Analysis of Tipping Points in Connected and Automated Vehicle (CAV) Adoption Scenarios

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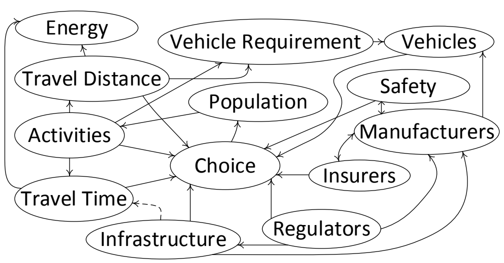
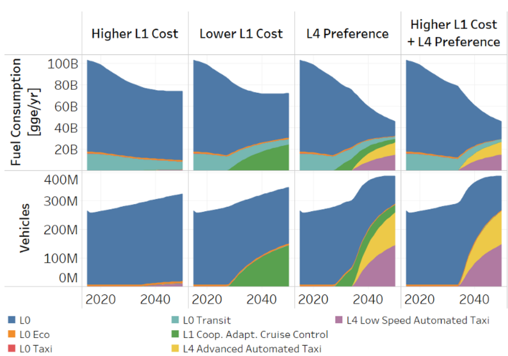
Objectives: Explore transitions to large-scale CAV adoption

- *Identify tipping points to large-scale adoption*
- *Understand sensitivity of adoption to key factors*
- *Examine technological, economic, demographic, and regulatory issues*
- *Highlight relevant data and data needs*
- *Explore effects of policy through scenario analysis*

Analytical Methods: The CAV tipping point model includes a broad range of stakeholders

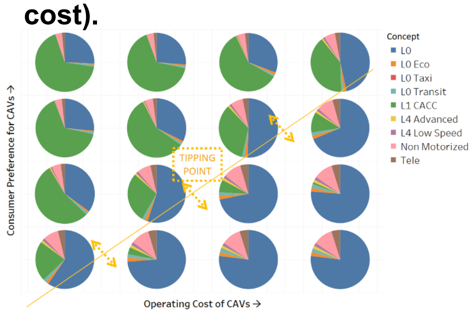


High-level structure of the CAV Tipping Point Model, where the arrows represent influences and feedbacks between sectors or stakeholders. (Source: NREL)

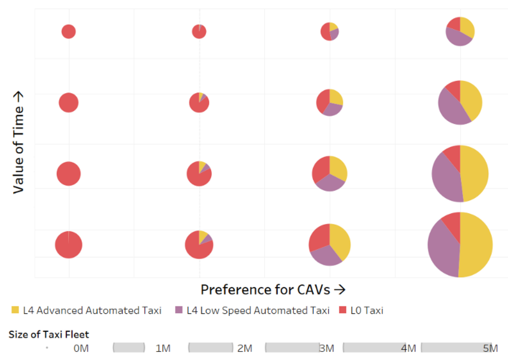


Comparison of simulations with higher and lower L1 costs and behavioral preference for L4 vehicles: The figure shows regimes with (from left) little CAV adoption, L1 adoption, both L1 and L4 adoption, and L4 adoption. Fuel consumption without CAVs reflects vehicle efficiency improvements. The figure illustrates capabilities to explore different end states. (Source: NREL)

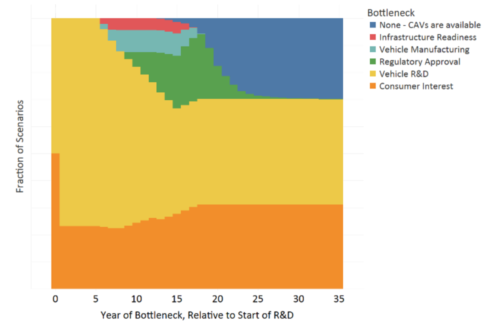
The results show different outcomes for CAV adoption and system-wide fuel use, given behavioral parameters such as consumer preferences (e.g., value of time) and financial parameters (e.g., operating cost).



