How, and for whom, will activity patterns be modified by self-driving cars? Expectations from the State of Georgia

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SMARTer Together Webinar, April 8, 2021

CREATING THE NEXT®

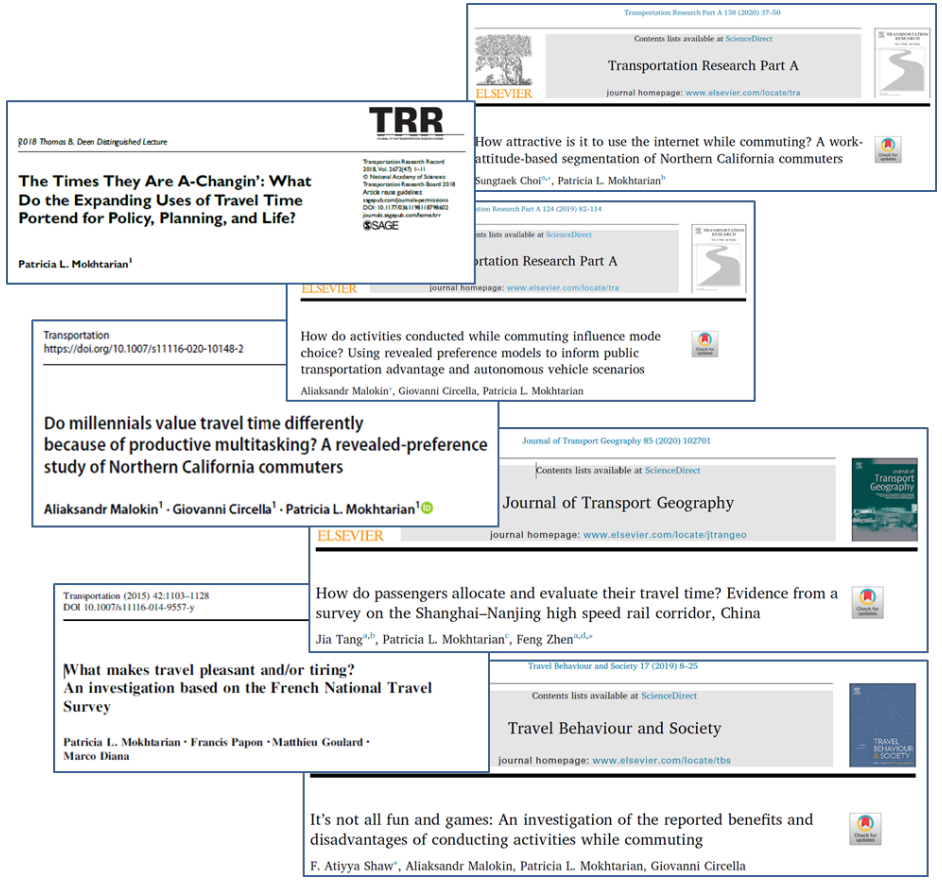
What is the relationship between our *use of travel time (TT)*, and our *travel choices*?

TT perceptions
- Nuisance?
- Pleasure?
- Little different from non-travel time?

TT use inclinations
- Work?
- Play?
- Exercise?
- Chill?

Travel choices
- Frequency
- Destination
- Mode
- Route
- Vehicle ownership
- Residential location

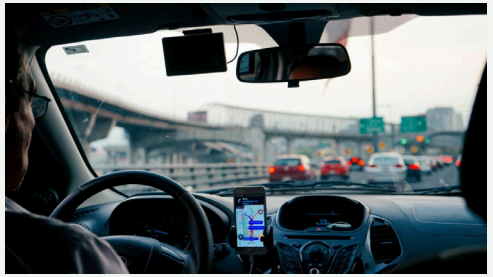
Actual TT use
- Work activities?
- Leisure/personal activities?
- "No" activities?



How will AVs change our travel choices?

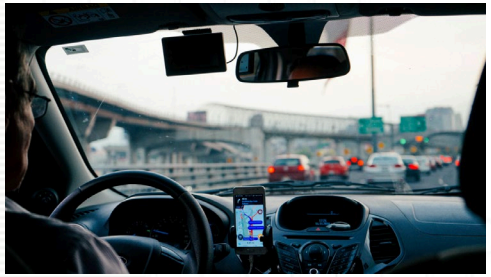
A day in 2021

Drive to work



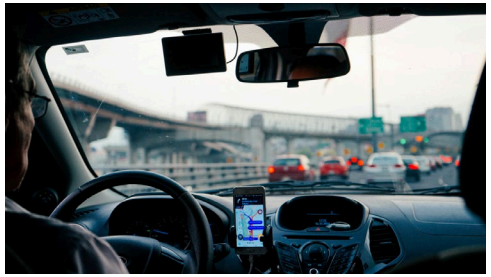
Work at the office

Drive to an activity location



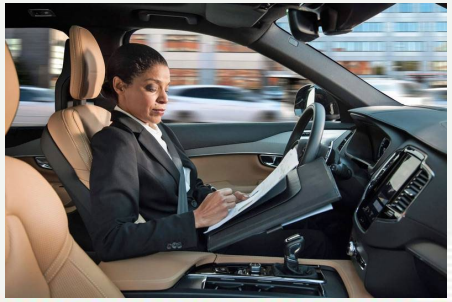
Social activity @ Ponce City Market

Drive home



A day when AVs give you hands-free travel in your personal vehicle

- *Prepare for the monthly meeting you will have tomorrow*



- *Reduce the amount of time at the office by working in the vehicle*

- *Read your book in the vehicle*

- *Go to Chattanooga to hang out with your friends there*

- *Watch TV show while coming back to ATL*

How do we study AV impacts?

AV studies

Survey (+ interview)

- ✓ Haboucha et al. 2017
- ✓ Daziano et al. 2017
- ✓ Payre et al. 2014
- ✓ ….

