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Features Classification Guideline for Intelligent Cockpit

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Preface

With the rapid development of automotive electrification and mobile internet in China, intelligent vehicle development is leading the automotive industry into a new era. In recent years, various policies and guidelines have been issued domestically and internationally to support the development of intelligent connected vehicles. Cockpit functionality has emerged as a key focus area for automakers, driving significant R&D investment as manufacturers seek to differentiate products and enhance consumer appeal through feature rich, user-centric in vehicle experiences.

As technologies such as artificial intelligence, voice recognition, and multimodal interaction continue to evolve, human–vehicle interaction is becoming increasingly natural and intuitive. This enhanced interaction paradigm not only elevates the overall user experience but also contributes meaningfully to improved driving safety and in-cabin comfort.

As the diversity of in cabin connectivity continues to expand, the vehicle is evolving from a traditional mode of transportation into a third space connected with the user's broader digital ecosystem. By enabling seamless integration with smart home systems, mobile devices, and cloud-based services, the intelligent cockpit provides customized information, entertainment, and connected service designed to diverse mobility scenarios and evolving user expectations.

Despite the explosion of use cases, the industry still lacks common standards or widely adopted methods to classify the functional domains of intelligent cockpits. Disparate categorization approaches across organizations have resulted in fragmented information and inconsistent terminology, underscoring the need for a standardized, market-aligned classification framework.

In response, the China Society of Automotive Engineers, in collaboration with Volkswagen Group (China), and with support from S&P Mobility, has developed the "Features Classification Guidelines of Intelligent Cockpit" (hereafter, 'the Guidelines'). Grounded by the principles of comprehensive coverage, scientific rigor, scalability, and practical applicability, the Guidelines aim to provide industry stakeholders with a structured reference for understanding, evaluating, and deploying intelligent cockpit features and applications in different scenarios.

The Guidelines establish a standardized taxonomy and explanatory framework for functions classification of automotive cockpit, supporting product development, data driven decision making, and strategic planning. By building industry consensus around a unified classification system, this initiative aims to deepen insight into emerging technology trends, streamline functional design, and accelerate innovation in the intelligent cockpit domain.

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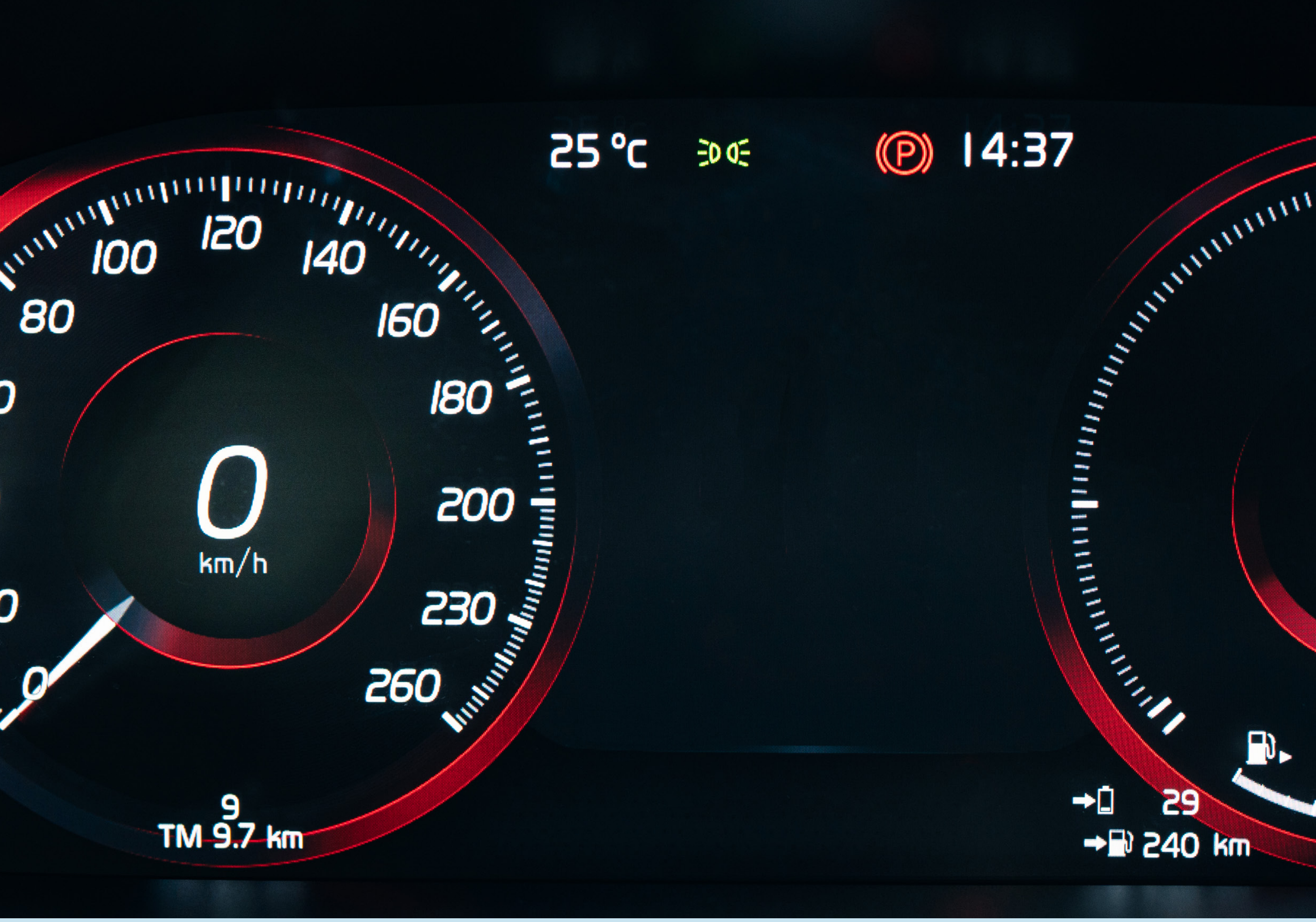

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1 Overview

1.1 Current Status

The integration of emerging technologies with the automotive sector introduces profounds challenges while unlocking transformative opportunities for the next generation mobility. Advanced driver assistance systems (ADAS) are already demonstrating measurable benefits to end users—minimizing cognitive load, reducing driving fatigue, and elevating the overall driving experience.

Propelled by rapid gains in semiconductor compute, data centric software iteration, and increasingly sophisticated AI, in vehicle systems are delivering steadily greater capability and user perceived value. The industry’s feature roadmap has shifted from adding isolated functions to a scenario driven approach—tailoring use case specific enhancements that enrich the mobility experience and elevate consumer expectations for intelligent cockpits.

According to a joint consumer insights study conducted by Volkswagen and the China Society of Automotive Engineers (C-SAE), A clear majority of respondents view the rise of intelligent vehicles as a defining industry trend. The results show that Chinese consumers hold especially high expectations for cockpit intelligence and its ability to add convenience and value to daily life: over 80% report moderate to high expectations, and nearly 20% report very high expectations. In response, automakers are accelerating innovation in in vehicle intelligence to meet growing consumer demand and create meaningful differentiation from competitor.

According to S&P Mobility, connected vehicles represented 74% of global new vehicle sales in 2024; China outpaced the average at 77%. The 5G equipped connected car share is forecast to increase from 11% in 2024 to 55% by 2030, advancing the global move to high bandwidth, low latency connectivity. China’s intelligent connected vehicle market leads internationally on adoption, functional scope, and ecosystem evolution. The market is also witnessing a shift toward continuous software upgrade capabilities enabled through over-the-air (OTA) technology. Post-sale function optimization in China is now common practice, with OEMs delivering periodic OTA updates that enhance vehicle performance, user experience, and feature sets. As of 2024, vehicles with ongoing upgrade capabilities represent 70% of the Chinese new vehicle market—a figure expected to rise to 85% by 2030, reinforcing China's lead in software-defined vehicle readiness.

Amid the industry megatrends of electrification, intelligence, and connectivity, the intelligent cockpit has emerged as the central touchpoint of the in-vehicle experience and is advancing into a phase of accelerated transformation. Whether through advancements in hardware integration or proliferation of software driven features and service ecosystems, the cockpit is becoming a scalable, unified digital space. In China in particular, the automotive digital cockpit is increasingly framed as the “third living space” carrying everyday living and productivity into the automotive context.

The current trajectory of intelligent cockpit development is marked by several key characteristics:

Cockpit multi-screen integration and multimodal interaction

The scope of intelligent cockpits has expanded far beyond traditional information display, evolving into a comprehensive digital experience platform that unifies navigation, media entertainment, climate control, and drive-related data. Large central displays and digital instrument clusters are increasingly becoming standard configurations across vehicle segments, reflecting the shift toward immersive and connected cabin environments. Advanced user experience-related technologies such as panoramic displays, intelligent seat configurations, and ambient lighting controls, all managed through a centralized digital cockpit system for seamless and intuitive user operation. These systems are underpinned by increasingly sophisticated human-machine interaction (HMI) technologies. Voice recognition has significantly improved in accuracy and response time, while touch and gesture-based interfaces continue to evolve, enabling more natural and fluid vehicle control.

Together, these innovations create a user-centric interaction model that simplifies command execution and reduces cognitive load. Looking ahead, intelligent cockpits will advance further through multimodal interaction frameworks that combine voice assistants, AI-driven agents, touchscreen inputs, gesture recognition, and eye-tracking technologies. These integrated systems will be essential for delivering intelligent, context-aware interactions and enhancing overall user convenience.

Advanced graphics rendering and immersive in-cabin experience

Alongside improvements in user interaction the digital experience within cockpits is undergoing a profound transformation. Advancements in graphical rendering technologies are enabling enhanced lighting effects, realistic texture with details, and smooth visual transitions, powered by high resolution displays and high-performance graphical processors. Immersive systems such as large multi high-definition displays, augmented reality (AR) head-up displays, customizable ambient lighting, and spatialized audio systems are converging to create a highly personalized and engaging in-vehicle environment. These innovations are increasingly recognized as key differentiators for next generation cockpit design.

The rise of automotive grade semiconductors with superior computing and graphic rendering capabilities is accelerating this shift, making real-time 3D visualization and multimedia-rich application a reality. For instance, AR navigation overlays real-world road views with dynamic routing and hazard indicators, helping drivers to interpret spatial context and directions more quickly and clearly, thereby enhancing both safety and situational awareness.

