Home Deliveries, Equity and New Technologies under the COVID-19 Pandemic

FMRI Webinar- April 28, 2021

Sabya Mishra

University of Memphis, TN, USA

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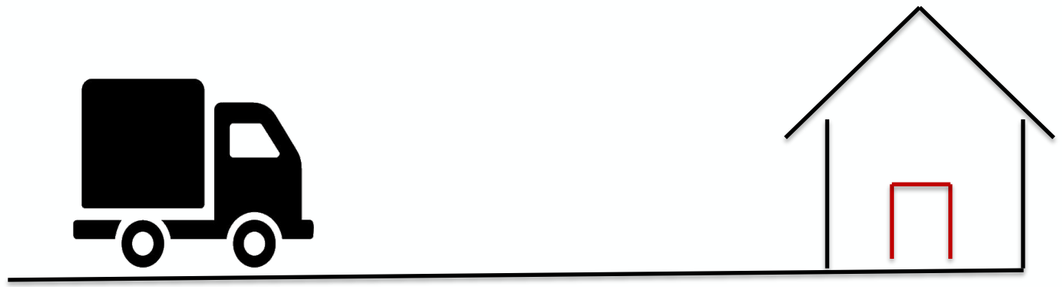
Outline

- Background on Last-Mile Delivery
- General Context on Autonomous Delivery Robots (ADRs)
  - How does it work?
  - Regulations
  - Deployment status
- What has Changed due to COVID?
  - Shift in consumer behavior
  - Shift in perceptions on automation
- Overview of our research and early-stage findings
- Future Research directions

Last-Mile Delivery

- What is Last-Mile? Movement of goods from retailer's transportation hub to consumer homes.
  - 40% of logistics cost
  - Significant human element
    (Sorting, Driving, Door-to-door drop-off)
  - Integral to consumer satisfaction
  - Integral to E-commerce experience and retail reputation
  - Generates approximately 158.4 g CO_2 per km per order

    Accepted last-mile emission target: 0.147 g of CO_2 per km per order (UNFCC)
  - Practical challenges to meet growing consumer demands
  - Major contributor to congestion and safety in urban areas



Light Commercial Vehicle

Technological Transformations and Research Need

- Managing last-mile delivery density
- Achieving routing efficiency
- Reducing the cost of deliveries
- Resolving the unpredictability in transit
- Solving delivery failures (Customer unavailability)

Technology Solutions →

- Fostering Fossil-fuel independent vehicles
- Reducing human elements
- Integrated fleet operation

What are the Types of Delivery Robots?

1. Sidewalk autonomous delivery robots (SADRs) are pedestrian sized robots that only utilize **sidewalks** or **pedestrian paths**
2. Road autonomous delivery robots (RADRs) are vehicles that travel on **roadways shared with conventional vehicles**

Amazon Scout

Starship

FedEx Roxo

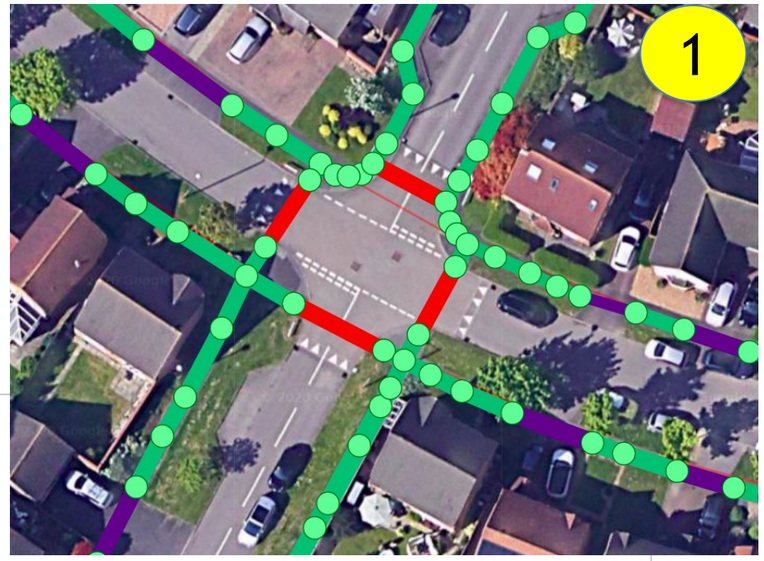
Nuro RADR

Udelv RADR

SADRs Vs RADRs
Tradeoffs: Payload, Speed, Range

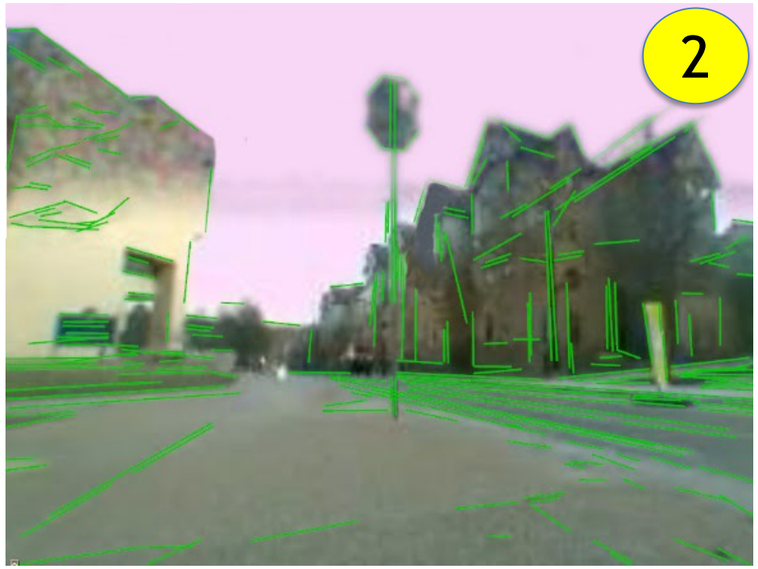
How do ADRs work? Mapping Process

Move from A to B? Node Graph



2D Satellite map - SW (green), CRS (red), DRW (purple)

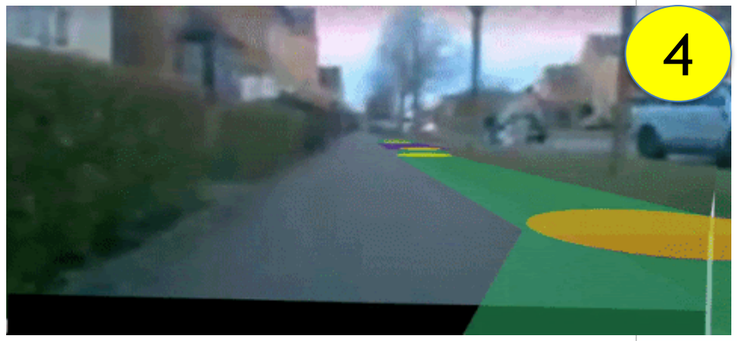
Interact with Surroundings? Guide Posts



3D World map – Cameras, computer vision, Sensors

Creating a Unified 3D map

Multiple mapping trips and combining with line data



Physical Mapping Process –
Where and how sidewalks are?
What are Safe zones?

How do ADRs work? Challenges in Real World

- World around us, however, is not static – daily and seasonal changes in landscape, constructions are renovations change our neighborhoods
- How does ADRs account the dynamic nature of our built environment?
- Map must be updated using each delivery tour of the ADRs – Keeping the map up to date is critical for delivering safely and autonomously

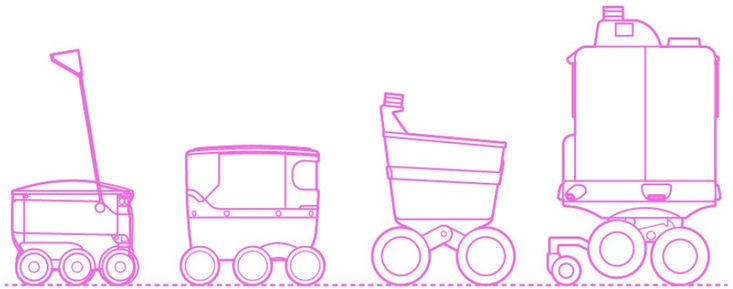
New Employment Opportunities:
Tele operators or "Fleet Supervisors"

How do ADRs work? Computational Back-end

- Different set of challenges as compared to self-driving cars
  - Traffic on roads is more structured and predictable (lanes, limited directional change)
  - Humans frequently stop abruptly, meander, do not give out signal lights!
- Object detection module – program that inputs images and returns list of objects – Machine learning for classifying pixel intensities
- Neural network annotation - Annotating data takes time and resources – factor in weather conditions too

What are Existing Regulations? SADRs

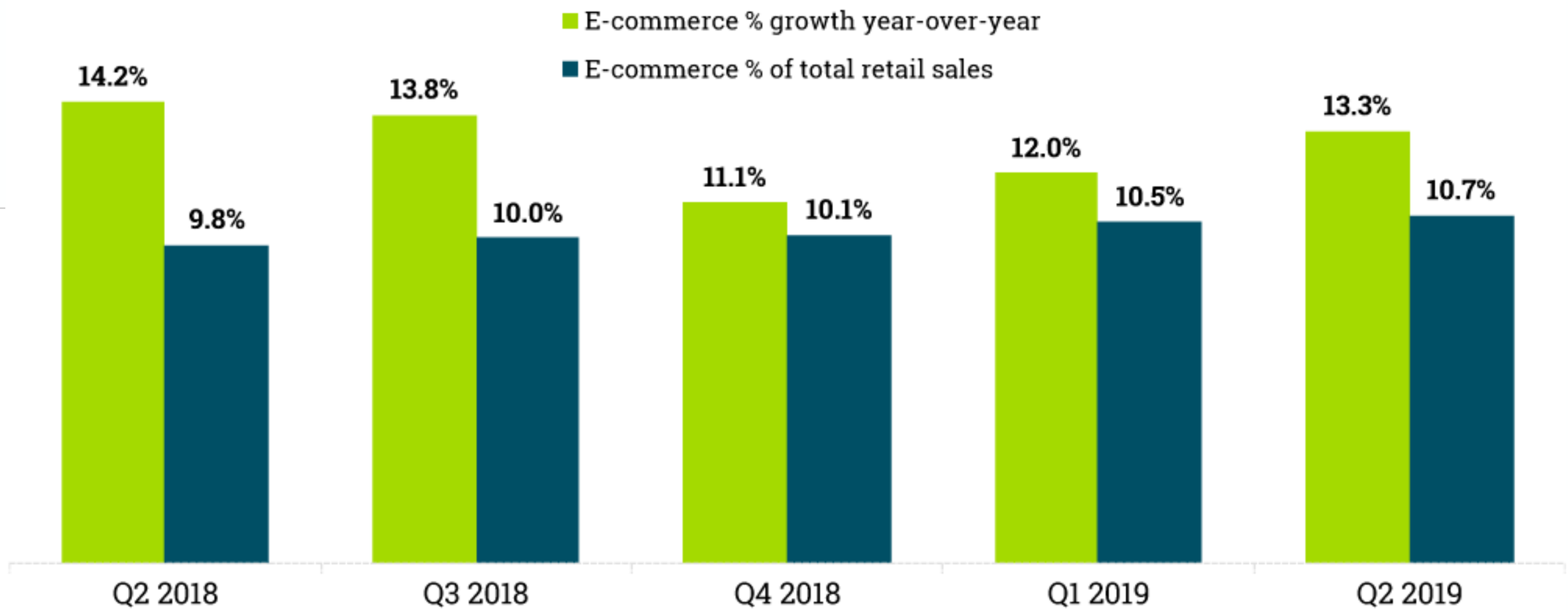
1. **Weight limit -** up to 80 pounds (Virginia, Idaho, Oregon, Arizona)
2. **Speed limit** – 10 mph (Issue of excluding competitors in the market)
3. **Pedestrian laws** - (Accessibility and Disability act)
4. **Operational Controls:**
    1. Emit piercing alarms when in conflict
    2. Headlights
    3. Brakes



5. **Legal considerations:** Tort liability, Privacy, Data Protection (More autonomous a robot is, less it can be accounted by traditional civil liability frameworks)
6. **Insurance** – ADR insurance with human monitoring

Technological Transformations and Research Need

Before COVID: We still used to shop the same way, we did 50 years ago.



