Rush-hour congestion had become a serious social problem by the 1960s due to the large number of commuters in Japan’s large cities. Train station workers were still punching each ticket by hand despite facing a throng of passengers at each gate. Efforts to relieve congestion through improved worker performance were limited in effect.

The automatic ticket gate system was first introduced at Kitasenri Station on the Keihan-shin Express Railway (currently the Hankyu Railway). This system allows a passenger to place a ticket into the ticket insertion slot of an automatic ticket gate and retrieve it from the take-out slot within 0.5 seconds. Within this short period of time, the automatic ticket gate processes a complex array of information, including departure time, boarding and exiting stations, fare and validity period.

The system spread rapidly, first within the Kinki region and gradually throughout Japan. The introduction of automatic ticket gate systems has significantly improved gate congestion and dramatically reduced the time station workers have to spend at gates, resulting in substantial cost savings. IC cards and other technological advances in recent years have made automatic ticket gate systems even more convenient for passengers. In 2007, the Institute of Electrical and Electronics Engineers, Inc. (IEEE) commemorated the development of automatic ticket gate systems by naming them an “IEEE Milestone.”

Train companies were not solely responsible for the research and development which led to automatic ticket gate systems. The cooperation of universities and private manufacturers was indispensable. The following section describes the history of the development of automatic ticket gate systems and the relevant technical issues.

Background to the innovation

(1) Train station congestion and automatic ticket gate systems

Japan was undergoing rapid economic development in the early 1960s. At major train stations, the rush-hour congestion at station gates reached extreme levels. Train tickets of the...
time had to be physically punched by station workers. Their efficiency reached its natural limits, and the areas around the gates were constantly crowded.

It was difficult to increase the number of station workers assigned to the gates. For a railway company, which needs to cover rising personnel costs, the simplest method would be to raise fares. However, this would have required government approval by a Diet that would have been reluctant to raise fares due to public opposition.

In response to these issues, Kintetsu Railway (“Kintetsu”) and other major train companies began discussing the possibility of solving the problem of train station congestion with an automatic ticket gate system. In February 1964, Kintetsu established a study group tasked with the development of an automatic ticket gate system and commenced joint research with Osaka University. Tateishi Denki (currently OMRON Corporation (name changed in 1990), hereinafter “OMRON”), an equipment manufacturer, joined the project in September 1964.

First, on a trial basis, engineers made an automatic ticket gate specifically for commuter passes. In Japan, the holder of a commuter pass is allowed to exit at any station along the commuting route. In order to produce an automatic ticket gate to handle commuter passes, it was necessary to solve two engineering issues: (a) assign a code to a commuting route using a minimum number of bits and (b) expedite the process of determining whether the boarding station or the exiting station is on the commuting route. These technical issues could not have been solved without a breakthrough made by Osaka University in the field of graph theory.

A certain degree of theoretical success was achieved through the efforts of Kintetsu and Osaka University. However, in order to make the technology practical, it was necessary to increase the processing speed. To tackle this challenge, the engineers decided to make more prototypes to determine the basic functions and structure.

(2) OMRON’s efforts

OMRON was a midsize equipment manufacturer founded in 1933. One of their major businesses at the time of the development of the automated ticket gate system was the production of automation equipment. As the market for automation equipment expanded, OMRON established the Central R&D Laboratory in 1960 to strengthen their product development capabilities. In 1961, in the wake of the “Chi-37 Case” (the discovery of a large number of counterfeit 1000 yen notes), OMRON successfully developed a counterfeit note detector within a short period of time. This achievement was featured in an industrial paper, leading to the conclusion of an automatic ticket gate system joint development agreement between OMRON and the Railway Technical Research Institute.

