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Research on the Profound Impact of Automobile Safety on Road Traffic and Social Stability

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ABSTRACT

Automotive safety is the cornerstone of transformation in the transportation sector and a key pillar for safeguarding road traffic safety and sustaining the steady development of the industry. The advancement of automotive safety is not only pertinent to the lives, health and property security of road users, but also exerts a profound impact on the high-quality development of the automotive industry and the harmonious and stable operation of society. Continuously promoting the improvement of automotive safety levels is of great significance.

KEYWORDS

Automotive Safety; Cornerstone; High Quality Development; Social Harmony and Stability.

1. AUTOMOTIVE SAFETY DATA ANALYSIS

Enhancing automotive safety contributes to the reduction of traffic accidents. Currently, traffic accidents have become a major threat to human life globally. In China, statistics released by the Ministry of Public Security show that 275,100 people were injured and 67,800 died in traffic accidents in 2024.Continuously improving the safety level of automobiles has key and irreplaceable industry practice value[1] for further strengthening the capacity to ensure the safety of occupants' lives and reducing the risk of traffic casualties.

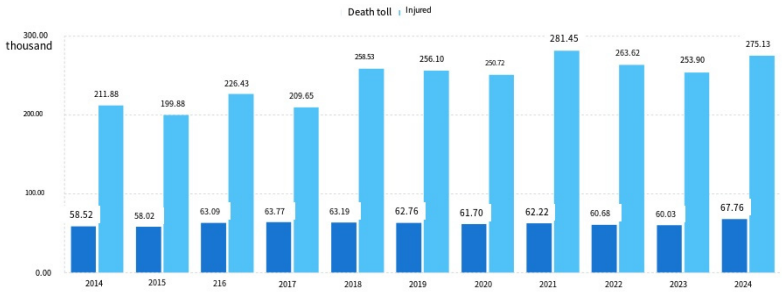


Figure 1. Trends in Traffic Accident casualties in China from 2014 to 2024 (Unit: Thousand people)

Data source: National Bureau of Statistics

Enhancing automotive safety helps mitigate personal and social economic losses. Personal economic losses caused by traffic accidents mainly include direct expenses such as vehicle repair and medical costs, as well as indirect losses such as income loss, which may exert short-term financial pressure

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on low- and middle-income families. From a social perspective, traffic accidents have exacerbated the consumption of public resources and the burden on social security. According to the World Health Organization, losses caused by road traffic accidents account for approximately 3% of the GDP of most countries; According to the China Statistical Yearbook 2024 issued by the National Bureau of Statistics, China's direct economic losses from traffic accidents reached 1.18 billion yuan in 2023, among which losses from motor vehicle accidents amounted to 943 million yuan, accounting for nearly 80%. If indirect social costs are added, the overall scale of economic loss will further expand.

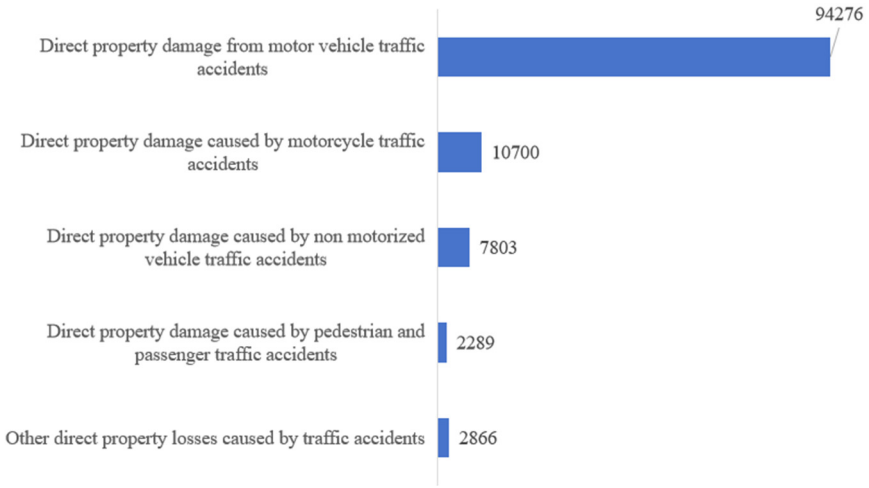


Figure 2. Direct Property losses from Traffic accidents in China in 2023 (Unit: ten thousand yuan)

