

SURFACE VEHICLE TECHNICAL INFORMATION REPORT

J3312™

FEB2025

Issued

2025-02

Artificial Intelligence Use Cases for Ground Vehicle Applications

RATIONALE

This SAE Technical Information Report prepared by SAE Ground Vehicle Artificial Intelligence (AI) Use Cases Task Force outlines the key applications and use cases of AI in ground vehicles and transportation infrastructure. It categorizes AI applications that improve safety, security, and efficiency in various vehicle operations. Examples include emissions control, battery health monitoring, vehicle automation, and advanced driver-assistance systems (ADAS). These AI technologies address challenges such as modeling complex vehicle behaviors, optimizing energy use in electric and hybrid vehicles, and enhancing real-time decision-making in autonomous systems. The report also discusses emerging AI trends, such as federated learning, which improves data security and privacy in connected vehicles, and physics-informed machine learning, which integrates physical principles into AI models for improved accuracy and reliability. Additionally, generative AI is highlighted as a tool for accelerating vehicle design, software development, and in-car personalization, showcasing its potential for revolutionizing the automotive industry. A roadmap for the adoption of these AI technologies includes recommendations for standardization, integration with existing vehicle systems, and addressing challenges like cybersecurity, data privacy, and continuous learning. AI-driven solutions are expected to play a crucial role in the future of vehicle design, operation, and maintenance, leading to more efficient, reliable, and safe ground transportation systems.

1. SCOPE

This SAE Technical Information Report identifies use cases for AI technology applications to ground vehicles and transportation infrastructure. Whenever applicable, functional definitions and noted issues and concerns are provided in consistent with the current industry mobility practices and published peer-reviewed literature.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

SAE J2735 V2X Communications Message Set Dictionary

SAE J2945 Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts™

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2025 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, or used for text and data mining, AI training, or similar technologies, without the prior written permission of SAE.

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
<http://www.sae.org>

SAE WEB ADDRESS:

Full document details: SAE J3312_202502

For more information on this standard, visit https://www.sae.org/standards/content/J3312_202502/

Documents



Standard, visit Sharing Hub

SAE J3016 Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles

SAE J3298 Artificial Intelligence Data for Ground Vehicle Applications

Alami Chentoufi, M. and Ellaia, R., "A Novel Metaheuristic for Adaptive Signal Timing Optimization Considering Emergency Vehicle Preemption and Tram Priority," *SAE Int. J. Trans. Safety* 7(2):129-151, 2019, <https://doi.org/10.4271/09-07-02-0007>.

Berman, B. (2020). *Smart tech revolutionizing the traffic light*. SAE International. <https://www.sae.org/news/2020/12/traffic-light-automation>.

Burton, S., "The Path to Safe Machine Learning for Automotive Applications," SAE Research Report EPR2023023, 2023, <https://doi.org/10.4271/EPR2023023>.

Eddy, C., Castanier, M., and Wagner, J., "Predictive Maintenance of a Ground Vehicle Using Digital Twin Technology," SAE Technical Paper 2024-01-2867, 2024, <https://doi.org/10.4271/2024-01-2867>.

Hiwase, S. and Jagtap, P., "Predictive Maintenance of Automotive Component Using Digital Twin Model," SAE Technical Paper 2022-28-0075, 2022, <https://doi.org/10.4271/2022-28-0075>.

Hulbert, S., Mollan, C., and Pandey, V., "Fault Diagnosis and Prediction in Automotive Systems with Real-Time Data Using Machine Learning," SAE Technical Paper 2022-01-0217, 2022, <https://doi.org/10.4271/2022-01-0217>.

Joo, K. and Kim, L., "AI-based EV Range Prediction with Personalization in the Vast Vehicle Data," SAE Technical Paper 2024-01-2868, 2024, <https://doi.org/10.4271/2024-01-2868>.

Ma, J., Bauer, T., Ova, K., Hatcher, K. et al., "Deliver Signal Phase and Timing (SPAT) for Energy Optimization of Vehicle Cohort Via Cloud-Computing and LTE Communications," SAE Technical Paper 2023-01-0717, 2023, <https://doi.org/10.4271/2023-01-0717>.

Noh, K., Lee, D., Jung, I., Tate, S. et al., "AI-Based Optimization Method of Motor Design Parameters for Enhanced NVH Performance in Electric Vehicles," SAE Technical Paper 2024-01-2927, 2024, <https://doi.org/10.4271/2024-01-2927>.

