Special Feature 3:Connected service

1. Overview of Connected Cars and Services

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1. Introduction

For more than 260 years since the invention of automobiles, the initial development of automotive technology was primarily focused on the technologies directly required for transportation, such as moving, turning, and stopping. However, with the development of wireless communication technology in the latter 10% of the history of automobiles, connectivity was added as a new function. In particular, telematics, a portmanteau that represents the interplay between telecommunications and informatics, provides various services to vehicles via a wireless communication system based primarily on a mobile phone network.

Vehicles equipped with this system are called "connected cars," and the services provided by this system are called "connected services." Continual innovations in these technologies and services benefit from the ongoing development of information and communication technology (ICT). This article describes Nissan's connected cars and services, mobility services, and its vision for the future.

2. Connected cars and services developed to date

Nissan's connected services began in 1998 as Compass Link. This system was designed to supplement the large volume of information processed by in-vehicle navigation systems, which started to spread in the mid-1990s. The system used a large-scale database located at an operation center to eliminate the inconvenience of finding destinations, and it featured a search service provided by a human operator and search results for navigation destinations, which was the first service of its kind in the world. Customers were able to find their desired destinations by talking to an operator via hands-free voice calls, and the navigation system automatically set the destination. This service required both voice and data communications and utilized a technology called Data and Voice (DV)*1, which split the 9.6-kbps bit rate into two channels: one for voice and the other for data communications. The customers' mobile phones were used as wireless communication devices. This system enabled the vehicle side to transmit customer and vehicle identification information to the operation center, and enabled the latter to transmit search result data to the vehicle side while the customer and operator were on a voice call.

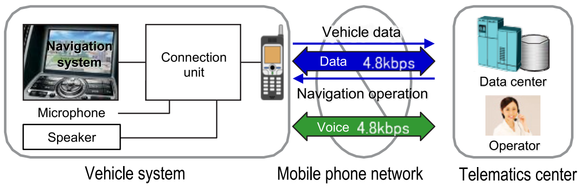

Fig. 1 System overview of the Compass Link service

In response to the spread and development of mobile phone-based information searches, CARWINGS was launched in 2002 as a service dedicated to customer experience, offering enhanced information services in addition to the aforementioned human operator service. This service included the "Information Channel," which provided a variety of content, the ability to receive e-mails, the "My car is here" service (which allowed users to send their vehicle's current location by e-mail), and the "Fastest Route Guidance" service (which searched for the quickest route to a destination based on traffic information). Instead of using the abovementioned DV technology, this service switched between voice and data communications because of the greater proportion of data communications available in such a setup. Drivers could utilize these services relatively undistracted by employing voice recognition technology for sending commands and text-to-speech technology for playing back the content downloaded to their vehicles. Since then, human-machine interfaces (HMI) have been continuously developed along with the systems and services that use them.

The CARWINGS service has also started utilizing information obtained from vehicles themselves (probe data). The abovementioned "Fastest Route Guidance" service combined traffic information obtained from the Vehicle Information and Communication System (VICS) Center with probe data to generate detailed real-time

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traffic information, using both estimated and statistical traffic information to calculate the fastest route. The service was also used to conduct a demonstration in which anti-lock braking system activation data (i.e., time and location) were collected, anonymized, and distributed as "slip information" to warn drivers about the road conditions and provide the information to road administrators.

Fig. 2 Examples of CARWINGS services

In 2010, Nissan launched the world's first mass-produced electric vehicle (EV), the LEAF, into the global market. To prepare for this world-first challenge, an in-vehicle telematics control unit (TCU) was deployed globally to monitor the quality of lithium-ion batteries in the market and relieve customer concerns about using EVs. Data on how vehicles were used in the market and the conditions of lithium-ion batteries were collected and centrally managed by the Global Data Center (GDC), which monitored the quality of vehicles and batteries to prepare for possible malfunctions and obtain information useful for subsequent EV and battery development. Customers were concerned about using EVs because of the cruising distance and insufficient number of charging stations. To allay these concerns, the cruising distance was calculated using information on the actual electricity consumed by the vehicle, and the range was displayed on the navigation map, which facilitated the search for information on nearby charging spots. Mobile phone applications were also improved to allow the driver to remotely activate the vehicle's air conditioner before entering the vehicle and to check the driving history after exiting it, which were functions only available in EVs. Since then, seamless functions that customers can enjoy while driving the vehicle as well as before and after using it have enhanced the user experience, and the technology has been integrated with the Internet of Things (IoT), which has now become widespread.

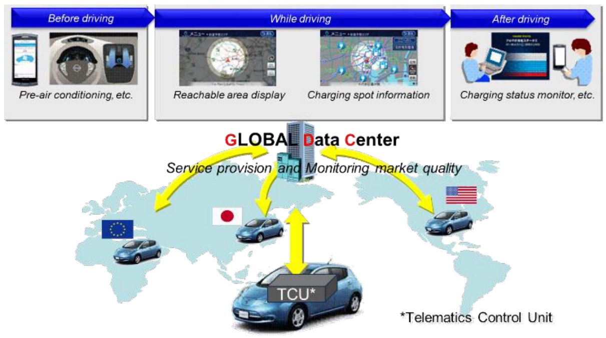

Fig. 3 Conceptual illustration of the GDC and EV services

3. Current connected cars and services

The development and commercialization of Nissan's vehicles, especially its EVs, have been carried out in line with changes in social acceptance and the evolution of technologies relevant to vehicles, such as advanced driver assistant systems (ADAS) and ICT. In 2019, the NissanConnect services were launched by linking connected cars to a cloud system called Alliance Intelligent Cloud, which was the result of an alliance with Renault. Although this system of connected cars was an off-board data center, the development and operation costs were hindrances for the connected service business; thus, the aim was to reduce the unit cost by leveraging the volume effect of the alliance and by shifting from an on-premise server to a cloud server. The vehicle components were also shared within the alliance and among its global operations to decrease the system and service development costs and to enable speedy deployment in the global market.

As smartphones are increasingly becoming the center of customers' digital lives, smartphone apps will be improved to enhance remote functions, such as the remote monitoring of vehicle information and remote operation of door locks. In addition, collaborations with business-to-business (B2B) services and third-party services such as Google and Amazon via cloud systems have been established.

One of the key values provided by connected cars is the provision of access to the latest information, through which the data and software for an in-vehicle system can be updated to the latest version. Based on this arrangement, navigation maps and software for the navigation system, as well as over-the-air (OTA) remote updates of high-definition maps used for ProPILOT 2.0, have been implemented. The ARIYA and later Nissan models also offer OTA updates of the vehicle electrical control unit (ECU) software. This update is called software over-the-air (SOTA) or firmware over-the-air (FOTA), depending on the software level, and is an important vehicle function.

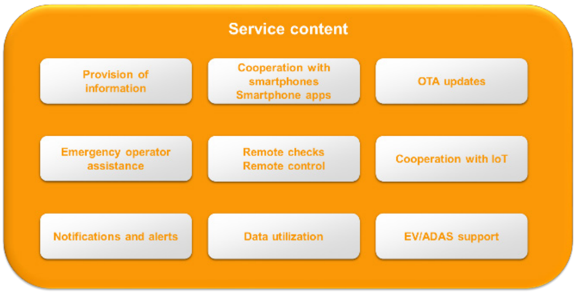

Fig. 4 Connected services of the ARIYA

In addition, the operations of in-vehicle systems are being expanded from simple navigation functions to multimedia functions, and applications and widgets are also being introduced. Accordingly, the conventional real-time OS (RTOS) has been transitioned to a general-purpose OS with high functional scalability, such as Linux. Nissan has adopted Android as the new OS for its in-vehicle infotainment system and will also provide built-in Google services. The services will perform navigation using Google Maps and utilize Google Assistant for the voice interface. It will also be possible to select and download applications through Google Play.

4. Vision for the future

Connected cars and services will continue to expand B2C/B2B/B2B2C services and to evolve HMI through the use of generative AI. However, as mentioned above, connected cars will not only be used to provide such connected services, but will also serve as a platform for future vehicles, services, and businesses to support the following initiatives.

・Mobility services

Starting with a car-sharing demonstration conducted in 1999 using HYPERMINI EVs, Nissan has demonstrated a number of mobility services, such as “Choimobi,” “e-sharemobi,” “Namie Smart Mobility” (in Namie-machi, Fukushima Prefecture), “Easy Ride ®” (for future self-driving services), and “robot taxi service” (in Suzhou, China). For such services, the remote monitoring of vehicle movement, including that of conventional rental cars, is necessary for effective management of the vehicles. Similarly, future automated mobility services will also require remote monitoring of the movement, surroundings, and interior of the vehicles. Moreover, in case of emergency, remote operation will be essential.

・Energy management

As vehicles shift to EV designs, they require more electric power, and their batteries are expected to temporarily store electric power. Nissan has already launched its “LEAF to Home” system, which uses the electricity stored in the LEAF for household electricity. LEAF to Home is expected to become part of the power system linked to large-scale systems, such as vehicle-to-building (V2B) and vehicle-to-grid (V2G). The connected car system can also be utilized to remotely monitor the power stored in EVs and remotely control the charging and discharging of the battery.

・Software-defined vehicles

Because vehicles are already electronically controlled, they are controlled by a combination of software and actuators. However, the recent attention on software-defined vehicles (SDVs) is based on the fact that innovations in vehicle electronic architecture, software that utilizes vehicle data, and OTA updates are becoming increasingly available. Automotive intelligence can be promoted by utilizing connected cars as a platform in which the ECUs, which are provided for each function, are integrated. Hence, the software of the integrated units will become increasingly important, and the software will need to be developed and improved by training it with actual vehicle data.

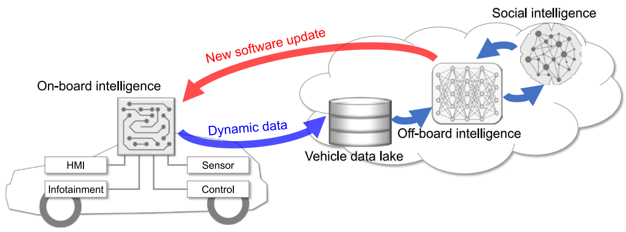

Fig. 5 Conceptual illustration of the automotive intelligence system of an SDV

In addition, the increasing number of connected cars has resulted in their exposure to cybersecurity risks. Although appropriate measures have already been taken in response to the UN-R155 cybersecurity regulations, it is necessary to closely monitor the latest trends and continue to implement countermeasures.

5. Conclusion

Since the launch of connected cars and services in 1998, Nissan has continuously innovated in response to the evolution of vehicles and ICT in society as well as the changes in customer needs. Connected, which is the "C" in "CASE," the keyword recently used to refer to the current once-in-a-century period of transformation, will soon be a normal characteristic of vehicles in addition to moving, turning, and stopping, and it will enable vehicles to connect to a wide range of systems and services. Vehicles will then be integrated into social systems, which will facilitate the continual development of technologies required to create such a future.

