Thanks for joining us!
The session will begin shortly.

Integrating Climate and Transportation Planning

Thanks for joining us!
The session will begin shortly.
Thank you to our event collaborators
Widgets are resizeable and movable

You can drag the presenter’s video around your screen.

Have a question for presenters? Click the ? icon.
Ida Sami
Ph.D. Candidate, University of Arizona
@AydaSami1

Increasing Heat Resilience Through Thermal Comfort Assessment in Sun Link Streetcar Stops, Tucson AZ
Outdoor Thermal Comfort Assessment at Tucson Sunlink Streetcar Stops

Ida Sami, PhD Candidate
Dr. Ladd Keith, Assistant Professor
Outdoor Thermal Comfort and Human

The heat exchanges in a space determine human comfort. As indicated in the diagram below, a number of elements influence a person's comfort in outdoor environments.
Why Thermal comfort planning?

- Design
- Policy

- Heat mitigation in cities increases extend activities
- More comfortable spaces makes
- Human health enhances
- Heat rash
- Heat cramps
- Heat exhaustion
- Heat stroke

- Climate Change has direct effect on extreme heat in cities
- Duration of heatwaves increases
- Average temperature magnifies the effect of

- Extreme heat in cities mostly effect
- Vulnerable groups such as
  - Elderly
  - Dysther workers
  - People with chronic illnesses
  - Children
  - Athletes
  - Low income
Aim of the Study

This study aims to gain a better understanding of streetcar users' thermal comfort in five distinct urban typologies: the University of Arizona, Main Gate Square, Fourth Avenue, Downtown, and the Mercado. In the spring, summer, and extremely hot summer of 2021, this research focuses on ambient and radiant temperatures in each station to better understand the impact of heat stress on users' thermal comfort while waiting for a streetcar. Co-production for Thermal Comfort Evaluation in Tucson Streetcar Stations involves the PAG, Shade Tucson, Sun Link, and The City of Tucson Transportation Planning Department.
Q: Do seasonal differences have different effects on streetcar rider's comfort levels?

M: The data was collected in the months of April and July of 2021, during the spring, summer, and extremely hot summer. Between 12 p.m. and 2 p.m., microclimatic variables were gathered. Air temperature (Ta), relative humidity (RH), wind speed (Ws), and globe temperature were all measured (Tg). The data was collected using a Kestrel 5400 and an Etekcity Infrared Thermometer 800.
Case Study Map
Outdoor Thermal Comfort Assessment

To analyze the outdoor thermal comfort, a quantitative method is used in which the thermal comfort is quantitated using a thermal index, Universal Thermal Climate Index (UTCI). UTCI is defined as "the isothermal air temperature of the reference condition that would elicit the same dynamic response (strain) of the physiological model" than the actual environment. One of the important factors to calculate the UTCI is MRT (Mean Radiant Temperature). MRT is a critical physical quantity that describes how humans react to radiation in their surroundings. We used the below formula to calculate MRT.

\[ T_{mrt} = T_{mrt}(T_a,V) \]
Outdoor Thermal Comfort Assessment

<table>
<thead>
<tr>
<th>UTCI (°C) range</th>
<th>Stress category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above +46</td>
<td>Extreme heat stress</td>
</tr>
<tr>
<td>+38 to +46</td>
<td>Very strong heat stress</td>
</tr>
<tr>
<td>+32 to +38</td>
<td>Strong heat stress</td>
</tr>
<tr>
<td>+26 to +32</td>
<td>Moderate heat stress</td>
</tr>
<tr>
<td>+9 to +26</td>
<td>No thermal stress</td>
</tr>
</tbody>
</table>
Surface Temperatures of Selected Streetcar Stops
Conclusion

• Data was taken using a Kestrel 5400 in five stops between 12 and 2 p.m. in the spring, summer, and extremely hot summer. In addition, surface temperatures for various materials were recorded every 15 minutes in the sun and shade.