Ouyang, C., Zhan, Z., Qian, L., and Zou, J., "Signal Control of Urban Expressway Ramp Based on Reinforcement Learning," SAE Technical Paper 2024-01-2875, 2024, <https://doi.org/10.4271/2024-01-2875>.

Puri, S., "Utilizing Machine Learning Algorithms in a Data-Driven Approach to the Prediction of Vehicle Battery State of Charge with BMW i3 Datasets," SAE Technical Paper 2022-01-5088, 2022, <https://doi.org/10.4271/2022-01-5088>.

Rajawat, S., Gautam, A., SJ, J., Soni, L. et al., "Adaptive EV Range Estimation and Optimization Based on Rider Demand and Terrain Requirements," SAE Technical Paper 2024-26-0095, 2024, <https://doi.org/10.4271/2024-26-0095>.

Sarmiento-Carnevali, M., Fly, A., and Piecha, P., "Electric Vehicle Cold Start Range Estimation through Battery-in-Loop Simulations within a Virtual Driving Environment," SAE Technical Paper 2020-01-0453, 2020, <https://doi.org/10.4271/2020-01-0453>.

Sugai, T., Shintani, K., Honda, T., Sakamoto, H. et al., "Reduced Order Modeling of Engine Coolant Temperature Model in Plug-In Hybrid Electric Vehicles," SAE Technical Paper 2024-01-2008, 2024, <https://doi.org/10.4271/2024-01-2008>.

Sun, Y., Xu, Z., and Zhang, T., "On-Board Predictive Maintenance with Machine Learning," SAE Technical Paper 2019-01-1048, 2019, <https://doi.org/10.4271/2019-01-1048>.

Wang, C., Fan, I., and King, S., "A Review of Digital Twin for Vehicle Predictive Maintenance System," SAE Technical Paper 2023-01-1024, 2023, <https://doi.org/10.4271/2023-01-1024>.

2.1.2 ISO/IEC Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH 1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

[ISO/IEC TR 24368:2022](#) Information technology — Artificial intelligence — Overview of ethical and societal concerns

2.1.3 Other Publications

Aliramezani, M., Koch, C.R., and Shahbakhti, M. (2022). Modeling, diagnostics, optimization, and control of internal combustion engines via modern machine learning techniques: A review and future directions. *Progress in Energy and Combustion Science*, 88, 100967. <https://doi.org/10.1016/j.pecs.2021.100967>.

Aykol, M., Gopal, C.B., Anapolsky, A., Herring, P.K., van Vlijmen, B., Berliner, M.D., Bazant, M.Z., Braatz, R.D., Chueh, W.C., and Storey, B.D. (2021). Perspective—Combining physics and machine learning to predict battery lifetime. *Journal of The Electrochemical Society*, 168(3).

Cui, C., Ma, Y., Cao, X., Ye, W., Zhou, Y., Liang, K., Chen, J., Lu, J., Yang, Z., Liao, K.-D., Gao, T., Li, E., Tang, K., Cao, Z., Zhou, T., Liu, A., Yan, X., Mei, S., Cao, J., ... Zheng, C. (2024). A survey on multimodal large language models for autonomous driving. *2024 IEEE/CVF Winter Conference on Applications of Computer Vision Workshops (WACVW)*, 958-979. IEEE.

Gupta, A., Anpalagan, A., Guan, L., and Khwaja, A.S. (2021). Deep learning for object detection and scene perception in self-driving cars: Survey, challenges, and open issues. *Array*, 10, 100057. <https://doi.org/10.1016/j.array.2021.100057>.

Liu, K., Wang, Y., and Lai, X. (2022). Key stages for battery full-lifespan management. In K. Liu, Y. Wang, and Z. Lai, *Data science-based full-lifespan management of lithium-ion battery*. Green Energy and Technology. Springer.

Ming, Y., Meng, X., Fan, C., and Yu, H. (2021). Deep learning for monocular depth estimation: A review. *Neurocomputing*, 438, 14-33. <https://doi.org/10.1016/j.neucom.2020.12.089>.

Molchanov, P., Gupta, S., Kim, K., and Pulli, K. (2015). Multi-sensor system for driver's hand-gesture recognition. *IEEE International Conference and Workshops on Automatic Face and Gesture Recognition (FG)*. IEEE.

