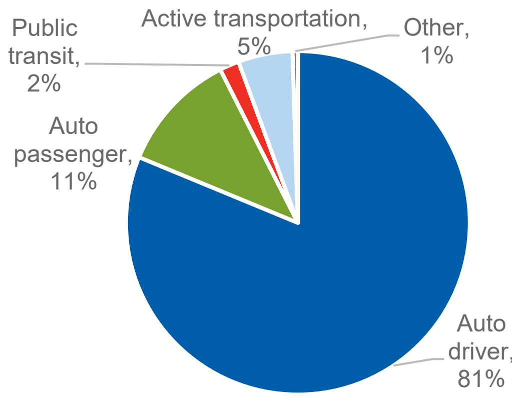


Source: CPCS analysis of 2021 TBI. Note: weighted trips; origin in study area. Shopping excludes gas. Only the portions of Sherburne and Wright counties that are within the study area (MPO area) are included. The other seven counties are within the study area in their entirety. Note that the analysis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

2. Mode share for shopping trips

For shopping trips, the primary mode of transportation utilized is private vehicle (see Figure 17). 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 5%.

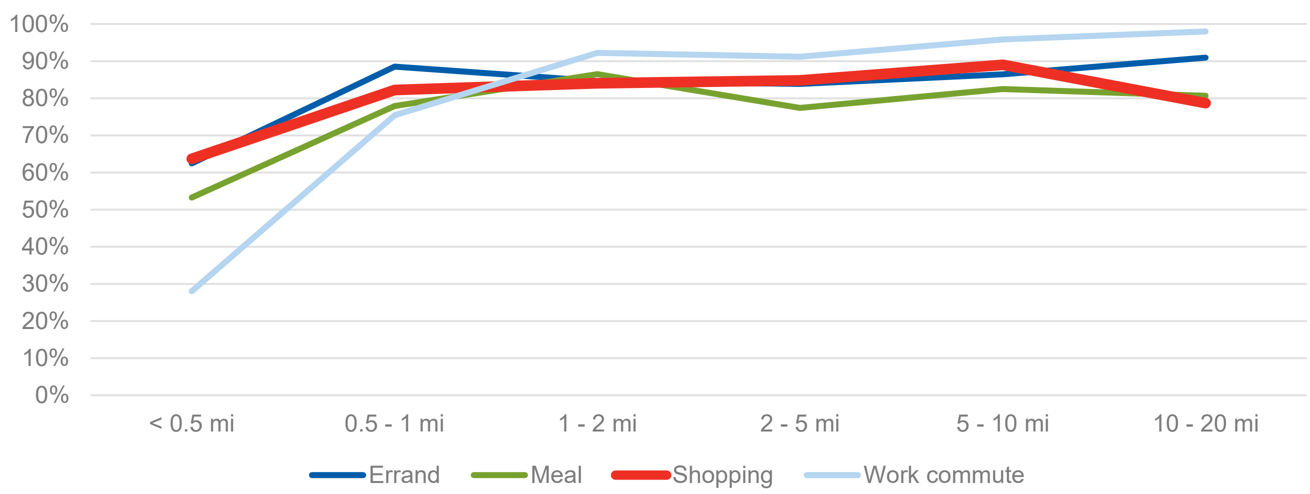
Figure 17: Mode share for shopping trips (2021)



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

The high dependence on personal automobiles for shopping trips is also illustrated in Figure 18. 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 18: 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.

3. Shopping trip lengths

Figure 19 summarizes some relevant statistics for shopping trips in the study area. Of note, 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.

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 19: 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.

4. 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 20 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 20: 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.

II. VMT and GHG impacts

KEY TAKEAWAY

Literature review of existing research shows e-commerce offers opportunities for overall reductions in Vehicle Miles Traveled (VMT) and associated greenhouse gas (GHG) impacts. However, the positive trends observed can be counteracted by e-commerce strategies such as offering free, same-day, or expedited deliveries. Additionally, the net impact of VMT and GHG emissions varies across different products and geographic contexts.

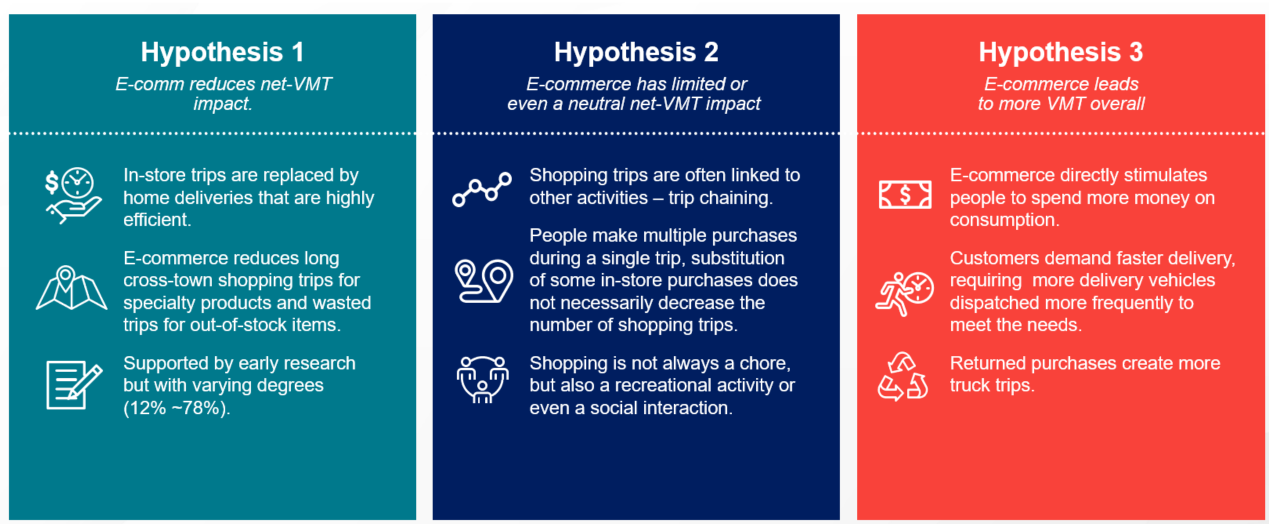
This chapter describes the study team's structured approach for evaluating the VMT and GHG emission impacts stemming from e-commerce deliveries and in-person shopping activities. This approach primarily utilizes NielsenIQ's e-commerce package, shipping, and carrier share insight data, Met Council's TBI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

The analysis finds that personal shopping trips accounted for the vast majority of the transportation impact of last-mile delivery and shopping activities. This disparity highlights the significant impact of personal vehicle use for shopping compared to the more centralized and possibly efficient logistics of package delivery.

A. 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 21).

Figure 21: 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.

1. 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.[27]
- 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.[28]
- Another study identified a reduction of VMT of nearly 20% when considering an e-commerce market penetration of 50%.[29]
- 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. [30]

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.

2. 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. [31] 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.[32, 33]

3. 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.[34] 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

[27] 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).

[28] 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.

[29] 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.

[30] 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.

[31] 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.

[32] 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.

[33] 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.

[34] 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.

impacts.[35] 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.

