

Short Lead Time Development of Customized Vehicles with Preventive Measures for COVID-19 Infection - Social Contribution through Swift Provision of Vehicles -

Keiichiro NAKAO¹ Toshiyuki TANAKA²

ABSTRACT

Honda has developed a vehicle for transporting infected persons in order to support local governments and medical institutions responding to COVID-19. Honda first developed specifications to protect drivers from infection while transporting infected persons or persons suspected to be infected to medical institutions and the like, then incorporated the specifications into an existing production vehicle and delivered the infected person transport vehicle to local governments within two weeks. In order to develop and provide the vehicle in a short period of time, simple infection-prevention mechanisms were adopted. These consisted of a flat partition attached to the rear of the driver's seat in the existing vehicle and the ventilation functions of the vehicle's air conditioner. Infection prevention performance indices were the differential pressure between the spaces fore and aft of the partition and the cabin ventilation capacity. The differential pressure target of over 2.5 Pa (standard for medical operating room) and the cabin ventilation capacity target value of over 12 times/h were achieved. Between April and December of 2020, 158 of these vehicles were assembled and provided to 25 municipalities and prefectures.

1. Introduction

In recent years, demand has been growing for social contribution from companies. The ESG approach, which stands for Environment, Social, and Governance, has attracted particular attention in recent years, and is playing an important role, in the same way as profitability, in the public determination of corporate value⁽¹⁾. As well, social contribution of the above "Social" category is being sought as an outcome of corporate activities, just as with environmental and corporate governance. Honda proactively works on social contribution, and has continued to contribute to society through traffic safety activities, disaster recovery support, and other activities⁽²⁾.

The global spread of the coronavirus disease (COVID-19) that has been ongoing since 2019 has not only threatened the health of citizens, but has also had a grave and serious impact on the scope of social activities due to movement restrictions and so on. In the midst of the first wave of the pandemic in Japan in April 2020, many issues appeared due to the rapid and wide-ranging spread of infection, and contributions in the medical field in particular were sought. In these circumstances, Honda took

on the increasing need for the safe transportation of infected individuals to medical institutions and medical supplies and medical equipment for the struggle against the infectious disease, viewing them as social issues that needed the company's support.

Honda has carried out the following three social contribution activities in response to the spread of the coronavirus pandemic.

- Provided vehicles for transporting infected persons to local governments
- Provided face shields to medical institutions
- Supported production of artificial respirators

Of these, this report will describe the development of vehicles for transporting infected persons. As this viral epidemic was not expected, Honda only began development when COVID-19 infections first began to spread. Therefore, with the shortage of vehicles for transporting infected persons, Honda found itself in a situation in which it had to start without any know-how to providing the vehicles as quickly as possible. The company developed infection prevention functionality, prepared for production, and assembled the vehicles within a short lead time.

¹ Honda R&D Europe (Deutschland) GmbH

E-mail: keiichiro_nakao@de.hrdeu.com

² Honda Motor Co., Ltd.

2. Development Goals

The goals in developing the vehicles for transporting COVID-19 infected persons (hereafter, “transport vehicles”) were as follows.

- (1) Simple construction with infection prevention functionality
- (2) Speedy provision of vehicles

At the start of development, many citizens who were infected or suspected of being infected had mild or no symptoms and were still capable of walking. In order to respond to the rapid increase in infections, not only ambulances but also commercial vehicles of health centers were used for transportation, and there was a risk of the infection spreading to medical staff such as ambulance crews and health center staff, inspiring Honda to begin developing a vehicle capable of protecting drivers from infection.

Development began on April 1, 2020. At that point, the shortage of vehicles for transporting infected persons due to the growing number of infections was not yet apparent. Honda made its own estimates about the need for transport vehicles, and set a provisional target of April 15, 2020, or two weeks from development start, to begin providing vehicles.

As well, at the start of development, the method of provision and number of vehicles were still undetermined. Honda aimed to make a wide-ranging societal contribution by adopting a simple structure in which production vehicles were used as the base and infection prevention functions could be easily added and removed.