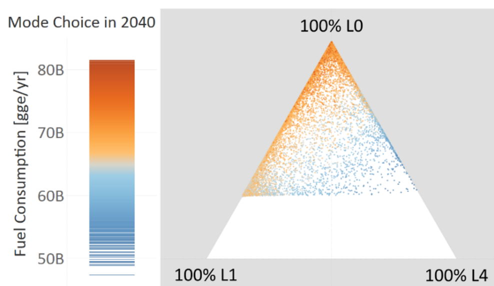
Sensitivity analysis of fuel consumption by concept type nationally in 2040 as a function of the operating cost for L1 and L4 CAV technologies and consumer preference for using CAVs. These results show a rapid separation of end states dominated by CAVs (left and top sides of figure) versus end states where CAVs play a minor role (right bottom corner of figure). This highlights the need for quantitative understandings of both consumer preferences and also operating costs for CAV technologies. (Source: NREL)



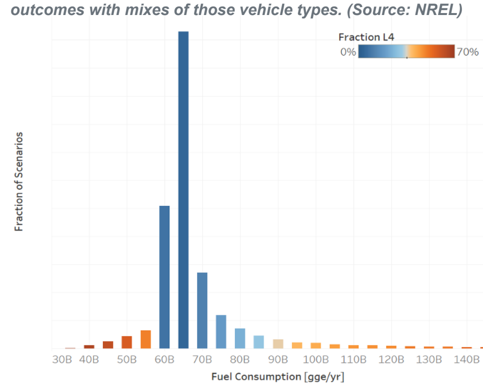
Sensitivity analysis of size of taxi fleet as a function of consumers' preference for using CAVs and the value consumers place on their time: These results suggest the possibility that the overall taxi or ride-source vehicle fleets may increase in scenarios where consumers show a substantial preference for the use of automated taxis (right side of figure), provided that such taxis are not disadvantaging in terms of travel time relative to non-taxis. (Source: NREL)



Summary of the frequency of different bottlenecks to CAV adoption among the scenarios. (Source: NREL)



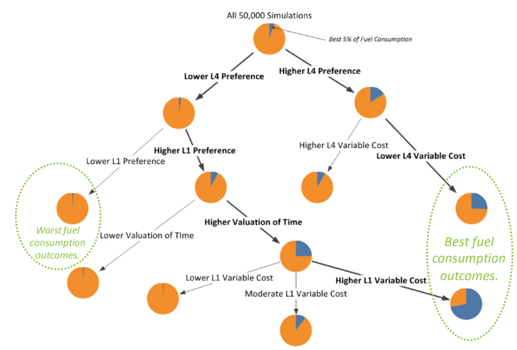
Fuel consumption outcomes for scenarios in the screening study. Each corner of the triangle represents a "pure" L0, L1, or L4 vehicle fleet and points in between those corners represent outcomes with mixes of those vehicle types. (Source: NREL)



Distribution of energy outcomes for scenarios, distinguished by the predominance of L4 CAVs in the scenarios. (Source: NREL)

Conclusions: The dynamic interplay of factors (e.g., stakeholder environment, costs, vehicle preferences, and freed time) contributes to large-scale CAV adoption scenarios.

- *Interaction and time delays of "stage gates" can summarize CAV scenario complexity.*
- *Synergies between technology pathways, CAV concepts, and adoption behavior lead to multiple potential end states.*
- *Freed time from driving appears to be a compelling CAV advantage.*
- *Long-term energy outcomes of various CAV scenarios differ by half an order of magnitude, contingent on deadhead miles, vehicle occupancy, and drivetrain variation.*



Regression tree showing major influences on energy consumption. Each pie chart shows the fraction of results that lie in the best 5% of fuel consumption, within simulations selected by the preceding branching criterion. (Source: NREL)

Future Work: Extension to commercial delivery, application at an urban regional scale, and data enhancements are expected to improve understanding of tipping points for transition to large-scale CAV adoption.

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