89% of commerce was still performed locally before COVID

Has COVID changed the way we interact with physical world?

Transformative Potential of Delivery Robots

After COVID: Transformative changes are expected in physical travel.

AVs: Replacing the driver

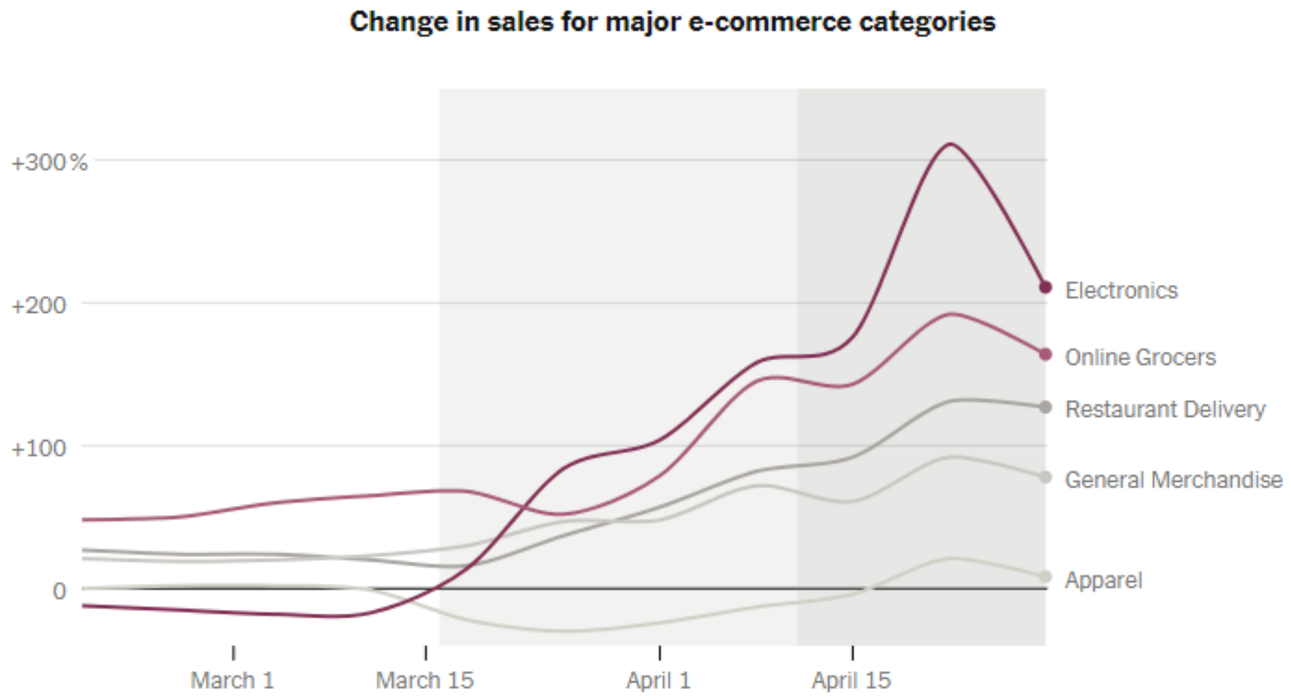
ADRs: Replacing the Driver and Passenger

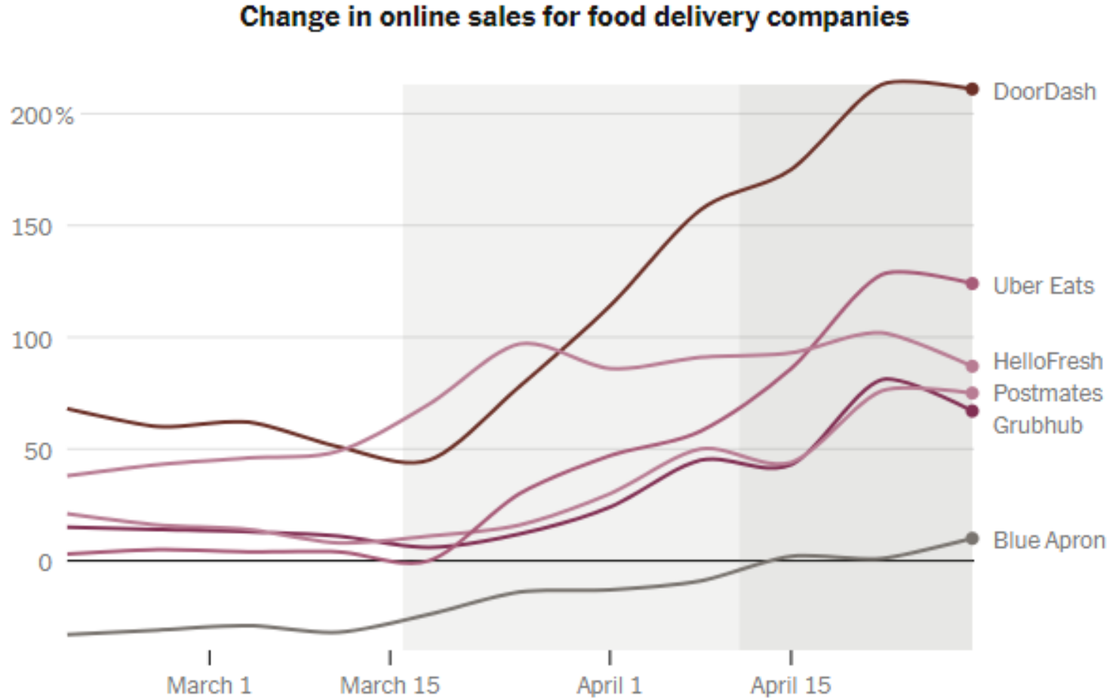
43%

Shopping + Errand Trips

Incredible opportunity to **give time back** to people who could use it for better things – Societal and economic benefits

What has Changed due to COVID (2020)?

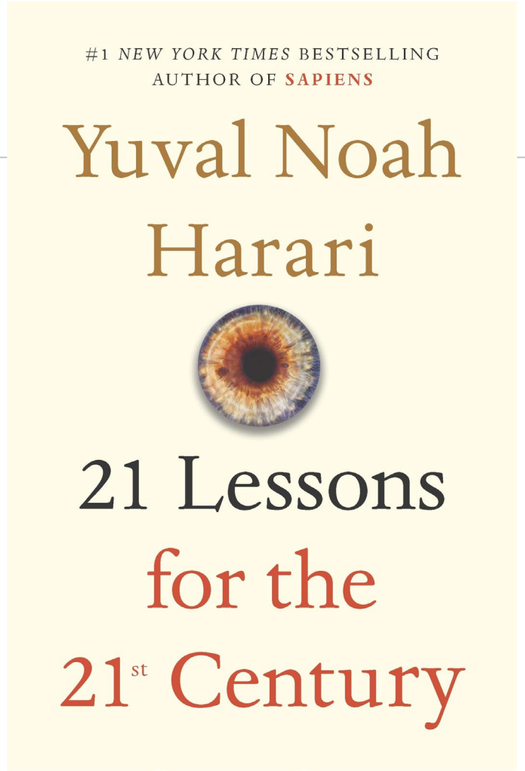




- Consumer habits changing in ways that may endure beyond COVID-19 (43%)
- Delivery services strained to meet demand
- Grocery delivery (70% consumers prefer scheduling)

What has Changed due to COVID?

- **Change in Consumer Perception:** Driving Robotics Adoption Worldwide ranging from delivery to health, warehouses and tourism



What robots and automation mean for the future of white-collar work?

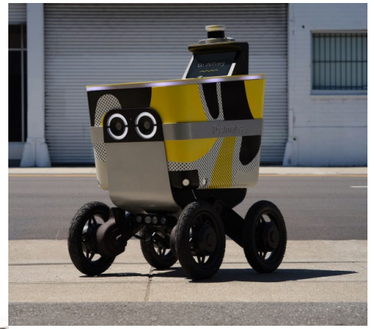
When it comes to automation, at least in the last-mile delivery sector, "time has indeed accelerated" and the deployment timelines have come closer by at least a decade!