As computational power continues to scale and immersive UX technologies become more widely adopted, intelligent cockpits are evolving into multifunctional digital spaces- serving not only vehicle function control but also as emotionally resonant environments that redefine the in-car experience.

Integration of cockpit operating systems with external IoT ecosystems

Intelligent cockpit operating systems are progressively evolving to support seamless connection with external smart devices such as smartphones, tablets, and wearables. This advancement is driving two major shifts: enhanced continuity between in-vehicle systems and users' personal digital ecosystems, and the emergence of broader cross-device experiences including smart home integration.

For example, future in-car entertainment experiences may automatically resume video content from a user's home once the vehicle detects their presence. Similarly, work related functions such as virtual meetings, call notifications, and messaging can be synchronized into the cockpit interface via secure and authorized access, positioning the vehicle as an extension of the user's connected lifestyle.

Moreover, the expansion of over-the-air (OTA) update capabilities and feature-on-demand (FoD) services model is enabling the continuous delivery of new applications and connected services. This evolution transforms the cockpit operating system from a core user interface into a strategic platform for OEMs and ecosystem partners to offer differentiated, value-added digital services.

Multi-domain fusion and scenario-based services

Automotive system architecture is entering a new phase defined by multi-domain fusion, wherein previously isolated domains—such as the digital cockpit, advanced driver assistance systems (ADAS), and chassis control, they are now dynamically coordinated through centralized computing platforms or multiple high-performance domain controllers.

This architectural evolution enables deeper cross-domain coordination. For example, the integration of intelligent driving and infotainment systems allows more diverse and context-aware automated driving scenarios. Vehicles can also utilize environmental sensing and V2X data to display real-time road and traffic conditions on the cockpit interface, enhancing route planning and offering proactive travel recommendations to both drivers and passengers.

By adopting a scenario-driven design approach, automakers can intelligently reconfigure and combine system functions based on user context and intent. This transforms discrete vehicle capabilities into targeted, service-oriented experiences, unlocking greater user value and pave the way for personalized mobility services.

China's leadership in Intelligent Vehicle innovation

China has established itself as a global leader in the development of intelligent connected vehicles (ICVs), driven by the rapid development and large-scale deployment of enabling technologies such as 5G communications, artificial intelligence (AI), cloud computing, and big data analytics. Combined with a strong consumer openness to new technologies, this has positioned China as a leading testbed for next-generation vehicle connectivity, intelligence, and user experience.

Domestic OEMs have shown unwavering strategic commitment through substantial investments in intelligent cockpit and autonomous driving technologies. Cross-industry collaboration with technology giants and startups have fostered a dynamic innovation ecosystem, accelerating progress of integrated software platforms, advanced hardware architectures, and multimodal interaction capabilities. Chinese automakers are setting global benchmarks in areas such as centralized computing platforms, vehicle operating systems, and AI-driven user experience, consistently delivering first-to-market solutions that influence international standards.

Looking ahead, the intelligent cockpit is evolving beyond the vehicle interior into a cross-scenario digital hub, integrating mobility services, entertainment, social interaction and smart home ecosystem. This transformation enables seamless connectivity across human, vehicle and environment interfaces, including vehicle-to-person (V2P), vehicle-to-vehicle (V2V), and vehicle-to-everything (V2X) applications. China is poised to play a pivotal role in defining global standards, shaping business models, and influencing consumer experiences in the era of intelligent mobility.

From a policy perspective, the Chinese government has consistently reinforced its commitment to the Intelligent Connected Vehicle sector. In February 2020, the National Development and Reform Commission introduced the Intelligent Vehicle Innovation Development Strategy, encouraging local governments to craft region specific policies and accelerate strategic implementation. In November 2020, the State Council issued the New Energy Vehicle Industry Development Plan (2021–2035), which advocates cross-sector collaboration among automotive, energy, transportation, and ICT enterprises to foster diversified production models and expand application scenarios.

The convergence of technological innovation, evolving consumer expectations, and supportive regulatory frameworks has accelerated advancements in intelligent vehicle systems and cockpit functionalities. As a result, China's intelligent cockpit market is undergoing rapid transformation, marked new market entrants, continuous product innovation, and restructuring of the industry value chain. While the future of intelligent cockpits offers significant opportunity for differentiation and monetization, it also introduces structural and competitive challenges that OEMs and suppliers must address strategically.

1.2 Significance

The rapid advancement of intelligent automotive cockpits has significantly expanded both the variety and adoption of cockpit-related functions. By the end of September 2024, China's new energy vehicle (NEV) market had introduced 185 new models or series—on average one new model launch every two days, representing 1.5 times increase compared to the same period in 2023. This surge underscores the highly competitive dynamics within China's NEV sector and highlights the accelerating pace of cockpit feature innovation.

However, the proliferation of cockpit features across brands and models has introduced notable challenges. OEMs often employ unique naming conventions for similar functions, while the scope and depth of sub-functional coverage varies considerably. These inconsistencies hinder market competition analysis, consumer research, and product evaluation due to the lack of standardized terminology and classification. The absence of a unified framework complicates industry benchmarking and creates friction for consumers, who struggle to compare feature sets across trims and models.

To address these challenges, establishing a standardized classification system for intelligent cockpit functions is essential. Such a framework enables consistent observation and comparison of cockpit function development across brands and models, providing a structured lens for industry stakeholders analyzing product evolution, identifying technological trends, and shaping product strategies. For automakers and cockpit system suppliers, this taxonomy supports product lifecycle management, enhances cross-functional coordination, and informs strategic decisions in cockpit application design and service innovation. For consumers, a unified classification standard improves transparency, facilitating informed comparisons and serving as a reference point for evaluating product value and making purchase decisions.

Given the current lack of globally recognized methodologies or frameworks for intelligent cockpit function classification, this guideline introduces a foundational approach. It defines a functional classification system tailored to the intelligent cockpit domain and offers recommendations for its application in product development, data analytics, and strategic planning. This initiative aims to establish a shared language and evaluation framework for the intelligent cockpit ecosystem, driving standardization and supporting the continued maturation of this critical domain within the automotive value chain.

2 Research Scope

This guideline presents a structured classification system for the functional domains of intelligent automotive cockpits. It defines and explains key functions and services, offering standardized terminology and illustrative examples. The classification framework is intended for use in passenger vehicles with intelligent cockpit systems, including those featuring in-vehicle infotainment, and serves as a reference for both product development and benchmarking activities.

3 Classification Methods

3.1 Overview of Classification

Intelligent automotive cockpits encompass a wide range of technologies and use cases, resulting in diverse functions that span human-machine interaction, connected services, and scenario-based applications. These functions can be categorized from multiple perspectives, including technical implementation, physical configuration, and application context.

To ensure consistency and comparability, this classification framework aligns with the evaluation methodology outlined in the White Paper on Comprehensive Evaluation of Intelligent Automotive Cockpits. According to the white paper, cockpit evaluation is structured around two primary dimensions: Safety and Intelligence. Secondary evaluation criteria covering human-machine interaction (HMI), connected services, and scenario-based function extensions.

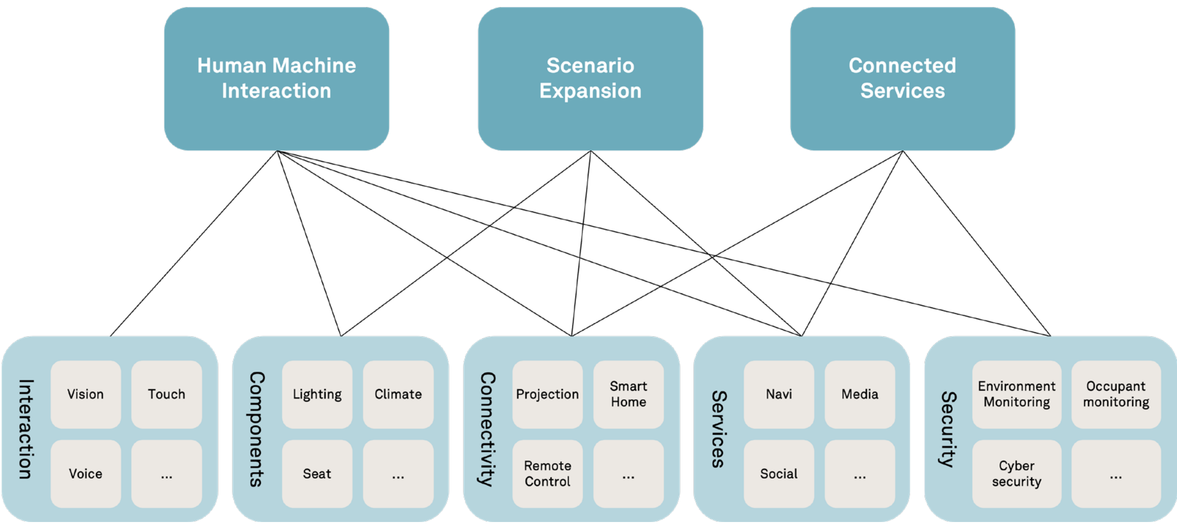

Figure 1: Intelligent cockpit capabilities reflected in functional layers

Building on this foundation, the classification methodology reorganizes intelligent cockpit functions based on hierarchical evaluation indicators and associated sub-functional logic. The structure consists of four levels:

LEVEL 1

Classification

Functions are grouped according to the fundamental components of the human–machine–environment system (see Figure 2).

LEVEL 2

Core Functional Domains

Primary functions are classified based on key technologies associated with the human-machine-environment.

LEVEL 3

Business Logic and Technical Classification

Within each domain, secondary functions are classified according to application logic and key underlying technologies (e.g., voice interaction, visual processing, connectivity protocols).

LEVEL 4

Sub-Function Expansion

The most detailed layer breaks down Level 3 categories into specific sub-functions, structured by technical characteristics and business logic.