Scenario-based projection

- ✓ Harper et al. 2016
- ✓ Truong et al. 2017
- ✓ …

Scenario-based simulation

- ✓ Zhang et al. 2018
- ✓ Liu et al. 2017
- ✓ Levin and Boyles 2015
- ✓ …

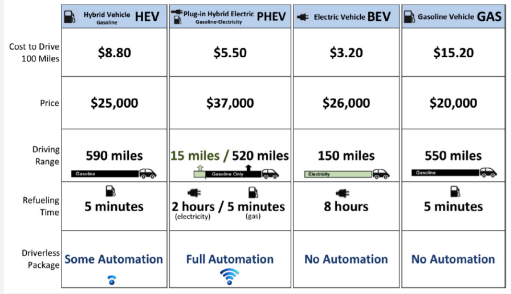
Naturalistic experiment

- ✓ Harb et al. 2018

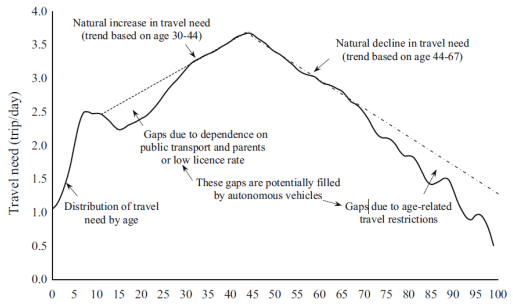
Virtual reality

- ✓ Sportillo et al. 2018
- ✓ Branzi et al. 2017
- ✓ …

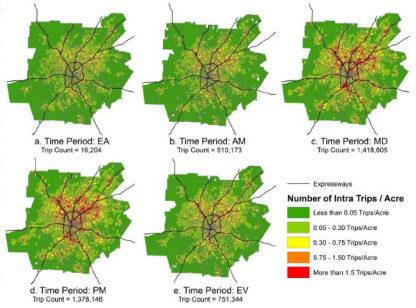
…



Daziano et al. 2017



Truong et al. 2017



Zhang et al. 2018

https://procarandlimo.com/termsfaqs/

Transport Systems Catapult

Limitations of the approaches

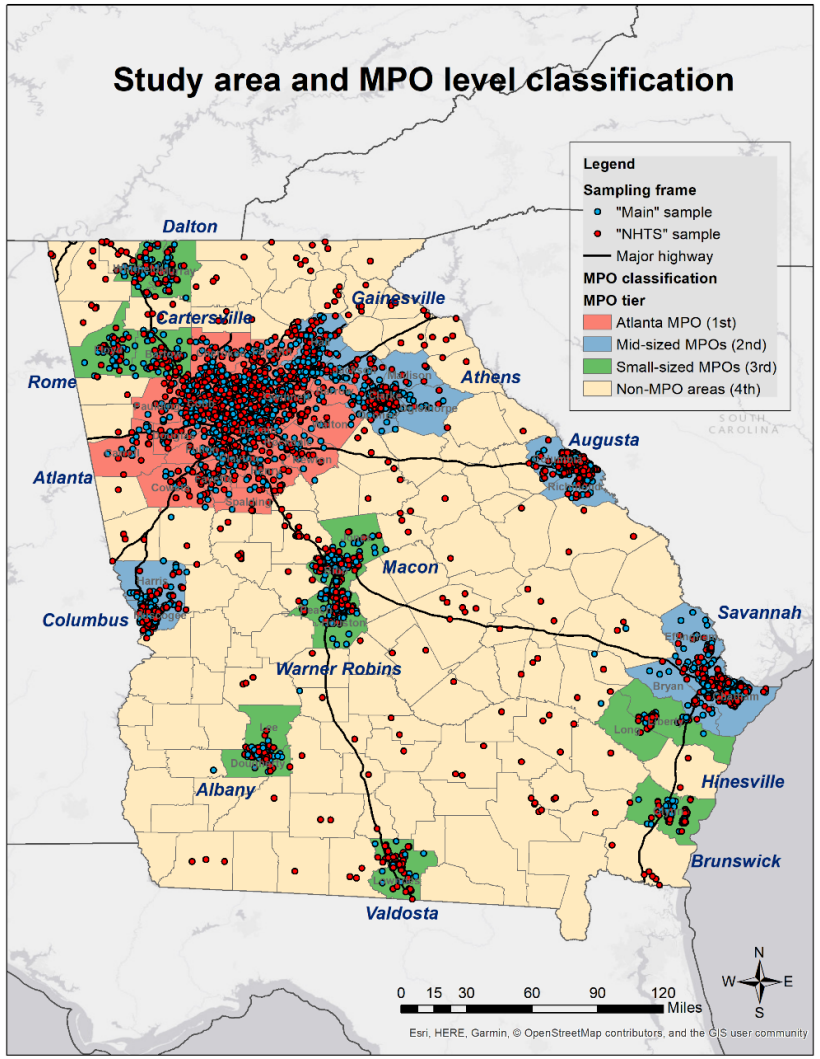
Great uncertainty
- ✓ Timing of market maturity
- ✓ AV business models
- ✓ AV related policy & regulations
- ✓ (new normal?)
- ✓ …

AV studies

Survey (+ interview)	Scenario-based projection	Scenario-based simulation	Naturalistic experiment	Virtual reality	…
✓ Expectations are not necessarily realized ✓ Current thoughts are shaped based on current settings	✓ Subjective and deterministic assumptions	✓ Behavioral models and parameters yet unknown	✓ High cost ✓ Limited number of subjects ✓ Not fully “driverless”	✓ High cost ✓ Limited experimental variability	

Empirical data

Content	Description
Project	The Impact of Emerging Technologies and Trends on Travel Demand in Georgia
PI/co-PI	Drs. Patricia Mokhtarian and Giovanni Circella
Timeline	2016-2017: Survey design 2017-2018: Data collection/cleaning
Study area	15 planning regions (MPOs) + rural counties in GA
Target population	Georgia residents (over 18 years old)
Sampling	1) Address-based stratified random sampling 2) Selected NHTS-2017 participants
Data collection channel(s)	Paper survey (with online option)
Sample size	~ 3,300
External data appended	American Community Survey (ACS), Longitudinal Employer-Household Dynamics (LEHD), Alltransit, Google Place API, and Google Map API



Kim, Mokhtarian, and Circella (2019) *The Impact of Emerging Technologies and Trends on Travel Demand in Georgia.* Georgia Department of Transportation.

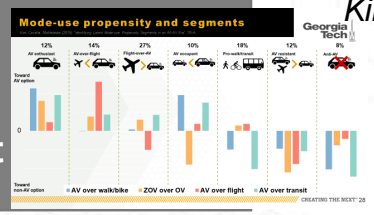
Potential behavioral responses to AVs

Perceptions → *Short-term responses* → *Medium-term responses* → *Long-term responses*

AV perceptions
- AV pros
- AV overuse cons

AV use intentions
- Own privately
- Use SAV alone/others
- Use SAV with strangers

Mode use propensity
- AV vs. walk
- ZOV vs. OV
- AV vs. flight
- AV vs. transit



Kim, Circella, Mokhtarian (2019) TR-A

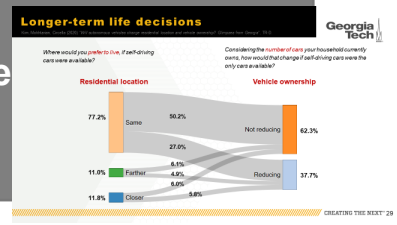
Trip/activity changes
- More distant
- Flexible time-use
- More frequent
- More long-distance

Kim, Mokhtarian, Circella (2020) TR-F

Residential relocation
- Close to frequented places
- Stay
- To attractive (farther) place

Kim, Mokhtarian, Circella (2020) TR-D

Number of vehicles
- Reduce
- Keep same
- Increase



Goals of the present study

1. To measure (at a general level) how people expect their travel/activity patterns to change in the AV era;
2. To identify population segments having similar profiles of expected changes; and
3. To further profile each segment on the basis of attitudinal, sociodemographic, and geographic characteristics