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2. HMI evolved by connectivity

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1. Introduction

In 2020, ARIYA adopted an integrated interface display and intuitive graphical user interface (GUI) to realize a human–machine interface (HMI) (Nissan Technical Review No. 88). The HMI allows easy access, even while driving, to in-vehicle infotainment information, which is increasing with changes in use cases and user experience (UX), as well as to vehicle system information, which is diversifying as driver assistance technologies evolve. In the years since, Nissan has expanded its range of vehicle models, adopting these HMI technologies.

This chapter describes the development of display contents such as the GUI and camera images as well as voice recognition technologies, together representing HMI-related technologies that assist the delivery of increasingly diversifying services and contents.

2. HMI adopted in ARIYA

2.1 Interface for combined visibility and operability

In ARIYA, the infotainment and meter displays are integrated into a unified information display area, as shown in Fig. 1. The dead angle created by the steering wheel was considered when arranging these displays and their contents.

Fig. 1 Integrated interface display

Meter information required for driving is displayed at a convenient distance from the driver to help ensure clear visibility. In contrast, infotainment information is displayed within easy reach of the driver to facilitate operation (Fig. 2). These two information panels are adjacent to each other because the human visual field is approximately 1.5 times wider in the horizontal direction than in the vertical direction. Eye movements in the horizontal direction are easier (Fig. 3).

The integration of these displays creates an HMI that is in harmony with the futuristic design of the cockpit interior.

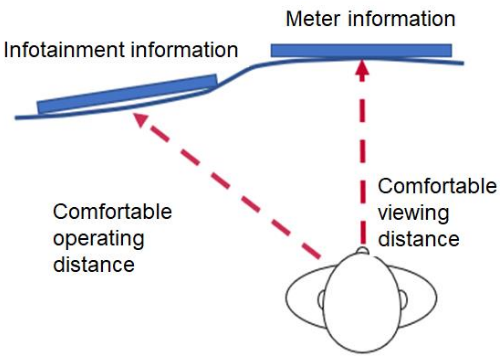

Fig. 2 Layout of information displays

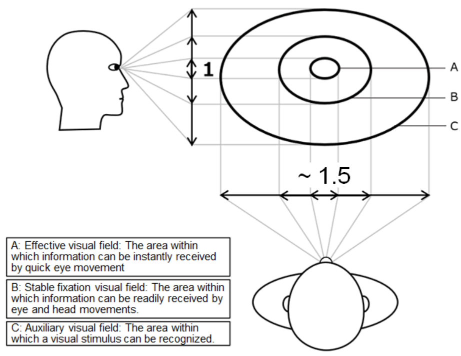

Fig. 3 Characteristics of the human visual field

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In addition to providing an effective layout and structure, integrating the two displays into a single display area achieves a sense of unity while allowing the displays to show different contents depending on the use case. To enable the driver to view map and audio information easily, a linkage function using Ethernet communication instantly transfers information from the infotainment display to the meter display through an intuitive swipe operation, illustrated in Fig. 4. This function supports various use cases such as displaying a map on the meter display. At the same time, a passenger enjoys other content on the infotainment display.

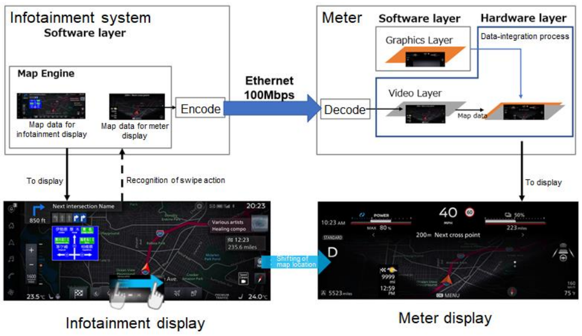


Fig. 4 Information integration of two displays using Ethernet

2.2 Simple and intuitive GUI

Because humans cannot process large volumes of information, the number and positions of the displayed menu items were carefully designed to help ensure ease of recognition. Furthermore, the recognizability and operability of each function were improved by displaying the corresponding widgets and tile menus in larger sizes and optimizing their numbers (Fig. 5).

As the ease of identification of interface users (defined as the rate of correct answers) differs depending on the number and arrangement of menu items, a four-column by two-row configuration was developed, resulting in a correct answer rate greater than 90% (Fig. 6).

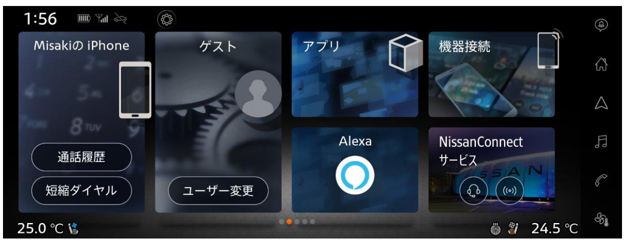


Fig. 5 Home widgets on infotainment display

Fig. 6 Four-by-two tile menu

3. Further evolution of UX

3.1 Display performance with emotional values

To provide emotional value to customers along with highly operable basic functions, Nissan developed approximately 50 interactive animations for ARIYA, including a full-screen opening animation when starting the system and a parallax effect animation when browsing widgets.

These emotional performances have further evolved to add comfort and fun to the new UX. For the GUI in the latest CONNECTED system, Nissan provided a sense of depth to the graphics on the display when browsing widgets on the home screen. Several techniques, including changing the widget size in conjunction with the current operation, adjusting the widget transparency, adding moving shadows on the background, and creating a background image that provides a sense of depth, were combined to make the widgets appear as if they are moving in the z-axis (depth) direction during browsing (Fig. 7).

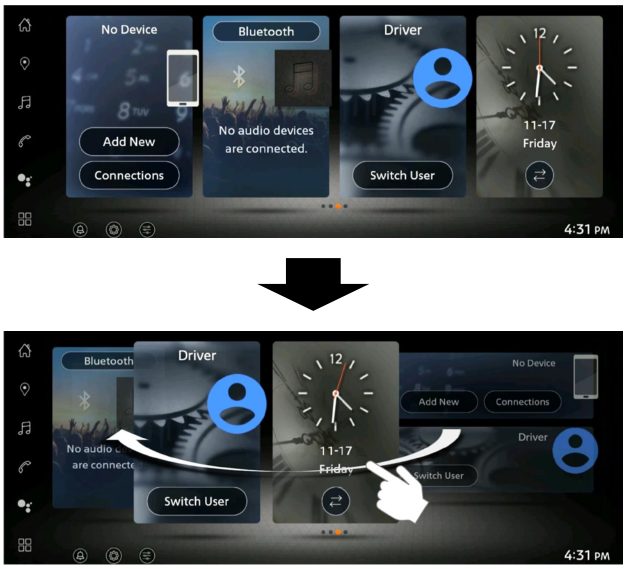


Fig. 7 Widget movement gives a sense of depth

3.2 Realistic camera display and its benefits

Many vehicles have adopted around view monitors that assist parking operations by providing images that appear to look down on the vehicle from directly above. In the latest camera systems, this conventional overhead image is augmented by 3D-view technologies developed to display real-time 3D 360° images.

As shown in Fig. 8, this technology creates a virtual 3D space by mapping the images captured by conventional cameras installed on the four sides of the vehicle onto a curved canvas wrapped around a representation of the vehicle.

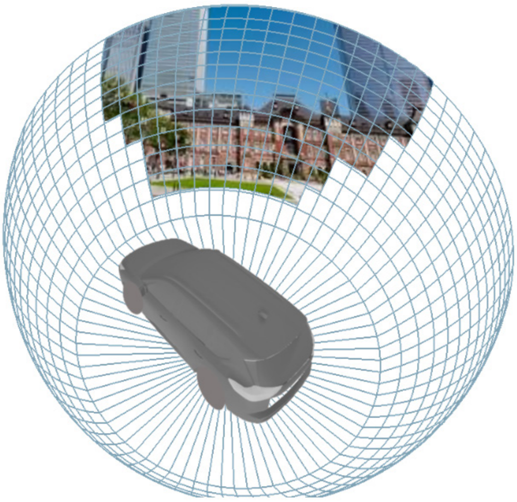


Fig. 8 3D image mapping

This virtual 3D space enables intuitive stereoscopic recognition of surrounding objects that are difficult to display using conventional around view monitors. In addition to these functional benefits, this technology provides a new, immersive experience by projecting panoramic images around a representation of the vehicle (Fig. 9).

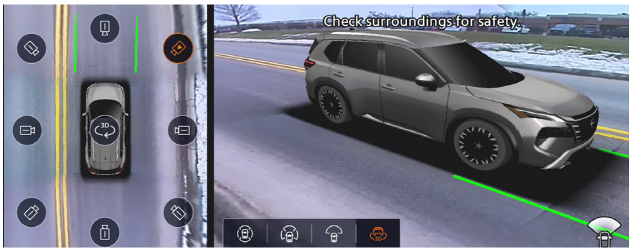


Fig. 9 3D view of vehicle surroundings

4. Evolution of voice recognition technologies by CONNECTED

Nissan has developed various voice recognition technologies to reduce the workload required to use infotainment functions while driving. Conventionally, a stand-alone system is used with a voice recognition engine and dictionary data installed in the vehicle. In contrast, ARIYA realizes voice command operations with ordinary and natural speech expressions (hereafter referred to as natural language) by adopting a server-based voice recognition method.

In this approach, natural-language speech is captured by a microphone and transferred to an off-vehicle server via an in-vehicle voice signal processing device. This signal is subsequently processed to first conduct word/sentence recognition followed by intention estimation (Fig. 10).

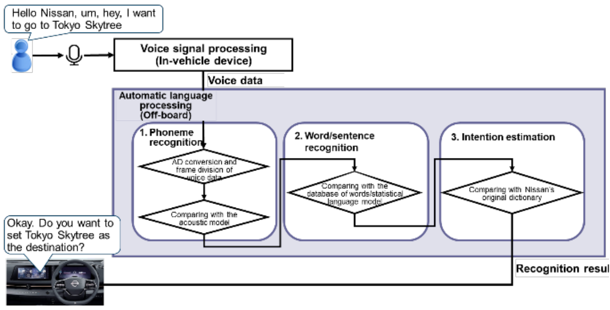


Fig. 10 Flow of natural-language speech recognition process

4.1 Word/sentence recognition

Word/sentence recognition utilizes the abundant computational resources available to the off-vehicle server as well as a statistical language model that learns the probability of transition from one word to another within a sentence (Fig. 11).

This system first selects a group of possible words by analyzing the chronological word arrangement in the collected speech, then identifies the most probable word from this group by finding a word pair that maximizes the sum of the probabilities of word-to-word transitions. For example, when the input “I want to go toukyou sukai turii” is provided, the system can recognize the accurate sentence “I want to go to the Tokyo Skytree,” which has the highest probability of word-to-word transitions within.