• The UTCI Index is calculated using air temperature, wind speed, mean radiant temperature, and relative humidity.

• According to the UTCI, stops are in the moderate heat range throughout the spring, the strong to very strong heat stress range during the summer, and the extreme heat stress range during the week of extremely hot weather.

• In the sun and shade, the most significant surface temperature differences were 21 °C in concrete and 25 °C in the warning pad.
Thank You

Thank you for your attention. This is part of my PhD dissertation research, and as part of this collaborative project, I will continue to collect surveys from streetcar users and conduct interviews with my stakeholders. If you have any additional questions, please contact me by email at: sami@email.arizona.edu.
Montana Eck
Ph.D. Candidate, University of North Carolina at Chapel Hill
@moaleck

How a Changing Climate Is Influencing Car Crash Risk in the Carolinas
How a Changing Climate is Influencing Car Crash Risk in the Carolinas

Montana A. Eck
Car Crashes a Concern in a Changing Climate

• **~23% of the average six million** annual U.S. car crashes are linked to adverse weather
  • Majority of which are attributed to rain or wet pavement in crash reports

• Increase in the frequency of **heavy rain events** has led to more severe and fatal car crashes
  • Response-time to assist those in crashes is also delayed significantly during heavy rain

• Despite improvements to car and driver safety in recent years, car crashes rank as **leading cause of death** for age groups under 35

<table>
<thead>
<tr>
<th>Road Weather Conditions</th>
<th>10 Year Average (2007 - 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Pavement</td>
<td>360,286 crashes</td>
</tr>
<tr>
<td></td>
<td>324,394 persons injured</td>
</tr>
<tr>
<td></td>
<td>4,050 persons killed</td>
</tr>
<tr>
<td>Rain</td>
<td>556,151 crashes</td>
</tr>
<tr>
<td></td>
<td>212,647 persons injured</td>
</tr>
<tr>
<td></td>
<td>2,473 persons killed</td>
</tr>
<tr>
<td>Snow/Sleet</td>
<td>219,942 crashes</td>
</tr>
<tr>
<td></td>
<td>54,839 persons injured</td>
</tr>
<tr>
<td></td>
<td>688 persons killed</td>
</tr>
<tr>
<td>Icy Pavement</td>
<td>156,164 crashes</td>
</tr>
<tr>
<td></td>
<td>41,860 persons injured</td>
</tr>
<tr>
<td></td>
<td>521 persons killed</td>
</tr>
</tbody>
</table>
Connecting Climate Research with the NCDOT

• SERCC and Carolinas Integrated Sciences and Assessment started collaborative project with NCDOT in 2018

• Preliminary comparisons were made between accidents and the weather conditions listed in police reports
  • Common Issues:
    • Conflicting weather conditions reported
    • Winter weather being present in the summer months

• Spatial variation in accidents highlighted the need for a more detailed regional analysis
  • Rain and snow can be spatially varied in the state. Important to compare across our unique geographic regions.
## Top 10 Statewide Accident Days

<table>
<thead>
<tr>
<th>Rank</th>
<th>Date</th>
<th>Number of Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>December 16, 2010</td>
<td>2690</td>
</tr>
<tr>
<td>2</td>
<td>January 25, 2013</td>
<td>2645</td>
</tr>
<tr>
<td>3</td>
<td>February 15, 2016</td>
<td>2444</td>
</tr>
<tr>
<td>4</td>
<td>December 8, 2017</td>
<td>2364</td>
</tr>
<tr>
<td>5</td>
<td>February 24, 2015</td>
<td>2335</td>
</tr>
<tr>
<td>6</td>
<td>January 23, 2003</td>
<td>2220</td>
</tr>
<tr>
<td>7</td>
<td>January 25, 2004</td>
<td>2011</td>
</tr>
<tr>
<td>8</td>
<td>January 28, 2014</td>
<td>1915</td>
</tr>
<tr>
<td>9</td>
<td>December 18, 2009</td>
<td>1862</td>
</tr>
<tr>
<td>10</td>
<td>January 17, 2018</td>
<td>1842</td>
</tr>
</tbody>
</table>
Accounting for NCDOT Needs