History has shown that crisis couples with technological innovation

Market Entry of ADRs

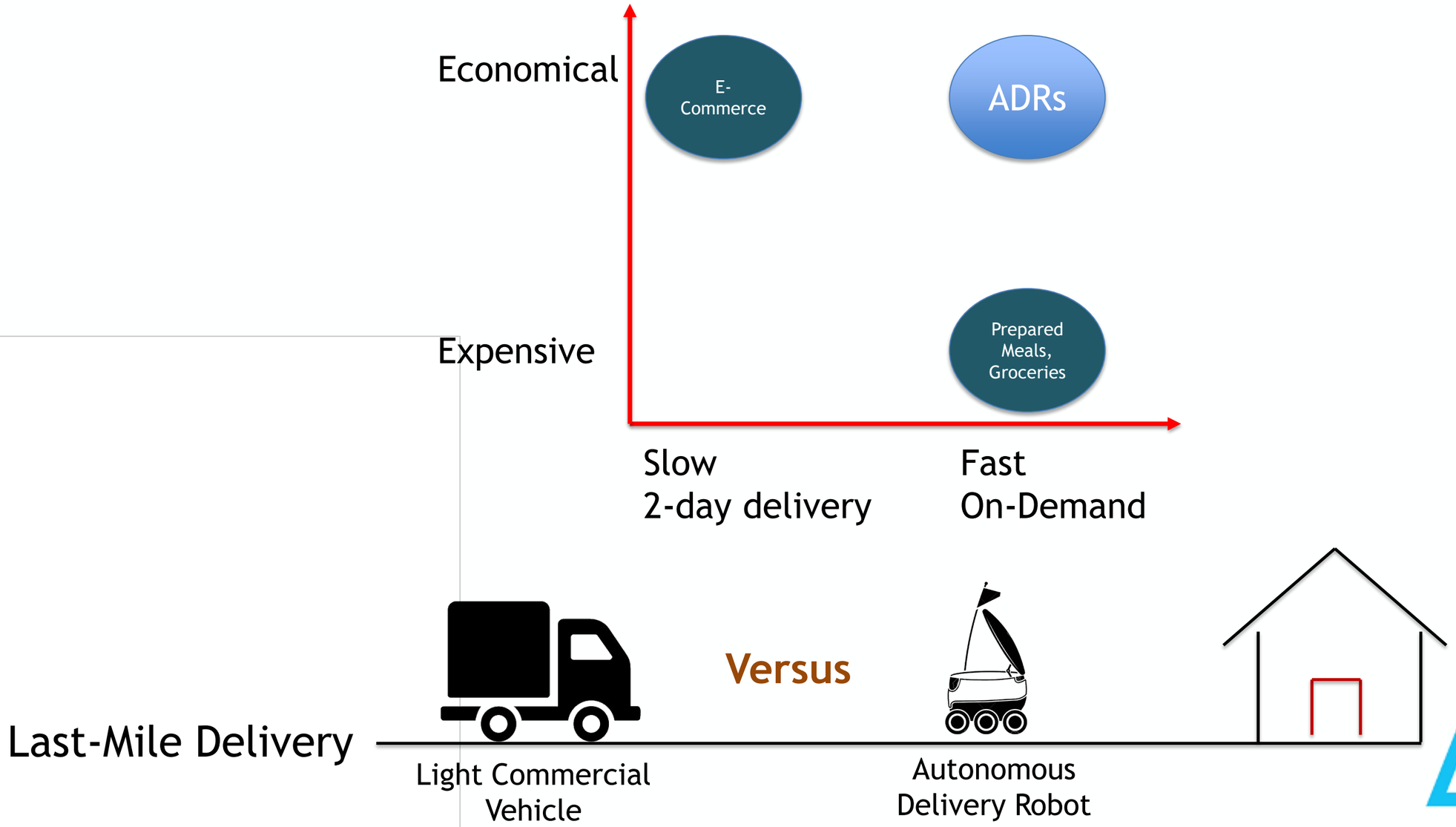
- COVID-19 has led to a surge in demand for contactless delivery robots
- Autonomous delivery robot (ADR) companies include Amazon, Google, FedEx, Starship Technologies, Robomart, and Kiwi.







Market Entry of ADRs: Replacing Status-Quo



Delivery Robot Demand: Changes during COVID-19

Ann Arbor robotics startup goes in on grocery delivery

NICK MANES

TWEET SHARE SHARE EMAIL REPRINTS PRINT

- The Produce Station customers can have their items delivered by REV-1 robot
- Autonomous machines have been delivering takeout food from handful of restaurants
- New expansion into grocery delivery is because of COVID-19 pandemic

Refraction AI – Rev1

THE VERGE TECH REVIEWS SCIENCE CREATORS ENTERTAINMENT VIDEO MORE

TECH TRANSPORTATION AUTONOMOUS CARS

Nuro's driverless delivery robots will transport medicine to CVS customers in Texas

This represents a shift in Nuro's typical operations

By Andrew J. Hawkins | @andyjayhawk | May 28, 2020, 9:00am EDT

SHARE

Nuro – R2

Starship Robots Now Delivering Groceries for Save Mart in Modesto, CA

by Chris Albrecht

- SEPTEMBER 29, 2020
- FILED UNDER:
  FUTURE OF GROCERY
  GROCERY
  ROBOTICS, AI & DATA

Starship

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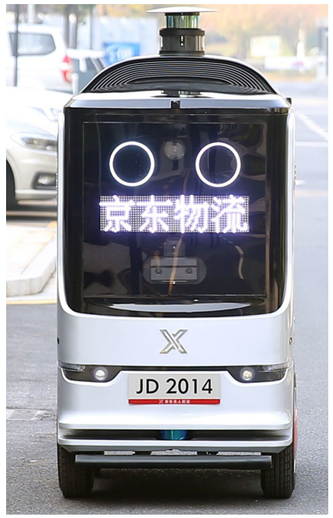
Delivery Robot Demand: Changes during COVID-19



Countries where ADRs are Currently Operational

- China
- Japan
- Hongkong
- Korea
- USA
- UK
- Netherlands
- Germany

https://asia.nikkei.com/Opinion/Coronavirus-lockdown-sparks-expansion-of-drones-and-robot-deliveries

Delivery Robot Demand: Changes during COVID-19

https://www.nytimes.com/2020/05/20/technology/delivery-robots-coronavirus-milton-keynes.html

A Starship robot crosses the road in Milton Keynes, a small city about 50 miles northwest of London. Ben Quinton for The New York Times

By Cade Metz and Erin Griffith

May 20, 2020

7

Milton, UK

Population of 270,000

Vast bicycle network

https://www.telegraph.co.uk/technology/2020/10/25/tiny-self-driving-robots-trying-win-locals-milton-keynes/

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Delivery Robot Demand: Changes during COVID-19

Mayo Clinic, Jacksonville: Transporting viral tests and supplies

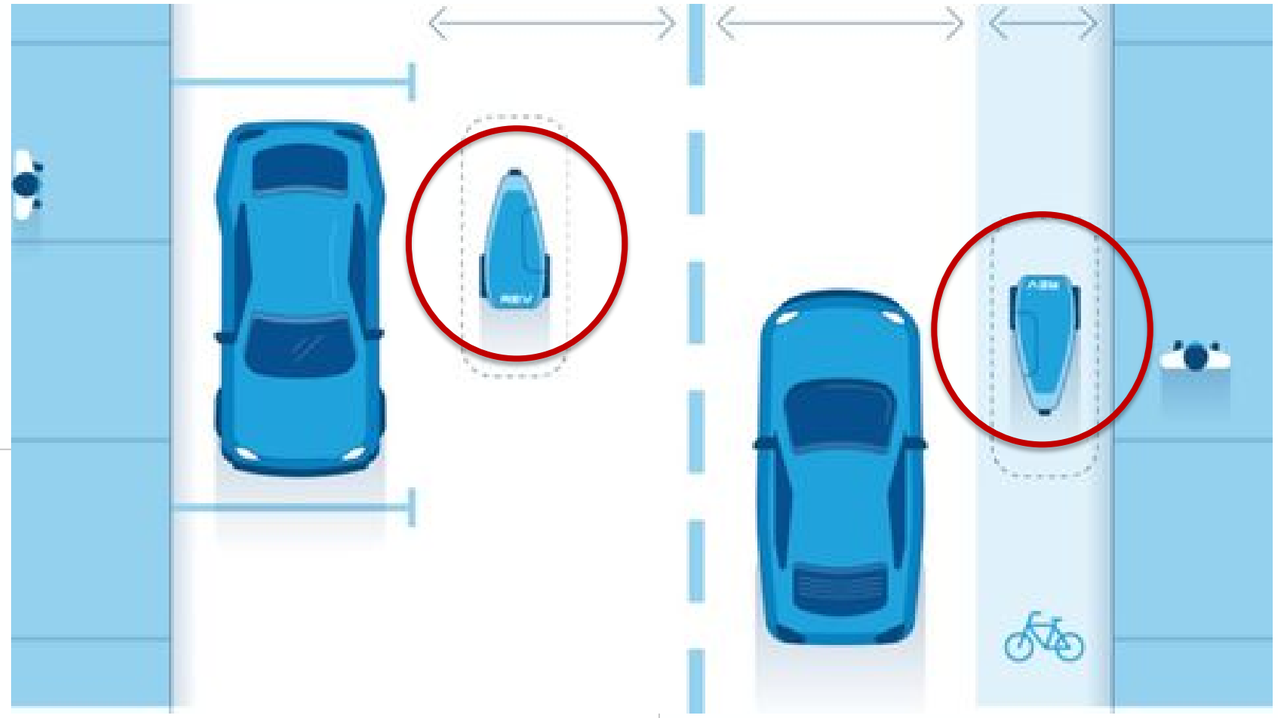
https://www.govtech.com/fs/automation/Autonomous-Shuttles-Find-Work-in-Fight-Against-Coronavirus.html

California: ferrying food, supplies, and medical equipment

https://roboticsandautomationnews.com/2020/04/27/nuro-puts-its-delivery-robot-into-action-against-coronavirus/31956/

Health Supply-Chain

Research Challenges Remain for Scalable Deployment



How to prepare our urban streets for seamless interaction between delivery robots, pedestrians, and other vehicles?

- Lack of effective regulations and legislative hurdles (Few states have legalized ADRs so far by treating them as pedestrians)
- Concerns about sharing curb space
- Pricing mechanisms – what is ideal? (ranges from $1 to $5 per delivery)
- Lack of operational models
- Infrastructure planning and maintenance

Overview of Our Research

Planning for effective deployment of ADRs in a way that fulfils consumer expectations and supply-side constraints

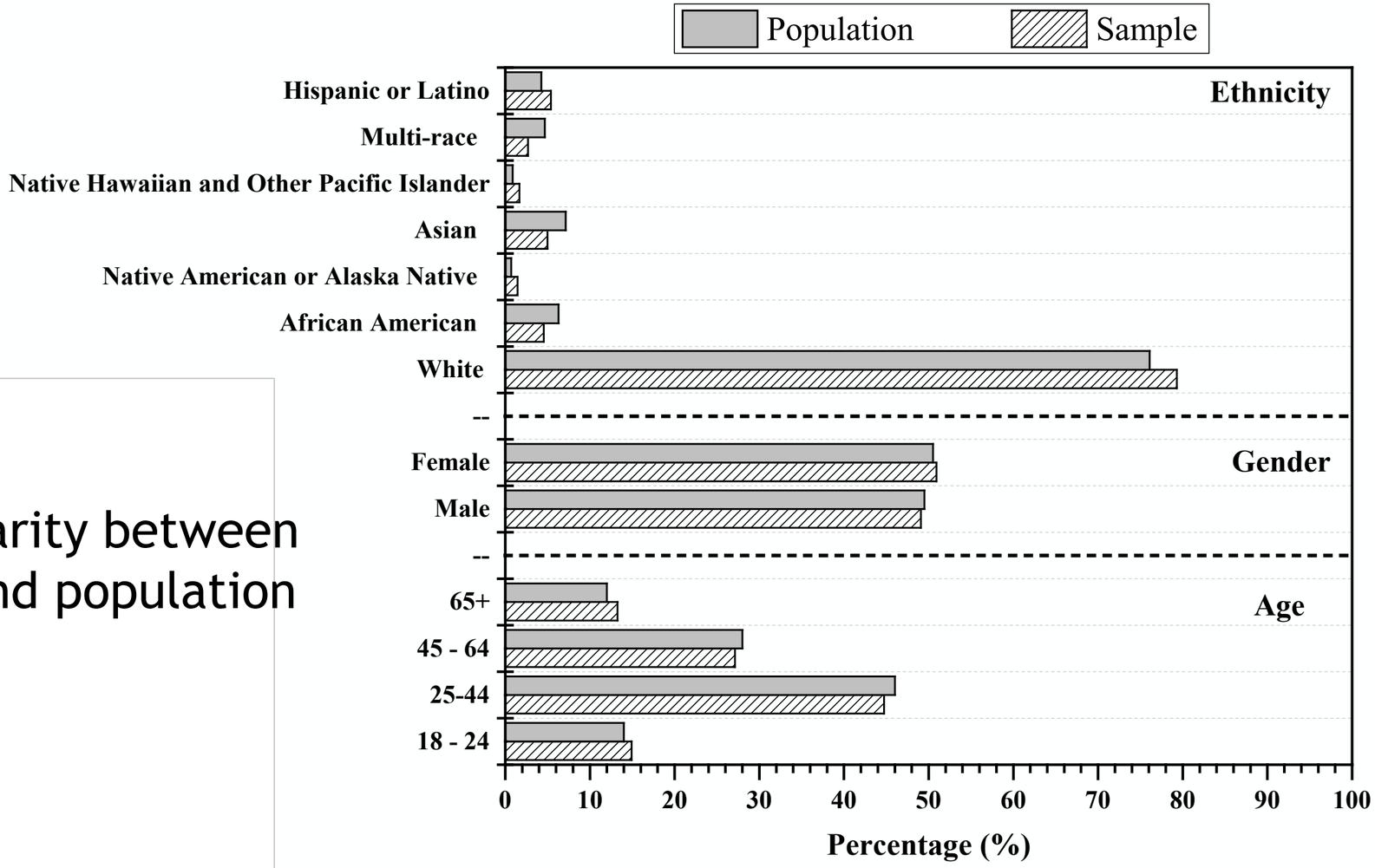
- **Research Need (Demand-Side):** To investigate how ADRs need to be deployed by logistics providers and government agencies conforming to expectations, needs, and motivations of consumers
- **Research Need (Supply-Side):** To investigate Infrastructure utilization and road/curb efficiency of autonomous delivery robots

