論文・報告

An AI Technologies Era – Latest Technology Trend for Logistics and Mobility

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Abstract

AI (Artificial Intelligence) is rapidly transforming logistics and commercial mobility. As ISUZU advances ISUZU Transformation – Growth to 2030 (IX*[1]) strategy, AI emerges as a foundational enabler for DX (Digital transformation), CN (Carbon Neutrality), and customer-centered mobility solutions. This paper reviews industrial challenges, state-of-the-art AI research and applications in logistics and mobility and proposes a unified, agentic AI–centric solution that can integrate ISUZU's autonomous driving solutions with connected fleet management solutions. Emerging AI frameworks—including world models, agentic AI, federated learning, self-evolving systems, and explainable AI—are pushing the boundaries of reasoning, adaptability, and real-world execution. Among these, agentic AI can be a rare opportunity for ISUZU to make new business breakthroughs. Despite significant AI adopt progress in areas like vehicle diagnostics, route optimization, energy management, and autonomous operations, current market solutions remain fragmented. ISUZU can create unique leading edges by integrating these capabilities into a unified solution, leveraging agentic AI.The proposed unified solution with agentic AI directly supports IX goals in safety, efficiency, sustainability, and customer satisfaction, giving ISUZU a competitive position as the first mover capable of deeply integrating autonomous driving technology and connected fleet management solutions.

*[1] IX (ISUZU's mid-term management plan "ISUZU Transformation – Growth to 2030")

1 Introduction

1.1 Industry Challenges

Logistics and mobility markets are growing. According to Precedence Research in 2024, the global fleet management market is expected to grow from 29.30 billion USD in 2025 to over 70 billion USD by 2034(10). McKinsey Company stated the global autonomous truck market can exceed 616 billion USD by 2035(8). The firm also stated that by 2035, truck OEM-relevant profit pool can grow from 3.2 billion to more than 10.4 billion by offering new mobility solutions, which is triple that of one-time vehicle sales revenue(9). But persistent challenges appear across long-haul, regional, and last-mile deliveries.

There is an undeniable driver shortage, with the US lacking 80,000 drivers in 2023 and the gap expected to double by 2030(1). Japan anticipates a 36% workforce decline by 2030(2) and Europe may face a 745,000 truck driver shortfall by 2028(3). At the same time, fleets must navigate increasingly strict labor and safety regulations, including Japan's 960-hour annual cap and US FMCSA (Federal Motor Carrier Safety Administration) HOS(Hours of Service) rules (4)(5). Environmental pressures are pressing as the governments and customers demand lower emissions and carbon footprints, prompting adoption of electric and alternative energy vehicles. Rising operational costs, such as fuel, labor, unplanned maintenance and empty miles, continue to reduce operation profit margins – especially in cold chain and time-sensitive logistics. Meanwhile, supply chain fragility, revealed by pandemic and climate events, has driven a shift toward decentralized and regional based distribution models which require more granular control and better planning visibility(5). The expansion of connected platforms and cloud systems has also escalated cybersecurity risks, promoting customers to adopt new tools for protection and data governance(7). Finally, customer expectations are evolving rapidly: demands for real-time visibility, autonomy-enabled delivery and dynamic routing are increasing the service standards and bars.

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1.2 Current Market Solutions

In response to these challenges, companies have developed a range of operational technologies, many of which use AI-powered tools and digital platforms. AD (Autonomous Driving) and ADAS (Advanced Driver Assistance Systems)can bridge labor shortages and increase driving safety. Fleet telematics and connectivity services support real-time diagnostics, cargo tracking and predictive analytics for ETA(Estimated Time of Arrival) optimization. Predictive maintenance systems use vehicle sensor data to forecast failures and schedule proactive servicing, reducing costly downtime. To meet sustainability demands, OEMs and logistics providers have introduced electric trucks, carbon-tracking tools, and carbon offsetting programs. Smart warehouses now rely on robotics and simulations to streamline inventory flows and optimize fulfillment operations. In urban context, last mile delivery is being transformed through drones and infrastructure for congestion relief. Meanwhile machine learning-based tools are applied for dynamic pricing, load matching, and route optimization to cut empty miles, improve fleet utilization and profit margins. On the data security front, blockchain is being used to enhance supply chain transparency, while cybersecurity solutions are safeguarding connected logistics networks.

1.3 Market Gaps

Even though current tools are effective at solving individual logistic problems, they remain highly fragmented and domain specific. Predictive maintenance, routing, AD/ADAS, compliance and energy management often operate independently, leading to missed opportunities for cross-functional optimization and many costly logistics issues remaining. In fleet operation and management domain, inaccurate prediction cost 1.1 trillion USD per year(11). Accident liability which involves a medium/heavy truck costs at an average of 148,279$ per accident(12) and unsafe operations erode profit margins. Regarding the autonomous driving solution, it requires 275 million miles to demonstrate its safety(13). A simple math of 1.5 USD/mile cost of operation leads to more than 400 million USD in autonomous vehicle's validation alone and makes autonomous driving a costly development.