• NCDOT understands the public concern and high numbers of accidents during winter weather but view rainfall as a more consistent threat to public safety
  • Considerable attention needs to be given to the rate and duration rather than just total precipitation

• NCDOT desires to understand how patterns of crashes in rural and suburban areas differ from the highly trafficked urban interstates

• Ultimate goal for the DOT is to pinpoint counties, towns, and roadways which experience a disproportionate number of crashes during a rain event
  • Viewed as a means for helping lower the number of fatal accidents on isolated roadways
Research on the Weather-Accident Relationship

- Research has relied heavily on the relative accident risk (RAR)
  - Number of crashes for hours with precip divided by crashes with no precip across matched pairs

- The effect of precipitation on crashes is frequently underestimated as many studies rely only on concurrent weather information

- Rainfall may have a lagged protective effect
  - Ex: Change in driver behavior after heavy rain event

- Use of weather station observations for analysis can introduce significant error as precipitation varies on small temporal and spatial scales
Rainfall Increases Risk and Influences Behavior

- 46% of all weather-related fatalities occur during active rainfall and **78% of all weather-related injuries** occur on wet pavement

- **Traffic volume decreases** proportional to the intensity of precipitation

- Perception of hazard risk can also influence the likelihood of individual-level driver behavior
  - Ex: Increased driving distance and decreased speed

- By not accounting for changes to traffic volume and driver behavior in the methods there is a chance of **misrepresentative risk estimates**

Liu, 2013
Severe Crash Outcomes More Frequent in Rural Areas

Rural roads experience a **2.6 times higher rate of fatal crashes** than those designated as urban. Lack of public transportation and **necessity for car usage** puts drivers in rural areas on the road for longer periods of time. Individual-level **safety measures** are less likely to be **taken** on rural roads during inclement weather.
Research Questions

1. What are the spatiotemporal patterns of precipitation-related car crash risk in the Carolinas?

2. How do precipitation characteristics such as duration, intensity, frequency, and time between precipitation events influence relative crash risk?

3. How does crash risk differ across the rural-urban gradient in the Carolinas and does this relative risk vary across physiographic regions?
Car Crash Data

- NCDOT and SCDPS maintain statewide crash databases that compile individual police-filed crash reports in each state
  - NCDOT Data (2003-2019)
  - SCDPS Data (2003-2019)

- Reportable motor vehicle crash must meet at least one of the following criteria
  - Results in a fatality, Non-fatal injury, or Property Damage > $1,000

- Crash reports do have reporting errors but remain the most robust dataset for estimating crash frequency and risk
  - Disregarding report-indicated weather condition and road condition

- Data allows for crashes to be aggregated by geographic location and time-of-day

Example segment of the North Carolina Crash Report Form (DMV-349)
Precipitation Data

• Hourly-gridded and daily precipitation data were collected from the NCEP Multi-Sensor Precipitation Estimates (MPE) dataset from 2003-2019
  • Blend of radar estimates and station gauge observations

• Resolution of the data helps overcome limitations of station-based research and is known for **high performance of capturing high rainfall rates**

• ERA-Interim reanalysis temperature data will be incorporated to remove help **remove potential winter-weather related contamination** of risk calculation
  • Improves upon previous research that limited analysis to “warm season” crashes
Rurality: An Elusive Concept in Crash Research

• The U.S. Census Bureau carefully defines urban areas through a set of pre-determined measures but simply designates rural as that which is not urban

• Black et al. (2017) attempts to overcome this problem by designating counties as urban or rural based on population density (50,000+ = urban)
  - Rural counties were divided into two distinct categories based on the presence of an interstate

