Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/GC03.20260328
Published: February 2, 2026

Designing Trust: A Human-Centered Communication Model for Autonomous Vehicle Adoption in Saudi Arabia

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Abstract

Public trust remains a critical determinant of autonomous vehicle (AV) adoption. Although technological reliability has improved significantly, human hesitation persists due to limited understanding, perceived risks, and the absence of human-like communication. This study develops a conceptual framework—the Trust Communication Model (TCM)—to guide the design of human-centered communication strategies for building public trust in AVs within the Saudi Arabian context. The model integrates four interconnected layers: (1) system transparency, (2) behavioral predictability, (3) human feedback and awareness, and (4) institutional support. Each layer emphasizes the importance of clear, culturally resonant communication that reflects local social norms and values. The paper situates the framework within the principles of human-centered design (HCD), trust in automation, and Vision 2030's mobility transformation agenda. By embedding human-centered communication into AV design and governance, Saudi Arabia can accelerate public acceptance of autonomous mobility while ensuring safety, inclusivity, and cultural alignment.

Keywords
Autonomous vehicles, Trust, Human-centered design, Communication, Saudi Arabia

1. Introduction
The transition toward autonomous mobility represents one of the most transformative shifts in modern transportation history. Autonomous vehicles promise safer, more efficient, and more sustainable transport systems by reducing human error—the leading cause of road crashes worldwide (Anderson et al., 2016). However, despite rapid advances in artificial intelligence, sensing, and automation technologies, the public's trust in these systems remains limited. Many potential users express hesitation to share the road with or ride in autonomous vehicles due to uncertainty about how these systems perceive their surroundings, make decisions, and ensure safety. The challenge is therefore not only technical but deeply human-centered, revolving around communication, transparency, and perceived reliability.

Trust plays a decisive role in determining whether people will accept and adopt emerging technologies (Lee and See, 2004). Research in human factors and human–automation interaction shows that trust is built when systems behave predictably, communicate transparently, and align with users' expectations and values. In the context of AVs, where traditional cues such as driver eye contact, gestures, or verbal reassurance are absent, effective human–machine communication becomes essential. External Human–Machine Interfaces (eHMIs), auditory signals, and visual feedback are increasingly used to communicate vehicle intentions, yet most designs focus on functionality rather than user psychology or cultural interpretation (Mahadevan et al., 2018; Habibovic et al., 2018). As a result, users often perceive AVs as opaque, unpredictable, or socially detached.

While global studies have investigated the role of communication techniques, such as eHMIs, in enhancing pedestrian understanding and trust, most research has been conducted in Western cultural settings (Alhawiti et al., 2024; Dey et al., 2020). These studies collectively demonstrate that clear visual and auditory cues can improve predictability and reduce hesitation during human–AV interactions. However, the cultural dimension of trust remains underexplored. Communication styles, color meanings, language preferences, and social behaviors differ across regions, and these factors can strongly influence how pedestrians interpret AV signals and behaviors. Therefore, as AV technology expands globally, it becomes critical to adapt human-centered communication frameworks to reflect local cultures, languages, and environmental conditions rather than assuming a universal response to automation.

In the Kingdom of Saudi Arabia, the movement toward intelligent mobility is progressing rapidly under the Vision 2030, which prioritizes innovation, sustainability, and human well-being. Mega-projects such as NEOM, The Line, and King Salman Park represent ambitious efforts to integrate autonomous mobility into the national landscape. However, as these technologies are introduced into public spaces, cultural adaptation and human-centered communication become crucial for building public confidence. Factors such as language, local traffic behavior, and social norms shape how users interpret and respond to automated systems. Without clear and trustworthy communication, even technically safe AVs may face public skepticism or resistance.

Given this background, the present study aims to develop a conceptual framework, the Trust Communication Model (TCM), that integrates human-centered communication and cultural adaptation principles to strengthen public trust in autonomous mobility within Saudi Arabia. The TCM identifies four interconnected dimensions: system transparency, behavioral predictability, human feedback and awareness, and institutional support that collectively form a holistic strategy for cultivating trust. By embedding these dimensions into design and policy, the framework offers guidance for creating AV systems that align technological intelligence with human expectations, cultural values, and national goals outlined in Vision 2030.