3. Infection Prevention Functions and Structure

3.1. Design Concept and Performance Target

The schematic diagram and an internal photograph of the transport vehicle that was developed are shown in Figs. 1 and 2, respectively. In general, spaces in medical institutions are protected from infectious diseases through differential pressure designs, with positive pressure in the protected space preventing the inflow of air. The same concept was used for the transport vehicle, wherein the front seat space (driver’s/front passenger’s seats), which required infection protection, was maintained in a state of positive pressure with respect to the rear seat area where the transported persons would sit. Furthermore, in order to rapidly provide the transport vehicles, it was necessary to provide this functionality in production vehicles using a simple mechanism. Thus, a mechanism was used which had a partition on the rear of the front seats of a production vehicle, with the in-vehicle air conditioner providing positive pressure in the front seat area to create the pressure differential.

First, the partition on the back of the front seats blocks air flow between front and rear seats. This causes positive

pressure relative to atmospheric pressure to build up in the front seat space, where the outside air is brought in via air conditioner vents located there. At the same time, air pressure is released via the exhaust vent in the cabin aft of the partition, creating a relative pressure differential between the high pressure of the front seat space and low pressure of the rear seat space. This pressure differential serves to block air flow from the rear seats to the front seats, preventing infection. This concept originated in knowledge about operating rooms of hospitals, which are kept at a positive pressure to prevent infection, and the fact that vehicle air conditioners have powerful fans in order to make vehicle cabins comfortable in a short period of time. This report uses the STEPWGN as an example, but the same mechanism was used for infection prevention functions in other models.

The next task was to set target values for infection prevention performance. For the pressure differential between the spaces fore and aft of the partition, which is at the core of prevention functionality, a target of 2.5 Pa or more was chosen, which is the target management value for medical operating rooms according to Japanese hospital facility design guidelines⁽³⁾. Ventilation capacity was set at 12 times/h ventilation rate (a value obtained by dividing the

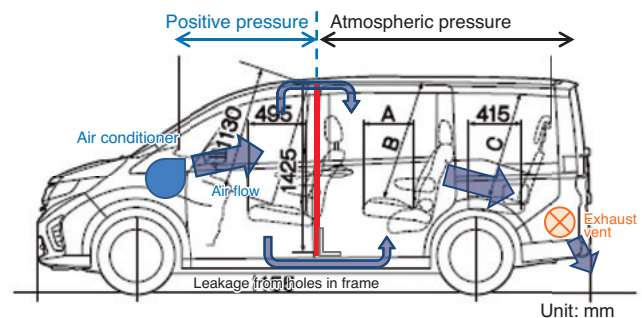


Fig. 1 Schematic diagram of vehicle



Fig. 2 Inside view of vehicle

hourly ventilation air volume by the cabin air volume). This was based on a request from local governments to meet a minimum number of air changes (ACH) of 12 times/h for airborne infections in isolated zones, as recommended by the U.S. Centers for Disease Control and Prevention (CDC)⁽⁴⁾.

The structural components are attached by bolts and can be easily removed. The materials are non-combustible and fire retardant. They were made to be safe when used and easy to install on production vehicles to create the transport vehicles. And to provide peace of mind for passengers, attention was also paid to the quality of the appearance.

3.2. Partition Structure

The partition on the rear of the front seats that blocks the flow of air is composed of panels, seals, and windows. In order to achieve the simplest structure possible, a single flat-plate structure was used without curves, welds, or other processing. To reduce weight, an aluminum alloy was used for the panel material, with rubber seal material protecting the edges. This maintains airtightness and helps avoid injury to occupants. The partition was installed at the rear edge of the center pillar that separates the front and rear door openings. Figure 3 shows the left side partition mounting point.

In vehicles with sliding doors, a grab rail was included near the rear edge of the center pillar to help occupants get in and out of the rear seats. Figure 3 shows how this grab rail is fastened together with the partition to the vehicle chassis. Using the grab rail as a fixing member for the partition hides the fixing bolts, as well as enabling occupants to use the grab rail when getting in and out of the rear seats. In addition, the left and right edges of the partition are positioned at the rear edge of the center pillars, and weather stripping is attached to seal the door openings. Using this weather stripping, the partition is fastened together with the chassis outer panels. Normally, the left and right edges of the partition would be visible to