In order to not slow a passenger’s walking speed, an automatic ticket gate system must be able to continuously handle 60 to 80 passengers per minute and convey a ticket or commuter pass from one side of the gate to the other within 0.6 seconds. To achieve this goal, four requirements must be met: (i) the ticket insertion and removal slots must be conspicuously positioned and have user-friendly shapes; (ii) it must be possible to insert a ticket or commuter pass from either side of a ticket facing either up or down; (iii) a ticket or commuter pass must be conveyed to the other side of the gate within 0.6 seconds; and (iv) tickets and passes can be inserted continuously. Although OMRON, a manufacturer of machine parts, lacked experience in the manufacture of machines of this type, the development team members carefully conducted on-site research and gathered data to identify and solve the problems posed by an automatic ticket gate system.

In 1965, engineers introduced an experimental prototype. OMRON faced various ongoing technical challenges, such as the development of technology to align and convey tickets. By 1966, OMRON had successfully developed an automatic ticket gate capable of conveying a
commuter pass from the insertion slot to the take-out slot without errors. However, Kintetsu was forced to abandon its plan to introduce an automatic ticket gate system the same year when it was unable to reach an agreement with the former Japan National Railways that would have allowed the automatic ticket gate system to seamlessly handle the commuter passes of both railway networks.iv

(3) Commencement and improvement of the system

After Kintetsu’s withdrawal from the project, OMRON made sales overtures to other railway companies and worked continuously to solve the remaining technical problems. In 1967, they were finally allowed to install a prototype for testing purposes at Kitasenri Station on the Keihanshin Express Railway (as it was then named).v Kitasenri Station was the station closest to Senri New Town, a major new residential development under construction at the time, and was in the area where Expo ’70 would be held. The automatic ticket gate system would form a part of a sophisticated, modern railway suitable for a new major residential development in Japan.vi

In March 1967, the commercial operation of the automatic ticket gate system commenced with the installation of newly developed ticket gates capable of handling regular tickets in addition to protocols developed specifically for commuter passes. However, a great deal of confusion accompanied the introduction of the system. For example, many passengers mistakenly inserted regular tickets into the slot specifically for commuter passes or inserted paper money, coins, or commuter pass cases directly into the slot. Also, the ticket gate often closed before passengers carrying large objects could pass through.

During the process of developing automatic ticket gates capable of accepting both commuter passes and regular tickets, many discussions were held to solve the issue of how to record information on a regular ticket, which is much smaller than a commuter pass. Conventional punch card techniques were inadequate. Engineers needed to develop a new technique. It was not easy to find a means of instantly reading complex data recorded on a ticket and making the necessary judgments. The engineers participating in these discussions finally came up with the idea of using a technique still in its infancy: digital signals recorded on magnetic tape. The aforementioned problem was solved by equipping each automatic ticket gate with simple judgment functions.

(4) Evolution of automatic ticket gates

After the successful introduction of an automatic ticket gate system at Kitasenri Station, many stations (mostly those of Kansai private railway companies) began introducing the sys-
tem. By the end of 1975, all of the major private railway companies and the Osaka Municipal Subway had introduced automatic ticket gates. However, the Kanto region railway network’s complex mixture of railway systems of many railway companies presented a much greater obstacle to the introduction of automatic ticket gates. The number of stations adopting automatic ticket gate systems gradually increased. In the first 30 years after the introduction of such systems in 1967, about 20,000 automatic ticket gates were installed throughout Japan.

The Congress of Japan Railway Cybernetics (CJRC) promoted the standardization of magnetic cards, and eventually established magnetic standards in May 1971. These standards provided a technical basis for the wide use of magnetic card-type automatic ticket gates. In 1990, the CJRC established new magnetic standards that significantly increased memory capacity, enabling the magnetic recording of complex transit information. As a result, commuter passes and regular tickets became usable across multiple railways. In 2001, the Suica IC card was released by Japan Railway East in the Tokyo metropolitan area, adding to the ever increasing sophistication of the automatic ticket gate system.