Source: National Bureau of Statistics

Enhancing automotive safety is the core driving force for improving consumer reputation. During the transition of the intelligent automotive industry, the logic of consumers' car-buying decisions has shifted fundamentally from function-oriented to value-oriented. Car safety has not only become a core concern for consumers, but also a key variable influencing brand word-of-mouth. According to CATARC's 2024 consumer research data, safety remains the top concern for consumers when purchasing a car. Improved safety leads to a lower accident rate, which reduces consumer complaints related to safety and sustains brand reputation stability at the source.

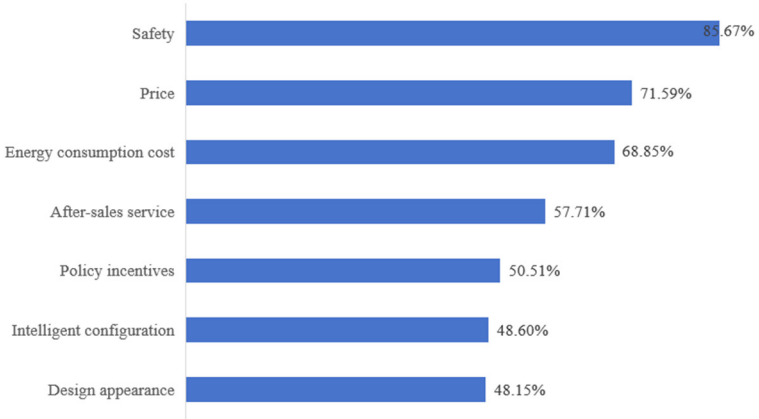


Figure 3. Attention of Chinese auto Consumers in 2024 (N=1000)

Source: CATARC

The core goal of automotive safety is to maximally protect the lives and health of vehicle occupants and other road users. Its iterative development path is not linear but phased, evolving with the improvement of policy standards, breakthroughs in key technologies and the upgrading of consumer demands.

1.1. The Passive Safety Period (1950s - 1990s)

Passive safety constitutes the foundation of the automotive safety system, focusing on post-accident protection. The core principle is that when a collision is unavoidable, the vehicle protects occupants to the maximum extent and minimizes occupant injuries through a series of designs and configurations.

Technologically, numerous landmark achievements have been made in passive safety. In 1951, the concept of the "passenger compartment and controllable energy-absorbing structure" was proposed, laying the foundation for vehicle passive protection. The invention of the airbag in 1953 marked a milestone in the development of passive safety; In 1959, the three-point seat belt became a key device for restraining occupants and reducing collision injuries;In addition, the European standardization of the ISOFIX child seat interface in 1990, which offered enhanced passive protection for child occupants, was another important achievement of this era.

Crash test regulations play a pivotal role in the advancement of passive safety. Test regulations impose higher requirements on the passive protection performance of vehicles and become the core driving force for the continuous advancement of passive safety technology.

1.2. Active Safety Era (1990s - 2020s)

With the rapid advancement of electronic technology, automotive safety entered the era of active safety..The core principle of this period was to equip vehicles with environmental perception and preliminary autonomous response capabilities to avoid collisions.

The anti-lock braking system (ABS), traction control system (TCS) and electronic stability control system (ESC/ESP) are landmark achievements in early active safety technologies, providing fundamental dynamic stability for moving vehicles; In the 21st century, active safety technologies have been further upgraded. Early warning systems such as blind spot monitoring (BSD), lane departure warning (LDW), and forward collision warning (FCW) can detect potential risks in advance and alert drivers, while intervention systems such as automatic emergency braking (AEB) can directly intervene in vehicle control in emergency situations.

Active safety technologies have been widely applied in intelligent vehicles, bringing a qualitative leap to their active safety protection capabilities.