Data Collection (July to August 2020)

Survey Cover Page

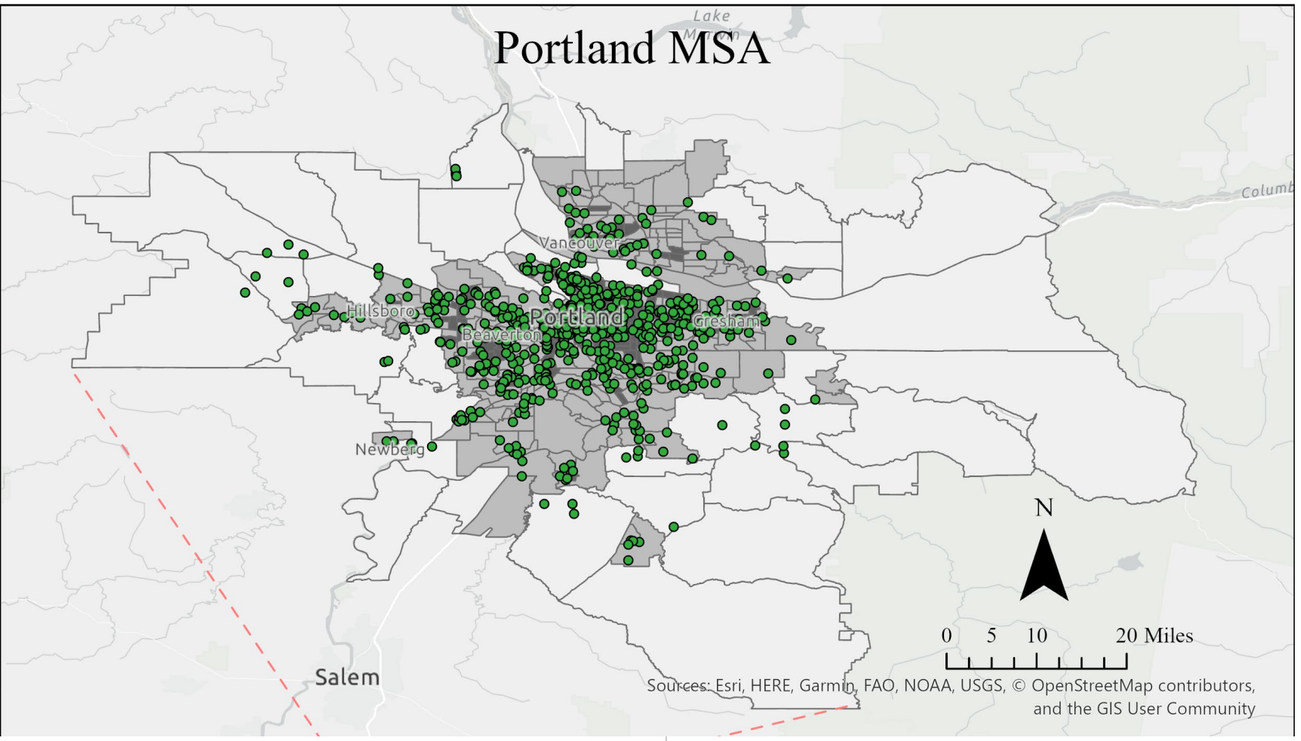
- **Two US Metropolitan Areas:** Portland (OR) and Nashville (TN)
- More than 1,300 respondents (Panel)
- Representative Sample
  - Age, Gender, Ethnicity, and Income
- Multi-use survey instrument
  - Shopping preferences
  - ADR perceptions (TPB-TAM construct)
    - Theory of Planned Behavior (TPB)
    - Technology Acceptance Model (TAM)
  - WTP protest intentions
  - WTP Choice experiment

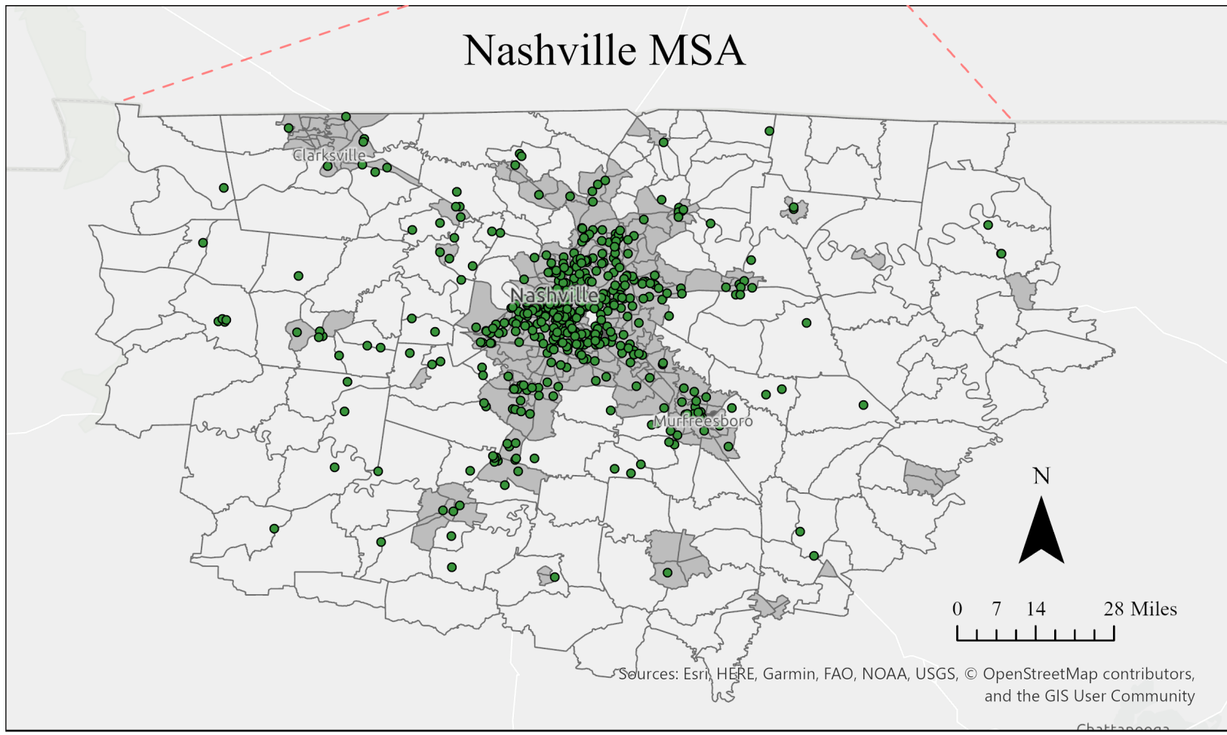
Sample Representativeness



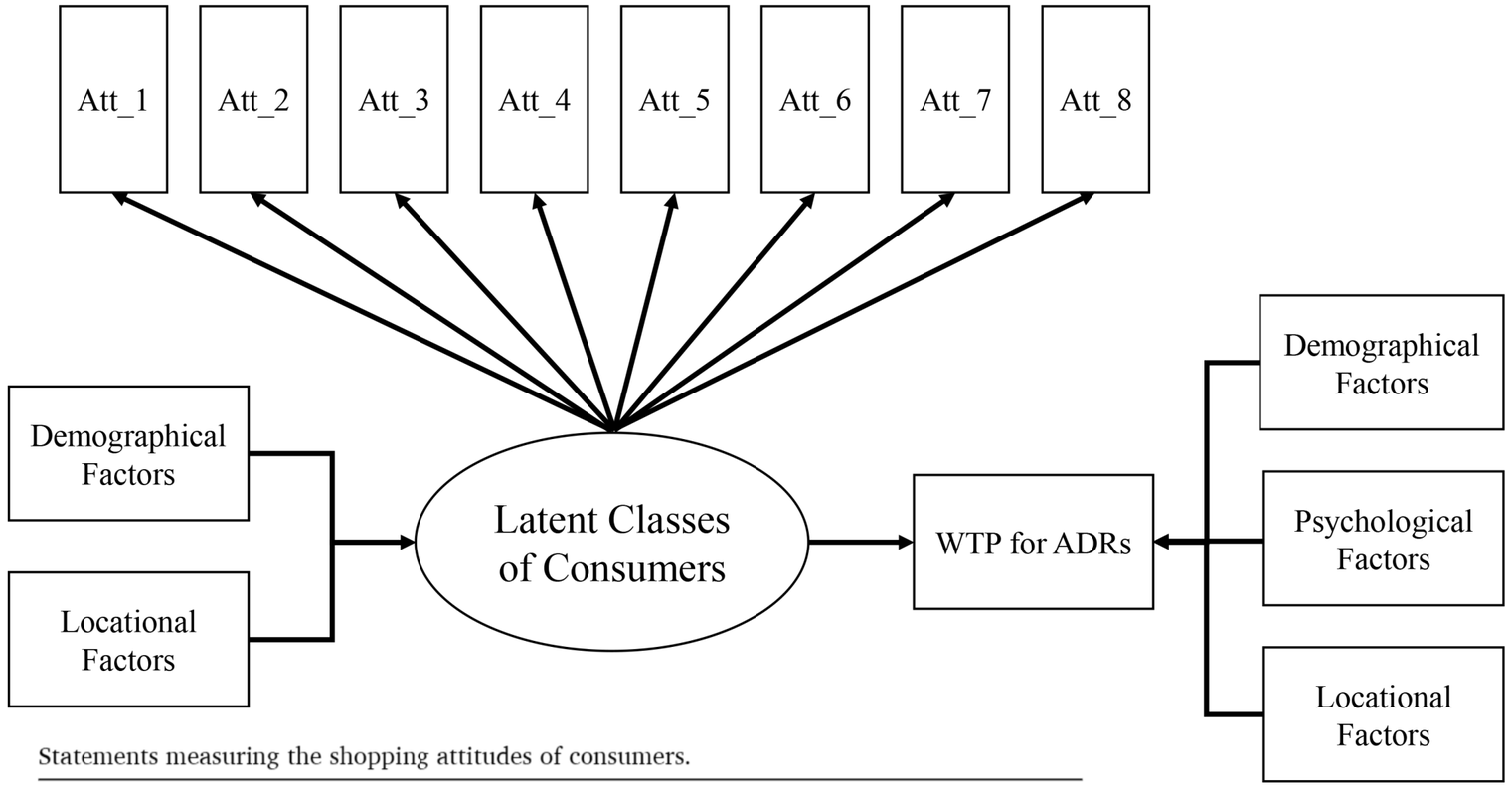
<2% disparity between sample and population

Sample Overview





Methodological Approach



1. **Latent class cluster analysis** to identify homogenous consumer segments
2. **Contingent valuation method** to estimate WTP (Latent class Tobit models)

Statements measuring the shopping attitudes of consumers.