• Lack of public transportation and distance to work/necessities requires drivers from rural areas to be on the road for longer periods of time

• N. Carolina is home to the 2nd largest rural population in the U.S.
Defining Rurality for this Project

- Building off Waldorff (2006) *Index of Relative Rurality* which provides a continuous multidimensional measure of rurality that moves beyond the assignment of a binary (Rural v. Urban)

- Index will place counties on a scale that allows for the designation of sub-urban, peri-urban, semi-rural, and isolated communities

- Logarithmic transformations for population size and density corrects for their skewed distributions

- **Geographic focus:**
  - Local scale: Rural/urban designation should be relative to each state/neighborhood state rather than across the whole United States
Applying Relative Rurality to the Carolinas

Most Isolated
Methods

- Matched-Pair design allows for analysis of precipitation-crash risk across unique time-steps
  - Matched with control days that occurred exactly one week prior to or following the identified event
- Odds ratio was calculated to represent the relative risk of a crash on an event day to the odds of a crash on a control day
  - Values greater than 1 indicate an increased risk of crash during a precipitation day
- Compared relative crash risk across the rural-urban spectrum using the Index of Relative Rurality
  - Considers more than population and goes beyond the traditional census definition of “rural”

\[ OR_i = \frac{(A_i/C)}{(B_i/D)} \]

- March 5th: 0.38"
- March 12th: 0.65"
- March 19th: 0.0"

Event

Precipitation
Event Crashes

Number of Safe Outcomes

Event-Match (Dry Period)
Comparing Risk Across the Rural Urban Index

- Highly developed and isolated counties in North Carolina have **much lower relative risk** of weather-related crashes.

- Important to consider how many rural and intermediary counties consist of residents that **commute greater distances** for work and leisure activities.

- North Carolina is home to the **2nd largest rural population** with an average 44.5 miles of commuting a day.

<table>
<thead>
<tr>
<th>Category</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban</td>
<td>1.14</td>
</tr>
<tr>
<td>Suburban</td>
<td>1.26</td>
</tr>
<tr>
<td><strong>Intermediary</strong></td>
<td><strong>1.40</strong></td>
</tr>
<tr>
<td>Rural</td>
<td>1.30</td>
</tr>
<tr>
<td>Isolated</td>
<td>0.95</td>
</tr>
</tbody>
</table>
Next Steps: Precipitation Characteristics

**Duration & Intensity**

- Investigate differences in car crashes relative to the rate and duration of weather events
  - Thunderstorm vs. Multi-Day Event

- Compare precipitation crash rates across accumulation thresholds
  - Minor Event (<.05”) vs. Major Event (2+”)

- Analyze differences in relative accident rates by time of day with precip
  - Rush Hour, Lunch Break
  - Weekend vs. Weekday
Applying the Results of the Work

- Despite no trend in annual precipitation totals, the Carolinas have experienced a significant increase in extreme rainfall events over the last 50 years.
  - 2018 set statewide records in North Carolina for wettest day, month, and year

- Results from analyses will be shared with the NCDOT and SCDPS in the hopes that they will be able to address areas where precipitation-related crash risk is significantly high
  - Ex: Variable speed limit road signage

- Data and visualizations will be incorporated into the Hazardous Extremes Risk Assessment Toolkit at SERCC/CISA

- Precipitation data and methodological routine will be used for future research on other climate-impact related research in the southeastern U.S.
Brian Yueshuai He
Postdoctoral Researcher, UCLA

Travel Behavior and Emission Analysis in the Era of CAV
Agenda

1. Background
2. State of the Art & Practice
3. Methodology
4. Research Findings
5. Conclusion
Background

Connected and Automated Vehicle (CAV)

- Connected Vehicles are vehicles that can communicate with other vehicles, infrastructure and devices.
- Automated Vehicles are vehicles that can operate with little to no human assistance.