1.3. Phase 3: The All-Domain Security Period (2020s -)

In recent years, the wave of electrification and intelligentization has swept across the global automotive industry. The market share of new energy vehicles has kept rising, and the intelligent configuration and functional iteration of products have accelerated. This series of changes has not only reshaped the industry's development logic, product form and technical architecture, but also driven a fundamental transformation in the connotation of vehicles - cars are no longer merely a "means of transportation" but are rapidly evolving into "intelligent entities" that integrate travel carriers, intelligent spaces and digital terminals. Against this backdrop, the traditional mechanical protection–centered safety system can no longer cover the increasingly complex digital and scenario-based risks, and the expansion and deepening of safety boundaries have given rise to new safety concepts. In 2020, Geely proposed the concept of "all-domain safety" for the industry. All-domain safety represents a revolutionary upgrade from traditional single collision protection to a full-coverage protection system, effectively addressing users' safety needs in diverse and segmented

scenarios in the intelligent era. The protective boundaries of all-domain safety continue to expand: from physical safety centered on collision avoidance to health care dimensions such as in-vehicle air quality monitoring and driving status alerts; From the full life-cycle safety management of power batteries to emerging intelligent fields such as vehicle data encryption, information security and AI safety, it builds a comprehensive technical safety system for vehicles. More importantly, all-domain security will break through the limitations of product technology security and extend the scope of protection to the dimensions of industry and social ecosystem development, which is a security system[3] covering the entire chain of products, technologies, industries and society.

In the future, as we step into the era of embedded intelligence, automotive safety will face a series of new risks and challenges: the "black box effect" in the autonomous decision-making process is becoming more prominent. Not only are misjudgments in long-tail scenarios difficult to avoid, but the traceability of the decision-making process has also become a technical bottleneck; In group collaboration scenarios, risks are highly contagious, and anomalies at a single node can easily lead to traffic paralysis or even chain accidents; The application of emotional interaction technology gives rise to new hidden dangers, which may lead to the perception system misjudging the scene, and may also raise the risk of users' excessive trust; The underlying digital base, once attacked, poses a fatal threat to driving safety. In response to the evolution of these risks, the automotive all-domain safety system is undergoing an all-round transformation and upgrade: at the decision-making logic level, it is shifting from traditional rule-driven to autonomous decision-making dominance, promoting safety attributes to upgrade from passive configuration to active instinct; In terms of protection scope, it is moving from the individual defense model of single-vehicle intelligence to the collaborative protection of group intelligence, achieving a leap in safety capabilities from single-point protection to cluster protection; At the regulatory dimension, it extends from simple behavioral supervision to full-scenario emotional care, reshaping the security protection system through multi-dimensional perception and intervention.

2. CHALLENGES AND OPPORTUNITIES FOR ALL-DOMAIN SAFETY IN INTELLIGENT VEHICLES

2.1. Challenges of All-domain Safety for Intelligent Vehicles

With the rapid development of the automotive industry, smart cars have become the mainstream direction of future automotive development. While vehicles are reshaping the travel experience through electrification, intelligentization and connectivity, they are also generating new safety challenges closely related to users’ lives, health, privacy and property due to multiple factors such as technological architecture innovation, application scenario expansion and industrial ecosystem changes.

(1) Adaptation challenges arising from the diversification of scene functions

The driving scenarios of intelligent vehicles have expanded from the traditional single road environment to diverse scenarios such as complex urban roads, high-speed intelligent navigation, vehicle-road coordination and extreme weather driving, and also need to deal with implicit scenarios such as electromagnetic interference and user health protection. Dynamic variables in different scenarios impose extremely high requirements on the adaptability of intelligent driving perception systems, vehicle control execution systems and connected communication systems, such as the accurate recognition of pedestrians and non-motor vehicles in urban congestion, the stability of battery thermal management systems in extreme low temperatures, and the anti-interference capability of connected vehicle communication in dense building areas, The complexity of the scenarios directly corresponds to the security adaptation requirements of core modules such as perception, control, connectivity, and energy in the safety of intelligent vehicles.