2. Literature Review

Trust is a foundational element in human–technology interactions, shaping how individuals perceive, adopt, and rely on automated systems. In the context of autonomous mobility, trust determines whether people are willing to ride in, share the road with, or allow autonomous vehicles to operate in public spaces (Lee and See 2004). Unlike conventional driving—where responsibility, situational awareness, and decision-making clearly rest with a human driver—AVs transfer these functions to algorithms and sensors, creating psychological distance between users and the system. Too little trust can lead to disuse or avoidance, while excessive trust may result in unsafe overreliance, where users fail to monitor or intervene when required (Parasuraman and Riley 1997). Thus, the goal of AV design is to achieve calibrated trust, where human confidence appropriately matches the vehicle's reliability and limitations. Empirical research confirms that perceived safety, controllability, and predictability strongly shape public willingness to interact with driverless vehicles (Choi and Ji 2015; Nordhoff et al. 2018). Accordingly, building trust requires not only technological robustness but also transparency and communication that render machine intent intelligible and socially interpretable.

As AVs eliminate the human driver from interaction loops, human-centered communication (HCC) becomes essential to bridge the gap between machine actions and human interpretation. HCC focuses on aligning system behavior and signaling with human cognitive processes and social norms. Communication in AV–pedestrian interaction operates through two complementary channels: implicit cues, such as speed modulation, yielding distance, or vehicle positioning; and explicit cues, including visual displays, light signals, sound cues, or projected messages (Alhawiti et al., 2024). Studies consistently demonstrate that when implicit movement patterns and explicit communication cues are coherent and predictable, pedestrians experience lower uncertainty and higher confidence (Mahadevan et al. 2018; Habibovic et al. 2018; Dey et al. 2020). These findings emphasize that trust emerges not only from AV capability but also from clarity, timing, and consistency of communication.

However, most research on AV communication has been conducted in Western contexts, often implicitly assuming universal interpretation of visual, linguistic, and symbolic cues (Ekman et al. 2017; Habibovic et al., 2018; Rasouli et al., 2019). In reality, cultural frameworks strongly influence how people decode intent and perceive safety. Color associations, gesture meaning, eye contact norms, and language preferences vary across regions, and public confidence increases when technology reflects familiar social behaviors and communication styles. These cultural dimensions are

especially important in emerging AV markets, where public exposure to AVs is still limited and social influence plays a key role in technology acceptance.

Saudi Arabia's Vision 2030 provides a strategic context for the introduction of autonomous mobility, emphasizing innovation, sustainability, and quality of life (Shatnawi et al., 2025). Mega-projects such as NEOM and The Line are positioned as testbeds for advanced transportation technologies, including autonomous systems integrated into the built environment. Cultural attitudes toward technology in the Kingdom are shaped by optimism toward modernization, national pride in innovation, and strong emphasis on family safety and social responsibility. While technological adoption is generally viewed positively, trust in automation will grow only when systems demonstrate transparency, predictability, and alignment with societal values such as safety, respect, and accountability (Hafeez et al., 2024). Environmental conditions including intense sunlight, dust, and multilingual public spaces further highlight the need for context-specific communication strategies. Therefore, designing adaptive communication mechanisms and establishing clear institutional guidelines will be key to cultivating public trust and enabling sustainable, human-centered deployment of AVs in Saudi Arabia.