Big Moves in the CAV Industry and Governments/Agencies

- Waymo officially started its commercial self-driving-car service in the suburbs of Phoenix in 2018. Other companies also include Argo AI, Cruise, and self-driving trucks from TuSimple, etc.
- The U.S. DOT issued Federal Automated Vehicles Policy in September 2016, and as of spring 2019, 44 states have proposed, and 30 states have enacted legislation pertaining to autonomous vehicles.
State of the Art & Practice

Transportation Demand Forecasting in CAV Era
- Impacts of intra-household shared CAV on ABM in the Chicago sub-area – Xu et al (2019)
- Incorporating features of CAVs in ABM for Columbus, OH – Vyas et al (2019)

Research Gaps
- Short of CAV related data or CAV preference data
- Unable to capture impacts on activity generation
- Not applicable for large scale models

Problem Statement
Our research aims to explore the changing trend of travel demand and traffic emission in the era of CAV.
State of the Art & Practice

This research is part of our ongoing project: “Developing Planning-level Analysis Tools for Connected Automated Vehicle Technologies and Services”, which is funded by the California Statewide Transportation Research Program (SB 1) Program. The project aims to investigate the changing trend in people’s travel behaviors and travel demand with the implementation of CAV and develop planning-level analysis tools based on existing models to support CAV-related decision-making for MPOs and other public agencies.

Contributions

• Collected people’s intent to use CAV in Southern California, and their activity-related preferences
• Incorporated behavior changes in the SCAG ABM framework, from long term to short term
  • Work arrangement
  • Location choice
  • Activity frequency
  • Mode choice
• Estimated the changes in VMT and GHG emissions across the SCAG area
Methodology

We adopted an activity-based approach which incorporates CAV features from long-term choice to short-term choice.

- **Long-term:**
  - Work arrangement
    - Weekly work duration
    - Workplace location type
    - Number of jobs
  - Location choice
  - School escort

- **Medium-term:**
  - Activity frequency
    - Mandatory activity,
    - Non-mandatory activity
  - Location choice
  - School escort

- **Short-term:**
  - Mode choice

Diagrams:

- Synthetic population
  - Will this household use AV for travel?
    - Yes
      - AV survey data
      - AV-incorporated ABM
      - New travel demand
      - Road and transit network
      - Estimation of traffic emission
    - No
      - SCAG ABM

References:

UCLA Institute of Transportation Studies
Methodology

SCAG ABM

• Activity-based travel demand model developed by SCAG, covering six counties in southern California
• One of the largest ABM in the world
• Detailed demographic and socio-economic information
• Addressed both household-level and person-level travel choices with the consideration of intrahousehold interactions

CAV-incorporated ABM

• Developed upon SCAG ABM framework
• Re-calibrate existing sub-models and develop new sub-models with new CAV preference data
• Incorporated both personal-owned and shared CAV in the mode choice model
Methodology

Data Collection

An online Stated Preference survey was designed and distributed to collect people’s intent to use CAV in their daily travels and activity-related changes due to CAV.

- Two-stage survey
  - CAV choice: ask questions about people’s intent to use CAV and their demographic information, 687 valid responses collected
  - Activity choice: for CAV users only, ask questions about changes in their daily activity choices, 675 valid responses collected

- Multiple control attributes
  - Household size/income/number of vehicles
  - Personal age/education attainment/work status

<table>
<thead>
<tr>
<th>Age</th>
<th>Quota</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>16~17</td>
<td>4.9%</td>
<td>2.9%</td>
</tr>
<tr>
<td>18~24</td>
<td>14.3%</td>
<td>14.3%</td>
</tr>
<tr>
<td>25~39</td>
<td>37.0%</td>
<td>34.4%</td>
</tr>
<tr>
<td>40~64</td>
<td>29.9%</td>
<td>30.1%</td>
</tr>
<tr>
<td>65+</td>
<td>14.0%</td>
<td>18.3%</td>
</tr>
</tbody>
</table>
Research Findings