Perception

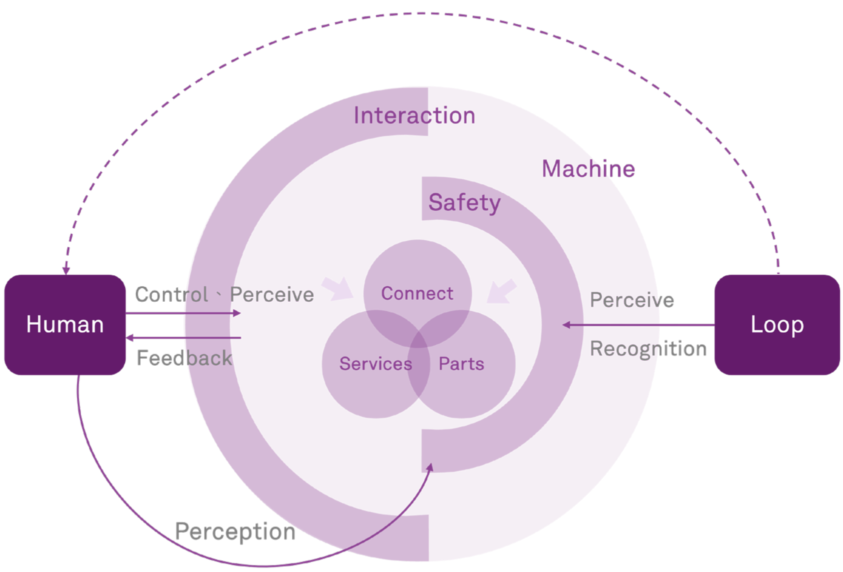

Figure 2: Composition elements of human machine environment

This multi-tiered classification provides a comprehensive, scalable structure to support intelligent cockpit function mapping, comparative analysis, and product planning across the industry value chain. It serves as a foundational reference for automakers, suppliers, and industry researchers in aligning feature development with user expectations, regulatory requirements, and technological evolution.

3.2 Classification Principles

The classification of intelligent automotive cockpit functions is guided by the following core principles to ensure clarity, consistency, and pratical applicability:

Comprehensive Coverage

The framework follows the MECE (Mutually Exclusive, Collectively Exhaustive) principle, ensuring that all intelligent cockpit functions are fully captured within the top-level classification structure, with no functional omissions. Sub-categories and sub-functions at each hierarchical level are clearly defined and mutually exclusive, eliminating overlap and redundancy.

Practical Usability

The framework prioritizes ease of interpretation and application across OEMs, suppliers, and industry stakeholders. Functional modules can be selectively disaggregated, combined, or adapted for specific use cases—such as product planning or competitive benchmarking, without the change of the overall hierarchy and functions.

Future Scalability

The system is designed to accommodate emerging technologies and functions. New elements can be integrated into the existing framework based on predefined attributes and classification logic, without altering the primary classification structure.

Scientific Structuring

Functional groupings are based on inherent technical characteristics and objective operational logic. The classification hierarchy is designed to reflect functional relevance and system-level architecture, supporting rational segmentation across levels.

4 Classification Structure

4.1 Classification Framework

The intelligent automotive cockpit function taxonomy is organized into four hierarchical levels, reflecting increasing granularity from primary domains to sub-functional elements. The updated framework reflects the growing complexity of cockpit systems by expanding both scope and depth.

Primary Functions

Expanded from five to seven categories, incorporating AI technologies and system-level digital foundations as distinct domains. The seven top-level categories now include:

1. Safety
2. Human Interaction
3. Hardware Components
4. Connectivity
5. Services
6. AI
7. System / Digital Foundation

Secondary Functions

Increased from 18 to 25 categories, offering more granular segmentation across domains.

Tertiary Functions

Expanded from 85 to 103 function groups, offering deeper coverage of technical and application-level capabilities.

Each level maintains a clear hierarchical relationship, enabling structured analysis and systematic mapping of cockpit functionality. Detailed classification information is provided in Section 4.2.

This framework supports cross-industry alignment, improves comparability across products and brands, and establishes a strategic foundation for cockpit system development, evaluation, and lifecycle management.

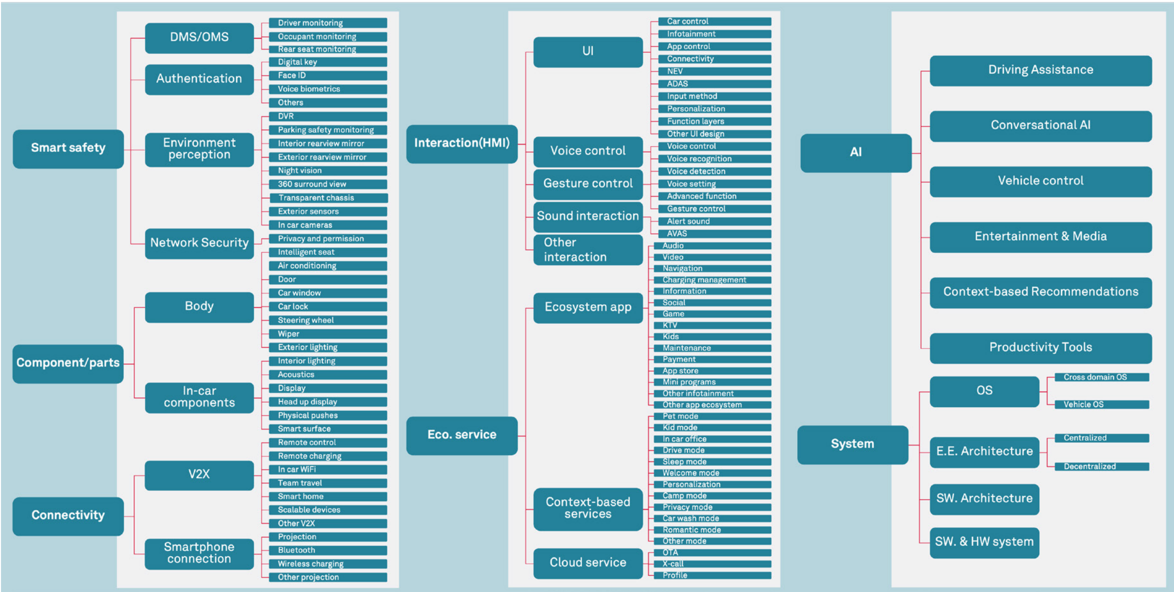

Figure 3: Updated Functions Classification

4.2 Classification Content

4.2.1 Safety Functions

"Safety functions" refer to features designed to protect drivers and passengers, including personal safety, information security, and anti-theft measures. These functions are organized into four secondary categories:

1. Environmental Perception

Functions that provide real time awareness of the vehicle external environment, whether stationary or in motion. Capabilities include capturing and synchronizing external data to deliver a broader and clearer view. When integrated with vehicle components or connected devices, these functions can enable advanced features, such as alerts and warnings for potential hazards.

2. In Cabin Perception

Functions that monitor the driver and passenger behaviors as well as pets within the vehicle. The primary objective is to detect abnormal or unsafe behaviors, reducing the risk of accidents and enhancing overall safety.

3. Authentication

Identity verification mechanisms such as biometric recognition, password validation, digital keys, etc. These functions control vehicle access and can activate personalized profiles or services upon successful authentication.

4. Network Security

Cybersecurity measures that safeguard the confidentiality, integrity, and availability of data collected, processed, stored, or transmitted by the cockpit system, ensuring continuous service and maintain system resilient against cyber threats.

Table 1: Safety functions classification

Second level	Third level	Description	Fourth level examples
Environmental Perception	Dashcam	Records images, videos and sounds of the driving environment	Video recording and viewing, event marking, saving, etc
	Parking Safety Monitoring/ (sentry mode)	Perceives threats to the vehicle in a parked state and triggers alarms and dashcam	Intrusion/collision alarm, video playback, remote access, etc
	Interior Rearview Mirror	Provides a broader view through real-time videos in the vehicle display, including rearview mirrors.	Examples include streaming rearview mirror, automatic anti-glare, etc.
	Exterior Rearview Mirror	Provides a broader view through real-time display devices outside the vehicle, including optical rearview mirrors and indirect vision devices.	Electronic rearview mirror view adjustment, exterior rearview mirror position memory, automatic anti-glare, etc.
	Night Vision	Enhances the driving environment at night or in low light, helping to obtain a clearer view.	Infrared lighting, danger warning, etc.
	360 Surround View	Uses multiple cameras installed around the vehicle to simultaneously capture images of the surroundings, then processes and stitches them together to form a 360-degree panoramic view.	Parking assistance, off-road condition assessment
	Transparent Chassis	Uses cameras and image processing technology to display real-time conditions under the chassis on the central stack display.	Off-road driving assistance, parking assistance.
	Exterior sensors	Sensors installed on the vehicle's exterior to identify road conditions, traffic signs, vehicles, pedestrians and obstacles, perceive the distance to surrounding vehicles; determine vehicle GPS positioning, etc.	Cameras, Lidars.
	Interior Camera	Installed inside the vehicle	Fatigue detection, attention monitoring, left items monitoring.
	Ultrasonic Sensor	Ultrasonic sensors for measurement and detection, applied outside intelligent vehicles.	Parking assistance, interior monitoring.
In cabin perception	Driver Monitoring	Uses sensors and monitoring devices to detect the driver's physiological state and behavior, mainly to reduce accidents caused by fatigue driving, distracted driving, and dangerous behavior.	Attention monitoring, action recognition, health and emotion monitoring.
	Passenger Monitoring	Monitors and identifies the physiological state and behavior of passengers in the front seat.	Action recognition, health and emotion monitoring.
	Rear Seat Occupant Monitoring	Monitors and ensures the behavior and status of rear seat passengers, such as detecting children or pets in the vehicle, or unsafe behavior by rear passengers during driving.	Child safety seat detection, living being monitoring.
Authentication	Digital Key	Lock/Unlock or remote start the vehicle without mechanical key.	NFC key, UWB key, mobile Bluetooth key
	Facial Recognition	Identifies passengers by analyzing facial features to provide personalized services.	Facial recognition login, personalized settings.

Second level	Third level	Description	Fourth level examples
Authentication	Voice Biometrics Recognition	Verifies the identity of passengers by detecting and comparing voice characteristics to provide personalized services.	Voice for login in, personalized settings.
	Other Identity Recognition	Other methods of identity recognition besides the above functions.	Fingerprint recognition, iris recognition.
Network Security	Privacy and Permissions	Protects the privacy and permissions of data collected by the vehicle (driving behavior, location information, in-vehicle activities, passenger information, etc.) to prevent improper use or potential security threats.	Anonymized data, strong passwords and authentication, security updates and vulnerability fixes, data encryption.

4.2.2 Interaction

“Interaction” refers to all in vehicle modalities through which drivers and passengers communicate and engage with the vehicle across various operational scenarios. These are classified into four secondary levels: graphical interface interaction, voice interaction, gesture interaction, and auditory interaction.

