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Integrating Engineering Research Experiences for Teachers into the K-12 Classroom

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Catherine Lugo graduated from Baylor University with a Bachelor of Science Degree in Mechanical Engineering and a Minor in Entrepreneurship. Before teaching at Fort Worth ISD, Lugo led the Robotics and Engineering K-12 Programs for the Girl Scouts of Northeast Texas. Lugo will be in her 6th year of teaching engineering and robotics at I.M. Terrell Academy, where she built and developed the robotics program which features VEX Robotics and Drones. I.M. Terrell's robotics teams have earned several awards, and most recently, team #17505B advanced to the VEX World Championship in the 2023-24 season.

Mrs. Meribah Marie Treadway, The University of Texas at Arlington

Meribah Treadway is a graduate of the University of North Texas where she earned a Bachelor of Arts degree in physics along with a secondary math and physics teaching certification through the Teach North Texas program. Treadway has spent her entire teaching career at James Martin High School (her own alma mater) where she is a part of the Arlington ISD STEM Academy faculty and is the co-coordinator for the annual STEM Leadership Conference. Treadway has taught both mathematics and engineering courses and will be teaching Pre-AP Geometry and Pre-AP Algebra 2 during the upcoming 2024 – 2025 school year.

Integrating Engineering Research Experiences for Teachers into the K-12 Classroom

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Abstract

As part of UT Arlington's Research Experience for Teachers (RET) in Engineering and Computer Science program, K-12 STEM teachers participated in research with the UTA faculty and graduate students with the goal to translate this research experience into classroom activities that will broaden the student's awareness of participation in computing and engineering pathways. High school teachers C. Lugo from Fort Worth ISD and M. Treadway from Arlington ISD researched with Dr. K. Hyun, Civil Engineering, UT Arlington and graduate students, A. Imran, and M. Rashidi on mixed methods to evaluate emerging transportation technology which studies America's future adoption of connected and autonomous vehicles (CAVs). These statistics can be predicted through a series of simulated scenarios where the technology cost decreases and the consumer willingness to pay (WTP) increases concurrently. Other factors for CAV adoption include household decisions on buying, selling, and replacing vehicles, access to public transportation, and policy regulations.

The areas of interest were selected to be block groups within Arlington, TX and census tracts within Coppell, TX. Data was then sourced for these two cities from the National Historic Geographic Information System (NHGIS) and the United States Census Bureau. The data was compiled into a spreadsheet and used to calculate variables needed to calculate a series of Monte Carlo simulations to generate 10 participant profiles for each census tract or block group. The profiles for each of these simulated individuals were then entered into a python program to apply the decision making matrix for car transactions to predict their adoption of the various levels of CAV technology for analysis. The results show the predicted adoption of varying levels of CAV technology over the next 16 years for residents at the census tract and block group level. Levels 1 and 2 technology appear to make up a majority of the technology adoption. Many of these features come standard in new cars and have been around long enough to be prevalent in the used car market.

Guided by the research and analysis, teachers Lugo and Treadway created lesson plans that would integrate their research experiences to increase their students' perceptions and interest in engineering majors and careers. For the Project-Based Research class, students will be introduced to ArcGIS Online as a method of understanding an engineering problem and analysis. Students will be required to identify an engineering problem and develop a solution to the identified problem over the course of the year. For Algebra 2, students will plot the coordinates of items with a mapping software and use a gradient to identify "hot spots" within the region. Students can then derive linear, quadratic, or exponential functions to demonstrate the relationship these hot spots have with their distances from other locations.

Introduction

Participants in the UTA Research Experience for Teachers (RET) program, funded by the National Science Foundation (NSF) are assigned to one of six projects focused on Sustainable and Resilient Infrastructure for Urban Communities. Lugo and Treadway were partnered with Dr. Kate Huyn to collaborate on Mixed Methods to Evaluate Emerging Transportation Technology.