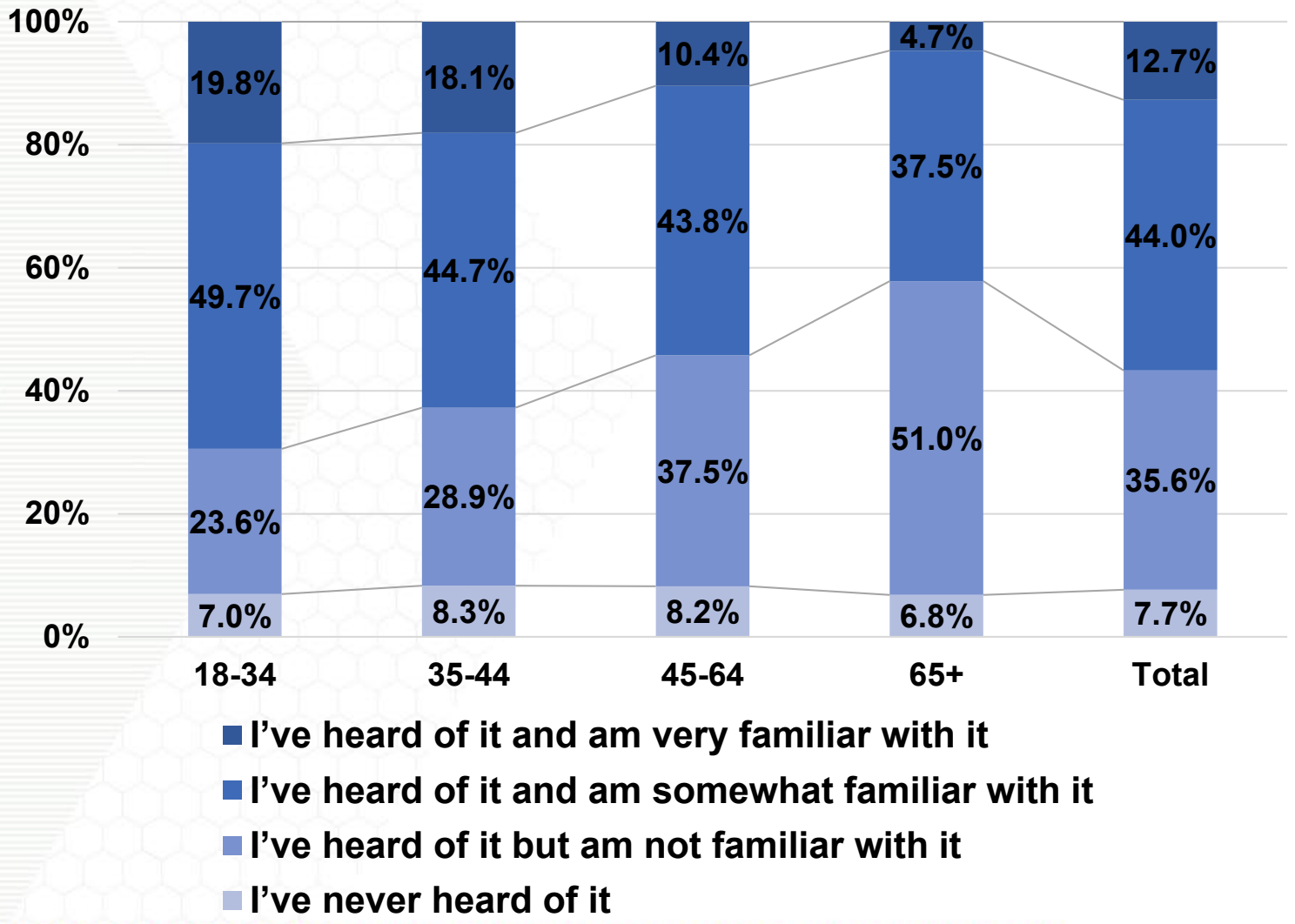
Contextual setting for AVs

- Assume a future where all cars are ***fully automated*** (level 5)
- Focus on ***behavioral response*** after sidestepping safety and cost concerns

- ✓ Traditional cars can no longer be used in regular traffic – self-driving cars are the *only way to go by car*.
- ✓ Driverless cars are *at least as safe* as today's cars are, and *cost about as much* as today's cars do.
- ✓ You could *furnish* your self-driving car with a TV, kitchenette, recliner, light exercise equipment, etc.
- ✓ You could send an empty self-driving car somewhere to *pick up other people or things, or to park* after dropping you off at work or the ball game.
- ✓ You could let a self-driving car take you places *while you are sleeping*.

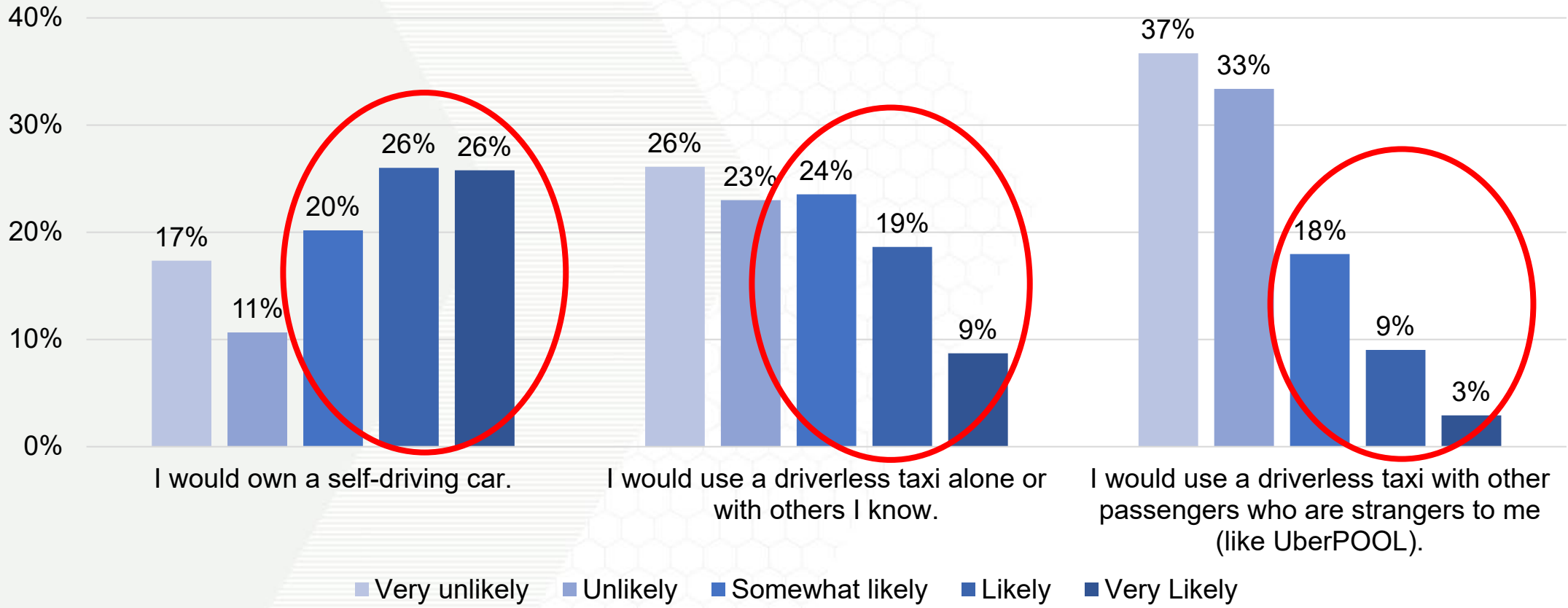
Familiarity with AVs

We are interested in your awareness of or familiarity with the concept of a self-driving car.



AV use intention

If self-driving cars were the only cars available, how likely would you be to ***own*** a self-driving car, ***use*** self-driving services (such as a driverless taxi), or do both?



Measurement of opinions about activities

How likely is it that self-driving cars would **change your behavior**, in each of the following ways?

I would…	*Very unlikely*	*Unlikely*	*Somewhat likely*	*Likely*	*Very likely*
a. Eat out in restaurants more often.	☐1	☐2	☐3	☐4	☐5
b. Go to grocery stores or shopping malls more often.	☐1	☐2	☐3	☐4	☐5

Statements	Mean
Eat out in restaurants more often.	2.04
Go to grocery stores or shopping malls more often.	2.06
Travel to social/leisure activities more often.	2.36
Go to more distant restaurants.	2.45
Go to more distant grocery stores or shopping malls.	2.28
Socialize with people who live farther away.	2.52
Travel to more distant locations for leisure.	2.73
Eliminate some overnight trips because it would be easier to come back the same day.	2.80
Make more overnight trips by car because it would be less burdensome to travel long distances.	2.87
Go to work/school at a different time to avoid traffic jams, since I can sleep/work in the car.	2.32
Take part in more leisure activities after dark, because I wouldn't need to drive myself.	2.63
Take vacations more often.	2.48
Reduce my time at the regular workplace and work more in the self-driving car.	2.03
Sleep less time at home and more time in the car, to be more efficient.	1.83
More often eat meals in a self-driving car instead of at home or in a restaurant.	1.96
Cultivate new hobbies or skills with the time I saved.	2.25

Generally expecting changes will be “unlikely”

Factor analysis of activity changes

Statements ↓ Factors →	Distance	Time flexibility	Fre-quency	Long-distance/ leisure
Eat out in restaurants more often.	0.062	0.069	**0.782**	0.043
Go to grocery stores or shopping malls more often.	0.076	0.066	**0.822**	0.023
Travel to social/leisure activities more often.	0.375	0.060	**0.452**	0.138
Go to more distant restaurants.	**0.666**	0.077	0.247	0.062
Go to more distant grocery stores or shopping malls.	**0.630**	0.114	0.254	0.027
Socialize with people who live farther away.	**0.654**	0.102	0.080	0.214
Travel to more distant locations for leisure.	**0.504**	0.049	0.038	0.444
Eliminate some overnight trips because it would be easier to come back the same day.	0.106	0.106	0.080	**0.652**
Make more overnight trips by car because it would be less burdensome to travel long distances.	0.086	0.054	0.047	**0.789**
Go to work/school at a different time to avoid traffic jams, since I can sleep/work in the car.	0.055	**0.428**	0.098	0.335
Take part in more leisure activities after dark, because I wouldn't need to drive myself.	0.185	0.147	0.184	**0.457**
Take vacations more often.	0.221	0.212	0.171	**0.417**
Reduce my time at the regular workplace and work more in the self-driving car.	0.039	**0.614**	0.127	0.120
Sleep less time at home and more time in the car, to be more efficient.	0.040	**0.817**	0.013	-0.025
More often eat meals in a self-driving car instead of at home or in a restaurant.	0.020	**0.687**	0.060	0.034
Cultivate new hobbies or skills with the time I saved.	0.181	**0.463**	0.117	0.196