B. Data sources

This section describes the methodology and data sources used to estimate VMT and GHG emission impact from e-commerce delivery and in-person shopping activities in the study area. Figure 22 gives an overview of primary data sources used for VMT estimation.

Figure 22: 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 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

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.

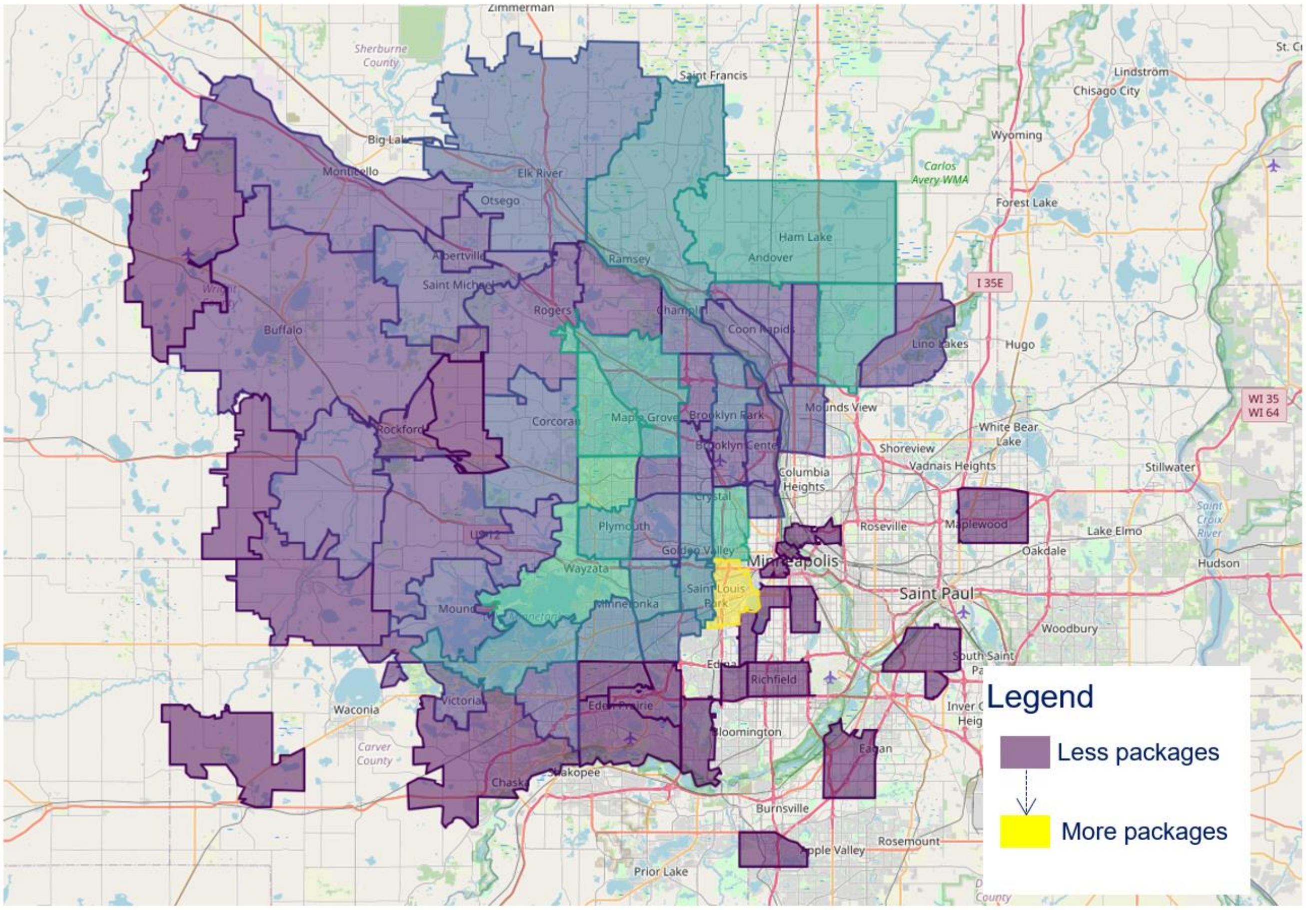
2. E-Commerce delivery scan data

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 23 illustrates the package destinations served by that facility for the last-mile deliveries.

[35] 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.

Figure 23: 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 24 shows the CO2 emission rate and vehicle population share by vehicle and fuel type for 2022.

Figure 24: 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%

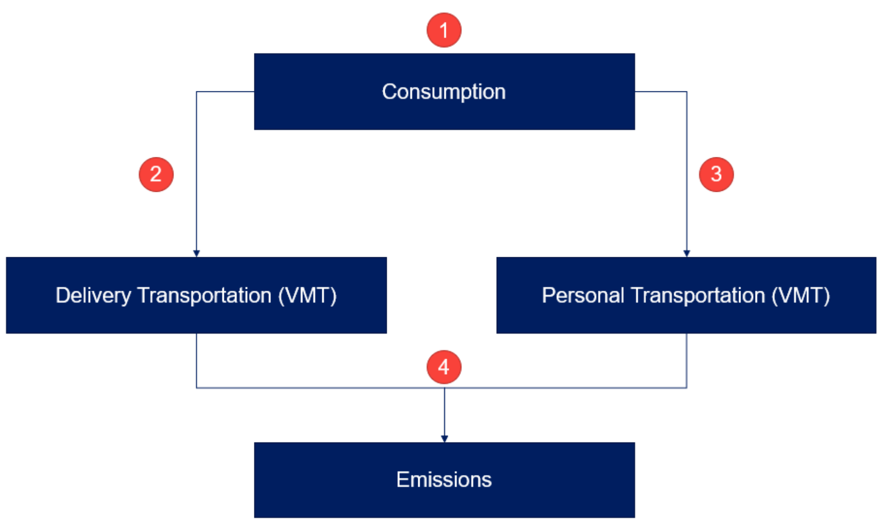
Source: CPCS analysis of MOVES4 model results

C. Methodology

1. VMT and Emission impact assessment approach

This section provides an overview of the study team's structured 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 25 illustrates the conceptual framework.

Figure 25: E-Commerce VMT and emission impact assessment approach



Source: CPCS

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 retail sales and the e-commerce share in overall retail sales, with key findings summarized in Sections I.A – I.B of this report.

