Development of Dual Mode Vehicle and its Effects

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Introduction

This year marks the twenty-second year since the Japanese National Railways (JNR) privatization and breakup, resulting in the establishment of JR Hokkaido. JR Hokkaido currently operates approximately 2500 km of track, of which a third—about 800 km—has less than 500 passengers a day per km (dotted lines in Figure 1). Passenger levels on these rural lines have continued to decline year-by-year with business conditions becoming severe and running at a loss, as is also the case with local bus services. The reasons include depopulation of rural areas due to declining birth rate and aging population, a critical situation for local bus businesses following deregulation and fewer government subsidies, and a greater ratio of households with private automobiles, although the public still wants public transportation. In response to this situation, JR Hokkaido has implemented management reforms for rural transport lines, substituting buses for some, running one-man trains, re-examining branch office business, re-examining station business, and making other changes to support continued operations. However, the limits of cost reduction are being reached. At the same time, people in these regions are strongly attached to 'their railways,' so it can take a lot of time and effort to gain their understanding about switching to substitute bus services. In these circumstances, JR Hokkaido has focused on developing a Dual Mode Vehicle (DMV) to support rural lines by operating a vehicle matching the transport volume by combining new ideas in transport with existing infrastructure.

The basic elements of the DMV approach consist of three parts. First, use microbuses to cut initial vehicle and maintenance costs for small to medium volume transport that matches transport volume and saves energy. Second, use tracks and other wayside infrastructure while reducing costs by using new technologies such as GPS given the fact that train detection systems, signalling systems and turnouts have been reduced. Third, increase convenience by offering seamless barrier-free services on roads and rails, contributing to regional revitalization.

To achieve these goals, a project office was set up in October 2002 and the DMV Promotion Centre was launched in June 2006 to conduct R&D into making the DMV practical.

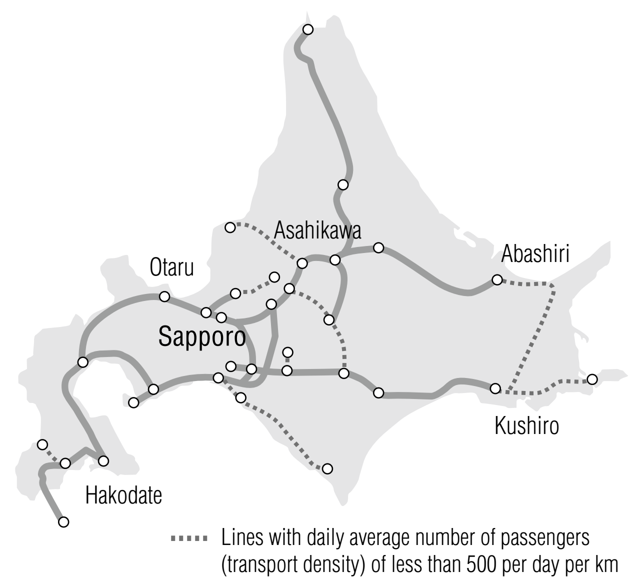
Overall DMV System

The JR Hokkaido DMV is a modified microbus that runs on both roads and rails. Attempts to build such a vehicle have been a transport dream for about 75 years. The system as a whole is composed of the DMV vehicle operating on roads and rails, the mode interchange system for changing between road and rail quickly, and the traffic control system managing DMV operation. Development of the overall system is ongoing at the Dual mode Transport System (DTS). Details of subsystems are described below.

The first subsystem is the DMV vehicle with rubber tyres for running on roads and rails and front and back guide wheels for guiding along rails.

The photograph shows the DMV911/912 prototype running on a road following successful testing in September 2005 after development of the first test vehicle (DMV901) in January 2004. The second photograph shows it running on rails. The capacity is 18 people for the bench-seat type (seated and standing) and 16 persons (seated only) for the cross-seat type.

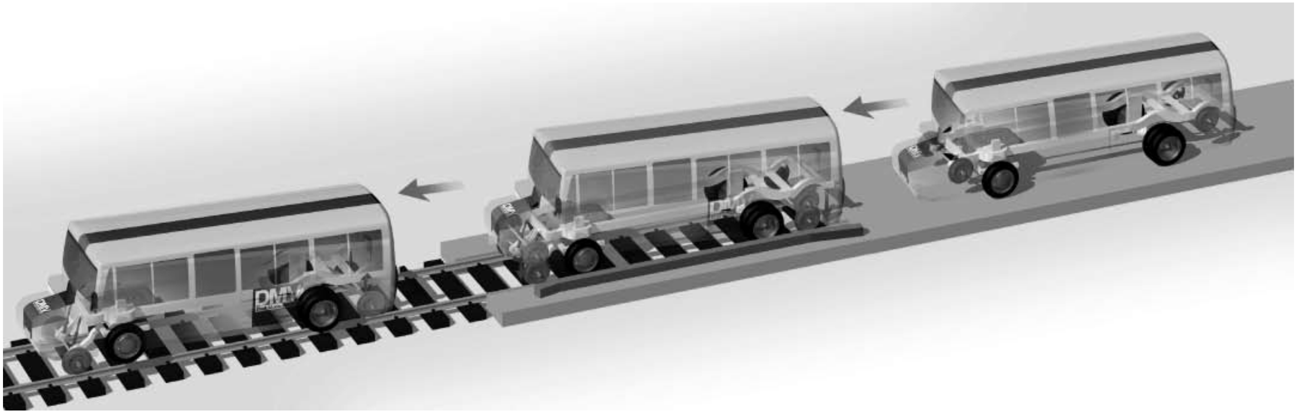
Figure 1 JR Hokkaido Current Passenger Densities