3. Methods

This study adopts a conceptual synthesis methodology aimed at developing the *Trust Communication Model (TCM)* for autonomous vehicle adoption in Saudi Arabia. Rather than conducting empirical experimentation, the research builds upon established theories of trust in automation, human-centered design, and cultural adaptation to synthesize a new integrative framework. The approach begins with a comprehensive review of existing literature on human–automation trust, human–machine communication, and user acceptance of AVs. The literature reviewed in this study was collected through targeted searches in Scopus, IEEE Xplore, and Google Scholar databases covering publications from 2015 to 2025. Keywords included "autonomous vehicles," "trust in automation," "human-centered design," "external human–machine interface," and "Saudi Arabia." Studies were selected based on relevance to trust formation, communication modalities, and cultural adaptation in AV contexts. Reference lists from key review papers were cross-checked to ensure comprehensive coverage of both global and regional perspectives. In parallel, principles of human-centered design provided the structural basis for incorporating usability, empathy, and inclusivity into AV communication strategies. The next phase involved contextual adaptation, mapping these theoretical dimensions to the Saudi Arabian mobility ecosystem characterized by Vision 2030's emphasis on smart transportation, innovation, and cultural authenticity. This step ensured that the framework would reflect the linguistic, social, and environmental nuances of Saudi society, such as the need for bilingual communication, visual clarity under intense sunlight, and culturally respectful interaction cues. The final stage of the methodology focused on integrating these insights into a cohesive conceptual model comprising four interrelated layers: System Transparency, Behavioral Predictability, Human Feedback and Awareness, and Institutional Support. Each layer represents a distinct yet interconnected component contributing to the development of public trust in AVs. Together, these methodological stages formed a structured, theory-driven foundation for the TCM, which can later be empirically validated through simulation studies, pilot deployments, and user perception assessments within Saudi smart mobility environments. Figure 1 illustrates the interconnection among these four layers, emphasizing that trust emerges from iterative feedback between users, technology, and institutions (Figure 1).

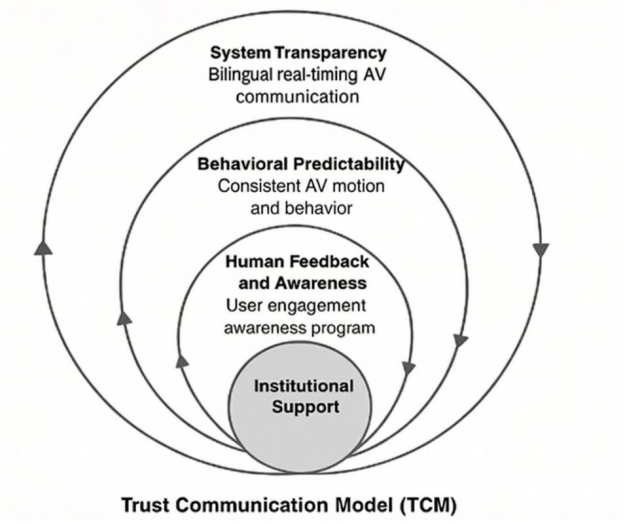

Figure 1. Conceptual structure of the Trust Communication Model (TCM). The model comprises four interrelated layers: System Transparency, Behavioral Predictability, Human Feedback and Awareness, and Institutional Support that interact dynamically to cultivate public trust in autonomous vehicles. Arrows indicate bidirectional feedback between layers, showing how transparency influences predictability, feedback informs institutional learning, and institutional measures reinforce transparency.

The Trust Communication Model (TCM) conceptualizes trust as a dynamic interaction between humans, autonomous systems, and institutions. It identifies four interconnected layers that reinforce one another to cultivate public trust:

Layer 1: System Transparency
Transparency allows users to understand what the AV is doing and why. Effective transparency employs clear visual, auditory, or textual cues to convey system state and intent (e.g., "Yielding to Pedestrian"). For inclusivity, bilingual Arabic–English displays or intuitive symbols should be standardized.
Layer 2: Behavioral Predictability
Predictability ensures consistency between communication and behavior. When an AV's actions such as maintaining a safe stop distance or waiting until pedestrians have crossed—match its signaled intent, users form positive mental models. Predictability can be reinforced through standardized movement patterns and timing cues, especially under varying traffic conditions and illumination typical of Saudi urban environments.
Layer 3: Human Feedback and Awareness
Trust evolves through repeated, positive interaction. Awareness programs, demonstrations, and public trials in controlled settings such as university campuses or innovation districts allow citizens to observe and interact safely with AVs. Feedback channels (mobile apps, online surveys) can capture user reactions, enabling iterative design improvement. Such participatory engagement transforms curiosity into confidence.
Layer 4: Institutional Support
Institutional trust forms the outer boundary of the model. When authorities such as the Ministry of Transport and Logistics Services (MOT), the Saudi Standards, Metrology and Quality Organization (SASO), and the Saudi Data and Artificial Intelligence Authority (SDAIA) establish transparent certification, data governance, and safety protocols, citizens are more likely to accept AVs as trustworthy systems. Public information campaigns should communicate safety performance and ethical guidelines openly to sustain credibility.

