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Research & Development in the Telecommunication Industry

in Prewar Japan

－Automatic Telephone Switchboard－

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－Automatic Telephone Switchboard－

Yuki Nakajima[†]

Abstract

The telephone system was not sufficiently developed in prewar Japan. This study examines the technological development of automatic telephone switchboard (ATS) to clarify the problems of telephone system in prewar Japan. Ministry of Communication(MOC) introduced automatic telephone system in 1923. From the standpoint of the telephone exchange service, it was a very opportune decision; however, it was technologically premature. Although they had conducted research on the system before WW1, their only choice was the primitive S × S system. Further, the dependence on import technology caused different A-type and H-type ATS to coexist. Each local telephone exchange district independently introduced a different type. The MOC had to prepare the specifications and parts for repair for two different systems. These factors hampered the improvement of the telecommunication quality. Standardizing the system by using independent technology became the biggest issue for the MOC in the 1930s. In the 1930s, some joint researches were organized with private enterprises. They tried to develop a “T-type” or “Electronic Tube-type” ATS. However, the T-type ATS was merely an improvement over the outdated S × S system with respect to the circuit design. On the other hand, Matsumae aimed at a novel technology, an electronic common control system. However, a suitable electronic tube was not invented. As a result, the telecommunication industry was unable to resolve the coexistence problem in the prewar period. However, the engineers of MOC and ATS suppliers recognized their technological backwardness and shared an awareness of the importance of standardization by independent technology. This was the starting point for the research and development system of the telecommunication industry in “Postwar Japan.”

Key Words: Telephone system, Automatic Telephone Switchboard, Ministry of Communication, Research & Development, Joint Research

JEL: N65, N75, O33

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Introduction

Telephone system has been used to exchange important information on numerous business transactions. However in Japan, some historical studies pointed out that telephone was in remarkable short supply in prewar period. Moreover, automation on telephone exchange, which was indispensable for rapid expansion of telephone network, did not become widespread enough. To explain such a backwardness of telephone system, these studies focused mainly on the government policy because it was under control by Ministry of Communications (MOC) in prewar period. MOC did not allocated their budged for telephone service sufficiently since they started telephone exchange in 1890. So they had to expand telephone system within the severe austerity budget and to prioritized cities to allocate them. It caused regional unbalanced expansion of telephone network.[1] MOC's budged allocation was a fundamental problem.

On the other hand, MOC depended on private companies in regard to supply of telephone equipment such as telephone set, cable and switchboard. Domestic manufacturers in prewar days were in the process of acquiring technologies from advanced countries by licensed production and patent contract.[2] Therefore, we should consider not only the government policy but also the technological problem which was involved in Japanese telephone industry. This study examines the introduction of the automatic telephone system as well as the technological development of Automatic Telephone Switchboard (ATS) to clarify the problems of telephone system in prewar Japan.

Some studies that dealt with the technological development of the telecommunication industry in "postwar" Japan give us the point at issue. These studies indicate that the joint research between Nippon Telegraph and Telephone Public Corporation (NTTpc) and private companies—called the "Den-Den Family"—played a crucial role in the establishment of an independent technology.[3] However, the prewar history of ATS technology was described only as an outline. Several studies have recently indicated that after the 1930s, private companies, government offices, universities, and military institutes were organized to conduct joint research in various fields.[4] ATS was no exception. This study investigates the type of joint researches established with regard to ATS in prewar Japan and estimates their role.

The process of introduction of the automatic telephone system in Japan is described in Section 1 of this paper. MOC engineers had begun to investigate the system before WW1 and took an initiative to automate the telephone exchange system. However, because of the immediate introduction of the system without waiting for the domestication of ATS, MOC had to depend on imports from advanced countries, such as the United States, Britain, and Germany. Hence, this resulted in a situation in which different systematized techniques existed simultaneously in Japan.

In Section 2, the domestication process of ATS by the Japanese companies is described. The promotion of domestic production [*Kokusan Shorei*] led by the Ministry of Commerce and Industry

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[1] Ishii (1994: Ch. 3); Fujii (1998: Ch.4); Fujii (2005: Ch.3); Fujii(2006).

[2] The following studies dealt with the introduction of foreign techniques by patents, contracts, and research and development activities in prewar Japan, especially in the electronics industry.: Hasegawa (1995); Nishimura (2002); Nishimura(2003).

[3] Denki Tsushin Seisaku Sougou Kenkyusyo (1994); Anchordoguy (2001); Nemoto(1992).

[4] Hiroshige (1973); Sawai (2004); Aoki and Hiramoto (2003); Aoki (2004).

affected the procurement policy of MOC. Only four companies, Nippon Electric Company., Ltd. (NEC), Oki Electric Industry Company., Ltd. (OKI), Toa Electric Co.（TOA）, and Fuji Electric Company, Ltd. (FUJI) could become the domestic suppliers of ATS.

In 1930s, a crucial matter for MOC and ATS suppliers was to eliminate or at least considerably reduce the drawbacks caused by disunited ATS system. Some joint research groups were organized to develop independent Japanese technology, which is examined in Section 3. By the experience of these R&D activities in prewar day, many engineers were aware of the necessity to standardize ATS and to nurse their original technology. In the conclusion, I briefly mention this impact for postwar days.