DMV911/912 driving on road

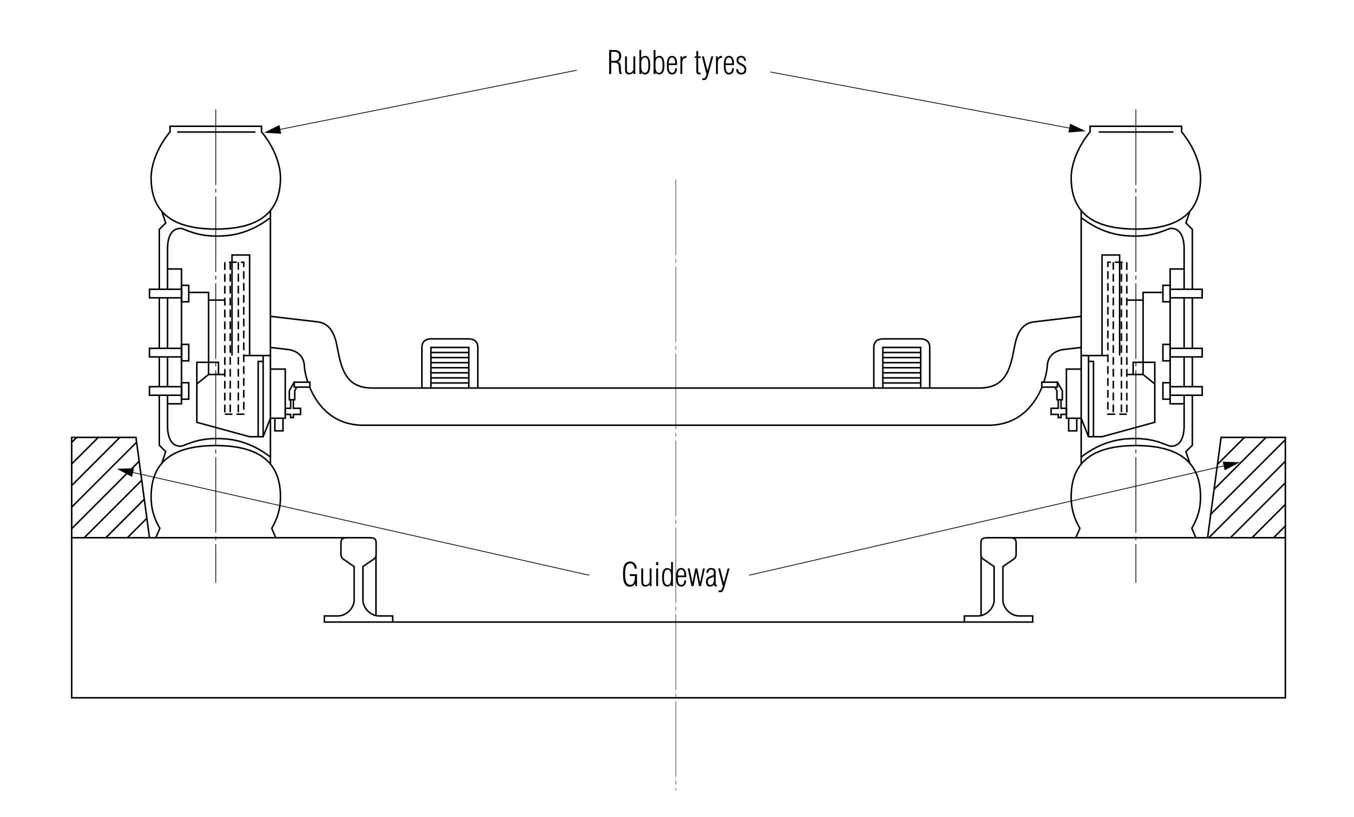
DMV911/912 running on rail

Figure 2 Mode Interchange System



Mode interchange (Hamakoshimizu Station)

Figure 3 Cross Section of Mode Interchange



The second subsystem is the mode interchange system comprised of wayside equipment for changing back and forth between road and rail. Figure 2 shows a diagram outlining the mode interchange system (guideway tyre guide method) where a DMV developed for passenger operation enters the mode interchange from road travel and changes to the mode for rail travel. The photograph opposite shows an actual mode interchange at the wayside.

A cross section of a DMV on the mode interchange is shown in Figure 3. This guideway tyre guide method is based on the guideway guide roller method developed at the same time as the test vehicle. However, it does not require a guide roller on the vehicle, allowing for a greatly reduced width of the steel wheel, lightening the vehicle and cutting costs.

The third subsystem is the traffic control system using features such as GPS and an operation safety system. Details are explained below.

DMV Technologies

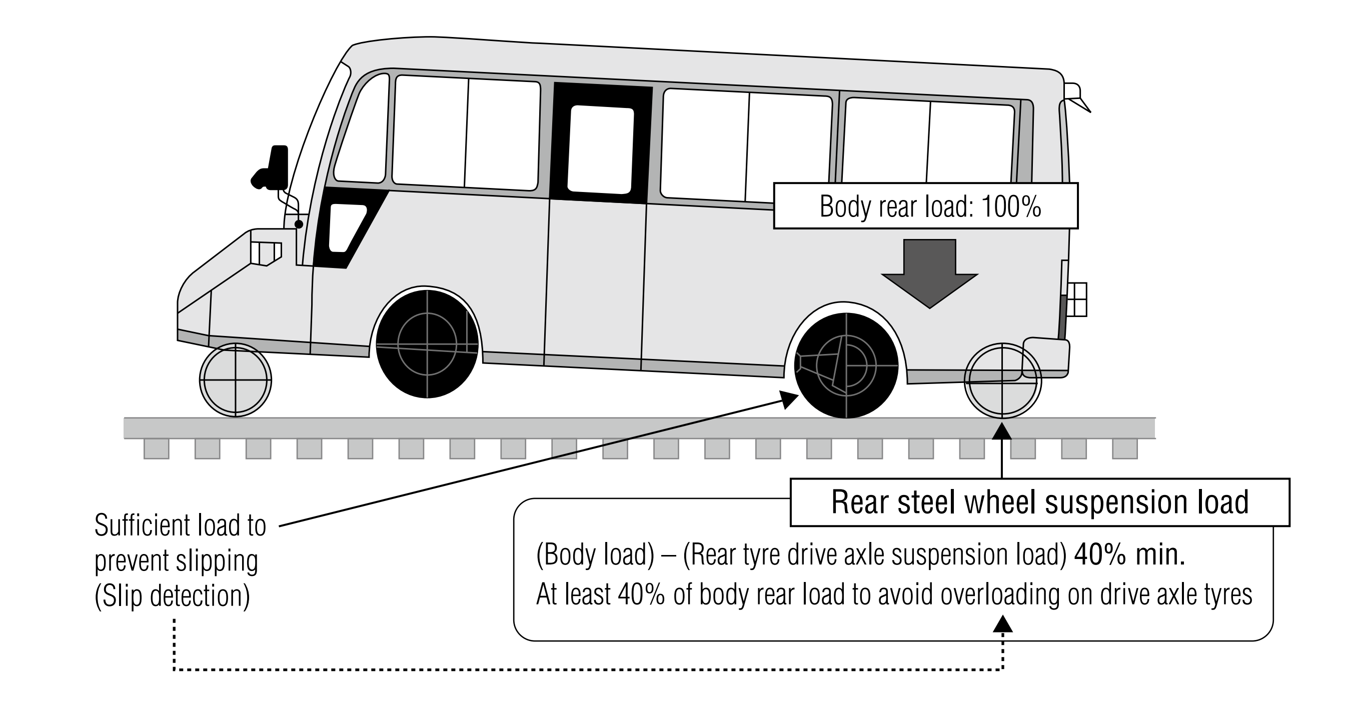
A DMV travels on roads using rubber tyres just like a normal bus, and on tracks it travels using guide wheels mounted on the front and rear of the body and rear rubber tyre drive wheels (inner wheels). Switching from road to track is done by entering the tracks along the guideway of the mode interchange composed of guideway, rails, and paved surface. At the interchange, the front and rear guide wheels are lowered hydraulically and the front rubber wheels are raised. When switching from track to road, the front rubber tyre wheels are lowered and the front and rear guide wheels are retracted into the car body to complete the switch in approximately 10 seconds.