Step 2: Estimating package delivery VMT

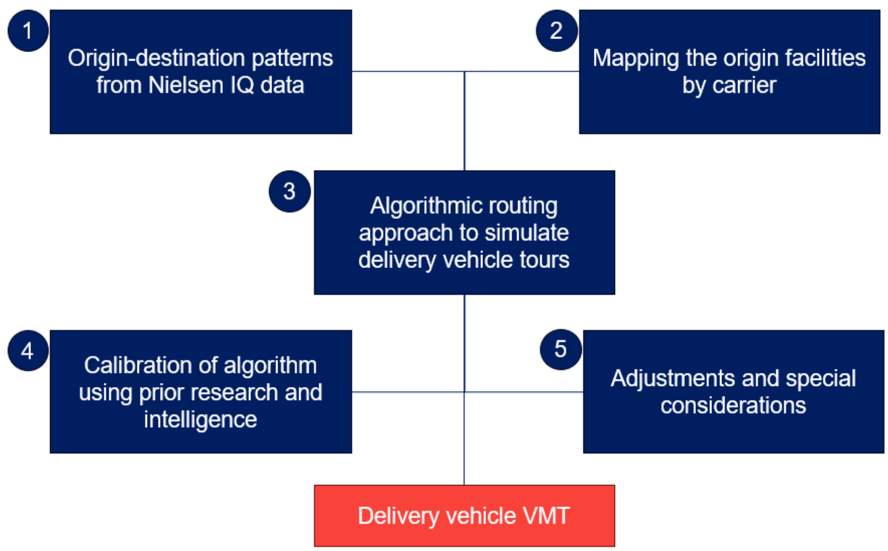
Subsequently, the focus shifts to evaluating the VMT attributable to package delivery operations. This involves understanding the distribution of package delivery destinations and the operational areas and characteristics of major delivery service providers, including factors like vehicle capacity and delivery tour lengths. A more detailed discussion on this will be presented in Section II.C.2.

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.

2. Package delivery VMT estimation approach
Figure 26 illustrates the steps taken to estimate delivery vehicle VMT by carrier facilities.

Figure 26: 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 27 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 28 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 27: E-Commerce last-mile distribution facilities by major carriers

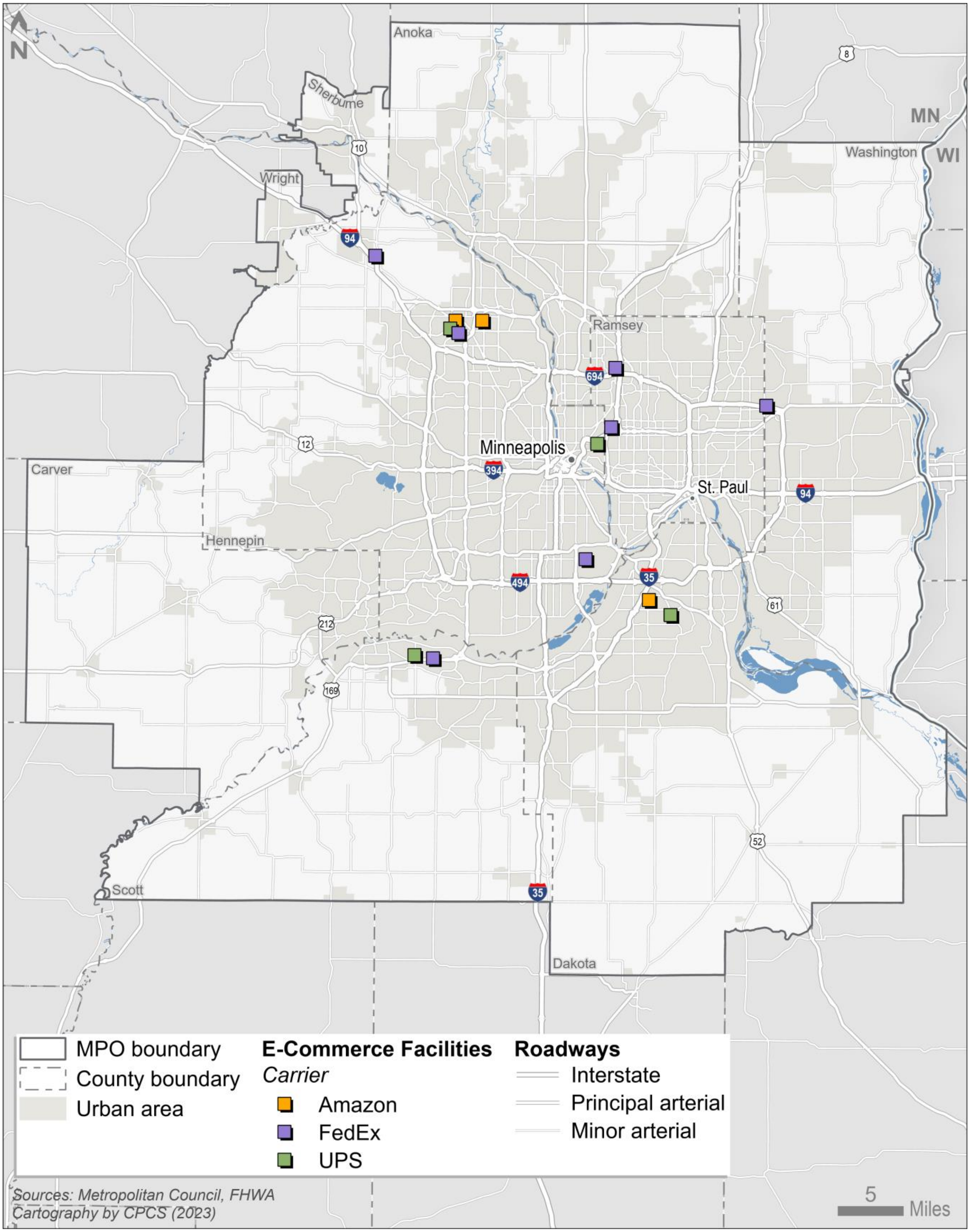


Figure 28: Major carrier last-mile delivery facilities and yearly package estimates

Carrier	Address	City	Zip	Yearly packages
Amazon	3130 Lexington Ave S	Eagan, MN	55121	21,344,994
Amazon	10750 89th Ave N	Maple Grove, MN	55369	21,344,994
Amazon	7500 Setzler Pkwy	Minneapolis, MN	55445	12,524,996
UPS	8601 Valley Forge Ln N	Maple Grove, MN	55369	2,424,115
UPS	555 Opperman Dr	Eagan, MN	55123	1,514,156
UPS	3312 Broadway St NE	Minneapolis, MN	55413	2,200,107
UPS	901 Canterbury Rd #500	Shakopee, MN	55379	865,969
FedEx	19705 Rogers Dr	Rogers, MN	55374	3,728,479
FedEx	5800 12th Ave E	Shakopee, MN	55379	1,733,166
FedEx	7 Long Lake Rd	Mahtomedi, MN	55115	1,835,164
FedEx	8450 Revere Ln N	Osseo, MN	55369	142,768
FedEx	2323 Terminal Rd	Roseville, MN	55113	417,382
FedEx	50 14th St NW	St Paul, MN	55112	242,010
FedEx	2825 Cargo Rd	Minneapolis, MN	55450	120,564

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.