Many independent corporations and government agencies have an interest in America's future adoption of connected and autonomous vehicles (CAVs). These statistics can be predicted through a series of simulated scenarios where the technology cost decreases and the consumer willingness to pay (WTP) increases concurrently. Other factors for CAV adoption include household decisions on buying, selling, and replacing vehicles, access to public transportation, and policy regulations. The results show the predicted adoption of varying levels of CAV technology over the next 16 years for residents at the census tract and block group level.

Research Objectives and Questions

Primary Research Goal
Analyze technology adoption trends of connected-autonomous vehicles to forecast how quickly and extensively Americans are likely to adopt CAV technologies by the year 2040.

Explanation of CAV Technology Levels
Levels 1 & 2 - Driver assistance and partial automation
Driver remains responsible for overall control of the vehicle and must take over when the automated system reaches its limits.

EX:

- Electronic stability control
- Lane centering
- Left turn assist
- Cross traffic sensor
- Adaptive headlights
- Pedestrian detection
- Adaptive cruise control
- Blind-spot monitoring
- Traffic sign recognition
- Emergency automatic braking
- Self-parking valet system
- Connectivity

Level 3 - Conditional Automation
Hands-free driving in specific conditions, such as highway traffic, without requiring constant driver attention.

EX:

- Audi's Traffic Jam Pilot
  - The system can accelerate, brake, and steer the vehicle in certain situations, typically at low speeds on highways or in traffic jams.
- Cadillac's Super Cruise System
  - Super Cruise allows the vehicle to control steering, acceleration, and braking on compatible highways.

Level 4 - High Automation
Hands-free driving in most conditions, including urban environments, without requiring constant driver attention or or requiring a driver at all.

EX:

- Automated Taxi Services
    - A taxi which can handle most driving tasks independently and operate autonomously, however a human must be present in the vehicle.
- Autonomous Delivery Vehicle
    - An autonomous delivery vehicle that may be produced without pedals or a steering wheel. It remains connected to a remote monitoring system which oversees the vehicle's status, location, and can intervene if necessary.

Data Metrics
Data was sourced from the National Historic Geographic Information Systems (NHGIS) and the United States Census Bureau. Statistics included:

- Population
- Gender
- Marital Status
- Employment Status
- Number of Households and Household Size
- Age
- Educational Attainment
- Disability Status
- Income
- Distance to Downtown
- Distance to Public Transit Stop
- Number of Vehicles in each Household
- Number of Workers in each Household

The raw data was compiled into a spreadsheet and used to calculate the following metrics:

- Average population age
- Average number of vehicles per household
- Percent male population
- Percent of households with income below the poverty line ($20,000)
- Percent of households with at least 2 workers
- Percent of unmarried individuals
- Percent of individuals with a Bachelor's degree
- Percent of individuals with a full time job
- Percent of disabled individuals
- Percent of households with at least one car
- Population density
- Distance to downtown city hall exceeds 5 miles

Methodology

Task 1: Become familiar with Bansal and Kockelman 2017 article to learn scenarios of CAV implementations predictions in an urban environment.

Task 2: Select unique study locations and scenarios to create simulated population and simulate CAV adoption rates using decision matrix framework.

