Stepping Stone or Stumbling Block? How Partial Driving Automation Shapes the Transition to Higher Automation

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Abstract

Industry roadmaps treat partial driving automation (SAE Level 2) as a stepping stone toward Level 4 and 5 vehicles, yet public trust in self-driving vehicles stayed flat while Level 2 fitment grew fastest. This study asks under what conditions the diffusion of partial automation accelerates, leaves unchanged or delays private owners' transition to higher automation. A system dynamics model makes trust in higher automation endogenous: built by transfer from owners' experience, eroded by socially amplified incidents, conditioned by calibrated understanding and complacency, and converted into upgrades through mooring factors and fleet turnover. The structure draws on 194 studies, is calibrated on United States data (2015 to 2025) and transferred to Indonesia. Three regimes emerge (stepping stone, decoupled, stumbling block); both base cases are decoupled. The learning-curve exponent on incidents is the most influential and least identified uncertainty; under calibrated United States conditions Level 2 diffusion lowers trust in four of five futures. Incident transparency with exposure context and continuity design raise trust in every sampled future, and together the four levers advance Indonesian take-off by about five years and double the Level 4 and 5 fleet share in 2060.

Keywords: automated vehicles; trust; technology diffusion; system dynamics; Indonesia

Introduction

Level 2 systems such as adaptive cruise control with lane centering were fitted to under 1 percent of model year 2015 vehicles in the United States and to 54 percent of model year 2023 vehicles. Over the same decade the share of drivers who would trust riding in a self-driving vehicle stayed between 9 and 15 percent, with falls after the prominent crashes of 2018 and 2023. Owners of Level 2 systems do report higher intentions toward higher automation, but the measured effects are small, sometimes absent and occasionally negative.

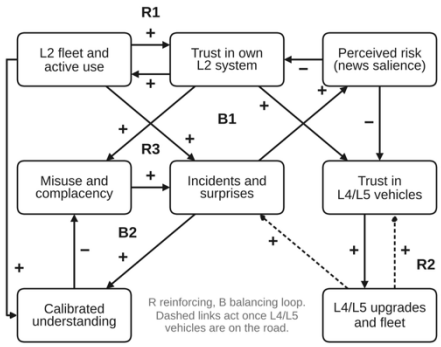
Existing diffusion and system dynamics models of vehicle automation take acceptance as exogenous or let it depend only on the automated fleet itself. None lets the installed base of partial automation shape trust in the next level, although that is the mechanism on which the stepping-stone narrative relies. The question is immediate for Indonesia, where Level 2 is arriving late and fast and the vehicle fleet is projected to nearly triple by 2060.

RQ1: under which conditions does Level 2 diffusion accelerate (stepping stone), leave unchanged (decoupled) or delay (stumbling block) the transition to Level 4 and 5 among private owners? **RQ2:** which feedback loops dominate in each regime, and which observable signature identifies it? **RQ3:** which strategies and policies are robust under deep uncertainty, in a mature market (United States) and in an emerging one (Indonesia), where Level 2 arrives late and fast?

The contribution is a feedback theory of the transition in which trust is endogenous, formalised in a model that is calibrated on secondary data, tested for identifiability and explored across thousands of plausible futures.

Research Method

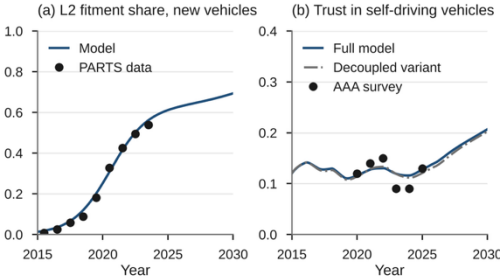
The study proceeds in three stages: (1) 194 empirical studies on trust, acceptance, misuse and the social amplification of incidents were coded into a causal map with graded evidence (Picture 1); (2) the map was formalised as a system dynamics model with 11 stocks covering the fleet (unautomated, Level 2, Level 4 and 5), experience, trust in the owner's own system, trust in higher automation among experienced and other owners, perceived risk, understanding, complacency and willingness to consider; (3) the model was calibrated, validated and explored under deep uncertainty.



Picture 1. Dynamic hypothesis: the five feedback loops of the model.

Data and calibration. United States reference modes, 2015 to 2025: lane centering fitment by model year (PARTS), trust in self-driving vehicles (AAA surveys), Level 2 crash reports (NHTSA Standing General Order), the owner trust gap and the 2018 fall in trust. Parameters were estimated by differential evolution; fit was assessed with Theil statistics, identifiability with profile likelihoods and structure with nested variants (Picture 2). Indonesia was parameterised from national fleet, survey and market data (Level 4 available from 2035).

Exploratory modelling. 3,000 Indonesian and 1,500 United States futures (21 uncertain parameters) were run to 2070 and classified against a decoupled counterfactual without the transfer and local-incident channels: stepping stone, decoupled, stumbling block or stalled. PRIM scenario discovery identified the conditions behind each regime; seven policies were tested across 800 futures.



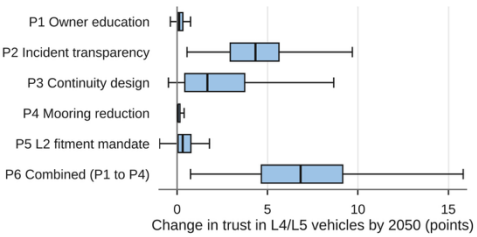
Picture 2. Calibration to United States data: (a) Level 2 fitment of new vehicles; (b) trust in self-driving vehicles, full model and decoupled variant.

Discussion & Result

Calibration. The model reproduces the rise of Level 2 fitment (RMSE 0.017, r = 0.997), the timing of the trust series (rise to 2022, dip 2023, recovery 2025), crash reports within 5 percent, the owner trust gap (0.072 against 0.075 observed) and the 2018 fall in trust (13 against 12 percent). A decoupled variant fits the trust series equally well but cannot produce the owner gap, which therefore identifies the structure.

Regimes. Both base cases are decoupled: the Level 2 installed base moves Level 4 take-off by less than a year, because transferred trust is offset by incident erosion. A stepping stone requires transfer of at least 0.37 per year, continuity of at least 0.44 and a learning exponent of at least 0.37; a stumbling block arises where local incidents are salient, the environment is demanding and learning is slow. The learning exponent is the most influential and least identified uncertainty. In trust terms, 48 percent of Indonesian futures and 84 percent of United States futures are stumbling blocks.

Policies. Incident transparency with exposure context raises trust in every future (mean +4.4 points); continuity design advances take-off by 3.1 years; a fitment mandate without education raises crashes by 28 percent for a gain of nine months. Together, the four behavioural levers advance Indonesian take-off by 5.4 years and double the 2060 fleet share (Picture 3).



Picture 3. Change in trust in Level 4 and 5 vehicles by 2050 under each policy, 800 Indonesian futures (boxes: interquartile range).

Conclusion

The Level 2 installed base is neither the stepping stone of the industrial narrative nor an obstacle by nature: its effect is decided by a race between learning and exposure, moderated by perceived continuity and by owners' calibrated understanding.

Manufacturers: continuity design, a visible pathway from the Level 2 system to the Level 4 product, paired with owner education at handover, lets earned trust travel; the owner trust gap is a leading indicator measurable in customer surveys.

Regulators: crash reporting with exposure context is the most robust trust lever; a fitment mandate pays off only with handover standards and licensing content.

Indonesia: the late and fast arrival of Level 2 is an opportunity if local design, a regulated handover and exposure-based reporting precede the first prominent automation crash. The Level 2 decade shapes the Level 4 market with ten years of lead time.