Section 1
Introduction of automatic telephone system in Japan

1.1 Preliminary research of automatic telephone system

Although the automatic telephone system was introduced in Japan in 1926, preliminary research had begun from early 20th century. One of the earliest reports was submitted by Ryuji Nakayama. Two years after joining MOC, he observed the telecommunication industry in European countries and the United States in 1896; subsequently, in 1904, he studied again in these countries.[5] In 1913, at a conference held by Institute of Electrical Engineers of Japan (IEEJ), he reported on mechanical switching that was about to be introduced in advanced western countries.[6]

Morisaburo Tonegawa conducted a detailed comparison research between the manual and automatic exchange systems on a full scale. Tonegawa graduated from the department of Electrical Engineering in Tokyo Imperial University in 1897, and entered MOC.[7] In 1907, he went to the United States and Britain to research the telephone business; after returning to Japan in November the following year, he worked for the Electro-Technical Laboratory under MOC as an engineer and was appointed as the chief of the Laboratory from 1914 to 1920. Tonegawa compared the two systems on the assumption that the number of subscribers was 100, 200, 300, 500, 2000, and 10000. The foundation costs and the yearly running costs for each number were estimated by calculating factors such as the necessary number of switchboards, wages of manual operators and assistant engineers, prices of telephone sets, etc. As listed in Table 1, the automatic telephone system was more expensive than the manual exchange system for all number of subscribers. However, he calculated the foundation cost assuming that the ATS was imported while the manual exchange equipments were produced in Japan. He pointed out that by domesticating ATS in Japan, the disparity in foundation costs would greatly reduce. He argued that if operating costs for both the systems were almost identical, ATS should be introduced even if its foundation cost is more expensive.[8]

Yukitomo Yamane was the first engineer who visited foreign countries with the aim of surveillance

[5] Musen Denpo Tsusinsya (1921: 118).
[6] Nakayama (1913: 533–594).
[7] Electro-Technical Laboratory (1944: no page number).
[8] Tonegawa (1914: 65–149).

study of the telephone exchange. He was an assistant section manager at Temporary Bureau for Constructing Telegraph and Telephone (TBCTT) of MOC that was established in October 1920 as a part of the third telephone expansion program.[9] He reported that WE had developed a fully-automatic telephone switchboard, which was about to be practically implemented in the United States. Yamane insisted on the absolute superiority of the automatic telephone system over the manual exchange system with regard to speed of operation and confidentiality of telephone calls. Moreover, the wage increase after WW1 would reduce the advantage of lower operational cost of the manual exchange system. Yamane also pointed that the adoption of the fully-automatic switching system in the United States was inevitable, even if the foundation cost was considerably higher than that for the manual exchange system.[10]

Having been based on the above investigations, MOC finally began experimenting with ATS from 1922, using a 300-line switchboard imported from a British company, Automatic Telephone Manufacturing Co. (ATM). The second division of the Electro-Technical Laboratory took charge of the mission.[11]

By the middle of the 1920s, the telephone subscriber had increased beyond the capacity of manual exchange. Moreover, the service quality of telephone exchange had been getting worse because of short supply and unskilled operators.[12] MOC engineers considered that a gradual conversion to the automatic telephone system was inevitable. However, as shown by Tonegawa, the foundation and running cost were expected to be more expensive. They were forced to make a difficult choice.[13]

1.2 Introduction of automatic telephone system

The Great Kanto Earthquake occurred in September 1923 did considerable damage to the telephone network. Thirteen of nineteen manual exchange offices in Tokyo, and two of all offices in Yokohama were completely demolished. However this disaster provided an opportunity for MOC to adopt an automatic telephone system.[14]

Sannosuke Inada significantly contributed to the introduction of the system. Inada graduated from the Department of Electrical Engineering, Tokyo Imperial University, in 1900 and became an assistant engineer in MOC. After he promoted to the post of an engineer, he studied in the United States, British, France, and Germany for two years from 1908. When TBCTT was founded in 1920, he was appointed as a chief engineer of the bureau.[15]

Inada visited London in 1922, where an automatic telephone system was being introduced into the British telephone network. His subordinate, Iwase Tetsujiro, who also visited Europe to investigate the same issue, supported Inada. Moreover, the British government, especially General Post Office (GPO) supplied him with important information. The chief engineer of GPO who was in charge of the introduction

[9] NTTpc (1953 Vol.3: 31); Dohi (1951: 23).
[10] Yamane (1921: 5–29).
[11] NTTpc (1953 Vol.3: 17).
[12] NTTpc (1960:4).
[13] In Kwantung Leased Territory, the telecommunication bureau of the Kwantung governor-general had investigated the ATS at Lüshun Engineering College from 1917. Automatic telephone exchange had begun at the Dalian telephone exchange office from April 1923. NTTpc (1953 Vol.1: 17).
[14] Ibid.
[15] Musen Denpo Tsusinsya (1921: 119).

the system in Britain strongly influenced Inada's decision to introduce the system.[16]

Immediately after Inada returned to Japan, the Great Kanto Earthquake occurred; he regarded it as a good opportunity to introduce the automatic telephone system. The month following the earthquake, Inada gathered engineers of the TBCTT and ordered further investigation of the system.[17]

However, the administrative vice-minister of MOC opposed Inada's proposal to introduce the automatic telephone system because importing and setting ATS would take a long time, and the restoration of the manual exchange system could be easier and faster.[18] This opinion is very reasonable in consideration of the situation that they couldn't purchase domestic ATS. But Inada strongly insisted on the automatic telephone system and tried to persuade his supervisor. Finally, he succeeded to introduce the system as departmental decision.[19] Minister of Communications at that time, Tsuyoshi Inukai, stated that if this system was capable of performing effectively and could be profitable in the future, it should be introduced immediately even if the foundation cost was high.[20] Inada gave top priority to improve telephone exchange service. In spite of the expensive cost, he decided to introduce the automatic telephone exchange before domestication of ATS was achieved in Japan.

1.3 Coexistence of Different Systems: the A-Type and the H-type

ATS is a mechanical telephone switching device that is operated by an interrupted electric current, i.e., an impulse current. In the early years, the Strowger system developed by Almon B.Strowger in 1891 was mainstream of ATS. This system is technologically belong to the Step by Step (S×S) system used a simple method that was operated directly in accordance with the impulse current transmitted from the subscriber's telephone. Strowger system was developed by Automatic Electric Inc. (AEI) in the United States and ATM in Britain. And Siemens & Halske Aktien Gesellschaft (SH) in Germany also developed their original S×S system that was called the Siemens Halske System.