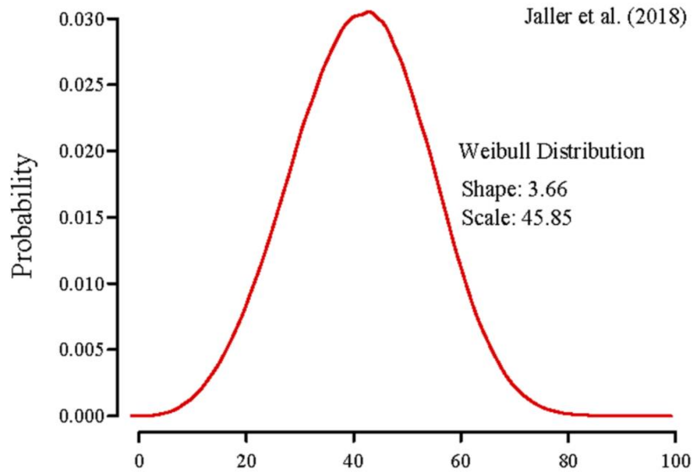
By defining the scope and scale of the delivery tours, including fleet’s size, the base of the deports from which they operation (the delivery facilities), and the geographic spread of the delivery points (derived from the carriers’ market share from NielsenIQ data), the algorithm identifies the best 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.

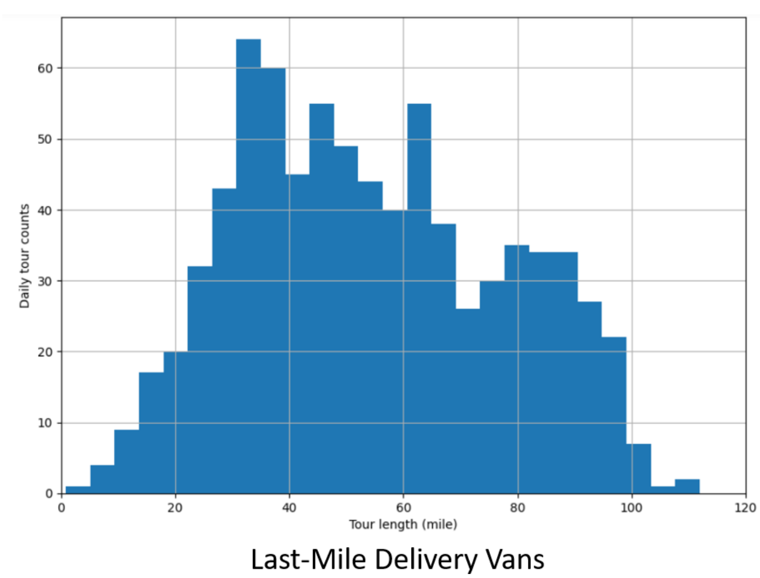
- Number of packages per delivery vehicle: Information obtained from field interviews and desk research suggests a typical value of approximately 250 packages per delivery van.
- Delivery route length: The study team's research indicates that the typical length of a delivery route, or tour, centers around 45 miles (Figure 29). 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 30). 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 29: 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 30: 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,[36] 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.[37] 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[38] (about 40%).[39] 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

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[36] 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.

[37] 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.

[38] 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.

[39]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.

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**

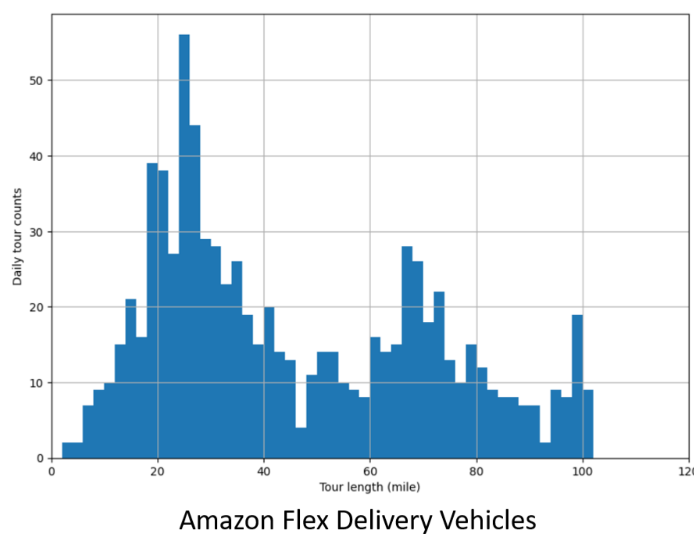
  The model also accounted for the role of Amazon Flex[40] drivers in the delivery network. In the simulation, it was assumed that each Amazon Flex driver, using their personal vehicle, can deliver up to 50 packages per trip. This differs from the use of commercial delivery vans or trucks.

  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. [41]

  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 31 shows the delivery tour length distribution modeled for Amazon Flex.

Figure 31: Modeled Delivery Tour Length Distribution – Amazon Flex



Source: CPCS

[40] 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.
[41] 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.

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"[42] 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. 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.

Summary of last-mile parcel delivery VMT by carriers

Figure 32 shows a summary of the modeled last-mile parcels delivered by major carriers and their associated VMT impacts.

A few key takeaways include:

- Amazon leads in total e-commerce package deliveries, carrying more than half (57%) of the total 80,308,538 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 VMT, respectively.
- Amazon Flex deliveries, primarily involving personal vehicles, exhibit a higher VMT per package (1.51 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.

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[42] See https://cdn.nrf.com/sites/default/files/2022-12/AR3021-Customer%20Returns%20in%20the%20Retail%20Industry_2022_Final.pdf

Figure 32: 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 per package	0.51	0.15	0.24	0.10	0.23	0.36
Flex VMT	1.51					
Van VMT	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

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 33). 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.

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.

Figure 33: 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.[43]

[43] 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.

3. In-person shopping VMT estimation approach

In-person shopping trip VMT is estimated from the 2021 TBI results by multiplying total shopping trips (excluding gas) by vehicle mode share and average vehicle shopping trips length by geographic types (e.g., urban, suburban, and rural). These results were profiled earlier.

Figure 34: 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%	
Shopping trip length, miles (round-trip)	8.4	9.6	11.0	16.2	
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. Note: Ring definitions are profiled in Section III.C.

4. Package delivery GHG emission estimation approach

Package delivery VMT estimates are multiplied by the emission factors (discussed in Section II.B. 3) for medium trucks to derive the package delivery GHG emissions.

5. In-person shopping GHG emission estimation approach

In-person shopping trip VMT estimates are multiplied by the emission factors (discussed in Section II.B. 3) for light duty vehicles to derive the in-person shopping trip GHG emissions.

6. Base-year VMT and GHG results

Figure 35 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 35: 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).

III. Projections, scenario analysis and recommendations

KEY TAKEAWAY

The following recommendations are proposed:

1) **Electrify last-mile deliveries**: Promote electrification of commercial fleets through planning and investments in public charging infrastructure.

2) **Enhance efficiencies where possible:** Leverage innovative solutions like cargo bikes, microhubs and delivery lockers at mobility hubs.

3) **Education and promotion:** Encourage information sharing by major parcel carriers and develop educational materials to promote actions that reduce Vehicles Miles Traveled (VMT) and greenhouse gas emissions (GHG).

4) **Further study:** Explore other research areas identified and incorporate the effects of e-commerce in freight and travel demand models.

A. Methodology

There are a large number of factors that can affect vehicle miles traveled, as shown in Figure 36. 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 36: 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.

B. Change drivers

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 eight change factors are described below:

1) **Demographics:** Changes in the demographic composition of the region will result in a change in the demand for 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, what the nature of these relationships will be at some point in the distant future is far from clear. (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).