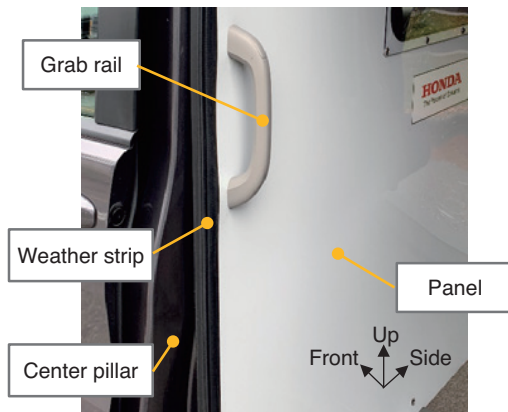


Fig. 3 Side part of panel fixed by using grab rail and weather strip

occupants who are in the rear seats, but because of this co-fastened structure, the edges of the partition are not visible to the rear seat occupants. The weather stripping was originally attached for sealing purposes, and here it also helps secure the airtightness of the partition.

In cases where the condition of the occupants being transported in the rear seats changes suddenly, a polycarbonate internal window is built into the center of the partition to provide a view of the rear seats. Figure 4 shows the partition window.

Generally, fastening parts of interior components are located so as not to be in the field of view of occupants. Therefore, while normally the partition window would be installed from the front seat side so the fastening parts were not visible to the rear seat occupants, at the suggestion of the welfare vehicle development team that cooperated in the design, the window was installed from the rear seat side to help prevent it being pushed out when a rear seat occupant leaned against the window in certain conditions. This window was assessed not only to confirm its safety but also for the sense of openness it provided in the rear seats.

3.3. Using the Air Conditioning System

Production vehicles have an air conditioning unit known as a Heating, Ventilating, and Air Conditioning unit (HVAC) built into the cabin. This conditions the air in the cabin with functions such as ventilation, heat exchange, switching between warm and cool air conditioning, and switching between internal circulation and outside air intake. In addition, there is an exhaust vent with a one-way valve in the rear of the vehicle, which discharges the air taken into the vehicle cabin. In other words, when the air conditioner is used in the mode that intakes outside air, the air flows from the front of the cabin to the rear in a positive pressure state relative to atmospheric pressure. In the case of the STEPWGN, the HVAC has a powerful ventilation capacity of 450 m³/h. With the belief that a sufficient pressure differential could be obtained using only the HVAC if the partition were airtight, a prototype was built and a target pressure differential of 2.5 Pa or more was confirmed. The

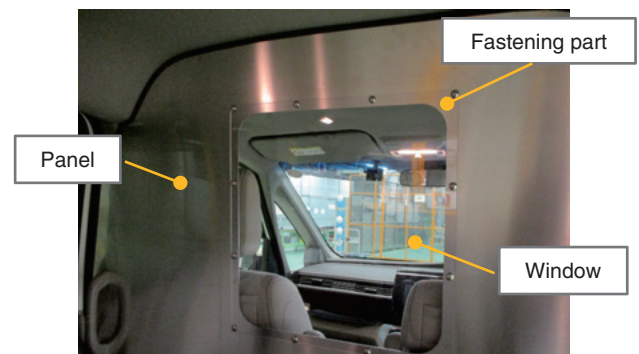


Fig. 4 Internal window of partition

appearance and installation location of the HVAC unit are shown in Fig. 5.

In the transport vehicle, it is necessary to set the air conditioner to “outside air intake” mode in order to generate a pressure differential fore and aft of the partition. If “internal circulation” is mistakenly selected, a pressure differential fore and aft of the partition is not generated, thus compromising the infection prevention function. Therefore, when assembling the transport vehicle, the actuator wiring of the HVAC flap was removed and the unit put in the “outside air intake” state. This meant the transport vehicle air conditioning was constantly operating in “outside air intake” mode. Also, to maximize the infection prevention performance, it was stipulated that the front seat air conditioner be run at full power.

3.4. Testing Fore and Aft Pressure Differential

To assess infection prevention function, the pressure differential fore and aft of the partition was measured. Measurements were taken with the front air conditioner at full “outside air intake.” An air hose was inserted from the side of the partition to measure the fore and aft pressure differential, using a differential pressure gauge. Figure 6 shows the pressure differential measurement setup.