Table 2: Interaction classification table

Second level	Third level	Description	Fourth level examples
Graphical Interface	Vehicle Control	Interface for vehicle control	Vehicle control interaction widgets
	Infotainment	Interface for obtaining or managing information and engaging in infotainment system activities.	Audio and video playback, games, calendar, weather, message center, etc
	Application Control	Interface for controlling and setting application access permissions and display settings.	App store, control panel, app settings, multitasking interaction experience, etc
	Connectivity	Interface for communication and connectivity-related interactions.	Phone call, communication and connectivity status in the status bar, etc
	NEV	Interface for new energy vehicle information	Battery information, energy flow display, range display, energy consumption display, mileage display, etc
	ADAS	Graphical elements in the interface related to advanced driver assistance functions.	3D vehicle model display, vehicle different views, driving information, etc
	Input Method	Interface for users to input text, commands, or search queries using touch screens or other touch devices in the vehicle.	Virtual keyboard, handwriting input, predictive text, text input, etc
	Customization	Interface for customizing the display information and settings	Display brightness settings, themes, wallpapers, multi-language support, etc
Graphical Interface	Functional Layers	Interface design related to functional interaction layers, page transitions, and layout.	Interface layout, interaction logic, etc
	Other UI Design	Other graphical interaction designs are not covered by the above graphical interface.	Automatic brightness, animations and visual effects, audio effects visualization, etc

Second level	Third level	Description	Fourth level examples
Voice Interaction	Vehicle Control	Allows drivers and passengers to use voice commands to control vehicle functions.	Voice search, voice-controlled navigation, voice commands vehicle control, voice-activated multimedia resources, etc
	Voice Recognition	Voice Recognition: converts users' spoken language into text or commands, including recognizable languages, wake-up methods, and recognizable command types.	Dialect recognition, mixed Chinese English recognition, etc
	Voice Settings	Settings for voice assistants and voice interactions.	Voice assistant image settings, custom voice wake-up words, voice volume and speed adjustments, voice control settings, etc
	Sound Localization	Supports sound source localization zones and related settings.	Four-zone voice detection
	Advanced Functions	More advanced voice interactions beyond basic functions, including recognition, understanding, and intent prediction, making the voice interaction process more natural and intelligent. Examples include	Casual conversation, dialogue, speak what you see, interrupt at any time, children's companions, etc
Gesture Interaction	Gesture Control	Controls cockpit functions through gestures, multimodal interactions combined with gesture control.	Gestures to accept the call, gesture for volume adjustment, gesture settings, etc
Sound Interaction	Warning Sounds	Sound alerts when potential dangers, abnormal situations, or specific information need to be conveyed to the driver, using built-in sensors, software systems, and audio devices.	Low-speed driving warnings, collision warnings, etc
	Exterior Sound Interaction	Communicates and interacts with people, other vehicles, or facilities in the external environment using sound speakers.	External entertainment sounds, etc

4.2.3 Components

"Components" refer to all controllable, adjustable physical elements located within the cockpit or integrated into the vehicle. They are classified into two secondary categories based on their technical domain: body components and cockpit interior components.

Table 3: Components classification table

Second level	Third level	Description	Fourth level examples
Body Components	Intelligent Seats	In addition to basic seat adjustment functions, these seats include features integrated with intelligent technology.	Seat adjustment, seat memory, seat heating, seat ventilation, seat massage, child seats, seatbelt and airbag settings, special features, and other accessories.
	Air Conditioning	Besides basic air conditioning adjustment functions, these systems include features integrated with intelligent technology.	Temperature adjustment, airflow direction adjustment, rear air conditioning adjustment, defrosting and defogging.
	Door Control	Controls or settings for vehicle doors.	Trunk control, front and rear door control, automatic door control, charging cover control, trunk memory, etc.
	Windows control	Controls or settings for vehicle windows	Door window control, sunroof control, etc.
	Door Lock	Controls or vehicle locks, including unlocking and locking logic	Door lock/unlock, children door lock
	Steering Wheel Control	Settings related to the steering wheel.	Steering wheel position memory function, steering force adjustment, etc.
	Wipers	Controls or settings for wipers, including features integrated with technology	Automatic sensing wipers, wiper heating, etc.
	Exterior Lights	Exterior lights (such as headlights, taillights, turn signals, etc.) can be automatically or semi-automatically adjusted and controlled based on the vehicle's environment, driving status, driving intentions, and traffic conditions, achieving various lighting and signal indication functions.	Lighting navigation assistance, welcome lighting effects, lighting shows, etc.
	Outdoor Storage	Enhances the convenience and functionality of the vehicle for outdoor use, involving comprehensive facilities and corresponding functions related to refrigeration, item towing.	Refrigerators, towing mode, etc.
	Storage	A series of facilities and functions related to optimizing the storage, retrieval, and management of items inside the vehicle.	Heated/cooled cup holders, rear seat trays, glove box function optimization, etc.
Cockpit Interior Components	Intelligent Interior Lights	The vehicle's interior lighting system can automatically, flexibly, and diversely adjust and control lighting based on the needs of the occupants, vehicle status, and surrounding environment.	Ambient lighting, reading lights, dome lights, footwell lights, etc.
	Intelligent Audio system	The audio system, combined with intelligent technology, provides more intelligent, personalized, and high-quality audio experience for vehicle occupants.	Volume adjustment, audio effects, audio zones, etc.

Second level	Third level	Description	Fourth level examples
Cockpit Interior Components	Display	Display shows various information to the driver and passengers, enables vehicle function control, and provides entertainment content.	Central stack display, instrument display, passenger display, head-up displays, AR-HUD, etc
	Vanity Mirrors	Meet driver and front passengers' need for makeup and grooming.	Vanity mirrors for the driver and front passenger, vanity mirrors with beauty, sun protection, and lighting functions

4.2.4 Services

Services refer to software and services delivered through the cockpit to drivers and passengers. These are categorized into three secondary categories: in-car application ecosystem services, scenario-driven services, and cloud enabled services.

Table 4: Services classification table

Second level	Third level	Description	Fourth level examples
In Car Apps	Audio	Online/Offline music platforms and audio resource from external connected devices provided in the cockpit, along with related settings.	Audio connection, audio settings, audio applications
	Video	The video resource playback service of the online/offline video platform and external connected devices provided in the cockpit, as well as related settings, etc	Video center, video connection, video Settings, video apps, and more
	Navigation	Different driving modes (manual driving, automated driving combined with different visual effects and voice prompts, help drivers plan routes, navigate, points of interest, provide real-time positioning, traffic and map information, and make relevant settings)	Map service, address management, high-precision map, route planning, energy planning, navigation setting
	Charging Management	Manage and set up battery charging and energy utilization for vehicles	Battery management, energy forecasting and management, charging planning, and more
	Information	Integrated information in the cockpit	Calendar, clock, date, schedule management, user manual, web browsing, weather, notifications/message center (message type, message list, etc.), mileage statistics, infotainment storage, etc
	Social Media	In-car WeChat app integrated into the cockpit	Voice calls, sending and receiving WeChat, sending location and destination, etc
	Game	In car games	A variety of games in various interactive forms such as touch screen, gestures, controllers, steering wheels, XR, etc
	KTV	KTV apps integrated in the cockpit	Sound adjustments, multiplayer mode, and more

Second level	Third level	Description	Fourth level examples
In Car Apps	Kids	Resources for children	Kid-friendly interface, children's radio, children's games, etc
	Maintenance	Manage and maintain the vehicle's features	Vehicle health status inquiry, fault inquiry, remote diagnosis, etc
	Payment	In-car payment	Gas payment, parking payment, toll payment, online shopping payment, etc
	App Store	Provide a platform for users to download, install, and update in-cabin applications	App installations, app categories, app updates, problem feedback, etc
	Mini Programs	Mini programs integrated in the cockpit	Mini programs management
	Other Entertainment	Entertainment other than the above	Photo albums, artboards, custom Q&A communities, fitness, and more
	Other Application Ecosystems	Application ecosystem services other than those listed above	AR glasses, owner communities, etc
Scenario-based services	Pet mode	When pets stay alone in the car, multiple functions are activated at the same time to ensure their comfort and prevent potential safety hazards	Air conditioner constant temperature management, turn on external circulation, etc
	Baby mode	The scene of children as passengers, activating multiple functions at the same time, providing relevant educational and entertainment resources, and preventing potential safety hazards	Set the maximum speed limit, set the maximum volume, Songs and story resources, etc
	In car office	In the work-study scenario, multiple activations are made at the same time functions, provide related applications, guaranteecomfort and ease of use in this scenario	Automatic seat adjustment, office learning software, etc
	Driving mode	Allows the driver to choose different driving settings and modes according to different driving situations and personal preferences, adjusting power, suspension, steering wheel	Mode options such as Sports Mode, Standard Mode, Economy Mode, Snow Mode, Custom Mode, etc
	Sleep mode	Scenes of sleeping or napping in the car, activating multiple functions at the same time, providing an environment for rest and relaxation in the car	Adjust the seat, keep the air conditioner at a constant temperature, wake up at a regular time, etc
	Welcome mode	When drivers and passengers are about to enter and exit the vehicle, create a ceremonial environment that is easy to get in and out of	Automatic seat and steering wheel adjustment, welcome lighting and much more personalization
	Custom mode	Allows the driver to adjust multiple settings in the cabin according to personal preferences and needs, enabling one-button start	Seat and driving position settings, cabin environment settings, audio and media settings, etc
	Camping mode	A range of preset combinations of features for camping scenarios.	Trunk setting, external discharge, automatic power replenishment, etc
	Privacy mode	The vehicle may restrict or adjust some functions to protect the private information of the occupants from being obtained by the outside world or unauthorized access by other persons in the vehicle.	Phone privacy, etc

Second level	Third level	Description	Fourth level examples
Scenario-based services	Car wash mode	A combination of functions that are pre-set for the vehicle's cleaning needs. It helps users clean the interior of the car more conveniently and efficiently by coordinating multiple systems in the car, such as air conditioning system, ventilation system, water spray system and seat cleaning system, etc., and keeps the interior environment clean and hygienic.	One-click to turn on car wash, screen cleaning, etc
	Romance mode	A special function mode that integrates a variety of interior systems to create a romantic atmosphere. It mainly creates a warm, pleasant and emotional environmental experience for the driver and passengers in the car by adjusting the lighting, music, seat position and fragrance system in the car.	
	Cinema mode	With the help of various hardware and software resources of smart cars, this mode is turned on to create an immersive audio-visual entertainment experience for the occupants in the car	The front seats can be folded down with one click, combining the projection screen with the theater-like Dynaudio sound, private mode, and movie mode.
	Energy saving mode	The core goal is to optimize the vehicle's energy consumption and improve energy efficiency to extend the range or reduce energy costs	Added screen-off mode, support for parking comfort when charging on low battery, etc
	Other modes	Other scenario modes and proactive scenario-based services. Proactive scenario-based services automatically perceive and identify the current state, understand scenarios, predict intentions, and proactively provide or recommend multiple services and settings	Active recommendation of scene music, automatic power-saving mode, etc
Cloud Services	OTA	Provide remote updates and upgrades to electronic control units or on-board systems in the vehicle via the cloud	FOTA (SOTA) OTA information and settings
	X-Call	Assistance is provided through a backend service center	Emergency calls, roadside assistance, contact customer service, etc
	Account/Personalization	Set up and manage different account categories, personalized settings under different accounts, distinguish rights and interests, and realize account interoperability between multiple platforms	Account management, account settings, query account information, etc

4.2.5 Connectivity

Connectivity refers to vehicle cockpit exchange data external systems and devices. It is classified into two primary domains: V2X communications and smartphone–vehicle connection.