2) **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 – reflecting that as the population tends to become wealthier over time, it spends more money on goods. 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.

3) **Marginal delivery VMT:** This represents the marginal impact that an additional package has on vehicle miles traveled 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 such companies, the locations of their delivery hubs, their network densities, their operating characteristics such as providing different levels of speed or priority, their routing decisions, etc.). Notably, it is nearly impossible to predict how the delivery landscape will evolve in the distant future – for example, the presence of new entrants into the market, the opening of new distribution hubs, and so on. Despite these limitations, there are a few things that can be modeled on 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.

4) **Marginal delivery GHG:** This represents the marginal impact than 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 and adopt zero-emission technologies, the marginal delivery GHG is expected to decrease. The impact on emissions will be a function of the rate of adoption of zero-emission vehicles within delivery fleets. 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).

5) **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 would 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.[44] 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.

6) **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

[44] 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.

acceptable substitutes within the network of stores. As with many other factors, there is no clear way to predict what the types of stores will be in the distant future, where they will be located and what products they will stock. What can be modeled with some confidence is that the marginal shopping VMT differs depending on whether one is located in urban, suburban or rural areas (including length of shopping trip and likelihood of using an automobile versus other modes of transportation). Thus, as the geographic distribution of population within the region changes, there will be impacts on shopping VMT.

7) **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).

8) **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.

More details on the data sources used are provided below:

Figure 37: 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

Change Driver	Data Input	Source
		(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

C. Sub-regional ringed areas for analysis

For the scenario analysis, a four-ring model was applied within the region, as shown in Figure 38. 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:

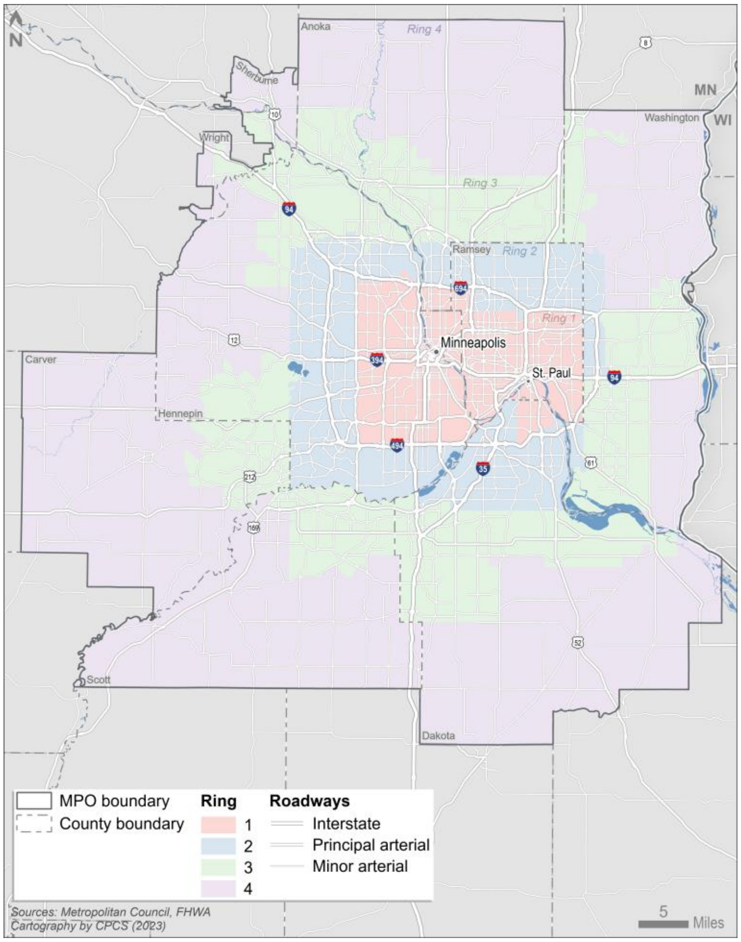
- From a transportation perspective, more central areas tend to have a denser road network and be closer to multiple transportation corridors such as highways; whereas in more rural areas the road network is less dense and may require more circuitous travel.
- From a land use perspective, more central 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 38: Ring structure used for modeling



Source: CPCS

D. Scenarios analyzed

1. Descriptions of the scenarios

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 the subsequent section.

Base year: 2022

The base year represents the outputs of the modeling as described in the previous chapter. The base year 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.

2. Detailed assumptions for the scenarios

Base year inputs

Figure 39 displays key model inputs for the base year.

Figure 39: 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

Population growth

Figure 40 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 40: 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	Future Baseline Case	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
Ring 3	30%	23%	30%	30%	30%
Ring 4	48%	34%	48%	48%	48%

Source: CPCS analysis

E-commerce sales growth

Figure 41 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;[45] 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 41: 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

[45] 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

Delivery vehicle VMT impact

Figure 42 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 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.[46] 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

[46] 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%.

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.[47]

Figure 42: 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

Delivery vehicle GHG emissions impact

Figure 43 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% 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 43: 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

[47] 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

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

Growth in personal shopping trips

Figure 44 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 44: 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 45 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.[48])

The Future Baseline Case assumes that the 8.6% value will be retained over time, as industry forecasts[49] 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 45: 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

Shopping trip VMT impact

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

Figure 46 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 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.

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

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 46: 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 47 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 47: 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

Passenger vehicle GHG emissions impact

Figure 48 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 48: 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

Figure 49 summarizes the key assumptions for the four scenarios.

Figure 49: 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
Delivery vehicle GHG impact (GHG per mile)	-	Lower due to full carrier fleet electrification	-	Somewhat lower due to more Flex-type ZEVs

Factor	Scenario 1: Urban Hub	Scenario 2: Techno-Freight Revolution	Scenario 3: Omni Breakthrough	Scenario 4: Eco-Conscious Consumer
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

E. Scenario results

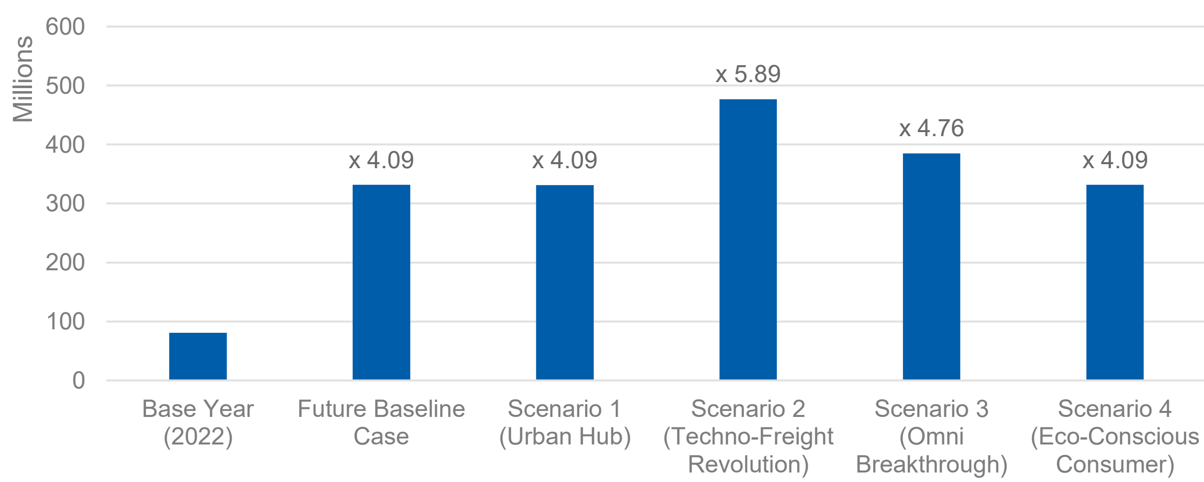
1. Intermediate outputs

E-commerce packages delivered

Figure 50 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 penetration rate increasing to 50% (i.e., half of all retail sales being online).