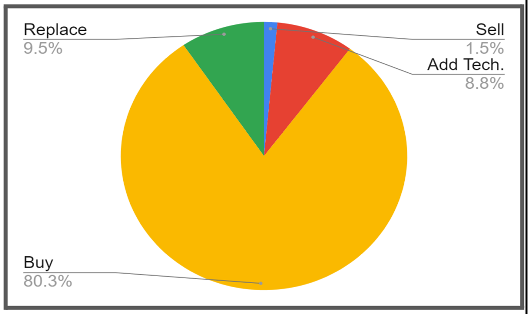
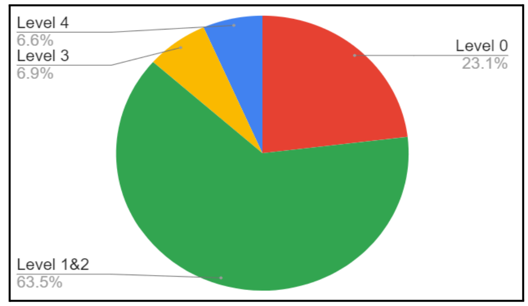
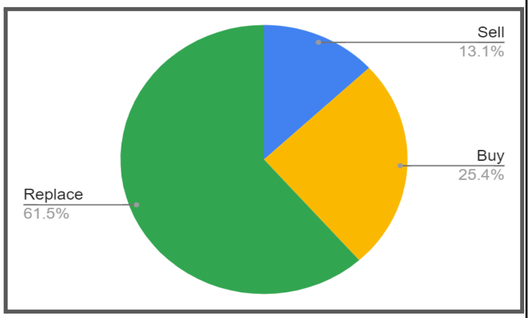
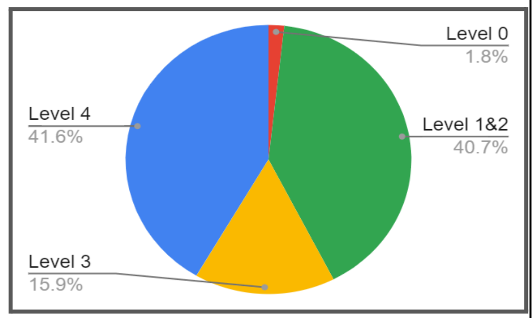
The areas of interest were selected to be block groups within Arlington, TX and census tracts within Coppell, TX. The data metrics as described above were collected and calculated for each block group and census tract.

Task 3: Use GIS for selected scenarios and geographical locations to demonstrate predictions