On the other hand, new system which used more sophisticated technology was developed by other company like WE. This was the Power Driven (PD) system, which used an indirect drive method controlled by a common control circuit in which the connecting and talking processes were operated separately. When a subscriber dials a certain telephone number, the connecting circuit begins to search for the caller and stores the impulses into a register once; then, it attempts to identify the receiver. Once the subscribers are connected, the circuit begins to revert to its original state to prepare for another call; meanwhile, the talking circuit continues to connect to the talking subscribers. Since the connecting process was operated independently, this system was superior to the S×S system with regard to avoiding wrong connections and was suitable for a large number of subscribers.

According to Yamane's above mentioned study, in America, WE started developing this system by 1910's, and succeeded to put them for practical use around early 1920's. The PD system was introduced

[16] Dohi (1951: 24).
[17] NTTpc Engineering Bureau (1976: 73).
[18] Yonezawa (1988: 123).
[19] Publishing Committee for The Biography of Inada Sannosuke (1965: 585).
[20] Dohi (1951: 22).

into the metropolis, such as New York, Chicago, Boston, Philadelphia, etc.[21] Not only American company, but also Sweden, France, and Belgium also introduced various versions of the PD system.[22]

Inada and the engineers in Telecommunication Engineering Bureau (TEB)[23] compared the systems to determine the most suitable one for Japan. It was considered extremely important to obtain a simple mechanism that was practicable for large-scale production and easy to repair. Inada received information from a chief engineer from GPO in Britain that they were planning to introduce the Strowger system in London instead of the PD system because the latter was more expensive.[24] As mentioned above, reduction of the foundation costs was also a serious problem in Japan. An issue of greater importance, which was discussed, was the ease in domestication of ATS. It was judged that the domestication of the PD system by Japanese companies would be difficult in the near future. Hence, they decided to introduce the Strowger system. For the first stage of construction, ATM supplied equipment for the Tokyo telephone exchange office, and AEI supplied it for the second stage. Since both ATM and AEI were subsidiary companies of WE, NEC imported the equipment through Standard Telephone and Cables (STC) and delivered to MOC.[25]

As mentioned above, cost reduction was a top priority. Nevertheless the total cost, which included a consultation fee for engineering guidance, amounted to over 8 million yen for only the first stage. MOC had never paid for imports such an enormous sum previously. Even the S×S system which was expected much cheaper than the PD system imposed a severe burden to MOC. So they had to try reducing ATS prices as much as possible.

To begin with, TEB engineers lacked sufficient knowledge on the market prices of ATS; hence, they were at a disadvantage with regard to price negotiation. Therefore they began to investigate the prices of ATS in detail and used the data for the subsequent negotiation with NEC. They succeeded to reduce the price of ATS for 12 percent at the second stage.

Secondly, MOC decided to purchase from not only ATM and AEI but also SH and Siemens Brothers (SB), and open the bidding on contracts. MOC intend to induce price competition by bidders for every time ATS was introduced. As a result, the Strowger system of ATM and AEI was introduced into Tokyo, Nagoya, Kyoto, and Kitakyusyu, while the Siemens Halske System of SH was introduced into Yokohama, Osaka, and Kobe. SB also produced the Siemens Halske System, which was introduced into Ashiya in Hyogo prefecture. In this manner, MOC succeeded in reducing the purchase price. For 7 contracts, the imports of ATS declined from over 9.9 million yen in 1925 to 889 thousand yen in 1929.[26]

However, the introduction of these two systems caused the coexistence of different systems in Japan. The engineers referred to the Strowger system as “the A-Type” and the Siemens Halske System as “the H-type”. Although both types used the S×S system, each had their distinctive features. They are completely different with regard to circuit design, production technique, operation system, maintenance procedure,

[21] NTTpc (1953 Vol.3: 493).
[22] Publishing Committee for The Biography of Inada Sannosuke (1965: 144).
[23] TEB was established to take charge of the TBCTT mission in 1925. Inada was appointed as the chief of the bureau.(Publishing Committee for The Biography of Inada Sannosuke (1965: 604).
[24] Ibid. 145.
[25] NEC (1972: 117).
[26] NTTpc (1953 Vol.1: 36–42).

material management, and engineer training.[27]Hence, mechanical adjustments were required to connect them. Each telephone exchange office selected one side of the two types to avoid confusion in local exchanges. However, the problem remained unsolved in toll exchanges that connected the lines outside the district.

MOC engineers were also confused because they had to manage ATS using two methods. A period of intensive training for engineers was inevitable to master their management and repair. As a result, the engineers were divided into two groups for the A-type and the H-type systems. Both these groups insisted on the superiority of theirs, worsening the conflict pertaining to the introduction of them. An engineer of TEB had to leave as a result of such conflicts.[28] Some engineers complained to Inada about this problem. Inada had recognized this problem earlier; however, competitive bidding was inevitable to reduce the foundation cost.[29]

Such a problem was caused by MOC's decision to introduce an automatic telephone switching system although it was neither an indigenously built system nor a domesticated ATS. In order to further improve the telephone service, domestication and standardization of telephones were the most important tasks to be achieved in prewar Japan.