Table 5: Connectivity classification table

Second level	Third level	Description	Fourth level examples
V2X	Remote Control	Vehicle owner or authorized user to remotely control the vehicle through a mobile application	Remote lock/unlock, find your car, remote control air conditioning, etc
	Remote Charging	Remote charging allows car owners to do so via a smartphone app to remotely control the charging of the vehicle	Remote charging control, set charging time, etc
	In-Car WiFi	WiFi hotspots, hotspot connection settings	In Car WiFi /hotspot switch, WiFi settings, etc
	Team Travel	Group travel features and related settings	Group travel navigation, team vehicle management, etc
	Smart Home	Control smart home appliances through vehicles. It allows remotely control vehicle or remotely check vehicle information and vehicle environment information via home devices does not belong to this category and belongs to remote control	Remotely control smart home appliances such as sweeping robots and home air conditioners
	Plug & Play IoT devices	Expand the cockpit functionality and experience by connecting other devices	Smartwatches, Karaoke microphones, etc
	Other V2X	In addition to the above functions, other connected	A variety of games in various interactive forms such as touch screen, gestures, controllers, steering wheels, XR, etc
Smartphone Projection	Phone Projection	After connecting the mobile phone to the cockpit, the apps in the mobile phone are projected to the vehicle infotainment system. It includes not only a simple phone mirroring function, but also a well-integrated interconnection system that can achieve a high degree of adaptation and seamless integration.	CarPlay, Android Auto, HiCar
	Bluetooth	Connect smartphone to the cockpit via Bluetooth pairing. It can synchronize phone calls, contacts, music, etc. to the car.	Bluetooth phone, Bluetooth music
	Charge your phone	Wireless charging function and related reminder function	Wireless charging in the front row, charging status display, wireless charging alerts
	Other Smartphone Connect	Other functions	Reminders, etc

This year's guideline expands new primary and secondary functions related to AI technology and digital foundation.

4.2.6 Artificial Intelligence (AI)

Artificial Intelligence is increasing central to China's intelligent vehicles, integrating multiple technological dimensions to elevate autonomy levels, user experience, safety, and overall vehicle performance.

AI Interaction and Communication

Defines human machine interfaces that enable efficient, natural interaction and information transmission between the vehicle, occupants, and the external environment. Leveraging multimodal interaction (voice/vision/motion) alongside LLM-enhanced voice technologies, these capabilities deliver smooth HMI, personalized services, and reliable in-vehicle and external communications.

AI Perception and Decision-Making

Equips intelligent vehicles to perceive their surroundings and understand in-cabin status, then respond appropriately. Utilizing eye-tracking and vision-language models for perception, and chassis control/ embodied-intelligence techniques for control, the system makes context-aware decisions to manage complex driving and usage scenarios.

AI driven Hardware

Covers the compute, storage and sensor stack that enables AI at scale. Representative elements include advanced-node storage/computer chips, AI-assisted simulation platforms, full-spectrum sensing arrays, chiplet architectures and emerging technologies (e.g., quantum-adjacent research). Together, they provide performance, perception, and data-processing backbone for intelligent vehicles.

AI Algorithms and Models

Constitutes the core intelligence layer. World-model approaches (e.g., "Cosmos" and related frameworks) learn from large-scale datasets to build structured representations of the real world. Model and system efficiency is enhanced via architecture such as Mixture-of-Experts (MoE); cloud orchestration coordinates large and small models for interaction and decision-making. Simulation and virtual calibration embed these capabilities into vehicle design, validation and optimization.

Overall, AI technology is implemented in different vehicle systems.

Classification Matching Principles

Entertainment & Media: Focus on "audio-visual, creation, entertainment interaction" functions, with the core goal of enhancing the in-vehicle entertainment experience through AI-generated content and interactive optimization.

Conversational AI: Focus on "voice interaction, large model Q&A, casual chat" functions, centering on natural language interaction technologies to achieve human-like dialogue between humans and vehicles.

Context-based Recommendations: Focus on "personalized recommendation based on scenarios/behavior" functions, using multi-source data fusion and scenario recognition to provide accurate and real-time recommendations.

Productivity Tools: Focus on "efficiency improvement, task processing" functions, aiming to enhance the efficiency of in-vehicle affairs handling through AI technology.

Vehicle Control: Focus on "intelligent adjustment of vehicle hardware/cockpit functions" functions, realizing closed-loop intelligent control of vehicle physical systems through AI algorithms.

Driving Assistance: Focus on "ADAS, intelligent driving algorithm optimization, active safety" functions, improving driving safety and comfort through AI perception and decision-making technologies.

Table 6: AI functions classification table

First level	Second level	Description	Use cases examples
AI	Driving Assistance	Relying on AI perception, decision-making, and planning-control technologies, it optimizes intelligent driving-related functions, covering scenarios such as highway/city NOA, parking, active safety, and driving behavior correction to improve driving safety and comfort	1. MAI enhances the response to cut-in vehicles and improves comfort during frequent starts and stops; 2. AI improves the accuracy of AEB (Automatic Emergency Braking) target recognition and active braking capability 3. The fatigue detection algorithm is optimized, and AI enhances the performance of eye opening/closing detection and detection in backlight scenarios
	Conversational AI	With large models and voice interaction technologies as the core, it realizes natural and efficient voice dialogue between humans and vehicles, covering scenarios such as Q&A, casual chat, multi-round interaction, and intent understanding, supporting wake-up-free, continuous dialogue, and context memory	1. Large model-based voice interaction for navigation scenarios (new user guidance for AI valte driving); 2.Upgraded voice assistant with enhanced intent understanding, multi-round dialogue, and mathematical reasoning capabilities
	Entertainment & Media	Centered on in-vehicle entertainment and multimedia scenarios, AI technologies enrich content supply, optimize interaction forms, and enhance the entertainment experience during driving, covering dimensions such as audio and video, creation, and personalized content generation	1. Customized in-vehicle version of a social content app is added, with AI recommending travel-related notes and linking with navigation; 2. AI-powered playlist recommendations (frequently played, million-collection, next favorite song) are added to a music app; 3. AI lab application is launched, supporting AI symbol drawing; AI story etc.
	Context-based Recommendations	Based on user behavior, scene characteristics (such as travel trajectory, driving habits, passenger attributes) and other data, AI algorithms achieve personalized and scenario-based content/function recommendations to improve service accuracy	1. Route prediction function is added, with AI predicting user behavior based on historical travel records and recommending routes; 2. AI recommends energy-saving power modes for high-speed driving combined with big data; 3. AI personalized content recommendations covering music, food/scenic spots, and short video retrieval
	Vehicle Control	Based on AI algorithms, it realizes intelligent adjustment and control of vehicle hardware/functions, covering dimensions such as chassis, air conditioning, cockpit environment, and equipment linkage, improving the intelligence and humanization of vehicle control	AI optimizes automatic defogging algorithm to accurately identify fogging risks and adjust defogging priority;

First level	Second level	Description	Use cases examples
	Productivity Tools/ Algorithms and Models	A wide range of advancedtechnologies and architecturesprovide powerful intelligentsupport for smart cars, enablingvehicles to process data moreefficiently, make decisions, andoptimize their capabilities. In thefield of intelligent cockpits, theapplication of AI algorithms andmodels will expand from voiceinteraction and entertainmentfunctions to more fieldssuch as health monitoringand emotion recognition,providing more care services fordrivers and passengers	Cosmos world basic model,world model, device-cloudintegrated large model,small language model, MoEarchitecture (hybrid expert systemarchitecture, D2D interconnectiontechnology (device-to-deviceinterconnection), cloudedgecollaboration, agent AI(AI agent), etc

4.2.7 System (Digital Foundation)

Digital foundation serves as the backbone for intelligent, automated, and connected vehicle operation. It encompasses the operating system, electronic & electrical (E/E) architecture, and software architecture, integrating critical technologies and components to support feature development, enhance performance, and ensure scalability. This foundation also underpins continuous delivery of updated cockpit software and services to end users.

In this guideline update, Digital Foundation is formalized as a new primary category, comprising three secondary domains:

Operating System

Electronic & Electrical (E/E) Architecture

Software Architecture

Table 7: System classification table

First level	Second level	Description	Use cases
System	Operating System	The software system that manages and controls the vehicle's hardware and software resources. It ensures seamless coordinated operation among various vehicle systems, and provides foundational support required for intelligent applications	Vehicle Operating System
	E/E Architecture	The integrated system architecture that organizes and connects the vehicle's electronic systems, communication networks, and related software. Its purpose is to enable efficient operation and coordination of various vehicle functions, support for the development of intelligent and connected vehicle capabilities.	Zonal architecture, central compute, cockpit-driving fusion solution based on single SoC chip, single board or multi domain functions integrated into one high performance computer.
	Software Architecture	The structural design that defines the organization of software components, modules, and their interrelationships. It provides the framework for implementing complex functionalities and ensuring scalability, maintainability, and performance.	Intelligent vehicle software architecture based on SOA (Service-Oriented Architecture); multi-core heterogeneous computing

5 Software defined Vehicle Key Technology Analysis

As outlined by Prof. Cao Dongpu's article “Definition of CL3 Advanced Cognitive Intelligent Cockpit”, a CL3 advanced intelligent cockpit requires “system integration - digital base: with state awareness, vehicle memory, large model orchestration, demand prediction, and system monitoring capabilities.”