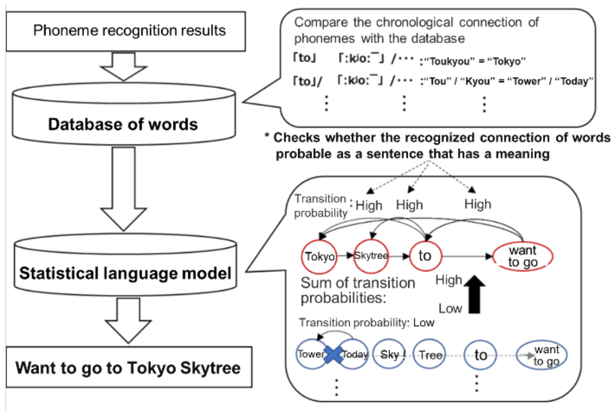


Fig. 11 Speech recognition using a statistical language model

4.2 Intention estimation

Because drivers must focus on driving tasks, their speech may include unnecessary words with no meaning, or they may express the same intention differently. Therefore, filtering is performed to remove unnecessary words (e.g., “um...,” “hey”), selectively extract only the necessary words (e.g., “Tokyo Skytree,” “want to go”), and correctly estimate the driver’s intentions accordingly. In addition, Nissan’s original dictionary database was developed to accommodate different expressions with the same intention, such as “I want to go to...” and “set the destination at...”. This database contains learned data from approximately 3,000 speech patterns collected in actual driving environments. Together, these technologies enable ARIYA to achieve a voice recognition rate of approximately 85% (Fig. 12).

Fig. 12 Intention estimation

4.3 Vehicle linkage function

By improving voice recognition rates using the various technologies discussed in this section, the adoption of voice control can be expanded beyond infotainment functions such as navigation and audio to include vehicle command functions. As a result, the new SERENA now allows voice commands, including "close the windows" and "turn on the air conditioner."

5. Summary

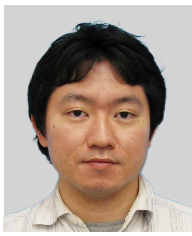
Since the introduction of ARIYA, Nissan has facilitated easy access to information by improving the UX with HMI technologies, broadening the adoption of integrated display packaging to deliver both visibility and operability and refining the GUI to structure the increasing amount of available information in an easy-to-understand and easy-to-use manner.

In future development efforts, Nissan intends to further evolve the cockpit HMI into a driving concierge that closely supports every user by linking it with various peripheral technologies under development.

Authors





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Special Feature 3:Connected service

3. Software update

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1. Introduction

The automobile industry is amid a major transformation defined by electrification, automation, and connectivity. The evolution of electronic components and software is at the heart of this transformation; today's vehicles are controlled not only by traditional mechanical components such as engines, transmissions, and brakes but also by sophisticated electronic devices and complex software.

1.1 Increasing number of electronic components and complexity of vehicle software

The world's first vehicle to incorporate microcomputer control utilized GM's engine control system (with a 10-bit custom microcomputer) in 1977; the first such vehicle in Japan was the Nissan CEDRIC (with an 8-bit Motorola 6802 microcomputer manufactured by Hitachi) in 1979. Since then, the number of electronic control components installed in automobiles has continuously increased. These components are essential for improving vehicle performance, energy efficiency, and driving experience. Multimedia infotainment systems, telematics units, and vehicle control systems for driving, turning, stopping, and, in recent years, driver assistance now operate at the core of a vehicle, providing many benefits to drivers and passengers.

Complex software programs manage electronic control unit (ECU) components and work together to maximize safety, performance, and efficiency. Critically, although software has provided major contributions to new features and performance improvements, its increasing scale and complexity make quality control more crucial than ever.

1.2 Advent of over-the-air updates

In 2012, Tesla used over-the-air (OTA) technology to update the software of the various ECUs installed in customer-owned Model S vehicles. Subsequently, OTA updates have rapidly spread to become a standard feature in the automobile industry. OTA updating allows vehicle software to be updated wirelessly, providing rapid benefits to customers without requiring them to take their vehicles to a dealership. Indeed, by streamlining the update and repair of vehicle software, OTA updates improve the quality of service and increase customer security.

Beginning with the implementation of OTA update functionality in the in-vehicle infotainment unit of the North American X-TRAIL (2018), Nissan Motors has expanded OTA updates to the telematics unit of LEAF (2019) and vehicle-control systems such as the driver assistance systems of ARIYA (2022) and SERENA (2022). This chapter introduces the technologies related to the OTA update functionality provided in ARIYA and SERENA (Fig. 1).

Fig. 1 OTA software updating

2. OTA Software update system for vehicle control systems

2.1 Goals and features

Three major goals for OTA vehicle control system software updates were defined as follows:

- Eliminate the hassle of requiring customers to visit the dealership to troubleshoot problems or add functionality.
- Avoid causing customers to feel anxious when updating software or requiring special knowledge or

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skills to do so.
- Help ensure that the OTA system can be operated stably under any circumstances.

Three basic features were required to achieve these goals:

A. Vehicle OTA software updates must be supported for infotainment systems as well as most ECUs related to vehicle control systems.
B. The vehicle immobility time during a software update must be extremely short.
C. Vehicle OTA updates must support accepted cybersecurity practices.

These three features are explained in detail below.

A. OTA software updates for control-related ECUs

In certain cases, it is desirable to update the ECU software for various vehicle systems to fix software issues and improve vehicle functionality and performance. There are 33 OTA-updatable ECUs in ARIYA and 22 in SERENA (C28). The ECUs of both models cover the in-vehicle infotainment, automated driving/advanced driver assistance, chassis, body electrical, and powertrain systems. Internal combustion engine (ICE), hybrid electric vehicle (HEV, e-POWER), and battery electric vehicle (BEV, Battery-EV) powertrains are all compatible with OTA updates.

B. Minimizing vehicle immobility during software updates

During updating of a smartphone's operating system, the device is non-operational for a period ranging from several minutes to over an hour. OTA systems also have non-operational periods ranging from several minutes to an hour. In contrast, Nissan's OTA updating system requires only a short non-operational period, achieved by providing OTA-updatable ECUs with a dual-bank memory structure comprising a primary execution-memory area and a sub-memory OTA area. Thus, the software update downloaded from the server is stored in the sub-memory area instead of the primary execution-memory area employed while the vehicle runs. This structure allows software updates to be downloaded without affecting the various vehicle control systems that are active while driving. In other words, the system allows an update to be downloaded when the vehicle is in use and only requires the vehicle to be immobile when the software is switched from the execution memory to the OTA memory to install the update, as the vehicle-control functions become non-operational at this time. When tested on ARIYA (FE0), the immobility time was approximately 1 min.

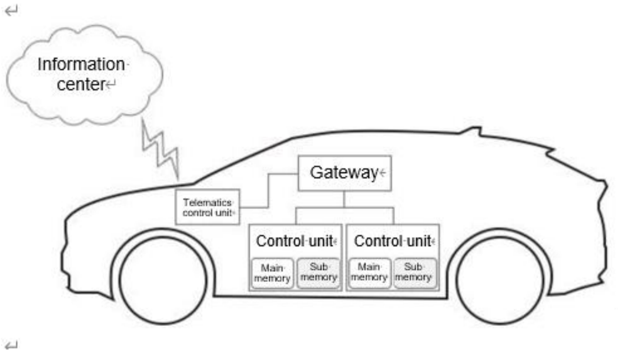

Fig. 2 Dual-bank memory configuration

C. Supporting accepted cybersecurity practices

Cybersecurity has become a critical issue in the automobile industry. Security measures must be included when providing OTA updates to prevent unauthorized software from being written to the vehicle. Therefore, the authenticity and completeness of the software update delivered by the server and the accompanying information must be verified. The following measures have been implemented accordingly:

- The updated software and accompanying information are packaged, and the entire package is protected with an electronic signature.
- Each package is layered and digitally signed with a different key.
- Multistage verification is provided such that signature verification for each package layer is carried out by different ECUs.

If a signature verification error is detected, it is sent to the information server, where it is stored along with a record of which vehicle and OTA update triggered it.

2.2 System configuration

The OTA updating system consists of an off-board side (information center in Fig. 2) outside the vehicle and an on-board side (information and communication, gateway, and control units in Fig. 2) inside the vehicle.

2.2.1 Off-board system

OTA- and dealer-applied software updates require an off-board system to manage software delivery to the appropriate vehicles. In addition, the same vehicle model can have different ECUs with different software versions according to the trim level, sales period, or individual circumstances, such as whether previous software updates have been implemented. This type of information must be managed individually for each vehicle.

The software update to be delivered is developed by each ECU supplier and is version-controlled off-board. When planning a software update, content such as objective, changes, etc. and its scope such as vehicle model, ECU and version of the software should be updated are defined. This information is registered in the off-board system.

The off-board system communicates with the on-board system (customer's vehicle); obtains information such as vehicle ID number (VIN), ECU, and software version; compares this information with the update scope to identify the vehicle for software distribution; and generates a delivery package accordingly. This delivery package includes information in addition to the update itself, such as the update content and electronic signatures.

After the update package is delivered to the target vehicle and the software update is completed, the history of software updates issued to the target vehicle, including update success/failure, is recorded by the off-board system. A summary of the off-board system functions is provided in Table 1.

Table 1 Off-board system functions

Function	Objective
Administration of vehicle information	Manages the VIN of the customer vehicle, installed ECUs, and software version of the ECUs in each vehicle history.
Administration of software version	Manages the software version for each ECU installed in the vehicle.
Administration of content and scope	Manages update scope information such as updated vehicles, delivered software, and links with recall notifications as necessary.
Creation of delivery packages	Creates a software update package appropriate for the target vehicle.
Generation of electronic signatures	Generates and attaches a signature to the delivery package.
Communicate with the on-board system	Exchanges a variety of information with the on-board system, including the version information of ECUs and software, update packages, and software update status.

2.2.2 On-board system

Regardless of the presence or absence of an OTA update, the vehicle information managed by the on-board system, including the VIN and each ECU, and its software version is sent to the off-board system. If a vehicle software is eligible for an update, the appropriate software package is received from the off-board system, and multi-step signature verification is performed. The timing of update activation (switching the software from the old version to the new version), which requires rebooting the ECU software, is determined by monitoring the vehicle speed and the status of each ECU; activation is only performed after the vehicle is confirmed to be in a safe state. At the time of activation, the updated content and operation restriction information are presented to the customer, and customer consent is sought. After activation is completed and the vehicle is switched to the new software version, a completion notification is sent to the off-board system. If the activation of a new software version fails owing to a signature verification error, the off-board system is notified of the error, and the old software version is retained. A summary of the on-board system functions is provided in Table 2.