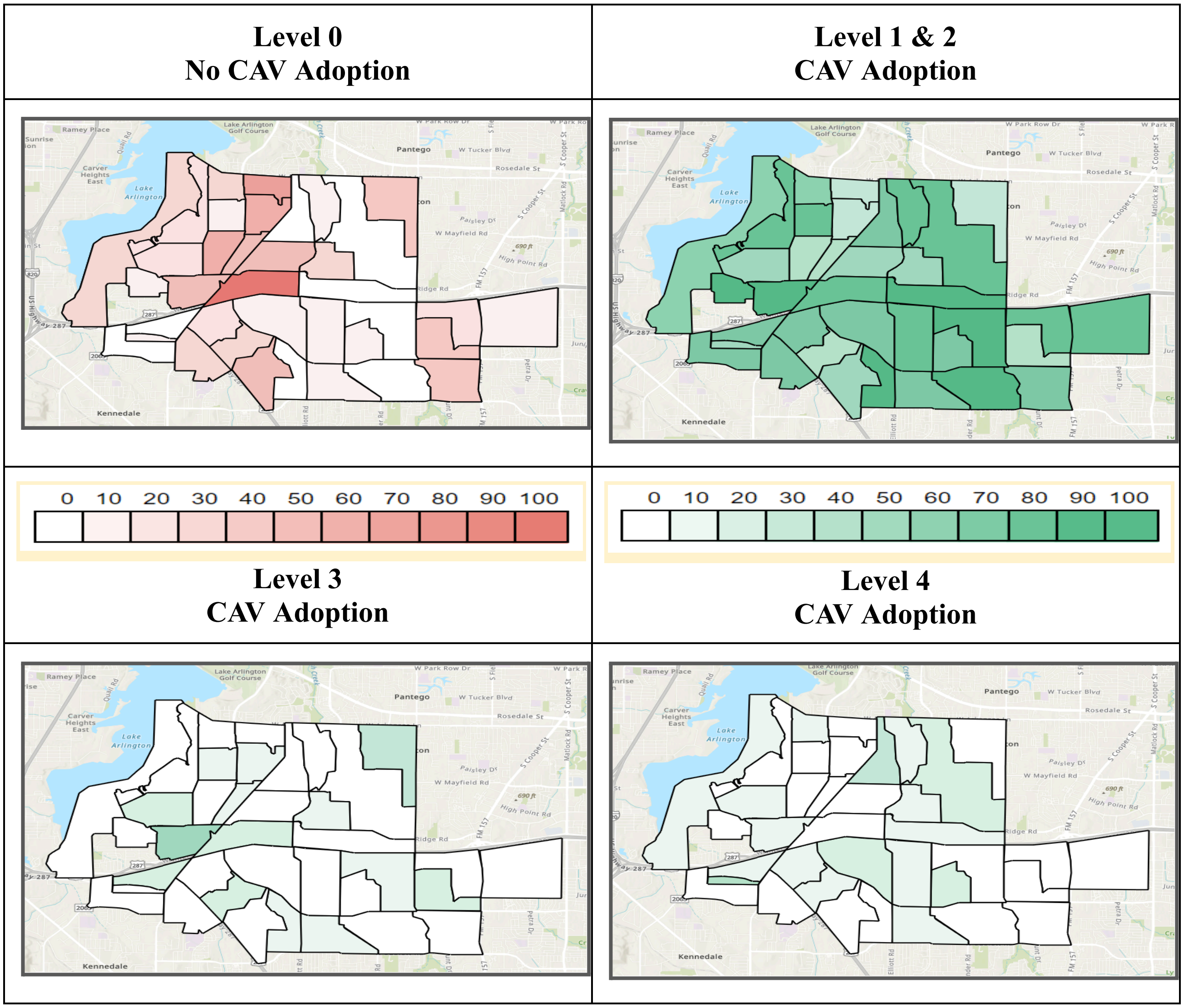
These summary statistics were run through a series of Monte Carlo simulations to generate 10 participant profiles for each census tract/block group. The profiles for each of these simulated individuals were then entered into code reflecting the decision making matrix for car transactions to predict their adoption of the various levels of CAV technology.