Numbers represent **strength of relationship between statement & factor**; closer to 1 means stronger relationship

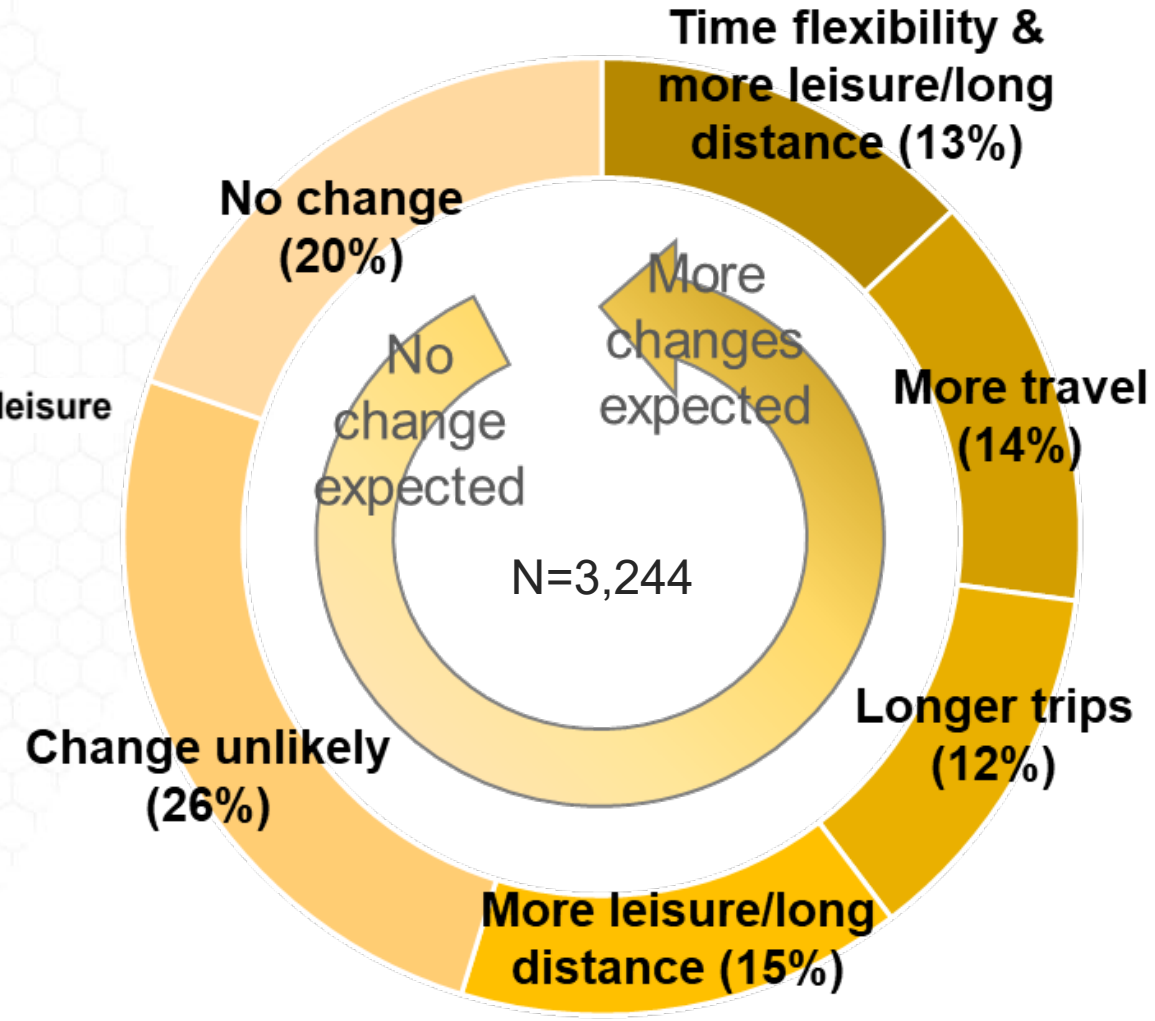
Cluster analysis on the resulting factors

- Purpose: Divide the sample into groups on the basis of having ***similar sets of scores on the four "activity change" factors:***

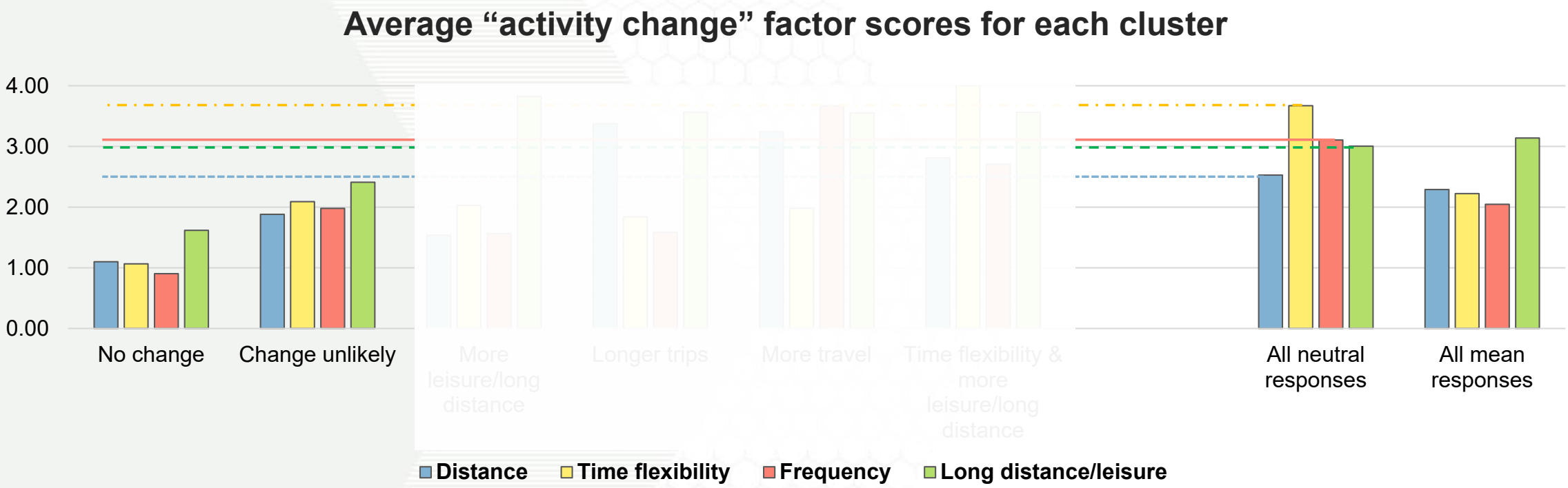
Distance Time flexibility Frequency Long distance/leisure

(composite scores will also range from 1 to 5)

- K-means algorithm
- 1000 sets of randomized starting points
- Selected the 6-cluster solution



Looking into market segments (1)