Table 2 On-board system functions

Function	Objective
Communication with off-board system	Exchanges a variety of information with the off-board system, including the version information of ECUs and software, update packages, and software update status.
Human–machine interface (HMI) status reporting	Displays the status and contents of software updates, update acceptance, update success/failure, etc.
Package signature verification	Verifies the signature attached to the package delivered by the off-board system.
Writing to the ECU	Writes the software update to the target ECU.
Activation and rollback	Switch the executed software to the new version or revert to the old version if an error occurs.
Administration of vehicle condition	Monitors the vehicle status to determine whether an update process can be performed and manages the progress of the update process from downloading to activation.

2.3 OTA updating system flow

The full OTA updating process flow is summarized in Table 3. An OTA software update generally proceeds from preparation to inventory, downloading packages to the vehicle, transferring the updated software to sub-memory areas of the target ECUs (installation), and activating new software versions (activation). Note that the original equipment manufacturer performs update preparation in collaboration with the supplier, and inventory is conducted regularly regardless of the existence of an OTA update.

All steps in this process except activation can be conducted while maintaining the normal use of vehicle control functions, and customer consent is obtained immediately before activation when vehicle-control functions must be disabled.

Table 3 Full OTA updating system flow

Step	Action type	Objective
Preparation	Posting of software	Posts the software update to the delivery server that will deliver it to the target vehicle.
Preparation	Creation of the OTA update	The off-board system determines whether software delivery is necessary and creates an update according to the targeted models, updates contents, etc.
S1	Inventory	Shares vehicle information between the on-board and off-board systems and updates individual vehicle information in the off-board system.
S1-1	Inventory	Collects the software versions of installed ECUs and periodically sends the collected version information from the on-board to the off-board system.
S2	Updating	Updates the software of the target ECUs.
S2-1	Downloading	The off-board system sends the package to the vehicle, and the vehicle verifies the received package.
S2-2	Installation	The on-board system writes the updated software to the target ECUs.
S2-3	Obtaining customer consent	The HMI presents the updated contents and operation restriction information to the driver and obtains their consent.
S2-4	Activation	The on-board system activates the new software version
S2-5	Notification of software update completion	The HMI displays the results of the OTA update to the customer, the on-board system notifies the off-board system of the results, and the off-board system updates the vehicle history.

2.4 Package parameters tailored to vehicles and ECUs

Several parameters are defined during the creation of software updates and included in the delivery package to apply the OTA system to different vehicle powertrains and use cases.

One such parameter is the condition of data transfer when the power switch is turned off (Table 4). When transferring (installing) a new software version from the off-board server to the sub-memory area of each target ECU, stable power must be supplied to the ECU. For a BEV with a large battery capacity, sufficient power can be supplied to ECUs even when the power switch is turned off; thus, the data transfer can continue regardless of the state of the power switch. However, in an ICE vehicle with a small battery capacity, data transfer can only be conducted when the power switch is turned on; thus, data transfer and processing are paused when the power switch is turned off. Such cases must be considered at the time of update creation, and the corresponding parameters must be defined as part of the package according to the individual vehicle information managed by the off-board system and the contents of the delivered update.

Table 4 Example of installation conditions

Installation parameter	Customer use case
Only when power is on	When ICE vehicles are running
When power is on or the BEV battery charge level is above a certain level	When BEVs are running or parked

2.5 Safety measures

As described previously, OTA-updatable ECUs use dual-bank memory such that the updated software can be written to an unused sub-memory area separate from the executed software, allowing the software in the primary memory of the target ECU to be executed normally. This prevents vehicle from being affected by update package downloading and installation while driving. However, activation requires the swapping and rebooting of the target ECU software, which causes the functions associated with that ECU to become temporarily unavailable, albeit for an extremely short time. Therefore, the following safety measures are implemented during the activation process.

2.5.1 Customer notification of activation

An activation notification is provided on the in-vehicle display when the software update can be activated, the signature verification and installation have been completed, and the vehicle is safe. The information provided in this notification comprises

- a summary of the updated contents,
- a statement that some functions may not be available during activation,
- a statement that the vehicle cannot be driven during activation,
- appropriate safety warnings
- the time required for activation.
- appropriate safety warnings

As shown in Fig. 3, the customer's consent is sought at the bottom of this notification, allowing the customer to select from three options: "Activate now," "Set timer within 24 hours," and "Postpone until next time."

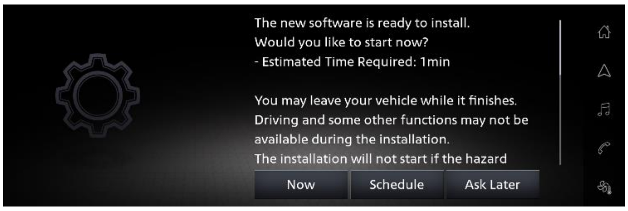

Fig. 3 Notification of software update activation (in-vehicle display)

2.5.2 Prohibition of engine start

To avoid potential destabilization of the power supplied to the target ECU owing to the operation of equipment that consumes a large quantity of power, such as the cranking motor of an ICE vehicle, and because update-targeted ECUs cannot be used during activation, engine-start prohibition control is applied to prevent the vehicle from being driven (Fig. 4). To inform drivers of this status, a message is provided on the meter display stating that the power cannot be turned on when they press the power switch during the activation process. Once activation is complete, the engine-start prohibition control is canceled, and the vehicle becomes operational with the new software version.

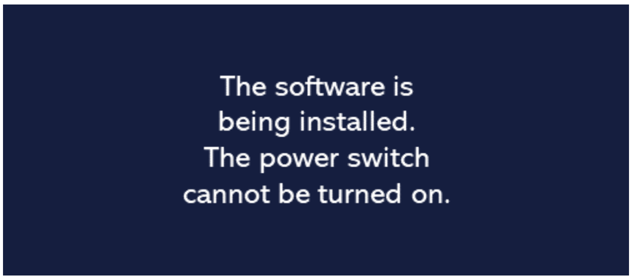

Fig. 4 Engine-start prohibition message on the meter display

2.5.3 Confirmation of vehicle stoppage using multiple ECUs

One of the prerequisite conditions for beginning update activation is that the vehicle must be in the stopped state. Multiple ECUs are used with multiple criteria to judge the vehicle-stop status. Specifically, the gateway ECU and target ECU have the different conditions to determine the vehicle-stop status. The determination process is made redundant by considering the input values for both the gateway and target ECU. Activation is prevented if either the gateway or target ECU determines that the vehicle is not stopped.

2.5.4 Rollback

After signature verification, if problems such as memory failure or data-bit corruption occur during data transmission through the on-board system, unintended data could be written to the target ECU's sub-memory. Therefore, when first booting a new software version after activation, the gateway and target ECUs confirm whether the intended version of the software is present. If data corruption or memory failure occurs, this version verification will fail, and the on-board system reactivates the previous software version retained in the primary memory. This process, called rollback, restores the vehicle to its state before the OTA software update is performed, keeping the vehicle operational for the customer. The customer is notified "successful" or "failed to update, run previous version software.

3. Postscript

Under Nissan Ambition 2030 long-term vision, Nissan strives to provide driving experiences that are defined by confidence and excitement, which can strengthen connections between people and society and expand mobility possibilities. Under this vision, Nissan intends to continue improving the customer experience by developing personalized services and innovative vehicle technologies, such as electric vehicles and advanced driver assistance. As software-defined vehicles can deliver these technologies and services, software is no longer simply a developmental means for improving vehicle functionality and performance but rather an elemental technology that continually excites customers. The development of software-defined vehicles typically requires first defining the services that can be continuously provided, then identifying the infrastructure required for such services, deciding on the ECU and electrical/electronic architecture, including connected services for their provision, and finally developing the software specifications.

Instead of following this procedure for each service and software function, OTA software updates can be applied to continuously update the vehicle software after it has been delivered to the customer. As an infrastructure function, OTA updating can aid the development of strategies for the future deployment of services and software, fully realizing the advantages of the software-defined vehicle; this dynamic moment in the history of its development is quite exciting.

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4. The Present and Future of IoT Collaboration Services Provided by Connected Cars.

Naoya Oka*　Toshimitsu Ishii*

1. Introduction

In recent years, the CASE (Connected, Autonomous, Shared, and Electric) concept has attracted increasing attention in the automobile industry. In particular, the “connected” attribute is the driving force behind the technological development and adoption of the Internet of Things (IoT) in automobiles. As connected vehicles are equipped with many communication devices and sensors, they can be considered mobile IoT devices. Connected vehicles can also provide services linked to external devices through on-board navigation systems and off-board smartphones. This chapter discusses examples of services offered through IoT linkages with external devices and explores the future prospects of this technology.

2. Amazon Alexa linkage services

Amazon Alexa (hereafter referred to as Alexa) *1 is a voice recognition service that allows control of a target device through voice commands. Owing to strong customer demand in the vehicle market for compatibility with Alexa, the Nissan business team requested the development of this feature using a different approach than conventional vehicle body development. This approach allowed the development, testing, and release of the service without depending on the vehicle release schedule and facilitated completely separate development from that of the vehicle itself.

Table 1 List of Alexa linkage functions

Function	Explanation
Account link	Links NC account with Amazon (Alexa) account
Conformation of battery status	Monitors the remaining battery level
Remote charging	Starts/stops remote charging
Remote air-con	Starts/stops remote air-conditioning, sets/cancels the air-conditioning timer
Route transmission	Transmits route search results to the vehicle

The Connected Car Off-board Development and Operations Department developed and released a function allowing voice control of vehicles from Alexa by linking the Amazon Alexa and NissanConnect (NC) services. Table 1 presents a list of NC services that can be operated via Alexa and have been released to the market. Alexa compatibility was developed using the agile development method to quickly release the product by first determining the minimum necessary function or minimum viable product. According to user feedback, this initial development stage was followed by lifecycle updates to improve functionality. Thus, the Alexa linkage service can be constantly improved to incorporate market requirements in a timely manner through lifecycle updates, which allow for the development of services in an agile manner and represent a critical ability for digital services essential to increasing customer satisfaction and preventing disinterest.

*1 [AMAZON BRAND], [AMAZON BRAND], and all related marks are trademarks of Amazon.com, Inc. or its affiliates.

3. Garage door opener linkage service

Conventional garage door opener linkage services use physical buttons located in the vehicle, as shown in Fig. 1. Although this technology makes it possible to open the garage door from inside the vehicle, the constraint on the physical distance between the garage door unit and buttons requires the vehicle to be near the garage door. In other words, the driver must first arrive at home, then press a button and wait for the garage door to open before finally entering the garage, representing a usability issue in that the driver cannot enter the garage smoothly.