Decision-Making Matrix:

Results and Findings

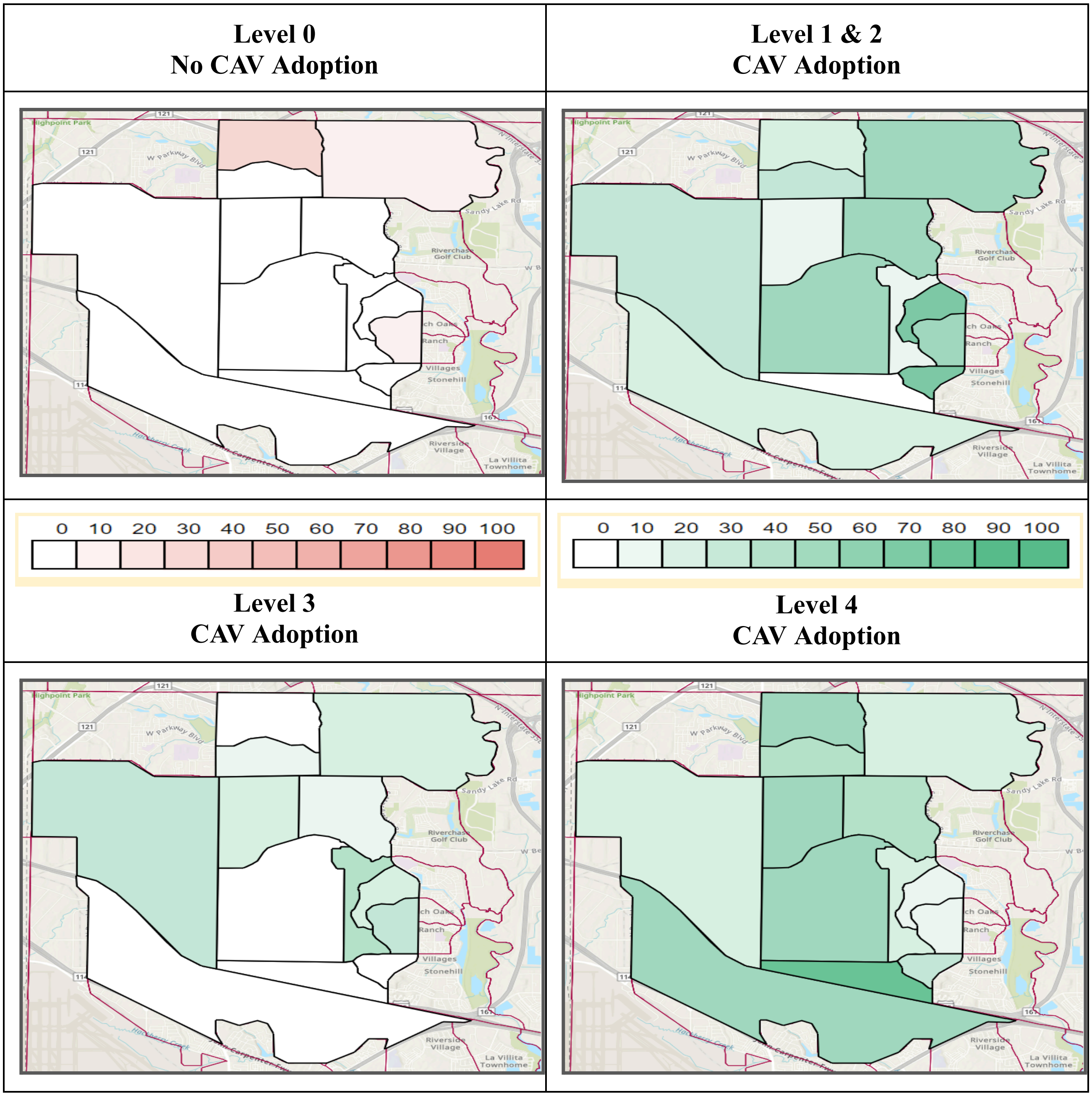
	Arlington Car Transaction Decisions	Arlington Distribution of CAV Adoption by Level
Simulated population of 400 individuals 40 block groups with 10 people each		
	Coppell Car Transaction Decisions	**Coppell Distribution of CAV Adoption by Level**
Simulated population of 130 individuals 13 census tracts with 10 people each		

Arlington Model Predictions



23% of the population would not adopt any CAV tech. 63.5% adoption rate of Level 1 and 2 CAV tech. Nearly 80% of car transactions resulted in the purchase of a vehicle. Level 3 and 4 technology adoption is predicted to be low (13.5% combined).

Coppell Model Predictions



High 98% adoption rate of CAV tech. at any Level. 41% adoption for Level 1 and 2. 42% adoption for Level 4. Nearly 62% of car transactions resulted in replacing a vehicle. Nearly 25% of car transactions resulted in the purchase of a vehicle.

Educational Impact

Treadway will implement GIS activities to help students make real-world connections between their lessons in mathematics and how it can be used in engineering applications. Examples for which Treadway will base her GIS activities are available from ESRI's GeoInquiries™.

Lugo's students were charged with identifying a research topic that a local university was researching to focus their own research projects within the identified topic. Students reached out to the research faculty teams to gain support and guidance with their high school research capstone projects. At the culmination of their research projects, students will demonstrate their learnings as a written paper and poster presentation.

Lessons Learned and Challenges

Participants experienced difficulties in gathering data from multiple sources with comparable but different statistical values. There were also challenges in extracting the data sets when using the advanced spreadsheet setting.

Another research challenge was understanding that subjectivity exists in predictive analysis and forecast modeling. Despite having a comprehensive decision matrix for car transactions and calculated metrics for the Monte Carlo simulations to create data samples, there were assumptions made about purchasing decisions that influenced the forecast model and subsequently, the results.