Figure 50: Number of e-commerce packages delivered in the region, under each scenario

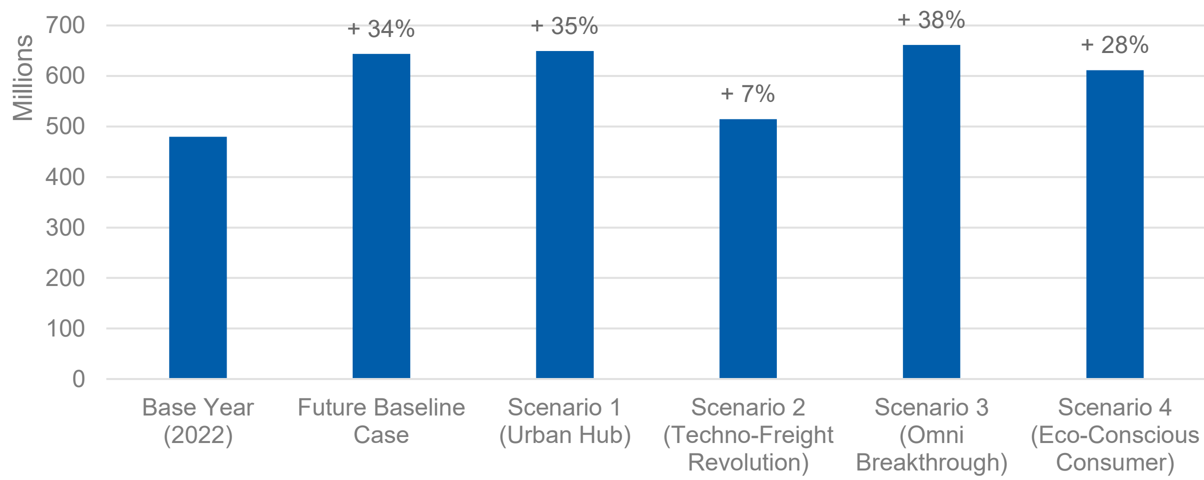


Source: CPCS analysis

Shopping trips
Figure 51 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%.

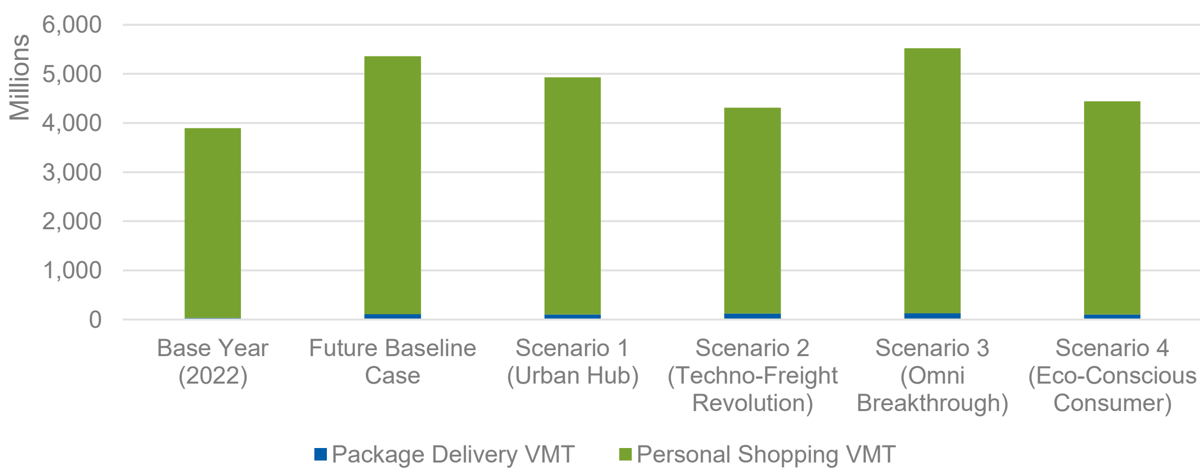
Figure 51: Number of personal shopping trips in the region, under each scenario



Source: CPCS analysis

2. Impacts on vehicle-miles traveled (VMT)
Figure 52 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 Future Baseline Case.

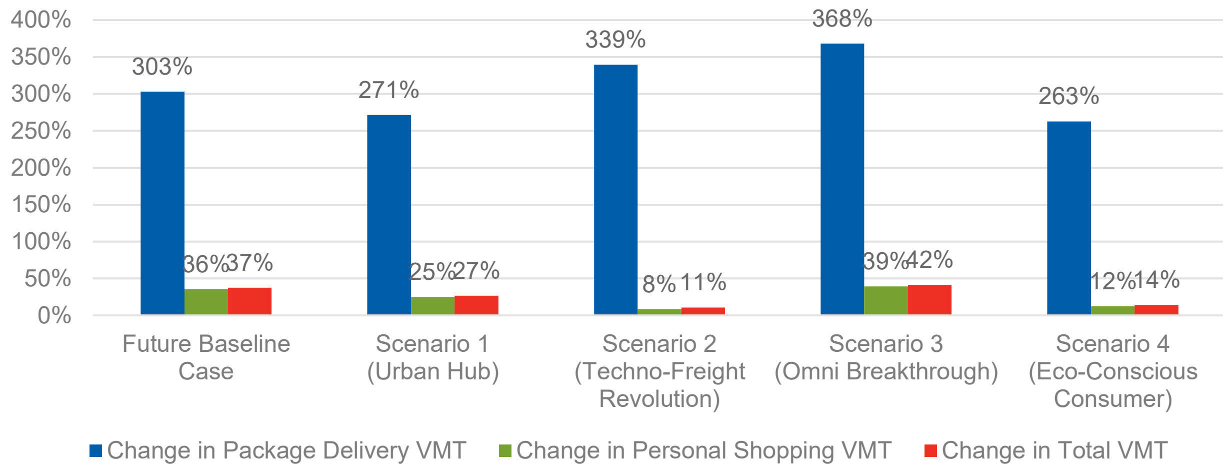
Figure 52: Total vehicle miles traveled in the region, under each scenario (miles, annual)



Source: CPCS analysis

Figure 53 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.