Section 2
Domestication of ATS

2.1 The Promotion Policy for Domestic Production in the 1920s

The biggest obstacle to the introduction of the automatic telephone system was the cost of installation. Since the Japanese suppliers were not sufficiently experienced to produce ATS, MOC was forced to import them at a considerable expense. Despite that MOC's efforts gradually reduced the cost, as mentioned previously, transportation fees and customs duty that fluctuated with the foreign exchange rate were unavoidable. Moreover, there still existed another problem—late delivery and inconvenience with regard to repairs.[30]

The promotion of domestic production was not an issue for just one department or agency, but a matter of priority for the entire government; this was especially so in the 1920s when Japan's trade balance fell in the red again. In order to restrict imports, Ministry of Commerce and Industry established the Domestication Promotion Committee [*Kokusan Shinko Iinkai*] in June 1926. Its primary purpose was to encourage the use of domestic products, and to deliberate a policy to promote Japanese industries.[31] Particularly, in the case of government procurement, a method of substituting a domestic product for imports was a very important subject of discussion. Hence the committee demanded all government organizations to submit a list of articles procured from foreign countries to the Ministry of Finance every

[27] Yonezawa (1988: 444).
[28] Yonezawa (1988: 229).
[29] Publishing Committee for The Biography of Inada Sannosuke (1965: 546).
[30] NTTpc (1953 Vol.1: 52).
[31] "Cyugai Syogyo Sinpo" Jun., 20th, 1926.

three months. And Ministry of Finance reported them to the committee. The committee then classified them into two categories—one that was approved for import because no domestic company could produce them and another that was disapproved because the domestication had been achieved.[32]

In November that year, the range of disapproval category was widened. If an item existed whose domestication was in progress but not achieved, the related domestic product would be prioritized over imports for government procurement.[33] Ministry of Commerce and Industry formed a list of items that should be prioritized. Moreover a law which allow the government to procure the above mentioned items by private tenders or voluntary contracts instead of competitive bidding was proclaimed in April 1927. Based on this law, the government was able to nominate Japanese companies as exclusive subcontractors for procurement, even if their price or quality was not satisfactory to compete with imports from advanced countries.[34]

In response to the committee's decision, MOC began investigating all their procurements to specify the items that must be domesticated.[35] In January 1929, the committee authorized NEC as a preferential supplier of ATS for MOC procurement.[36] However, the foreign suppliers such as AEI, ATM, and SH were not excluded from the Japanese market at that time, because NEC was unable to meet MOC's demands.

The committee decided to apply the law to ATS at the meeting held in May 1931. ATS supplier was limited to only Japanese companies with some exceptions such as the Siemens Halske system.[37] In the preceding year, MOC had defined "domestic product" as commodities manufactured in Japanese territory by a company that has more than half of its capital held by Japanese citizens utilizing Japanese technology and labor.[38] Table 2 lists the ATS suppliers for the newly established telephone exchange office. From 1931, the domestic market was protected by policies for Japanese companies such as NEC, OKI, FUJI, and TOA.

As mentioned in the previous section, the reduction of foundation cost was a major issue for MOC. Therefore the domestic ATS should be improved to a level that met the demand of MOC in terms of price and quality, even if not to the same level of imports before the exclusion of foreign companies. Seiichi Shindo, an MOC official who was concerned with the policy making, in retrospect, commented that the domesticated items were not extremely expensive, and their financial burden on MOC's budget did not increase after the market protection policy in 1931.[39] This implies that the domestication of ATS by Japanese companies had developed considerably by the end of the 1920s. In the remainder of this section, I will examine the domestication of ATS by Japanese companies.

2.2 Domestication of ATS by Japanese Companies

Nippon Electric Company., Ltd. (NEC) was founded in 1898 as a subsidiary company of WE; it first

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[32] "Jiji Shinpo" Oct., 1st, 1926.

[33] "Osaka Asahi Shinbun" Nov., 11th, 1926.

[34] "Osaka Asahi Shinbun" Jan., 10th, 1928.

[35] NTTpc (1953 Vol.2: 41).

[36] Shimazu (1980: 84).

[37] Kokumin Shinbun May, 8th, 1931.

[38] NEC (1972: 150); NTTpc (1953 Vol.2: 41).

[39] Publishing Committee for The Biography of Inada Sannosuke (1965: 580).

succeeded in the domestic production of ATS. NEC had been an importer of ATS before it began indigenous production. When the telephone exchange office in Dalian, Kwantung Leased Territory, planned to introduce ATS in 1922, NEC delivered a semi-automatic telephone system manufactured by WE to the Kwantung governor-general. When MOC decided to introduce the automatic telephone system in 1923, an inquiry on the domestic production of ATS was made to NEC first.[40]

The focal points in the production of ATS were sets of tools, machine tools, and materials. ATS in the prewar days was a mechanical system comprising a number of relays and other parts. Therefore, it was extremely important to standardize the parts and improve their compatibility. In order to achieve this, a set of tools was required to precisely improve processing accuracy. Further, a high-quality machine tools were indispensable to make good tools. WE sent all blueprints and tools to NEC.[41] However, they were found to be inadequate for use in the production line. Primary materials such as phosphor bronze and nickel silver rusted quickly in Japan because Japan has higher humidity than western countries and the material quality was not at par with the advanced countries. The engineers in NEC attempted to overcome this problem by plating. On occasions, they had to indigenously change the materials and devise new tools different from those supplied by WE.[42] MOC procurement had to be approved by the Electro-Technical Laboratory that was first established under MOC in 1891 and had become an independent organization in 1918. All the ATS parts produced by NEC, such as dials, switches, and selectors, were accepted one by one from 1926 to 1927. The Electro-Technical Laboratory commented that their quality was not inferior to that manufactured by WE.[43]

NEC delivered the first domesticated ATS to the Mitsukoshi Department Store in July 1927, then made a bid for MOC's ATS procurement which had been to introduced into Tokyo-Nakano telephone exchange office in 1929. At the competitive bidding, despite that the cheapest estimate was 160 thousand Yen by AEI, while NEC offered 170 thousand Yen, NEC became a successful bidder.[44] This result was not only because of the promotion policy by MOC. NEC had improved the price competitiveness to a level comparable with that of foreign companies.