*Connected Car Off-board Development and Operation Department

Fig. 1 Map lamp linkage

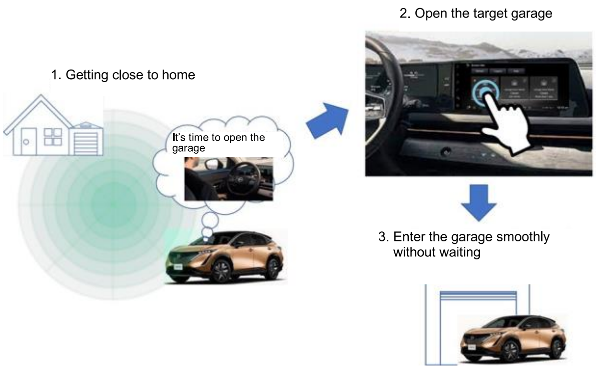

Fig. 2 Use case with IVI linkage

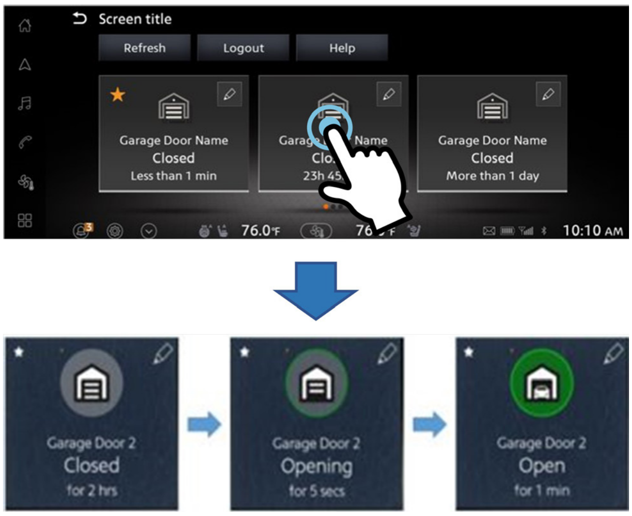

Fig. 3 Image of IVI display

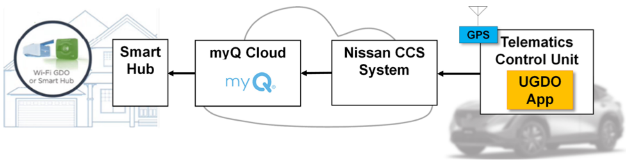

Fig. 4 System configuration

To address this issue, a new garage door opener service will be introduced in the North American market that uses telematics services in connected vehicles equipped with the CCS2 platform and works with the in-vehicle infotainment (IVI) system. Fig. 2 shows the use case of a garage door opener service using an IVI linkage. When the driver approaches the target garage, they can change the garage door status from closed to open by pressing a button on the IVI screen, as shown in Fig. 3. By relying upon telematics, this feature allows drivers to control the target garage door from anywhere within wireless data service coverage. In addition, because multiple garage doors can be registered in the system, this feature can be made available at home and work, assuming the systems are compatible. Thus, the IoT linkage services included in connected vehicles can provide new value to customers from a usability perspective.

Fig. 4 shows the system configuration diagram for connected vehicles' garage door opener linkage service. As the Chamberlain Group has gained a significant market share in the sale of garage door opener units and solutions, Nissan will launch its connected service using a linkage with the myQ Cloud provided by this manufacturer. The content of communications with the myQ Cloud using this IoT connection service comprises:

2-1) Registering the target garage door

2-2) Obtaining the status of the garage door

2-3) Opening and closing the garage door.

The target garage door can be operated on the IVI screen while driving through communication between the in-house cloud (Nissan CCS System) and external cloud (myQ) using publicly available APIs to perform the control actions described above. By linking the Nissan CCS System and myQ Cloud using IoT technology, the connected vehicle can communicate with devices and solutions widely used in the market, making it possible for customers to operate their devices and services which they normally use in different and more convenient ways. Since customers often resist using completely new products and are more likely to accept improved versions of products they are familiar with, this IoT linkage capability can improve the convenience and recognition of Nissan's connected vehicles and create new business opportunities for collaboration with other companies.

4. IoT home appliance linkage service

The application of IoT technology to home appliances has been advancing since before vehicles were connected to network environments. Today, the control of appliances from outside the home has become commonplace. Nissan is actively creating services to improve convenience by connecting IoT home appliances to vehicles.

Fig. 5 depicts a use case for several of the functions of the NC service that Nissan has implemented to connect vehicles to a smartphone app of the same name (the NC app). This app provides new value to users by linking them to various IoT-based home appliances. In a practical application, the user connects their NC account identification (NCID) to the home appliance manufacturer's account identification (appliance ID). The user can subsequently select which actions to send to their IoT devices out of the various notification functions offered by the NC service, listed in Table 2. For example, the car alarm function in the crime prevention category envisages a user experience in which a “Car alarm” notification is sent to a home device (TV, etc.) when the user is at home away from their vehicle, creating new value by linking vehicles to devices other than smartphones.

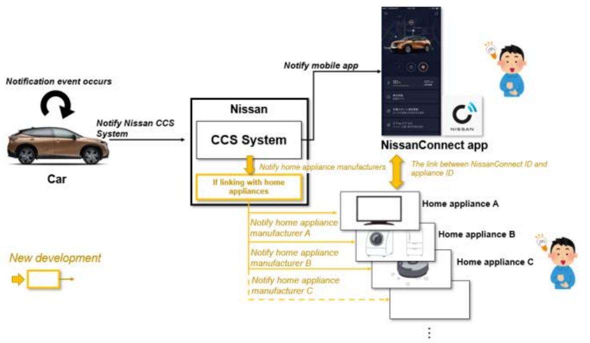

Fig. 5 IoT home appliance linkage use case

Table 2 List of notification functions

Category	Notification
Charging	Charging timer started
	Charging stopped
	Stop error
Navigation	Pre-departure reminder
Air conditioner	Recommendation of air conditioner use before boarding
Crime prevention	Power switch on
	Car alarm
Zone alert	Return home notification

When translating business requirements into system design, the user experience, or how users will use the system, must be emphasized. The following aspects were considered in the system design and function delivery accordingly.

4.1 Improvement of user experience

The IoT linkage service is intended to improve user convenience and value by connecting IoT-based home appliances with the notification functions of NC services delivered by connecting the NC app and Nissan vehicles. The system running this service was designed to provide intuitive and stress-free functions to customers. To achieve this goal, highly experienced and knowledgeable professionals in web/information technology fields, including user interface and user experience designers, backend engineers, mobile application engineers, product owners, and project managers, worked together as a team to create customer journey design, system, and operation designs by streamlining the development from the NC app to the backend. As a result, Nissan has achieved service development using a method centered on user experience, which would be difficult to achieve through the traditional vertical division of labor by function.

4.2 NCID linkage with external IoT-based home appliances

To connect to IoT-based home appliances, users must link their NCID with the appliance ID managed by each manufacturer. This linkage allows Nissan's system to recognize which users are linked to which home appliances using authentication and authorization protocols, such as OpenID Connect*, ensuring the security of system connections between companies. (*Other authentication/approval technologies may also be introduced depending on the linked home appliance manufacturer.)

4.3 Close-yet-sparse linkage with external IoT-based home appliances

Though technologies such as OpenID Connect can be used to closely link NCIDs with appliance IDs, situations in which NC services become unavailable to the connected vehicle system because of linkages with external IoT-based home appliance systems must be avoided. Therefore, Nissan adopted the system architecture shown in Fig. 6 to separate the notification function for home appliance IoT linkages from the existing connected vehicle system. This keeps the existing NC service protected, as it will be unaffected even if a problem occurs with Nissan's linkage system (IoT adapter) or an external home appliance system.

4.4 Scalability and versatility considering business development

When designing the system architecture, the aforementioned close-yet-sparse linkage with home appliance IoT systems was not the only critical consideration; the system's scalability and versatility were also considered in the context of business development. In the digital world, a common software development approach is to quickly release services in small batches and then grow and expand these services based on user feedback. Nissan introduced a versatile system architecture that was not limited to a single company, and it accommodated the possibility of business partnerships with various home appliance manufacturers. The tactics used to realize this architecture included the introduction of commonly used authentication and authorization technologies, such as OpenID Connect, and modularizing functions that link with external home appliances by creating new microservices in the existing connected vehicle system. This has resulted in a versatile system that can scale to future business development.

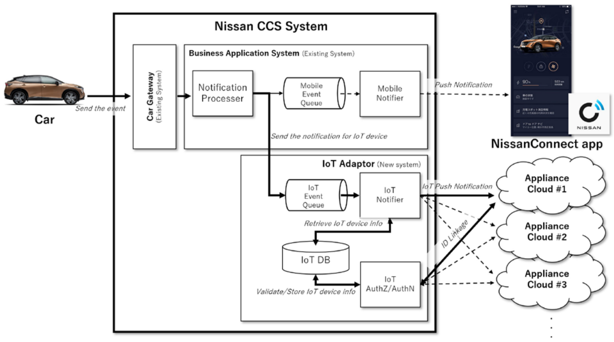

Fig. 6 System configuration

4.5 Introduction of development and operations program

As the IoT linkage system is intended to be constantly improved based on user feedback, system development does not end with a single release. This necessitates introducing a development and operations (DevOps) program that considers the potential for post-release issues from the development stage onward. To implement this program, quality improvement was automated to the extent possible using continuous integration/continuous delivery, creating an environment in which ongoing software releases can be quickly issued. In particular, system monitoring and log collection were strengthened to enable early detection and troubleshooting of problems, leading to further improvements and better user experience.

In this manner, Nissan has created a home appliance IoT linkage system that emphasizes user experience while providing versatility and scalability, anticipates future business development, and minimizes any impact on existing connected vehicle systems.

5. Conclusion: The future of IoT linkage services

New products and services are created daily in the web/information technology and consumer product industries. The ability to perform IoT linkages in a network environment that connects vehicles with widespread devices and services represents a major point of evolution and can only be realized by the connected vehicle system. This ability can also significantly expand the possibilities of automobiles. While the conventional vehicle manufacturing business generates profits by selling vehicles and providing maintenance, connected vehicles can deliver new conveniences to customers after the vehicle sale, thereby providing new value and additional profits to the business. Under this model, customers are charged for the necessary services when they want them through a corresponding subscription. This mode of operation represents a new revenue source for Nissan and changes how customers relate to their vehicles. The case studies discussed in this chapter are part of the IoT linkage system that connects Nissan vehicles with other companies’ services, and Nissan plans to continue introducing similar services to the market. These efforts to expand the capabilities of connected vehicles will create a new circular business model that encourages customers to buy another Nissan by offering them a more enjoyable and engaging everyday life with their vehicle.