Compared to other companies, ISUZU has a unique technical and business combination in commercial vehicle engineering, autonomous driving development and connected fleet management tools. Such growing markets, with costly logistics issues to solve, create a significant opportunity for ISUZU to lead by offering safe, efficient, precise and scalable logistic and mobility solutions.

2 ISUZU's opportunities to leverage AI

2.1 Autonomous Driving Solutions

A key trend in the evolution of AV(Autonomous Driving Vehicle) solutions is the shift from disjointed, modular pipelines toward a unified and E2E(End-to-End) AI architecture. This progression is illustrated in **Figure 1**, which depicts the technological evolution from AV 1.0 to AV 3.0. Each stage reflects increasing integration, reasoning capability, and real-world robustness.

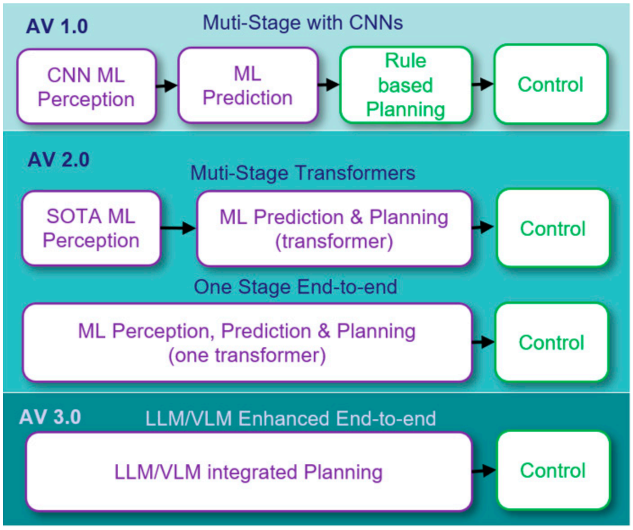

Figure1　Evolution from AV1.0 to AV3.0

AV 1.0 relied on a traditional modular design, with separate components for perception, prediction, planning, and control. While this architecture was stable and interpretable, it required extensive hand-tuning and interface engineering between modules.

ITCA (Isuzu Technical Center of America,Inc.) has made significant contributions to this paradigm, publishing numerous papers on AV 1.0 topics including scenario generation, trajectory planning, and perception-prediction pipelines, for example, ITCA implemented reinforcement learning algorithms alongside MPC(Model Predictive Control) to enhance the lateral control performance of autonomous trucks, validating these models through real-world and simulation-based testing[14][15].

AV 2.0 marked the beginning of a shift toward end-to-end learning architectures, where neural networks replaced manually engineered interfaces. With the emergence of transformer architectures, AI began to unify perception, prediction, and planning through shared representations and attention mechanisms.

E2E frameworks reduced system complexity and enabled scalable training across large datasets, promoting robust generalization and behavior understanding. Compared to AV 1.0, AV 2.0 reduces module-to-module error accumulation and enables more cohesive, data-driven decision making across the stack. ITCA is actively advancing AV 2.0 architecture through ongoing projects. These projects focus on transformer-based prediction and planning systems that emphasize interpretability and computational efficiency, with performance improvements over established baselines such as Wayformer[16].

AV 3.0, now at the research frontier, incorporates LLMs(Large Language Models), VLMs(Vision-Language Models), and xAI(Explainable AI) into autonomous systems. These models improve decision robustness, interpretability, and real-world reliability. AV 3.0 systems are designed not only to perceive and plan but also to explain their reasoning, adapt to novel situations, and collaborate with human operators, enabling higher-level reasoning, human-AI interaction, and explainability, enabling safer and more adaptable operations in complex logistics scenarios.

As the industry transitions to AV 3.0, the demand for high-quality and diverse data increases significantly. 2 key technological directions have emerged in parallel with AV 3.0 development: Generative AI and Physical AI. These technologies offer scalable solutions for generating data, simulating environments, and validating autonomous systems before physical deployment.

Generative AI has become essential for creating synthetic driving data and virtual scenarios. These models can simulate complex delivery environments, reconstruct rare or hazardous accident cases, and generate edge and corner conditions, allowing to test AV stacks with rare and safety-critical cases[17].