Oki Electric Industry Co. (OKI), the oldest telephone equipment company, was founded in 1881; they developed a manual exchange switchboard without any support from foreign companies.[45] However, MOC adopted OKI's ATS only 10 years after telephone system had begun in 1890. It appeared that the domestication of the ATS without technical support by OKI would be more difficult, and that a technical tie up with a foreign company was inevitable. Therefore, OKI signed a contract with the General Electric Company (GEC) in Britain, as its exclusive supplier of ATS in Japan. OKI dispatched some engineers to Britain, one of whom, Cyuichi Yoshino, entered a training school for ATS engineer in GPO and received training. In 1926, OKI and GEC signed a contract to establish a technical tie up. GEC supplied OKI with

[40] Denki Tsushin Editorial Office (1940: 132).
[41] NEC (1972: 126).
[42] Denki Tsushin Editorial Office (1940: 135).
[43] Ministry of Communication (1927).
[44] Editorial Committee for The Photo Album of Tozuka Factory (1987: 236).
[45] The story of OKI is based on the following study.: Oki Electric Industry Co. (1981: 122–131); Japan Business History Institute (2001: 49–57).

the blueprints and tools, while the former paid the latter a royalty of 3% of their sales.

At that time, the workers were still indirectly managed by OKI. In the factories, masters [*Oyakata*] used indigenous tools. However, ATS requires standardized parts, and these tools were inadequate for its mass production. Moreover, since each work group independently proceeded with their operation at different speeds, the assembling process for the parts was not uniform. Experts in toolmaking and machine production were dispatched from GEC to OKI, and they built new section to produce ATS without depending on masters. Their products—dial and switches—were approved by the Electro-Technical Laboratory from 1927. The Nakano telephone exchange office decided to adopt OKI's ATS in 1929 and it was delivered in the subsequent year.

The third ATS supplier in Japan was Toa Electric Co. (TOA), which was founded in 1918 then became an affiliate company of Tobata Casting Ltd in 1923. In 1934, both these companies were merged with two other companies to form the Kokusan Industrial Company; they were merged into Hitachi Ltd. in 1937 as Tozuka factory. TOA, which had produced manual exchange switchboards from the time of its establishment, undertook the domestication of ATS from 1927. TOA did not enter into any technical tie up with a foreign company. They borrowed the ATS manufactured by AEI from the Tokyo central telephone office and imitated them. However, they were unable to easily understand its mechanism. A trial product manufactured on a small scale worked satisfactorily; however, achieving good results with large-scale production took a long time. The test of durability was repeated many times. Their first delivery to MOC was a tentative introduction into the Shizuoka-Atami telephone exchange office in 1934. After their ATS produced good results, it was adopted formally.[46]

These three Japanese companies developed and produced the A-type ATS. In contrast, Fuji Electric Co. (FUJI) promoted the domestic production of the H-type ATS. Its parent company, Furukawa Electric Co., planned manual exchange switchboard production and hired over 10 engineers like Morisaburo Tonegawa, from MOC and the Electro-Technical Laboratory. Subsequently, in 1923, The company established FUJI as a joint collaboration with a German company, Siemens Schckert. From 1925, FUJI assumed responsibility for the functioning of the Tokyo branch of the company; it also became an agency of Siemens Halske for importing ATS and telephone sets.[47] In addition, SH and FUJI signed a contract according to which the former supplied parts and semifinished goods to the latter to assemble electric appliances in Japan.[48] At that time, MOC formulated a plan to introduce an automatic telephone system into the area that includes the Osaka and Hyogo prefectures. FUJI sent the data necessary for design of ATS to SH. SH offered the cheapest estimate and became a successful bidder.

FUJI and Furukawa Electric Co. set up a committee to discuss the domestication of ATS and decided not to domesticate it immediately. However, MOC clarified their policy to restrain imports, and in 1932, informed FUJI that MOC would never adopt imported ATS in the Osaka area; they further stated that if FUJI would not domesticate the H-type ATS, MOC would abolish them and shift to the A-type ATS. In response to this, FUJI obtained a license from SH to produce the H-type ATS and began domestication. In

[46] NTTpc (1953 Vol.3: 376).
[47] Ibid. 384.
[48] Takeuchi (1966: 122).

April 1933, FUJI established a telephone department and hired engineers from MOC. These engineers were then sent to Germany for acquiring the production technology. In the beginning, all parts were imported from SH, and FUJI merely assembled them. However, the blueprints sent from SH had to be adapted for the Japanese environment such as the requirements of NEC. Then, they attempted to indigenously produce parts and raise their production technology to the level of Deutsche Industrie Norm (DIN), which was the standard specification in Germany. In 1934, FUJI was nominated by MOC as a supplier of the H-type ATS, and they delivered their products to the telephone exchange offices in Osaka and Yokohama in the subsequent year. In 1935, the telephone department of the company was spun off and was founded as Fuji Tsushinki Seizo Co. (FUJITSU).[49]

Since FUJI was the only Japanese supplier of the H-type ATS, MOC planned to increase the number of suppliers, and they requested NEC to produce them. In May 1934, NEC received permission to produce the H-type ATS from SH. Mix und Genest A.E. (MG) which was a German subsidiary company of the International Telephone and Telegraph Corporation (ITT) supplied tools and blueprints of the H-type ATS.[50] In 1936, NEC completed their first H-type ATS.[51]

Four companies became ATS suppliers—NEC in cooperation with WE and MG, OKI with GEC, FUJI with SH, and TOA. With the exception of TOA, these companies introduced production technology obtained from foreign companies and immediately achieved domestic production. In contrast, it was a long time before TOA acquired the manufacturing technique and it delivered the smallest number of ATS to MOC. In their domestication process, they not only imitated the foreign products but also rewrote blueprints and devised tools that were suitable for Japan.

However, these companies did not develop original systems like the Strowger system, the Siemens Halske system, and the PD system. They simply introduced existing technologies and adapted them to Japanese environment. Therefore, each company domesticated a system that was previously developed by their partner, such as AEI, ATM, GEC, and SH. Hence, different exchange systems, namely the A type and the H type, coexisted in Japan. Both the mechanical design and technological features were completely different, and it was impossible to unify them into one single type.