Illustrative example:
Consider an autonomous vehicle operating on a Saudi urban road near a university campus. As a pedestrian approaches a marked crosswalk, the AV gradually decelerates and activates a clear external display showing "**تفضل بالعبور** / Please Cross," accompanied by a steady green light band. The vehicle maintains a culturally appropriate stopping distance and remains stationary until the pedestrian fully clears the crossing. This alignment between visual communication and vehicle behavior enhances predictability and reassures pedestrians that the vehicle is aware, respectful, and safe to interact with.

Table 1 summarizes the four layers of the Trust Communication Model (TCM), outlining each layer's core purpose, representative communication mechanisms, and its contribution to building public trust in autonomous vehicles.

Table 1. Summary of the Trust Communication Model (TCM) Layers

TCM Layer	Core Purpose	Example Communication Mechanisms	Trust Contribution
System Transparency	Make AV intentions and system state understandable	Bilingual Arabic–English messages, icons, light signals indicating yielding or stopping	Reduces uncertainty and perceived opacity
Behavioral Predictability	Ensure consistency between signals and vehicle actions	Smooth deceleration, standardized yielding distance, consistent timing	Builds reliability and calibrated trust
Human Feedback and Awareness	Enable learning and familiarity through interaction	Public demonstrations, campus pilots, feedback apps, awareness campaigns	Converts curiosity into confidence
Institutional Support	Establish legitimacy and accountability	Certification, safety standards, public reporting by MOT, SASO, SDAIA	Reinforces long-term societal trust

The four layers interact as a feedback ecosystem. Transparency fosters understanding; predictability builds reliability; feedback nurtures learning; and institutional validation consolidates confidence. A failure in one layer such as inconsistent signaling can undermine overall trust. The model thus promotes an iterative, multi-stakeholder approach to trust cultivation.

4. Discussion and Implications

The proposed Trust Communication Model underscores that public trust in autonomous vehicles cannot be achieved solely through technical advancement but must instead be cultivated through deliberate, human-centered communication strategies embedded within policy, design, research, and public engagement. From a governance perspective, the TCM highlights the critical role of policymaking institutions in shaping public confidence through transparent and enforceable standards. Governmental bodies such as the MOT, the SASO, and the SDAIA can operationalize the TCM by establishing national guidelines that mandate bilingual communication protocols, consistent color codes for external human–machine interfaces, and the inclusion of human-centered design principles in AV testing and certification. The creation of transparent ethical and data-governance frameworks would further assure the public that automation aligns with national safety and privacy values. These policies not only enhance user confidence but also align directly with Saudi Vision 2030's goal of developing an innovative and safe transportation ecosystem.

For the industry, the TCM provides a roadmap for integrating trust-centered design thinking into AV development. Manufacturers and technology firms should adopt human-centered communication as a fundamental design criterion rather than an optional feature. Early implementation of these principles can be achieved through controlled pilot projects in smart mobility zones such as NEOM, The Line, and university campuses where people can observe and interact with AVs in real-world yet safe settings. Incorporating local cultural aesthetics such as color schemes, language, and courteous vehicle behavior can transform AVs from foreign technologies into socially familiar entities. The inclusion of multidisciplinary teams comprising engineers, behavioral scientists, and communication designers is vital to ensure that both technological functionality and cultural empathy are embedded within each system.

From an academic standpoint, Saudi universities are well positioned to lead the empirical exploration of trust in AVs through interdisciplinary collaboration. The TCM invites researchers to bridge transportation engineering with human factors, psychology, and interaction design to better understand how trust evolves across user groups and contexts. Virtual reality simulations, driving simulators, and field trials could be employed to test the effectiveness of communication cues and system behaviors derived from the TCM framework. By developing local expertise and

generating context-specific evidence, academia can provide scientific validation for future policy and design decisions while contributing to global discourse on human-centered automation.

Public engagement also represents a cornerstone of the TCM. Trust is strengthened when citizens feel informed, involved, and respected. Awareness campaigns, educational workshops, and media outreach should be implemented to introduce the public to AV technologies, emphasizing both their benefits and limitations. Open communication regarding challenges such as sensor limitations under weather extremes can paradoxically increase public confidence by demonstrating transparency and accountability. Continuous public feedback loops, where user experiences inform subsequent iterations of AV communication systems, ensure that trust remains dynamic and sustained over time.