On tracks, the vehicle is guided along the rails by the guide wheels, making steering unnecessary. Operation is easier than a bus, involving just the accelerator and brake pedals.

The background to making the DMV possible started with the inspiration that a microbus would just fit on tracks. Ideas that go against what had been thought common sense for railways were introduced and unconventional thinking supported the DMV development. The major issues facing practical use were the time and effort needed to change mode, the short life of rubber tyres, and difficulty in securing stable running. Each was analyzed and overcome by advances in technology, and by using combinations of technologies as described below.

The first measure was to reduce the time required to change mode. To change from road to track quickly, the vehicle and track centres must be easy to align no matter who is driving. The mode change system is the opposite of previous trials where railway stock was adapted to run on roads and development was made easier by having a bus run on tracks.

Figure 4 Rear-axle Load Distribution Control System (Variable Axle Load Control)



Smooth and certain mode change must be possible even when rails, guideway, tyres, and parts are not exactly at specified dimensions. Therefore, the wayside mode interchange part gauge was widened 70 mm to 1137 mm and the guide wheel rim width on the vehicle was widened 25 mm to 150 mm.

The second measure was lengthening the lifespan of rubber tyres. The rear rubber tyre drive wheels and rear guide wheels are located close to each other, so the load of the rear car body is distributed between these wheels. However, the drive performance of the rear rubber tyre drive wheels and rail tracking ability of the rear guide wheel drop with such placement. Furthermore, the contact width of the rear rubber tyre drive wheels when on rails is about 30% that on the road, placing an extra burden on the tyres. To achieve both drive performance and rail tracking ability, a rear axle load distribution control system (variable axle load control) is under development (Figure 4). This system determines the load status and conditions such as rear tyre slip, and maintains the optimum drive force for the rear rubber tyre drive wheels while placing the rest of the load on the rear steel wheels. This reduces wear on the rear rubber tyres and helps prevent derailment of rear steel wheels.

The third measure is improved stable running. In addition to the rear axle load distribution control system, improvements have been made to the soft suspension of the axle box and guide wheel tread shape.

Concerning soft suspension, the DMV wheelbase is about 6 m longer than railway rolling stock and the lateral force on guide wheels travelling through curves is large in relation to the wheel load, increasing the risk of derailment. To reduce lateral force, the guide wheel axle box suspension is soft-supported by a tubular rubber spring and the guide wheel is steered by lateral force when travelling through curves. Figure 5 shows the axle box soft-suspension system.

For the guide wheel tread shape, the load of the body back end is distributed between the rear rubber tyre drive wheels and rear guide wheels. Therefore, there is insufficient load on the rear guide wheels, increasing the risk of derailment. To relieve the insufficient axle load, the flange angle of the guide wheels has been increased to 87°, much more than conventional rolling stock, and the flange height is 33 mm (Figure 6), giving a derailment quotient of 2.33.

An additional fourth measure is the traffic control system described later.

Since the completion of the DMV test vehicle in January 2004, many people have observed and made test rides. One request was to increase passenger capacity. The microbus has a smaller allowable load than the DMV test vehicle, so it was difficult to secure a capacity equivalent to the test vehicle. As a result, efforts were made to increase transport capacity by coupled operation as shown in the two photographs. Forward-direction coupling has two vehicles connected in the same direction. This method has the benefit of using the drive power of both vehicles, and acceleration, braking, and other operations of the front and back car are synchronized. Actions such as opening and closing passenger doors can be synchronized too.