Moreover, even the same type ATS were not compatible with each other because the parts and components differed depending on the manufacturer. For example, for the A type, the parts of ATS manufactured by NEC could not be assembled with those manufactured by OKI or TOA. Similarly for the H type, NEC and FUJI, which introduced the technology from MG and SH respectively, the parts and components were not compatible. As long as each ATS was used independently, the problem was not so significant for suppliers. However, MOC had to bear the burden of managing an enormous variety of parts.

Domesticating foreign technology was not sufficient to improve the telephone exchange service; standardizing the systems and mechanical parts was an essential problem. However, the existing S×S systems such as the A type and the H type could not be a choice for a future standard because its technology was outdated and on the decline. In contrast, the PD system, which was in use in the U.S. and other

[49] NTTpc (1953 Vol.3: 385–386).
[50] NEC (1972: 175).
[51] NTTpc (1953 Vol.3: 175).

countries, was suitable for large cities. However, it was not introduced in Japan. Therefore, MOC had no alternative but to create a new system by themselves.

Section 3
Research and Development Activities for the New Systems

3.1 Independent ATS Technology

The domestication process has displayed a growing tendency toward the development of independent technology in the 1930s. All technical specifications written by MOC at that time included a phrase, "All parts, materials, and patents for this procurement must be Japanese".[52] In particular, patents were considered to be very important. From 1924, the number of patents concerning ATS increased, immediately after the decision to introduce the automatic telephone system; by 1945, it reached over 700. [53] Japanese companies and individuals obtained 233 patents. NEC obtained 104 patents, 62 of which were invented by foreign companies such as WE, and NEC engineers procured 42 patents for inventions. MOC had 51 patents; FUJI, 33; OKI, 12; all of these were Japanese inventions.[54] While the Japanese telecommunication industry generally depended on foreign technology, they began research and development activities.

In the 1920s, TEB in MOC began research activities, particularly with regard to the circuit design of ATS. NEC and FUJI supported TEB, manufacturing a trial product on the basis of its design. In 1928, TEB established a small laboratory for ATS research and performed simple tests on the trial product.[55] The Electro-Technical Laboratory conducted more advanced tests that required larger equipment and fundamental research on telephones in the second division, sometimes on the request of TEB.[56]

In order to further improve the telecommunication technology, MOC cooperated with some universities, and in 1933, established a Telecommunication Technology Committee as an advisory committee to Minister of Communications. The committee was primarily constituted by the engineers of the MOC, especially the TEB and the Electro-Technical Laboratory, and a scientist who belonged to the Research Institute of Electrical Communication in Tohoku Imperial University and the Department of Electrical Engineering in Tokyo Imperial University joined this committee. The committee established four research divisions. The second division, which dealt with wire-telephone and telephony, discussed ATS. MOC allocated a budget greater than 201 thousand yen in 1935, and 185 thousand yen in 1936 for the committee. With respect to the ATS, 11 thousand yen were allocated in 1935, 9.8 thousand yen in 1936, respectively, for the research of circuit design and mechanical technology.[57]

NEC had also established its own research department to invent original technology. In 1924, the

[52] NTTpc Engineering Bureau (1976: 74).
[53] Patent specifications; Japanese Patent Office (1958:797-799).
[54] No patent obtained by HITACHI was found. However, it is possible that some individuals belonging to the company obtained patents.
[55] Yonezawa (1988: 26–27).
[56] Electro-Technical Laboratory (1944: 398–400).
[57] Ministry of Communication (1935: 1).

company hired Yasujiro Niwa from the Electro-Technical Laboratory. He joined the Electro-Technical Laboratory in 1916 after he graduated from the Department of Electrical Engineering in Tokyo Imperial University and became a lecturer in the department. After joining NEC, Niwa was promoted to chief engineer in 1927, and he added two laboratories—the Equipment Laboratory and the Transmission Laboratory.[58] The chief of the Equipment Laboratory, Yasujiro Shimazu, who entered NEC in 1925 after graduating from the Department of Electrical Engineering in Tokyo Imperial University, devoted himself to ATS research.[59] His subordinate, Akira Nakajima who joined NEC in 1930, and Harisawa Masao who joined in 1934, designed a relay circuit. Designing a relay circuit at that time was a tedious task; they were required to confirm circuit functions by checking how each relay worked in the circuit individually. This job depended on experienced engineers, and there were few academic researches on the relay circuit. Nakajima and Harisawa believed that an appropriate theory was indispensable for an advanced technology and created a mathematical technique to express the connecting pattern in the circuit. They presented their researches at the Institute of Electrical Communication Engineers of Japan and received international acclaim.[60]

3.2 The T-type ATS

On the basis of these research activities, the MOC began to standardize ATS by developing new systems from the mid-1930s. TEB engineers who assumed responsibility emphasized on an independent technology from foreign patents.[61] Hiroshi Origasa, an TEB engineer, created a new circuit design and obtained three patents on ATS from 1937 to 1938; he then devised a new system, “the T-type” ATS, which was named after Teishin-sho (MOC).[62] Since the research on relay circuits had progressed considerably in Japan, the T-type ATS had a more simplified circuit design than the existing S×S system. For example, the T-type ATS was assembled by 19,521 relays, whereas the H-type ATS required 29,411 relays, at the same processing capacity.[63] It was highly regarded as the first original Japanese ATS. MOC decided to formally introduce the T-type ATS in 1940 to commemorate the “2600th anniversary” of the mythological foundation of Japan. The Nara Telephone exchange office in Nara prefecture, the ancient capital of Japan, first introduced the T-type ATS.[64]

Although the circuit design was an original technology invented by a Japanese engineer, the T-type ATS did not have any original parts.[65] All the relays, switches, and dials were borrowed from the H-type ATS produced by FUJISTU. From the beginning, FUJITSU collaborated with MOC to develop the T-type trial product. Therefore, the development of its parts became the next objective. Since the standardization of the ATS was an essential objective, not only FUJITSU but also other suppliers were required to