Overall, the TCM's integrated approach demonstrates that trust in AVs is not the responsibility of a single sector but the collective outcome of interaction between technology, institutions, and society. Policymakers ensure legitimacy, designers enable understanding, researchers provide evidence, and the public shapes acceptance. Together, these elements form a coherent ecosystem that allows Saudi Arabia to not only achieve its Vision 2030 mobility ambitions but also set an international benchmark for culturally aligned, human-centered autonomous transportation.

6. Conclusion

The evolution of autonomous mobility represents not only a technological milestone but also a profound human and societal transformation. As autonomous vehicles become increasingly capable, their success ultimately depends on the degree of public trust they inspire. This study introduced the Trust Communication Model (TCM) as a human-centered conceptual framework designed to foster trust in AVs through transparent, predictable, and culturally resonant communication strategies. Grounded in established theories of trust in automation and human-centered design, the TCM outlines four interdependent layers: System Transparency, Behavioral Predictability, Human Feedback and Awareness, and Institutional Support that together form a holistic ecosystem of trust. Each layer reinforces the others, creating a continuous cycle of communication and feedback between users, technology, and governance systems. Within the Saudi Arabian context, the TCM aligns directly with Vision 2030, emphasizing innovation, inclusivity, and the cultural localization of emerging technologies.

As a conceptual study, this research is primarily theoretical and does not include empirical validation of the proposed framework. The absence of experimental or survey data limits the ability to quantify the effectiveness of each trust dimension or to assess behavioral differences among diverse user groups. Additionally, the model is developed within the Saudi Arabian socio-cultural context; therefore, its applicability to other cultural or regulatory settings may require contextual adaptation. Environmental variables such as lighting conditions, traffic behavior, and infrastructure readiness, also represent potential sources of variability not addressed in the present framework.

Future research should focus on empirically validating the TCM through both experimental and field-based approaches. Pilot projects in smart mobility environments such as NEOM, The Line, and university campuses can provide valuable data on user perceptions, behavioral responses, and interaction patterns with autonomous systems. Additionally, simulation and virtual reality platforms can be used to test variations in communication modalities, language preferences, and interface designs across diverse demographic groups. Comparative studies across regions can also reveal how cultural differences influence trust formation and communication effectiveness. Ultimately, this model serves as a foundation for a broader discourse on ethical and inclusive automation—one that places human trust, communication, and cultural understanding at the heart of technological progress. By operationalizing these principles, Saudi Arabia has the potential to lead globally in shaping a future where intelligent mobility is not only smart and efficient but profoundly human-centered.

In practical terms, the TCM provides policymakers, engineers, and designers with a structured roadmap for integrating human-centered communication principles into Saudi Arabia's autonomous mobility initiatives. The model emphasizes the need to standardize bilingual (Arabic–English) communication within AV interfaces to ensure inclusivity and clarity for diverse road users. It also highlights the importance of implementing public demonstration projects and continuous feedback programs to enhance transparency and build user familiarity with autonomous systems. Furthermore, establishing national standards for eHMIs and data transparency through organizations such as the SASO and the MOT will foster consistency and accountability across deployments. Finally, the development of measurable trust indicators such as perceived safety, acceptance rates, and public confidence levels can provide evidence-based metrics to guide policy and design decisions. Collectively, these actions will support the responsible

and sustainable deployment of autonomous vehicles that are not only technologically advanced but also socially trusted and culturally resonant within the context of Vision 2030.

Although this study adopts a conceptual synthesis approach, the resulting framework is designed for empirical validation. Future research can test the TCM through virtual-reality pedestrian interaction experiments, user trust questionnaires, and controlled field pilots within smart mobility zones such as NEOM. These studies would enable quantitative evaluation of key trust metrics such as perceived safety, hesitation time, and system predictability, thereby operationalizing and validating the model.

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Biography

Ali Alhawiti is a faculty member in the Department of Civil Engineering at the University of Tabuk, Dr. Ali holds a PhD in Civil Engineering with a specialization in Transportation Engineering. He has extensive experience in teaching and curriculum development in areas such as Traffic Engineering, Highway Design, and Smart Transportation. His

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