The long-tail effect poses a major challenge to the all-domain safety of intelligent vehicles in diverse scenarios and functions.Conventional scenarios such as urban roads and highways have been well adapted through technical optimization, but complex environments such as heavy rain and snow, intersections in urban-rural fringe areas and sudden traffic incidents—with numerous unpredictable factors—have become high-risk areas for safety hazards. The scenario long-tail effect refers to the accumulation of persistent safety risks caused by insufficient technical coverage in extreme or special driving scenarios that are low-probability but highly diverse.

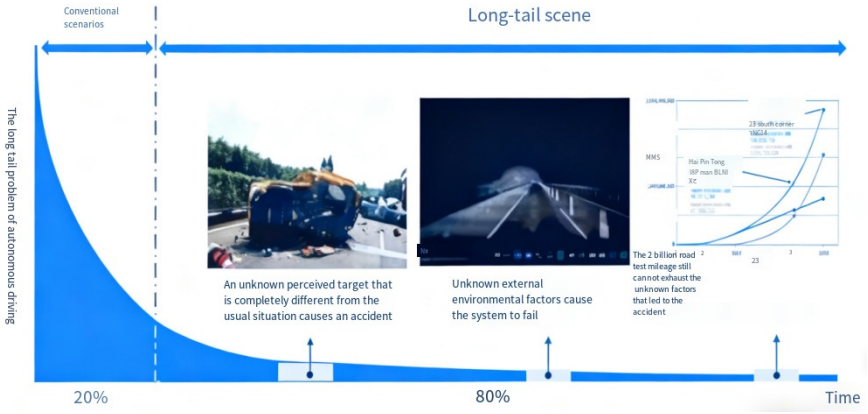


Figure 4. The Long tail problem of autonomous driving

The core problem of long-tail scenarios is the contradiction between the infinite complexity of the driving environment and the limited coverage of technical verification. That is to say, even if the vehicle completes real vehicle tests of billions of kilometers, it is still difficult to exhaust all potential risk scenarios. Generally, accidents caused by the long-tail effect fall into two main categories. One is accidents caused by cognitive blind spots. When a vehicle encounters an unknown target that differs completely from conventional training samples—such as irregular obstacles or special operation vehicles—the system fails to recognize it; The second is failure caused by environmental interference, such as sudden strong magnetic interference, special terrain and other unknown extreme external conditions, which can paralyze core systems such as perception and decision-making. These two types of situations together constitute the technical bottlenecks that are difficult to break through in the safety verification of intelligent vehicles.



Figure 5. Potential risk scenarios for autonomous driving

(2) The underlying challenges brought by technological shortcomings and innovation risks

Intelligent vehicles feature high innovation in technical architecture and components. Centralized domain control, high-voltage platform architecture and intelligent-connected architecture are being widely adopted. New components such as power batteries, intelligent chips and connected-vehicle modules are extensively applied. These new technologies and components pose many unprecedented safety challenges. [4]

As the core configuration of automotive intelligence, the temporary failure of integrated driver assistance system functions and insufficient perception capabilities have become the main hidden dangers to product quality and safety. According to the U.S. Department of Transportation's vehicle combined driving assistance accident report, the number of vehicle combined driving assistance accidents has been increasing year by year, with a year-on-year growth of 88% in 2024.