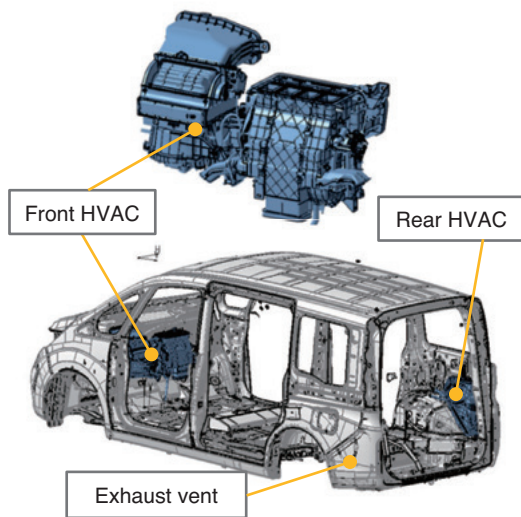


Fig. 5 HVAC unit and its layout in vehicle



Fig. 6 Pressure differential measuring test

The subject vehicles were 19 modified STEPWGN vehicles (DBA-RP1 1.5 L Turbo, CVT, FF, air conditioner blow rate manually set to full) that were assembled in April 2020. Measurements were taken while the vehicle was stopped, resulting in pressure differentials from 11 to 20 Pa (average of 15.4 Pa), greatly exceeding the target of 2.5 Pa. In addition, when the vehicle is moving, negative pressure is generated at the rear exhaust vent due to the external air flow, so the pressure differential fore and aft of the partition rises relatively. When the STEPWGN vehicles above were measured at 20 km/h, pressure differential increased by 5 Pa.

3.5. Testing Ventilation Capacity

Next, ventilation capacity was tested to see if it met local government requirements. Ventilation capacity was assessed according to CDC regulations as the ventilation rate per hour, a value obtained by dividing the hourly ventilation air volume by the cabin air volume. For the transport vehicle measurements, the wind speed at the exit of the interior exhaust vent in the rear of the cabin was measured, and the hourly ventilation volume was calculated from this figure and the cross-sectional area of the exhaust vent. This figure was divided by the cabin air volume to calculate the ventilation rate. Figure 7 shows the wind speed measurement setup at the exhaust vent.

As with the pressure differential measurements, the same STEPWGN vehicles were used and a ventilation capacity of 73 to 111 times/h (average of 90.2 times/h) was obtained, exceeding the target of 12 times/h.

3.6. Confirming Airtightness

A smoke test was performed to check visually for air leakage into the front seat area.

With all the doors closed, a tester sat in the driver’s seat, turned the air conditioner off, and used a remote control to activate a smoke machine in the rear seat space aft of the partition. After the rear space was filled with smoke, the air conditioner was started to generate a pressure differential fore and aft of the partition, and the tester checked for smoke intrusion into the front seat area from the corners of the partition, the window frame seal of the partition, and other locations. Figure 8 shows the smoke test setup.

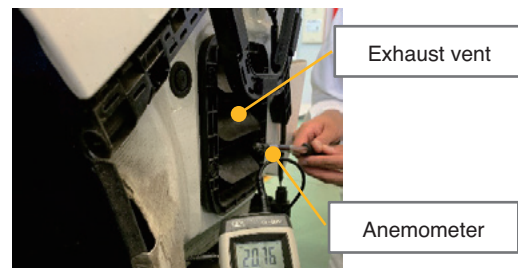


Fig. 7 Ventilation capacity measuring test



Fig. 8 Smoke leak test

3.7. Checking Droplet Scatter Prevention Performance

With COVID-19, airborne infection is an issue when infected persons cough or sneeze and cause droplets to scatter. The vigorous scattering of droplets was therefore replicated and checks were performed on the possibility of intrusion into the front seat area.