Authors


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Special Feature 3:Connected service

5. Mobility service

Susumu Fujita* Takeshi Kimura* Naoki Miyashita**

1. Introduction

The history of mobility services research and development at Nissan Motor Co., Ltd. dates back to September 1999, when joint experiments on electric vehicles were first conducted. In response to potential future social issues such as population decline, aging, and rural depopulation, Nissan quickly recognized the promise of the sharing economy concept, not just from the perspective of improving usability for individuals but also as a means of solving regional issues. Therefore, Nissan has developed carsharing as one of mobility services. Furthermore, Nissan is investigating the multi-purpose use of electric vehicles, including carsharing and power interchange between vehicles and buildings. Nissan has also worked to develop ridesharing in recent years, exemplified by an on-demand vehicle dispatch service presently operated in the Coastal region of Fukushima Prefecture. This chapter describes the ongoing development of these mobility services at Nissan.

2. History of mobility services

Mobility services began with carsharing, in which multiple individuals jointly own a vehicle. This section first explains the differences between carsharing and ridesharing, then describes the mobility as a service (MaaS) concept that seamlessly connects all means of mobility except privately owned vehicles, including public transport.

2.1 Carsharing

The carsharing concept began in the 1970s in Zurich, Switzerland, when the government implemented large-scale vehicle influx restrictions and provided high-frequency, high-quality public transportation services through trams, buses, and trains. Residents who could no longer own cars in the city center began to own cars in the suburbs jointly, and carsharing began. In Japan, Seeds Co., Ltd. introduced carsharing services specializing in foreign cars in 1988. However, carsharing was not widespread until recently, when it was commercialized in earnest. Today, the mobility and transportation industries are rapidly changing, and MaaS businesses are diversifying and expanding to include bicycles, motorcycles, and electric scooters.

2.2 Ridesharing

In the United States, carpooling in private vehicles has become a common means of transportation for people commuting to a workplace from the same origin. With the continued progress of motorization and changes in the flow of people, carpooling has expanded into ridesharing. There are two types of rideshare: conventional, in which people share a ride to travel to the same destination, and transportation network company (TNC) services that match people to rides using a mobile app (1)(2).

Traditional ridesharing includes carpooling, vanpooling, and casual carpooling but excludes taxis that collect fares. In San Francisco, carpooling has become a primary mode of transportation. Today, people can search for carpooling opportunities at any time using smartphones, and drivers are generally allowed to collect fees to cover their actual expenses, such as fuel costs. Similarly, vanpooling uses a larger shared vehicle to transport many people, and the costs are borne by the passengers or subsidized by companies and governments. Finally, casual carpooling is a form of ridesharing in which the driver of a private vehicle picks up a commuter from a queue at a roadside stop; it is characterized by the fact that the driver and the passenger do not know each other.

The TNC is a new type of transportation service that began in San Francisco in 2012 and has developed rapidly since. In this type of rideshare, the TNC service does not operate as a means of transportation but mediates between passengers and drivers of private vehicles through a digital platform to provide paid transportation. The reservation, evaluation, and payment processes are performed using a mobile app , and fares, often quoted before the ride is initiated, are determined by region and vehicle type according to travel distance and time. Typical examples of TNCs include Uber and Lyft in the United States and DiDi in China.

The Road Transportation Act in Japan states that common taxicab operators must obtain a license to operate paid transportation businesses that use

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passenger vehicles. Private paid passenger transport, in which ordinary drivers transport passengers for a fee, is given special permission limited to sparsely populated areas where transportation services are

otherwise poor. Currently, the government is evaluating options for expanding the applicable areas for private paid passenger transport or allowing such transport when taxis are in short supply. Considering the progress of such legal reforms, various companies are conducting field tests of ridesharing services under names such as "mobi," "KnowRoute," and " AI Unkou Bus®."

2.3 MaaS

The MaaS concept seamlessly connects all forms of transportation except private vehicles, including public transportation and ridesharing, to integrate the services of multiple transportation operators and handle everything from route search to reservation and payment in a single application. For example, MaaS Global Ltd began operating the MaaS app named as "Whim" in Finland in 2016.

In Japan, the Toyota Motor Corporation released the MaaS app named as "my route" in Fukuoka City and Kitakyushu City in 2019. This app integrates various transportation-related functions, including searching for transportation, booking reservations, and making payments, to provide multimodal mobility services that support smooth movement around the city. It also describes nearby stores and event spots that contribute to the vibrant urban atmosphere.

3. Nissan Motors initiatives

This section describes several examples of Nissan's efforts to develop carsharing, including a park-and-ride trial of a vehicle-sharing system using HYPERMINI, Choi-Mobi, and e-Share m

obi, and discusses the Namie Smart Mobility and Easy Ride® ridesharing services.

3.1 Carsharing initiatives

3.1.1 Shared usage systems using HYPERMINI

Since September 1999, Nissan has participated in two joint field test projects related to carsharing using HYPERMINI, a two-seater ultra-compact electric vehicle with a special body developed to serve the urban commuter (Fig. 1, Table 1).

Fig. 1 HYPERMINI

Table 1 Specifications

<table>
<tr><td rowspan="3">Dimension</td><td>Length x width x height (mm)</td><td>2665 × 1475 × 1550</td></tr>
<tr><td>Wheelbase (mm)</td><td>1890</td></tr>
<tr><td>Tread (mm)</td><td>1290 / 1270</td></tr>
<tr><td>Weight</td><td>Gross vehicle weight (kg)</td><td>840</td></tr>
<tr><td>Capacity</td><td>Passenger capacity (persons)</td><td>2</td></tr>
<tr><td rowspan="2">Performance</td><td>Minimum turning radius (m)</td><td>3.9</td></tr>
<tr><td>Driving distance per charge (km)</td><td>115</td></tr>
<tr><td rowspan="3">Motor</td><td>Types</td><td>AC synchronous motor</td></tr>
<tr><td>Maximum output (kW)</td><td>24</td></tr>
<tr><td>Maximum torque (Nm)</td><td>130</td></tr>
<tr><td rowspan="3">Main battery</td><td>Type</td><td>Lithium-ion battery</td></tr>
<tr><td>Capacity (Ah/3hr)</td><td>90</td></tr>
<tr><td>Cell quantity (pcs)</td><td>4</td></tr>
<tr><td rowspan="8">Other</td><td>Drive system</td><td>Rear wheel drive</td></tr>
<tr><td rowspan="2">Tire size</td><td>Front: 145/65R14</td></tr>
<tr><td>Rear: 165/60R14</td></tr>
<tr><td rowspan="2">Suspension</td><td>Front: Strut type</td></tr>
<tr><td>Rear: Strut type</td></tr>
<tr><td rowspan="2">Brakes</td><td>Front: Ventilated disc type</td></tr>
<tr><td>Rear: Disk type</td></tr>
<tr><td>Steering</td><td>Rack and Pinion type</td></tr>
</table>

The Downtown Rental Car System was a field test comprising 20 HYPERMINIs implemented in the Yokohama Minato Mirai 21 district and run by the Association of Electronic Technology for Automotive Traffic and Driving (now the Japan Automobile Research Institute). It attempted to promote the widespread use of electric vehicles to realize a new environmentally friendly intelligent transportation system emphasizing user convenience. Vehicles were rented and returned to an uncrewed vehicle station (Fig. 2). A control center accepted reservations, detected each vehicle's location and monitored its condition using intelligent transportation system functions, authenticated users, and communicated with the vehicle driver to send appropriate information to the vehicle. The vehicles were equipped with a navigation system that included functions to enable efficient and convenient communication between the vehicle, control center, and user.

Fig. 2 The Downtown Rental Car System station

In terms of usability, the vehicles were equipped with a "one-shot" button that allowed the driver to easily search for a route from their current location to the vehicle station by pressing a single button, a call button that contacted the control center in case of trouble, an environmental contribution display that displayed the CO2 emissions prevented each time the vehicle was used, a battery level warning function that issued a warning before the vehicle was unable to return to the station on its remaining charge, and a customer service button that monitored user dissatisfaction, all of which helped improve usability during the test. In addition, after starting the field test, the service was adapted to provide sightseeing along the route between accommodation facilities and tourist attractions in the Yokohama Minato Mirai 21 district to improve the occupancy rate and environmental image of the district.

Similarly, the Ebina Project, conducted in Ebina City over the same period, was a park-and-ride experiment comprising 15 HYPERMINIs run by the Ministry of Construction, Kanagawa Prefecture, and Ebina City. This experiment elucidated the effects and problems arising from ridesharing by recruiting citizen volunteers to use the HYPERMINI for commuting in the morning and evening and as an official vehicle for city hall workers during working hours. Through actual field operation, including the use of an IC card-based system for vehicle management, an effort will be made to identify and resolve issues with an eye toward practical implementation of vehicle-sharing in the future. At the same time, the associated challenges were analyzed to expand the implementation area and extend ridesharing applications to the private sector.

3.1.2 Choi-Mobi

With support from the Promoting the Introduction of Ultra-Small Mobility project led by the Ministry of Land, Infrastructure, Transport and Tourism, Nissan and Yokohama City conducted a field experiment running Japan's first one-way carsharing service, Choi-Mobi Yokohama, for two years from October 2013 to September 2015. This service comprises 25 ultra-compact "Nissan New Mobility" concept electric vehicles (Fig. 3, Table 2). Its purpose was to promote low-carbon transportation, improve the quality of urban life and transportation, and develop tourism. The business entities involved were Nissan Motor Co., Ltd. and the City of Yokohama. The operating entity was Nissan Car Rental Solutions Co., Ltd., and Surge Co., Ltd. handled the carsharing system's development. Since the experiment, the service has been used as a rent-a-car operation for tourists and local businesses.

For approximately two years, from March 2017 to 2019, a new Choi-Mobi Yokohama round-trip carsharing service was tested in the vehicles and returned to the dispatch stations after use. Based on the knowledge accumulated in previous experiments, it promoted the concept of ultra-compact mobility closely connected to the local community and attempted to create a sustainable public–private partnership and business model. This service provided guided tours specializing in the central area of Yokohama and long-term rentals to local companies.

Renting and returning of vehicles were conducted at 14 stations in the central Yokohama area. Once a user registered as a service member through a dedicated website, the service was managed using a registered authentication card (driver's license, FeliCa-compatible transportation integrated circuit cards, or mobile terminals). Reservation was possible up to 30 min before the scheduled start time. In addition, 2 dedicated free parking spaces (23 spaces) were offered. A driver's license, smartphone, and credit card issued in Japan were required to use the service, and a user fee of 250 yen was charged every 15 min in addition to a basic fee of 200 yen; the maximum fee for a full day's use was 3,000 yen.