[58] NEC (1972: 130).
[59] Shimazu (1980: 79).
[60] Umezawa (1981: 9–20).
[61] NTTpc (1953 Vol.2: 152).
[62] NTTpc Engineering Bureau (1976: 77).
[63] Kojima, S. (1942: 105).
[64] NTTpc (1953 Vol.1: 241).
[65] Yonezawa (1988: 444).

cooperate with them. In January 1942, MOC established the Automatic Telephone System Standardizing Committee.[66] The committee comprised engineers of NEC, OKI, FUJITSU, HITACHI (former TOA), and MOC. In the first meeting, they discussed the design of parts suitable for the T-type ATS, and then they gathered again for another meeting held in October the same year to discuss a prototype.[67]

However, a serious problem was that the T type ATS could not improve on the old-fashioned S×S system. There was no alternative other than to develop an advanced "S×S system" instead of the PD system. At the same time in the U.S., WE succeeded in practically implementing the crossbar system, from 1938. The crossbar system inherited the technology such as the common control system of the PD system. In fact, in 1931, NEC had already been informed about the crossbar system by WE, and they were advised to apply for a patent. Inada, who had retired from MOC, became a technical advisor of NEC, judged that it would be impossible to commercialize the technology within the term of license, which was fifteen years. They decided not to apply for patents.[68] After the war began, Japanese engineers were unable to obtain detailed information on the crossbar system. Hence, in Japan, ATS technology was considerably less developed that that of the U.S.

Material shortage became more serious during the war. The committee was unable to continue the meetings and was dissolved after the fourth meeting held in March 1943. MOC was forced to defer the introduction of automatic telephone exchange; further, rural districts stopped the operation of ATS and returned to manual exchange. For the purpose of national defense, a new telephone office was established in Tokyo and Osaka and the T-type ATS was adopted only there. After the end of the war, they were replaced in the Nagano telephone exchange offices. However, the T-type ATS was never produced again.[69]

3.3 The Electronic Tube-type ATS

While Origasa was developing the T-type ATS, TEB established another research project. This project was proposed by Shigeyoshi Matsumae, a section chief of TEB. He criticized the Japanese telecommunication industry in the 1930s stating that domestic production was achieved not by technological superiority, but by low wages.[70] He recognized that an independent technology could not be developed by improving the existing S×S system.

Matsumae planned to develop "the Electronic Tube-type" ATS after he had developed the non-loaded cable that made him famous.[71] In this system, an electronic tube generates an electron beam controlled by electromagnetic forces to select the telephone number. The ATS technology existing at that time, including the latest crossbar system, was a mechanical system using a number of relays. However, if an electronic tube was applied in ATS, a mechanical relay would not be assembled. This system would have definitely become an epoch-making technology.

Matsumae requested NEC to cooperate with TEB. Simazu and his colleague in NEC thought it would

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66 Shimazu (1980: 91).
67 NTTpc (1953 Vol.1: 410–414).
68 Shimazu (1980: 89).
69 Ibid. 241.
70 Matsumae and Nishizaki (1938: 146).
71 NTTpc (1953 Vol.1: 452).

never be successful in the near future; however, they accepted the request.[72] In May 1939, an ad hoc Committee on Automatic Telephone System was established. The committee comprised four engineers of TEB including Origasa, five engineers of NEC including Niwa and Shimazu, and Yukio Okada, an associate professor of Tohoku Imperial University.[73]

At the first meeting, they discussed the basic policy for their research activities and decided to pursue technological possibilities of the system without hastening the practical implementation. Considerable importance was attached to the development of an common control circuit operated by an electron beam. In order to achieve this objective, it was inevitable to develop a new electronic tube that was adequate for them. NEC attempted to develop a prototype of the electronic tube and submitted it at the third meeting held in the subsequent month.[74]

However, this tube could not generate an electron beam that was sufficient for system control. Moreover, the production technology had some problems. As a result, they had to relinquish the idea of developing a new electronic tube and decided to use the existing discharge tube, thyratron. And to make matters worse, the circuit design had to be changed for an single control which was used in the S×S system. If they adopted the single control instead of common control, the advantages of high-speed operation by electronic tube would be diminished drastically. This implied that they had to give up their highest priority of the project.

At 31st meeting held in February 1941, they reaffirmed their R&D policy, that is to develop new electronic tube for common control circuit, to pursue technological possibilities not a practical utility. Then NEC succeeded in developing new electronic tube in October the year. It seemed as if they would reach to their goal finally. But this electronic tube had fatal defect such as high electricity consumption, short product age, and high heat generation; thus, it was not useful for ATS. The practical utility and reliability which was outside of member's interest were major obstacles to the goal. [75]

They held meetings very frequently—at least once every month, and sometimes three times a month—and attempted to improve the quality of the electronic tube and its circuit design. However, after the T type was introduced in the Nara telephone exchange office in 1940, the members gradually came to the conclusion that they should have developed a more practical ATS despite their earlier decision not to haste the practical implementation. The 45th meeting held in April 1942 became the last meeting. They stopped their project, then all members joined the T-type ATS project, which was also ended in March 1943.[76]

The electronic Tube-type ATS was an innovative idea and the related research and development activities were very intensive. However, the technological level at that time was not sufficient to accomplish the project; in particular, the electronic tube was the biggest obstacle. It can be considered that Matsumae's project was premature and ahead of its time.

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[72] Shimazu (1980: 89).
[73] Kojima (1971a: 23).
[74] Ibid. 25.
[75] Kojima (1971b: 22–26).
[76] Kojima (1971a: 26–28).

Conclusion

MOC decided to introduce the automatic telephone system quickly, immediately after the Great Kanto Earthquake in 1923. From the standpoint of the telephone exchange service, it was a very opportune decision; however, it was technologically premature.

Their dependence on import technology caused different the A-type and the H-type ATS to coexist in a small country like Japan. Each local telephone exchange district independently introduced a different type. MOC had to prepare the specifications and parts for repair for two different systems. The engineers also had to be trained for both and were divided into two groups. These factors hampered the improvement of the telecommunication quality.

Moreover MOC judged that the domestication of the PD system would be impossible in near future. Their only choice was the primitive S×S system. As indicated in Table 3, the ratio of the telephone call which completed without disconnection was getting worse in 1930's, and automatic telephone system was inferior to manual exchange. An MOC engineer recollects that if the MOC had introduced the PD system which used indirect drive method with a common control circuit, most problems could be avoided in large cities such as Tokyo and Osaka.[77] ATS technology didn't develop to be alternative to manual exchange in Japan. In addition to the budget constraint as mentioned before, such a poor performance was also major reason for low automation level in prewar Japan.

To deal with these problem, standardizing the system with independent technology became the biggest issue for MOC in the 1930s. In the 1930s, some joint researches were organized with private enterprises that achieved domestic production. They tried to develop a the T-type or the Electronic Tube-type ATS. However, the T-type ATS was merely an improvement over the outdated S×S system with respect to the circuit design. On the other hand, Matsumae aimed at a novel technology, an electronic common control circuit. However, a suitable electronic tube was not invented. As a result, the telecommunication industry couldn't resolve the technological problem till the end of the war.

Many engineers considered this problem very seriously and attempted to standardize the system again after end of the war. MOC was divided into Ministry of Posts and Ministry of Telecommunication in 1949. The latter had jurisdiction over telephone systems; it was reorganized into Nippon Telegraph and Telephone Public Corporation (NTTpc) in 1952. The first president of NTTpc was Tsuyoshi Kajii. He was an engineer of TEB, and as the chief of the bureau in the 1930s, had been troubled with the problem of coexistence. As soon as NTTpc was established, he planned to introduce the crossbar system. At the beginning of the research and development for the new system in 1953, Kajii ordered that "All suppliers must ensure full compatibility in system and parts."[78] Their research activities have not been explained in detail in this paper; however, its process was very similar to those of the committees I have mentioned above. At the first stage, NTTpc and NEC conducted investigation in cooperation; then OKI, HITACHI, and FUJITSU were given access to the research results so that all suppliers could produce ATS with the same specifications. Further, at the second stage, all companies cooperated in improving the system.

[77] Yonezawa (1988: 52).
[78] Ibid. 250.

Standardization of the telephone exchange system was accomplished in Japan for the first time[79].

After having achieved the domestication of the crossbar system, NTTpc and suppliers attempted to develop the Electronic Switching System, which took over Matsumae's idea and utilized an integrated circuit instead of an electronic tube. NTTpc and NEC, OKI, HITACHI, and FUJITSU established a committee for joint research again from 1964. The Bell Laboratories had already developed this system in 1963; however, Japanese engineers created some independent technologies.[80]

NTTpc and four companies established a joint research system, and they formed the so-called "DEN-DEN Family" in which NTTpc nominated only these companies as a supplier. It is pointed out that such a research system was formed during the postwar high-growth era.[81] However, as discussed in the third section, MOC cooperated with FUJITSU and NEC in the development of the T-type ATS and Electronic Tube-type ATS. In addition, the Automatic Telephone System Standardizing Committee established in 1942 was the first joint research in which all suppliers participated; they exchanged their research results with each other.

Before the end of the war, the telecommunication industry was unable to solve problems such as wrong connections and disconnection of the line. However, the engineers in telecommunication industry recognized their technological backwardness and shared an awareness of the importance of standardization by independent technology. This was the starting point for the research and development system of the telecommunication industry in "Postwar Japan."

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[79] NTTpc Engineering Bureau (1976: Ch.4).
[80] NTTpc Engineering Bureau (1976: Ch.5).
[81] Denki Tsushin Seisaku Sougou Kenkyusyo (1994: Ch.2).

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Table1: The Costs of Telephone Exchange Service (Trial Calculation by Morisaburo Tonegawa in 1914)

(Yen、%)

The Number of Subscribers	Foundation Cost		Running Cost		Total		A÷B
	Manual	Automatic	Manual	Automatic	Manual(A)	Automatic(B)	
10,000	2,409,651	2,817,001	344,366	367,431	2,754,017	3,184,432	86
2,000	124,362	258,552	23,219	35,553	147,581	294,105	50
500	20,676	65,928	6,222	9,426	26,898	75,354	36
300	11,713	41,791	3,275	5,953	14,988	47,744	31
200	7,440	29,577	2,242	4,184	9,682	33,761	29
100	4,154	15,347	1,242	2,222	5,396	17,569	31

Source:Tonegawa (1914: 65-149)

Table2: Number of Established Automatic Telephone Exchange Office and ATS supplier (1926-1939)

Supplier	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	1936	1937	1938	1939	Total
ATM	5	1													6
AEI		4	4	2	4										14
SH	2		5	2					1		1				11
SB					1										1
NEC				1		4	1	4	7	1	4	3	4	1	30
OKI					1			4	3	1	3	2	2	1	17
TOA										1	3	2	2	1	9
FUJI									1	3	4	3	2	1	14
Total	7	5	9	5	6	4	1	8	12	6	15	10	10	4	102

Note: Limited to the mainland Japan.

Sources : Ministry of Communication (1940: 340-342); Nippon Electric Company Editorial Committee (NEC) (eds.) (1972: 126,174); Oki Electric Industry Co. (1981)

Table3 : Ratio of the completed telephone call without disconnection

(%)

	Automatic	Manual
1927	72.2	67.6
1931		78.3
1932		78.2
1933		77.0
1934	75.1	77.5
1935	76.0	78.1
1936	74.9	76.4
1937	72.8	76.4
1938	67.9	75.4
1939	66.3	74.1
1940	61.8	71.5

Sources: NTTpc (1953 Vol.3: 106,113,192,194)