Variable	Description of Statement (*5-point Likert scale*)
Att_1	*"I like having merchandise delivered to me at home"*
Att_2	*"I find it hard to judge merchandise quality on Internet"*
Att_3	*"I like not having to leave home for shopping"*
Att_4	*"I use internet shopping mainly because of the COVID-19 outbreak"*
Att_5	*"I like that car is not necessary in the case of Internet shopping"*
Att_6	*"I like the helpfulness available at local stores"*
Att_7	*"I think Internet buying has delivery problems"*
Att_8	*"I do not want to give my credit card number to a computer"*

Latent Class Cluster Analysis

- Six classes are optimal

Model fit statistics where the number of classes is varied from one to eight.

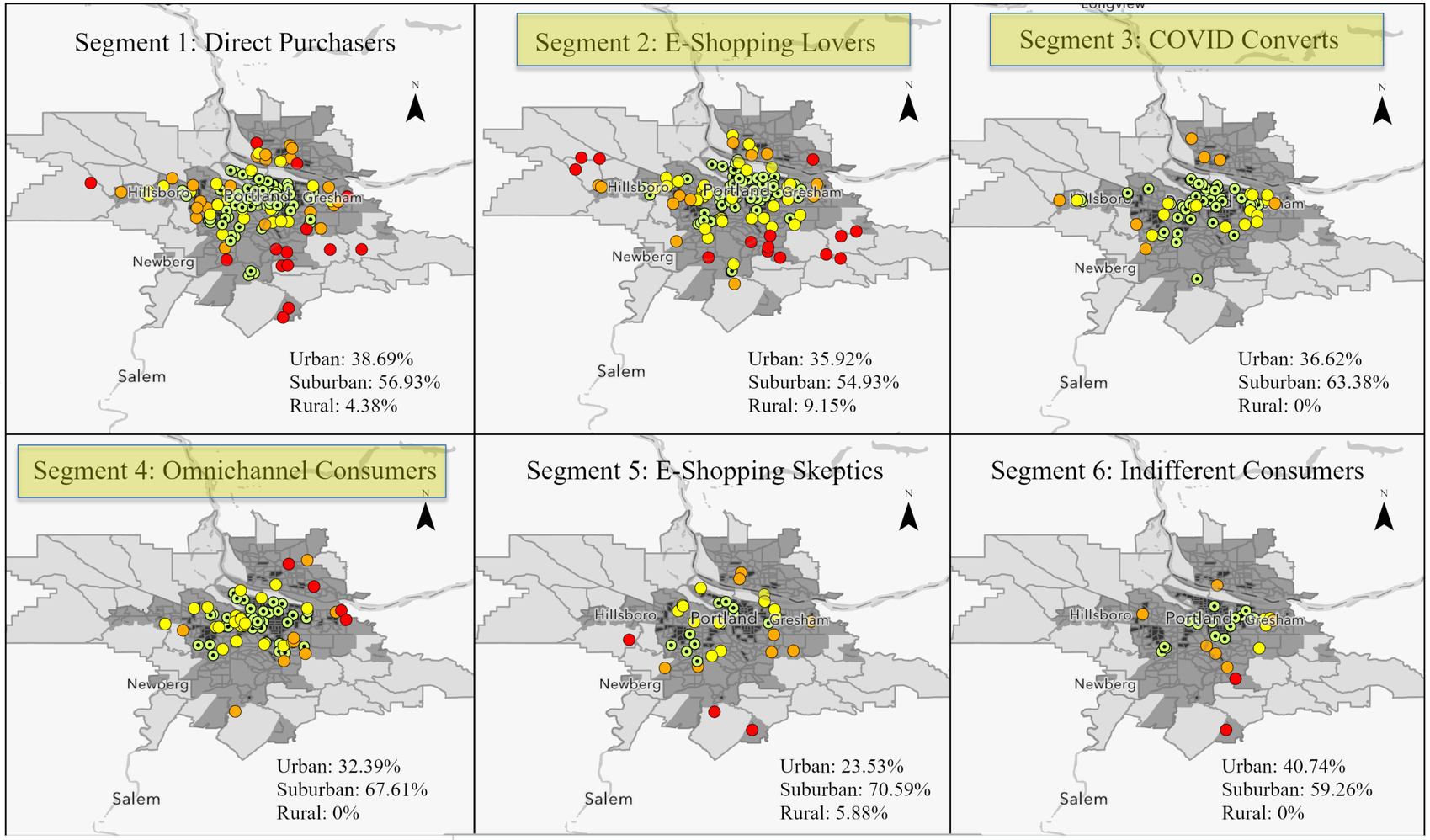
Model	*Npar*	*LL*	BIC(LL)	Bivariate Residuals for 6-Class Solution							
					Att_1	Att_2	Att_3	Att_4	Att_5	Att_6	Att_7	Att_8
1-Class	32	−5673.83	11433.55	**Att_1**	–							
2-Class	86	−5448.49	11127.80	**Att_2**	0.52	–						
3-Class	140	−5319.68	11015.11	**Att_3**	0.79	1.88	–					
4-Class	194	−5214.08	10948.85	**Att_4**	0.50	0.38	0.78	–				
5-Class	248	−5127.91	10921.44	**Att_5**	0.93	0.48	0.82	1.73	–			
6-Class	302	−5052.55	10915.65	**Att_6**	0.53	0.61	1.32	0.66	0.51	–		
7-Class	356	−5000.05	10955.59	**Att_7**	0.55	0.61	1.26	1.61	0.96	0.36	–	
8-Class	410	−4939.27	10978.96	**Att_8**	0.59	0.54	0.98	1.64	0.69	0.46	2.26	–

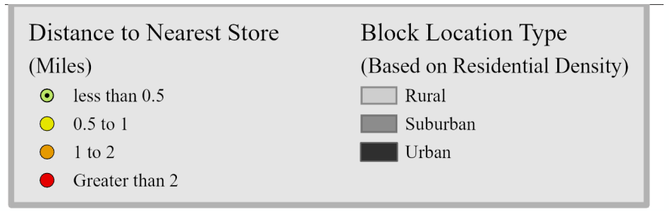
Npar indicate the number of model parameters; *LL* indicates the log-likelihood of the model.

Latent Consumer Segments

1. Direct Purchasers (28.98%) – *"Prefer physical stores and dislike home delivery"*
2. E-Shopping Lovers (25.45%) – *"Prefer home delivery and dislike shopping at stores"*
3. COVID Converts (13.21%) – *"Thinks E-shopping has delivery problems, still use it due to COVID"*
4. Omnichannel Consumers (13.08%) – *"Prefer using both physical stores and E-shopping"*
5. E-Shopping Skeptics (12.61%) – *"Strong Privacy concerns about E-shopping"*
6. Indifferent Consumers (6.67%) – *"Neutral response to shopping without clear preference"*

Latent Consumer Segments



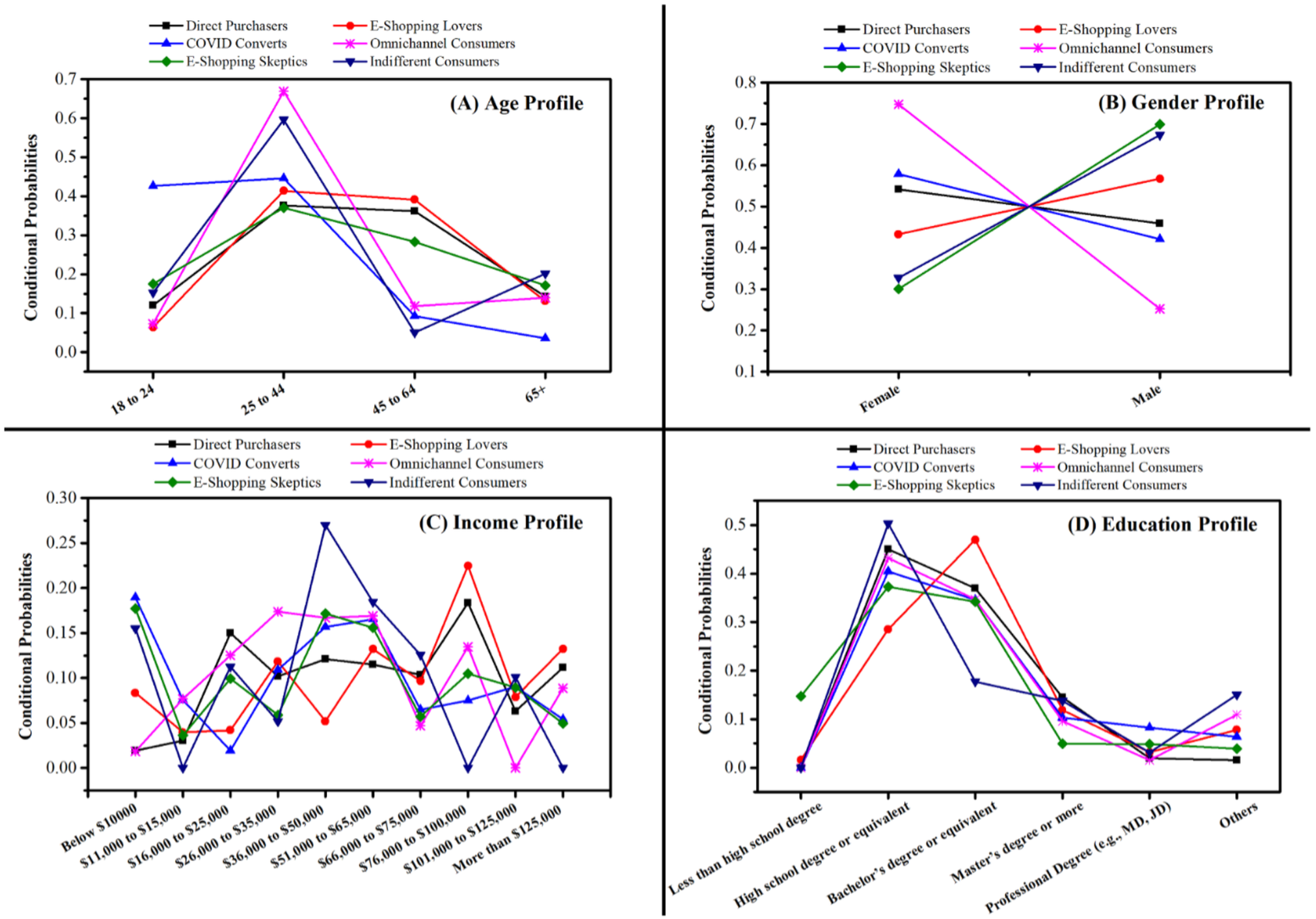


Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Latent Class Prediction Models