Fig. 3 Nissan New Mobility concept

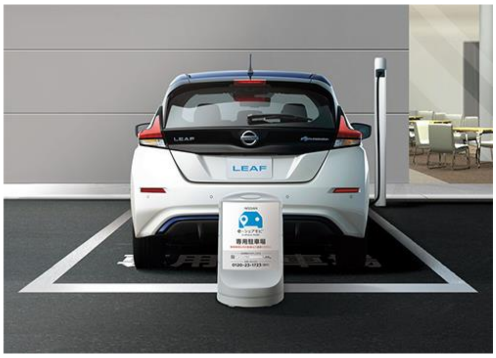


Fig. 4 Example of an e-share mobi station

Table 2 Specifications

Dimension	Length x width x height (mm)	2340 × 1230 × 1450
	Wheelbase (mm)	1685
	Tread (mm)	1095 / 1080
Weight	Vehicle weight (kg)	500 (with doors)
Capacity	Passenger capacity (persons)	2
Performance	Minimum turning radius (m)	3.4
	Driving distance per charge (km)	100
	Maximum output (kW)	Standard: 8
		Maximum: 15
Other	Tire size	Front: 125/80R13
		Rear: 145/80R13

3.1.3 e-share mobi

"e-share mobi" is Nissan's carsharing service that does not require membership fees or distance charges, providing a vehicle for 200 yen per 15 min of use. Because a rental license is required to operate this business, the service is provided jointly with Nissan Car Rental Solution Co., Ltd., which operates a rent-a-car business within the Nissan Group. The service began in January 2018 and was expanded to include 514 stations nationwide by the end of March 2019. As shown in Fig. 4, a station comprises a delineated parking space, a vehicle, and a sign cube. Nissan Group dealerships and Nissan Rent-A-Car stores are typically utilized to provide parking spaces, but securing spaces at suitable locations remains a critical issue as few such businesses near train stations. Currently, the SAKURA and LEAF electric vehicles and NOTE, AURA, KICKS, and SERENA e-POWER vehicles are available for rental; they all offer a fun and comfortable driving experience that is unique to electric vehicles as well as intelligent technologies such as autonomous drive assistance technology and automated parking functions.

As "Smart Oasis®," a registered trademark of Nippon Unisys Co., Ltd. (currently BIPROGY Co., Ltd.). has a proven track record as a carsharing service platform, it was customized and integrated into ".e-share mobi" The resulting system provides cloud-based functions to facilitate member management, operations management, and billing settlement, all of which are necessary for the business operations of mobility services. Customers who register online and reserve a vehicle can unlock the door by holding their driver's license over the card reader installed in the rear window of the vehicle parked at the station at the reservation date and time. Once in the vehicle, the customer can retrieve the smart key stored in the dashboard to use the vehicle, eliminating the need for formalities at a physical store.

3.2 Ridesharing

3.2.1 Field test in the Coastal region of Fukushima Prefecture

In February 2021, three local governments in Fukushima Prefecture (Namie Town, Futaba Town, and Minamisoma City) and eight companies, including Nissan Motor Co., signed the Collaboration Agreement for Community Development Utilizing New Mobility in the Coastal region of Fukushima Prefecture. Since February 2021, Nissan Motors has intermittently provided on-demand vehicle dispatch services as part of its efforts to provide mobility services as a new means of transportation. This service picks customers up at the appropriate time and transfers them to their destination when they indicate their need for immediate travel.

3.2.1.1. History of service

1) Approximately two weeks from February 2021

The acceptability of the service among residents and visitors was first evaluated as part of the Namie Smart Mobility Challenge. This field test comprised a hub-and-spoke type in-town public transportation service using Michi-no-Eki Namie as a mobility hub (connection base), town-circle shuttles to connect major locations within the town center, and spoke vehicles to connect Michi-no-Eki Namie with homes in the suburbs and other destinations (Fig. 5, top row). This service used two eNV200 vehicles as town-circle shuttles within the town center and three LEAFs as spoke vehicles for transportation to the surrounding regions. In addition, a shopping delivery service was offered in which products purchased in-store or ordered online were delivered using mixed passenger and freight transportation (Fig. 5, bottom row).

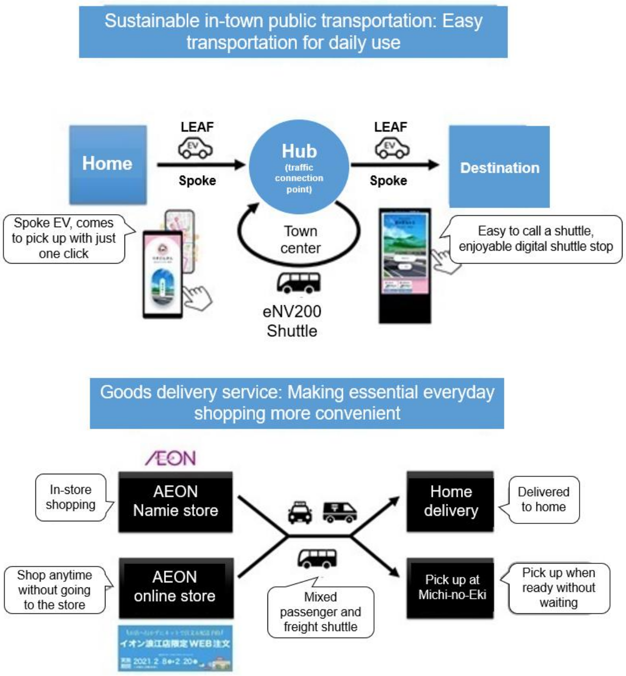


Fig. 5 Implemented mobility service (top: in-town public transport, bottom: delivery service for purchased goods)

Using the town-circle shuttle, customers could move within the town center by first verifying their identity at the digital shuttle stops at eight pick-up and drop-off points (Fig. 6) using facial recognition, then setting their destination. Each digital shuttle stop used a 43-inch digital signage board operating Android OS and running a vehicle dispatch app. Amazon Rekognition, provided by Amazon Web Services, was used for facial recognition.

Fig. 6 Digital shuttle stop

The spoke vehicles allowed customers to travel between the Michi-no-Eki Namie, their homes in the suburbs, and other destinations by specifying their boarding locations and destinations using the smartphone app. Without passengers, the town-circle shuttles and spoke vehicles remained parked at a predetermined waiting location.

2) Approximately two months from November 2021

The results of the two-week field test suggested that meeting the transportation needs of all customers in the service area was impossible with the limited number of boarding locations in the city center and that the waiting time for boarding was too long. Consequently, a two-month field test of the Namie Smart Mobility on-demand vehicle dispatch service was conducted with more advanced functionality. The waiting time for boarding was reduced by increasing the number of pick-up and drop-off points in the city center from 8 to 120 locations to allow travel to destinations within a one-minute walk. In addition, the service hours were extended on Thursdays and Fridays [to 9 pm, supporting a wider range of user needs, such as visiting restaurants in Namie Town. Again, one eNV200 and two NV350 vehicles were used. Starting in January 2022, to support the local economy, the Namie Virtual Shopping Street service began to offer delivery of goods by combining the virtual reality shopping support service provided by Toppan Printing Co., Ltd. (currently Toppan Holdings Co., Ltd.) with the Namie Smart Mobility service provided by Nissan Motors. This service allowed customers to view the sales floors of three companies in Namie Town (Shibaei Suisan, Michi-no-Eki Namie, and AEON Namie Store) online in real-time, check products, and place orders from the comfort of their homes (Fig. 7). The purchased products were delivered to the user's address by mixed passenger and freight shuttles. The field test validated the utility of remote purchasing to the home delivery service chain, improved the area's livability, and revitalized local businesses.

Residents were repeatedly interviewed to inform the

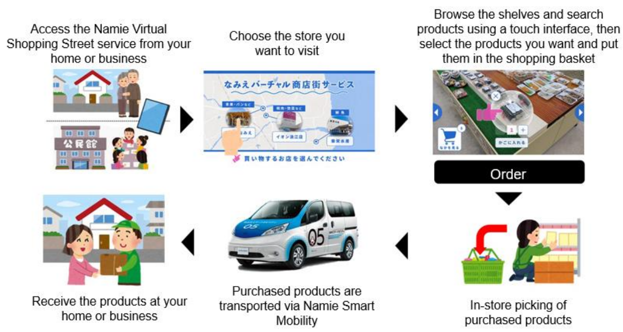


Fig. 7 Namie Virtual Shopping Street service

development of a smartphone app that allowed anyone, especially the aging population in Namie Town, to quickly request a ride and select their destination, even within the city center (Fig. 8).

Fig. 8 Mobile app for vehicle delivery

3) From June 2022 to end of 2023

Based on feedback from residents, the next field test was conducted for one year using two NV350s. Starting in October 2022, mini digital shuttle stops (Fig. 9) with user interfaces similar to those at the existing digital shuttle stops were installed at 14 locations, including major restaurants, landmarks, and hotels, to promote local residents' use of the service. These stops were specifically chosen to improve and expand user convenience while supporting customers' transportation to and from commercial areas. Critically, this service was offered to unregistered users.

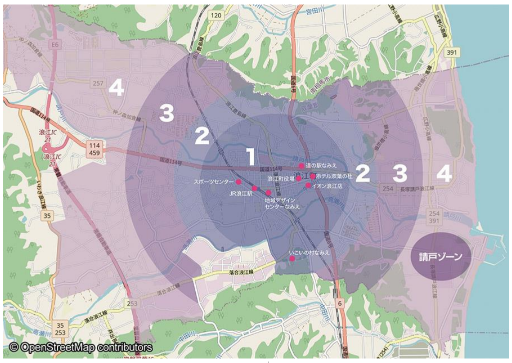
Fig. 9 Mini digital shuttle stop

Furthermore, the Suma-mobi Kids transportation service for children (Fig. 10) was launched in December 2022. In Namie Town, children generally travel between home and school on school buses, but if they want to visit children's facilities, they must be transported by their parents. Suma-mobi Kids attempted to reduce this burden on parents and encourage independent and active out-of-school activities to support the changing lifestyles of children. The service was made available for children without smartphones by providing them with keychains containing 2D codes read at special "kids shuttle stops." The information taken at the terminal device was linked to a control center, and parents were notified when their child entered or exited the facility or entered or exited a vehicle. Furthermore, the service allowed .parents to restrict where their child could go using a smartphone app. It also allowed parents to consent to their children coming home to avoid having them return when no parents were present. In addition, the driver kept an eye on each child from the time they got off the shuttle until they entered the house, allowing parents to use the service with peace of mind.

Fig. 10 Suma-mobi Kids
(top: reading 2D code, bottom: boarding the vehicle)

4) From January 5th, 2023

In January 2023, Nissan moved to the final field testing phase to verify how users and local communities accepted the paid transportation services. This step is necessary to design a commercialization scheme for sustainable mobility services, even in remote areas, considering future service expansion. Fig. 11 shows the service area and basic fares for Namie Town. The service area is divided into Zones 1–4, with Zone 1 representing central Namie Town. This service provides transportation within Zone 1 and also between Zone 1 and the other zones. As an exception, direct transportation service is provided to the Ukedo zone in Zone 4 for convenience, because there are earthquake ruins caused by the Great East Japan Earthquake in this zone and visitors are expected to travel around the area. The three companies operating the vehicles—Kanko Taxi, Tohoku Access, and Joko Taxi—received permission under Article 21 of the Road Transport Act to charge for the service, and fare payments can now be made via PayPay or cash.