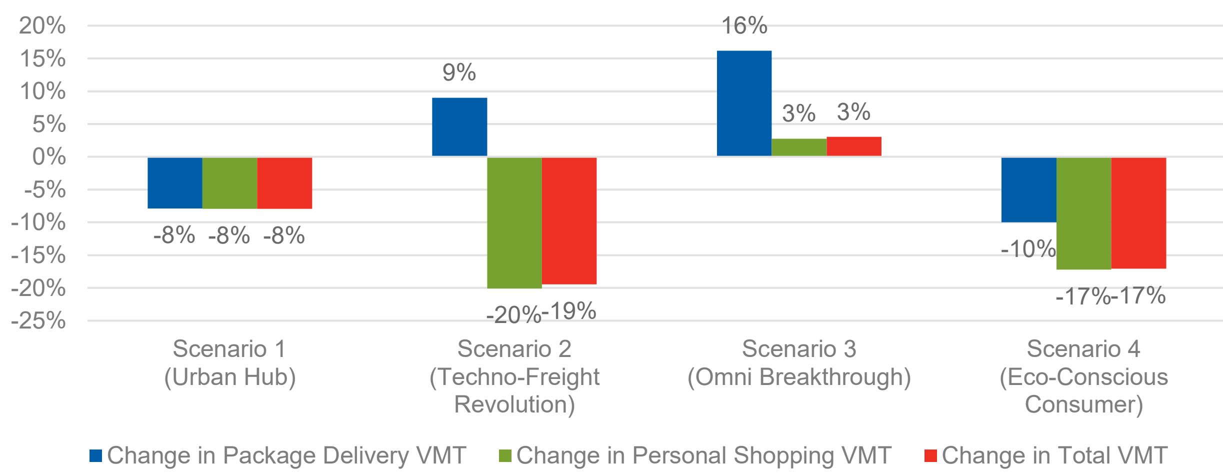
Figure 53: Change in total vehicle miles traveled in the region, for each scenario relative to Base Year



Source: CPCS analysis

Figure 54 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 54: Change in total vehicle miles traveled in the region, for each scenario relative to Future Baseline Case



Source: CPCS analysis

Figure 55 provides a summary of the change in VMT for each scenario, when compared to both the Future Baseline Case and the base year.

Figure 55: 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

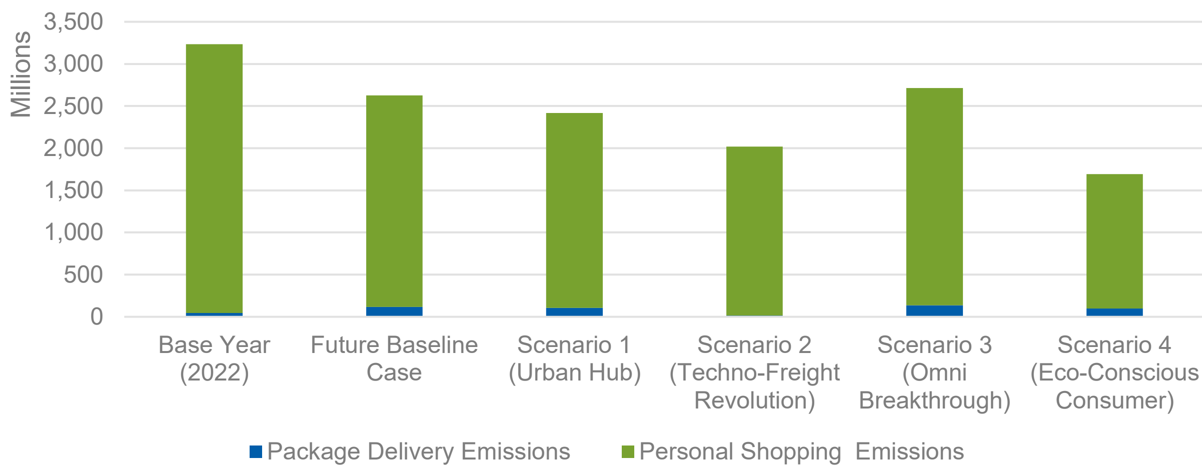
Summary of VMT impacts of the scenarios

- **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.

3. Impacts on greenhouse gas emissions (GHG)

Figure 56 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.

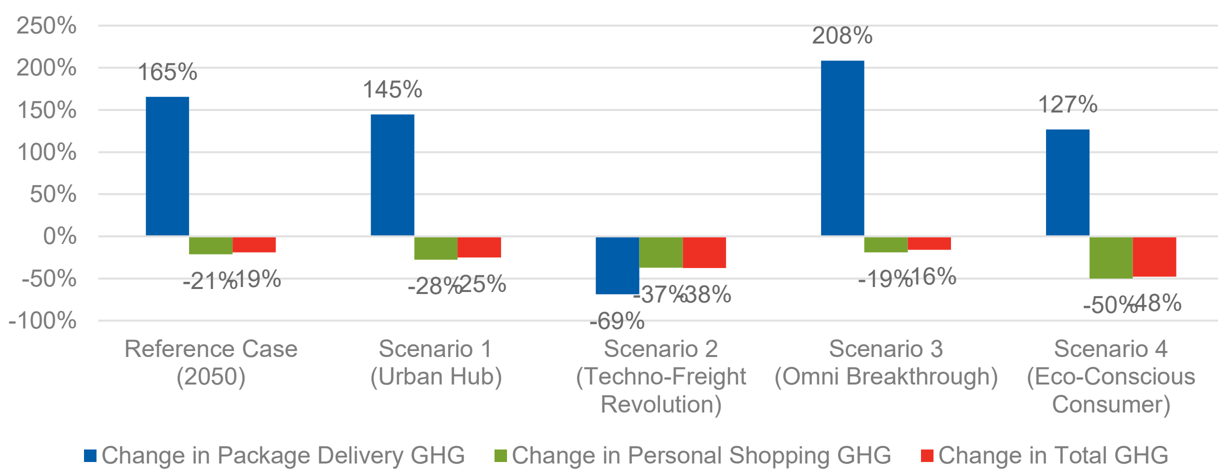
Figure 56: Total greenhouse gas emissions in the region, under each scenario (pounds, annual)



Source: CPCS analysis

Figure 57 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.