Figure 5 Soft Suspension System

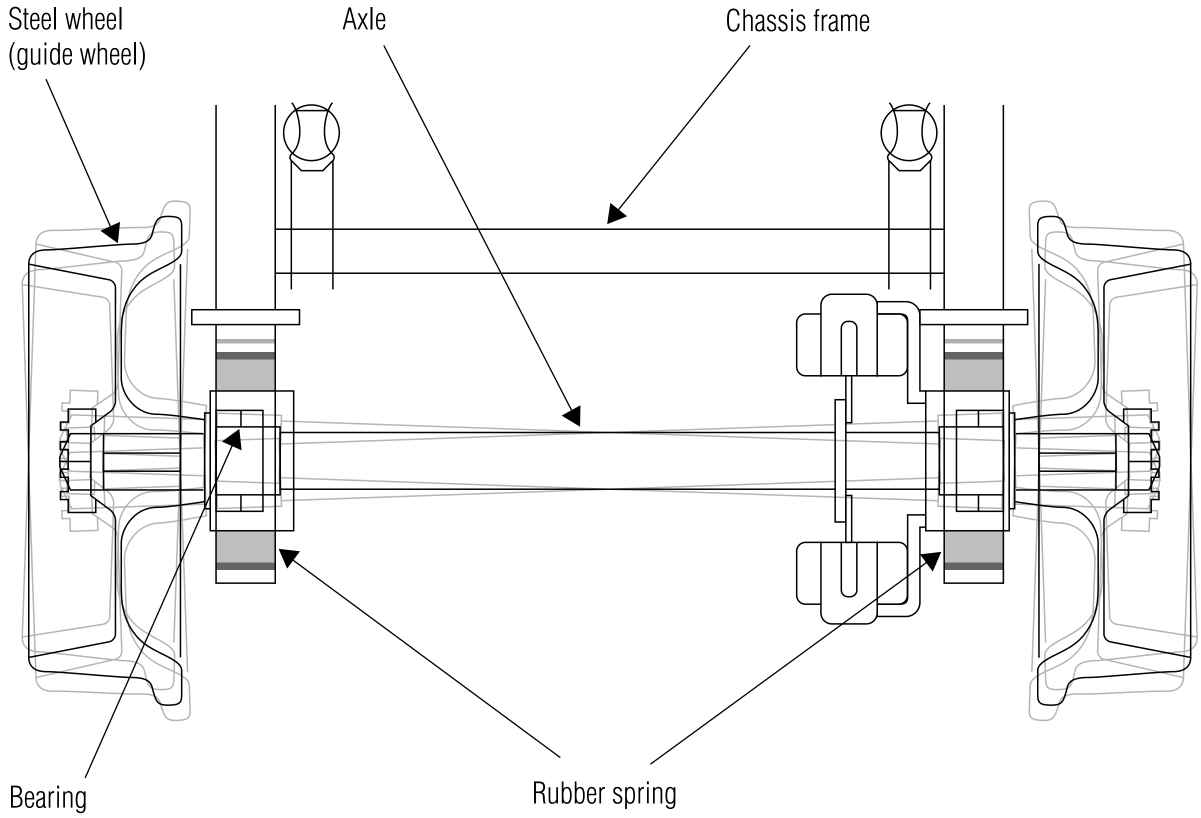
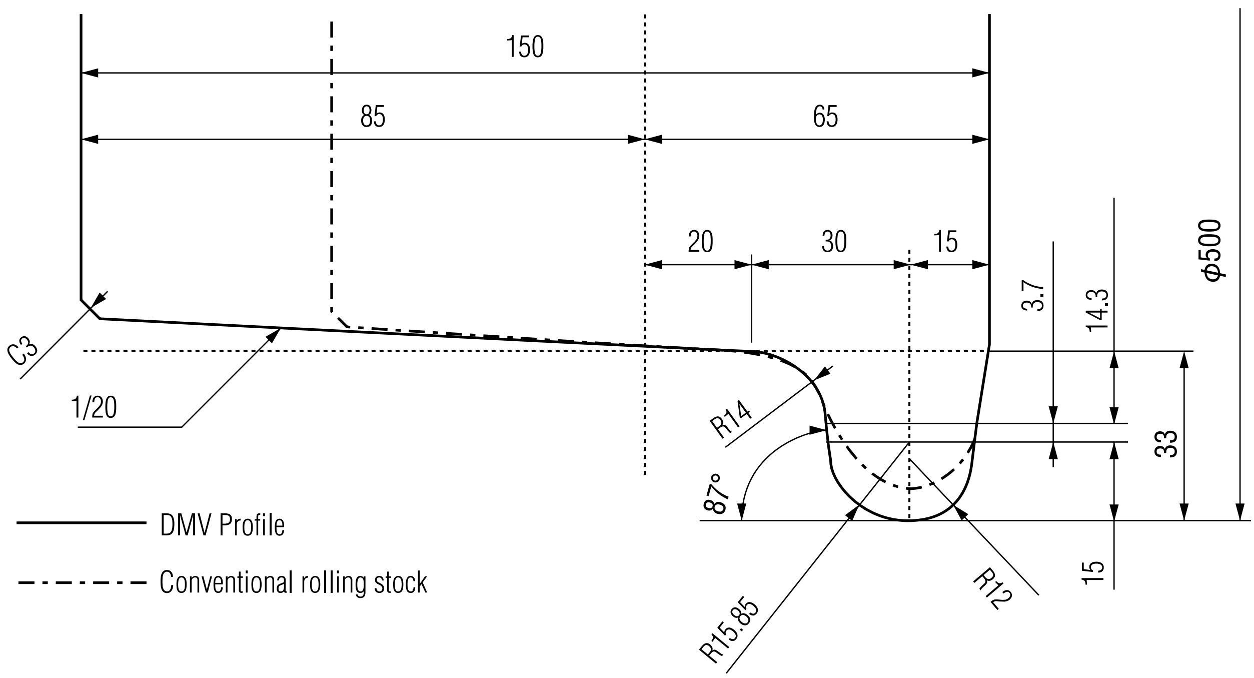


Figure 6 Steel Wheel (Guide Wheel) Profile



Forward coupling

Reverse coupling

Reverse-direction coupling has driver's seats at the front and back, giving the benefit of moving easily between cabs when operating only on tracks. However, damage to transmission and other parts can happen to automobiles running in reverse at high speeds over long distances, so a disconnecting device that cuts the power transmission at the rear car, allowing operation as a trailer, has been trialled although the long-term effects of reverse wheel rotation need further verification.

Expected Effects

The DMV is expected to have the following business effects (Figure 7).

First, unlike other transportation modes requiring large investment in new infrastructure, the DMV uses existing infrastructure, cutting costs such as initial investment for purchase of vehicles and wayside equipment, running costs such as fuel, and maintenance costs for upkeep of cars and tracks. Compared to railway rolling stock, vehicle purchase expenses are anticipated to be 80% lower, vehicle maintenance expenses 25% lower, and power costs 80% lower (Figure 8). Thus, huge cost reductions can be expected.

Second is increased convenience and service. Railways are linear means of travel while roads are planar, requiring railway passengers to change modes to reach their destination. The DMV allows passengers to reach their destination in the

Figure 7 DMV Characteristics and Features

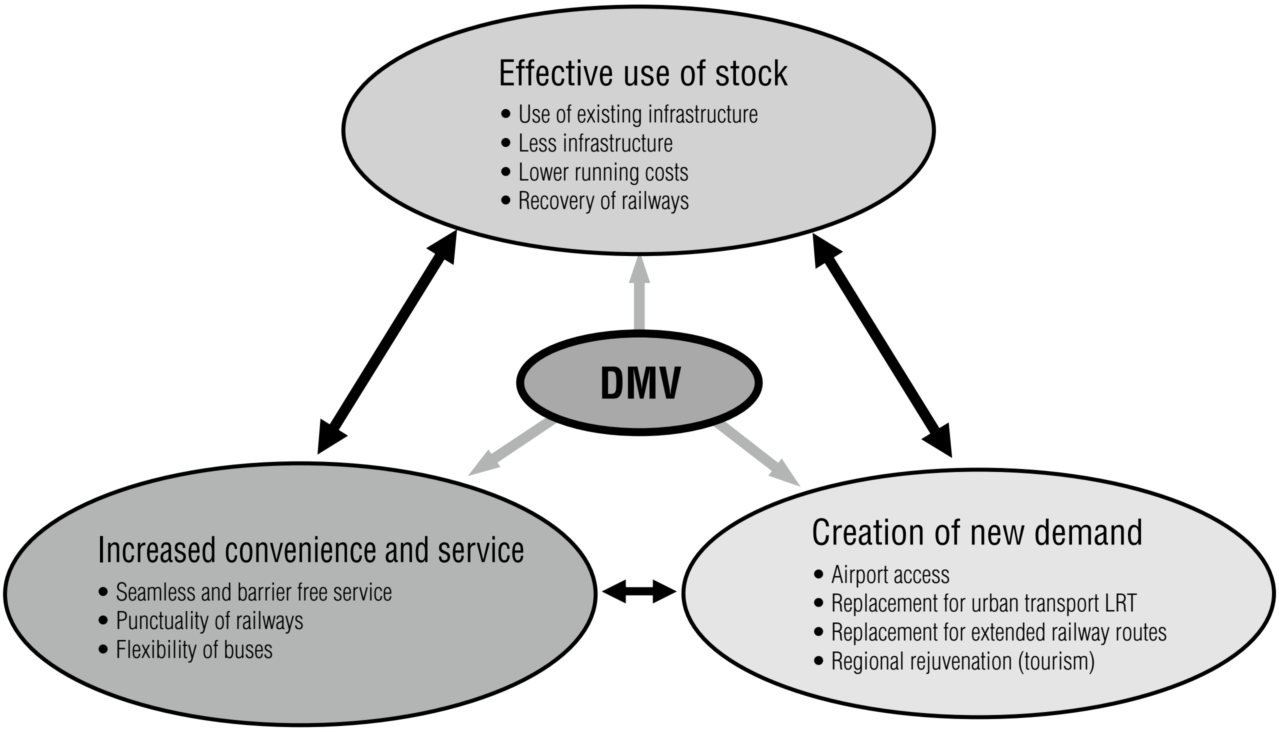
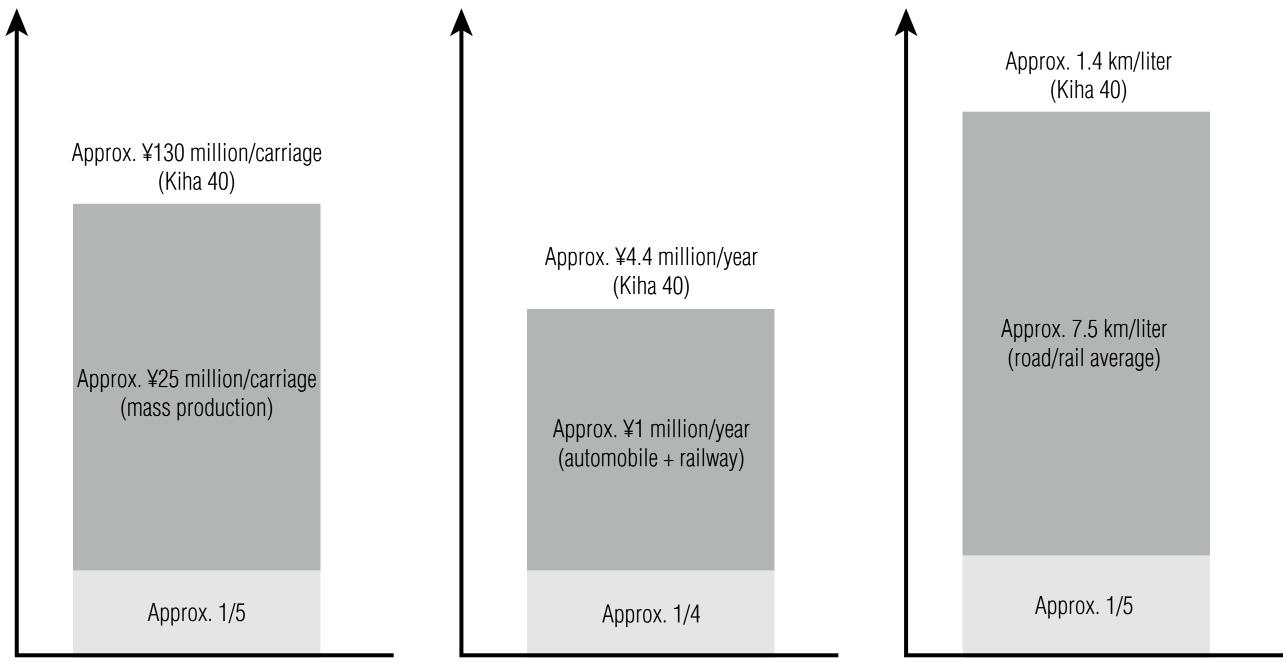


Figure 8 Effective Use of Stock (Lower Cost/Energy)



Purchase cost

Mass production price assuming DMV in actual passenger operation (vehicle used for trial passenger operation)

Maintenance cost

Inspection expenses, etc., for automobile legally mandated inspection expenses + railway inspection (steel wheels, hydraulic devices, etc.)

Fuel consumption

Fuel consumption of DMV in actual passenger operation (vehicle used for trial passenger operation)

Figure 9 Increased Convenience and Service (Seamless Railway and Road Services)

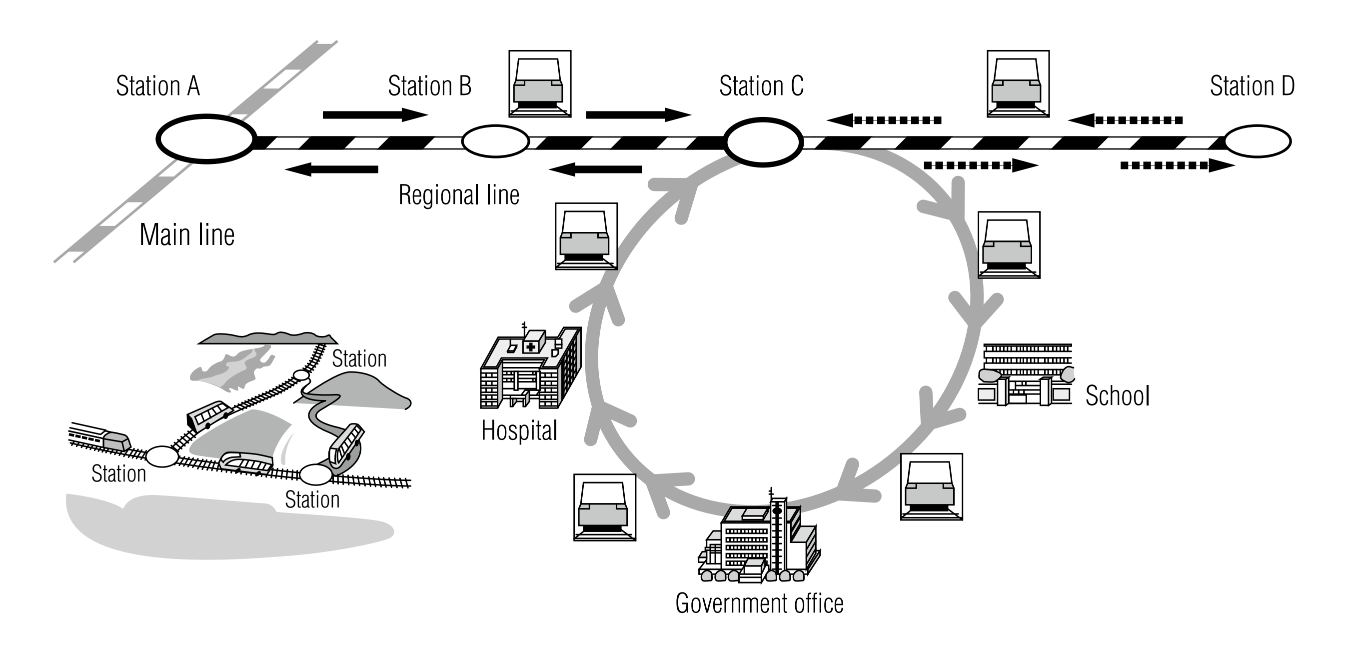


Figure 10 Creating New Demand

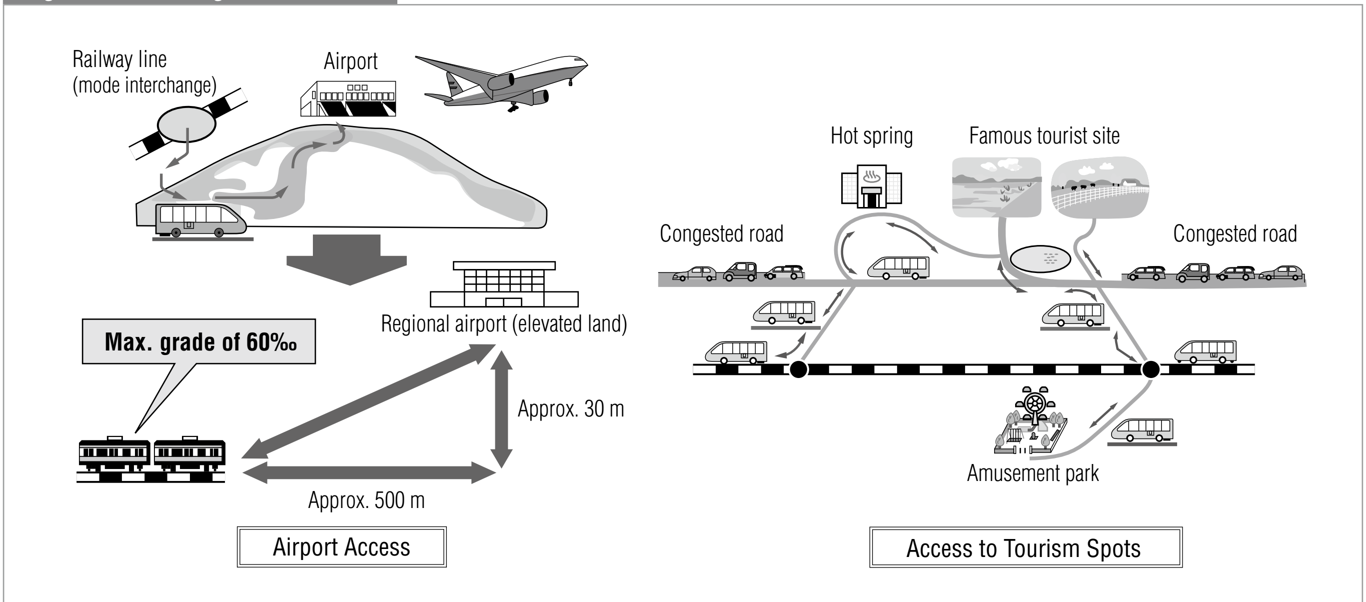


Figure 11 Congestion Avoidance

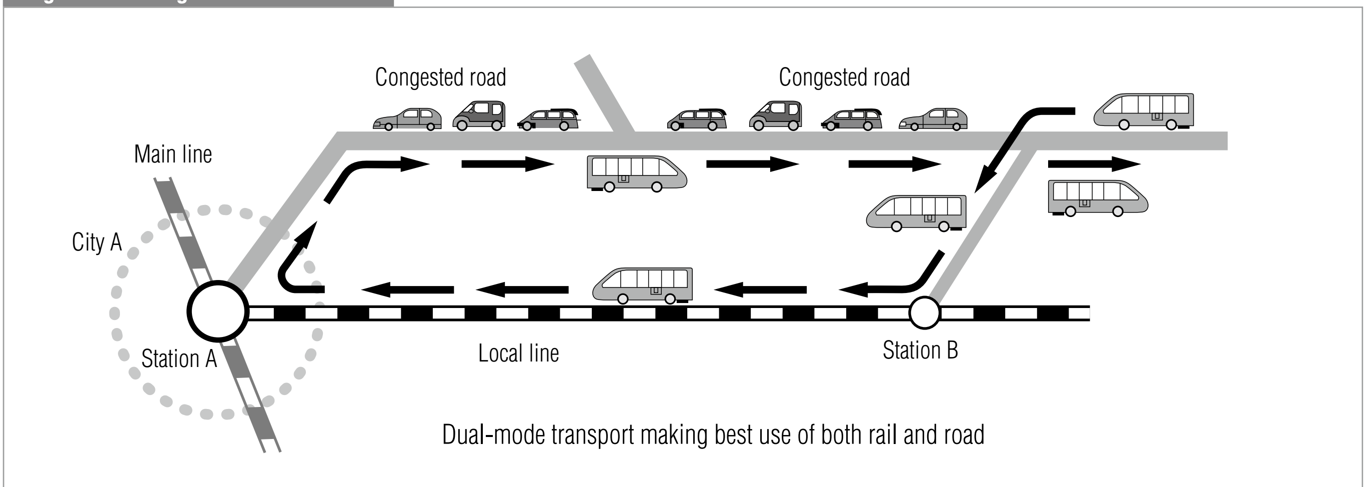
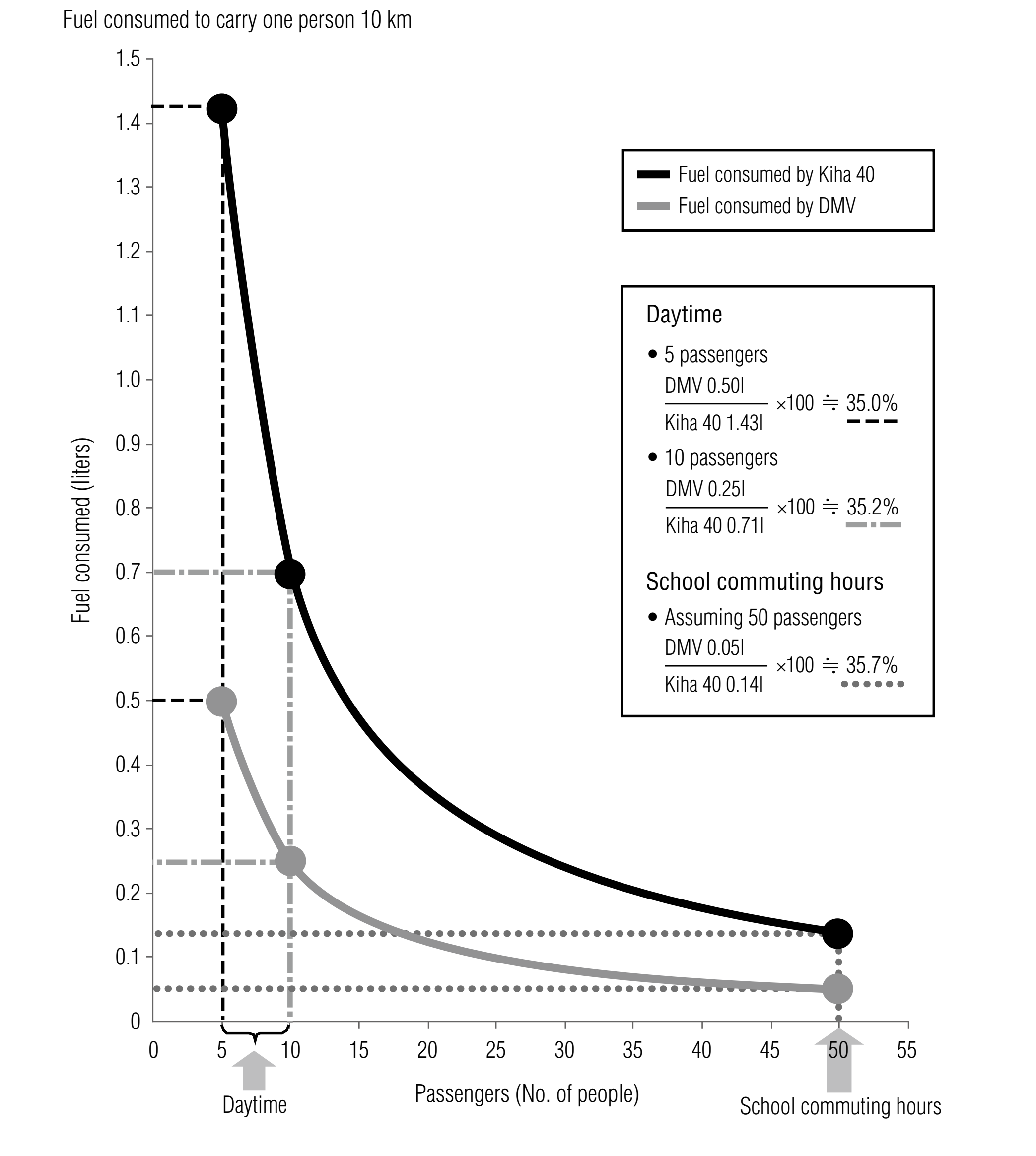


Figure 12 DMV Energy Conservation



same vehicle (Figure 9). The DMV is also practically barrier-free, helping create a new transport paradigm for aging societies.

Third is creation of new demand because the DMV can serve new areas outside existing rural networks, such as airports, urban LRTs, and tourist spots (Figure 10) to support regional revitalization.

Furthermore, in track sections, passengers reach destinations quicker than on congested roads, so the punctuality and reliability of railways can be used as business tools again (Figure 11).

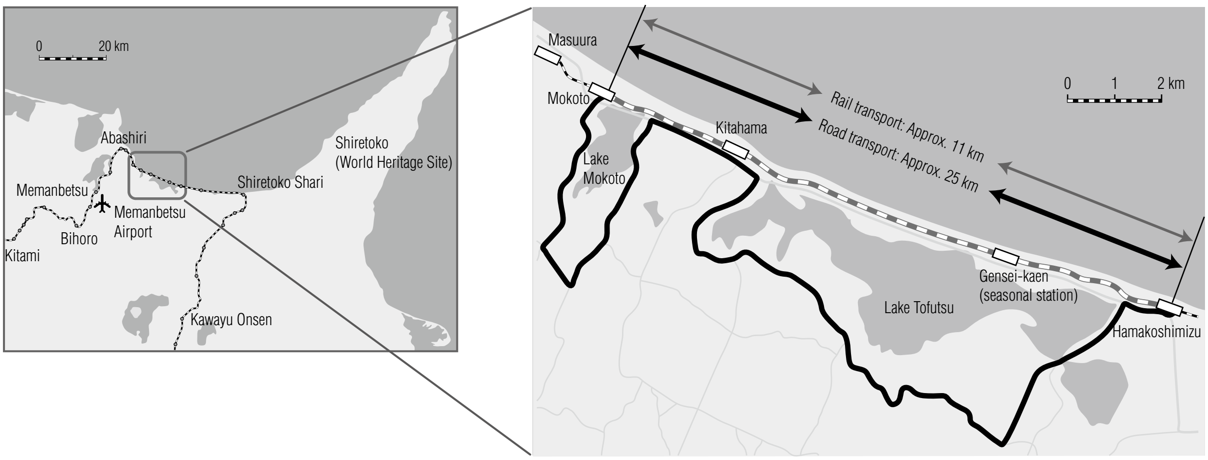
Also, the flexibility of DMV routes frees it from disruptions during problems such as washed-away tracks or roads buried under snow. In other words, the DMV supplements the need for alternate modes and other weak points of railways.