Basic fare (per adult) Unit: Yen

Arrival / Departure	Zone 1	Zone 2	Zone 3	Zone 4
Zone 1	◉ 200	300	500	800
Zone 2	300			
Zone 3	500			
Zone 4	800			★ 300

Fig. 11 Service area (top image) and basic fare structure (bottom image)

3.2.1.2 Mobility service platform

In conventional taxis, when a customer requests a ride over the phone, the taxi company wirelessly asks all drivers if they can be dispatched, and then an available driver takes their vehicle to the customer's location. If a customer wishes to hail a running taxi, they must visually check the taxi's sign, which indicates whether it is available, rented, or out of service, and raise their hand to indicate their intention to take the taxi. The taxi driver must recognize the customer and determine a location to stop and pull up near the customer. Once the customer boards the taxi and informs the driver of the destination, the driver begins moving the vehicle toward the destination, where they again determine a nearby stopping location considering the surrounding conditions. Payment is processed before the door is opened, and the service is completed by the driver opening the door, allowing the customer to exit the taxi.

To realize Namie Smart Mobility, a mobility service platform (MSPF) was developed comprising the complete set of systems (vehicles, dispatch terminals, control systems, cloud-based dispatch systems, etc.) necessary to automate the aforementioned on-demand vehicle dispatch. Thus, customers can request a ride via a smartphone app instead of requesting a taxi over the phone or raising a hand to indicate the intention to catch a taxi. The fleet management system, a cloud-based vehicle dispatch system, receives the dispatch request from the app, determines the most suitable vehicle for the taxi company and the customer, and issues dispatch instructions. The dispatch of self-driving vehicles is supported by an autonomous drive gateway established to filter the required information. The overall configuration of the MSPF is shown in Fig. 12.

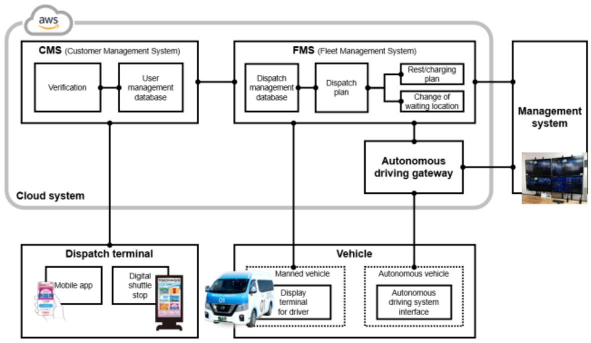


Fig. 12 Overall configuration of MSPF

The allocation of an available vehicle is determined by calculating the driving route of each vehicle from its current location to the customer's requested boarding location according to its present and predicted dispatch status. A trip is defined as the dispatch of a vehicle from the pick-up point to the destination, and a tour is defined as multiple trips arranged in chronological order. As shown in Fig. 13, assuming that there is currently no dispatch request and all vehicles are stationed at their waiting locations, when a new dispatch order is issued, driving routes are calculated for Trip A (travel from the current waiting location to the pick-up location), Trip B (travel from the pick-up location to the drop-off location), and Trip C (travel from the drop-off location back to the waiting location). As shown in Fig. 14, when ridesharing is enabled, if another customer requests a ride (Trip D), all possible insertion points of the pick-up and drop-off locations for Trip D are analyzed. It is inserted at the position where the traveling time is the shortest, while restrictions are placed on the maximum pick-up and drop-off times for the first customer to limit unnecessary waiting and riding times. When ridesharing is not enabled, Trip D is inserted into a trip when no customer is on board (i.e., from the waiting location to the pick-up location or from the drop-off location to the waiting location), and a tour with multiple drop-offs is created as shown in (1) and (6) in Fig. 14.

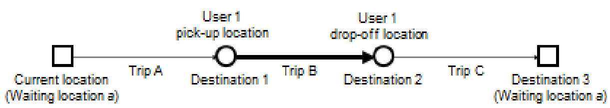


Fig. 13 Trip creation

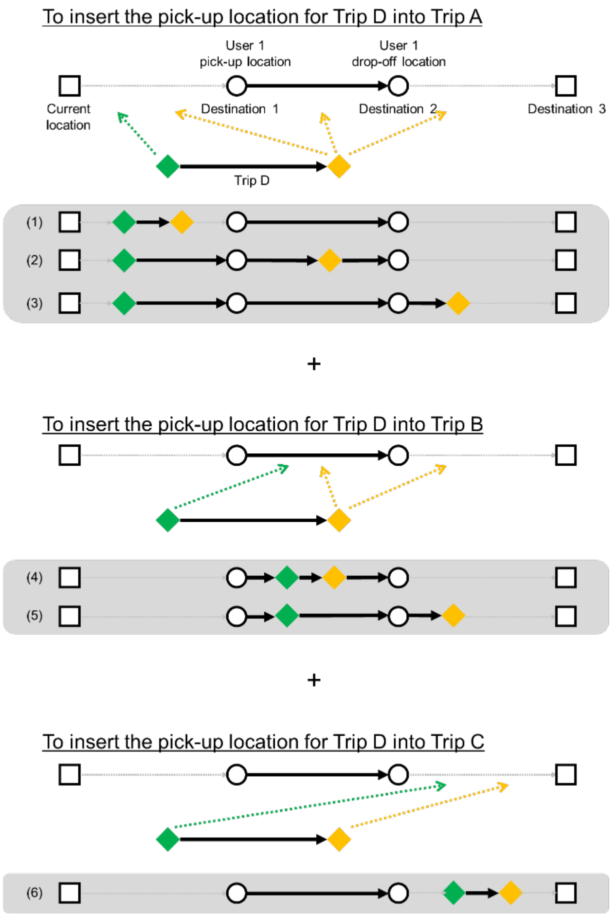


Fig. 14 Creation of a tour by inserting a trip
(Bold lines indicate trips with customers on board)

Notably, while conventional taxi drivers select their routes to travel in areas where demand is likely to occur based on the knowledge they have accumulated through practical experience, in an MSPF, vehicles are stationed in areas where demand is expected to enable services with high customer satisfaction and high dispatch efficiency.

3.2.2 Easy Ride®

Nissan Motors conducted a field test of a new transportation service using autonomous vehicle and ride-hailing technologies to explore the use of autonomous drive vehicles in the Yokohama Minato Mirai area. Created to enable increased freedom of mobility, Easy Ride®, a registered trademark of DeNA Co. Ltd. (hereafter referred to as DeNA) and Nissan Motor Co. Ltd., is a transportation service for anyone who wants to travel freely to their destination. In addition to providing a means of transportation, Easy Ride® also aims to facilitate encounters with local attractions.

1) FY2017 (from March 5th, 2018)

In collaboration with DeNA, Nissan Motors conducted a field test to identify issues related to the onboard experience of general users and identify and engage with the stakeholders who build the ecosystem around autonomous rideshare vehicles.

This field test was conducted for a round trip of approximately 4.5 km between Nissan Global Headquarters and Yokohama World Porters using LEAF-based autonomous drive vehicles. Approximately 300 participants were recruited through an official website and provided with basic services, such as setting a destination and dispatching a ride, as well as new riding experiences beyond transportation. For example, when passengers input "what they want to do" into the dedicated smartphone application via text or voice, it displays a list of recommended destinations. While the passengers were in the vehicle, an in-car tablet screen displayed a selection of nearly 500 recommended places of interest and events near the destination. In addition, approximately 40 discount coupons were offered to passengers for retailers in the area.

To develop an autonomous vehicle service that provides customers peace of mind, a remote monitoring center was established by combining Nissan seamless autonomous mobility technology and DeNA's service design and operation expertise. This remote monitoring center kept track of vehicle locations and cabin conditions and managed vehicle logistics and schedules.

2) FY2018 (February 19th to March 16th, 2019)

A field test was conducted in the Yokohama Minato Mirai and Chinatown areas (Fig. 15) using a newly developed autonomous drive vehicle based on the e-NV200. Because this vehicle was intended for daily use, no limit was set on the number of times it could be used during the test period, and users could choose a destination from 15 pick-up and drop-off points when requesting a ride. The vehicles were stationed at a waiting location at the northern end of the test area and dispatched upon customer request. Assuming that the service would be unmanned in the future, no staff was placed at the pick-up locations, and passengers were allowed to board the vehicle by scanning a QR code attached to the vehicle.

Fig. 15 Field test area

During the test period, the vehicles were dispatched 170 times, with one customer using them 16 times, indicating their use as daily transportation. However, several problems were identified related to long customer waiting times owing to the density of pick-up and drop-off points, the time it took to pick up and drop off, and the shortage of vehicles due to maintenance, resulting in cancellations.

3) FY2021 (September 21st to October 30th, 2021)

In collaboration with NTT DOCOMO, Inc., a larger field test was conducted in the area shown in Fig. 15, leveraging the latest technologies of both companies to solve transportation service issues faced by local communities, such as the shortage of public transportation drivers owing to the declining birthrate and aging population. This field test evaluated a future transportation service employing fully autonomous vehicles and verified its usefulness to approximately 200 participants recruited from Minato Mirai residents and workers. The test was conducted by combining the AI Unkou Bus® on-demand transportation system, which utilizes artificial intelligence for autonomous vehicle dispatch (Fig. 16). AI Unkou Bus® is a registered trademark of NTT DOCOMO, Inc., and uses the Smart Access Vehicle Service (3) developed by Mirai Share, Inc.

Fig. 16 Field test in collaboration with NTT DOCOMO

By incorporating an electronic control unit into the autonomous drive system and expanding the monitoring and diagnostic functions, the need for a human operator in the vehicle was eliminated, and the number of passenger seats was increased from two to three. In addition, the average pick-up time was shortened by setting up one vehicle-waiting location on the north side and another on the south side of the field test area and increasing the number of pick-up and drop-off points from 15 to 23. As a result, the number of users increased, and the vehicles were dispatched 513 times (approximately three times more than in FY 2018). Furthermore, a positive response rate of 84% was received for the in-vehicle experience with no driver. When asked about the fee for the mobile service, approximately half of respondents said that 500 yen/time was reasonable and that the use of a subscription service was preferable.

4. Conclusion

As the sharing economy becomes increasingly popular internationally, various carsharing and ridesharing instances have been implemented in the transportation field. This chapter described the shared mobility services that Nissan Motors has been developing. Nissan Motors will continue developing mobility service technologies that utilize autonomous vehicles to create a sustainable and convenient means of transportation.

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