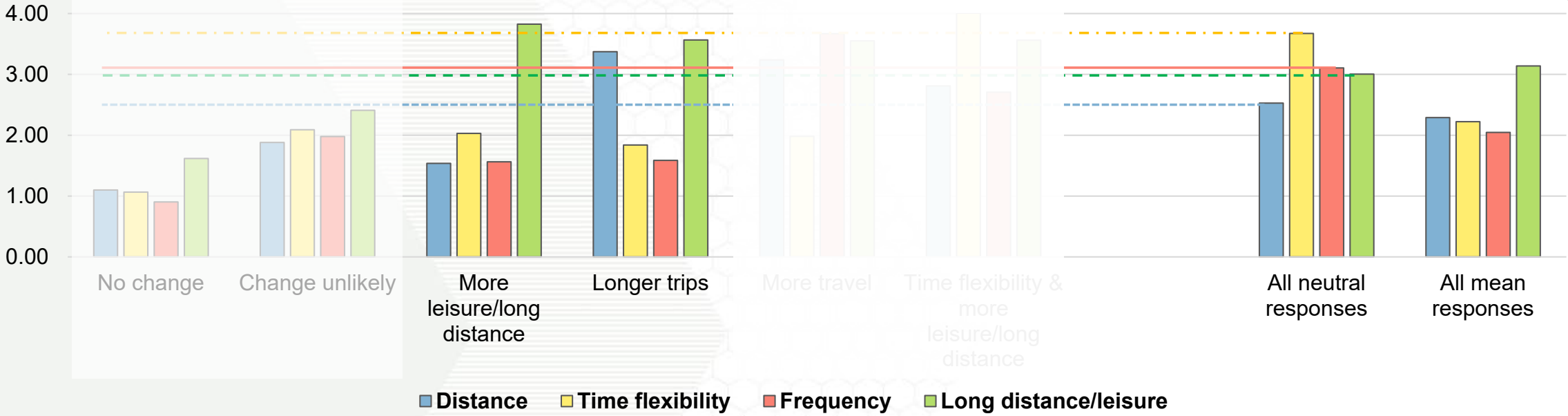
No change (20%)

- Presents the most negative reactions to any activity changes
- Mostly expecting “very unlikely”

Change unlikely (26%)

- Exhibits less optimistic responses for all four activity changes
- Mostly expecting “unlikely”

Looking into market segments (2)



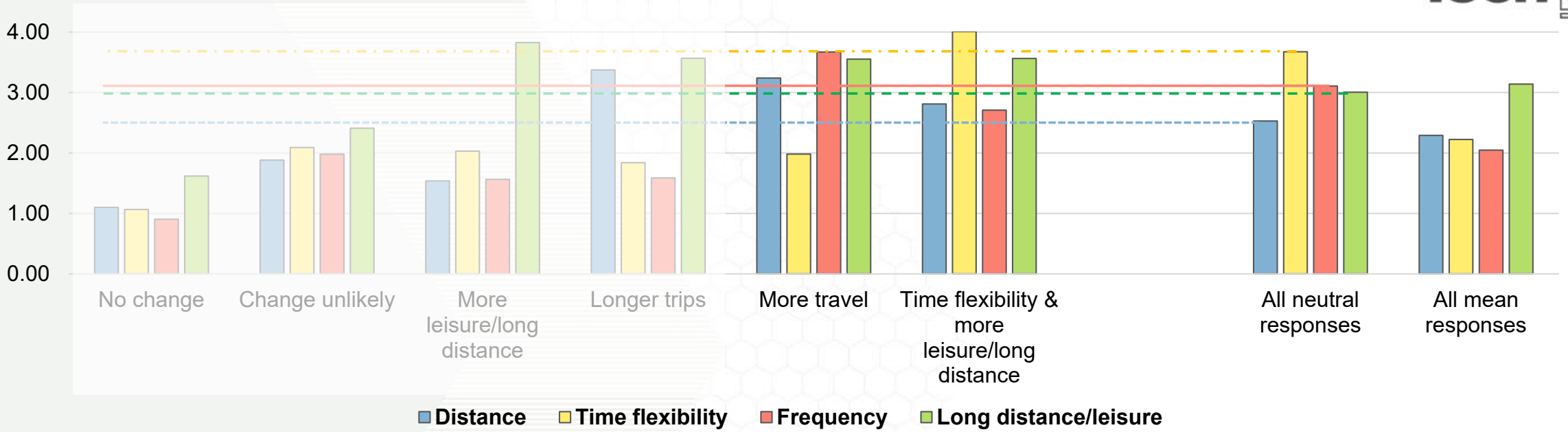
More leisure/long distance (15%)

- "Unlikely" reactions to three of the activity dimensions
- But distinctively high expectations of making more leisure and long distance trips
- Expects little change in daily travel, but would like to take advantage of AVs for occasional long distance trips

Longer trips (12%)

- Expresses less enthusiasm for using time more flexibly and making trips more frequently
- But envisions traveling to more distant places, for both daily (e.g. grocery, restaurant) and long-distance trips

Looking into market segments (3)



More travel (14%)

- Exhibits greater enthusiasm for changing the quantity of travel
- But, still thinks it unlikely that they will employ time more flexibly because of AVs

Time flexibility & more leisure/LD travel (13%)

- Shows a generally high level of enthusiasm
- Distinctively presents positive reactions to time flexibility

Profiles

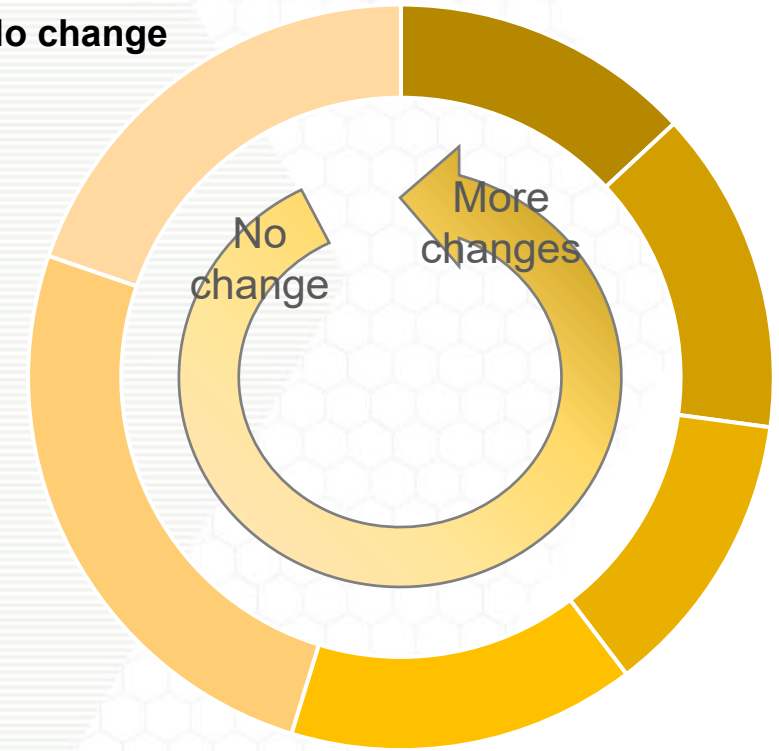
Based on relative comparisons

Time flexibility & more leisure/long distance

- ✓ Favorable to non-car modes
- ✓ Tech-savvy
- ✓ Travel-liking
- ✓ Perceiving AV benefits
- ✓ Youngest

No change

- ✓ Least favorable to non-car modes
- ✓ Least tech-savvy
- ✓ Least urbanite
- ✓ Lowest perceived AV benefits
- ✓ Living in least dense areas
- ✓ Oldest
- ✓ Lowest income



More travel

- ✓ Urbanite
- ✓ Black
- ✓ Lower income
- ✓ Fewer vehicles

Change unlikely

- ✓ Age of 45-64
- ✓ Middle income
- ✓ Living in mid-sized regions

Longer trips

- ✓ Living in densest areas
- ✓ Living in greatest accessibility to amenities
- ✓ Female
- ✓ Atlantan

More leisure/long distance

- ✓ White
- ✓ Male
- ✓ Higher income

Some implications (1)

- Based on people's current (well, 2017!) opinions, the expected shifts are *relatively modest* on average
- People reported particularly *lower expectations with respect to time flexibility*
  - However, some fraction of people will take advantage of hands-free travel (the *time flexibility & more leisure/long distance* segment); such people are more likely to be *tech-savvy, younger, and workers*
- AVs will have *stronger impacts on distance than on frequency*
  - Important to distinguish between more versus longer trips in efforts to predict aggregate increases in travel time due to AVs
  - Relatively less burdensome to add more travel time to existing trips than to make entirely new trips

Some implications (2)

- Increased overall trip distance implies that the *service areas* of some types of places (e.g. restaurants or shopping malls) could be *enlarged* in the AV era
- Behavioral responses will *vary across demographics and regions*
  - AVs could facilitate the potential travel needs of younger/middle-age adults, higher income individuals, and Atlantans more than others
  - In addition, such travel generation may occur only for long distance trips for some, whereas others may employ AV benefits more in daily life, for example by using time differently
  - As such, future modeling for demand forecasting or prescriptive planning in preparation for the AV era should consider these heterogeneous responses of people

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- **Mokhtarian, PL F Papon, M Goulard, & M Diana** (2015) What Makes Travel Pleasant and/or Tiring? An Investigation Based on the French National Travel Survey. *Transportation* **42(6)**, 1103-1128. DOI 10.1007/s11116-014-9557-y.
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- **Tang J, F Zhen, & PL Mokhtarian** (2020) How do passengers allocate and evaluate their travel time? Evidence from a survey on the Shanghai–Nanjing high speed rail corridor, China. *Journal of Transport Geography* **85**, 102701.