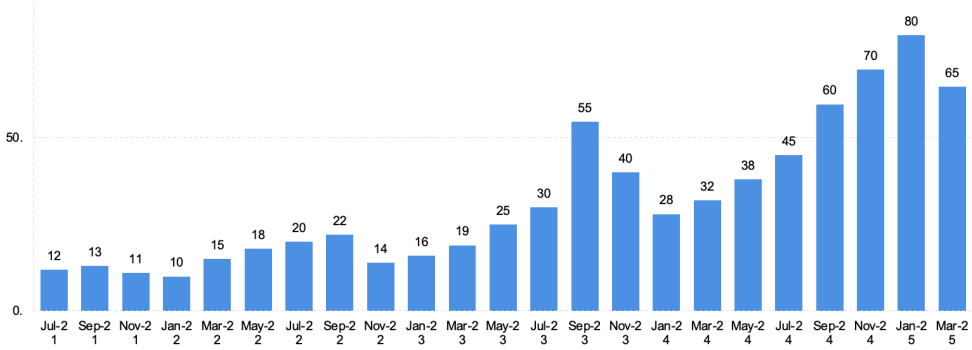


Figure 6. Trends in American ADS accidents 2021-2025 (Partial months, unit: incidents) Source: U.S. Department of Transportation, Understanding Safety Challenges of Vehicles Equipped with Automated Driving Systems (ADS), 2024

The surge in functional failures has led to a growing number of related recalls. According to the State Administration for Market Regulation, electrical equipment accounted for the largest share of vehicle recalls in China in 2024, at 25%, reflecting imperfections in the initial system design.

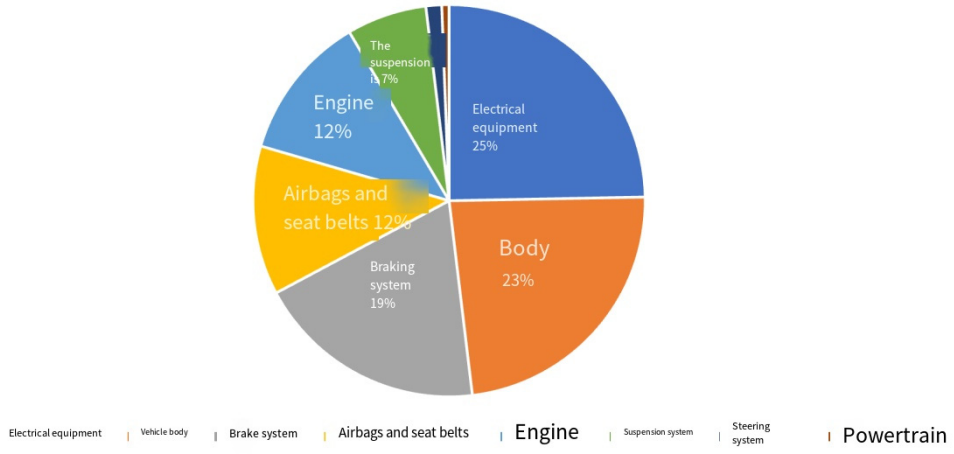


Figure 7. Distribution of vehicle recall issues in China in 2024 Source: State Administration for Market Regulation

New energy is the best power source for smart vehicles, but power batteries are prone to internal short circuits when subjected to external forces such as collisions, squeezes, and punctures, triggering thermal runaway reactions and causing serious accidents such as battery fires and explosions.

To enhance the user experience, intelligent vehicles are equipped with innovative features such as zero-gravity seats and hidden door handles.. The zero-gravity seat, also known as the high-tilt seat, precisely adjusts the angles of the seat backrest, seat cushion and leg rest to form an Angle of about 120° or more between the passenger's torso and thigh, evenly distributing the body weight onto the seat surface to minimize spinal and joint pressure, meeting the user's demand for comfort during long-distance driving and effectively alleviating muscle fatigue. According to statistics, the proportion of models equipped with zero-gravity seats as standard rose from 0.97% in 2023 to 14.47% from January to October 2025. However, zero-gravity seats have obvious safety shortcomings. In large-angle reclining positions, occupants are prone to submarining (sliding forward) and may slip out of seatbelt restraints during a collision, leading to spinal compression injuries and abdominal contusions. The traditional restraint system does not match the seat position, and the side air curtains do not cover the head area after reclining, increasing the risk of serious injury.