Additional challenges included using new programming languages and software. Python programming was used to conduct the Monte Carlo simulations and GIS software was used to analyze and represent the car transaction findings.

When working on the classroom implementation, Lugo was challenged to convert their summer project into a format that was manageable for high school students taking a Project-Based Research Capstone. Lugo's students also experienced difficulty in obtaining mentorship from identified subject matter experts and university faculty members, which was a required component of their assignment.

While Treadway has not executed the lesson in the classroom yet, they have experienced challenges with the Google Earth mapping software when going through the instructions. More troubleshooting is needed to be done before students are given their assignment.

Conclusion

Overall, both Lugo and Treadway benefitted from the summer RET program offered and supported by the faculty of UT Arlington. Both participants enjoyed the challenges of the engineering research and the opportunity to design and implement real-world engineering activities into their on-going curriculum.

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CATHERINE E LUGO
Catherine Lugo graduated from Baylor University with a Bachelor of Science Degree in Mechanical Engineering and a Minor in Entrepreneurship. Before teaching at Fort Worth ISD, Lugo led the Robotics and Engineering K-12 Programs for the Girl Scouts of Northeast Texas. Lugo will be in her 6th year of teaching engineering and robotics at I.M. Terrell Academy, where she built and developed the robotics program which features VEX Robotics and Drones. I.M. Terrell's robotics teams have earned several awards, and most recently, team #17505B advanced to the VEX World Championship in the 2023-24 season.

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Mixed Methods to Evaluate Emerging Transportation Technology
UT Arlington RET Site on Sustainable and Resilient Infrastructure for Urban Communities

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Background and Merit

Many independent corporations and government agencies have an interest in America's future adoption of connected and autonomous vehicles (CAVs). These statistics can be predicted through a series of simulated scenarios where the technology cost decreases and the consumer willingness to pay (WTP) increases concurrently. Other factors for CAV adoption include household decisions on buying, selling, and replacing vehicles, access to public transportation, and policy regulations. The results show the predicted adoption of varying levels of CAV technology over the next 16 years for residents at the census tract and block group level.

Objective

Analyze technology adoption trends of connected-autonomous vehicles to forecast how quickly and extensively Americans are likely to adopt CAV technologies by the year 2040.

Procedure

- The areas of interest were selected to be block groups within Arlington, TX and census tracts within Coppell, TX.
- Data was then sourced for these two cities from the National Historic Geographic Information System (NHGIS) and the United States Census Bureau. Statistics for these regions included:
  - Population
  - Gender
  - Marital Status
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  - Number of Households & Household Size
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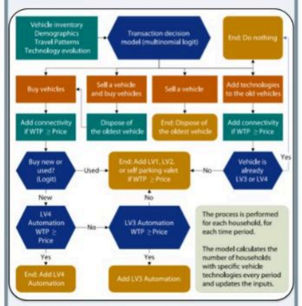
  - Distance to Downtown
  - Distance to Public Transit Stop
  - Income
  - Number of Vehicles in each Household
  - Number of workers in each Household
- The raw data was compiled into a spreadsheet and used to calculate the following metrics:
  - Average
    - Population age
    - Number of vehicles per household
  - Percent
    - Male population
    - Households with income below the poverty line ($20,000)
    - Households with at least 2 workers
    - Unmarried individuals
    - Individuals with a Bachelor's degree
    - Individuals with a full time job
    - Disabled individuals
    - Households with at least one car
  - Other
    - Population density
    - Distance to downtown city hall exceeds 5 miles
- These summary statistics were run through a series of Monte Carlo simulations to generate 10 participant profiles for each census tract/block group
- The profiles for each of these simulated individuals were then entered into code reflecting the decision making matrix for car transactions to predict their adoption of the various levels of CAV technology.