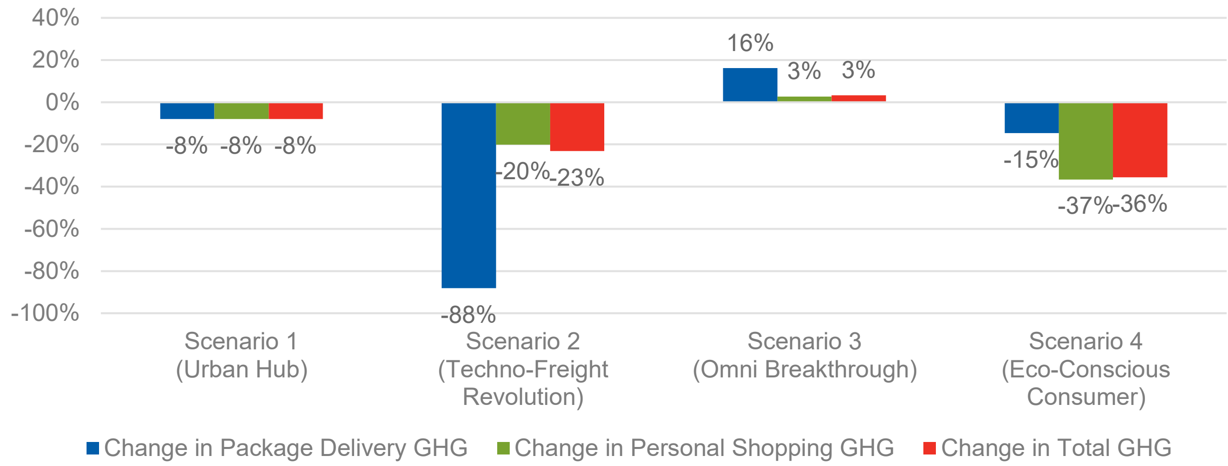
Figure 57: Change in total GHG emissions in the region, for each scenario relative to Base Year



Source: CPCS analysis

Figure 58 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 58: Change in total GHG emissions in the region, for each scenario relative to Future Baseline Case



Source: CPCS analysis

Figure 55 provides a summary of the change in GHG emissions for each scenario, when compared to both the Future Baseline Case and the base year.

Figure 59: 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

Summary of GHG impacts of the scenarios

- **Scenario 1** results in a reduction of emissions of 8% compared to the Future Baseline Case. The change in GHG emissions is proportional to the change in VMT.
- **Scenario 2** results in a reduction of emissions of 23% compared to the Future 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 increase of 3% compared to the Future Baseline Case. The change in GHG emissions is proportional to the change in VMT.
- **Scenario 4** results in a reduction of emissions of 36% compared to the Future Baseline Case. The emissions reduction is even larger than the VMT reduction, because of the increased adoption of ZEV among the passenger vehicle fleet.

F. Conclusions

1. Largest impact drivers

Figure 60 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 60: 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.

2. 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 focuses 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. Despite our relatively conservative estimates of the number of packages fulfilled by Flex, we find these packages to have an outsized impact on VMT due to the smaller capacity of Flex-type personal vehicles compared to delivery vans. 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. Customers may first order the types of products online where the benefit or convenience of doing so may be highest – for instance, products that might require long shopping trips to specialized retailers, may not be in stock, or may not even be available locally. Over time, they also order regular supplies that are readily available but simply more convenient to order online. The final items to be ordered online may be those that may be less convenient to order, 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. Similar conclusions about non-linearities can be drawn about other assumptions, such as the nature of e-commerce delivery company operations. 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.

3. Study recommendations

Although e-commerce poses a significant challenge to traditional approaches, the findings of the study suggest that it also has a lot of promise in helping to reduce regional VMT when it can substitute for personal shopping trips. This is because the traditional shopping model puts a large (if sometimes ignored) 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” delivering benefits to consumers (convenience, choice), businesses (greater market reach, less need for real estate), and society (reduced VMT and emissions).

The following recommendations are proposed:

1) **Electrify last-mile deliveries:** Electrifying last-mile deliveries represents a crucial strategy for significantly reducing greenhouse gas emissions in the transportation sector. The adoption of electric vehicles (EVs) in this segment offers a unique advantage because it involves fewer decision-makers compared to other parts of the supply chain. This means changes can be implemented more swiftly and efficiently. Businesses stand to benefit greatly from this transition. By incorporating electric vehicles into their fleets, they can experience considerable cost savings over time. Electric vehicles generally have lower fueling costs compared to traditional gasoline or diesel vehicles. Additionally, EVs typically require less maintenance due to fewer moving parts and simpler mechanical systems. This aspect is particularly advantageous for businesses that operate large fleets of vehicles for delivery purposes, as it can lead to substantial reductions in operational costs. Furthermore, the shift to electric last-mile deliveries can catalyze broader changes in urban infrastructure. As more businesses adopt EVs, there will be a growing need for widespread and accessible charging infrastructure. This can encourage public and private investments in EV charging stations, further facilitating the transition to a more sustainable transportation ecosystem.

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

2) **Enhance efficiencies where possible:** Although home deliveries are VMT-efficient compared to traditional shopping models, this study finds that there are certain other models that have the potential to further reduce regional VMT in certain situations. In particular, the opportunity to locate “microhubs” or consolidated pickup points near the customer can significantly reduce Vehicle Miles Traveled (VMT). This is especially true if it is assumed that from these facilities, 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. However, if the customer has to make an additional car trip to pick up the package, the VMT reduction benefits essentially disappear. Therefore, these types of solutions are highly context specific.

   Recommendation: Urban municipalities 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.

3) **Education and promotion:** There are direct actions that industry and resident consumers can take to minimize their contributions to regional VMT. Companies should be encouraged to report to maintain regional scorecards on how they are improving their operations to reduce excess emissions – considering that many of the most conspicuous inefficiencies (such as receiving multiple packages in an uncoordinated and haphazard manner) may push customers to buy fewer products online in favor of traditional shopping, out of the (likely mistaken) view that the latter is less wasteful. Similarly, residents should be reminded that their own shopping decisions can have an impact on regional VMT and encouraged to take actions like reducing wasteful ordering (online or otherwise), combining multiple trips into one (also known as "trip chaining"), using non-automobile or zero-emission travel modes, and shopping closer to home when possible.

   Recommendation: Met Council and MnDOT should consider developing a strategy to encourage major e-commerce parcel carriers to provide summary data related to delivery vehicle VMT and to develop aggregated data metrics to track progress for the region/Metro District.

   Recommendation: Met Council should consider developing educational materials to inform the public and promote actions that residents and businesses can take to minimize VMT and greenhouse gas emissions.

4) **Further study:** This study finds that traditional shopping activity has an impact on regional VMT that is an order of magnitude greater than the last-mile impacts of e-commerce – which corroborates previous findings on this subject by others. This suggests that if the region wishes to reduce regional VMT and greenhouse gas emissions, it would be more effective to do so across the wider context of all trips. For example, the pandemic experience has revealed that working-from-home offers the opportunity to significantly reduce commuting VMT. Given these insights, it becomes crucial for the Met Council to consider the effects of e-commerce on regional freight travel and household shopping trips.

   Recommendation: Met Council should explore how to incorporate ecommerce's influences on regional freight travel and household shopping trips during planned updates to the Council's freight and Activity Based forecast models.

4. Possible areas for further study

There are many areas for possible further study, but here 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 represents a potential area for further study. 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 would 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, as the work trip would take place anyway. However, this becomes less clear when

multiple discretionary trips (such as shopping, errand and social/recreational trips) are bundled together. 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 flex-type delivery vehicles is challenging due to the limited availability of data on the extent and characteristics of these deliveries. Therefore, 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, as this can be done electronically. For example, music streaming has reduced the need to buy CDs and other physical media. Similarly, smaller, higher-value products can take up less space, increasing the efficiency of deliveries. To this end, reducing both the size of products and the packaging can be beneficial towards reducing VMT. 3D printing also offers an opportunity to reduce VMT, not only in the last-mile but throughout the freight and goods supply chain.

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