CL3 Advanced Intelligent Cockpit Guideline

VOLKSWAGEN GROUP CHINA | CHINA SAE

Level	Key Characteristics	Human Machine Interaction	Connected Services	Scenario Expansion
CL3 Advanced Intelligent Cockpit	Tasks can be done across different scenarios in cabin and outside of vehicle; Able to active perceive driver and passenger, automate part of tasks; Open connected services	Partially active interaction	Open connected services	Expansion of in vehicle and external vehicle scenarios

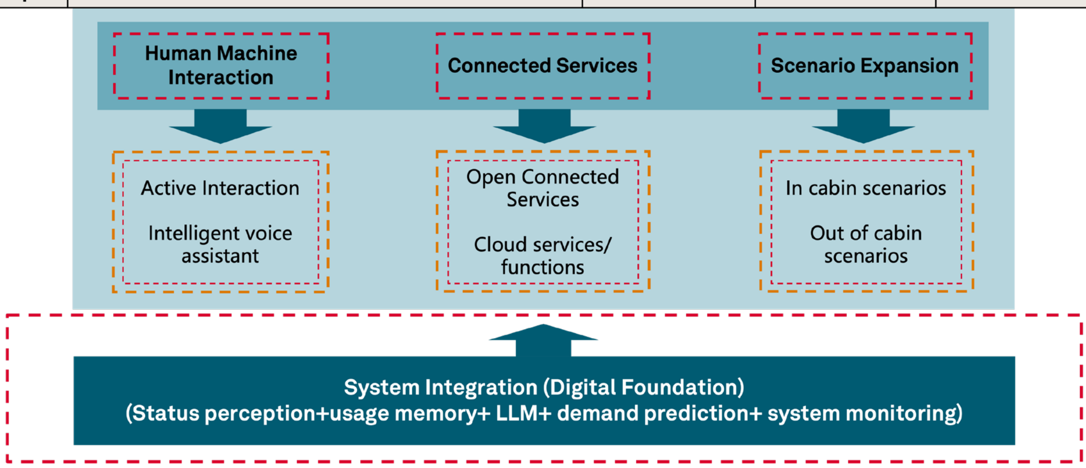

Figure 4: CL3 Advanced Intelligent Cockpit Guideline Framework

5.1 Core Concepts of Software defined Vehicle (SDV)

Software-Defined Vehicle (SDV) is a concept where vehicle functions are delivered, evolved and monetized primarily via software. By decoupling software from hardware, and adopting a service-oriented architecture, SDVs enable continuous software upgrades and expansion of vehicle functions over the vehicle lifecyle.

Essentials

Hardware Platform

Standardized and modular hardware design reduces the system complexity arising from hardware diversity, enabling reuse and consistent performance scaling.

Service-Oriented Architecture

Vehicle functions spanning perception, control, cockpit, connectivity, and subsystem modules can be managed as services, allowing dynamic reconfiguration and features updates via over the air updates.

As electrification, intelligence, and connectivity converge, SDV has become a defining direction for automotive development, reshaping traditional engineering and operation models and accelerating industry transformation.

Key Outcomes

Continuous Function Evolution

Through OTA updates and upgrades, ADAS/AD functions, cockpit infotainment and digital experiences can be iterated post-launch. This supports personalized feature bundles tailored to differentiated user needs.

Reduce Development Cost

A unified software architecture with lower component complexity, cross platform software reuse, and shortens development and iteration cycles for faster time-to-market.

Business Model Innovation

Revenue shifts from one-time hardware sales toward recurring software subscriptions and value-added services (e.g., advanced driving capabilities, online entertainment, cloud analytics). With data operations and ecosystem partnerships, OEMs extend lifecycle value beyond the initial sale.

5.2 Key components of the Digital Foundation

5.2.1 Centralized E/E architecture

Domain Centralized Architecture: The vehicle E/E system is partitioned into domains (e.g., cockpit, ADAS, powertrain, chassis, body), orchestrated by high-performance domain controller. Controllers coordinate over a backbone network (e.g., Ethernet), simplifying wiring, boosting performance and enabling functional integration while providing a smooth transition from legacy to next-gen design. Domain controllers handle most of the data processing and coordination within the domain and inter domain changes through the vehicle's backbone network.

Central Compute Architecture: Core compute and data processing are consolidated into a central computing unit (CCU), with all functional modules interfacing through a high-bandwidth, low-latency network. This maximizes cross domain data fusion and communication efficiency, for example, the autonomous driving function and cockpit system can share some data through the central computer platform, achieving deep interconnection and functional coupling across domains. It further reduces the latency of data interaction between domains within the vehicle. The system is designed to be scalable for future high-level autonomous driving and large-scale sensor deployment needs.

Overall, the technological evolution path from domain architecture to central compute, from multi-domain control to cross-domain integration, will gradually move towards a more efficient and centralized computer architecture as vehicle computing power demands increase and semiconductor technology continues to upgrade over time.

5.2.2 Network Architecture and Data Bandwidth

High-Bandwidth Ethernet as Backbone

As sensor counts and resolutions (cameras, radars, lidars, etc.) rise, high throughput data transport becomes essential. Traditional CAN/LIN buses cannot meet these high-bandwidth requirements, and automotive-grade Ethernet (e.g.100BASE-T1, 1000BASE-T1) is increasingly adopted as the backbone to enable timely data processing and reliable system operation.

5.2.3 Vehicle Communication Protocols

Traditional communication (CAN, LIN, FlexRay, etc.) remains essential for cost efficient, deterministic and safety critical functions (e.g. powertrain, chassis control, etc.).

Ethernet coexists with these CAN/LIN network with gateways ensuring stable, secure interoperability and end-to-end real-time performance where required.

5.2.4 Software Architecture and Function Layers

Software Architecture

Signal-based software architecture: Simple, deterministic interfaces for tightly coupled safety-critical functions.

Service-Oriented Architecture (SOA): Functions exposed as services to accelerate integration, deployment and updates.

Hybrid: Combines signal-based determinism where needed with SOA flexibility for rapid iteration and modular management.

Operating System and Middleware

Vehicle operating systems (such as RTOS, hypervisor) and middleware abstract heterogeneous hardware, orchestrate shared resources and provide standardized interfaces to upper-layer applications. This enables software reuse across domains and platforms and enabling coordinated, cross-domain applications.

Cloud and Edge Network Security

Vehicle cybersecurity threats span network and physical layers, including vehicle communication, sensor data integrity and protection, OTA upgrade process security verification, cloud service and edge node access security, etc. Safeguards include hardware security modules (HSMs), cryptographic authentication, multi layer firewalls, and comprehensive security event monitoring and incident response across the vehicle lifecycle.

5.2.5 Connectivity

Network Bandwidth and Communication

With the advancement of 4G LTE and 5G, the communication speed and stability between vehicles and the cloud have significantly improved, enabling larger-scale real-time data exchanges and edge computing. OEMs can deliver high-value services such as remote diagnostics, cloud-assisted perception, and data analytics to enhance functionality and user experience.

Over-the-Air (OTA) Updates

Remote software upgrades of the vehicle's functionality, including vehicle control, cockpit systems, ADAS/AD systems, and other functions reduce recall cost and enable rapid response to market feedback. This significantly shortens feature iteration cycles and optimizes the overall digital experience.

5.3 SDV Challenges and Outlook

5.3.1 Challenges

Software and Hardware Decoupling

Mitigating legacy platforms and supply chains to a SDV paradigm is a multi-year transformation. Existing E/E architectures and standards must be reengineered to support decoupled software layers, while OEMs must manage BEV-native and legacy vehicle platforms in parallel. The development model also needs to shift from a traditional V-cycle to software iterative and agile development.

High Upfront Investment

OEMs face significant initial capex and opex to build high-compute hardware platforms, vehicle operating systems, and modern development/testing toolchains. Organizational capabilities must evolve as well, expanding capabilities in software engineering, AI/algorithms, data, and DevOps, alongside broad reskilling initiatives and new ways of working.

Ecosystem

SDV success hinges on aligned standards and interoperable technology stacks among OEMs, Tier-1s, software vendors, cloud providers, and broader tech partners. Achieving the right balance between open interfaces and robust data protection is essential for ecosystem vitality and sustainable business.

5.3.2 Prospects

New Auto Value Chain

The center of gravity shifts from mechanical hardware to a blended hardware–software–services model. Continuous, user-centric experience improvement becomes a primary differentiator and the core driver of enterprise value.

Advancing Toward "Intelligent" Mobility

SDV enables deep integration with external digital ecosystems (intelligent transport, smart home), linking people–vehicle–environment across scenarios. Higher-level automated driving and intelligent personal assistant will depend on SDV's cross-domain data fusion, rapid software iteration and over-the-air updates.

Faster Innovation and New Revenue Streams

A standardized vehicle software platform accelerates the development and integration of new applications (entertainment, productivity, information services, personalized assistants). Data-driven business models—subscriptions, usage-based insurance, vehicle health management and prognostic, and more, unlocks recurring revenue streams beyond the initial sale.

In summary, software-defined vehicles are reshaping the industry from one-off product transaction to ongoing value creation centered on software and services. Progress rests on: E/E architecture evolution from domain-centric to centralized compute architecture; higher in-vehicle communication bandwidth; modular, service-oriented software; and robust security and data compliance. While decoupling complexity, upfront cost, and ecosystem coordination remain non-trivial, maturing technology and deeper cross-industry collaboration are set to deliver safer, more efficient, and personalized mobility experiences at scale.

6 Cases Studies

6.1 Over-the-air updates

OTA (Over-the-Air) updates enables automakers to deliver software fixes, performance optimizations, and add new vehicle functions over cellular networks. As vehicle intelligence and connectivity bandwidth improves, OTA technology reduces time to remedy software defects, add new features, and continuously improves user experience.

Based on the data in Figure 5, three trends emerge:

At first, the proportion of component-related functions is decreasing year by year: In 2022, component-related OTA functions accounted for 23%, which decreased to 16% by 2024, reflecting the increase maturity and stability of underlying hardware.

Secondly, the proportion of service-related and interaction-related functions fluctuates: The proportion of service-related functions reached a high of 29% in 2023 but decreased in 2024; interaction-related functions showed similar fluctuations. This indicates ongoing experimentation by automakers as they calibrate service and interaction to adapt to market and user needs.

Thirdly, rising share of ADAS functions, ADAS related OTA increased from 15% in 2022 to 23% in 2024, underscoring growing demand for driver-assistance functions and the industry's expanding investment in related software functionality.