Survey results

• At the first stage, about 54% of people choose to use CAV for their daily travel, which is close to the result (52%) of the 2017 California Vehicle Survey. The data collected from the second stage were used to re-calibrate/develop activity-related sub-models.
Research Findings

CHANGES IN WORK ARRANGEMENT

Distribution of work arrangement type

Lookup table of work arrangement type

<table>
<thead>
<tr>
<th>ID</th>
<th>Work Duration</th>
<th>Workplace Type</th>
<th>Number of Jobs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Short</td>
<td>Fixed</td>
<td>One</td>
</tr>
<tr>
<td>2</td>
<td>Short</td>
<td>Fixed</td>
<td>Multiple</td>
</tr>
<tr>
<td>3</td>
<td>Short</td>
<td>Home</td>
<td>One</td>
</tr>
<tr>
<td>4</td>
<td>Short</td>
<td>Home</td>
<td>Multiple</td>
</tr>
<tr>
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<td>Short</td>
<td>Variable</td>
<td>One</td>
</tr>
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<tr>
<td>7</td>
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</tr>
<tr>
<td>8</td>
<td>Medium</td>
<td>Fixed</td>
<td>Multiple</td>
</tr>
<tr>
<td>9</td>
<td>Medium</td>
<td>Home</td>
<td>One</td>
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<tr>
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</tr>
<tr>
<td>18</td>
<td>Long</td>
<td>Variable</td>
<td>Multiple</td>
</tr>
</tbody>
</table>
Research Findings

CHANGES IN WORK LOCATION CHOICE

In SCAG model, the candidates of work location choice model are determined by a sample-by-importance approach. The utility of a candidate TAZ is:

\[ V_{ij} = -\beta_1 \cdot d_{ij} - \beta_2 \cdot d_{ij}^2 + \ln(S_j) \]

where \( S_j \) is the number of employment at the workplace TAZ. At most 30 TAZs can be selected for each worker.

In the CAV-incorporated model, we calibrated the \( \beta_1 \) and \( \beta_2 \) with the consideration of additional travel time accepted by CAV users.

Average home-work distance changed from 16.47 miles to 21.71 miles.
Research Findings

CHANGES IN ACTIVITY FREQUENCY

Distribution of work frequency/order type

Work frequency and order type explanation
• “W” represents for Work activity, which refers to usual work activity.
• “B” means Business activity, which indicates short and flexible business activity, e.g., business meeting.

Lookup table of work frequency/order type

<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>ID</th>
<th>Type</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>B</td>
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<td>6</td>
<td>WW</td>
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<tr>
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<td>W</td>
<td>7</td>
<td>WWB</td>
</tr>
<tr>
<td>4</td>
<td>WB</td>
<td>8</td>
<td>WWBB</td>
</tr>
</tbody>
</table>

The number of work trips increased from 20.5M to 23.5M when CAV is available.
Non-mandatory activity is categorized as household maintenance activity and individual discretionary activity under the SCAG ABM framework.

Under the household maintenance activity, there are three sub-categories: grocery shopping (“S”), household errand (note as “M”), and escort (“E”).

<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>ID</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>S</td>
</tr>
<tr>
<td>2</td>
<td>E</td>
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<tr>
<td>4</td>
<td>ME</td>
<td>8</td>
<td>SME</td>
</tr>
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</table>

The number of household maintenance trips increased from 15.3M to 16.9M when CAV is available.
Research Findings

CHANGES IN ACTIVITY FREQUENCY

Distribution of discretionary activity type

Under the individual discretionary activity, there are 3 sub-categories: visit (“V”), discretionary (“D”), and individual maintenance (“M”).