- Consumer segments are predicted based on
  - **Age** (e.g., older consumers are more likely direct purchasers)
  - **Gender** (e.g., women are more likely omnichannel consumers)
  - **Income** (e.g., income has a positive effect on E-shopping classes)
  - **Education** (e.g., education has positive effect on direct purchasers)
  - **Residential Location** (e.g., suburban consumers tend to be omnichannel)
  - **Distance to nearest shopping store** (e.g., longer distance -> E-shopping)
- Prediction accuracy ranged between 83% to 96% across latent classes

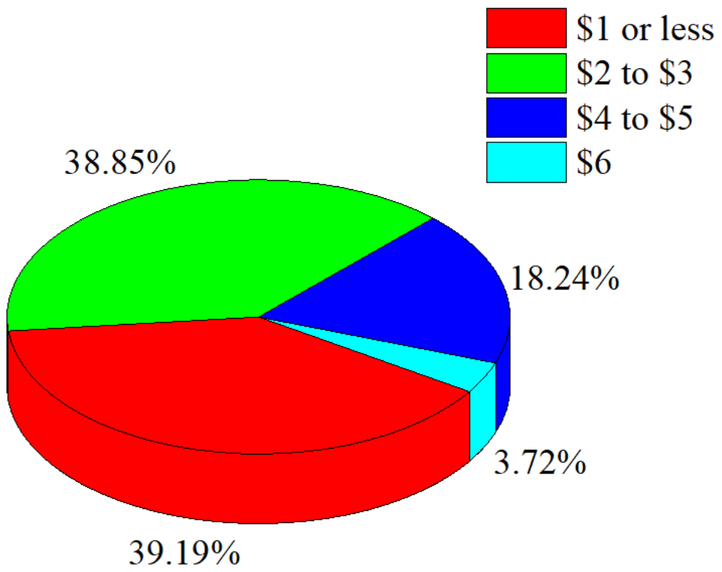
Profiles of Latent Classes



Willingness to Pay for ADRs: Overall Sample

Overall Sample

61%
Positive WTP



39%
Non-Positive WTP

20%
Genuine Zero Responses

"Existing delivery methods does not require any improvement"

"Willing to pay, but my income constraints does not allow"

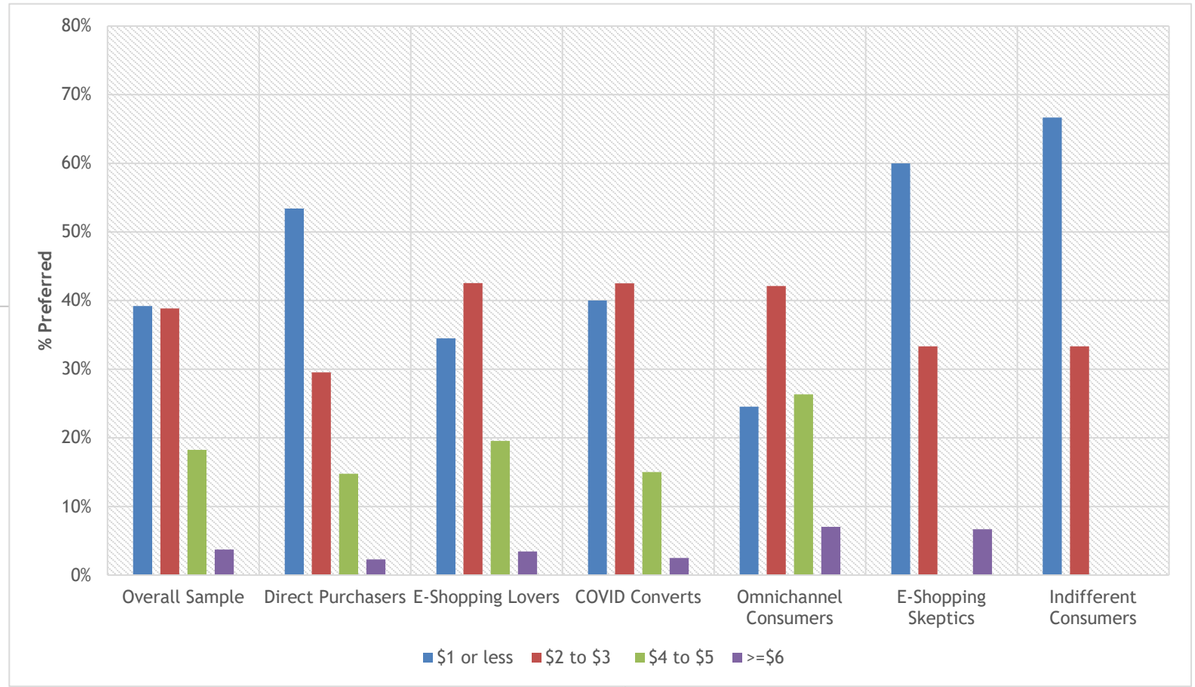
19%
Protest Responses

"Additional cost should be paid by Govt. or E-commerce companies"

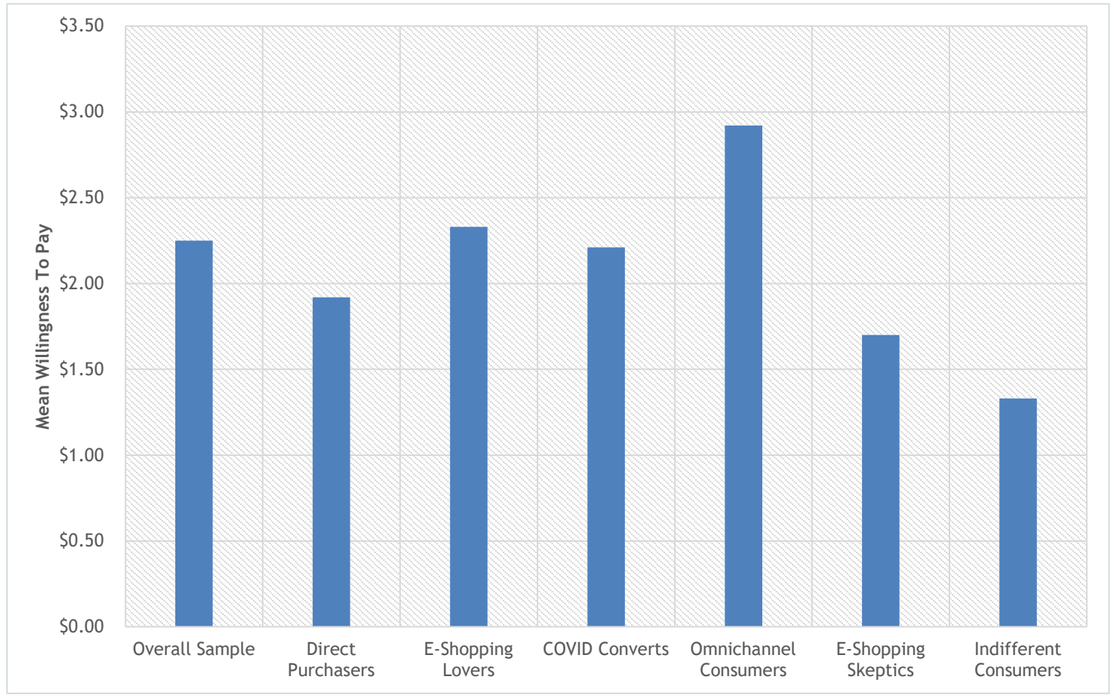
"Cost has been included in the taxes and fees"

Willingness to Pay for ADRs: Latent Classes

Willingness-To-Pay With Varying Prices



Mean Willingness-To-Pay



Willingness to Pay Model: Key Insights

- **Age** has a strong inverse relationship with WTP
- **Income and Education levels** are positively associated with WTP
- **Familiarity, Perceived trust, Tech-Savvy Attitude:** +ve Association
- **Early Adopters:** COVID Converts and Omnichannel Consumers
- **Urban consumers** located beyond **0.5 miles from nearest stores** exhibit higher WTP
- **Spatially induced WTP heterogeneity** indicate the need for area-specific targeted pricing mechanisms for ADRs

For More Information

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journal homepage: www.elsevier.com/locate/trd

Evaluating public acceptance of autonomous delivery robots during COVID-19 pandemic

Agnivesh Pani [a], Sabya Mishra [a,*], Mihalis Golias [a], Miguel Figliozzi [b]

[a] Department of Civil Engineering, University of Memphis, Memphis, TN 38152, United States
[b] Department of Civil and Environmental Engineering, Portland State University, OR 97201, United States

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ABSTRACT

Autonomous delivery robot (ADR) technology for last-mile freight deliveries is a valuable step towards low-carbon logistics. The ongoing COVID-19 pandemic has put a global spotlight on ADRs for contactless package deliveries, and tremendous market interest has been pushing ADR developers to provide large-scale operation in several US cities. The deployment and penetration of ADR technology in this emerging marketplace calls for collection and analysis of consumer preference data on ADRs. This study addresses the need for research on public acceptance of ADRs and offers a detailed analysis of consumer preferences, trust, attitudes, and willingness to pay (WTP) using a representative sample of 483 consumers in Portland. The results reveal six underlying consumer segments: Direct Shoppers, E-Shopping Lovers, COVID Converts, Omnichannel Consumers, E-Shopping Skeptics, and Indifferent Consumers. By identifying the WTP determinants of these latent classes, this study provides actionable guidance for fostering mass adoption of low-carbon deliveries in the last-mile.

For More Information -

Pani, A., Mishra, S., Golias, M., and Figliozzi, M. (2020) "*Evaluating public acceptance of autonomous delivery robots during COVID-19 pandemic*", Transportation Research Part D. Vol. 89. https://doi.org/10.1016/j.trd.2020.102600

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  - Dr. Miguel Figliozzi
  - Dr. Evangelos Kaisar
  - Dr. Agnivesh Pani
- More Details
  - http://eng.fau.edu/research/fmri/
  - https://www.memphis.edu/ctier/

Questions

Contact us.

Dr. Sabya Mishra
Associate Professor
Department of Civil Engineering
Center for Transportation Innovations
In Education And Research (C-TIER)
University of Memphis
Email: smishra3@memphis.edu

Home-deliveries Before-During COVID-19 Lockdown: Accessibility, Environmental Justice, Equity, and Policy Implications

April 28, 2021 – FMRI Webinar

Presenter: Professor Miguel Figliozzi

Authors: Professors Miguel Figliozzi and Avinash Unnikrishnan

Presentation based on this paper:

Figliozzi, M. and Unnikrishnan, A., 2021. Home-deliveries Before-During COVID-19 Lockdown: Accessibility, Environmental Justice, Equity, and Policy Implications. Transportation Research Part D: Transport and Environment.