Hidden door handles not only boost technological sophistication and design aesthetics, but also optimize body contours to reduce aerodynamic drag. Driven by Tesla, hidden door handles have become a standard feature in new car models, rising from 30.68% in 2023 to 55.35% in the January-October 2025 period, according to statistics. But there are also obvious shortcomings. On the one hand, the complex telescopic structure relies on more electronic and mechanical components and is prone to jamming or malfunction in extreme weather conditions such as low temperatures and heavy rain; On the other hand, in emergency situations such as vehicle collisions and fires, power outages can cause the electric handle to fail, hindering the escape of occupants and external rescue, and the emergency unlock device in some models is not clearly marked, making it difficult to quickly identify and operate in the dark.

Meanwhile, driven by the optimization of cabin experience in the automotive industry, many models have begun to reduce the number of physical buttons and simplify some traditional functions. Physical buttons that were originally independent, such as air conditioning adjustment, volume control, seat heating/ventilation, and driving mode switching, have been integrated into the central control touch screen or voice control system. Some models have even removed the physical multi-function buttons on the steering wheel and instead adopted touch-sensing or sliding operation designs. However, the reduction in physical buttons also poses safety risks. Touch operation requires the driver to briefly take their eyes off the road to confirm the operation position, increasing the risk of driver distraction. Euro NCAP has explicitly included the retention of physical buttons in the safety rating system, stating that models that completely remove physical buttons for core functions will not receive the highest five-star safety rating. In addition to the reduction of physical buttons, some automakers have removed the traditional radio module, which is the in-vehicle radio receiving system, from new vehicles to further simplify the configuration and reduce costs. In remote areas or scenarios where network signals are weak/interrupted, smart cars can only locate through radios, so eliminating radios would also pose safety concerns.

(3) The challenge of missing core user demands due to an imbalance in industrial orientation

Enterprises are overly focused on experience competition, emphasizing the entertainment functions of intelligent cockpits while ignoring key areas that are not intuitively perceptible to users but critical to core safety. Some enterprises prioritize voice interaction and scenario-based entertainment functions in the cockpit domain but neglect the emergency braking redundancy design in the driving domain, user privacy data encryption in the connectivity domain and battery thermal runaway warning accuracy in the energy domain; Due to the lack of significant differences in short-term user experience, there is a reduction in iterative investment in the active safety system of the chassis domain and optimization and upgrading of the passive protection structure of the body domain, resulting in insufficient technical accumulation of the implicit safety module, creating a structural risk of emphasizing experience over safety, and ultimately affecting the overall safety bottom line of intelligent vehicles.

Excessive promotion by enterprises also brings safety challenges to driving automation systems. 2025 is regarded as the first year of intelligent driving for all. The adoption rate of combined driving assistance functions is constantly increasing and has entered the stage of large-scale application in the market. The application of related functions such as navigation driving assistance is rapidly spreading. However, excessive enterprise promotion has created a mismatch between technological maturity and market enthusiasm, leading to increasingly prominent problems such as user cognitive bias. This has not only caused numerous traffic accidents but also brought multiple challenges such as trust crises and compliance pressure to the automotive industry.

The misuse and abuse of combined driving assistance by users are mainly manifested in three scenarios: First, equating combined driving assistance systems with autonomous driving and implementing fully managed driving; 2. Ignoring the application scenarios of the functions and forcing them to be activated in bad weather and complex road conditions; The third is to deceive monitoring systems through physical means, such as so-called "smart driving gadgets", to evade the obligation of human takeover. These actions are due to excessive promotion by companies, which leads to cognitive biases among users regarding combined driving assistance functions and violates the legal principle that "the driver is the first responsible person."

(4) Intelligentization brings challenges to the synergy of the automotive industry ecosystem

Industrial ecological synergy plays a vital role in the operation of the automotive industry. In the process of intelligentization, automotive safety is confronted with challenges in industrial ecological synergy. The full-chain safety standard system is still incomplete. Standards in passive safety, active safety, intelligent safety, cyber security and other links are not well connected. A disconnection exists between technological iteration and standard updates. The industry also has insufficient influence in international standard formulation. Facing multiple compliance and certification pressures; Prominent technical barriers in the industry, closed core security technology patents, inefficient transfer of results, uneven distribution of high-end testing and inspection resources, and difficulty for small, medium and micro enterprises to obtain key technical support have led to insufficient accessibility of security technology; The absence of a cross-subject ecosystem collaboration mechanism, where governments, vehicle manufacturers, component enterprises, and technology companies fight on their own, and there is a lack of concentrated efforts to tackle "bottleneck" security problems such as chips and operating systems, makes it difficult to deal with complex security risks such as cyber attacks and data leaks brought about by intelligence, and restricts the overall improvement of the industry's security level and the construction of a harmonious automotive society.