Outline of innovations and technological developments

This section briefly describes the graph theory invented by Osaka University, which provided the theoretical basis for the automatic ticket gate system, and outlines OMRON’s technological developments.

- Theory

Osaka University’s theory was intended to solve the following two engineering problems: (a) encoding commutation routes using the minimum possible number of bits and (b) accelerating the process of determining whether the boarding or exiting station is on the commuting route. This requires conceiving a route on a railway network as a linear graph. Problems (a) and (b) then “boil down to encoding every route that does not go through a given node in a given graph, making the determination of whether a given node or branch exists on the designated route mechanically easy.” The essence of the theory lies in the following two points: (1) the commuting route was expressed by indicating the codes of the stations at both ends of the route and the cotree branches through which the route passes and (2) the determination of whether a certain station exists on the commuting route is made by determining “whether the station exists on a route on the tree” and “whether the station exists on the fundamental pattern determined by the cotree branches that overlap with the commuting route.”

- Ticket alignment technology

The ticket alignment technology needs to be so accurate that tickets can be aligned with an accuracy of 100 μm or less. This was one of the major challenges of this project. Various conveyors were used on a trial basis to identify the merits and demerits of each design. Eventually, eccentric roller technology was adopted.

- Ticket conveyance technology

To improve ticket conveyance technology, experiments were repeatedly conducted to find a conveyer belt capable of high speed operation. At the time of the automatic ticket gate system’s initial development, a flat conveyor belt was used merely for the purpose of providing power. Based on the technology used in car stereo equipment flywheels, engineers first created a structure to convey tickets by sandwiching them between a drum and a flat belt. Engineers initially used a cold rolled steel sheet to make the guide frame, and subsequently changed this to an aluminum-based material. However, engineers faced contortion, distortion
and running surface abrasion issues. Engineers used Shimadzu Corporation’s machines to resolve the first issue, and anodized the frame to resolve the second.

- Information reading technology

  Magnetic heads were the most important component of the ticket information reading technology. At the time of the development of the automatic ticket gate system, magnetic heads were being produced by only a few audio equipment manufacturers and one division of a large electronics manufacturer.

  The information reading head developed by OMRON was designed to function in concert with a ticket punching machine. The punched ticket was conveyed to the exit side of the gate to trigger the opening or closing of the gate bar.

- Gate bar technology

  The decision to open or close the gate bar was made by a light sensor that was installed at the entry side of the gate to detect passengers. However, the sensor was unable to differentiate between baggage and passengers, causing it to malfunction repeatedly. Engineers conducted many tests by having passengers pass through the gates. Based on the data obtained from the tests, the engineers discovered that some space always exists between passengers and successfully invented a sensor that could instantly distinguish between baggage and passengers.

- Control circuit technology

  Among the various automatic ticket gate system-related technologies, control circuit technology has changed to the greatest extent. Initially, a semiconductor circuit was made by combining transistors with diodes. At the time of the development of control circuit technology, IC technology was already known, but was initially unsuitable for practical use due to a noise problem. Even after the adoption of IC technology, many failures occurred, which various measures had to be taken to prevent. The foundations of the current station administration system were laid during the development of microcomputers for calculators. Today, information is sent by an automatic ticket gate’s built-in computer to the railway system’s central computer and not merely to certain station equipment.

(Notes)

- The company names, product names, etc. used in this article are trademarks or registered trademarks of the relevant companies.
- Parts of company names, such as Co., Ltd., etc., have been omitted.
- Honorific titles have been omitted.

(Endnotes)


ii Akio Shibashi, Jidou kaisatsu no himitsu (Secret of an automatic ticket gate system) (Seizando Shoten Publishing, 2005), p. 41

iii Tateishi Denki, Tsukuru sodateru — Tateishi Denki 55 nen no ayumi (Foundation and Growth – the 55 year history of Tateishi Denki) (Tateishi Denki, 1988) p. 115

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xi Shirakawa, op. cit., footnote 1, p. 13

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