Paper available at: http://web.cecs.pdx.edu/~maf/published.html

Lockdown timing in Oregon

- March 8: state of emergency in Oregon
- March 17: restricted gathering and restaurants
- March 23: "stay at home order"
- March 16-30: school closures

...

- May 2: emergency extended till July 6th

....

Traffic volumes

- Data from ODOT counters on freeways and main highways

- Traffic down 40% to 60% in May

- No congestion

Context

E-commerce rapid increase

US retail e-commerce sales for the second quarter of 2020 increased by 31.8% from the first quarter of 2020 and 44.5% from the second quarter of 2019
(Source: US Department of Commerce, 2020).

Total global retail sales declined 3.0% in 2020 but retail e-commerce sales grew 27.6%
(Source: Davis and Toney, 2021).

Context

June Scorecard: Online Grocery Delivery & Pickup

Total US – Past 30-day activity*

Performance Metrics	Aug 2019	March 2020	April 2020	May 2020	June 2020
Sales (Past 30 days)	$1.2 B	$4.0 B	$5.3 B	$6.6 B	$7.2 B
Spend (Average per order)	$72	$85	$85	$90	$84
Orders (# Past 30 days)	16.1 M	46.9 M	62.5 M	73.5 M	85.0 M
Customers (# Active during past 30 days)	16.1 M	39.5 M	40.0 M	43.0 M	45.6 M
Frequency (Monthly average/customer)	1.0	1.2	1.6	1.7	1.9

* Excludes online orders shipped to home via common or contract parcel carriers.

Sources: **Brick Meets Click/Mercatus Grocery Survey, June 2020**; Brick Meets Click/Mercatus Grocery Survey, May 2020; Brick Meets Click/Symphony RetailAI Grocery Survey, April 2020; Brick Meets Click/ShopperKit Grocery Survey, March 2020; Brick Meets Click Grocery Survey, August 2019.

brick meets click

mercātus

Source: Perez, S., 2020. TechCrunch: US online grocery sales hit record $ 7.2 billion in June. https://tinyurl.com/y277g2u4, Last Accessed: January 2021.

Data collection

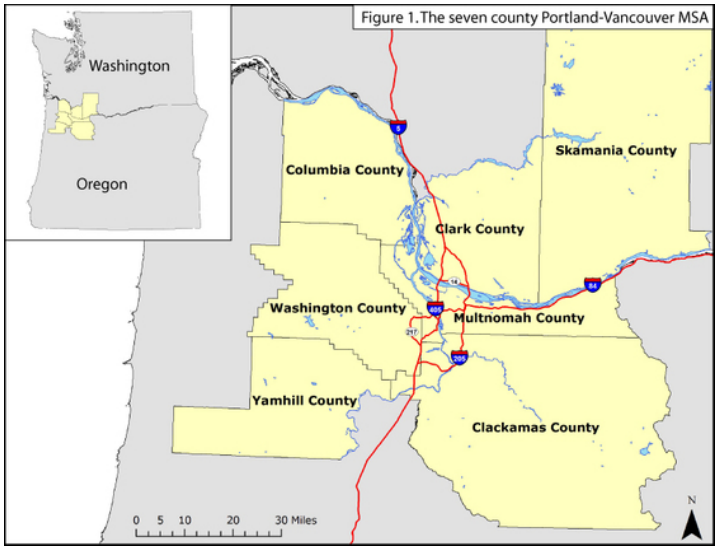
- Online survey
- Last week of May/first week of June
- 1015 complete observations after cleaning and consistency checks
- Representative of population (quotas)
- Questions about sociodemographic, attitudes, delivery rates, etc.

Data collection

Source: Wikipedia, Portland metropolitan area

Portland (OR) –Vancouver (WA)

MSA: 5 counties in OR and 2 in WA

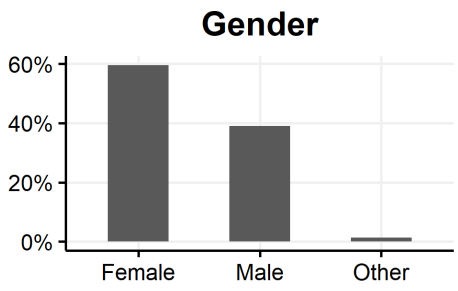


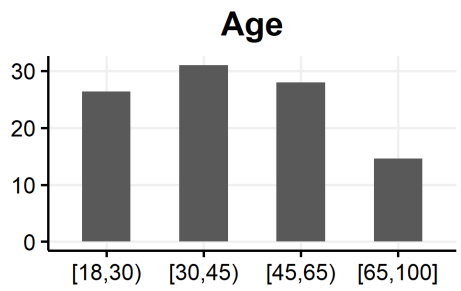
Source: https://portlandweird.weebly.com/

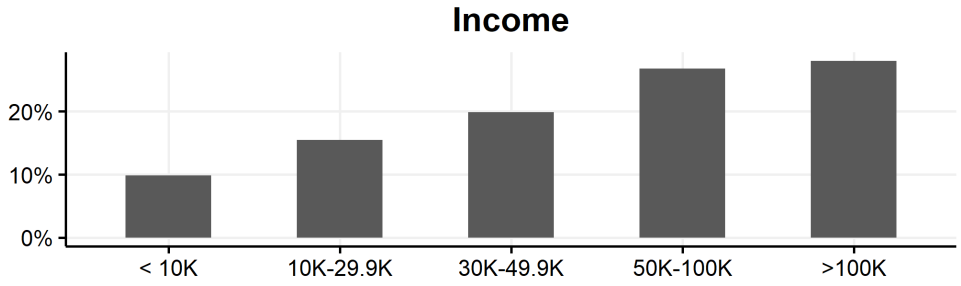
Survey Quotas

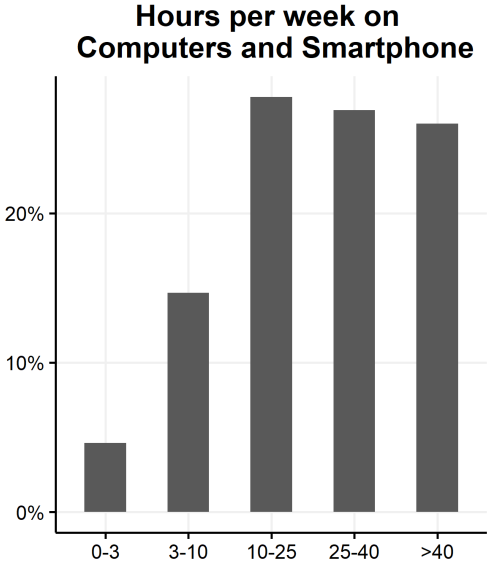
- 40% representation of males or females
- 20% representation in the three income levels of 0-$50,000, $50,000 - $100,000, and > $100,000
- 20% representation in ages 18-19, 30-44, 45-64 and at least 8% of the respondents must be over the age of 65
- Respondents above 18 years old only