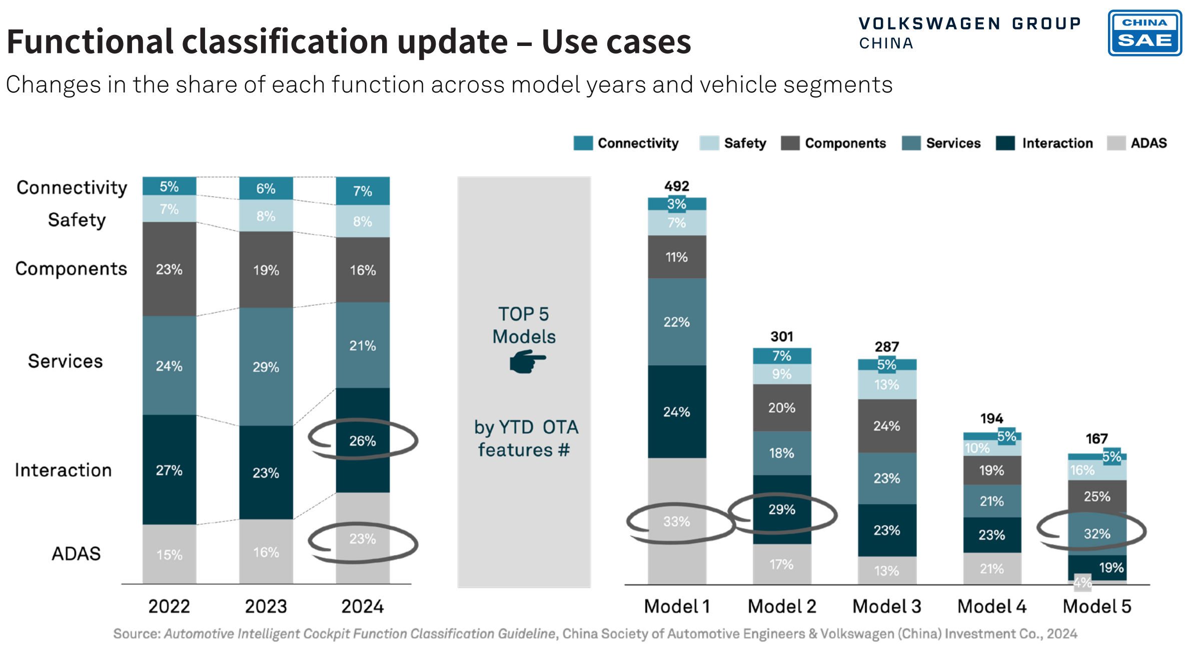

Figure 5: Recent three years top 5 sales models OTA functions changes

TOP 10 OTA feature in terms of YTD feature number

VOLKSWAGEN GROUP CHINA

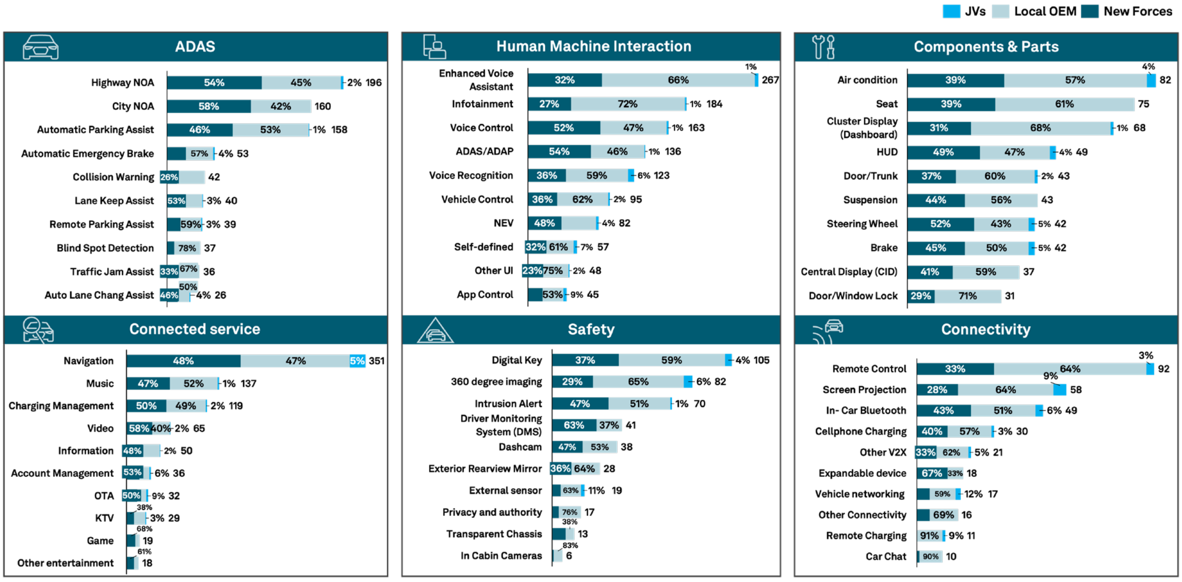

Figure 6: OTA functions classification

6.2 Adoption vs Consumer Importance – Analytics Framework

By mapping feature adoption rates against consumer perceived importance, we can identify the gap between current feature deployment and consumer expectations. Figure 7 illustrates a matrix comparing intelligent function adoption rates with consumer importance. The analysis reveals four strategic quadrants:

Quadrant I
Star Functions

Features that are both highly valued by users and widely adopted include intelligent seats, premium acoustic systems, voice command, navigation, and remote control. These functions represent mainstream demand and have become standard offerings in the market.

Quadrant II
Rationalize/ Refocus Strategy

Features with high adoption but relatively low consumer-perceived value, such as intelligent exterior lights, scenario-based services and scalable connectivity. Despite broad availability, these functions deliver limited perceived benefit, signaling the need to refine value proposition, streamline portfolio and rebalance investment.

Quadrant III
Exploration

Features with low adoption and low consumer importance, such as biometric authentication and occupant monitoring. These remain niche or non-core, best positioned as optional or personalized packages for targeted segments without diverting focus from core roadmaps.

Quadrant IV
Differentiation Strategy

Features highly valued by consumers but with low adoption rates, including driver fatigue monitoring, HUD/ AR-HUD systems, ambient lighting, and surround-view solutions that enhance safety and comfort. These represent unmet demand and potential differentiation opportunities, contingent on supply chain readiness and cost optimization.

Strategic value of feature classification: User x installation rate x experience

Strategic value of feature classification

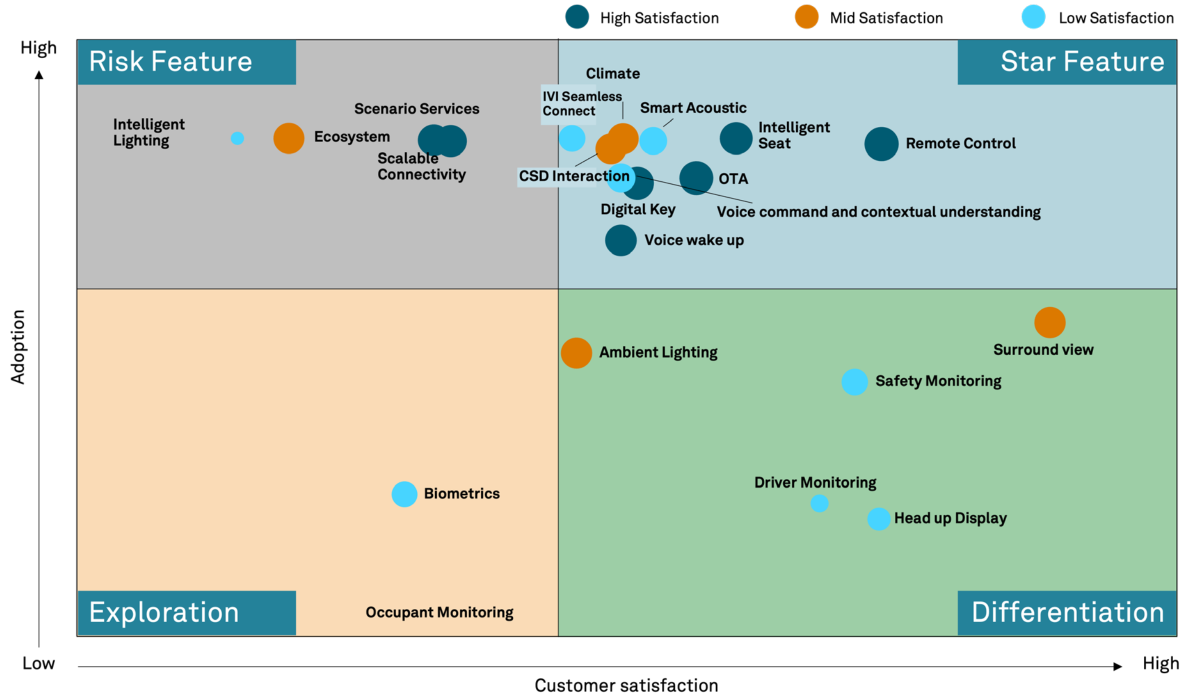

Figure 7: Features adoption rate/ Consumer importance Matrix Satisfaction

6.3 Adoption vs Industry Evaluation – Cross Analysis

The functional taxonomy outlined in this guideline is fully integrated in the Automotive Intelligent Cockpit Intelligence Test Evaluation Standard (the "Test Evaluation Standard"). This classification is consistently applied throughout testing and scoring, ensuring methodological alignment and enabling direct comparability with this guideline. Such consistency facilitates cross-referencing between research findings and evaluation results, supporting the development of coherent industry standards.

In 2024, under the Test Evaluation Standard, the Society of Automotive Engineers conducted an assessment of 33 intelligent functions across 11 mainstream electric vehicle models. The evaluation results show that:

High satisfaction (top 10 by scores)

Functions include intelligent seats, scenario-based services, extensible device connectivity, remote vehicle control, and other functions.

Medium satisfaction (ranked 11-20)

Functions include central stack display interaction, ecosystem services, air conditioning, and steering wheel control.

Low satisfaction (ranked below 20)

Functions include exterior rearview mirrors, seamless infotainment connectivity and intelligent exterior lighting, despite relatively high adoption rates received lower evaluation scores.