Thank you!
Questions?

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APRIL 7, 2020

MINNESOTA'S NEXT STAGE IN AUTONOMOUS VEHICLES

#SMARTER TOGETHER WEBINAR

MIKE KRONZER
Senior Project Manager, MnDOT CAV - X

DESTINATIONCAV

DEPARTMENT OF TRANSPORTATION

ROCHESTER AUTOMATED SHUTTLE PILOT

PROJECT BACKGROUND

- Project selected through the MnDOT CAV Challenge RFP process.
- Operation of two (2) EasyMile EZ10 's:
  - low speed, 12 passenger, level 4 automated shuttles (no steering wheel or pedals).
- Onboard ambassador has ability to take over operation from the shuttle if needed.
- Project proposes an urban route in downtown Rochester.
- Open to the public with a minimum of 12 months of operation.

PROJECT PARTNERS

AN INNOVATIVE COLLABORATION BETWEEN GOVERNMENT, KEY STAKEHOLDERS, AND INDUSTRY.

PROJECT LEAD
MNDOT

PROJECT PARTNERS
CITY OF ROCHESTER
MAYO CLINIC
DESTINATION MEDICAL CENTER

TECHNOLOGY PARTNERS
FIRST TRANSIT
EASYMILE

DESTINATIONCAV

DEPARTMENT OF TRANSPORTATION

PROJECT GOALS

WINTER WEATHER

ADVANCE THE OPERATION OF AUTOMATED VEHICLE (AV) TECHNOLOGY IN WINTER WEATHER CONDITIONS

INFRASTRUCTURE

IDENTIFY INFRASTRUCTURE GAPS AND SOLUTIONS TO SAFELY OPERATE AV TECHNOLOGY ON PUBLIC ROADWAYS

PUBLIC EDUCATION

ENGAGE AND EDUCATE THE PUBLIC ON THE BENEFITS AND OPPORTUNITIES AFFORDED BY AV TECHNOLOGY

MOBILITY

ENHANCE THE TRANSIT EXPERIENCE FOR THE CITIZENS OF ROCHESTER AND INCREASE MOBILITY IN A HIGH DEMAND DOWNTOWN URBAN ENVIRONMENT

CAV DESTINATIONCAV

DEPARTMENT OF TRANSPORTATION

SHUTTLE ROUTE LOCATION

CIRCULATOR ROUTE THAT OPERATES ON 6TH ST SE, 3RD AVE SW, W CENTER ST, AND S BROADWAY.

SERVICE HOURS

- Launch shuttle service Summer 2021
- 12 months of operation
- Hours: 9am-3pm, 7 days a week

Visit EasyMile's website for more information on the EZ10 automated shuttle: https://easymile.com/driverless-technology-easymile-how-does-it-work/

DESTINATIONCAV

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LESSONS LEARNED: INFRASTRUCTURE

- Signals, road signage, pedestrian signage, road quality, pavement markings, curb management
- Minnesota **not** investing in DSRC
- Dual mode RSU solution at signals
- **Systems Engineering!**
  - **Conduct route analysis, infrastructure analysis, cost analysis, and assign task responsibility prior to any operations work**

COMMUNICATIONS & ENGAGEMENT

- KEY MESSAGING
- WEBSITE
- PUBLIC BROCHURES
- LAUNCH EVENT
- MEDIA OUTREACH AT KEY MILESTONES
- SOCIAL MEDIA PRESENCE
- CRISIS PROTOCOL AND RESPONSE
- EMERGENCY SERVICES EDUCATION

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THANK YOU

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#SMARTer Together - EasyMile's success is built on building true partnerships

*EasyMile brings **driverless vehicle solutions** for people and goods to life with leading technology that provides a real service*

EasyMile Background

*EasyMile brings **automated vehicle solutions***
for people and goods to life with leading technology
that provides a real service