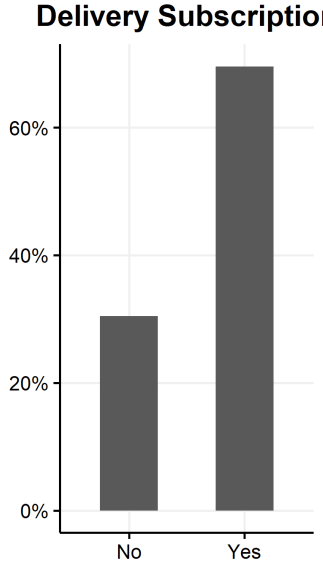
Descriptive Statistics



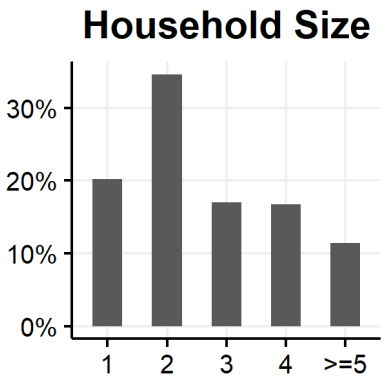


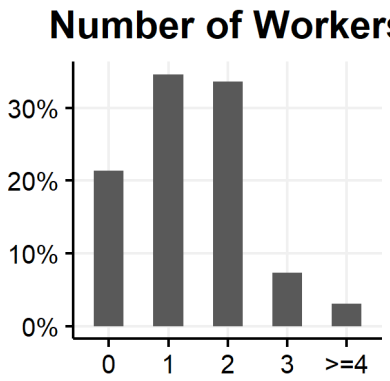


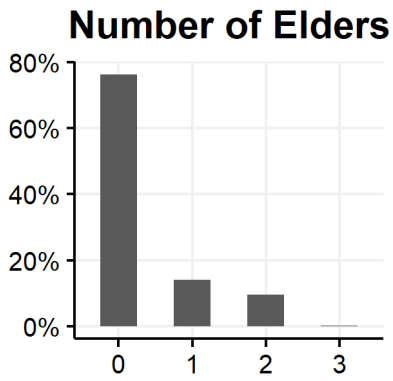


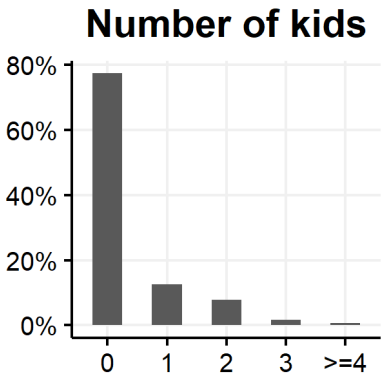


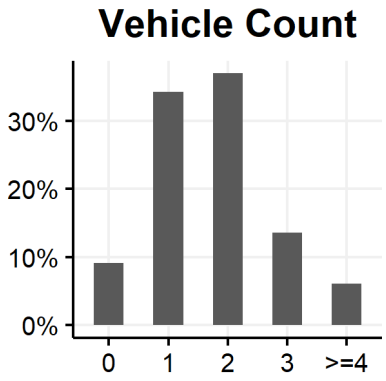
Descriptive Statistics

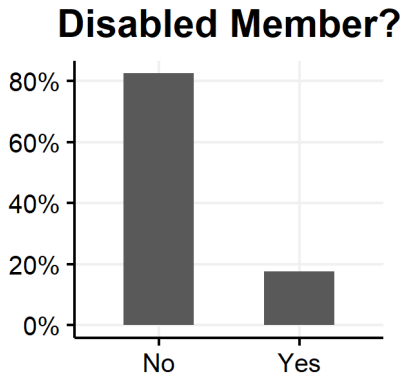












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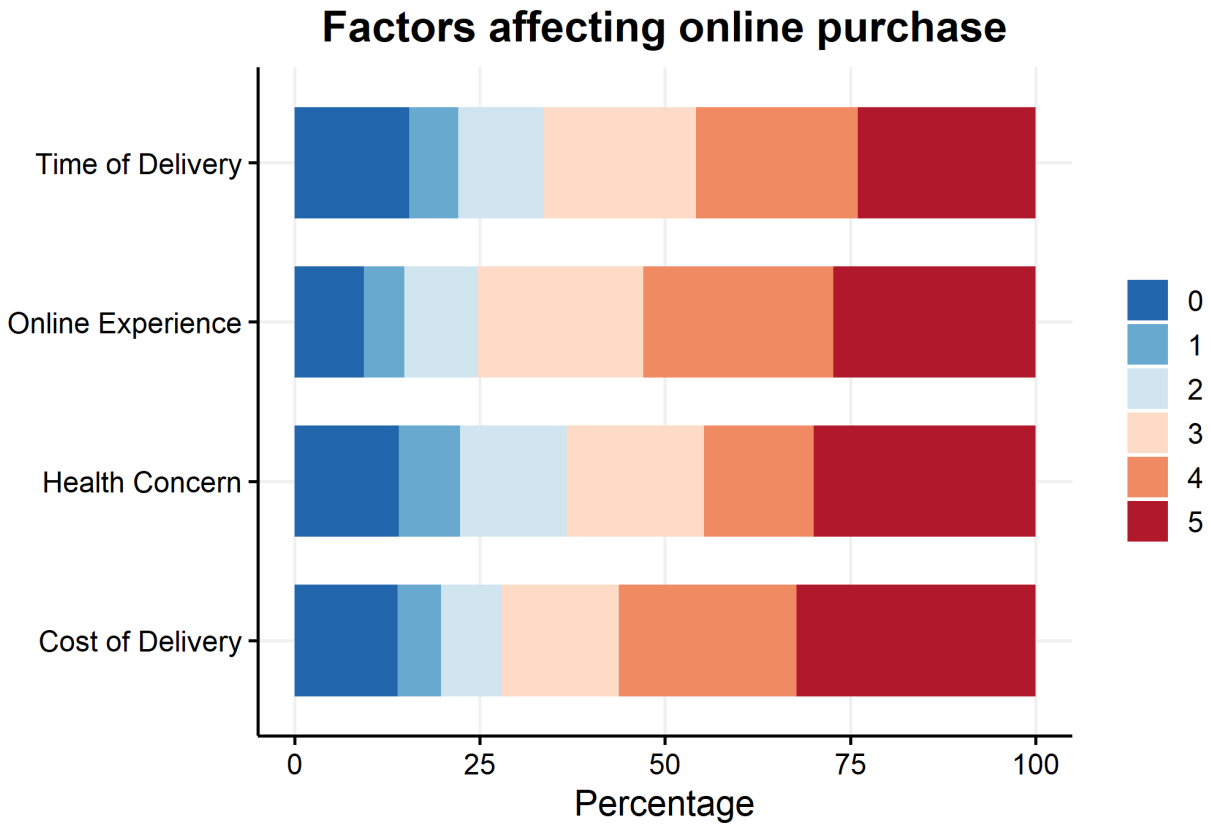


Major changes in home delivery rates

- A major increase in home delivery rates was observed comparing pre-lockdown and lockdown responses.
- A conservative estimate is that during the lockdown house deliveries were 53% higher than before the lockdown.

Preliminary Equity Indicators

Variable	Level	Less than $10,000	$10,000 to $30,000	$30,000 to $50,000	$50,000 to $100,000	Greater than $100,000
Race	African American	24.2	18.2	27.3	18.2	12.1
	Asian	3.9	14.3	20.8	33.8	27.3
	Hispanic-Latino	15.7	11.8	33.3	15.7	23.5
	Native American	9.1	36.4	36.4	18.2	0.0
	White	9.5	15.2	18.3	27.3	29.6
	Other	8.5	19.1	21.3	27.7	23.4
Educational Level	Less than HS	71.4	5.7	11.4	8.6	2.9
	HS - GED	21.3	26.4	23.0	18.0	11.2
	College Associate	7.5	23.2	25.5	24.6	19.1
	Bachelor	2.6	6.6	16.8	36.0	38.0
	Graduate	1.9	5.2	11.7	27.9	53.2
Vehicles per Househ.	0	41.9	29.0	19.4	5.4	4.3
	1	6.9	23.1	27.1	28.8	14.1
	2	6.4	8.5	15.7	30.4	38.9
	3	6.5	9.4	18.1	28.3	37.7
	4+	6.5	8.1	9.7	22.6	53.2

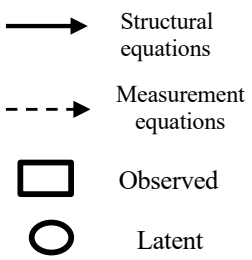
Preliminary Equity Indicators

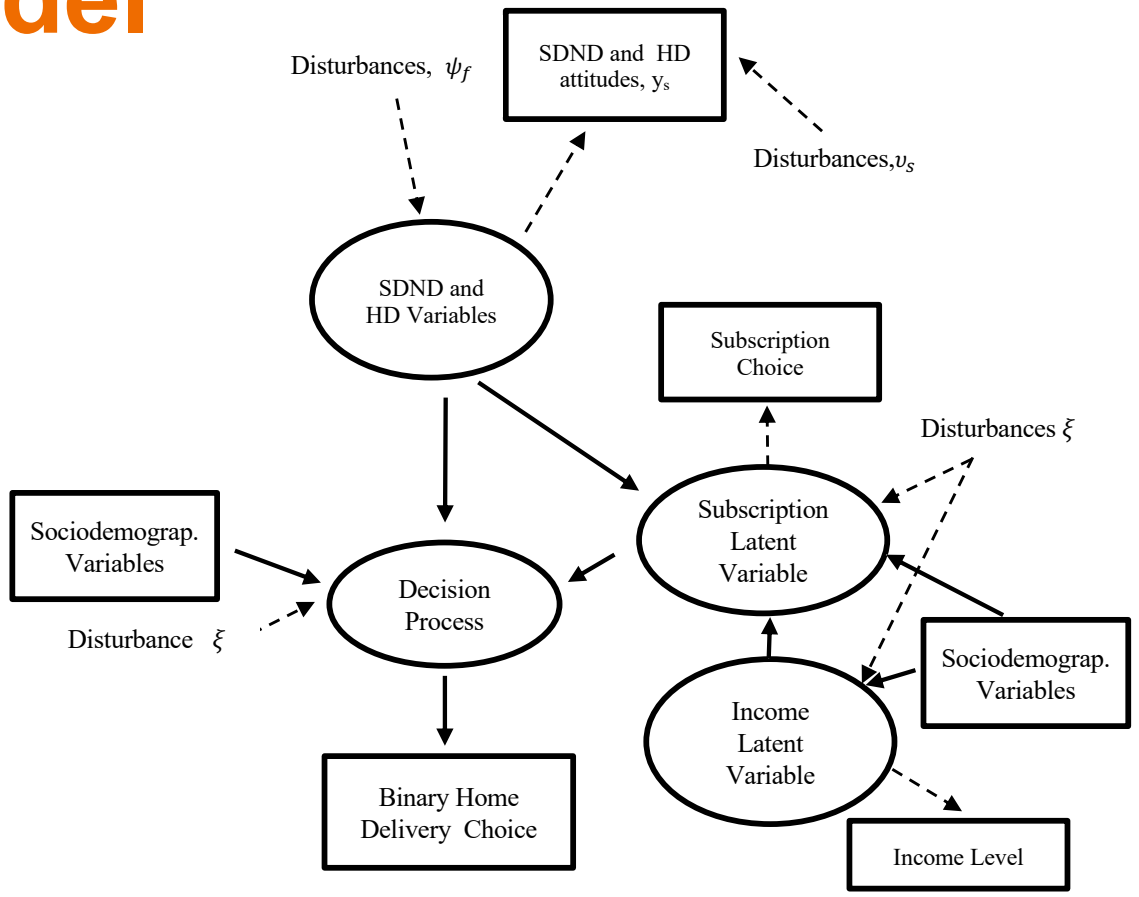
Variable	Level	Less than $10,000	$10,000 to $30,000	$30,000 to $50,000	$50,000 to $100,000	Greater than $100,000
Delivery Subscription	No	18.4	21.1	21.0	25.6	13.9
	Yes	6.1	13.0	19.4	27.4	34.1
Pre-COVID Monthly Delivery Rate	0	18.8	27.5	20.3	23.2	10.1
	1 to 2	9.6	18.0	20.1	28.1	24.2
	3 to 5	9.7	12.8	20.3	27.8	29.4
	6 to 10	6.7	7.7	17.3	26.9	41.3
	More than 10	8.3	11.9	20.2	19.0	40.5
COVID Monthly Delivery Rate	0	27.1	24.3	18.6	20.0	10.0
	1 to 2	13.7	19.8	21.3	27.9	17.3
	3 to 5	8.4	19.0	20.9	26.2	25.5
	6 to 10	6.8	9.1	20.1	29.9	34.1
	More than 10	5.5	9.8	16.6	24.5	43.6

Modeling

- Exploratory analysis: ordered logit
- Issues: endogeneity, correlations
- Confirmatory analysis: latent variables, factor analysis, and simultaneous estimation of structural model

Structural model





SDND: same day/next day delivery
HD: home delivery

Key Findings

Groups less likely to benefit from home deliveries:

- Low-income households
- Households with lower educational levels
- Small size and/or single member households
- Households with less access to electronic devices/internet
- Households that do not usually commute by auto or WFH
- Non-white households

Environmental Justice Issues

- Deliveries generate traffic, safety issues, and air pollution.
- Distribution and warehousing activities are usually located in low-income and/or minority neighborhoods (Yuan, 2018).
- In the outskirts of metropolitan areas land values are cheaper but facilities are close enough to deliver within a day.

Source: Yuan, Q. (2018) 'Location of warehouses and environmental justice', *Journal of Planning Education and Research*

HBA

Home deliveries have become a health-supporting and essential service for many at-risk populations.

Home-based accessibility (HBA): defined as the ease of accessing essential home deliveries of products such as groceries and medicines without leaving home.

Policy Implications

Expand traditional thinking around accessibility

HBA *reverses* the traditional *direction* of access

HBA focuses on a *stationary* individual or household, the challenge is to ensure that essential services reach traditionally underserved populations.

Potential solutions

- Proactive solutions, mapping of underserved users/populations.
- Logistics companies (Socially Responsible Logistics)
- Postal service, transit agencies, or other entities.
- Ancillary and support services: internet service, electronic devices, and online literacy.
- Support new technologies for contactless and/or cheaper deliveries (autonomous delivery robots).

Conclusions

- COVID-19 has brought to surface access inequalities that preceded the pandemic
- Time to rethink accessibility metrics and improve home-based accessibility (HBA) for underserved and mobility impaired populations
- Potential solutions and technologies

Acknowledgments

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Portland State UNIVERSITY

Maseeh College of Engineering and Computer Science
PORTLAND STATE UNIVERSITY

TTP Lab

Questions or to get the paper

For questions, please email us at:

figliozzi@pdx.edu or uavinash@pdx.edu

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