Decision Matrix for Car Transactions



Note. This framework forecasts long-term technology adoption and is used to simulate CAV adoption in our research analysis. From "Forecasting Americans' long-term adoption of connected and autonomous vehicle technologies," by P. Bansal and K.M. Kockelman. 2016. *Transportation Research Part A: Policy and Practice*, 95, pp. 49-63. Copyright 2017 by Fair Use for Educational Purpose.

Explanation of Technology Levels

Levels 1 & 2 - Driver Assistance/Partial Automation

- Electronic stability control
- Lane centering
- Left turn assist
- Cross traffic sensor
- Adaptive headlights
- Pedestrian detection
- Adaptive cruise control
- Blind-spot monitoring
- Traffic sign recognition
- Emergency automatic braking
- Self-parking valet system
- Connectivity

Level 3 - Conditional Automation

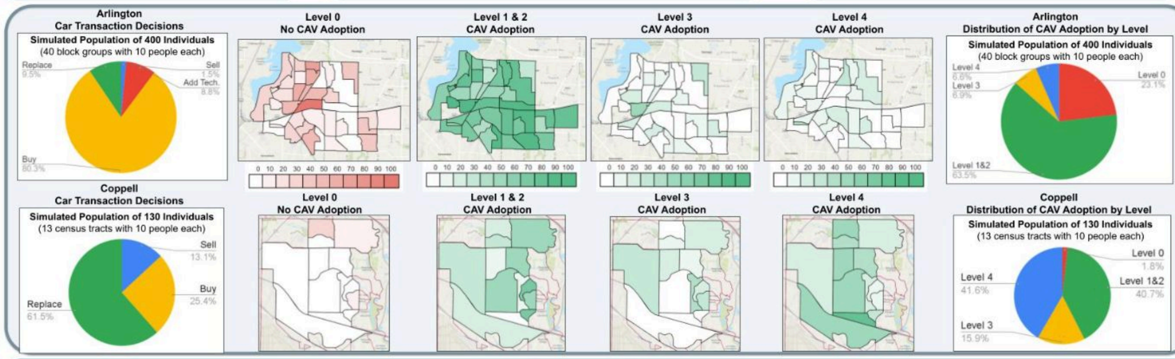
Hands-free driving in specific conditions, such as highway traffic, without requiring constant driver attention

Level 4 - High Automation

Hands-free driving in most conditions, including urban environments, without requiring constant driver attention or or requiring a driver at all

Conclusions

Levels 1 and 2 technology appear to make up a majority of the technology adoption. Many of these features come standard in new cars and have been around long enough to be prevalent in the used car market. By the year 2040, it is likely that even a 20 year old vehicle would have this technology. The car market is still recovering following the 2020 pandemic and surge in pricing for used vehicles. While costs are on their way down, prices for new and used vehicles are still at a record high due to supply/demand and inflation. The simulated scenarios predicted decreases in technology costs which has proven not to be the current reality. Given these factors, consumer WTP is not as high as would be necessary for widespread adoption of more advanced level CAVs.



Results

For the city of Arlington, the model predicted a 63.5% adoption rate of Level 1 and 2 CAV technology while approximately 23% of the population would not adopt any CAV technologies. Nearly 80% of car transaction decisions resulted in the purchase of a vehicle which explains the majority Level 1 and 2 adoption as many newer vehicles models include this technology as standard. Level 3 and 4 technology adoption was predicted to be low (13.5% combined). For the city of Coppell, the model predicted about a 98% adoption rate of CAV at any Level, with about 40% percent for Level 1 and 2, and about 40% for Level 4 adoption.

Classroom Implementation Plan

Algebra 2

Students will plot the coordinates of items with a mapping software and use a gradient to identify "hot spots" within the region. Students can then derive linear, quadratic, or exponential functions to demonstrate the relationship these hot spots have with their distances from other locations.

Engineering Capstone

Students will be introduced to ArcGIS Online as a method of understanding an engineering problem and analysis. Students are required to identify an engineering problem and develop a solution to the identified problem over the course of the year. This research project will be demonstrated as a case study for the impact of geography in an engineering research project.