EasyMile at a glance

Since
2014

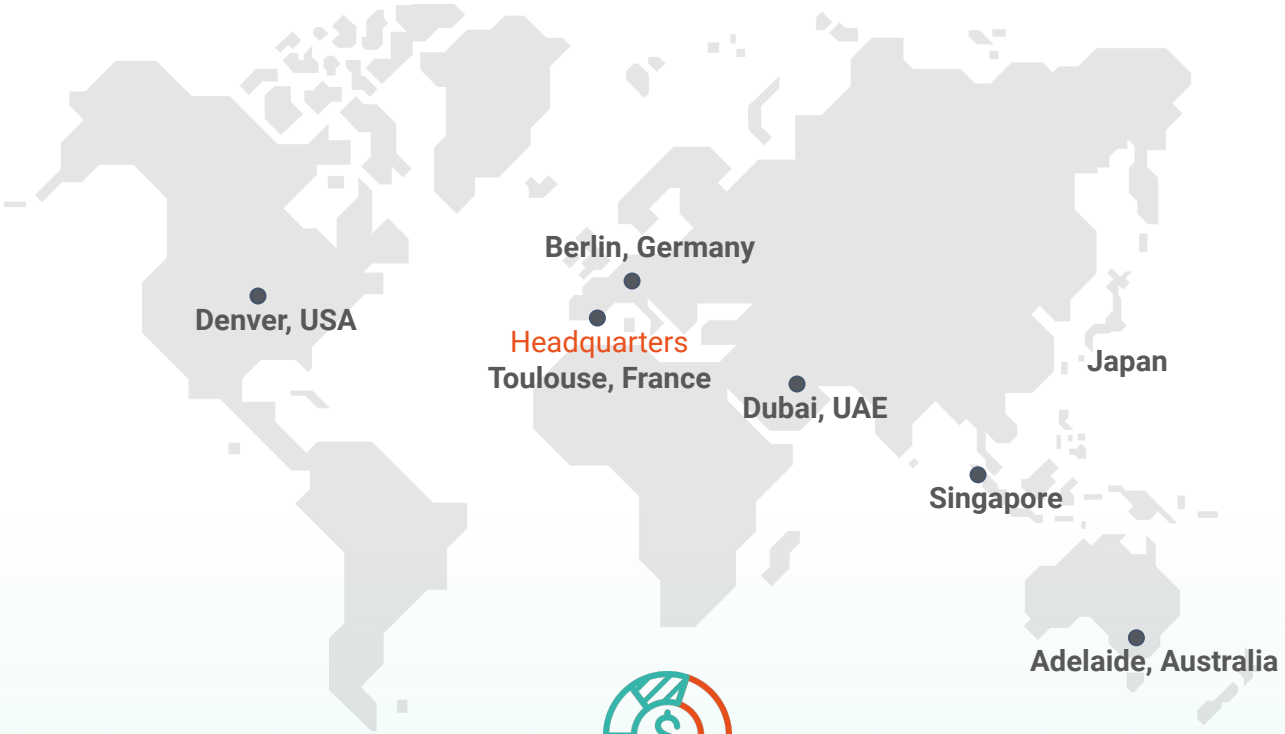
30+ PhDs

220+

Leader
in R&D

7
locations

22
nationalities



Shareholders

Founders, Continental, Alstom and Bpifrance

EZ10 automated shuttle

Driverless and electric shuttle

6

6 seats with seatbelts

16h autonomy, 10h with A/C

ADA Compliant

Pre-mapped network of roads

150

Shuttles worldwide - nearly 30 in US

SPEED LIMIT 12

EZ10 maximum speed

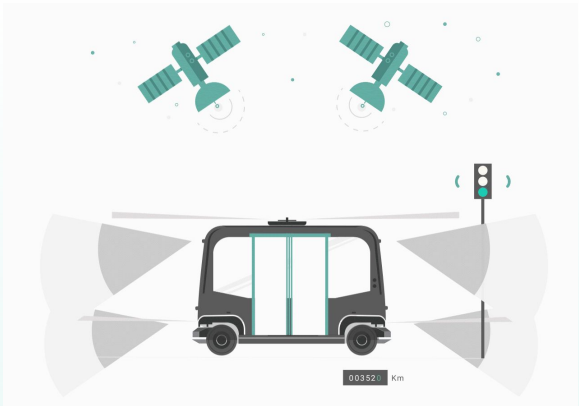
SPEED LIMIT 25

Other vehicles' maximum speed

>300

Deployments In 30+ countries

EZ10



TractEasy Specifications

VEHICLE CHARACTERISTICS

Energy

Electric

Battery technology

Lead-acid or Li-ion

Maximum towing capacity

25 tonnes / 55k lbs

Maximum speed

* Up to 15 mph in Manual Mode*

* Up to 10 mph in Autonomous Mode

*Speed depends on weight towing

Dimensions (l * w * h, mm)

3200 * 1940 * 2050

Turning radius, wall-to-wall

4.25m minimum, depending on trailers

Gross Vehicle Weight

8,500 lbs

Available Today!

Flagship locations

Various use cases including, Department of Transportations, Airports, Fortune 500 firms and University Campuses

Rochester Project Introduction

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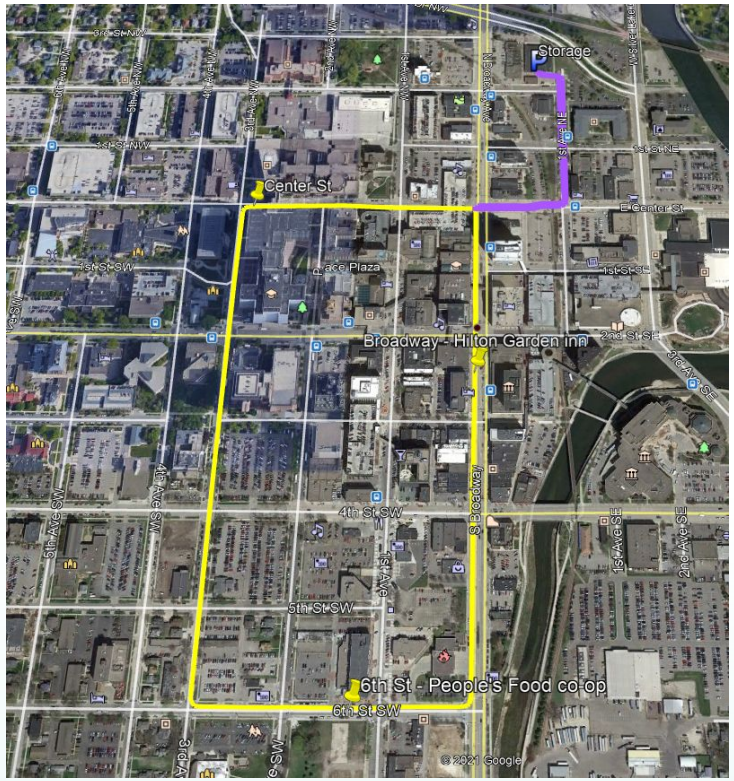
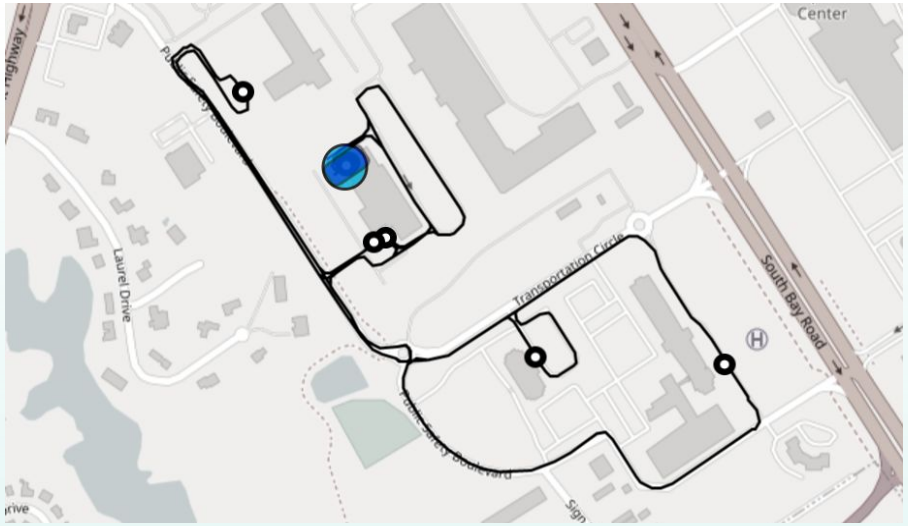
- 2 EZ10 Gen3s will connect Methodist Hospital with hotels, shops, restaurants, and parking for 12 months.
- Projected passenger operation hours are 9am to 3pm.
- The site involves mixed traffic, signalized intersections, and Minnesota weather!
- NHTSA approval will be required
- Project will leverage MnDOT's EZ10 winter testing experience from 2017 project
- Project can show potential for applying AVs in transit setting
- Project will identify any infrastructure improvements that might be necessary for AVs while ensuring safety on public roadways.



Delaware DOT and DART, Dover, Delaware

Delaware Department of Transportation is partnering with EasyMile to deploy Delaware's first electric, fleet of 2 self-driving transit shuttles, at various locations throughout the State in 3 different phases over the next few years.

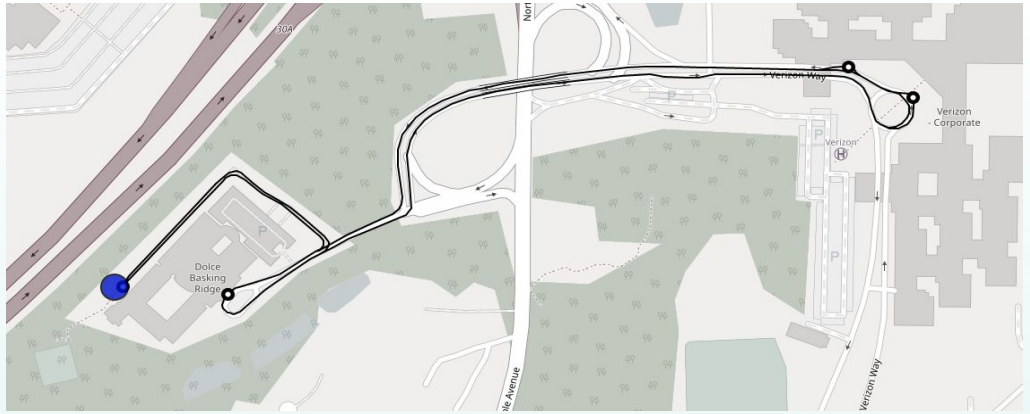
Customers and Client URL	Delaware DOT
Environment	Public Road
Description of the project scope	Mixed Traffic with Pedestrians, Bikes and Motorized Vehicles
Route length / Number of stops	1.9 miles with 5 stops
Make, Model and Number of shuttles used	Two EasyMile EZ10 Gen-3s
Project Duration, hours of service	Long term relationship Monday to Friday, 10am to 2pm.
Average temperatures and weather encountered	The highest average temperature is 85° and the lowest average temperature is 19°F. Weather includes rain, wind, fog, hail, snow.