Mueller, C. and Mezhyuev, V. (2022). AI models and methods in automotive manufacturing: A systematic literature review. In M. Al-Emran and K. Shaalan (Eds.), *Recent innovations in artificial intelligence and smart applications. Studies in Computational Intelligence*, 1061. Springer.

Norouzi, A., Heidarifar, H., Borhan, H., Shahbakhti, M., and Koch, C.R. (2023). Integrating Machine Learning and Model Predictive Control for automotive applications: A review and future directions. *Engineering Applications of Artificial Intelligence*, 120, 105878. <https://doi.org/10.1016/j.engappai.2023.105878>.

Trilles, S., Hammad, S.S., and Iskandaryan, D. (2024). Anomaly detection based on Artificial Intelligence of Things: A systematic literature mapping. *Internet of Things*, 25, 101063. <https://doi.org/10.1016/j.iot.2024.101063>.

Voigt, P. and von dem Bussche, A. (2017). *The EU General Data Protection Regulation (GDPR): A practical guide*. Springer International Publishing.

Wang, R., Keyantuo, P., Zeng, T., Sandoval, J., Vishwanath, A., Borhan, H., and Moura, S. (2024). Robust routing for a mixed fleet of heavy-duty trucks with pickup and delivery under energy consumption uncertainty. *Applied Energy*, 368, 123407. <https://doi.org/10.1016/j.apenergy.2024.123407>.

Wei, Z., Liu, K., Liu, X., Li, Y., Du, L., and Gao, F. (2023). Multilevel data-driven battery management: From internal sensing to big data utilization. *IEEE Transactions on Transportation Electrification*, 9(4), 4805-4823.

Yang, Q., Liu, Y., Chen, T., and Tong, Y. (2019). Federated machine learning: Concept and applications. *ACM Transactions on Intelligent Systems and Technology (TIST)*, 10(2), 1-19.

Yaqoob, S., Morabito, G., Cafiso, S., Pappalardo, G., and Ullah, A. (2024). AI-driven driver behavior assessment through vehicle and health monitoring for safe driving—A survey. *IEEE Access*, 12, 48044-48056.

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

Olin, P., Aggoune, K., Tang, L., Confer, K. et al., "Reducing Fuel Consumption by Using Information from Connected and Automated Vehicle Modules to Optimize Propulsion System Control," SAE Technical Paper 2019-01-1213, 2019, <https://doi.org/10.4271/2019-01-1213>.

Rajakumar Deshpande, S., Gupta, S., Kibalama, D., Pivaro, N. et al., "In-Vehicle Test Results for Advanced Propulsion and Vehicle System Controls Using Connected and Automated Vehicle Information," *SAE Int. J. Adv. & Curr. Prac. in Mobility* 3(6):2915-2930, 2021, <https://doi.org/10.4271/2021-01-0430>.

2.2.2 ISO/IEC Publications

While the following standards encompass a broader scope than ground vehicle and transportation applications, they raise applicable points and may be considered for product and process development within the ground vehicle industry.

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH 1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

Available from IEC Central Office, 3, rue de Varembe, P.O. Box 131, CH-1211 Geneva 20, Switzerland, Tel: +41 22 919 02 11, www.iec.ch.

ISO/IEC TS 4213:2022	Information technology — Artificial intelligence — Assessment of machine learning classification performance
ISO/IEC 5259-1:2024	Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 1: Overview, terminology, and examples
ISO/IEC 5259-3:2024	Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 3: Data quality management requirements and guidelines
ISO/IEC 5259-4:2024	Artificial intelligence — Data quality for analytics and machine learning (ML) — Part 4: Data quality process framework
ISO/IEC 5338:2023	Information technology — Artificial intelligence — AI system life cycle processes
ISO/IEC 5339:2024	Information technology — Artificial intelligence — Guidance for AI applications
ISO/IEC 5392:2024	Information technology — Artificial intelligence — Reference architecture of knowledge engineering