Airborne droplet scattering from coughing and sneezing is assumed to reach from 1 to 2 m⁽⁵⁾. To replicate and visualize droplet scattering, a test was adopted in which an aqueous solution of a fluorescent agent that emits light under an ultraviolet lamp is used to simulate the droplets, and this solution is scattered with compressed air. Test conditions were sought by gradually adjusting a volume of compressed air at 0.4 MPa until a volume of 5 ml of the fluorescent aqueous solution was sprayed 2 m or further. 5 ml was a sufficient volume to be visually confirmed under the ultraviolet lamp. The result was a test condition that simulated droplets being scattered 2.7 m in distance from a height of 1.6 m, which was judged to be the height of the mouth of an infected person. Under this condition, a device for scattering droplets was positioned behind the partition, and with a pressure differential generated fore and aft of the partition, the solution was horizontally scattered forward in the direction of the partition, from a height of 700 mm from the seat surface and 850 mm from the partition, which was the estimated position of the head of a person seated on the rear seat. The spread of the droplets was observed under the ultraviolet lamp, and it was confirmed that there was no droplet scatter ahead of the partition. Figure 9 shows the droplet scatter test setup.

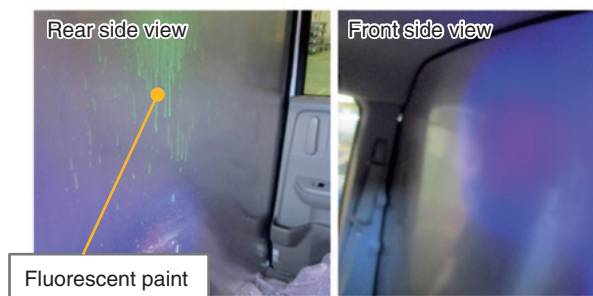


Fig. 9 Scattering test of cough droplets

4. Production Technology for Speedy Provision

In this development, production preparation took place in parallel with specification development in order to achieve the target of “delivery within two weeks.” The flexible production process developed by the Production engineering supervisory unit contributed to the shortening of the production preparation period. As a result, the lead time required from the start of partition design for one model of transport vehicle to the completion of assembly and testing of the transport vehicle was three to four days. An explanation of the transport vehicle production process and its characteristics follows.

4.1. Development and Prototyping

For each vehicle model, the shape of the partition had to be designed with due consideration of the installation location, installation method, edge parting line, and so on.

The shape was designed based on the cross-sectional shape of the cabin space at the partition installation position at the rear edge of the center pillars. The vertical dimensions were shortened to allow clearance for the rubber sealing material in order to achieve airtightness. Also, since the partition supports its own weight and withstands the pressure differential, it is installed so it curves slightly left and right. For this reason, the design dimensions were increased by several tens of millimeters on the left and right. The installation holes for the rear slide door grab rail used for installation were also reflected in the panel shapes. Since the actual partition deforms when installed in the vehicle body, repeated checks were performed as the partition was designed, prototyped, and installed in the actual vehicle, in order to determine the final cutting shape.

4.2. Partition Panel Cutting

The reduction in the partition production lead time was due to the use of single flat-plate partition panel that only required cutting to produce, and which used a flexible and high-speed Intelligent Laser Blanking System (ILBS) laser cutting machine.

Figure 10 shows an outline of the ILBS and applied technology.

The ILBS used in this production is a Honda original vehicle chassis steel sheet high-speed laser cutting machine. With the development of high-speed laser cutting technology, high-acceleration laser head drive technology, and high-speed synchronized conveyors, the system has a world top-class cutting speed of 120 m/min (Fe plate, 0.6 mm thickness). ILBS blanking is a process in which pre-pressed steel sheet blanks for vehicle bodies are produced from roll-shaped steel sheet coils. This is usually performed by pressing processes. Press blanking has a high production speed, but incurs die costs and die manufacturing lead times for each component. With its high-speed technology, the

ILBS removes the need for dies by replacing pressing with laser cutting. The system has been introduced at Honda's Saitama Factory Yorii Automobile Plant. Figure 11 shows a panel being cut with the ILBS.