Verizon, Basking Ridge Campus, New Jersey

The EZ10 shuttle services Verizon employees from the Verizon Employee Hotel to the Corporate Campus working with their current shuttle service provided on the campus. This project is an exciting R&D opportunity of between Verizon and EasyMile, using the EZ10 as a mobile 5G test bed.

Customers and Client URL	Verizon - www.verizon.com
Environment	Private campus
Description of the project scope	Mixed Traffic with Pedestrians, Bikes and Motorized Vehicles
Route length / Number of stops	1.1 mile with 3 stops
Make, Model and Number of shuttles used	One EasyMile EZ10 Gen-3
Project Duration, hours of service	Long term relationship Monday to Friday, 10am to 3pm.
Average temperatures and weather encountered	The highest average temperature is 85° and the lowest average temperature is 19°F. Weather includes rain, wind, fog, hail, snow.



***Reference**: Available upon request*

Columbus, Ohio

EasyMiles Gen-3 shuttles are now taking pre-packaged food boxes from St. Stephen's Food and Nutrition Center to the Rosewind Community Center in Columbus OH, where residents can meet the shuttle to pick up the boxes as well as face masks Monday through Friday. A trained operator rides on board the shuttle to ensure safety and then helps distribute the boxes once at the community center.

Customer and Client URL	City of Columbus, OH - https://smart.columbus.gov/
Environment	Public Road
Description of the project scope	Mixed Traffic with Pedestrians, Bikes and Motorized Vehicles
Route length / Number of stops	1.7 miles
Make, Model and Number of shuttles used	Two EasyMile EZ10 Gen-3s
Project Duration, hours of service	Ongoing 6am to 7pm Monday to Sunday
Average temperatures and weather encountered	Temperatures in Columbus OH can range from a high 105° to a low of -22°. Weather conditions included wind, rain, snow, and fog.

Moving engines to the assembly line

Mid West, USA

"Integrating the TractEasy into one of the busiest car plants in North America the TractEasy is a perfect compliment to our vision of clean technologies driving efficiencies to processes"

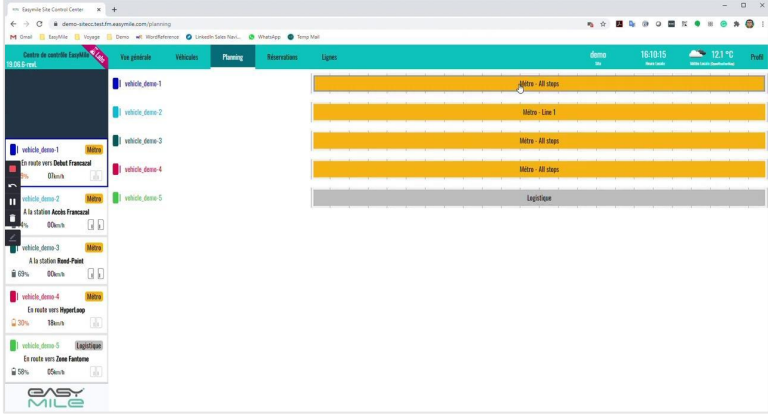
The challenge

- High labor costs
- One of the largest car manufacturing plant in the US
- Automate indoor and outdoor processes
- Towing 14,000lbs

The solution

- 100% driverless
- No Safety Driver on-board
- Transporting engines from powertrain to assembly line
- Mixed-traffic operations
- 1.68 mile loop with indoor and outdoor phases
- Through intersections, pedestrian crosswalks, a roundabout and a railway crossing
- V2I communication with doors and traffic light

EZFleet - Fleet Management System



Control Center

- Interface to supervise vehicles' performance and safety
- Interaction with vehicles: access to cameras, change mode, re-arm etc…

Mission & Fleet Management

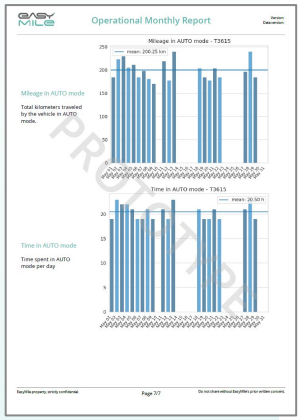
- Mission assignment to the vehicles
- Manage vehicles' behavior at stations
- Send alerts to point of contact

System Integration

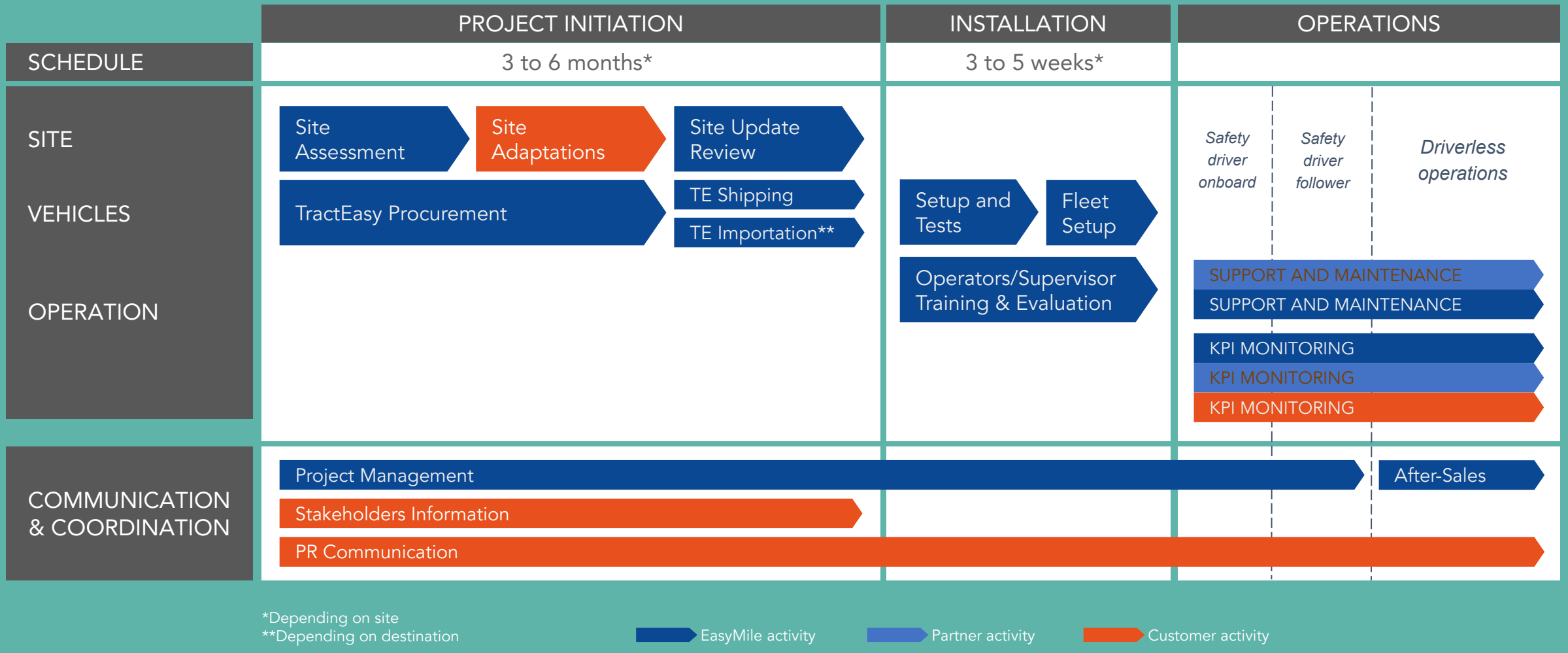
- Ability to connect to third party systems (e.g. Warehouse Management Systems) to increase coordination and flexibility

Data Reports & Statistics

- Aggregate information from operating vehicles
- Provide operations insights through recurrent reporting



Building Partnerships to enable success



*Depending on site
**Depending on destination

EasyMile activity Partner activity Customer activity

Thank you

Connect with us:

#EasyMile