2.2. Opportunities for All-domain Safety of Intelligent Vehicles

While intelligentization brings new challenges to the all-domain safety of intelligent vehicles, the in-depth transformation of the automotive industry toward intelligentization has spawned brand-new development opportunities in the field of all-domain safety. Intelligentization achieves multi-dimensional breakthroughs in safety scenario function upgrading, rapid technological iteration and industrial ecosystem optimization through core approaches such as data-driven development, AI empowerment and value reshaping.

(1) Intelligentization drives the upgrade of automotive safety scenarios and functions

The popularization of intelligent vehicles has shifted users’ safety demands from passive protection to all-scenario active protection. Demands for scenario-specific functions such as congestion avoidance during daily commutes, fatigue monitoring during long-distance driving and extreme weather risk warnings have become increasingly explicit. This demand has pushed R&D to focus on practical pain points and promoted the deep integration of perception technologies such as millimeter-wave radar and LiDAR with driving scenarios, giving rise to precise functions such as adaptive cruise control safety optimization and automatic parking risk prediction. Automakers create a virtuous cycle of "demand mining - technology matching - product iteration" by converting user demands into

technical indicators and then verifying the effectiveness of the functions of mass-produced models, which not only meets users' core demands for safe travel but also provides a clear direction for safety function innovation.

(2) AI empowers a leapfrog upgrade in safety technology

Traditional safety technologies are constrained by fixed algorithms and passive response patterns, and have obvious limitations in complex road condition recognition and emergency risk management, making it difficult to adapt to the dynamic safety requirements of intelligent vehicles. The deep application of AI technology breaks this limitation, and its continuous learning and dynamic adaptation capabilities shift security defense from post-event remediation to pre-event warning and in-event blocking. Relying on the computing power advantage of large models, AI can conduct real-time analysis of massive heterogeneous data to improve the accuracy of identifying sudden obstacles and abnormal driver conditions; By building digital twin scenarios, AI can also conduct virtual simulation tests of safety technologies, significantly reducing the cost of real vehicle verification and accelerating the cycle of new technology implementation. With a responsible AI governance framework, technological innovation is always within the safe and controllable range, providing long-term breakthrough momentum for the safety of smart vehicles.

(3) Intelligence provides core competitiveness for the development of China's automotive industry

Intelligentization offers opportunities for the Chinese automotive industry to achieve breakthrough upgrading and build core competitiveness, fully unlocking industrial development potential from the four dimensions of ecology, policy, society and the globe. At the industrial ecosystem level, cross-sectoral entities are deeply building a collaborative system. Automakers, technology companies, and component manufacturers break down industry barriers to form a full-chain innovation network covering key links such as chip research and development, intelligent driving, and in-vehicle systems, accelerating technological iteration and transformation, and building an independent and controllable industrial ecosystem closed loop. National policies continue to increase support, clarify development paths through top-level design, improve the intelligent vehicle standard system, promote autonomous driving pilot demonstrations and infrastructure construction, and at the same time provide special support funds and tax incentives to lay a solid policy foundation for the intelligent transformation of the industry. At the social level, intelligent vehicles precisely meet the needs of social co-prosperity, providing convenient and safe travel experiences for the public through technology inclusion, and promoting the deep integration of the automotive industry with smart cities and intelligent transportation to facilitate the upgrading of the transportation system. In the global market, China's technological superiority in automotive intelligence continues to stand out, driving the industry to upgrade from product export to technology and standard export, significantly enhancing global market voice and competitiveness, and injecting strong impetus into the realization of the strategy of becoming a strong automotive nation.

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