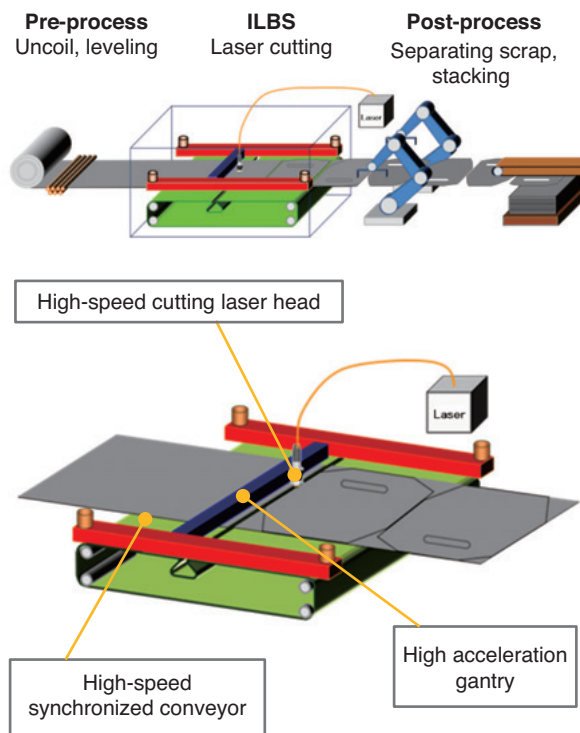


Fig. 10 ILBS and attached technology

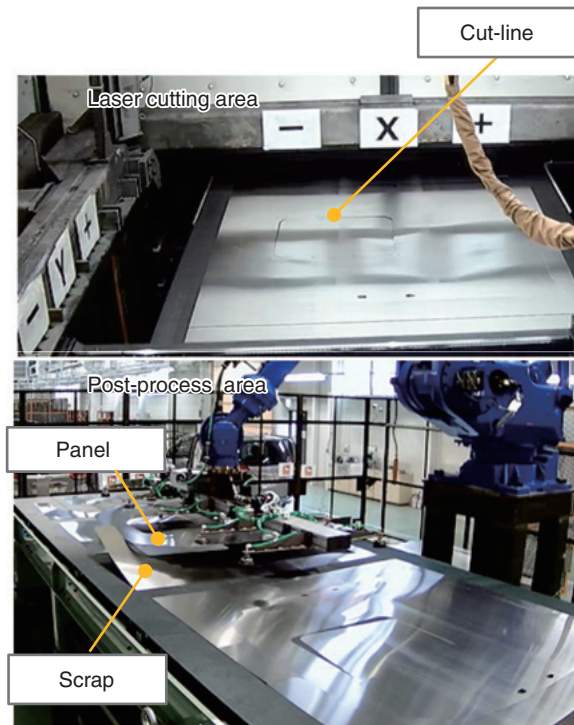


Fig. 11 Cutting panel by ILBS

Since ILBS does not require dies and performs laser cutting suitable for prototyping at a speed that can keep up with mass production, there is no need to change facilities when transitioning from prototyping to mass production. Therefore, once the cutting shape has been determined, a cutting program can be immediately created and mass production cutting launched, shortening production preparation lead times. In this project, partition panel dimensions had to be adjusted from one to three times for each vehicle model, but the lead time for design, prototyping, and the start of cutting was only one day. This is the result of work done in developing flexible production technologies.

4.3. Painting

The cut partition panels were immediately transported to Saitama Factory Sayama Automobile Plant or cooperating manufacturers for painting and appearance inspection.

4.4. Assembly

The painted panels were installed in vehicles as partitions and the transport vehicles assembled. Assembly was performed by installing the panels, window and edge seals, and modifying the HVAC unit to continuously take in outside air. The takt time for assembly was 20 to 30 minutes per vehicle, with two workers. Assembly was easy due to the simple construction. When supplying vehicles to local governments across the country, not only were vehicles assembled in company locations in Japan, but partitions could be supplied to sales companies throughout the country so that they could assemble transport vehicles and provide them to local governments. Figure 12 shows the assembly work.

4.5. Inspection

After assembly, all vehicles were inspected.

Tests were performed for pressure differential and ventilation capacity, and a smoke test for infection prevention. In addition, product quality was checked with external inspections and noise inspections conducted as the vehicle was driven around company grounds. Only then were the transport vehicles provided to local governments.