Sim2Real and Physical AI further bridges the gap between virtual validation and real-world deployment of AV 3.0. Physical AI refers to the deployment of AI models directly onto embedded hardware in vehicles, warehouses, and infrastructure, while Sim2Real enables those models to be trained, stress-tested, and optimized in digital twin environments before rollout. NeRF (Neural Radiance Fields) and 3DGS (3D Gaussian Splatting) allow photorealistic scene reconstructions, enabling improved scenario realism in simulation-based testing. This is particularly relevant for AV and robotic systems, which require greater reliability, adaptation, and environmental coverage[18]

ITCA has been actively engaged in these frontiers, with several multimodal AI and simulation workflows under development. One notable effort is the 2025 joint publication with the University of Michigan's MCity, where authors applied a generative simulation platform to evaluate AV behavior in long-tail and adversarial scenario, which is an example of state-of-the-art Sim2Real application[19]. These initiatives strengthen ITCA's position in developing scalable, intelligent, and resilient AV systems tailored for real-world logistics deployment.

2.2 Fleet management Solutions

Traditional intelligent fleet and logistics systems are typically built around modular layers—sensing, learning, modeling, and managing, leading to fragmentations in data and functionalities. As ISUZU transitions toward intelligent, autonomous and sustainable operations, a shift is needed: from fragmented fleet management functions towards unified optimization using all logistic informatics across diverse logistic networks as shown in **Figure 2**.

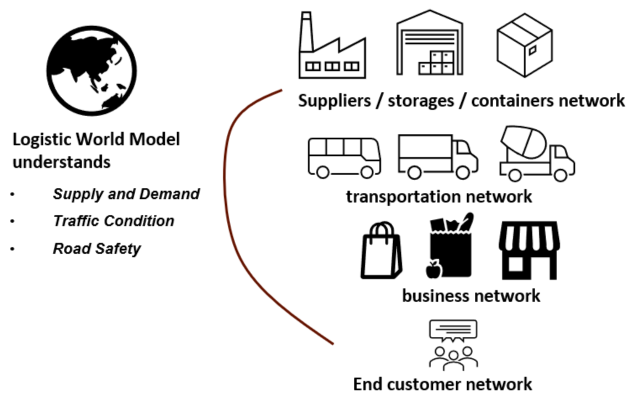

Figure2 The logistic world model which understands the dynamics across diverse networks from supply to demand and anything in between

A world model is an AI framework that simulates real-world dynamics—such as goods and cargos' supply patterns from supplier and storage networks, demand patterns from business and customer networks, traffic flow, congestion and road safety from transportation network— to support predictive and adaptive decision-making. It enables logistics systems to reason across time and different traffic context, powering unified fleet planning. Federated learning complements this by allowing models to train on decentralized fleet and regional data without sharing raw information, ensuring privacy while enabling continuous, localized optimization across all logistic networks.

Unlike domain-specific tools, the logistic world model enables comprehensive understanding and decision-making across the full logistics cycle— forecasting supply and demand, predicting traffic evolution, and assessing road safety in a unified architecture.

World models can simulate future demand fluctuations across multiple logistic networks as well as predicting how traffic conditions could evolve over time. LLMs trained for supply chain applications can improve inventory planning. Retrieval-augmented LLMs(RAG) like OptiGuide[20] let operators ask "what-if" questions to evaluate disruptions or delays. QTNN (Queueing-Theory-based Neural Network) from Sumitomo can simulate and boost Tokyo's traffic congestion forecast accuracy[6]. This paper utilizes graph neural networks to model supply/demand interactions across networks, improving planning precision in complex logistics. These examples justify current state-of-the-art deep learning and transformer-based AI can allow ISUZU to build a comprehensive logistic world model and to anticipate logistics flows.

In the age of classic machine learning techniques and traditional fleet management solutions, ITCA had developed CNN(Convolutional Neural Network)-based perception systems and LSTM(Long Short-Term Memory)-powered models for vehicle health monitoring and parts' remaining useful life forecasting, supporting predictive maintenance in fleet operations[21]. Moving towards the state-of-the-art world model age, ITCA is actively proposing projects towards a unified logistic world model and decentralized federated learning.

2.3 Unifying Autonomous Driving Solutions and Fleet Management Solutions with Agentic AI.

2.3.1 the proposed Agentic AI framework

As discussed in **Section 2.1** and **Section 2.2**, AV systems and logistics planning platforms have each advanced rapidly and showed unifying trends within themselves, they remain largely separated in current markets. Full value of autonomy and digital logistics operations can only be realized when these systems are unified – operating in a shared framework of planning, execution, and continual feedback. Unifying these solutions can provide ISUZU with a competitive edge.

A critical enabler of this integration is agentic AI – a framework where multiple AI based agents can perceive, decide and act across systems autonomously and collaboratively with targets and goals. In our vision, AVs serve as execution agents that work, sense and report data in the real physical world. The logistic planning system, enabled by logistic world model and optimization tools, serves as prediction, planning and decision-making agents that predict logistic situations, assign tasks, adjust plans and manage resources.