Lookup table of discretionary activity type

<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>ID</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>5</td>
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<td>2</td>
<td>M</td>
<td>6</td>
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<tr>
<td>3</td>
<td>D</td>
<td>7</td>
<td>VD</td>
</tr>
<tr>
<td>4</td>
<td>DM</td>
<td>8</td>
<td>VDM</td>
</tr>
</tbody>
</table>

The number of individual discretionary trips increased from 18.0M to 20.4M when CAV is available.
Research Findings

CHANGES IN MODE CHOICE

Comparison of Mode Choice

<table>
<thead>
<tr>
<th>Mode</th>
<th>SCAG</th>
<th>SCAG_CAV</th>
<th>Change in %</th>
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</thead>
<tbody>
<tr>
<td>SOV Driver</td>
<td>28938995</td>
<td>29604931</td>
<td>+2%</td>
</tr>
<tr>
<td>HOV Driver + Passenger</td>
<td>33380974</td>
<td>25515985</td>
<td>-24%</td>
</tr>
<tr>
<td>Taxi</td>
<td>560894</td>
<td>607587</td>
<td>+8%</td>
</tr>
<tr>
<td>Transit, walk access</td>
<td>1143218</td>
<td>4695632</td>
<td>+311%</td>
</tr>
<tr>
<td>Transit, drive access</td>
<td>119466</td>
<td>220067</td>
<td>+84%</td>
</tr>
<tr>
<td>Walk</td>
<td>5182693</td>
<td>5015013</td>
<td>-3%</td>
</tr>
<tr>
<td>Bike</td>
<td>861157</td>
<td>651143</td>
<td>-24%</td>
</tr>
<tr>
<td>School bus</td>
<td>850162</td>
<td>903878</td>
<td>+6%</td>
</tr>
<tr>
<td>PAV</td>
<td>N/A</td>
<td>7863047</td>
<td>N/A</td>
</tr>
<tr>
<td>SAV</td>
<td>N/A</td>
<td>3129376</td>
<td>N/A</td>
</tr>
<tr>
<td>Total</td>
<td>71037559</td>
<td>78206659</td>
<td>+10%</td>
</tr>
</tbody>
</table>

PAV and SAV take about 14.1% of total trips.
Research Findings

**DEPARTURE TIME ADJUSTMENT**

Eliminate 50% of Maintenance and Discretionary tours during nighttime.

Distribution of trip departure time

Increase rate of trip departure time
Research Findings

<table>
<thead>
<tr>
<th>Trip Purpose</th>
<th>SCAG</th>
<th>SCAG_CAV</th>
<th>Change in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work</td>
<td>20,533,312</td>
<td>23,641,137</td>
<td>+15%</td>
</tr>
<tr>
<td>Household Maintenance</td>
<td>15,262,859</td>
<td>14,858,406</td>
<td>-3%</td>
</tr>
<tr>
<td>Discretionary</td>
<td>18,005,284</td>
<td>18,693,853</td>
<td>+4%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Changes in Total VMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Changes in Work-Home Distance (mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg. Distance</td>
</tr>
</tbody>
</table>
Research Findings

• We adopted the Emission Factors (EMFAC) model to calculate the transportation emission
• Calculated the running exhaust emissions from passenger cars using gasoline
Conclusion

- According our survey, only half (54%) of the population is willing to adopt CAV for travel.
- When CAV is available, people’s travel behaviors changed significantly:
  - More flexible work arrangement is preferred.
  - Longer home-work distance is accepted.
  - More business/non-mandatory trips are expected.
  - SOV trips are more likely to shift to CAV.
- The total number of trips increased by 4.9% and the VMT increased by 22% after the CAV implementation.
- GHG emissions increased significantly in sub-urban area.
Acknowledgement

This research is funded by the California Statewide Transportation Research Program (SB 1) Program. The model development is supported by the Southern California Association of Governments.
Thank You

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Emerging Research on Financial Adaptations to Climate Impacts
Wading into the Economic Impacts of Climate Change on Water
Equitable Adaptation to Climate-Related Flood Risks: Part 2
Thanks for tuning in!