ISO/IEC TR 5469:2024	Artificial intelligence — Functional safety and AI systems
ISO/IEC 8183:2023	Information technology — Artificial intelligence — Data life cycle framework
ISO/IEC TS 8200:2024	Information technology — Artificial intelligence — Controllability of automated artificial intelligence systems
ISO/IEC TR 17903:2024	Information technology — Artificial intelligence — Overview of machine learning computing devices
ISO/IEC 20546:2019	Information technology — Big data — Overview and vocabulary
ISO/IEC TR 20547-1:2020	Information technology — Big data reference architecture — Part 1: Framework and application process
ISO/IEC TR 20547-2:2018	Information technology — Big data reference architecture — Part 2: Use cases and derived requirements
ISO/IEC 20547-3:2020	Information technology — Big data reference architecture — Part 3: Reference architecture
ISO/IEC TR 20547-5:2018	Information technology — Big data reference architecture — Part 5: Standards roadmap
ISO/IEC 22989:2022	Information technology — Artificial intelligence — Artificial intelligence concepts and terminology
ISO/IEC 23053:2022	Framework for Artificial Intelligence (AI) Systems Using Machine Learning (ML)
ISO/IEC 23894:2023	Information technology — Artificial intelligence — Guidance on risk management
ISO/IEC TR 24027:2021	Information technology — Artificial intelligence (AI) — Bias in AI systems and AI aided decision making
ISO/IEC TR 24028:2020	Information technology — Artificial intelligence — Overview of trustworthiness in artificial intelligence
ISO/IEC TR 24029-1:2021	Artificial Intelligence (AI) — Assessment of the robustness of neural networks — Part 1: Overview
ISO/IEC 24029-2:2023	Artificial intelligence (AI) — Assessment of the robustness of neural networks — Part 2: Methodology for the use of formal methods
ISO/IEC TR 24030:2024	Information technology — Artificial intelligence (AI) — Use cases
ISO/IEC TR 24372:2021	Information technology — Artificial intelligence (AI) — Overview of computational approaches for AI systems
ISO/IEC 24668:2022	Information technology — Artificial intelligence — Process management framework for big data analytics
ISO/IEC TS 25058:2024	Systems and software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Guidance for quality evaluation of artificial intelligence (AI) systems

ISO/IEC 25059:2023	Software engineering — Systems and software Quality Requirements and Evaluation (SQuaRE) — Quality model for AI systems
ISO/IEC 38507:2022	Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations
ISO/IEC 42001:2023	Information technology — Artificial intelligence — Management system

2.2.3 Other Publications

Deshpande, S.R., Gupta, S., Gupta, A., and Canova, M. (2022). Real-time ecodriving control in electrified connected and autonomous vehicles using approximate dynamic programming. *Journal of Dynamic Systems, Measurement and Control*, 144(1). <https://doi.org/10.1115/1.4053292>.

Deshpande, S.R., Jung, D., Bauer, L., and Canova, M. (2021). Integrated approximate dynamic programming and equivalent consumption minimization strategy for eco-driving in a connected and automated vehicle. *IEEE Transactions on Vehicular Technology*, 70(11), 11204-11215.

Yongkang Liu, C.W. (2024). Federated learning for connected and automated vehicles: A survey of existing approaches and challenges. *IEEE Transactions on Intelligent Vehicles* 1, 119-137.

3. ABBREVIATIONS

ANN	Artificial Neural Network
ADAS	Advanced Driver Assistance Systems
AI	Artificial Intelligence
ACC	Adaptive Cruise Control
ACS	Automotive Control Software
BEV	Battery Electric Vehicle
BMS	Battery Management System
CAV	Connected and Autonomous Vehicles
CNN	Convolutional Neural Network
C-V2X	Cellular Vehicle-to-Everything
EV	Electric Vehicle
ELM	Extreme Learning Machine
FCEV	Fuel Cell Electric Vehicle
FC	Fuel Cell
FCM	Fuzzy C-Means
GAN	Generative Adversarial Network
GP	Gaussian Processes

HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engine
LLM	Large Language Model
MPC	Model Predictive Control
PC5	Proximity Communication Interface 5 (Vehicle-to-Vehicle)
PEM	Proton Exchange Membrane
PHEV	Plug-In Hybrid Electric Vehicle
RNN	Recurrent Neural Network
RUL	Remaining Useful Life
RL	Reinforcement Learning
RKHS	Reproducing Kernel Hilbert Space
RVM	Relevance Vector Machine
SOC	State of Charge
SOH	State of Health
SOP	State of Power
SOM	Self-Organizing Map
SVM	Support Vector Machine
SL	Supervised Learning
UL	Unsupervised Learning
UGMM	Unsupervised Gaussian Mixture Model
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle