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# Development and Introduction of Automatically Guided Vehicle for Steel Product Distribution

Juichirou Hashimoto*1 Norifusa Kawabata*1
Keiji Nakanishi*2

**Abstract:**

*The automatically guided vehicle (AGV) is highlighted as a flexible transport vehicle for existing lines in a variety of industrial fields. In the steel industry, heavy coils are currently carried by trucks and lift cars from one process to another. The transportation of heavy steel coils requires AGVs that are as compact as possible, highly mobile and stable. Also necessary are systems to manage and control the operation of AGVs in an optimum manner. Vehicle manufactures are unable to supply AGVs and AGV systems that can meet the layout, direct transfer, and continuous operation requirements of existing lines in the steel industry. Nippon Steel developed a prototype AGV by making use of its functional design expertise and tested the prototype to verify its performance and to check and refine its initial design concept. It then developed and introduced commercial AGVs at some of its steelworks.*

## Introduction

The employment environment is severe in the entire transportation sector of Japan's steel industry. Given stiff competition in the labor market, the steel industry is faced with difficulty in employing adequate numbers of truck and lift car drivers who account for the majority of the personnel engaged in transportation in the steel industry. With this trend predicted to continue in the future, the steel industry must take drastic measures that will remain effective well into the next century. The movement of semifinished and finished steel products comprises three basic work elements: loading, carrying, and unloading. These operations are low-value added. Employees are exposed to the risk of contact with material handling machinery, putting their jobs in the 3-K category [*Kitsui* (demanding), *Kitanai* (dirty) and *Kiken* (dangerous)].

*1 Technical Development Bureau

*2 Yawata Works

Against this background, Nippon Steel began work on the development and introduction of an AGV to perform all of the three basic transportation tasks and an AGV operation control system. As the first step toward the realization of an unmanned factory, it also began combining the AGV and the AGV operation management and control system with automatic cranes.

## 2. Development of AGV

### 2.1 Functions required of AGV

(1) High applicability to existing facilities

The AGV should require a minimum amount of foundation modification and a moderate degree of foundation levelness.

(2) Compactness and self-loading/unloading capability

The AGV should measure not more than 2.1 m wide, 2.3 m long, and 1.5 m high. (This size is the same as the projected area of a 30-ton coil and is aimed at improving coil yard efficiency.)

(3) Avoiding interference with existing equipment and high mobility to prevent reduced coil yard efficiency

The AGV should be capable of changing direction (or traversing at right angles, moving diagonally and turning on a small radius), loading and unloading coils at high speed, and traveling loaded with large coils at a speed of 60 m/min or more.

(4) Improvement in stopping accuracy

The AGV should be capable of stopping within ±20 mm of a desired position to interface with line equipment.

(5) Railless type

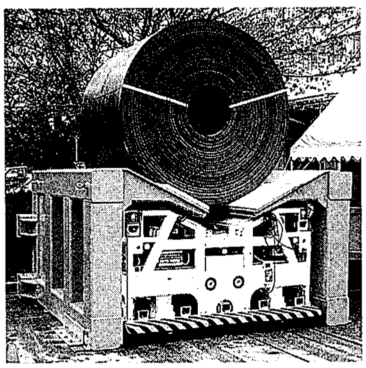
It should be possible to change the layout and route of the AGV.

### 2.2 Description of prototype AGV

The prototype AGV built on the basis of the above-mentioned functions is shown in **Photo 1**, and its main technical specifications are described in **Table 1**.

## 3. Transfer to Commercial AGVs

The technical findings obtained through the development of the prototype AGV with respect to basic technology, basic functions, parts composition, and the like were transferred to commercial AGVs as much as possible by considering the operating conditions and equipment constraints characteristic of specific steelworks. As a result of these efforts, low-cost AGV models are now operating at Nippon Steel's works as shown in **Photos 2** to **4**. Their operating routes and rules are designed to meet the pattern and frequency of distribution operations at each works. An example of operating route simulation is shown in **Fig. 1**.



Basic specifications
Width: 2,100 mm
Length: 2,300 mm
Height: 1,300 mm
Maximum payload: 30 tons
Maximum speed: 70 m/min
Maximum gradient: 3%
Stopping accuracy: ±20 mm
Steering modes: Forward and backward, traverse, diagonal, and turning

**Photo 1** 30-ton self-loading AGV

**Table 1** Main technical specifications

| Specificatin | Description |
|---|---|
| Chassis size reduction | • Independent steering system with double-wheel differential gear<br>• Small-sized turning mechanism<br>• Size reduction and optimum arrangement of assembly components (such as coil support, lift mechanism, and battery) |
| Travel stability | • Wheel load equalizing support mechanism<br>• Differential functional control between drive units<br>• 4-WD and 4-WS high-accuracy steering mechanism |
| Guidance method | • Combination of magnet guide method and autonomous travel method |
| Minimum maintenance | • Simplification of chassis structure and modularization of component parts<br>• Adoption of miniature AC servo motor<br>• Rapid automatic charging method (adoption of small-sized NiCad battery) |
| Malfunction prediction and diagnosis | • Prediction and feedback of malfunctions that may cause system to crash<br>• Diagnosis and optimum correction of troubles, and judgment of whether or not system can be automatically reset<br>• Automatic detour route setup function |
| Multiple-redundancy system | • Construction of multiple-redundancy system to ensure reliability of fail-safe, continuous operation |

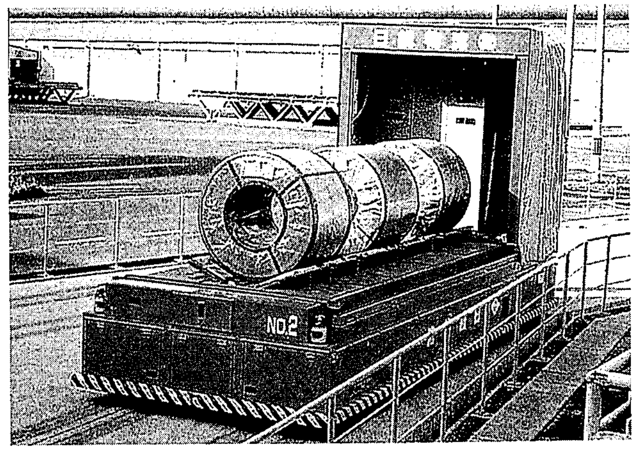



**Photo 2** 30-ton AGV at Hirohata Works (three coils loaded in series)

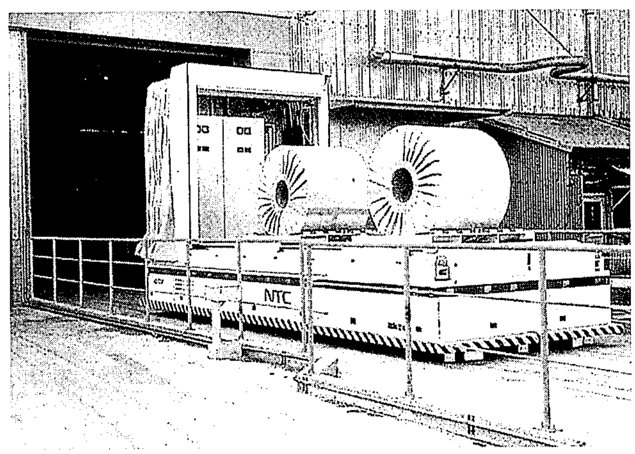



**Photo 3** 30-ton AGV at Yawata Works (2 coils loaded in parallel)

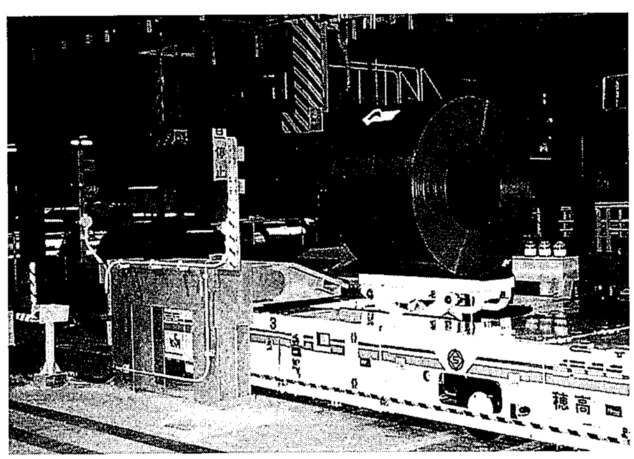
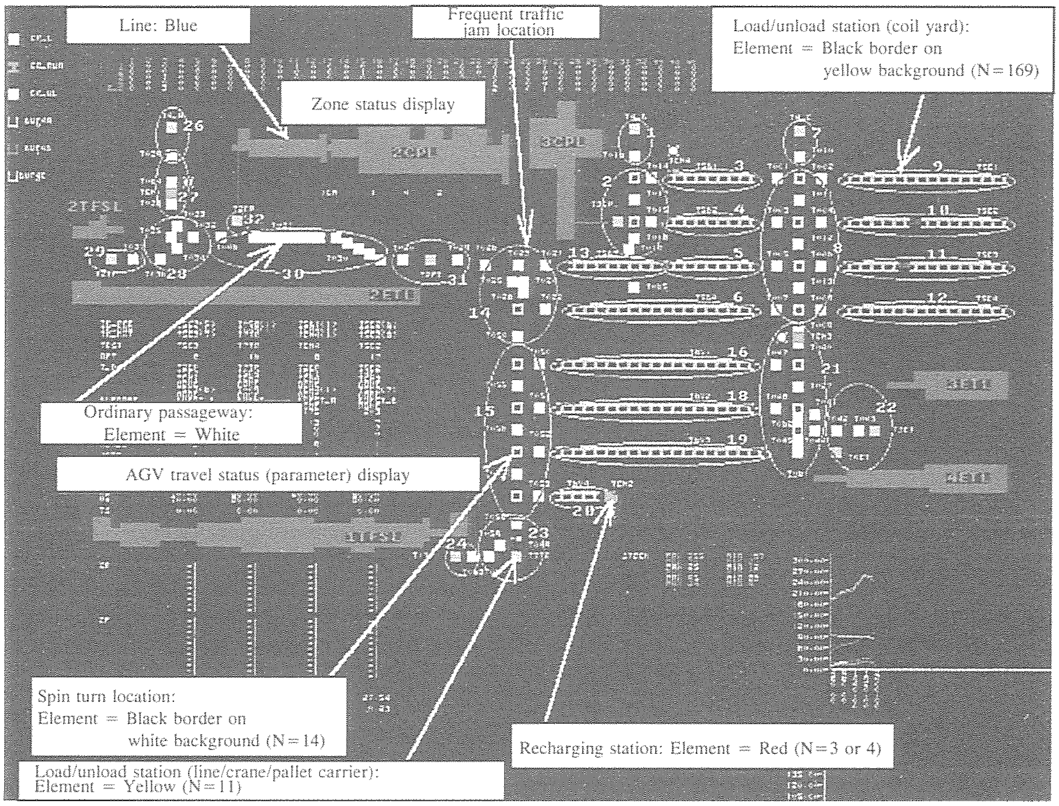


**Photo 4** 25-ton AGV at Nagoya Works (low-deck type to carry one coil)

(a) Simulation model




(b) Simulation results

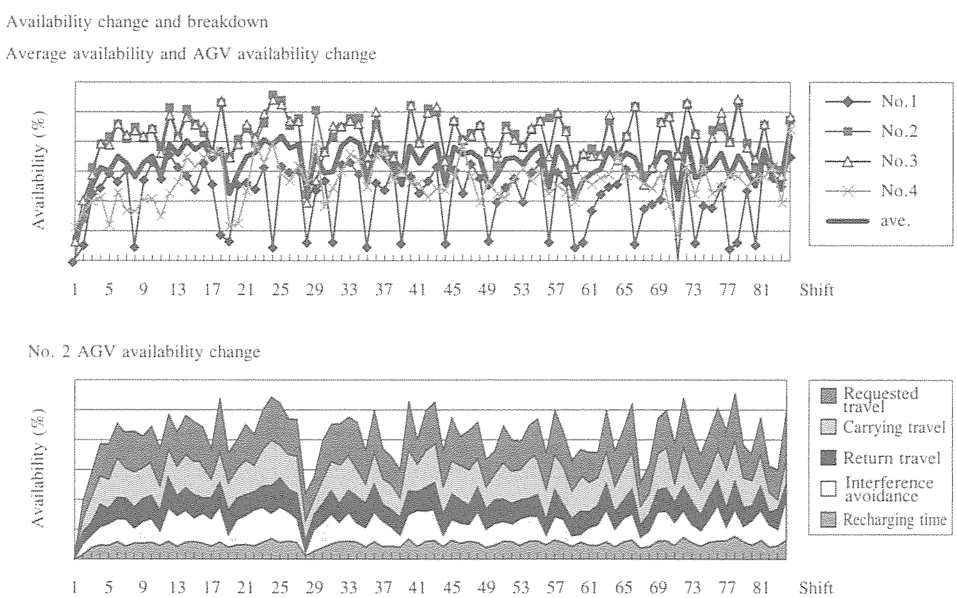



**Fig. 1** Example of operating rule simulation

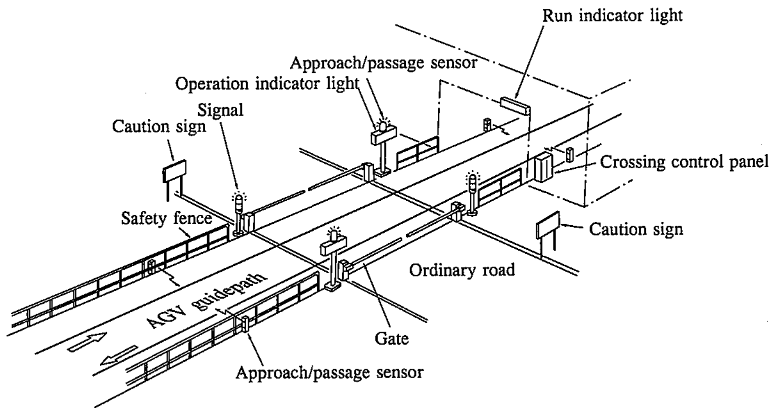



**Fig. 2** Road safety measures

## 4. Safety Measures Implemented with Introduction of AGVs

Each AGV is equipped with an obstacle sensor, bumper switch, emergency stop pushbutton, and other safety devices required to carry heavy coils as well as an automatic stop function in the event its control system malfunctions. Intersections with ordinary roads are equipped with gates, obstacle sensors, and other safety devices as shown in **Fig. 2**.

## 5. AGV Operation Management and Control System

### 5.1 Hardware configuration

The AGV operation management and control system consists of a factory automation (FA) computer performing the main operation control functions and remote input/output devices connected to the FA computer as shown in **Fig. 3**. A workstation or FA personal computer is used as the FA computer depending

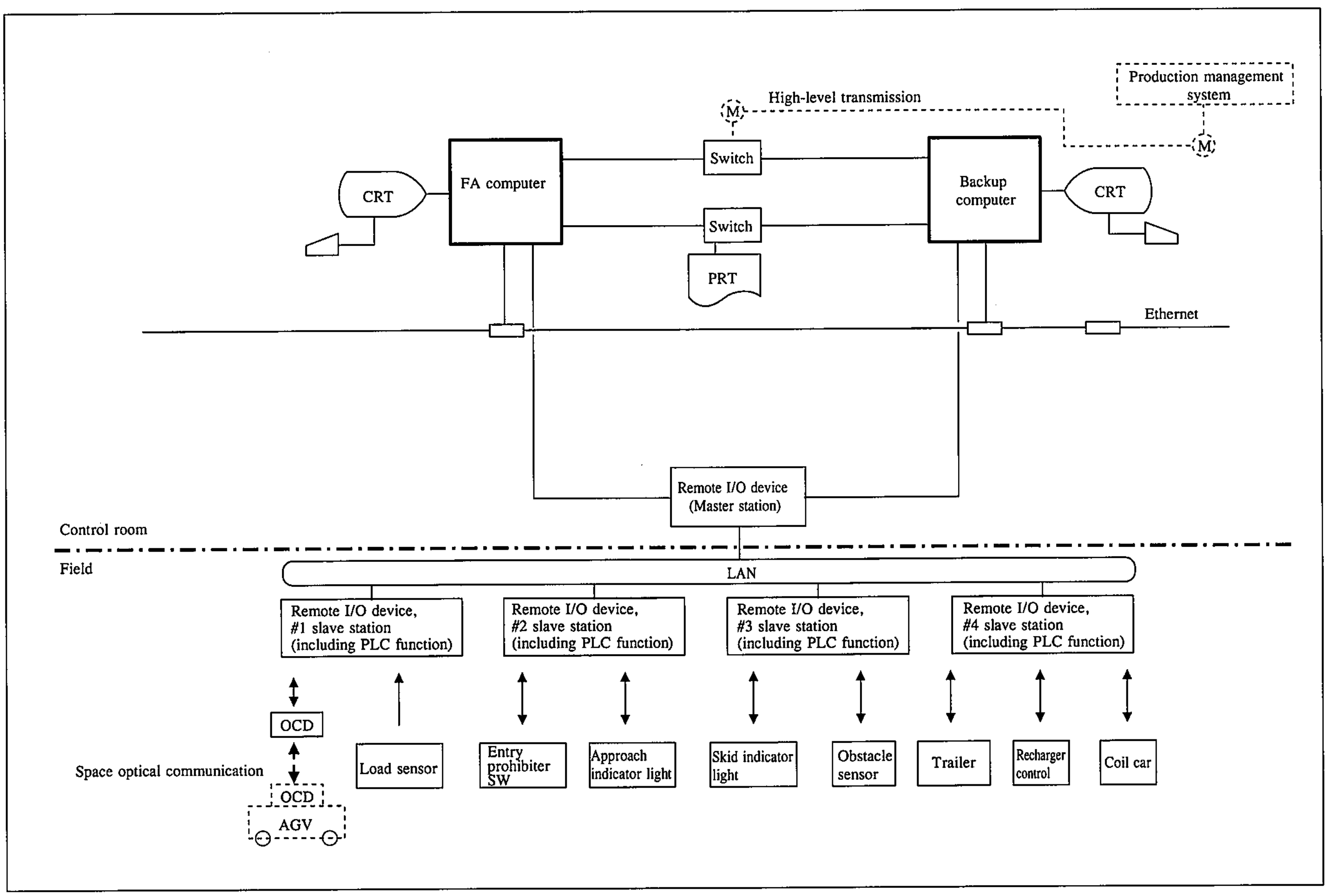



**Fig. 3** Hardware configuration of AGV operation management and control system

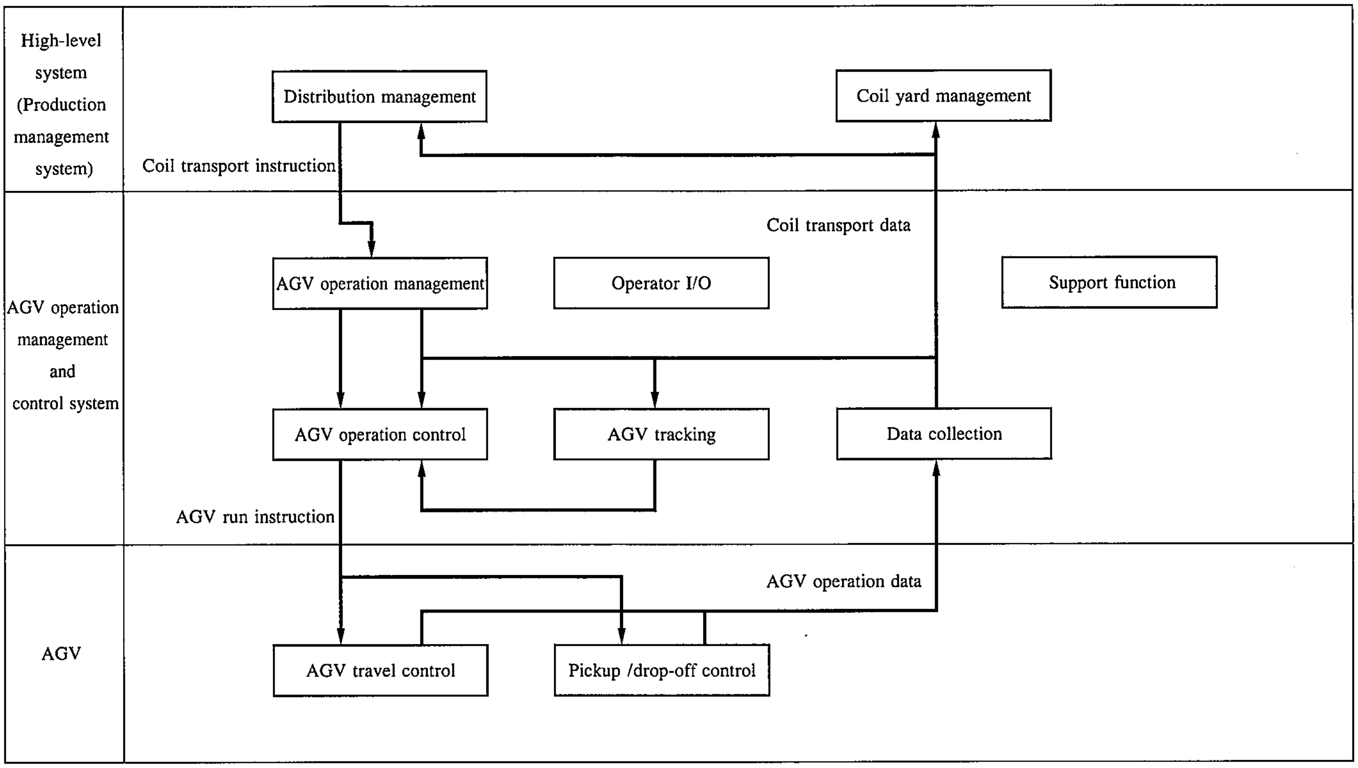



**Fig. 4** Functional configuration of AGV operation management and control system

on the scale of the system and the maintenance requirements of each works. The remote input/output devices are usually general-purpose sequencers and are composed of the master station that is directly linked with the FA computer and the slave stations that are installed where required in field locations. The largest factor that governs the type of sequencer to be selected is its connectivity with the FA computer.

The main external input/output device of the AGV operation management and control system is a space optical communication device (OCD) for communication with the AGV.

The AGV operation management and control system can communicate with the AGVs by radio and several other methods. The OCD has been chiefly used for this purpose in view of control needs and noise avoidance. Since the OCD also acts as the AGV tracking sensor, a few dozen OCDs are installed along the AGV guidepaths in some of the systems installed.

**5.2 Functional description**

The functional configuration of the AGV operation management and control system is shown in **Fig. 4**.

5.2.1 Distribution management

Normally, coil transport plans and instructions are prepared by the high-level system or production management system. The high-level system prepares and issues coil transport instructions for production lines in the automatic transport area. The high-level system also manages the coil yard according to the coil transport results conveyed from the AGV operation management and control system.

5.2.2 AGV operation management

The coil transport instructions issued at random by the high-level system are managed according to their time series and priority. The operator can control the transport route to decide on whether or not to allow the AGV to pass a specified guidepath and to determine the sequence of executing the coil transport instructions when managing AGV failures.

5.2.3 AGV operation control

The AGVs are allocated and the AGV guidepaths are planned and established for efficiently operating the AGVs and for observing the time series and priority requirements of the coil transport instructions. Such control activities are also implemented to prevent interference between the AGVs, regulate crossing gates and other guidepath safety devices, to interlock the AGVs with the production lines to transfer coils, and to charge the AGV batteries.

5.2.4 AGV tracking

The positions and conditions of individual AGVs are managed and used as data for AGV operation control to prevent interference between the AGVs and regulating the safety devices.

5.2.5 AGV operation data collection

AGV operations data, such as loading and unloading, traveling unloaded, traveling loaded, and recharging, are collected and used to manage the AGV availability and battery recharging time.

**5.3 Future issues**

5.3.1 Shorter construction period

Shortening the AGV system's construction period would allow its labor-saving benefits to be enjoyed as soon as possible.

After being applied at various mills, various models of AGVs can be built and delivered within a short lead time. In the future, AGV operation management and control systems will have to be designed and installed over shorter periods of time.

Through in-house system engineering, Nippon Steel is implementing corrective measures, such as design standardization and software packaging.

5.3.2 More efficient AGV operation

To control the cost of introducing an AGV system, the AGVs must be efficiently operated to deliver their transport capacity to the fullest possible extent. Further improvement in AGV operation efficiency calls for the training of schedulers who can effectively manage distribution operations and control AGV allocation at high speed. Nippon Steel is aggressively working to foster such schedulers.

## 6. Conclusions

Some of the AGVs developed and introduced to mainly transport sheet steel coils have been described here. As AGVs are increasingly applied to the transportation of plates, pipe and tubes, bars, rods, rails, and other shapes, their types and loading methods will diversify to meet the equipment and operating conditions of the lines manufacturing these types of steel products. The AGV travel technology, part composition, guidance and communication methods, operation management and control, and other results accomplished in the development project discussed here will be transferred as common resources for the development and implementation of AGVs for transporting other types of steel products at the steelworks.