Agentic AI framework uses LLMs, xAIs, CoT (Chain-of-Thought) and GoT(Graph-of-Thought) to support its multi-stage decision workflows. These models and methods allow agentic AI to have strong reasoning capabilities and can handle long and complex tasks step-by-step. It also allows AI to provide human interpretable reasons and logical explanations to justify its decision-making process, giving logistic users confidence in the agentic AI proposed plans.

Planning and decision-making agent, powered by logistic world model, handles tasks such as:

- Vehicle grounding and routing based on AVs' and human drivers' safety constraints and traffic rules, predicted traffic congestion or disruptive events
- Updating ETAs and providing customers with traceability
- Rescheduling deliveries to reduce further delays, which might be caused by unplanned events in the real world
- Allocating fleet assets in response to real-time and future vehicle health status and cargo status

AVs as execution agents take planned operation routes (e.g. from location A to location B) and can handle tasks such as:

- Perform precise and safe fleet operations
- Detecting real world safety-critical events and traffic participants' behaviors
- Using AVs' verification and validation metrics to influence planning decisions
- Feeding operational data into simulation and enabling Sim2Real for cost efficient and safety prioritized AI deployment

2.3.2 Unified Benefits

Integrating autonomous driving systems with logistic world model based fleet planning enables a shift from fragmented tools to a unified, agentic AI-centric solution as shown in **Figure3**.

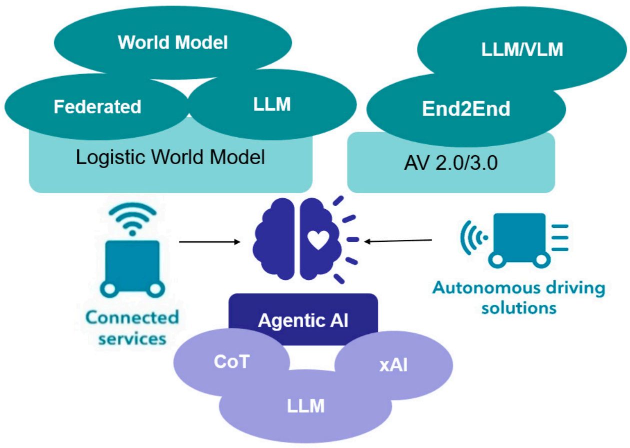

Figure3 A unified, AI centric solution and its related AI technics

Segmented logistics management tools and AIs often lack vehicle-native, comprehensive, and feature-rich feedback from autonomous vehicles' advanced sensors. Therefore, traditional fleet management tools have limited information to prioritize safety and do not necessarily align with vehicle safety designs. In contrast, to unify autonomous solutions with logistic fleet management solutions, traffic conditions and safety related monitors from AV development (e.g., disengagements, edge-case detection, unsafe scenarios) can be directly reflected in logistics decisions, enabling safety-aware fleet routing and schedule reallocation.

Such a unified solution allows a comprehensive view of all data and data sources, enabling a true logistic system level optimal plan. In this architecture, vehicle-level data – such as traffic behavior, energy use, and safety events – continuously flows in from AV deployments. Traffic congestion, cargo status and logistic demand and supply are continuously monitored and predicted by logistic world model. Based on comprehensive global information from both sides, agentic AI framework makes optimal planning decisions for AV operations. The result is an efficient and safety-aware logistic planning and precise autonomous execution system.

4 Conclusion

This paper analyzes the key challenges faced by logistics and commercial mobility customers and proposes a unified, AI-centric solution that leverages ISUZU's combined expertise in vehicle engineering, fleet management, and autonomous driving development. While a variety of digital tools exist today—sauch as predictive maintenance systems, route optimizers, and autonomous driving —these solutions largely operate in separation. As a result, they fall short in delivering comprehensive operational optimization across planning and execution.

To address this gap, this paper proposes an integrated solution that fuses AV2.0/AV3.0 technology stacks with a logistics world model, orchestrated by an agentic AI system. This architecture enables ISUZU to not only generate optimal operational plans but also execute them autonomously with full awareness of real-world logistics dynamics. The key differentiator lies in the deep integration of various systems: no other company today has developed a fully integrated agentic AI framework that bridges both autonomous driving and fleet business intelligence. Fleet management software companies lack an autonomous driving business while autonomous driving companies are focusing on AVs' safety advancement and either lack the deep vehicle-native integration, such as health diagnosis and prognosis, or the business developed in commercial fleet management with deep commercial customer understanding.

AI technics and tools are emerging nowadays. By acting now, ISUZU has the strategic opportunity to become the first mover in unified agentic AI for commercial mobility—creating a unified system that continuously learns, adapts, and delivers measurable value across planning, safety, energy, and operational efficiency. This would offer a lasting competitive advantage in the rapidly evolving logistics and autonomous mobility market.

あとがき

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(ITCA Advanced Engineering　深井泰雄)

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