While railways are often seen as environment friendly, they are not in rural sections where large and heavy rolling stock is carrying only a few people each day. Since the DMV only uses about 30% of the fuel of a conventional diesel railcar (Figure 12) it is much more environment friendly on rural railways.

Approach to Trial Passenger Operation

Trial passenger operation of the DMV has been underway since 4 April 2007 on the Senmo Line between Mokoto and Hamakoshimizu (Figure 13). The operation follows a circular route with a single car, composed of rail from Hamakoshimizu to Mokoto (about 11 km) and road from Mokoto to Hamakoshimizu (about 25 km). Three round trips are made each day in between conventional train services (time sharing). One round trip takes about 1 hour. Maximum

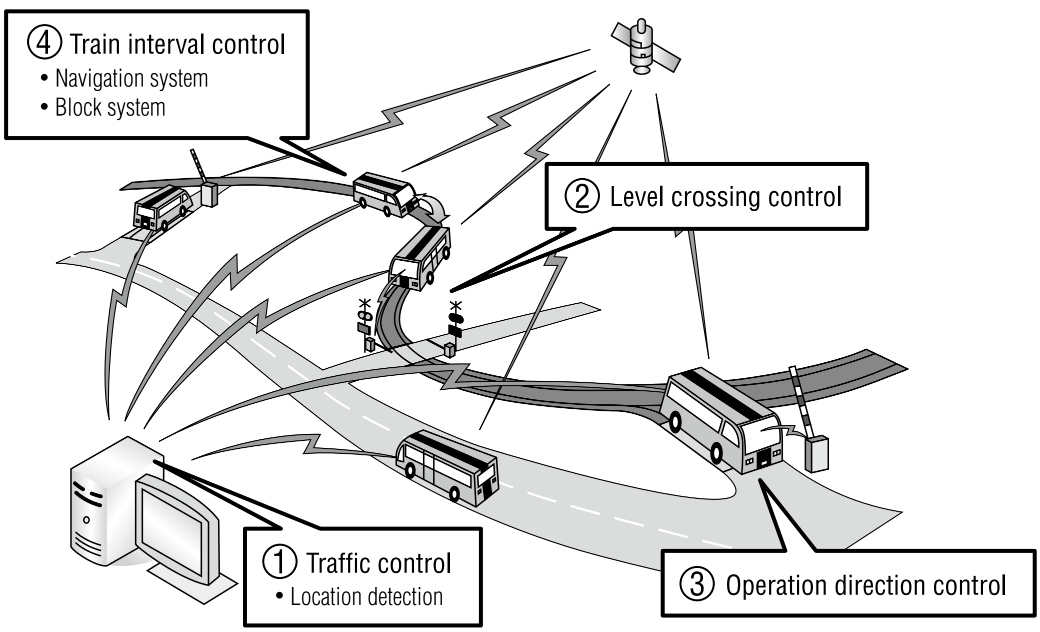
Figure 13 DMV Trial Passenger Operation Section



Exterior of new DMV test car model

Interior of new DMV test car model

Figure 14 DMV Operations Safety System



speed on tracks is 70 km/h, and is at the posted legal speed limits on roads.

In fiscal 2007, the DMV operated for 91 days, making 271 trips carrying 3095 passengers (approximately 94% of capacity). Service was well accepted by passengers who provided opinions and feedback. Operation until the end of fiscal August 2008 has been troublefree too.

Efforts to Achieve Full-scale Commercial Use

The current focus for expanding introduction of the DMV is development of a new model with increased capacity and development of an operation safety system. Automakers have cooperated in supplying larger microbuses for 25 persons or more. The two photographs opposite show the new DMV test car model (DMV920) completed in June 2008, with capacity for 28 persons demonstrated at the G8 Hokkaido Toyako Summit. Basic operation data will be collected from the DMV920 and another new model with capacity for more than 25 persons will be developed targeting full-scale commercial operation in about 3 years.

Figure 14 shows the development of the operation safety system. Trials are underway and operation tests are being conducted for a level-crossing control system with a goal of practical use in 3 years when the first DMV enters commercial operation.

Conclusion

The DMV was born from a shift in thinking and creativity, as well as from a sense of urgency to keep rural railways operating. However, many issues remain for using it an as effective transport mode suited to the community. Most importantly, users, operators, and government must work together to solve problems presented by an aging society and growing private automobile use. Significantly we must think about how to use the DMV from the standpoint of creating a far-sighted transport network. The current situation sees users avoiding railways, operators in a difficult business environment, and government in a difficult financial situation. To create a viable transport network, local users must understand the DMV and view it as their own railway, the community's railway, and as a method for restoring their community. As the operator, we must make the maximum self-supporting efforts and raise service levels. For its part, the government must recognize the limits of users and the operator and help support a new transport network for the community. As expressed by naming it *Darwin* (Figure 15), there are hopes that the DMV will engender technical, community, and policy innovations.

Present passenger trials are being used to verify future expanded DMV introduction. On the other hand, trials do not use all the DMV's characteristics and features sufficiently and as many people as possible should be allowed to take test rides and give feedback, so development can be stepped-up in anticipation of commercial operations in 3 years with expanded forms of operation in the future. ■

Figure 15 DMV Nickname—Darwin

Darwinism

- Species don't survive just because they are strong.
- Species don't survive just because they are exceptional.
- Species survive because they evolve.

DMV

- Transport can't survive on tracks alone.
- It can't survive on roads alone, either.
- So it has evolved into the DMV running on tracks and roads.

Hirohiko Kakinuma

Mr Hirohiko Kakinuma is Vice President of JR Hokkaido. He joined Japanese National Railways in 1969 and moved to JR Hokkaido when the company was established in 1987. Prior to his current position, he served as the Executive Managing Director, and General Manager of Railway Operation Headquarters.