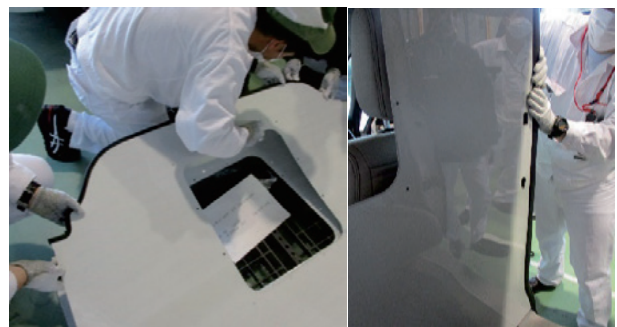


Fig. 12 Assembly process

5. Social Contribution Results

Vehicles with simple construction and effective infection prevention functions were rapidly developed, enabling them to be provided to local governments across the country before infection spread. At the beginning of development, the target date for start of vehicle provision was set at April 15, 2020. However, the first vehicle was provided two days earlier, on April 13, from the Saitama Factory to Shibuya Ward. This was 10 days after development began. Figure 13 shows the number of transport vehicles provided and the number of positives for coronavirus tests throughout the country⁽⁶⁾.

In accordance with the development aim, Honda was able to provide vehicles in response to the spread of the first wave of infection in April. Provision of vehicles continued in May and onward in response to requests from local governments, and many vehicles were able to be provided in advance of the large increase in infection from the second and subsequent waves.

Figure 14 shows vehicles as they were provided. By the end of December 2020, 158 transport vehicles had been delivered to 25 municipal and prefectural governments.

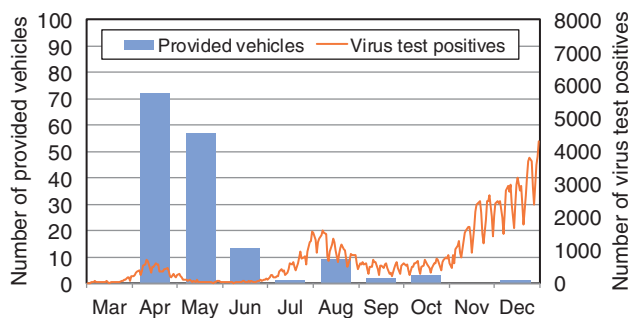


Fig. 13 Actual result of customized vehicle supplies



Fig. 14 Delivering for autonomy

Centered on the Tokyo metropolitan area, vehicles were delivered to municipalities and prefectures throughout the country.

The following feedback was received from local government supervisors who actually used the vehicles.

- The metal partition gave a sense of security
- The partition window was large, making it easy to monitor the condition of the transported persons
- As standard vehicles were used, they did not stand out, which helped protect privacy

Many responses were received about the provided vehicles not just from users, but from traditional media and social media.

6. Conclusion

Honda developed and provided a vehicle for transporting infected persons to support local governments and medical institutions responding to the spread of coronavirus disease.

- (1) By installing partitions in the cabins of production vehicles and using their air conditioning units, vehicles were assembled with a differential pressure of 2.5 Pa or more and a ventilation capacity of 12 times/hour or more, targets established in domestic and foreign guidelines for the prevention of infectious disease.
- (2) Efforts were made to shorten production preparation lead times by using a simple single flat-plate construction for the partition. By adopting high-speed laser cutting processes and using existing grab rails and weather strips for part of the partitions, completed vehicles were provided only 10 days after development began.

The simple modifications that added infection prevention functions to production vehicles enabled speedy development and production preparation, and ultimately the delivery of 158 vehicles to 25 municipal and prefectural governments throughout the country.

References

- (1) Ministry of Economy, Trade and Industry: Report of the SDG Management / ESG Investment Study Group, p. 13-15, (2019) (in Japanese)
- (2) Honda Motor Co., Ltd.: Honda Sustainability Report 2020, p. 150-156, (2020)
- (3) Healthcare Engineering Association of Japan: Chapter 2 Hospitals infection control, Hospital Facilities Design Guidelines (Air Conditioning Systems), HEAS-02-2013, p. 15, (2013) (in Japanese)
- (4) U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC): Guidelines for Environmental Infection Control in Health-Care Facilities, p. 19, (2003)
- (5) Shingata infuruenza oyobi toriinfuruenza ni kansuru kankeishocho taisaku kaigi: Jigyosha, shokuba ni okeru shingata infuruenza taisaku gaidorain, p. 97, (2009) (in Japanese)

- (6) Ministry of Health, Labour and Welfare: Novel Coronavirus (COVID-19) Open data, https://www.mhlw.go.jp/stf/covid-19/open-data_english.html, 2021/4/21

■ Author ■



Keiichiro NAKAO



Toshiyuki TANAKA