Feature Name	Category Level One	Installation Rate	Satisfaction Level
Center Screen Interaction	Interaction	100.0%	Medium Satisfaction
Center Screen Interaction	Interaction	100.0%	Medium Satisfaction
Center Screen Interaction	Interaction	100.0%	Medium Satisfaction
Center Screen Interaction	Interaction	100.0%	Low Satisfaction
Exterior view mirror	Safety	100.0%	Low Satisfaction
Seamless connect with infotainment	Connectivity	100.0%	Low Satisfaction
Smart seat	Interaction	100.0%	High Satisfaction
Ecosystem	Services	100.0%	Medium Satisfaction
Smart Exterior Lighting	Interaction	100.0%	Low Satisfaction
Smart Climate	Interaction	99.9%	High Satisfaction
Scenario Services	Services	99.6%	High Satisfaction
Smart Acoustic System	Interaction	99.5%	Low Satisfaction
Scalable Devices Connect	Connectivity	99.4%	High Satisfaction
Remote Control	Connectivity	98.9%	High Satisfaction
Steering Wheel Control	Interaction	97.9%	Medium Satisfaction
Voice Recognition and Context Understanding	Interaction	92.0%	Low Satisfaction
Remote Update	Services	91.9%	High Satisfaction
Digital Key	Safety	90.9%	High Satisfaction
Voice Location Detection	Interaction	79.3%	High Satisfaction
Voice Command Wake Up	Interaction	79.3%	High Satisfaction
Vehicle Surround View	Safety	62.7%	Medium Satisfaction
Ambient Lighting	Interaction	56.5%	Medium Satisfaction
Vehicle Safety Monitoring	Safety	50.6%	Low Satisfaction
Account Management	Services	41.4%	High Satisfaction
Biometrics	Safety	27.8%	Low Satisfaction
Driver Monitoring System	Safety	26.0%	Low Satisfaction
Head up Display	Interaction	22.8%	Low Satisfaction
Smart Home Connect	Connectivity	7.6%	Low Satisfaction
Occupancy Status Monitoring	Safety	3.4%	Low Satisfaction

Based on the evaluation results, two key optimization strategies are proposed:

1. Enhanced Features with High Adoption but Low Satisfaction

Conduct comprehensive user research on features such as "seamless vehicle-applications transfer," "exterior rearview mirrors," and central control screen interaction (Type 3: Task 3 Navigation to Destination). Identify specific pain points impacting user experience (such as operational complexity, slow response speed, limited functional utility, etc.). Apply targeted improvements to address these issues and elevate overall satisfaction.

2. Leverage high adoption rate features for brand differentiation

Prioritize R&D and marketing efforts around selected high adoption features that align with the manufacturer's technical strengths. Enhance user experience of these features and position them as key differentiators in branding and promotional campaigns. This approach can strengthen brand competitiveness and increase market appeal.

6.4 AI Applications in Intelligent Cockpit

AI applications within digital cockpit are categories into three primary functional and services domain, forming the foundation for next generation intelligent user experiences.

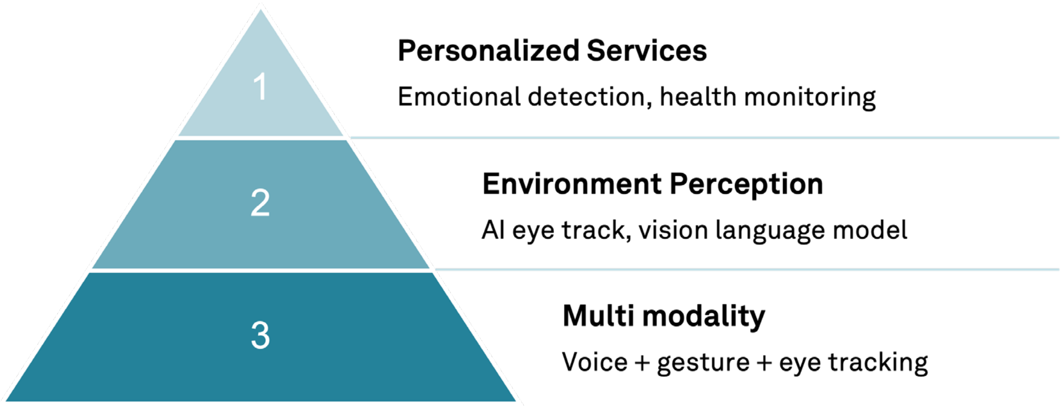

Figure 8: AI applications

In China market, 55 automotive brands have already applied AI technologies into intelligent cockpits. Among them, new energy vehicle (NEV) brands are at the forefront of this trend, while traditional car companies are accelerating their innovation. AI empowers intelligent cockpits through OTA updates rather than factory-installed equipment, enabling continuous feature evolution post-delivery.

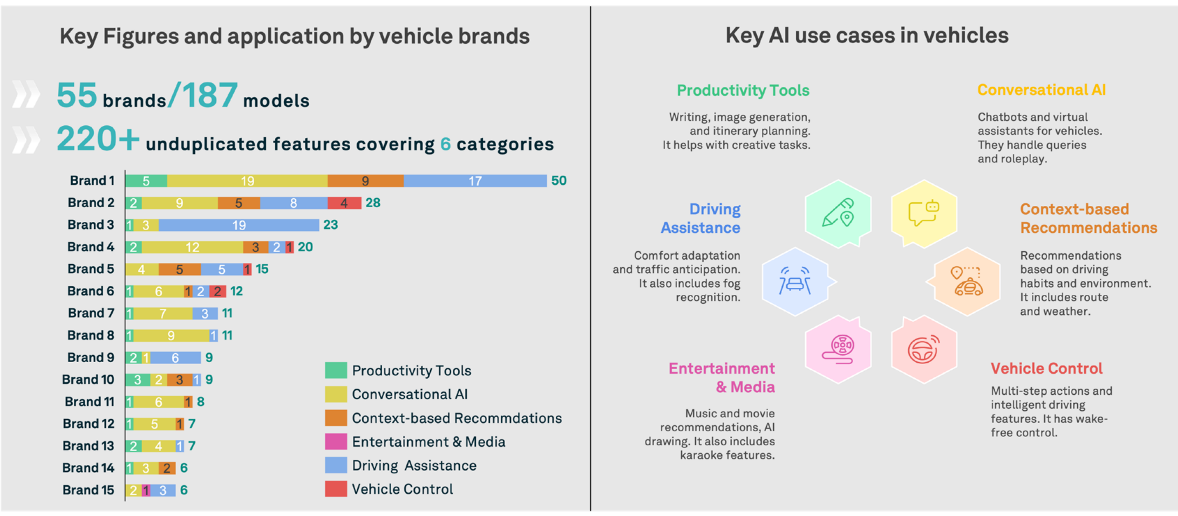

Figure 9: Key AI use cases and applications

The most common applications of AI in cockpit functions are in cockpit interaction and intelligent driving. Industry research has confirmed that the deployment of AI large model, several vehicle models in China now achieve over 95% accuracy in voice command recognition. Additionally, driver monitoring systems (DMS) can detect abnormal behaviors with over 85% accuracy. However, advanced capabilities such as emotion, intent, and preference recognition for both drivers and passengers remain in early development stages. Looking ahead, emerging trends in AI Assistants for the

Digital Cockpit:

1. Emotional Companion and Personalization

Next-generation AI assistants are evolving into empathetic companions, offering personalized interaction modes such as Kid Mode for child passengers, while tailoring responses, voice, and content to individual user profiles.

2. Multi-Modality and AI-Generated Content

AI assistants are moving beyond voice interaction to incorporate vision, gesture, and touch inputs, enabling seamless multimodal interaction. Coupled with AI-generated content, these systems deliver dynamic entertainment, personalized information, and contextual recommendations.

3. Task-Oriented Agent Mode with Service Integration

Advanced AI assistants are adopting agent based architectures, orchestrating complex tasks by integrating vehicle data with external services such as Points of Interest (POI) search, restaurant booking and and other location-based services, delivering end-to-end in-car service experiences.

4. Driving Safety Enhancement through AI Guidance

Embedded AI "driving tutors" provide real-time driving feedback, hazard alerts, and safety coaching, helping drivers improve skills and maintain safer on-road behavior.

10 standout use cases with strong customer impact

VOLKSWAGEN GROUP CHINA

Use Case	Description	Value	Use Case	Description	Value
Wake-free full-scene dialogue	Understands without wake-up words	Seamless, natural cockpit UX	Voice assistant appointment	Set future tasks by voice	Agentic behavior inside the car
AI Travel Assistant (GPT)	Recommends destinations, routes, POIs	Real travel concierge in-car	Dynamic emotional design	Festival wishes, birthday greetings, mood responses	Humanized AI, delight factor
"AI Draw" w/ Style Choice	Text-to-image generation with voice control	Highly engaging for kids/family	AI Driving Tutor	Comfort adjustment in deceleration	Safer & smoother rides
Meituan food recommendations + Douyin video	Integrated POI & media recommendation	Scenario fusion: map, video, voice	Child Mode Assistant	Child-focused UI, blocked unsafe functions	Family-focused trust builder
Cabin assistant memory	Personalized scene triggers based on seat position	Truly adaptive cockpit	One-shot third-party control	One command triggers cross-app sequences	Seamless cross-app orchestration

Figure 10: AI use cases with strong consumer impact

7 Summary

Driven by rapid technological advancements, evolving consumer expectations, and supportive policies for intelligent connected vehicles, the automotive intelligent cockpit has entered a phase of accelerated growth. As cockpit functions expand in scope and complexity, the need for standardized and regulated functional classification frameworks becomes increasingly critical. Such frameworks provide essential benchmarks for product design, data analytics, and strategic decision-making, enabling the industry to navigate this fast-evolving landscape with clarity and consistency.

This whitepaper introduces a structured classification and detailed explanation of intelligent cockpit features for passenger vehicles. The framework is built around the core elements of human–machine–environment interaction, supported by enabling technologies and relevant business logic. It adheres to the principles of comprehensive coverage, scientific structuring, future scalability, and practical applicability, and is organized into a four-tier functional hierarchy.

The current scope focuses on user-facing features within the passenger vehicle cockpit, including graphical interfaces, intelligent driving interactions, and remote-control functions via mobile applications. Features related to intelligent driving systems and standalone mobile applications not directly connected to cockpit operations are excluded. However, as cockpit and driving systems increasingly converge, future iterations of this framework may incorporate integrated functionalities bridging these domains.

We invite industry stakeholders, technology partners, and researchers to engage with us in refining classification standards, defining feature sets and sharing best practices. Your insights and collaboration will be instrumental in advancing a unified understanding of intelligent cockpit capabilities and shaping the future of this domain.

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